Working Group Name: Working group on Spatial Fisheries Data (WGSFD)

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 inter-sessionally 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 2017-2019.

1 Administrative details

Working Group name

Working Group on Spatial Fisheries Data (WGSFD)

Year of Appointment within the current cycle

2016

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

1

Chair

Josefine Egekvist, Denmark

Meeting venue

Ifremer, Brest, France.

Meeting dates

17-20 May 2016

2 Terms of Reference a) – h)

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 ToR's a, b, c and d, WGSFD had received ToR's 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 15th January with deadline 15th 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 ToR's:

- 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 availabe. 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 2017-2019.

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

- R-script and guidelines for answering the ICES datacall 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 15th 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 15th 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 ToR's 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 instead of DRB and OTT coded as OTB.

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

Still missing

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 center 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 position 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 missin Overlapping vessel length cate gories No information on total value o 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	Comme
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										Logboo position possible betwee 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
Iceland										Data s only to maps f quest, 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
Spain										Some c but not
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 (*eg* 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 a 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 ToR's 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 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 inter-sessional 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 figure 5.6.1.1 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 larger 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.

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

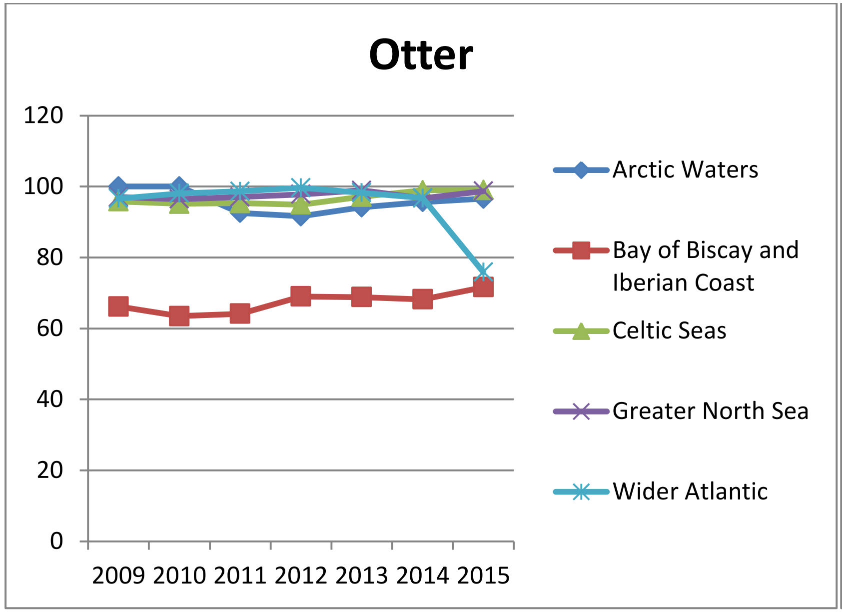
		Seine	4	169	97.7	2,057	169,952	98.8
		Static	102,291	26,273	20.4	20,932,920	17,149,149	45.0
		Other/NA	10,091	41	0.4	3,638,507	389,697	9.7
	Celtic Seas	Beam	296	7,740	96.3	33,735	4,650,331	99.3
		Dredge	3,862	8,314	68.3	542,698	3,313,157	85.9
		Midwater	266	2,864	91.5	17,183,579	204,981,213	92.3
		Otter	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


Otter
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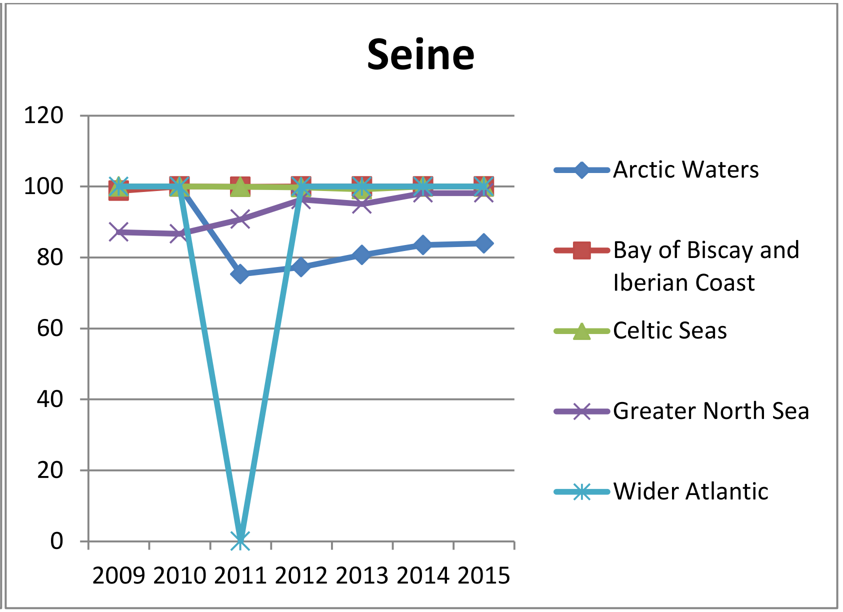
Arctic Waters
Bay of Biscay and Iberian Coast
Celtic Seas
Greater North Sea
Wider Atlantic


Seine
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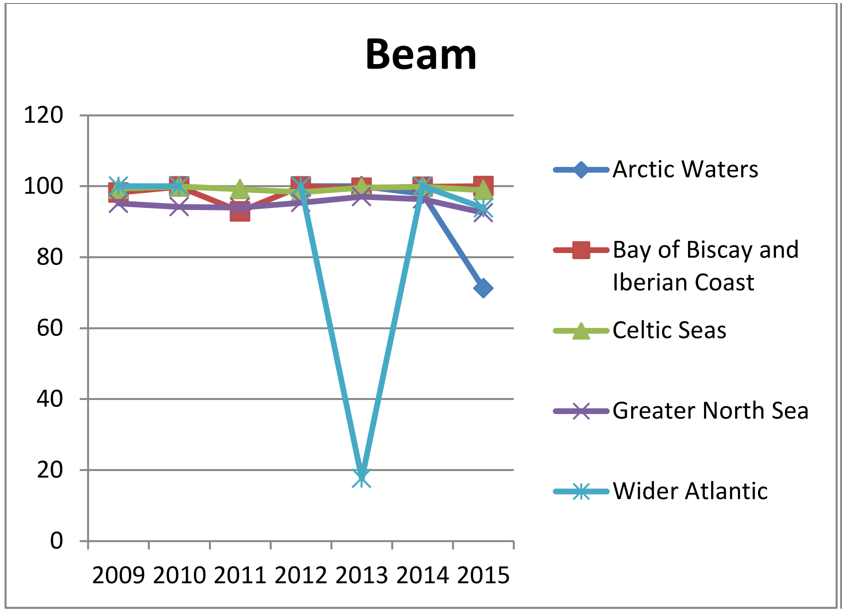
Wider Atlantic


Beam
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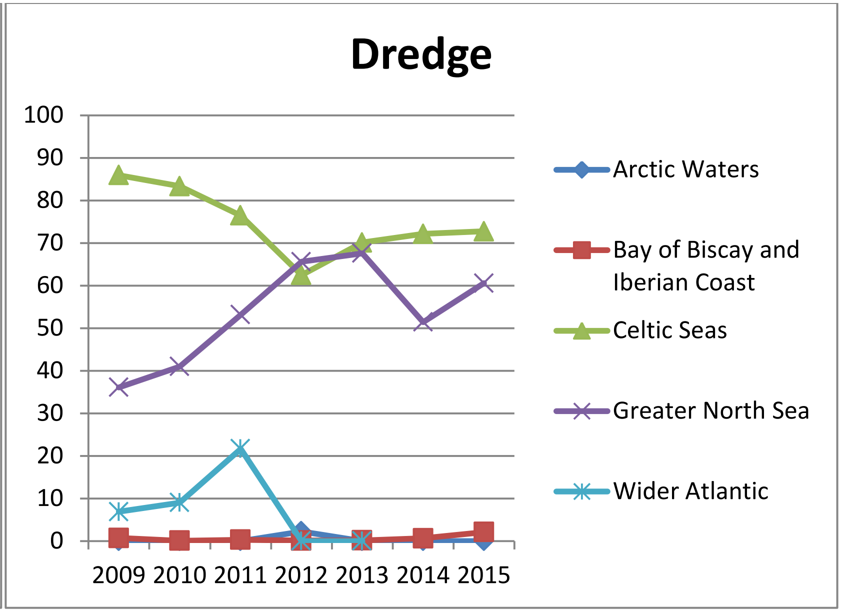
Greater North Sea
Wider Atlantic


Dredge
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Bay of Biscay and Iberian Coast
Celtic Seas
Greater North Sea
Wider Atlantic

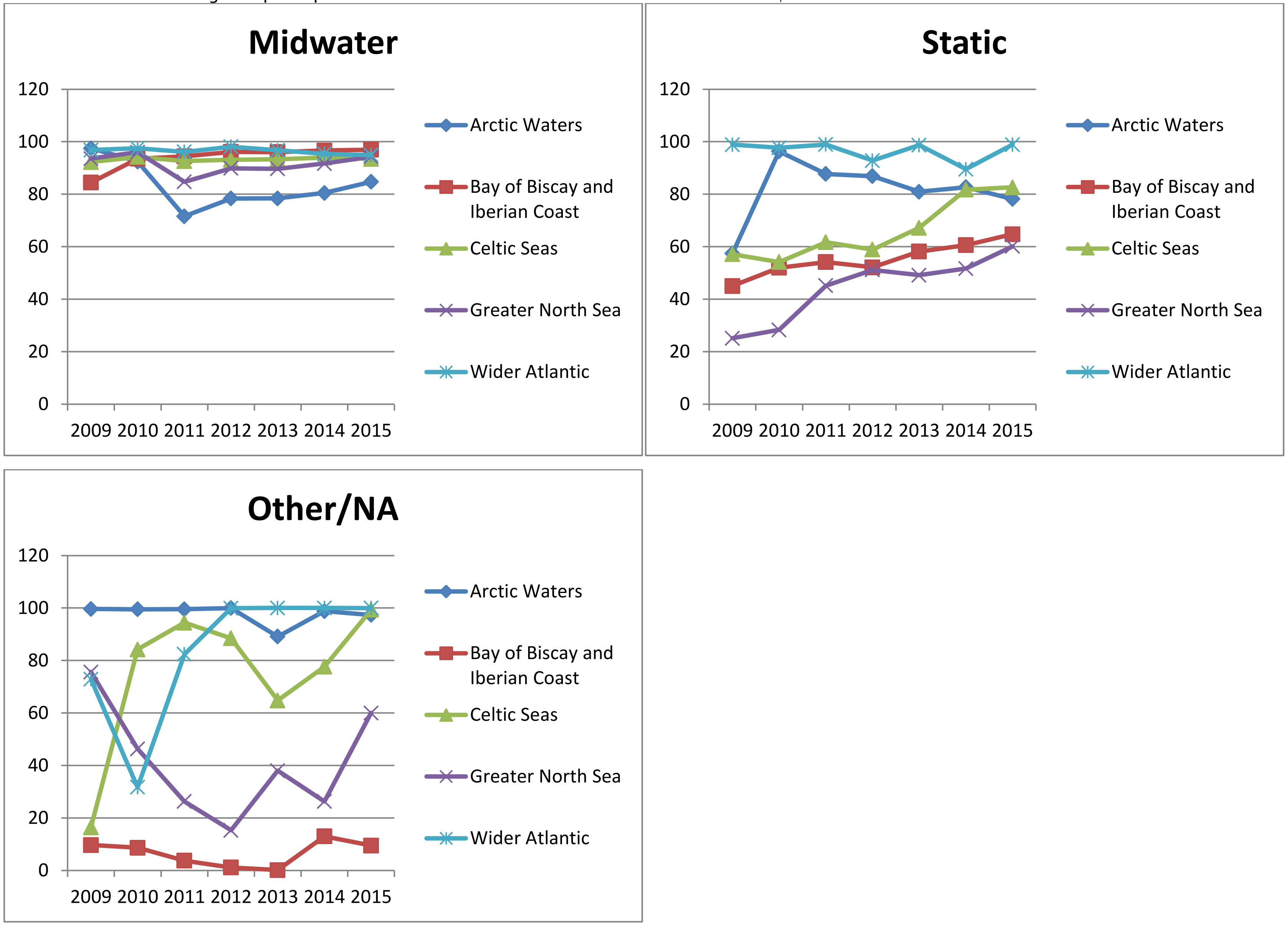


Figure 5.6.1.1: Percentage of landed weight represented by the VMS data by non-bottom contact fishing categories and the OSPAR regions for the years 2009 to 2015.

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 (figures 5.6.2.1 and annex 3).

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.

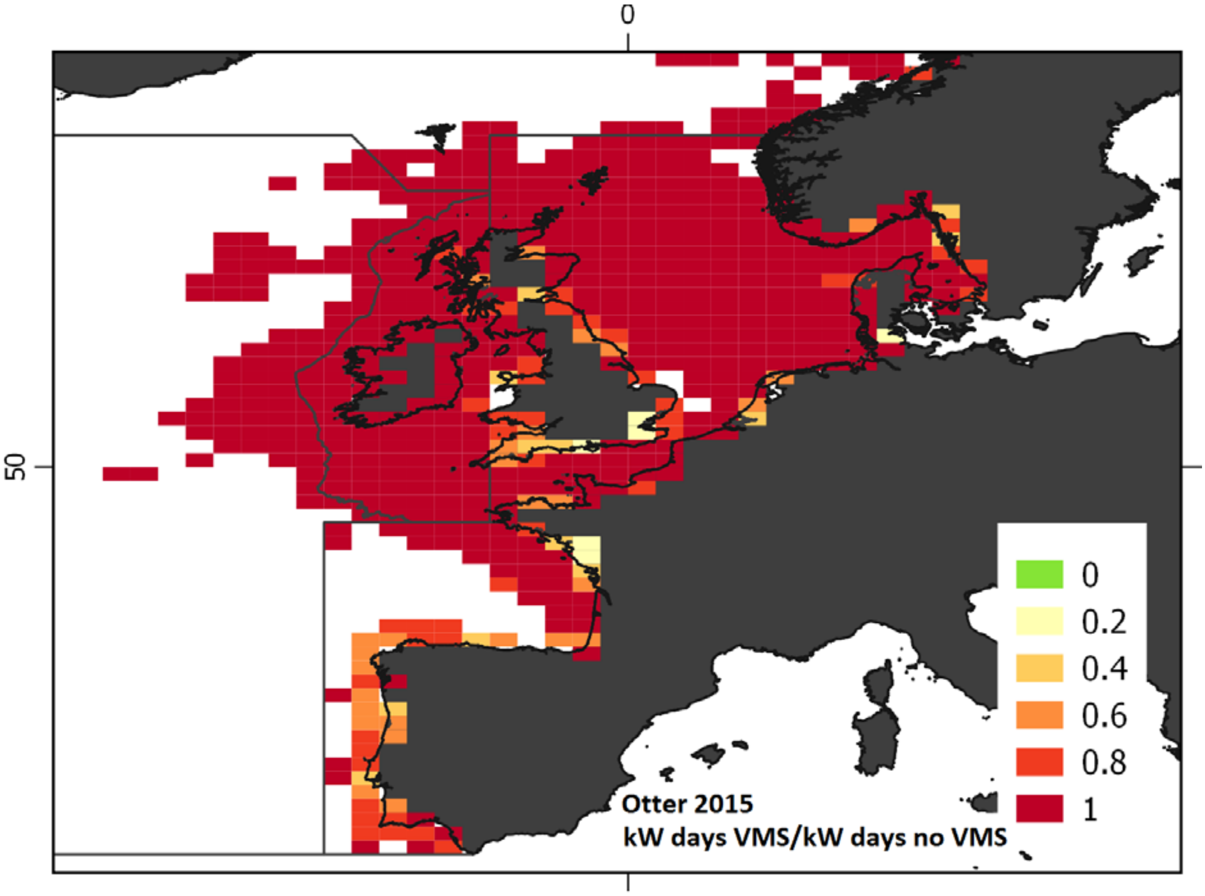


Figure 5.6.2.1: Proportion of VMS coverage for otter trawls based on logbook data. kW fishing days with VMS/kW fishing days without VMS.

Table 5.6.2.1: Effort in kW Fishing Days within the OSPAR region.

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

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. The figures are included below as they give a valuable overview of the importance of the small-scale fishery in relation to the different 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.

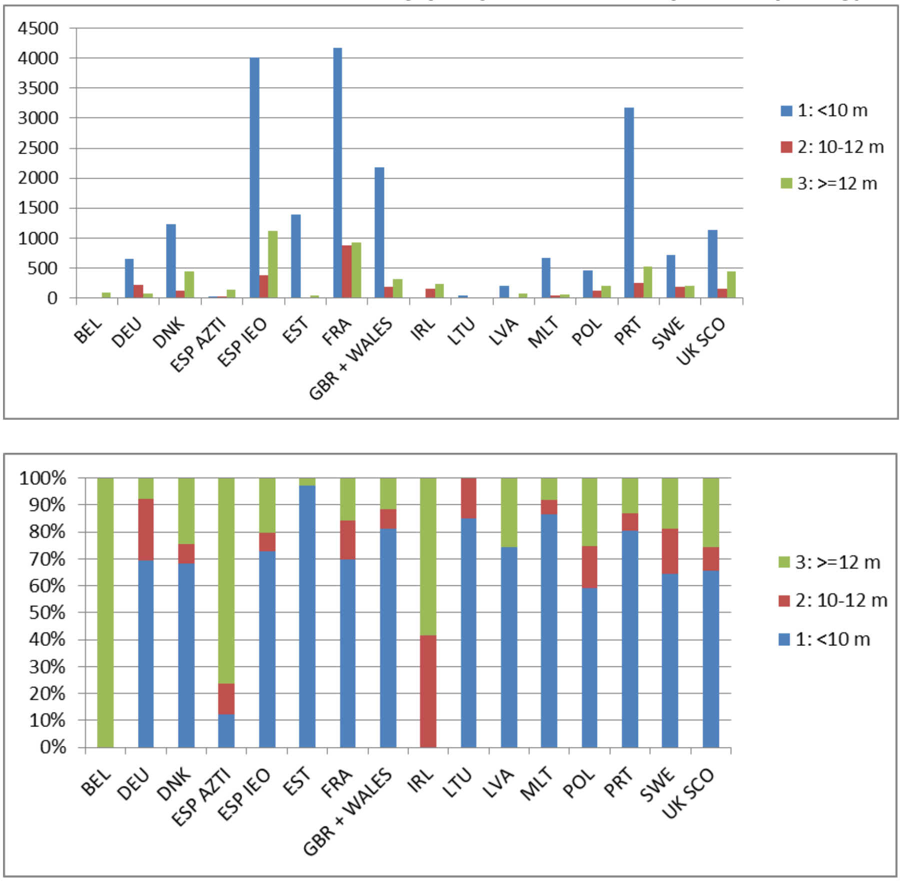
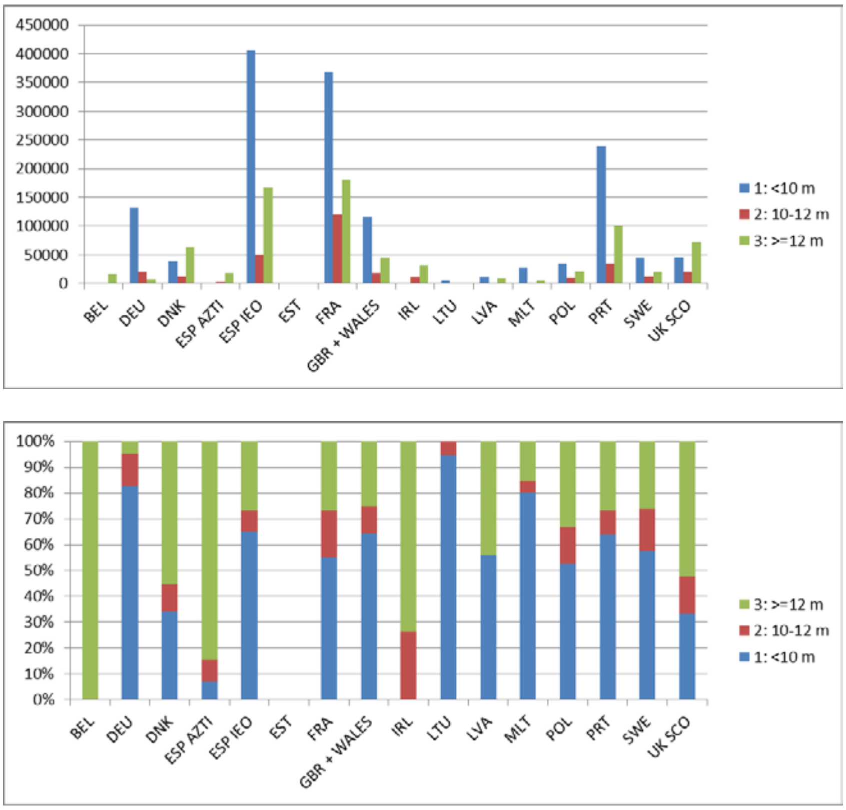


Figure 5.6.2.2: Number of active vessels per country and vessel length group in number (upper graph) and percentage (lower graph) 2012. Source: ICES WGCATCH 2015 (ICES, 2016)



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)

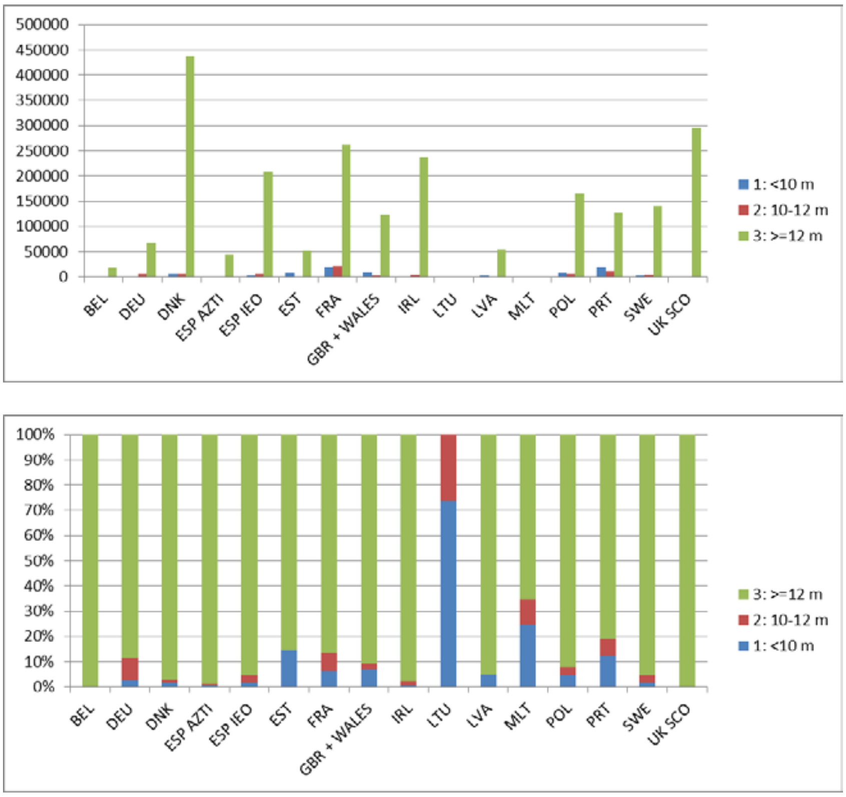


Figure 5.6.2.4: Total fish landings per country and vessel length group in tons (upper graph) and percentage (lower graph) 2012. Source: ICES WGCATCH 2015 (ICES, 2016)

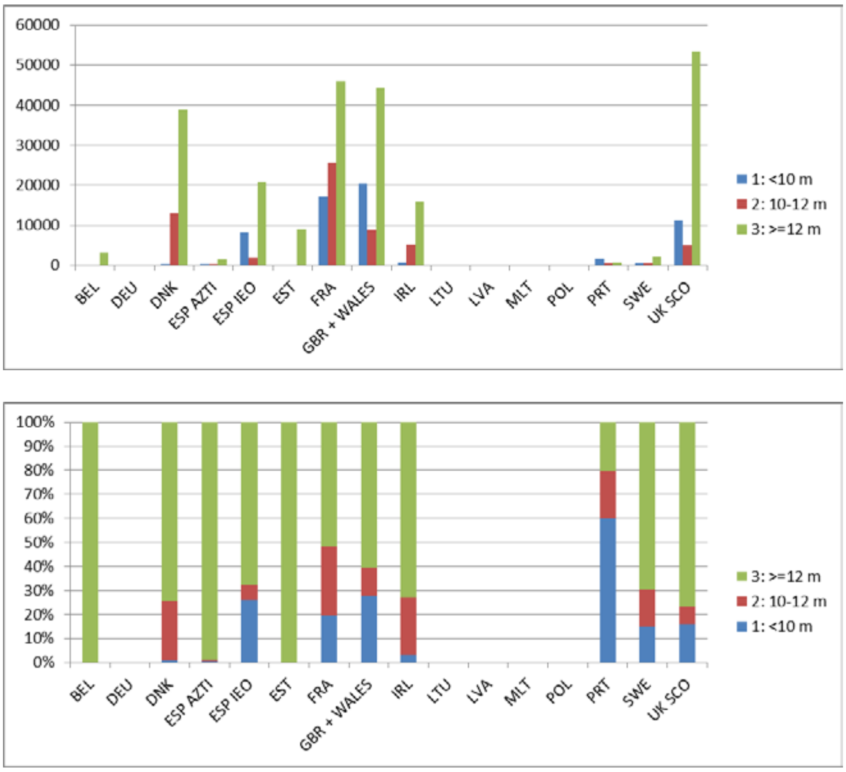


Figure 5.6.2.5: Total shellfish landings per country and vessel length group in tons (upper graph) and percentage (lower graph) 2012. Source: ICES WGCATCH 2015 (ICES, 2016)

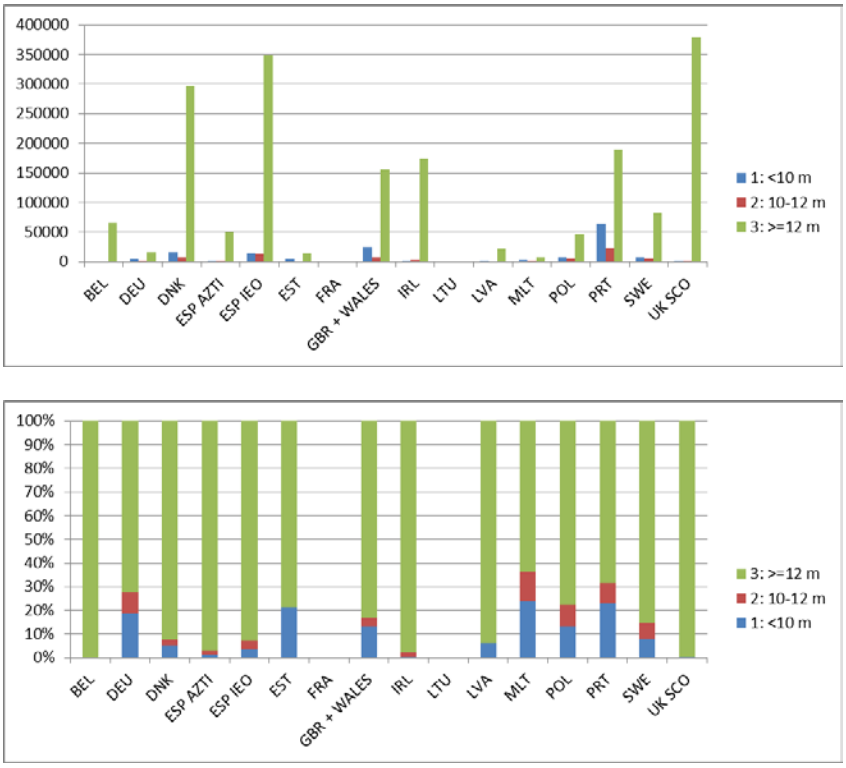


Figure 5.6.2.6: Total fish landings per country and vessel length group in value (euros*1000, upper graph) and percentage (lower graph) 2012. Source: ICES WGCATCH 2015 (ICES, 2016)

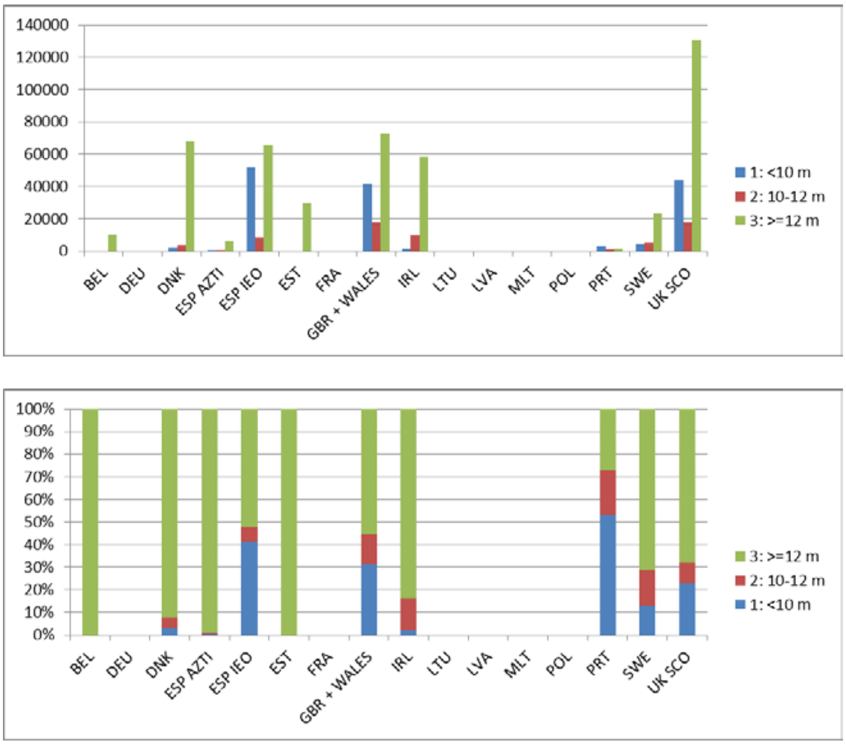


Figure 5.6.2.7: Total shellfish landings per country and vessel length group in value (euros*1000, upper graph) and percentage (lower graph) 2012. Source: ICES WGCATCH 2015 (ICES, 2016)

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 to estimate gear widths 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). The method is described in detail in section 5.8.1 of this report, and reviewed in section 5.3.

The fishing intensity expressed as fishing abrasion 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 fig 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 fig. 5.6.3.2 - 5.6.3.5)

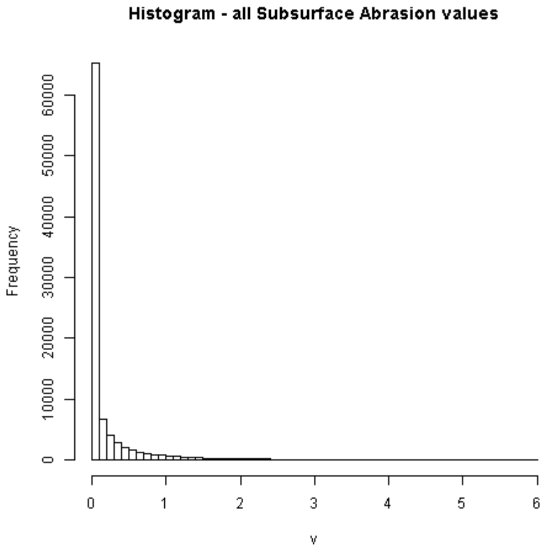


Figure 5.6.3.1: Histogram showing the frequency of all subsurface abrasion values

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. The maps by gear group are available in Annex 4. 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 slope of each c-square was masked using a confidence level of 95%, to be able to map only significant slopes. The trend-map of surface and subsurface swept area ratios is found as figures 5.6.3.6 and 5.6.3.7.

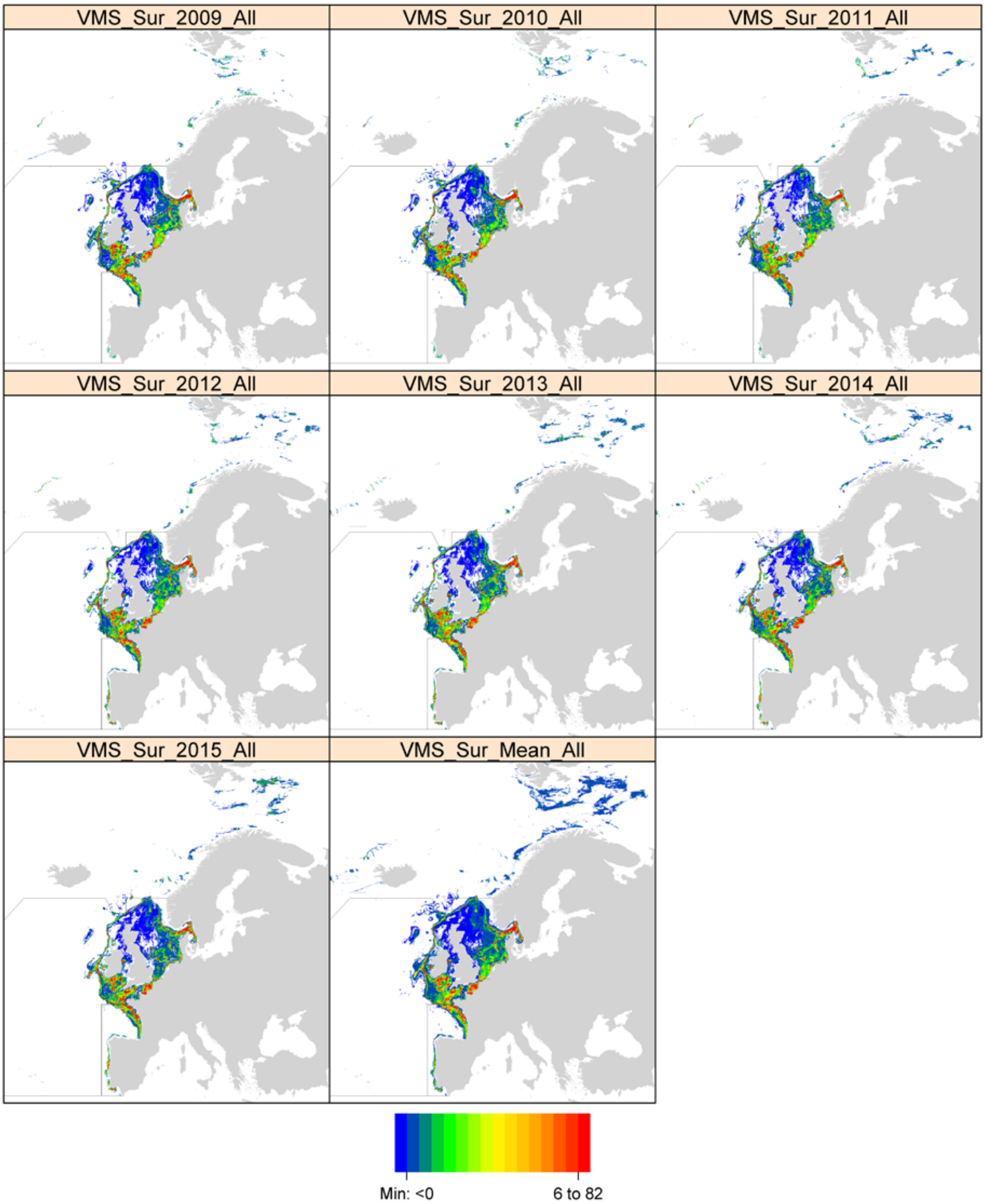


Figure 5.6.3.2: Total surface swept area ratio for each year 2009-2015 and the average of the time period. Zoom to most of the OSPAR region.

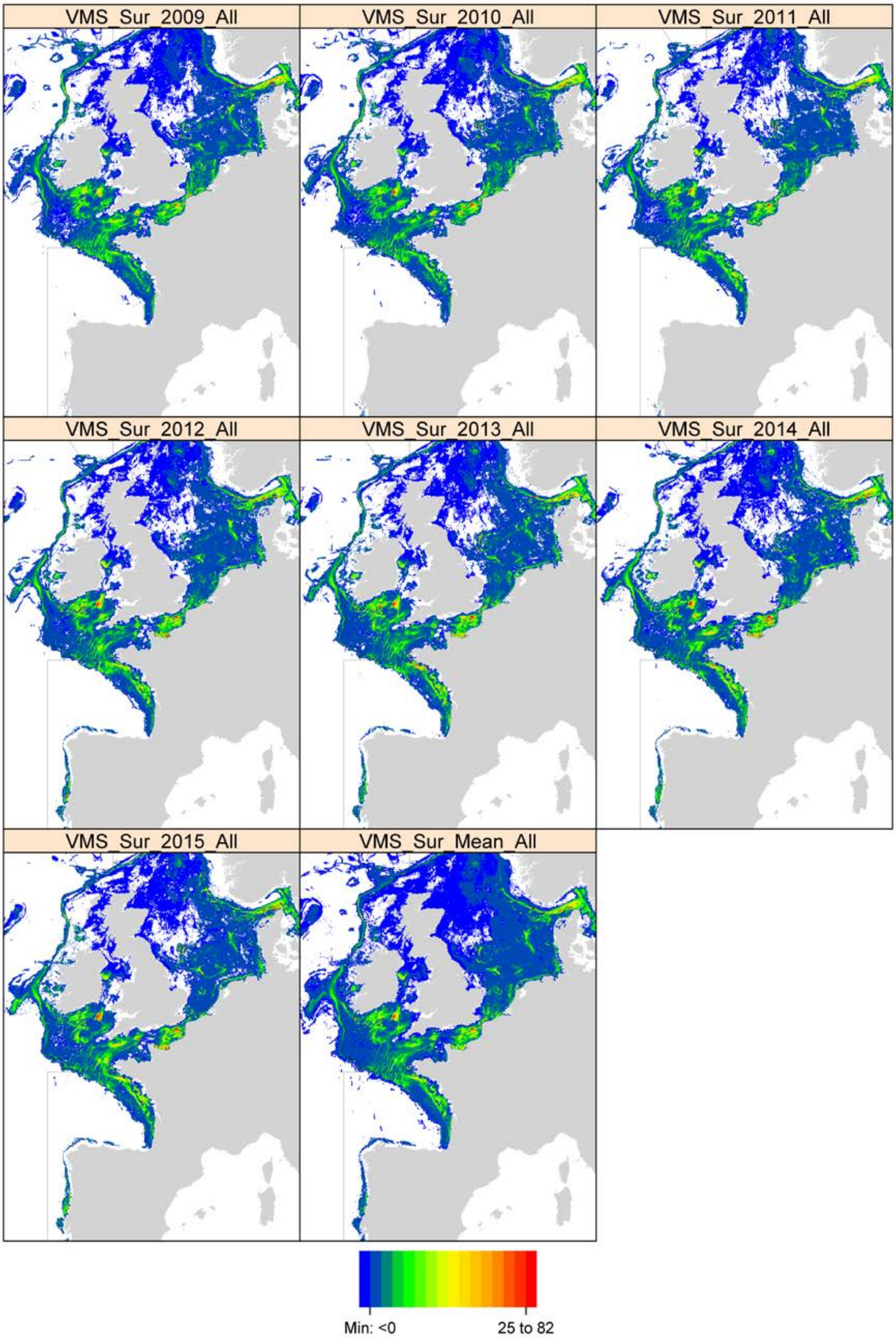


Figure 5.6.3.3: Total surface swept area ratio for each year 2009-2015 and the average of the time period. Zoom to the area around the North Sea.

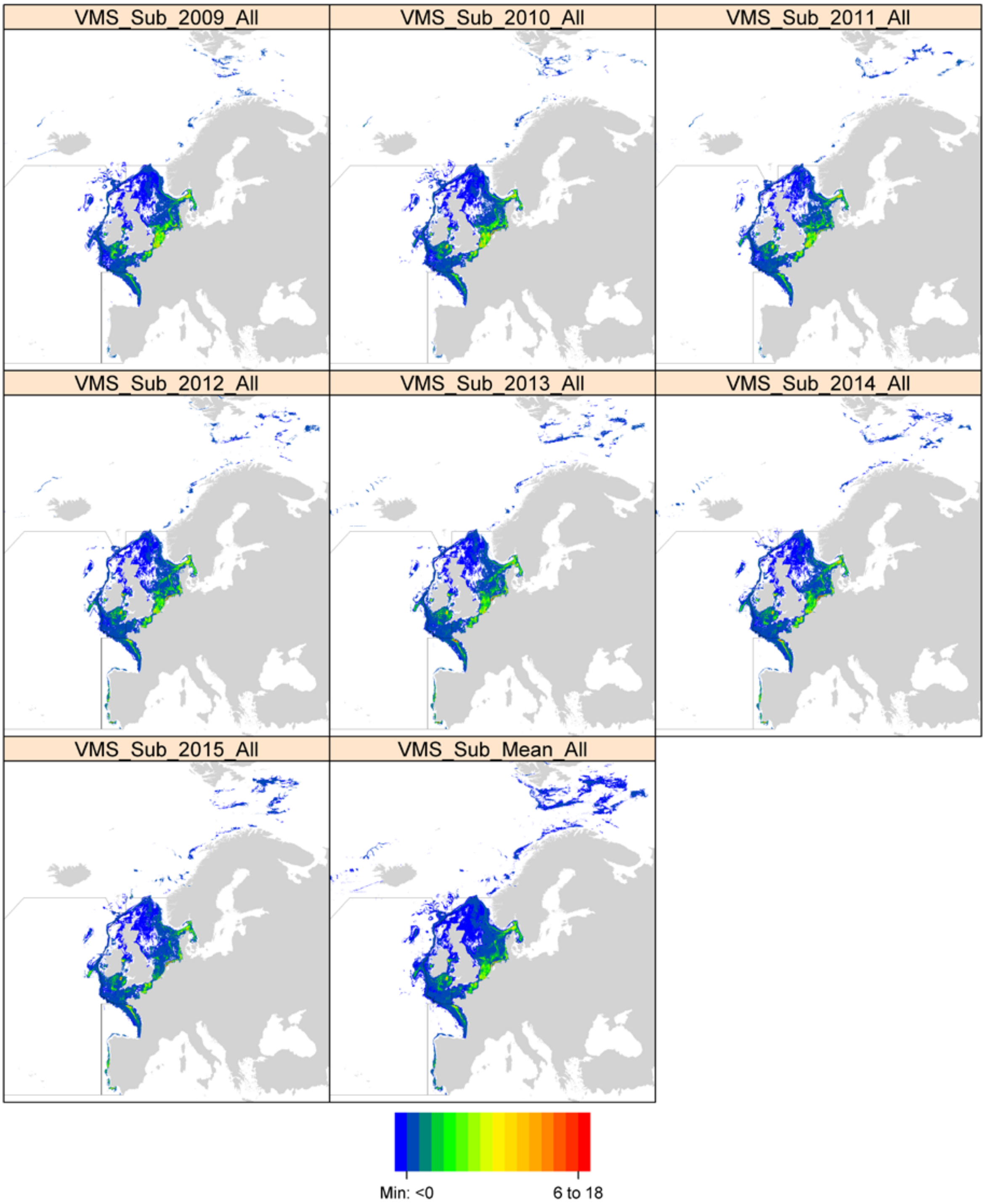


Figure 5.6.3.4: Total subsurface swept area ratio for each year 2009-2015 and the average of the time period. Zoom to most of the OSPAR region.

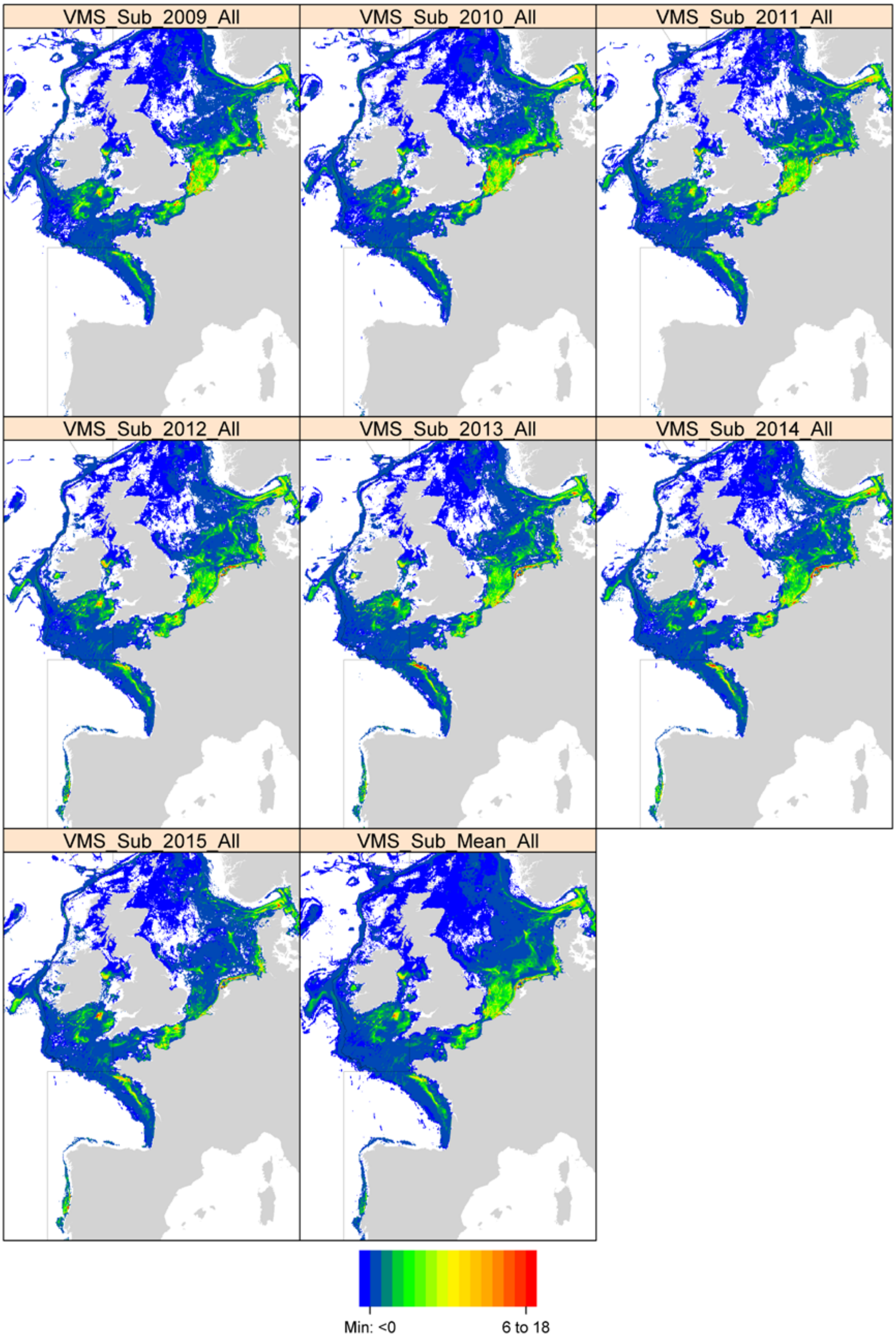


Figure 5.6.3.5: Total subsurface swept area ratio for each year 2009-2015 and the average of the time period. Zoom to the area around the North Sea.

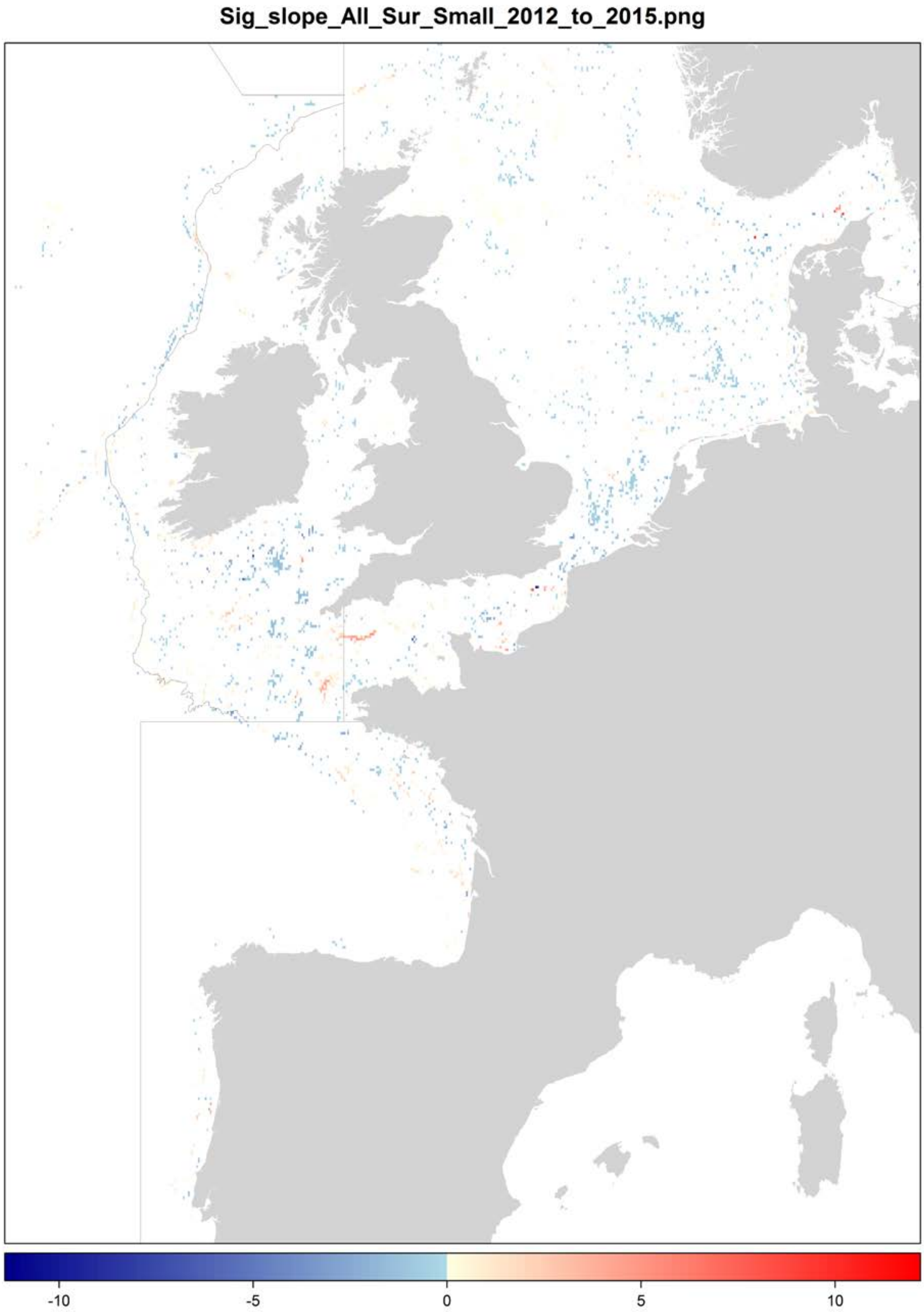


Fig. 5.6.3.6: Surface swept area ratio trend map. Plot of the slope of the trend (only significant with a confidence interval of 95%) for the time period 2012-2015.

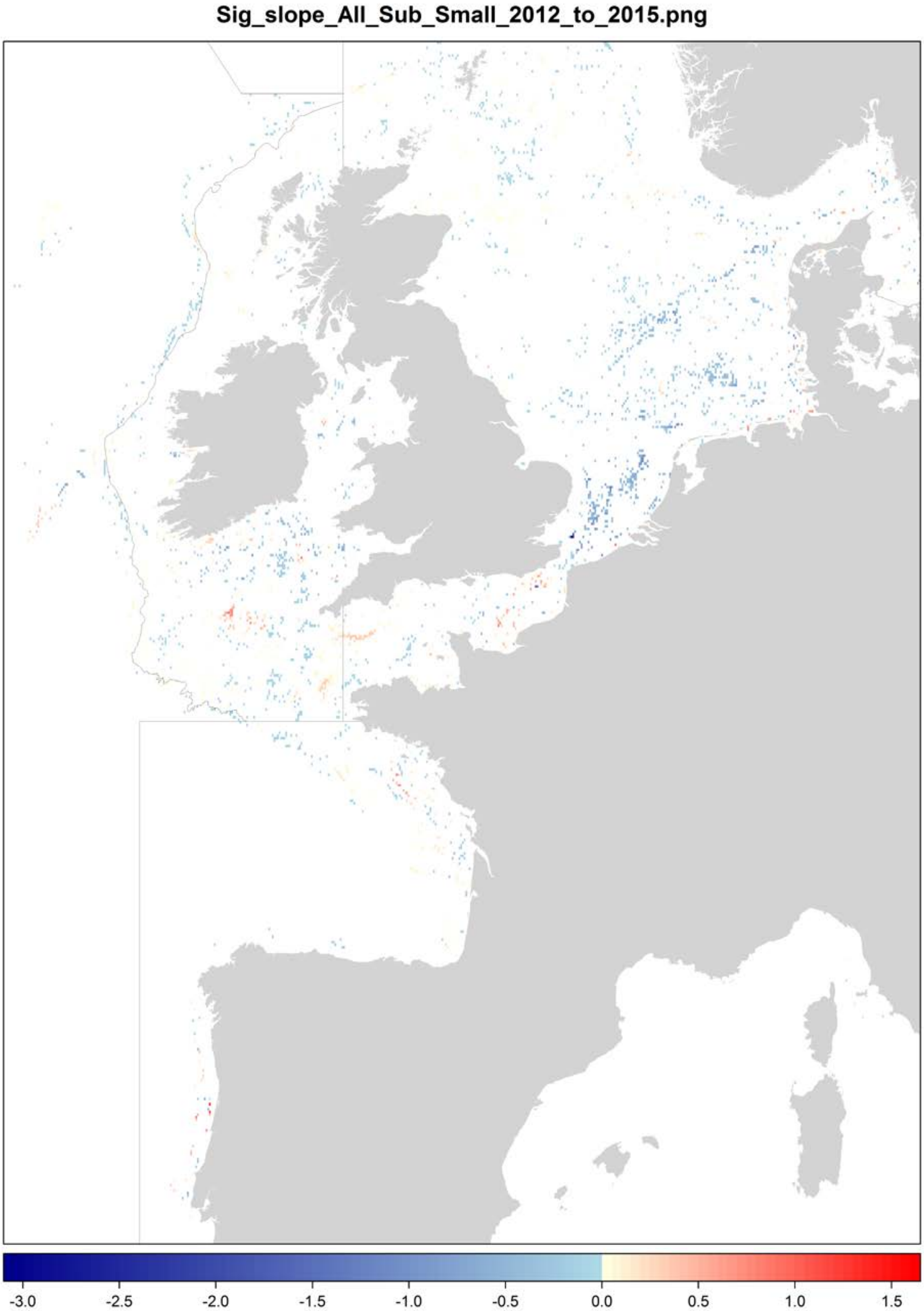


Fig. 5.6.3.7: Subsurface swept area ratio trend map. Plot of the slope of the trend (only significant with a confidence interval of 95%) for the time period 2012-2015.

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 lower 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

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

1) AIS can be used in supporting spatial analysis of fisheries 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 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[1]sampling rate and spans through a year period, from 1st October 2014 to 30th 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 to identify 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 (Fig. 5.6.5.1).

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1 In signal processing decimation is the process of the reducing the sampling rate of sa ignal. AIS data have 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 minutes.

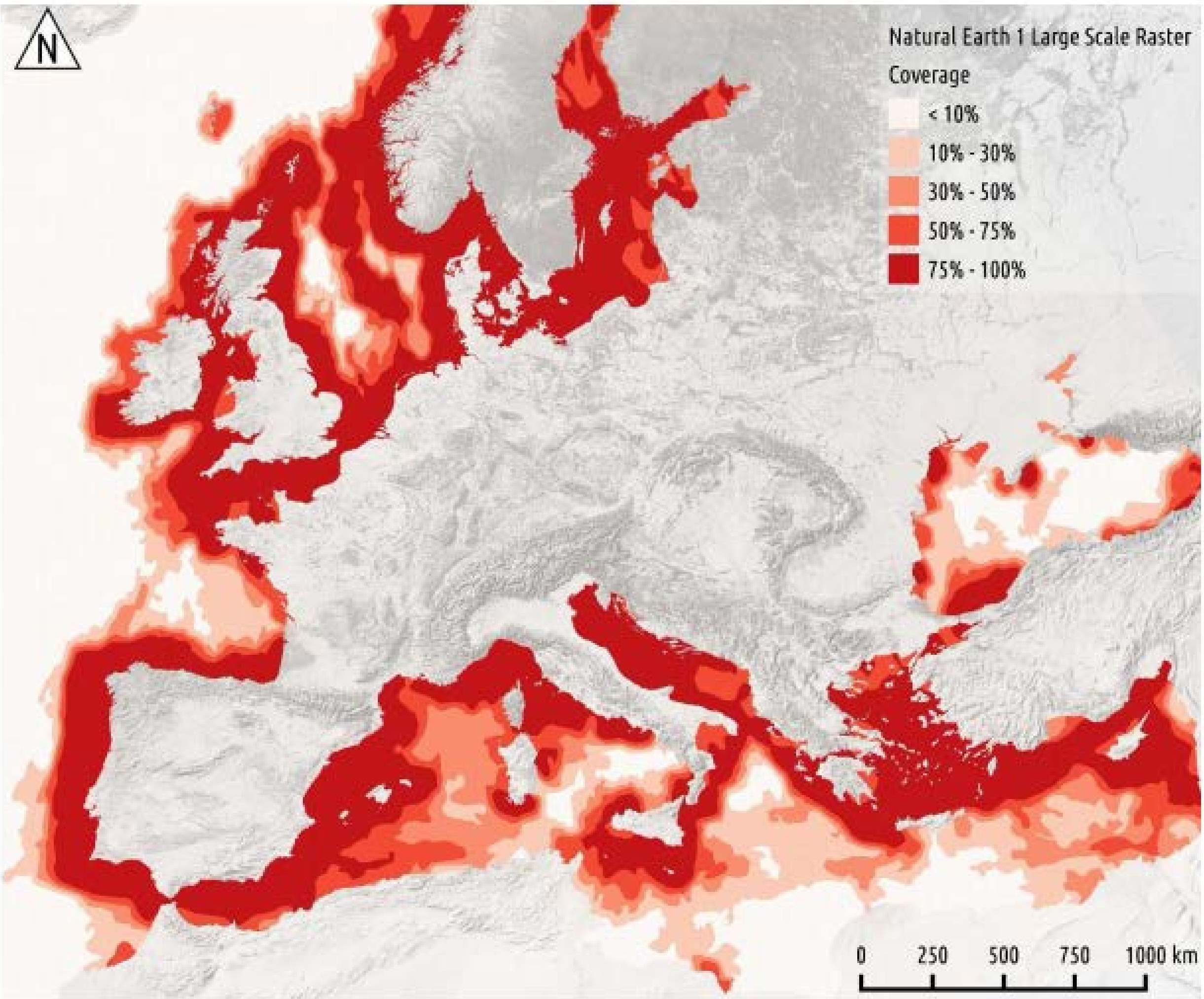

Figure 5.6.5.1 - Spatial coverage and reliability of AIS data, image from (Vespe et al. 2016)

5.6.5.2 Effort calculation using AIS data information

The AIS dataset described in the previous chapter comprised six trawled gears, at DCF level 4: such level does not contain any information on the target species or mesh size. The Terms of Reference for the data call issued 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 algorithm.

However there are some little 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[2].

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 (please refer to the Appendix for Maps ans Graphs and statistical analysis) as:

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2 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.

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.

5.6.5.3 Issues in the comparison of Effort calculated with AIS and VMS data

AIS estimated effort was then compared to the effort calculated using VMS and Logbook data. Effort calculated on VMS data was obtained through VMStools (Hintzen et al. 2012): a successful software used for the calculation of effort by Member States in the ICES[3].Every effort calculation is biased by a series of arbitrary choices dictated by common sense or domain expert knowledge. Such arbitrary choices[4] are either taken in the data preparation phase or implemented in the softwares 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 vessel power 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 per fishing hours[5]. When using VMS data such information is obtained from logbook data[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.

The complications presented forced to transform the AIS and VMS effort using 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 for the overlapping c-squares of AIS and VMS effort. In spatial terms the AIS effort captures the spatial extent of VMS effort. 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 comparison demonstrated that AIS is of support to spatial fisheries as it can improve the spatial resolution of fishing effort, it provides a reliable measure of the spatial extent of fishing effort for the large fleet. When observing absolute values AIS effort tends to be lower than VMS[7]. Only for OTB effort AIS data max is higher than the VMS data. 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 of more than 15 meters. However, it is the combination of the two datasets that would allow a precise effort estimation: while VMS data con-

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3 Unfortunately, the AIS dataset could not be used in VMStools as the software was not capable of managing the dataset size.

4 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.

5 Fishing hours was preferred to Fishing days. As the allocation of effort to a day is not unique and uniform among the member states.

6 Even logbook information is different among member states. In Sweden for example, logbook contain information soaking for passive gears.

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

tains 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 subject to confidentiality issues to fisheries scientist upon negotiation.

Effort data is submitted at EU fleet level yearly by member states to the EU data framework collection in two occasions for the FDI data call (Fisheries Dependent Information) and the Economic Data call of the European Data Collection Framework (DCF). DCF data is submitted at ICES rectangle level, which is too coarse to allow for any detailed analysis. The introduction of the Marine Strategy Framework Directive (Directive 2008/56/EC) and its need to assess the importance of fisheries on the marine ecosystems fueled the search for better resolution effort estimation and for data not subjected to confidentiality issues as VMS data is. AIS estimated effort represents a dramatic improvement in spatial resolution compared to the DCF data that are at ICES rectangle level (ICES 2015).

The results of the comparison highlighted the urgent need for a EU wide agreed and harmonized effort calculation that will allow in the future to directly compare effort estimations among member states. The standardization of practices. definitions and methodologies have been has been the main objective behind the two workshops on transversal variables promoted by PGECON and with DGMARE support (Castro et al. 2015 and 2016).

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

Term of reference

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 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	Cover-age
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 nota-tion of (0.05x0.05 de-gree 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 5 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 sea-bed 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): $\boldsymbol{SA = \sum evw}$,

For Danish seines (SDN_DMF): $\boldsymbol{SA = \sum(pi * (w/2pi)^\wedge 2 * (e/2.591234))}$,

For Scottish seines (SSC_DMF): $\boldsymbol{SA = \sum(pi * (w/2pi)^\wedge 2 * (e/1.9125) * 1.5)}$,

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:

$\boldsymbol{SAR = SA/CA}$,

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).

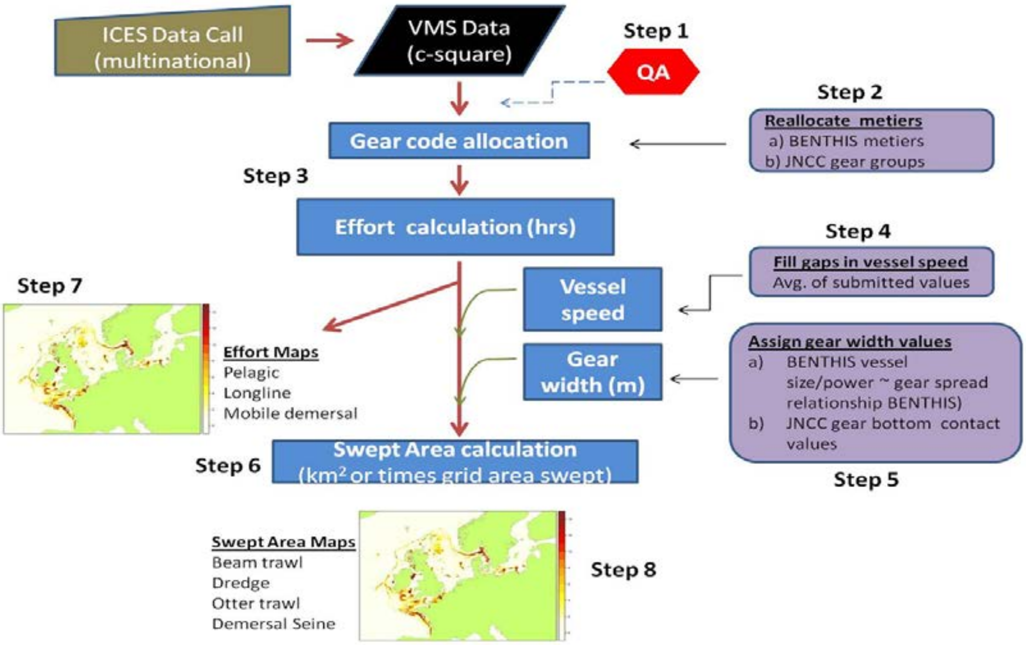


Figure 5.8.1.1. Workflow for production of fishing effort and swept area maps from aggregated VMS data (0.05°x0.05° C-square resolution) (from ICES 2015).

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

Gear class	Benthis metier	Model	Average gear width (m)	Subsurface proportion (%)	Fishing speed (knots)
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 represents not necessarily the prevailing habitat of the grid cell

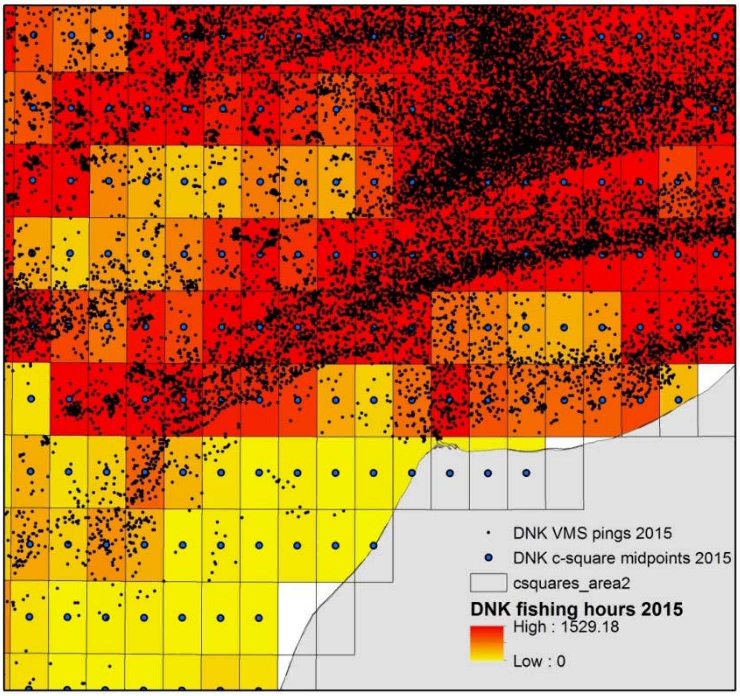


Figure 5.8.2.1. Spatial distribution of VMS pings from the Danish fleet recorded in a small area at the Danish North Sea coast in 2015. Pings are shown in relation to the respective swept area ratio grid cell estimates (0.05°x0.05°) Blue dots represent c-square midpoints.

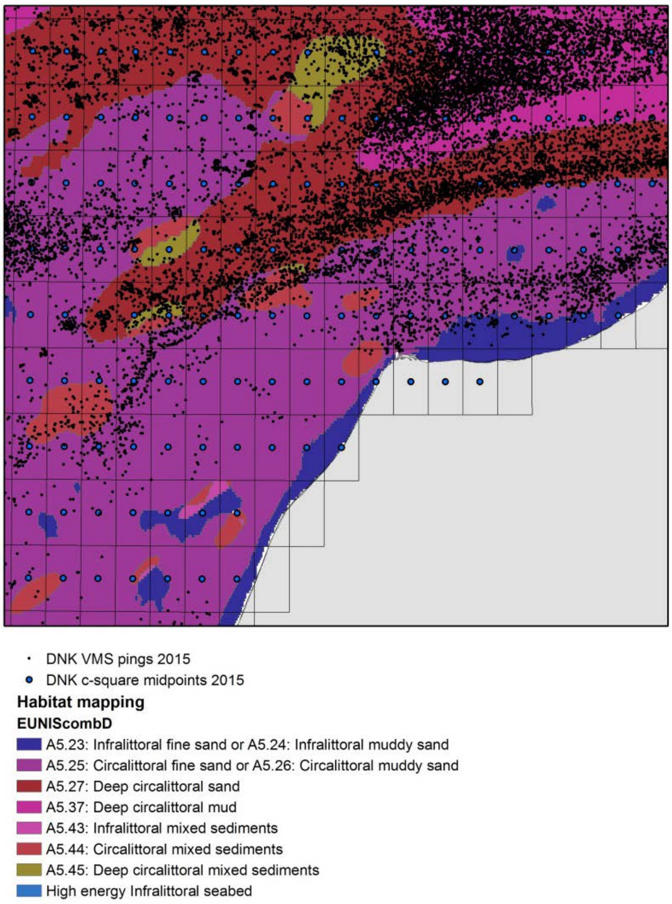


Figure 5.8.2.2. Spatial distribution of VMS pings from the Danish fleet recorded in a small area at the Danish North Sea coast in 2015. Pings are shown in relation to the underlying habitat (EUNIS level 3) and the c-square border-lines (0.05°x0.05°). Blue dots represent c-square midpoints.

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.

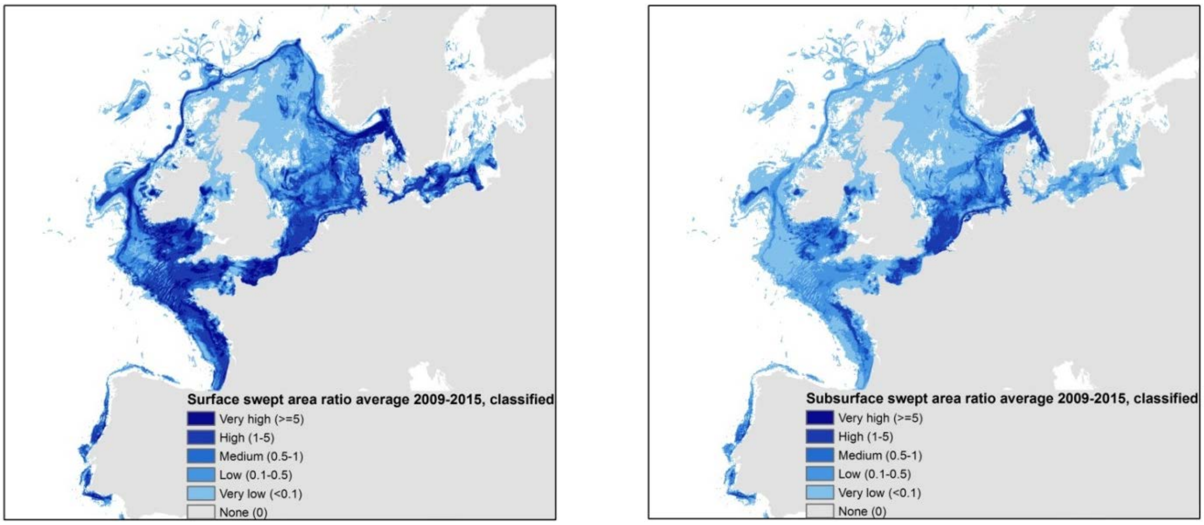


Figure 5.8.3.1. Surface (left) and subsurface (right) abrasion from bottom-contacting fishing gears classified into five categories (from very low to very high) based on swept area ratio estimates.

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.

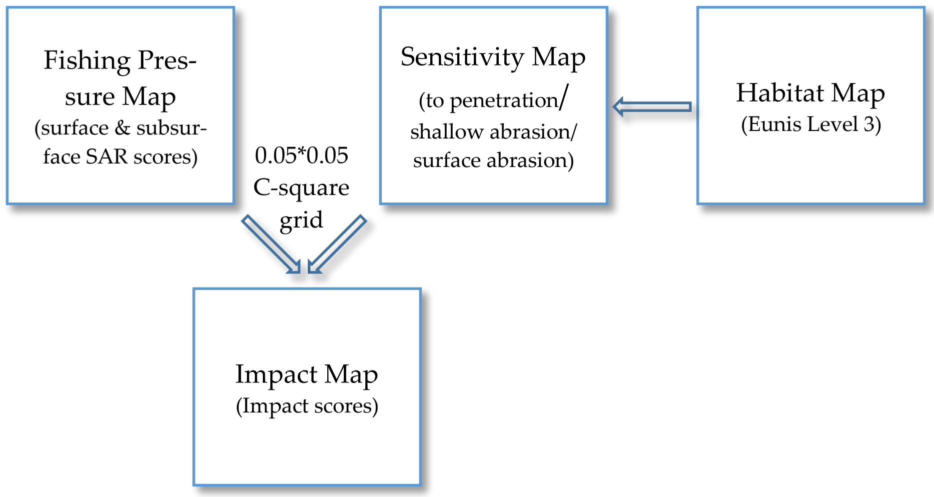


Fig. 5.8.3.2. Conceptual diagram describing how categorical impact scores were estimated from the overlay between habitat and the respective sensitivity maps and the fishing pressure maps (expressed as surface or subsurface SAR).

	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

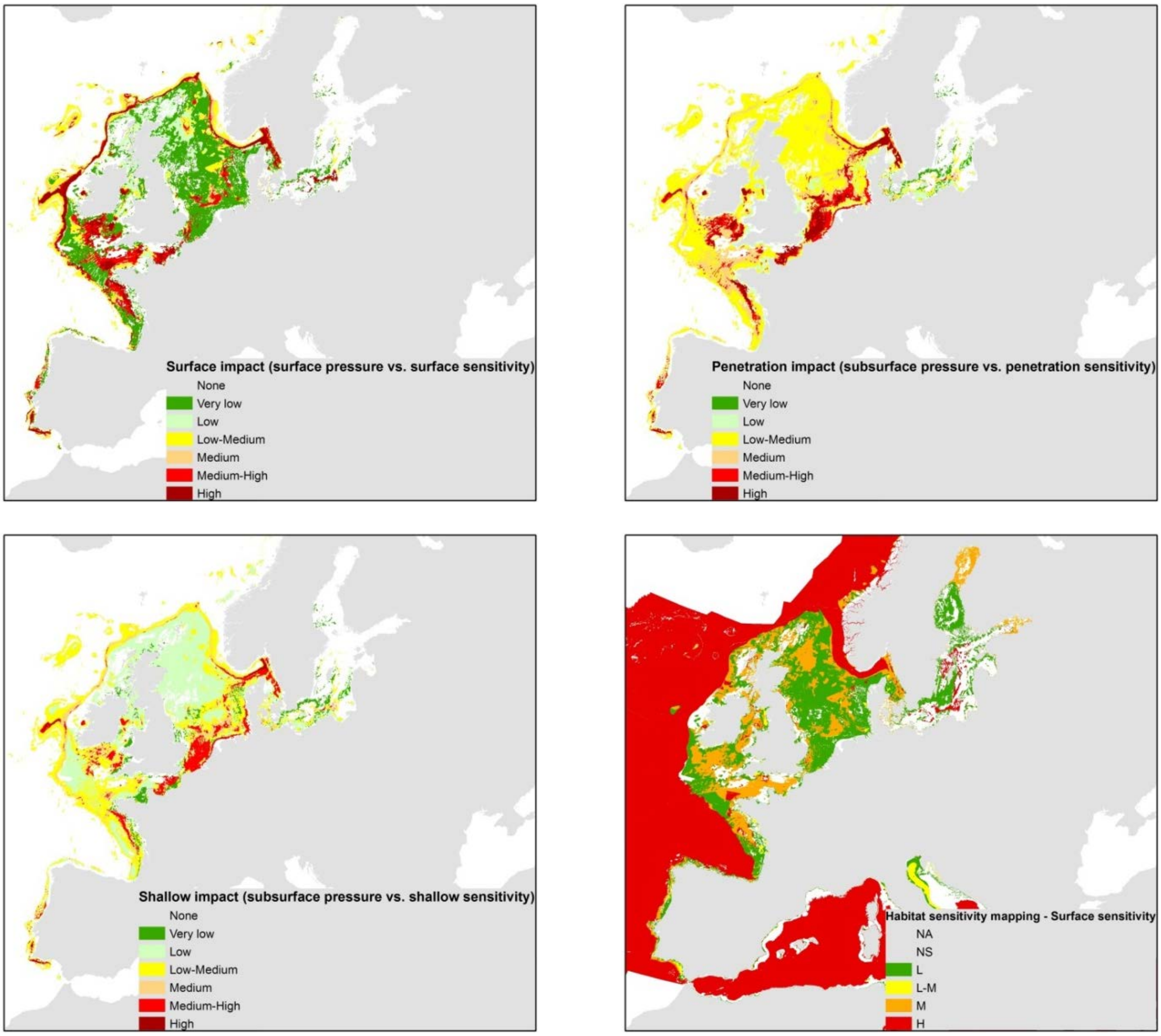
Figure 5.8.3.3. Impact matrix relating five fishing pressure levels to four sensitivity levels (surface abrasion).

	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.



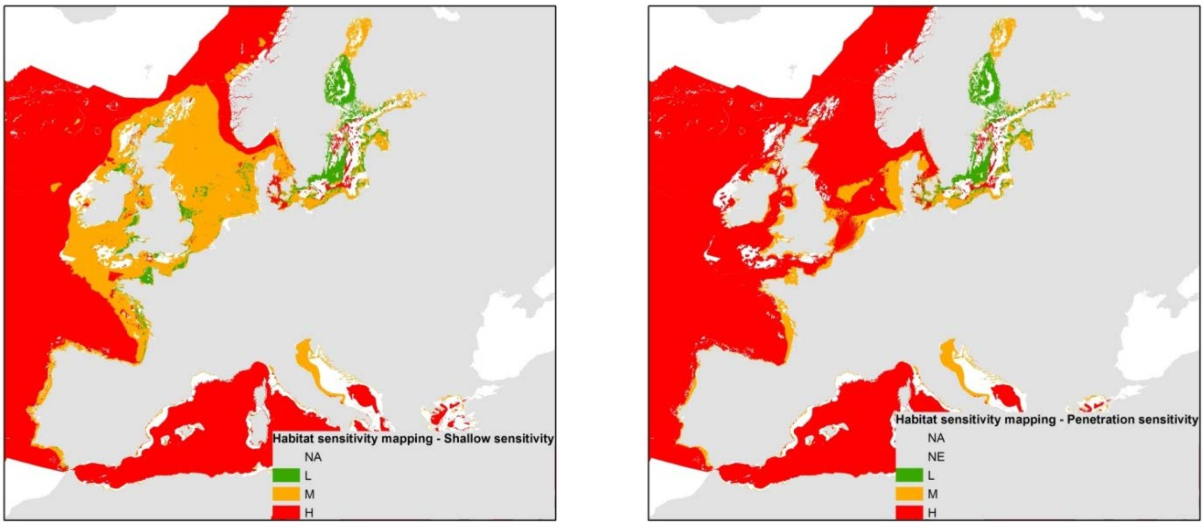
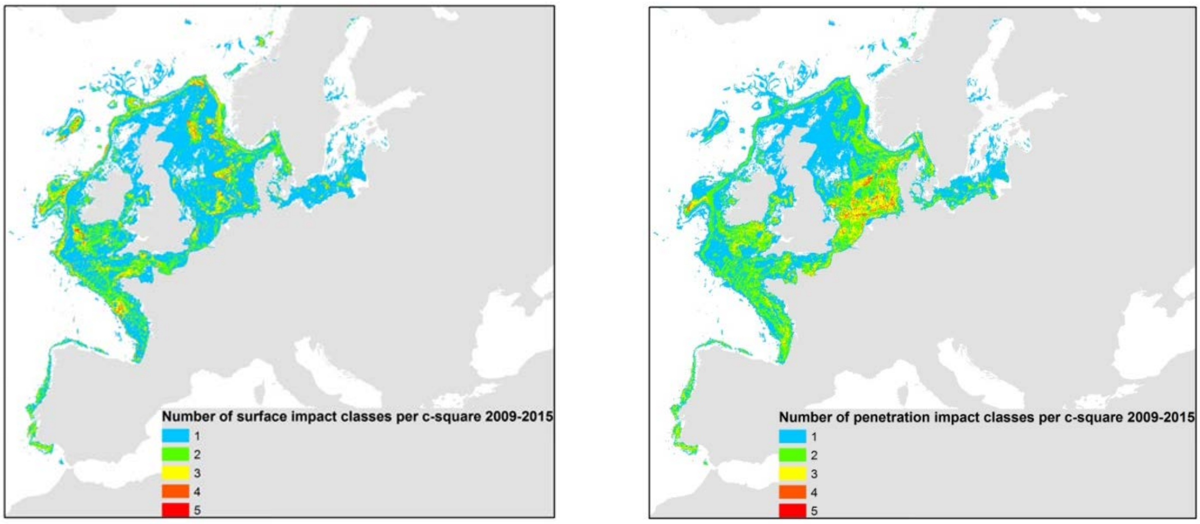


Figure 5.8.3.5. Fishing impact scores (left panels) resulting from the combination of swept area ratio categories (Figure 5.8.3.1) and the habitat sensitivity (right panels) to surface abrasion (upper panels), shallow abrasion (central panels) and penetration (lower panels).

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.



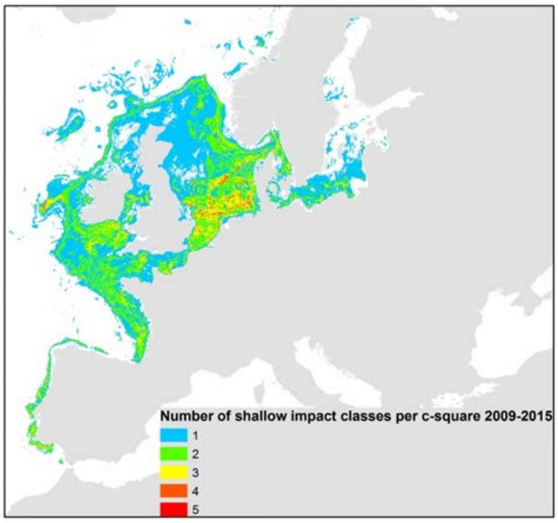


Figure 5.8.3.6. Temporal variability in fishing impact scores caused by surface abrasion (upper left), shallow abrasion (upper right) and penetration (lower left) over the seven year time period (2009-2015). Variability is expressed as the number of different impact classes found within each grid cell.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

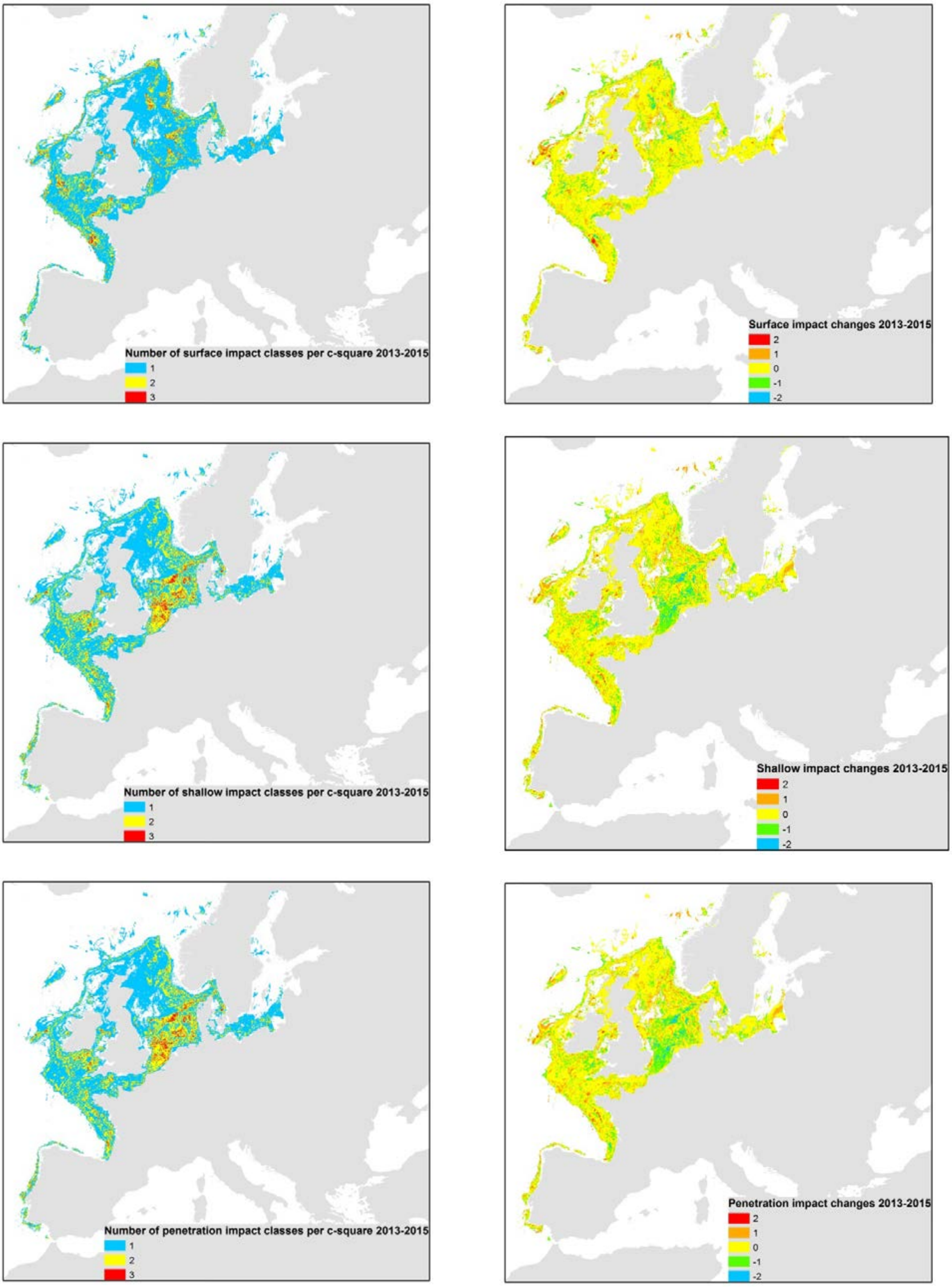


Figure 5.8.3.7. Temporal variability in fishing impact scores caused by surface abrasion (upper panels), shallow abrasion (central panels) and penetration (lower panels) from 2013 to 2015. Variability is expressed as the number of different impact classes found within each grid cell (left panels), as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

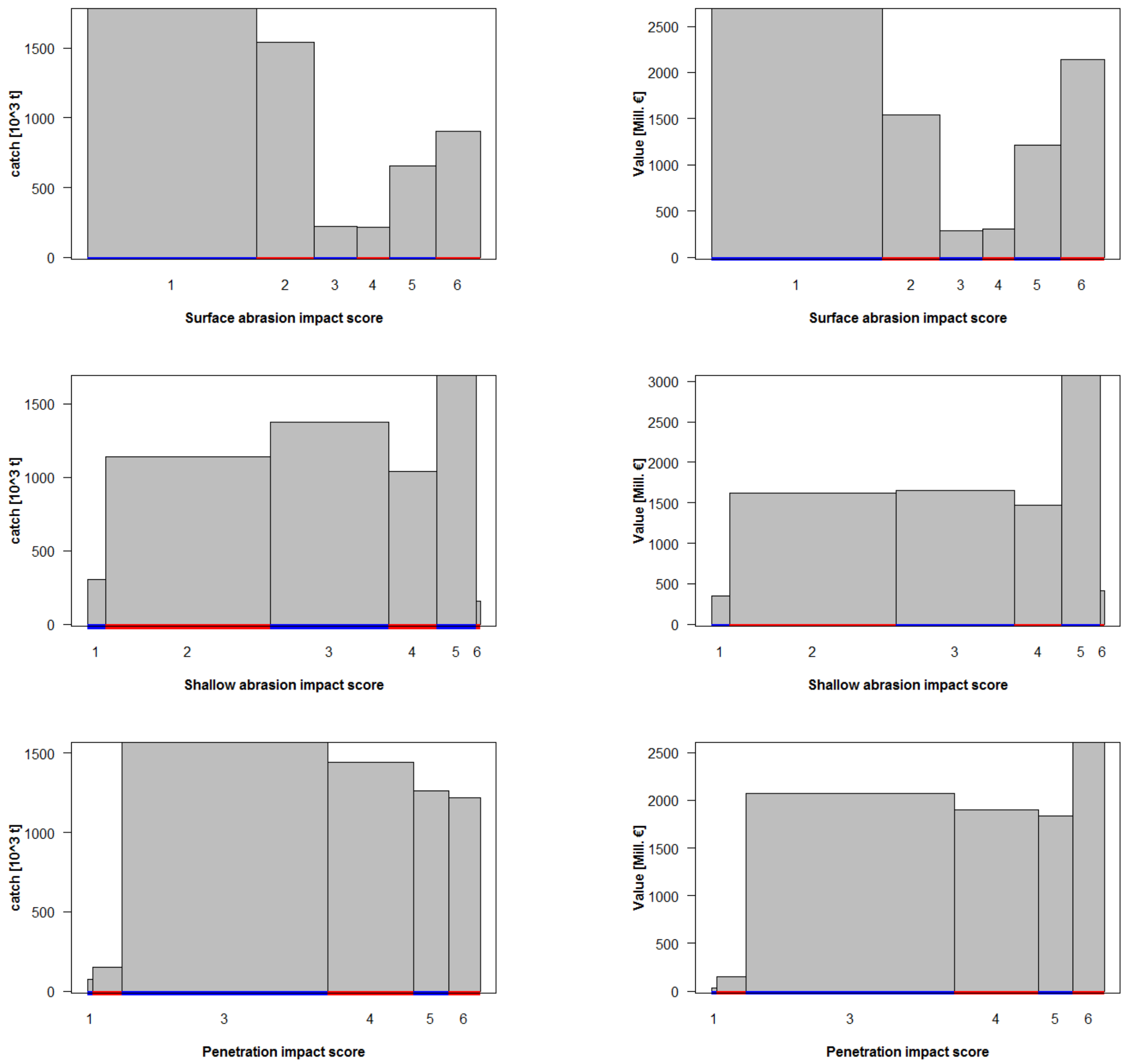


Figure 5.8.3.8. Fisheries catch (in 1000t, left panels) and value (in Mill. €, right panels) from grid cells with the same impact score. Bar width corresponds to the number of grid cells with the respective impact score. Impact Scores correspond to 1 – very low, 2 – low, 3 – low-medium, 4 – medium, 5 – 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).

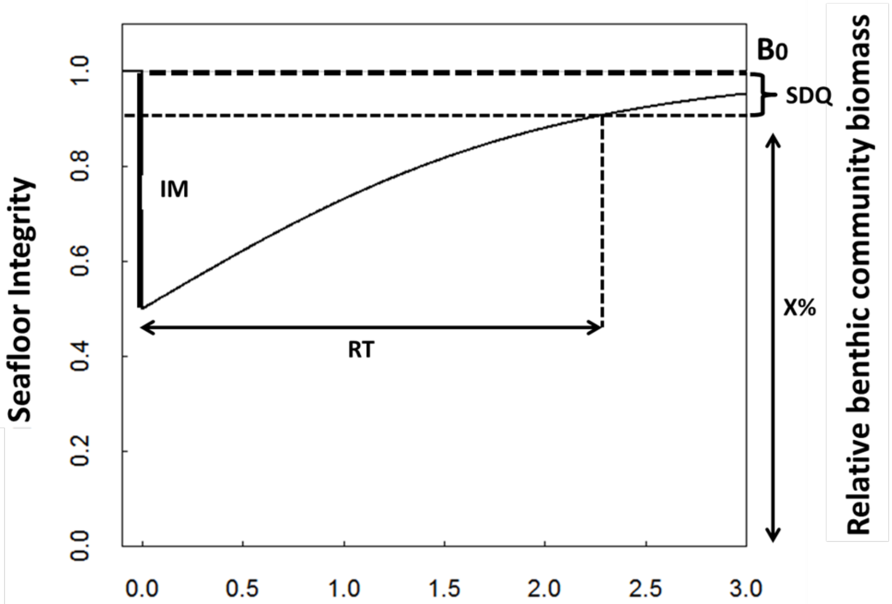


Figure 5.8.5.1 Decrease in benthic biomass following the mortality imposed by a trawling event and the subsequent recovery to the carrying capacity B0. The relative biomass can be used as an indicator of the Seafloor Integrity. IM denotes the proportion at which the biomass is reduced by a trawling event. 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

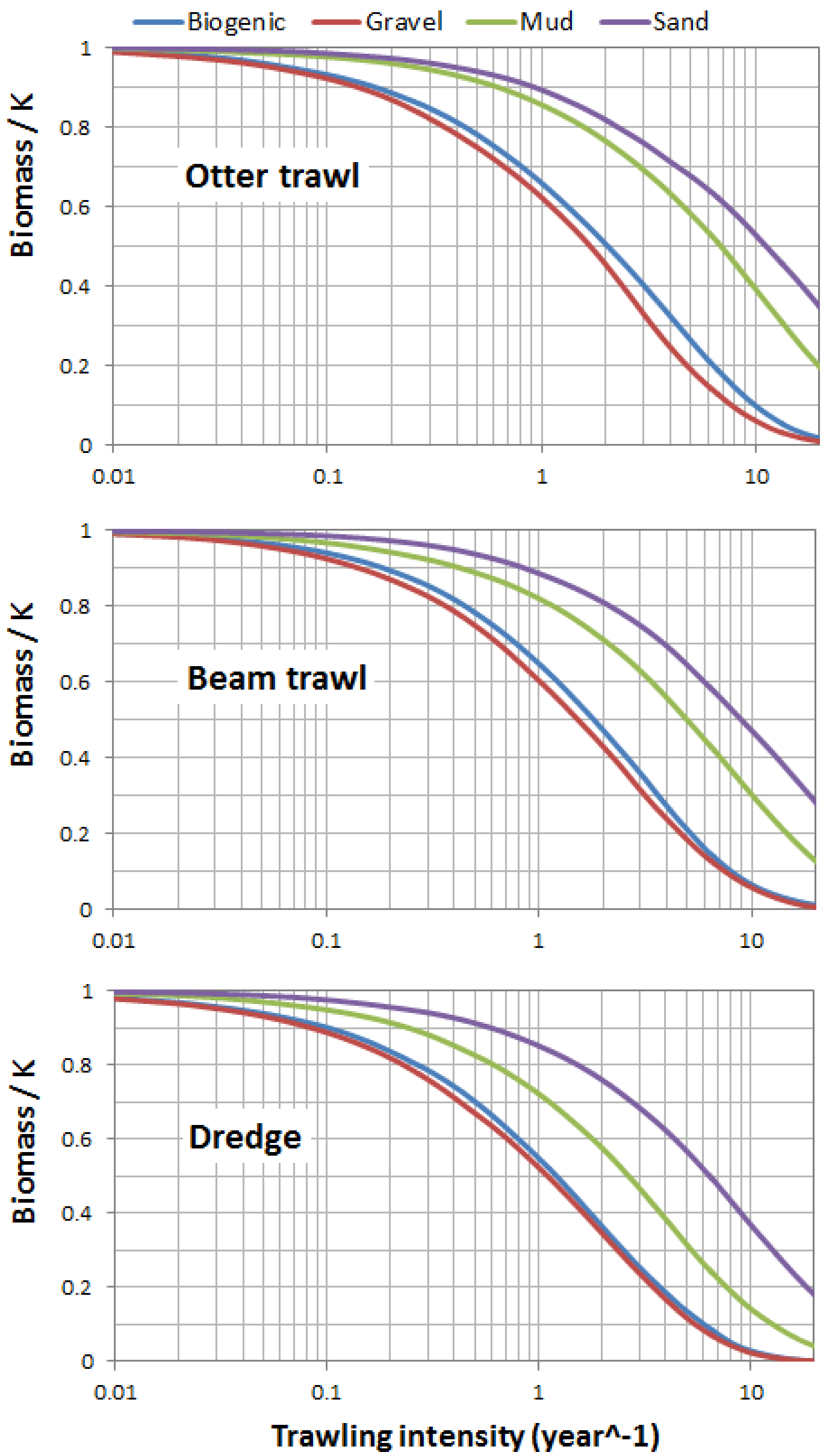


Figure 5.8.5.2. State of the seafloor, i.e. Seafloor Integrity (Biomass / K), at different trawling intensities for three trawling gears (Otter trawl, Beam trawl and Dredge) and four habitats.

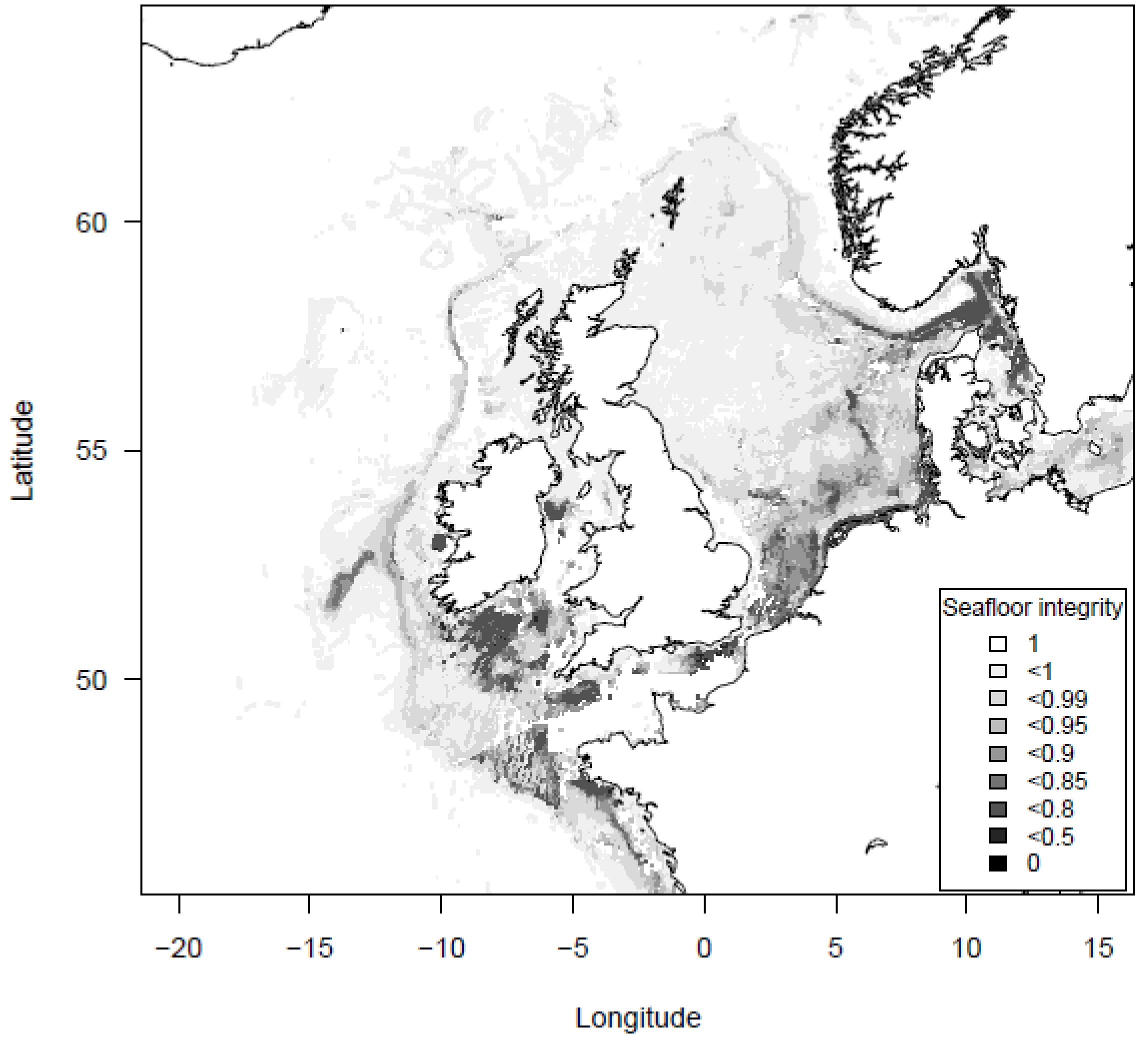


Figure 5.8.5.3. Equilibrium biomass (B/K) remaining in the Greater North Sea given the mean annual subsurface bottom trawling intensities observed between 2009-2015.

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) $B \sim a + b_1 L + H + b_2 L{*}H + b_3 F + b_4 F{*}H + \varepsilon_1 +$

random(station intercept and slope) + ε_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

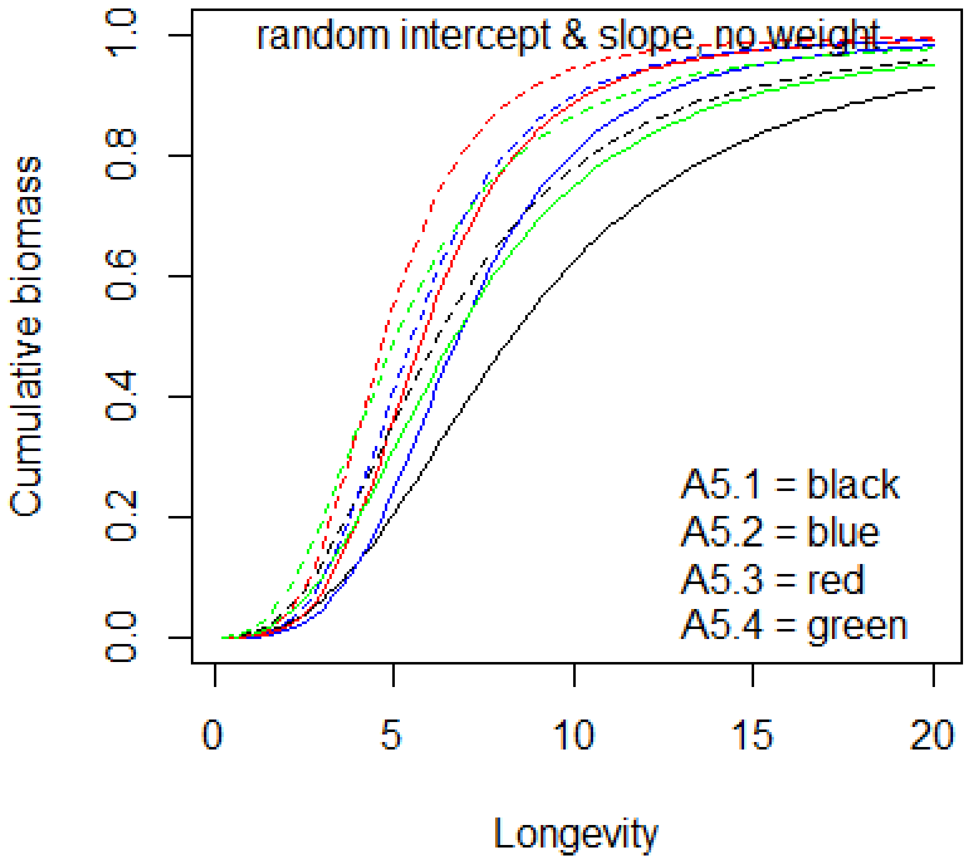


Figure 5.8.5.4. Cumulative biomass in relation to the longevity of the taxa for four EUNIS-3 habitats: sublittoral coarse sediment (A5.1); sublittoral sand (A5.2); sublittoral mud (A5.3); sublittoral mixed sediments (A5.4) for two levels of trawling pressure (full line - un-fished, dashed line - trawled 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.

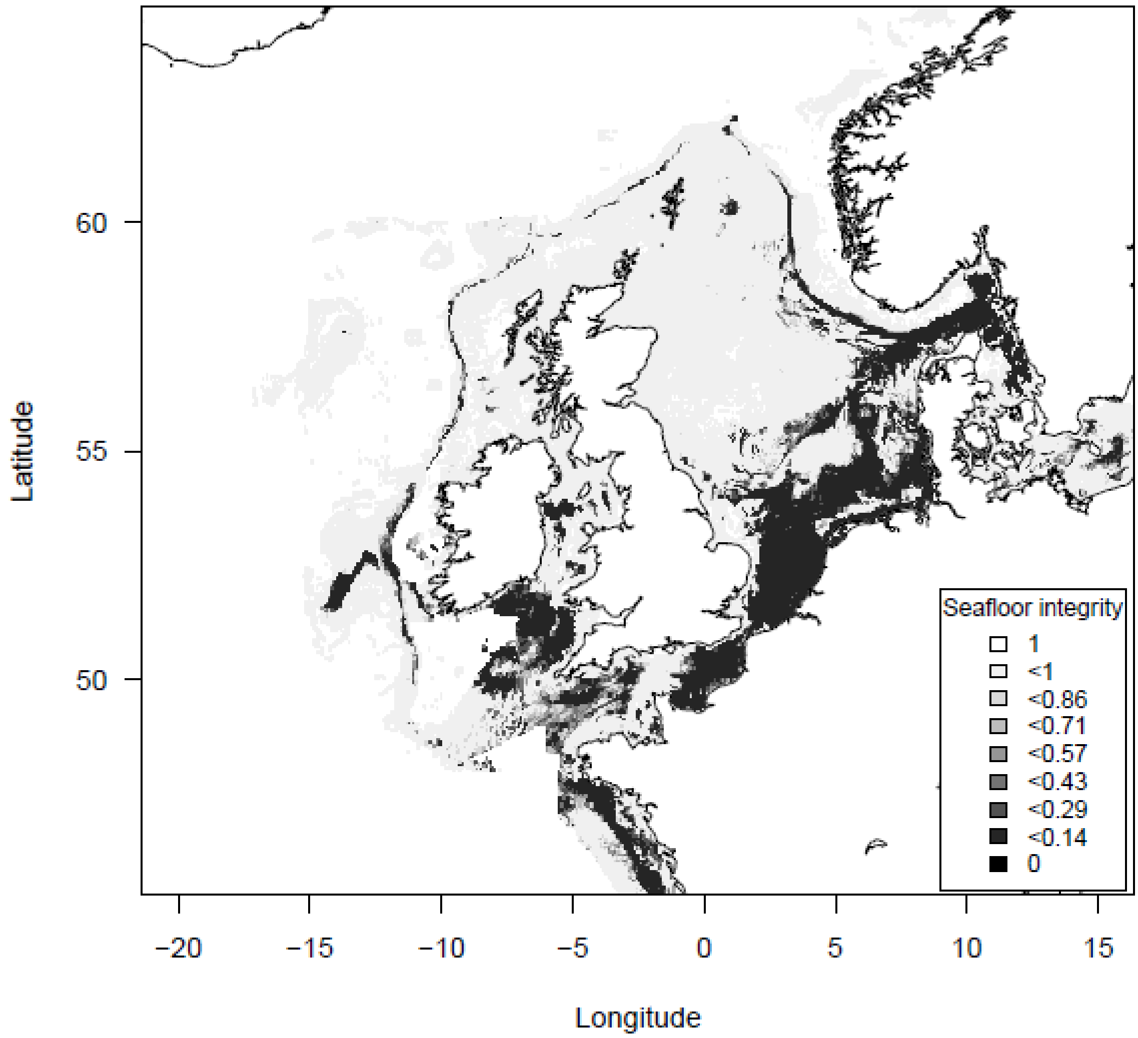


Figure 5.8.5.5. Seafloor integrity in the Greater North Sea estimated using the longevity distribution by habitat and the mean annual subsurface bottom trawling intensities observed between 2009-2015.

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 (fig. 5.9.1).

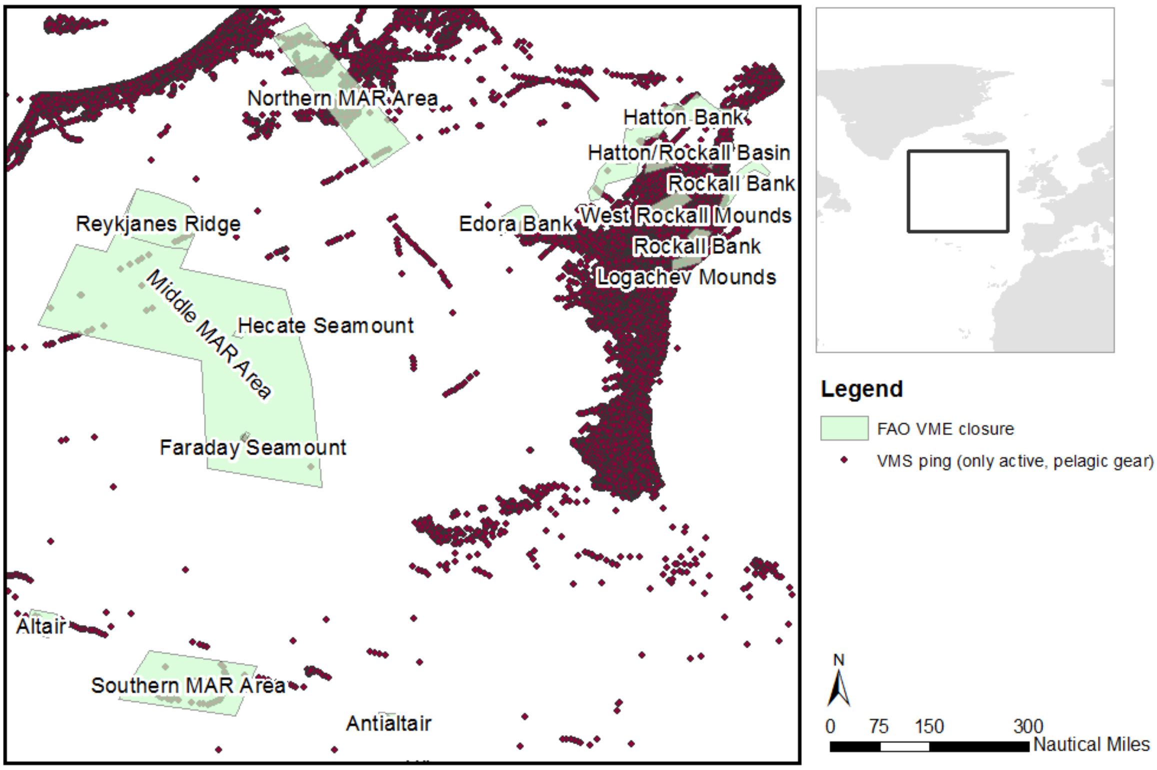


Figure 5.9.1: Distribution of positions of vessels with active, pelagic gear registered in and around the VME (Vulnerable Marine Ecosystem) closures, in the NEAFC area, from VMS data.

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 (fig. 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 (fig. 5.9.3).

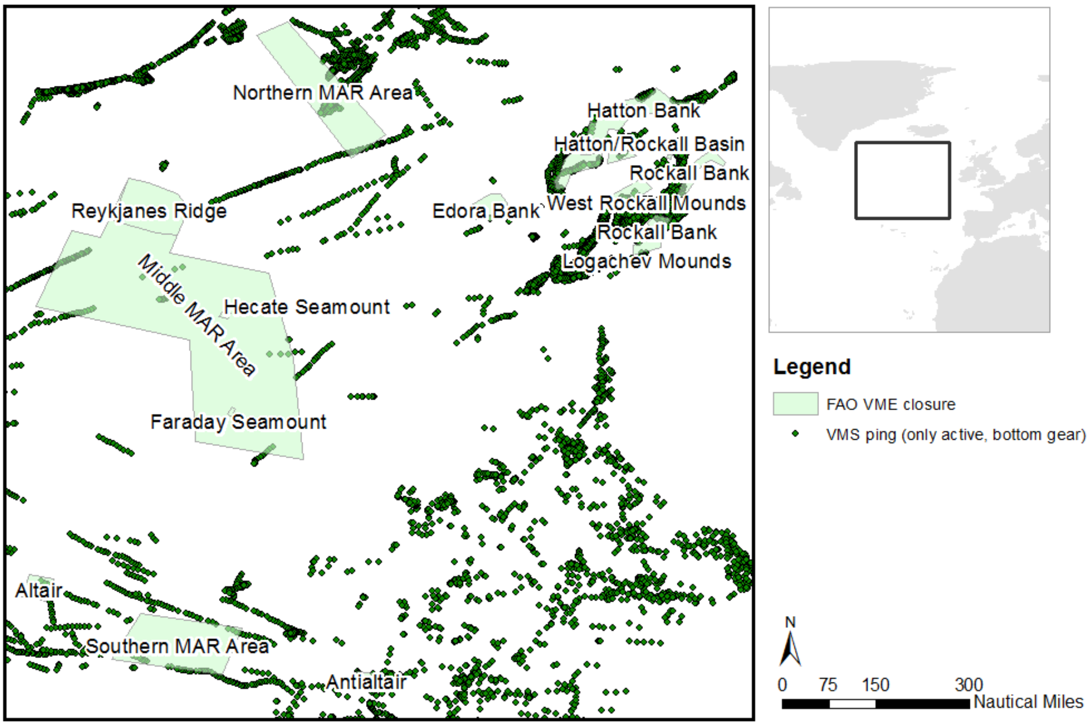


Figure 5.9.2: Distribution of positions of vessels with active, bottom-contacting (demersal) gears registered in and around the VME (Vulnerable Marine Ecosystem) closures, in the NEAFC area, from VMS data (for speeds between 1 and 6 knots).

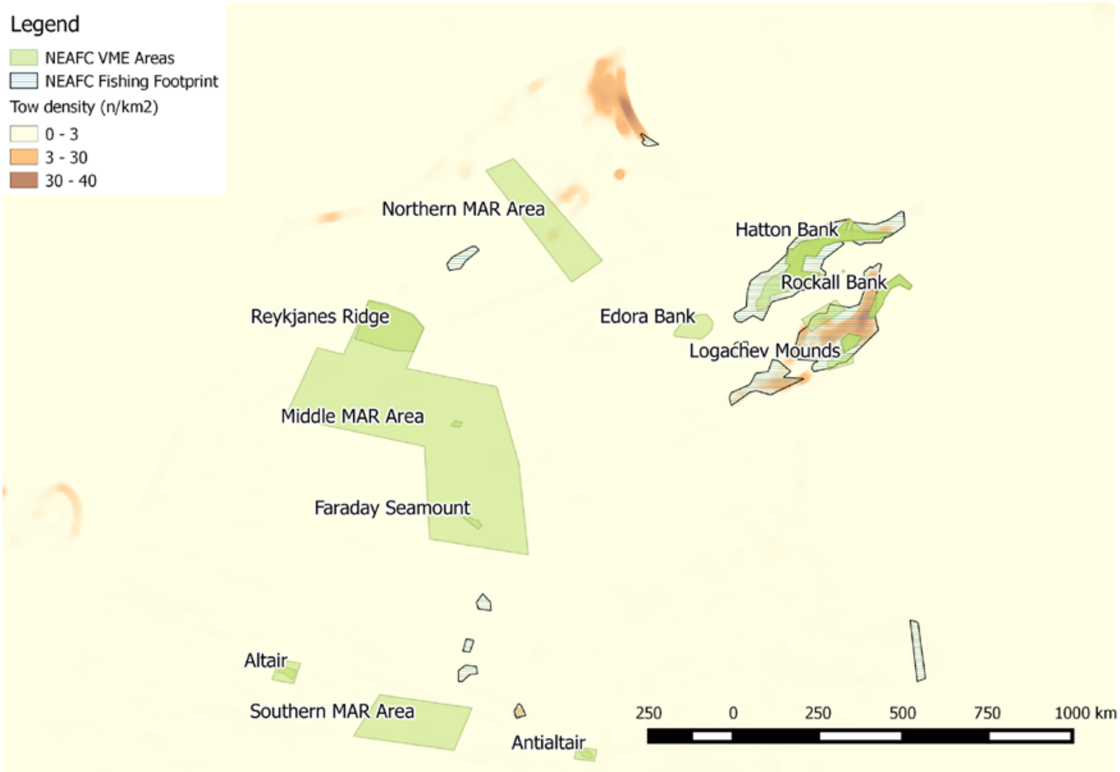


Figure 5.9.3: Distribution of tow density in relation to the NEAFC VME and fishing footprint areas

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.

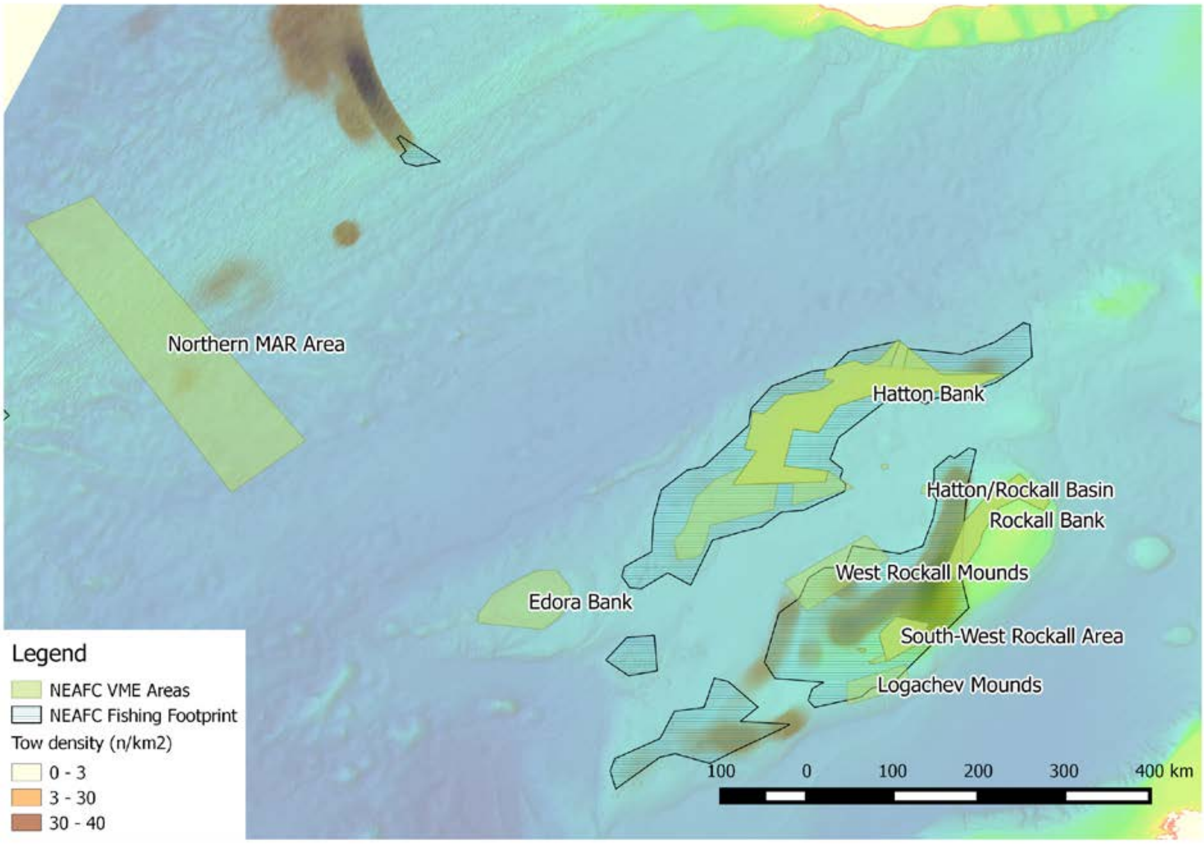


Figure 5.9.4: Distribution of tow density in relation to the NEAFC VME and fishing footprint areas overlaid over the bathymetry, for the Northern MAR area, and Hatton and Rockall banks.

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 (fig. 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).

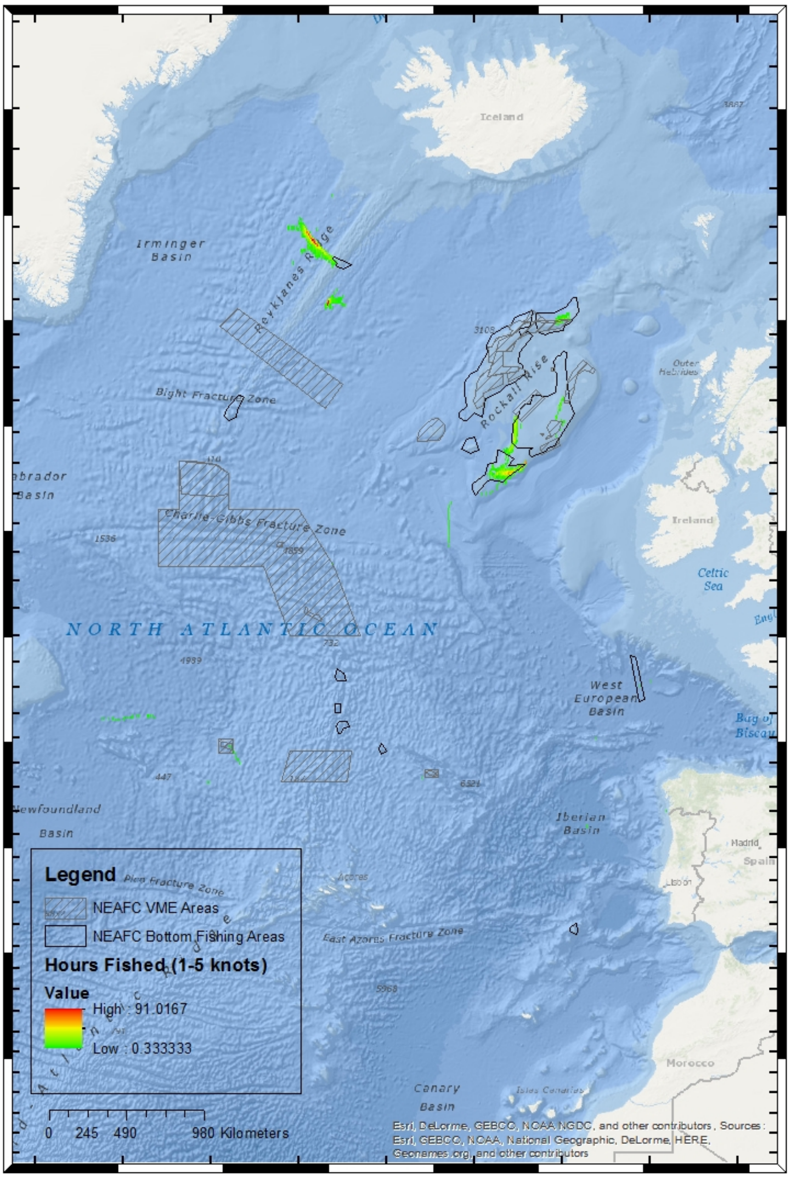


Figure 5.9.5a. Distribution of bottom fishing activity in the NEAFC regulatory area during 2015.

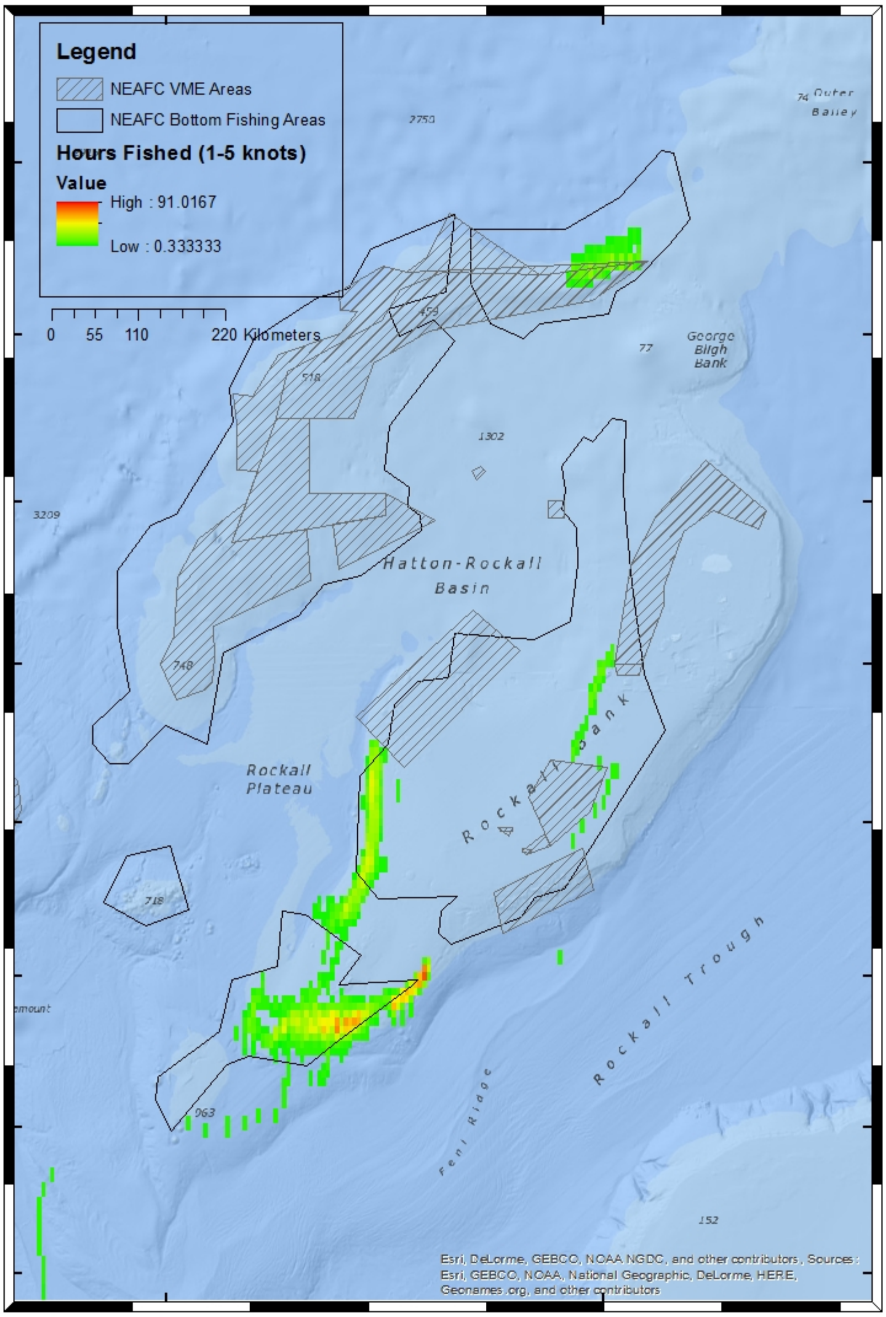


Figure 5.9.5b. Bottom fishing activity at Rockall and Hatton Bank during 2015.

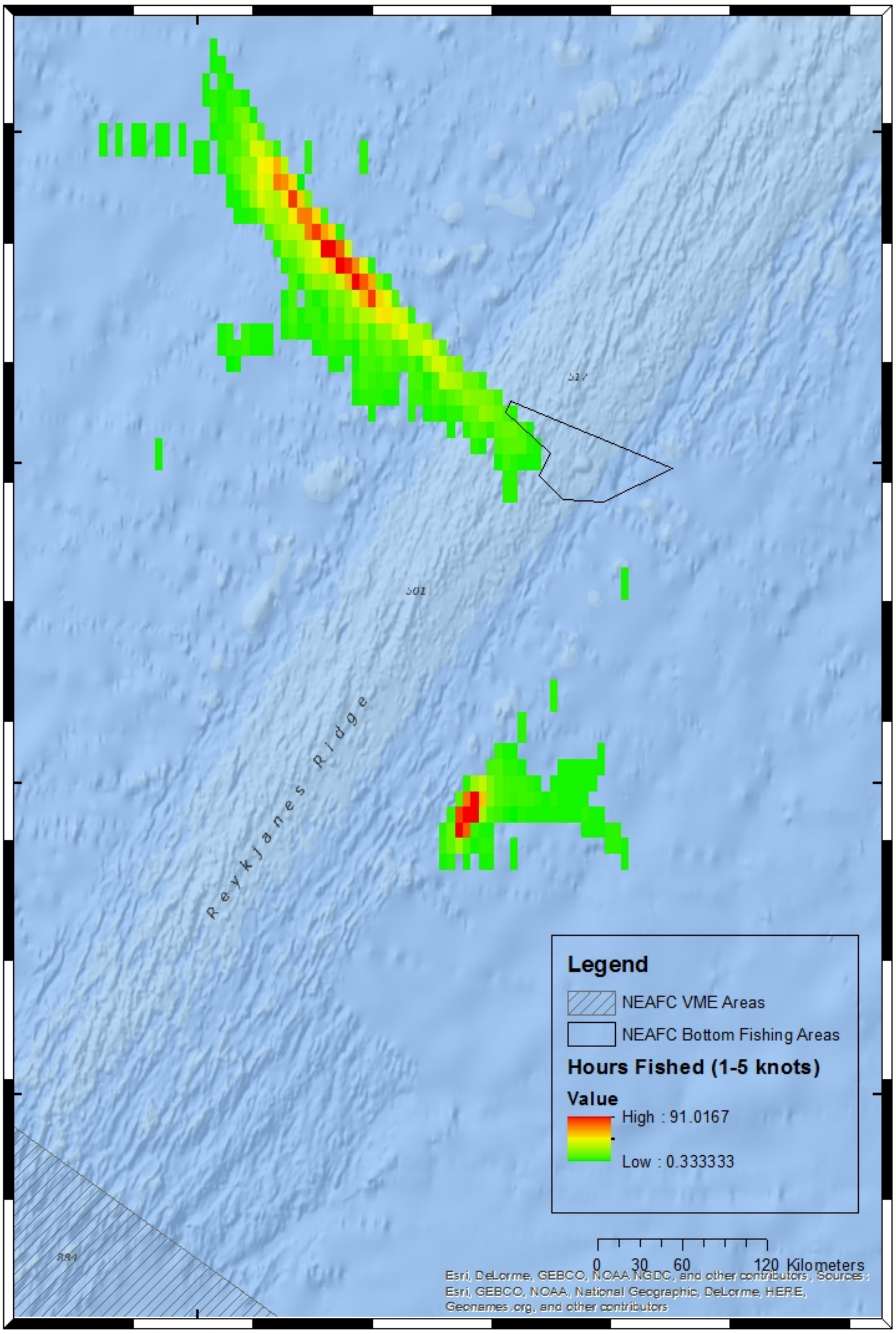


Figure 5.9.5c. Bottom fishing activity at Rockall and Hatton Bank during 2015.

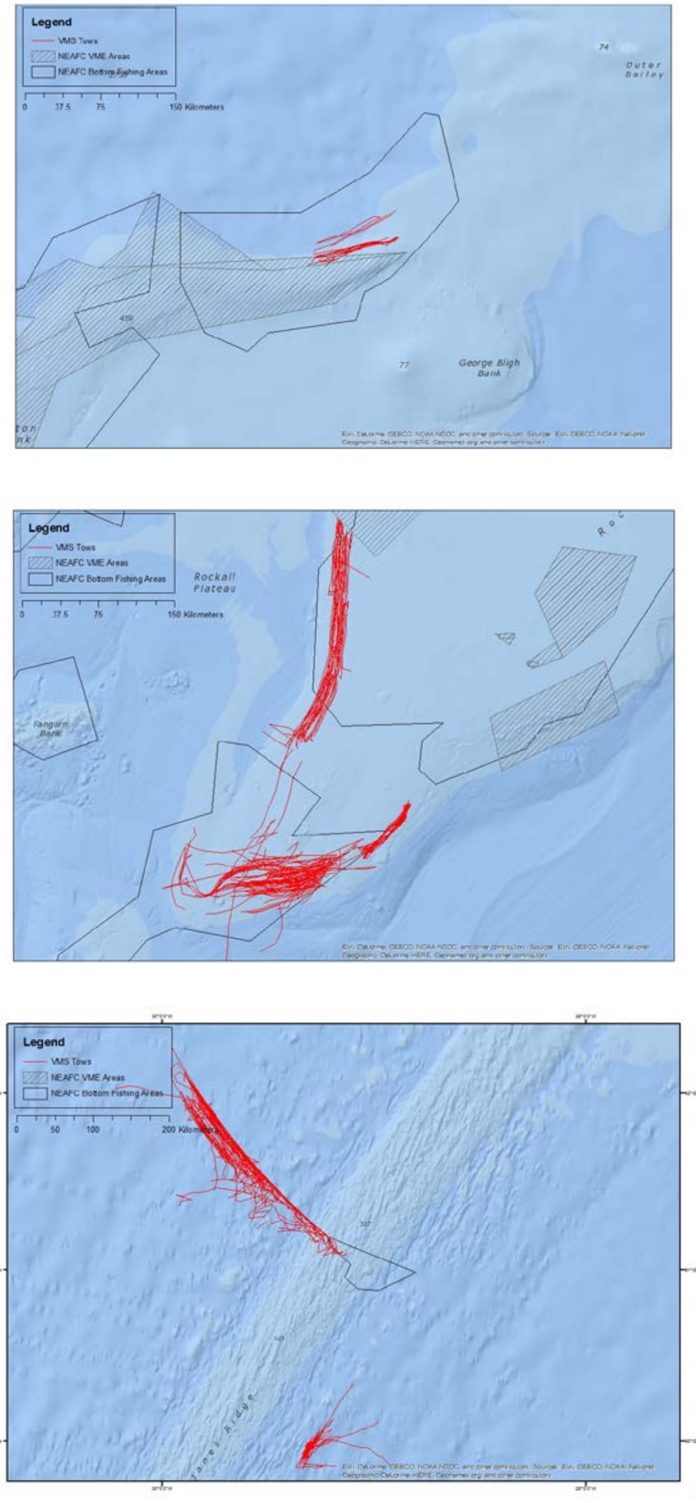


Figure 5.9.6. Direction of tows on Hatton Bank (top), Rockall (Centre) and around the mid-Atlantic ridge (bottom).

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

29 May 13.00 – 2 June 13.00 2017. Hamburg, Germany. Chaired by Niels Hintzen (the Netherlands) and Christian von Dorrien (Germany)

8 References

Bolam SG, Coggan RC, Eggleton J, Diesing M, Stephens D (2014) Sensitivity of macrobenthic secondary production to trawling in the English sector of the Greater North Sea: A biological trait approach. Journal of Sea Research, 85: 162-177.

Castro Ribeiro, C., Holmes, S., Scott, F., Berkenhagen, J., Demaneche, S., Prista, N., Reis, D., Reilly,T., Andriukaitiene, J., Aquilina, M., Avdič Mravlje, E., Calvo Santos, A., Charilaou, C., Dalskov, J., Davidiuk, I.,Diamant, A., Egekvist, J., Elliot, M., Ioannou, M., Jakovleva, I. Kuzebski, E., Ozernaja, O., Pinnelo, D., Thasitis,I., Verlé, K., Vitarnen, J., Wójcik, I. (2015). Report On The Workshop On Transversal Variables (Linking economic and biological effort data call design), 19th -23rd January 2015. JRC Report 27135.

Castro Ribeiro, C., Holmes, S., Scott, F., Berkenhagen, J., Demaneche, S., Prista, N., Reis, D., Reilly,T., Andriukaitiene, J., Aquilina, M., Avdič Mravlje, E., Calvo Santos, A., Charilaou, C., Dalskov, J., Davidiuk, I.,Diamant, A., Egekvist, J., Elliot, M., Ioannou, M., Jakovleva, I. Kuzebski, E., Ozernaja, O., Pinnelo, D., Thasitis,I., Verlé, K., Vitarnen, J., Wójcik, I. (2016). Report of the 2nd Workshop on Transversal Variables. Nicosia, Cyprus., 22-26 February 2016. A DCF ad-hoc workshop EUR, in press.

Collie JS, Hall SJ, Kaiser MJ, Poiner IR (2000) A quantitative analysis of fishing impacts on shelf-sea benthos. Journal of Animal Ecology, 69: 785-798

Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive).

Eigaard OR, Bastardie F, Breen M, et al. (2016) Estimating seabed pressure from demersal trawls, seines, and dredges based on gear design and dimensions. ICES Journal of Marine Science, 73: i27-i43

Fernandez Arguedas V., Pallotta G., Vespe M. (2014) "Automatic generation of geographical networks for maritime traffic surveillance", 17th Int. Conf. on Information Fusion (FUSION).

Hiddink JG, Jennings S., Kaiser MJ, Queiros AM, Duplisea DE, Piet GJ (2006). Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. Canadian Journal of Fisheries and Aquatic Sciences, 63: 721-736

Hintzen NT, Bastardie F, Beare D, Piet GJ, Ulrich C, Deporte N, Egekvist J, Degel H (2012) VMStools: Open-source software for the processing, analysis and visualisation of fisheries logbook and VMS data. Fisheries Research 115–116:31-43

ICES 2014. Second Interim Report of the Working Group on Spatial Fisheries Data (WGSFD), 10-13 June 2014, ICES Headquarters, Copenhagen, Denmark. ICES CM 2014/SSGSUE:05. 102pp.

ICES 2015. Report of the Working Group on Spatial Fisheries Data (WGSFD), 8–12 June 2015, ICES Headquarters, Copenhagen, Denmark. ICES CM 2015/SSGEPI:18. 150pp.

ICES. 2016. Report of the Working Group on Commercial Catches (WGCATCH), 9-13 November 2015, Lisbon, Portugal. ICES CM 2015/SSGIEOM:34. 159 pp.

ISSCFG (1980), International Standard Statistical Classification of Fishing Gear (ISSCFG), 29 July 1980.

Kaiser MJ, Clarke KR, Hinz H, Austen MCV, Somerfield PJ, Karakassis I (2006) Global analysis of response and recovery of benthic biota to fishing. Marine Ecology Progress Series 311:1-14

Lambert GI, Jennings S, Kaiser MJ, Davies TW, Hiddink JG (2014). Quantifying recovery rates and resilience of seabed habitats impacted by bottom fishing. Journal of Applied Ecology, 51: 1326–1336

Natale F., Gibin M., Alessandrini A., Vespe M., Paulrud A. (2015) "Mapping Fishing Effort through AIS Data", PLoS ONE 10(6): e0130746. doi: 10.1371/journal.pone.0130746

Piet GJ, Hiddink JG, Hintzen NT, van der Reijden K, Rijnsdorp AD. A risk-based approach for ecosystem-based fisheries management aimed at conserving seafloor integrity. In preparation

Pitcher CR, Ellis N, Jennings S, Hiddink JG, et al. A simple quantitative risk assessment method for estimating the sustainability risk of trawl and dredge impacts on seabed habitats; applicable to many data-poor fisheries. In prep.

Rees T (2003) "C-Squares", a New Spatial Indexing System and its Applicability to the Description of Oceanographic Datasets. Oceanography 16:11-19

Rijnsdorp AD, Bastardie F, Bolam SG, et al. (2016) Towards a framework for the quantitative assessment of trawling impact on the seabed and benthic ecosystem. ICES Journal of Marine Science, 73: i127-i138

Thrush SF, Lundquist CJ, Hewitt JE (2005). Spatial and temporal scales of disturbance to the seafloor: A generalized framework for active habitat management. American Fisheries Society Symposium, 41: 639-649

van Denderen PD, Hintzen NT, Rijnsdorp AD, Ruardij P, and van Kooten T (2014) Habitat-Specific Effects of Fishing Disturbance on Benthic Species Richness in Marine Soft Sediments. Ecosystems, 17: 1216-1226

van Denderen PD, Bolam SG, Hiddink JG, et al. (2015) Similar effects of bottom trawling and natural disturbance on composition and function of benthic communities across habitats. Marine Ecology Progress Series, 541: 31-43.

Vespe M., Gibin M., Alessandrini A., Vespe M., Mazzarella, F., Osio G (2016). "Mapping EU fishing activities using ship tracking data". ArXiv:1603.03826. Doi:10.1080/17445647.2016.1195299.

Annex 1: List of participants

Name	Address	Phone/Fax	Email
Francois Bastardie	Charlottenlund Slot Jægersborg Allé 1 2920 Charlottenlund Denmark	+45 35883398	fba@aqua.dtu.dk
Neil Campbell	Marine Scotland Science Marine Laboratory 375 Victoria Road AB11 9DB Aberdeen United Kingdom	+44 (0) 1224 275572	Neil.Campbell@gov.scot
Rabea Diekmann	Thünen Institute (of Fisher-ies Ecology) Palmaille 9 22767 Hamburg Germany	040 38905 135	Rabea.diekmann@thuenen.de
Christian von Dorrien	Thuenen-Institute of Baltic Sea Fisheries Alter Hafen Sued 2 18069 Rostock Germany	+49 381 8116 106	christi-an.dorrien@thuenen.de
Dan Edwards	Joint Nature Conservation Committee, Inverdee House, Torry, Aberdeen, AB11 9QA, UK	+44 7793677536	Dan.edwards@jncc.gov.uk
Josefine Egekvist (Chair)	Charlottenlund Slot Jægersborg Allé 1 2920 Charlottenlund Denmark	+45 35883438	jsv@aqua.dtu.dk
Maurizio Gibin	European Commission Joint Research Centre Institute for the Protection and Security of the Citizen (IPSC) Maritime Affairs Unit TP05A Via Enrico Fermi 2749 I-21027 Ispra (VA)	+39 0332 786770	mauri-zio.gibin@jrc.ec.europa.eu
Genoveva Gonzalez-Mirelis	Institute of Marine Re-search Nordnesgaten 50 5005 Bergen, Norway	+47 55906504	Genoveva.gonzales-mirelis@imr.no
Cristina Vina-Herbon	Joint Nature Conservation Committee, Monkstone House, City Road, Peter-borough, PE1 1JY, UK	00 44 (0) 1733 866912	cristi-na.herbon@jncc.gov.uk
Niels Hintzen	Haringkade 1, 1976CP, Ijmuiden, The Netherlands	+31 317 487090	Niels.hintzen@wur.nl
Irina Jakovleva	Irina Jakovleva Fisheries Service under the Ministry of Agriculture Naujoji uosto str. 8 A Klaipeda Lithuania	+37046310660	Irina.Jakovleva@zuv.lt

Patrik Jonsson	Swedish University of Agricultural Sciences Institute of Marine Research Turistgatan 5 P.O. Box 4 453 21 Lysekil Sweden	+46 733 842283	Patrik.jonsson@slu.se
Maksims Kovsars	Institute of Food Safety, Animal Health and Environment (BIOR) Fish Resources Research Department 8 Daugavgrivas Str. 1048 Riga Latvia		Maksims.Kovsars@bior.lv
Roi Martinez	Pakefield Road Lowestoft Suffolk NR33 0HT United Kingdom	+44 (0) 1502 562244	roi.martinez@cefas.co.uk
Jeppe Olsen	Charlottenlund Slot Jægersborg Allé 1 2920 Charlottenlund Denmark		jepol@aqua.dtu.dk
Carlos Pinto	H. C. Andersens Boulevard 44-46 DK 1553 Copenhagen V Denmark	+45 33386713	carlos.pinto@ices.dk
Perttu Rantanen	Natural Resources Institute Finland (Luke) Itäinen Pitkäkatu 3 20520 Turku Finland	+358 404801606	perttu.rantanen@luke.fi
Yves Reecht	Marine Institute Rinville ORANMORE – Co. Galway H91 R673 Ireland	+353 91 38 7536	Yves.Reecht@marine.ie
Torsten Schulze	Johann Heinrich von Thünen-Institute Institute of Sea Fisheries Palmaille 9 22767 Hamburg Germany	+49 40 38905 117	Torsten.Schulze@thuenen.de
Hans Hagen Stockhausen	Havforskningsinstituttet Postboks 1870 Nordnes 5817 Bergen Norway	+47 489 50 287	hans.hagen.stockhausen@imr.no
Lena Szymanek	National Marine Fisheries Research Institute, Kollataja 1 81-332 Gdynia Poland	+48 58 7356135	lena.szymanek@mir.gdynia.pl
Mathieu Woillez	Ifremer, STH Centre de Brest	+33 (0)2 29 00 85 65	Mathieu.Woillez@ifremer.fr

Technopole de Brest
-Iroise
P.O. Box 70
29280 Plouzané
France

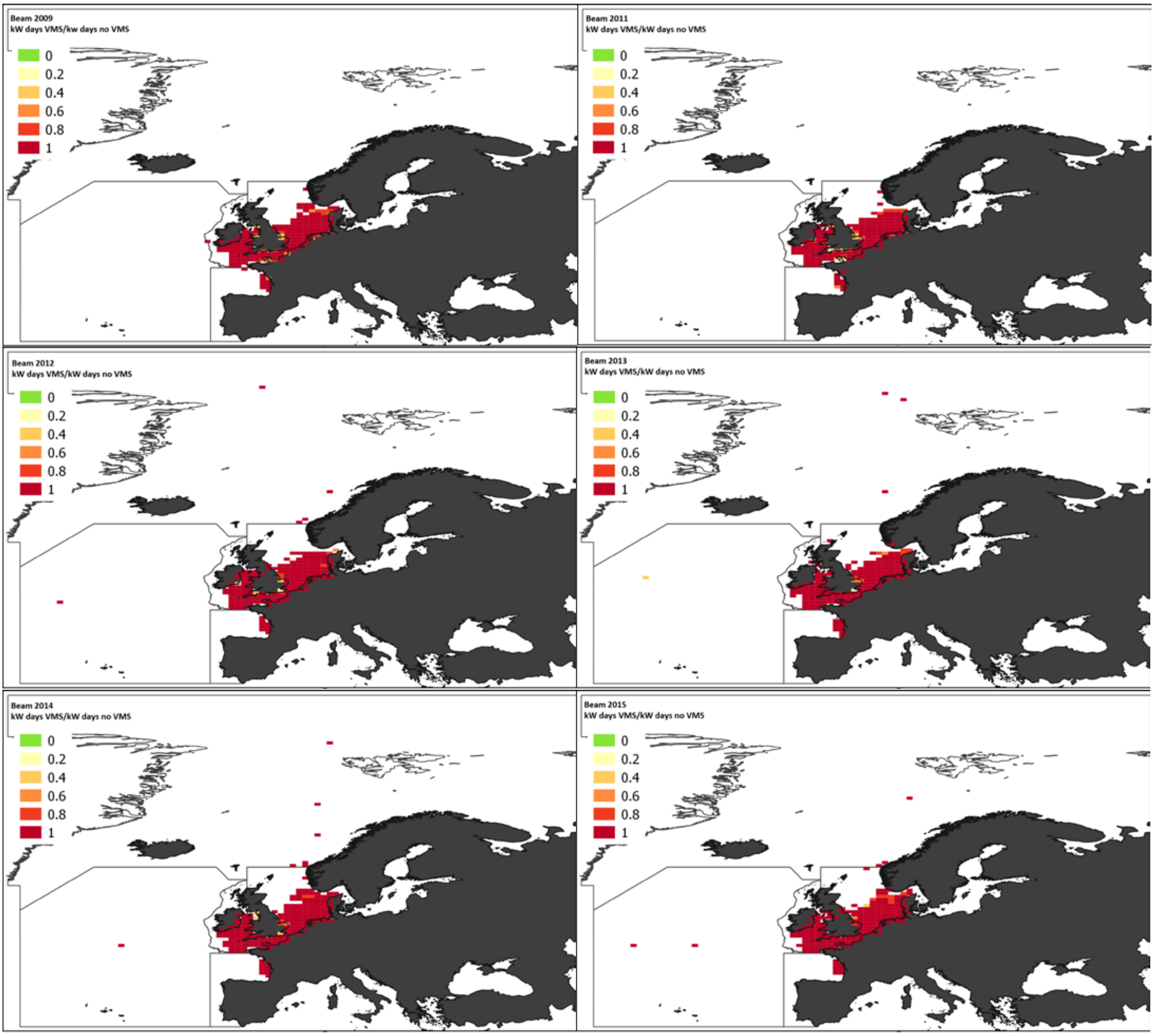
Annex 2: Abbreviations list

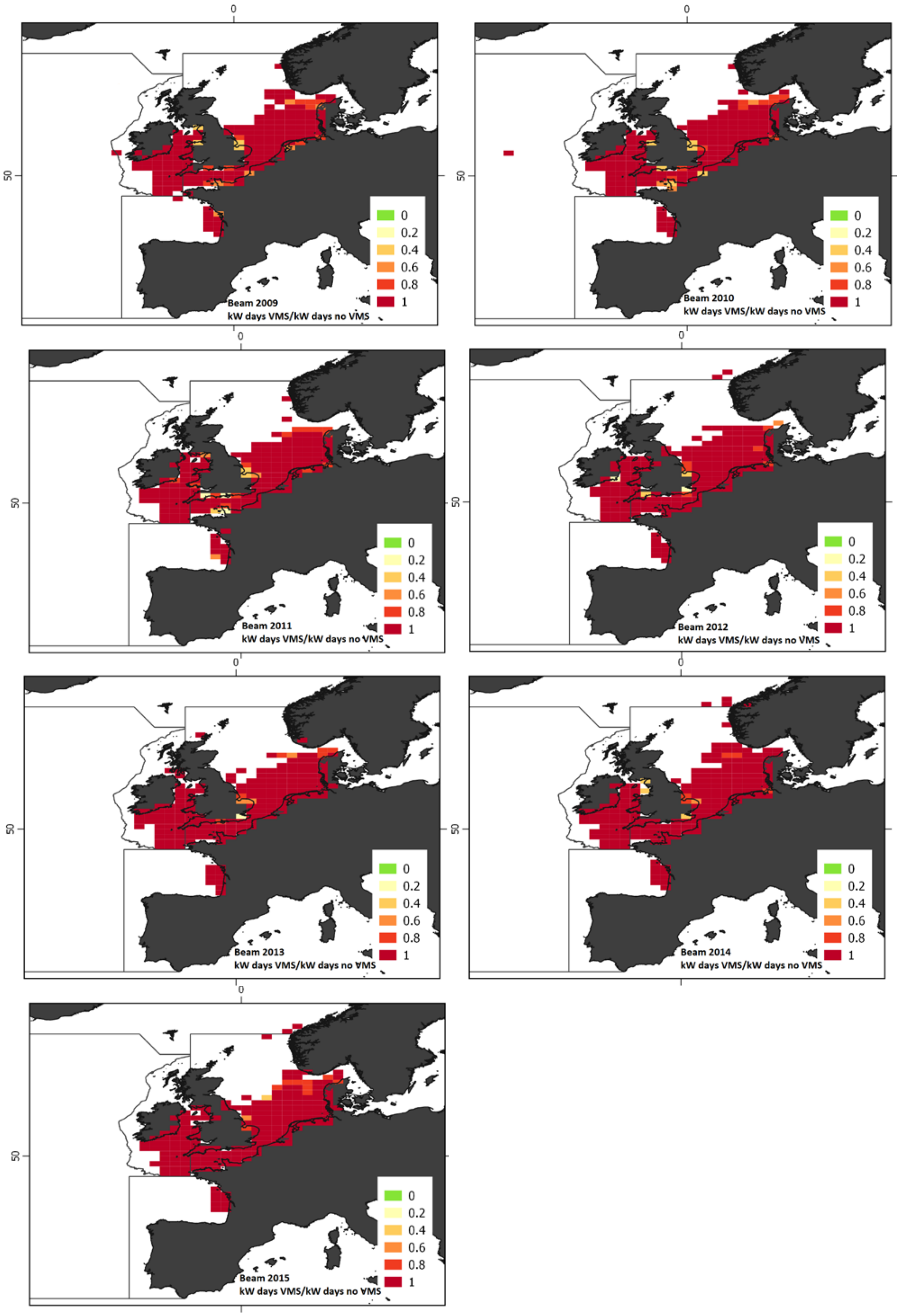
ABNJ	Areas Beyond National Jurisdiction
ACOM	ICES Advisory Committee
AIS	Automatic Identification System
BENTHIS	Studies the impacts of fishing on benthic ecosystems (bottom systems) and will provide the science base to assess the impact of current fishing practices
BH1	OSPAR Indicator - Condition of 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 showing VMS coverage

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Beam 2011
kW days VMS/kW days no VMS
Beam 2012
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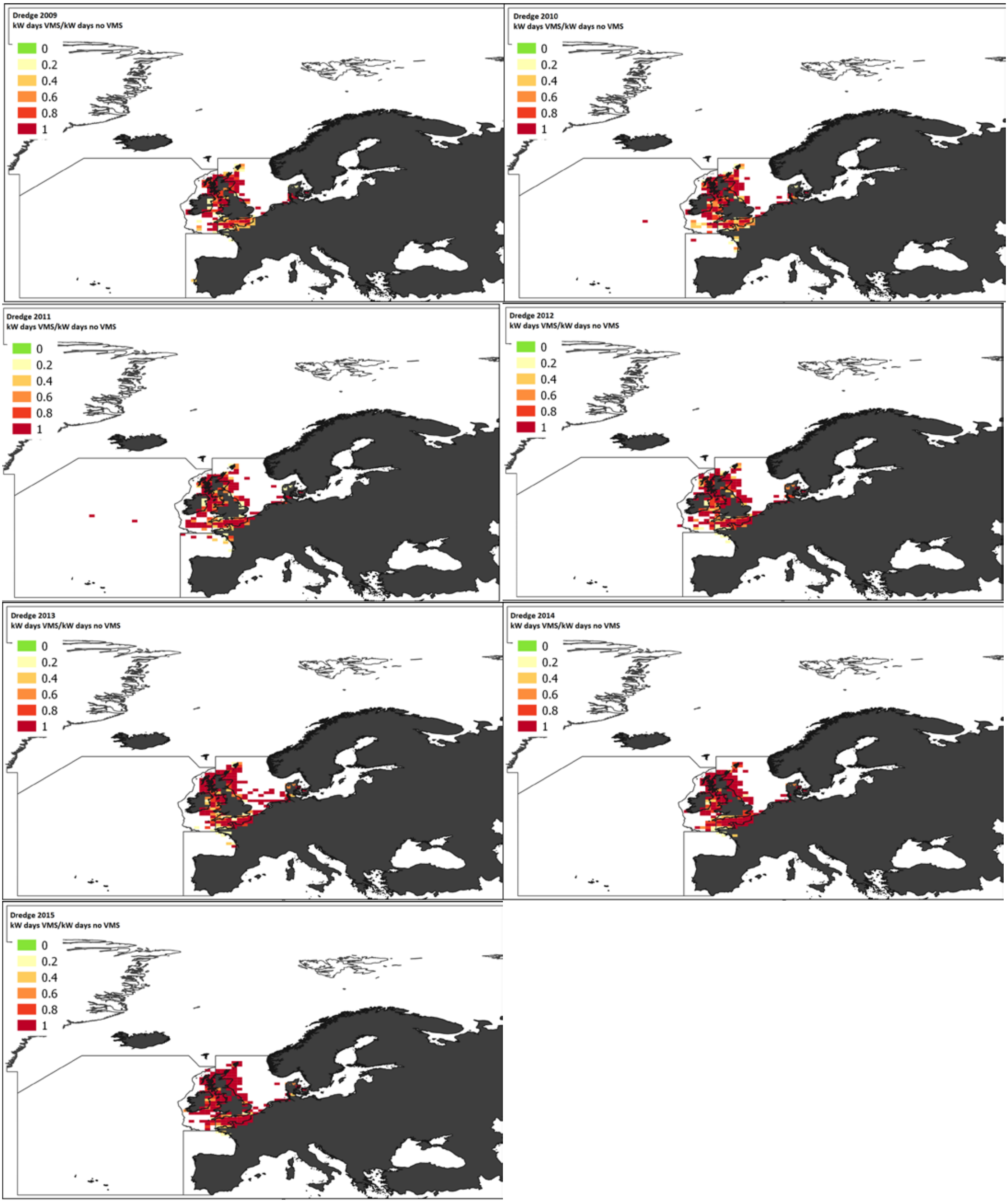
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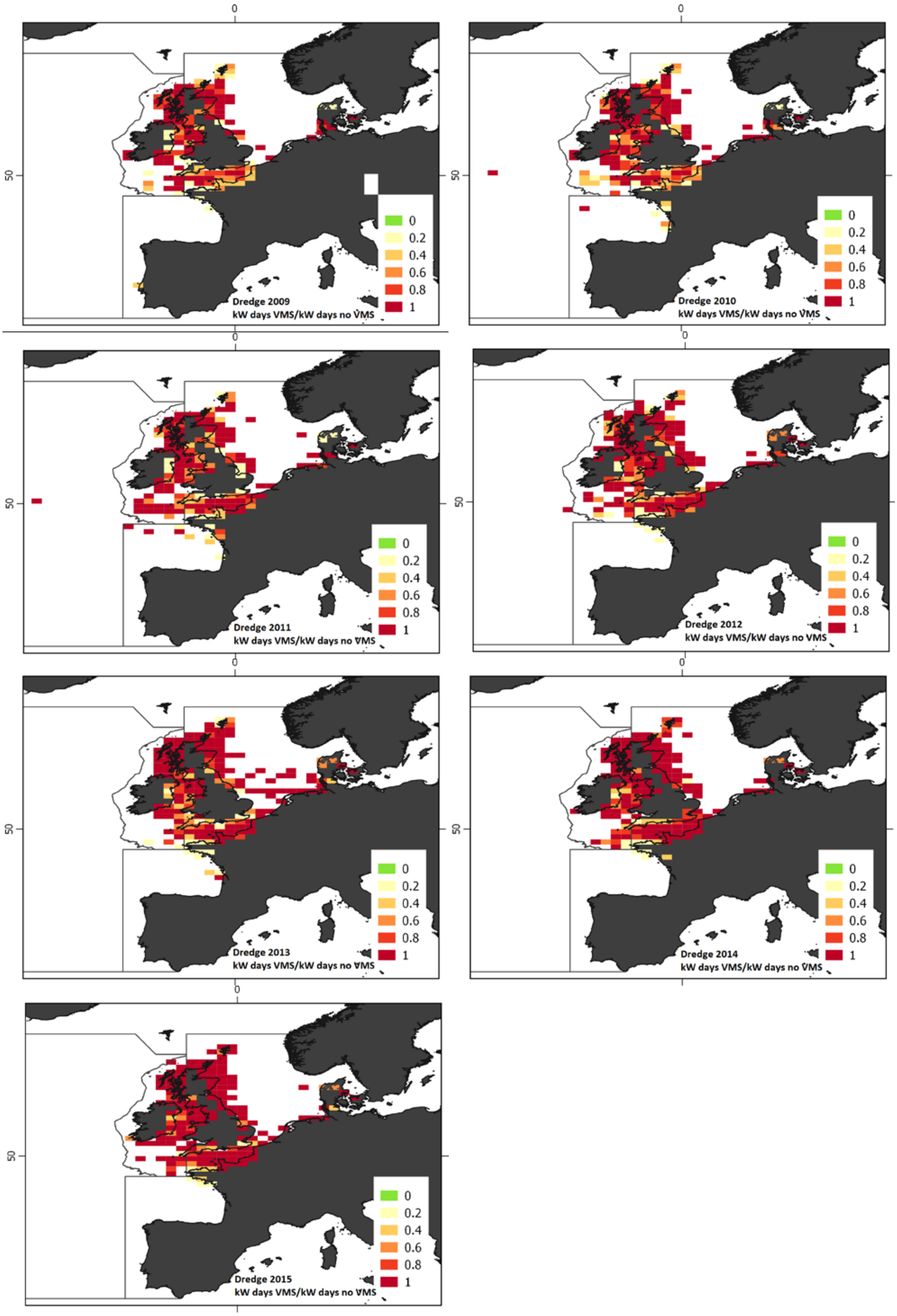
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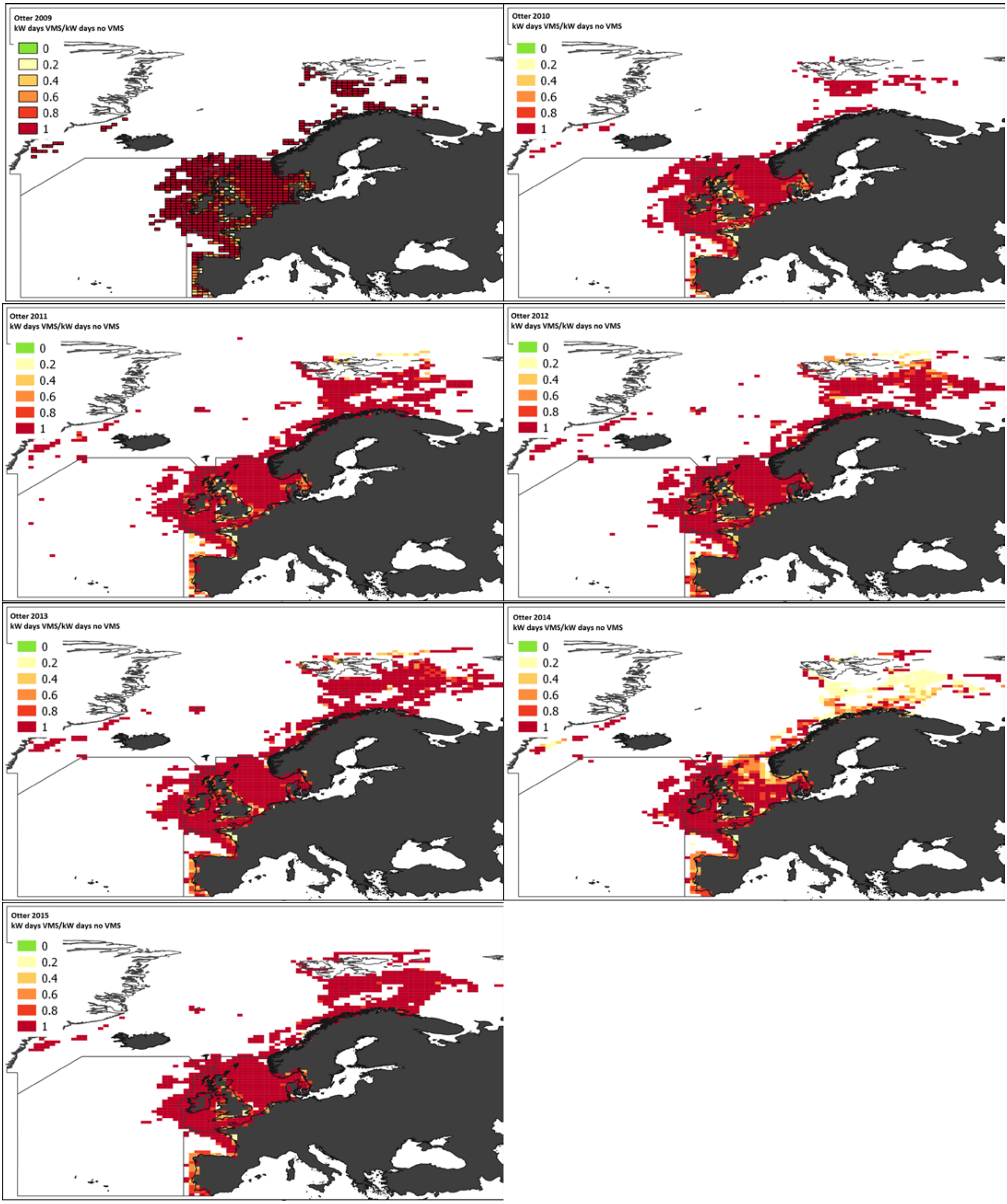
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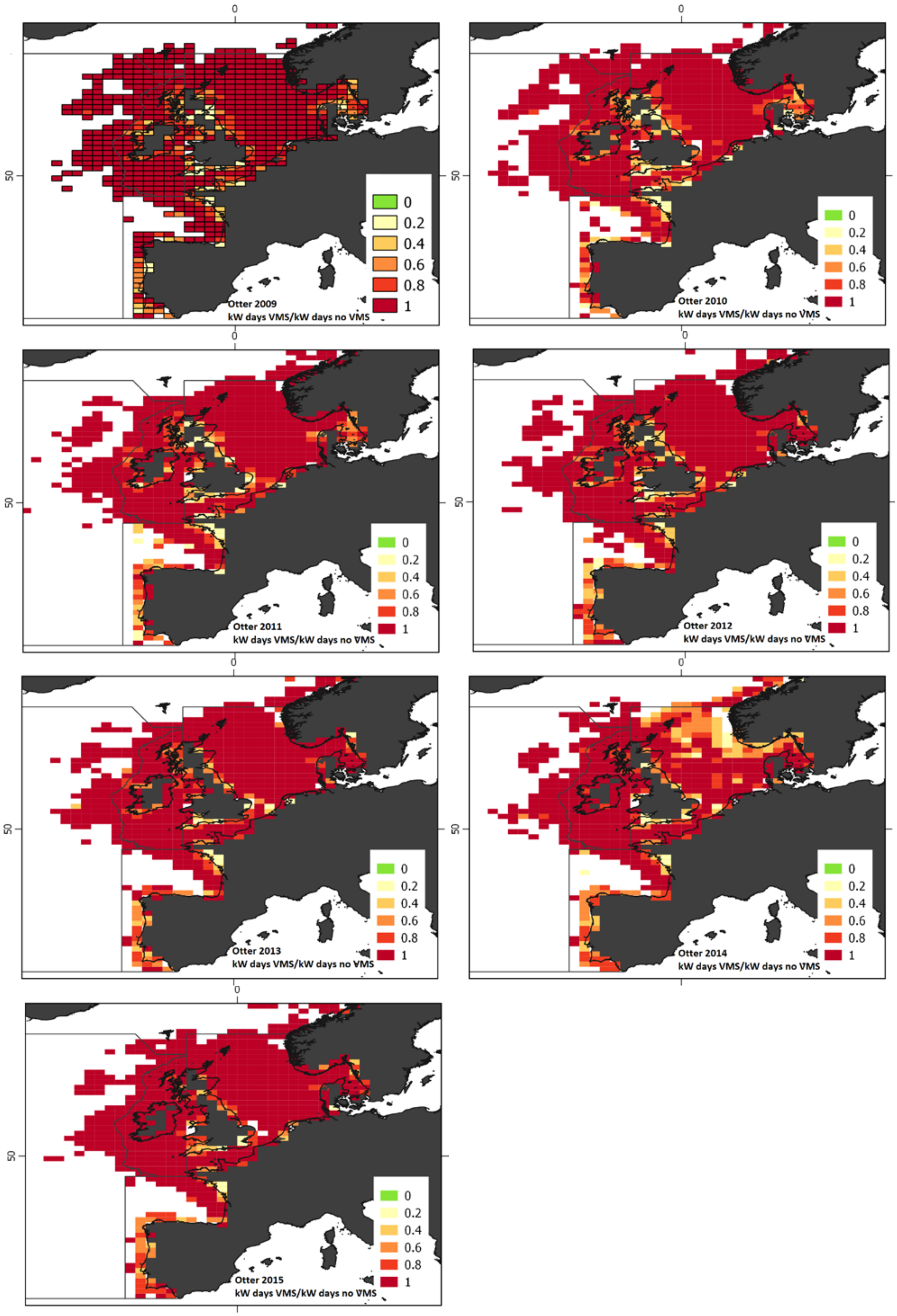
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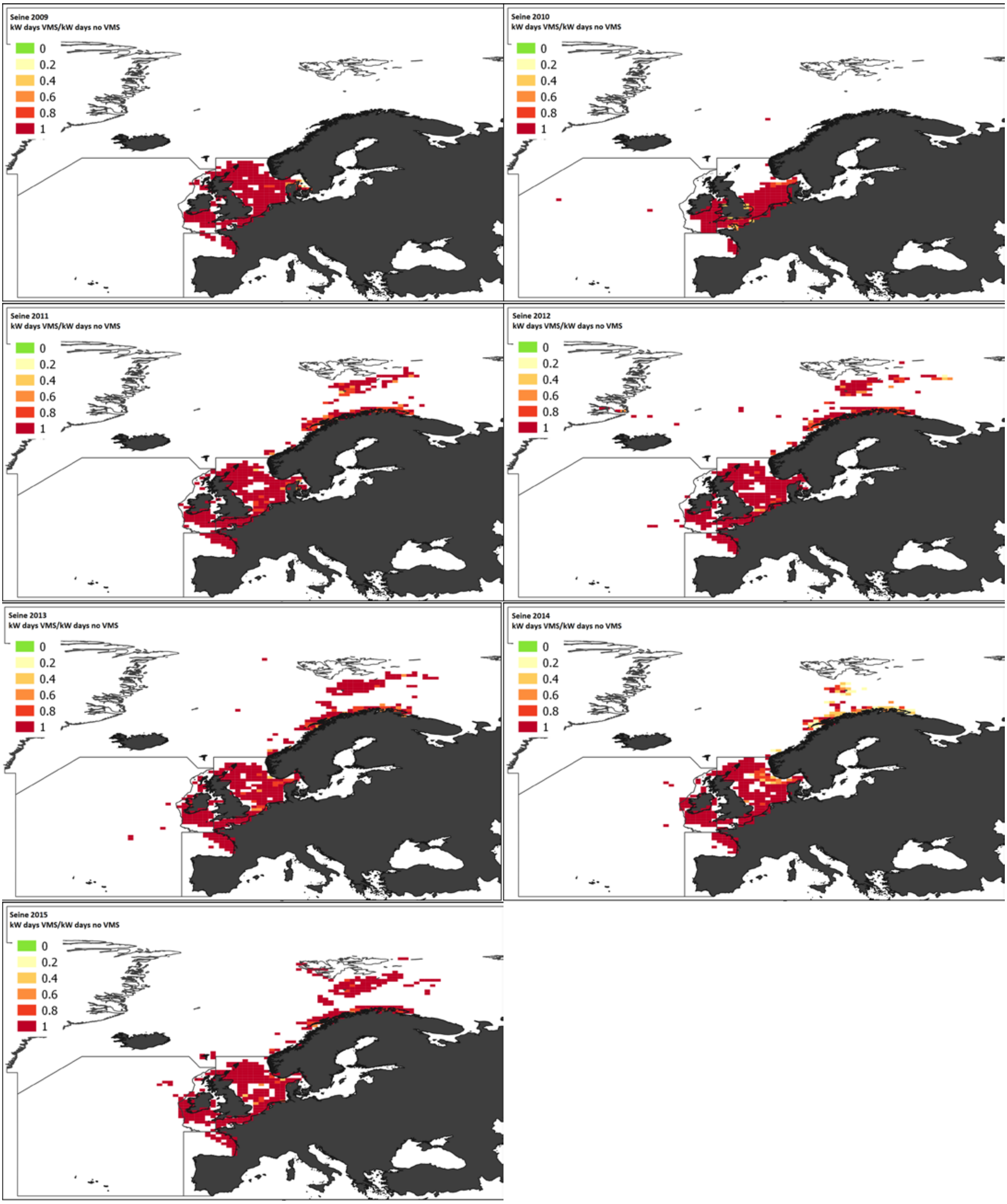
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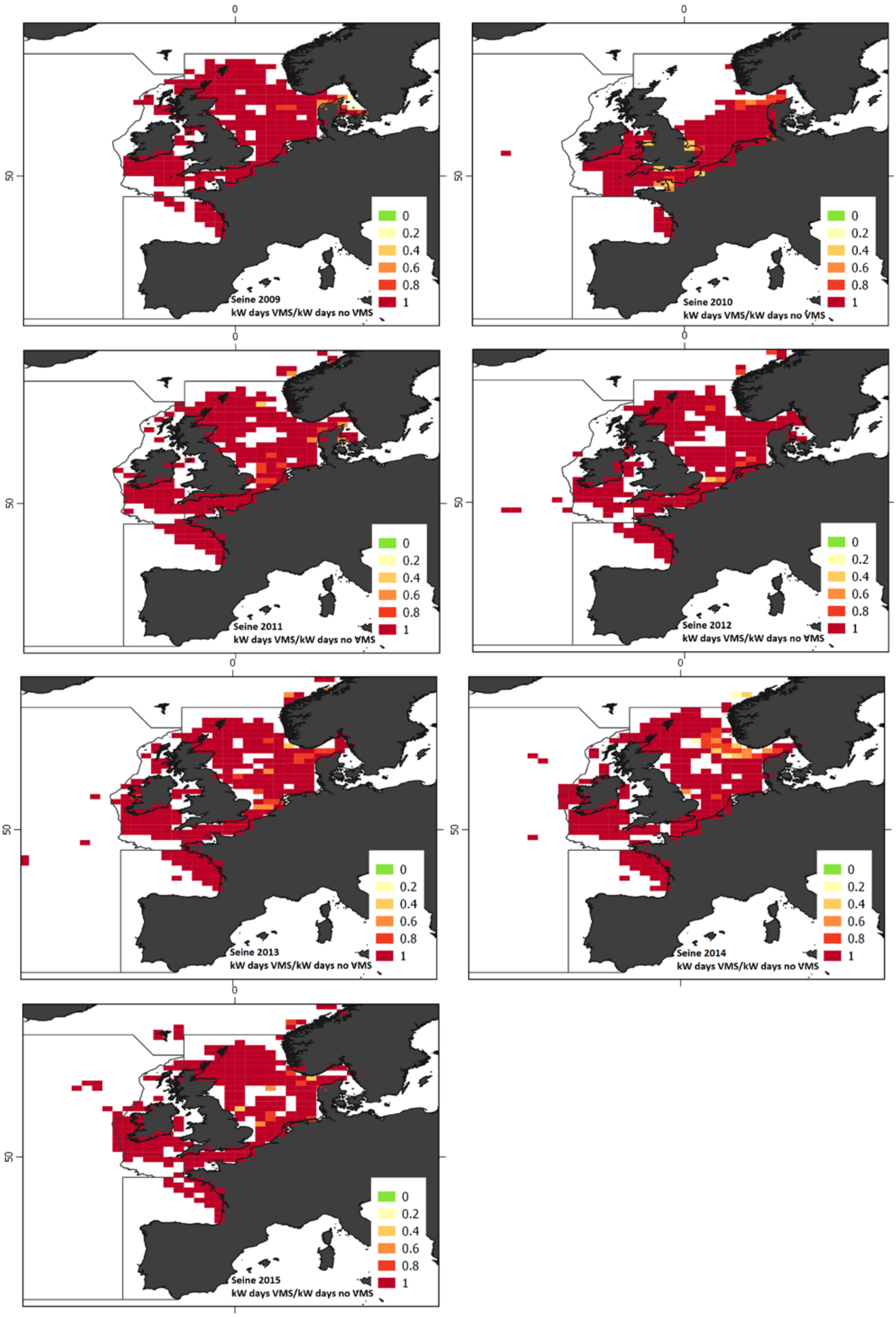
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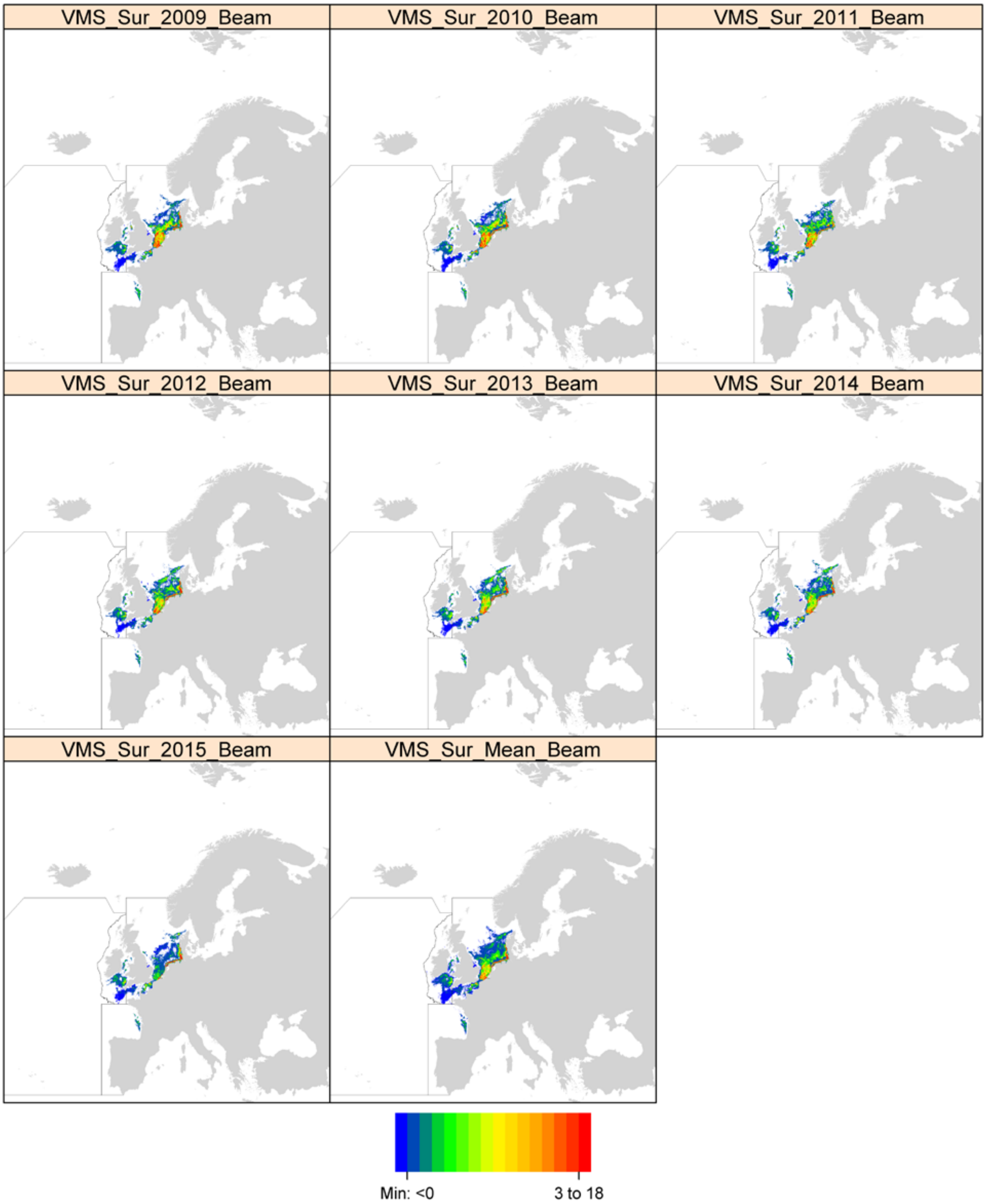
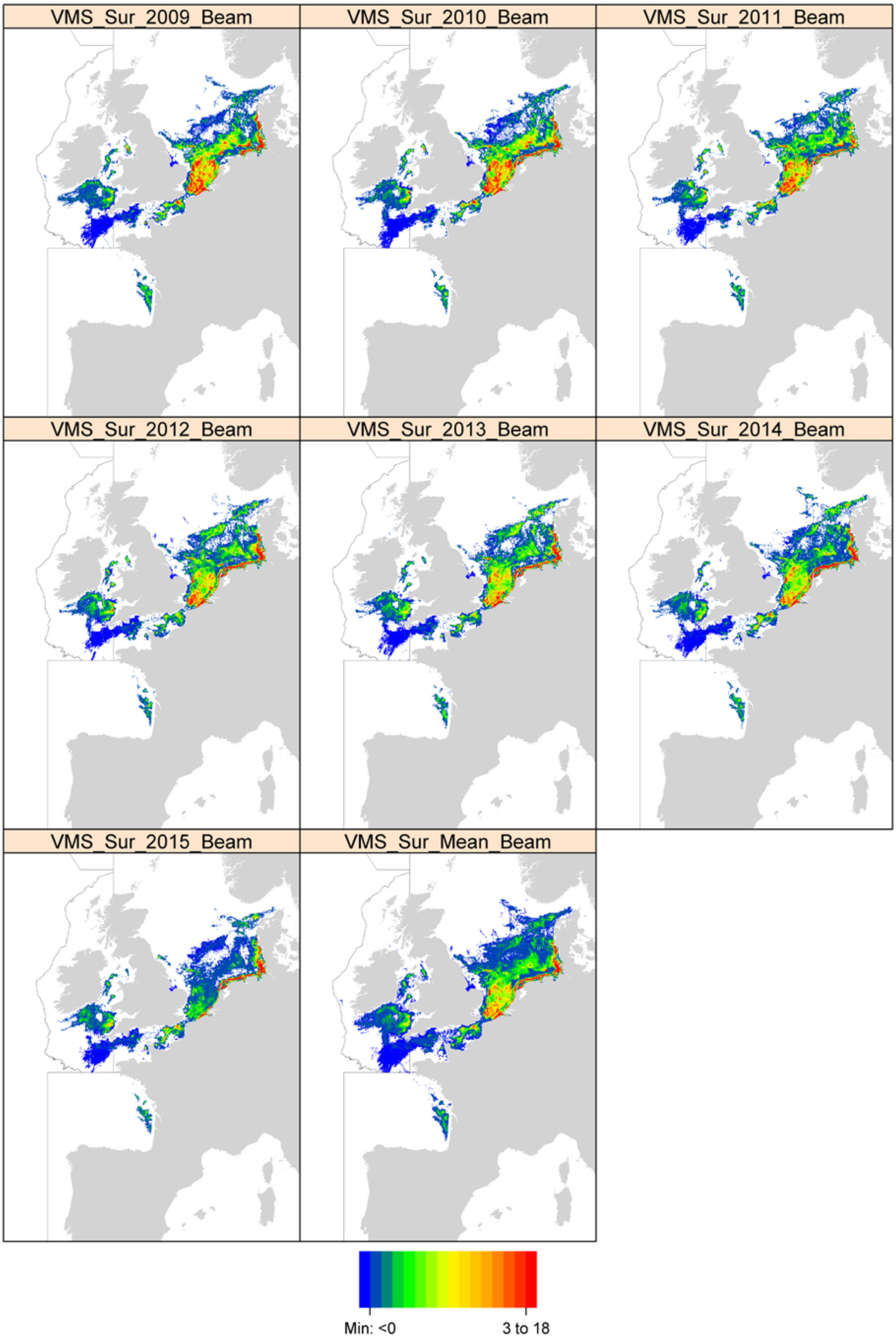
Annex 4: Maps prepared for the OSPAR request

In the headings of the maps "Sur" mean surface swept area ratio. "Sub" mean sub-surface swept area ratio.

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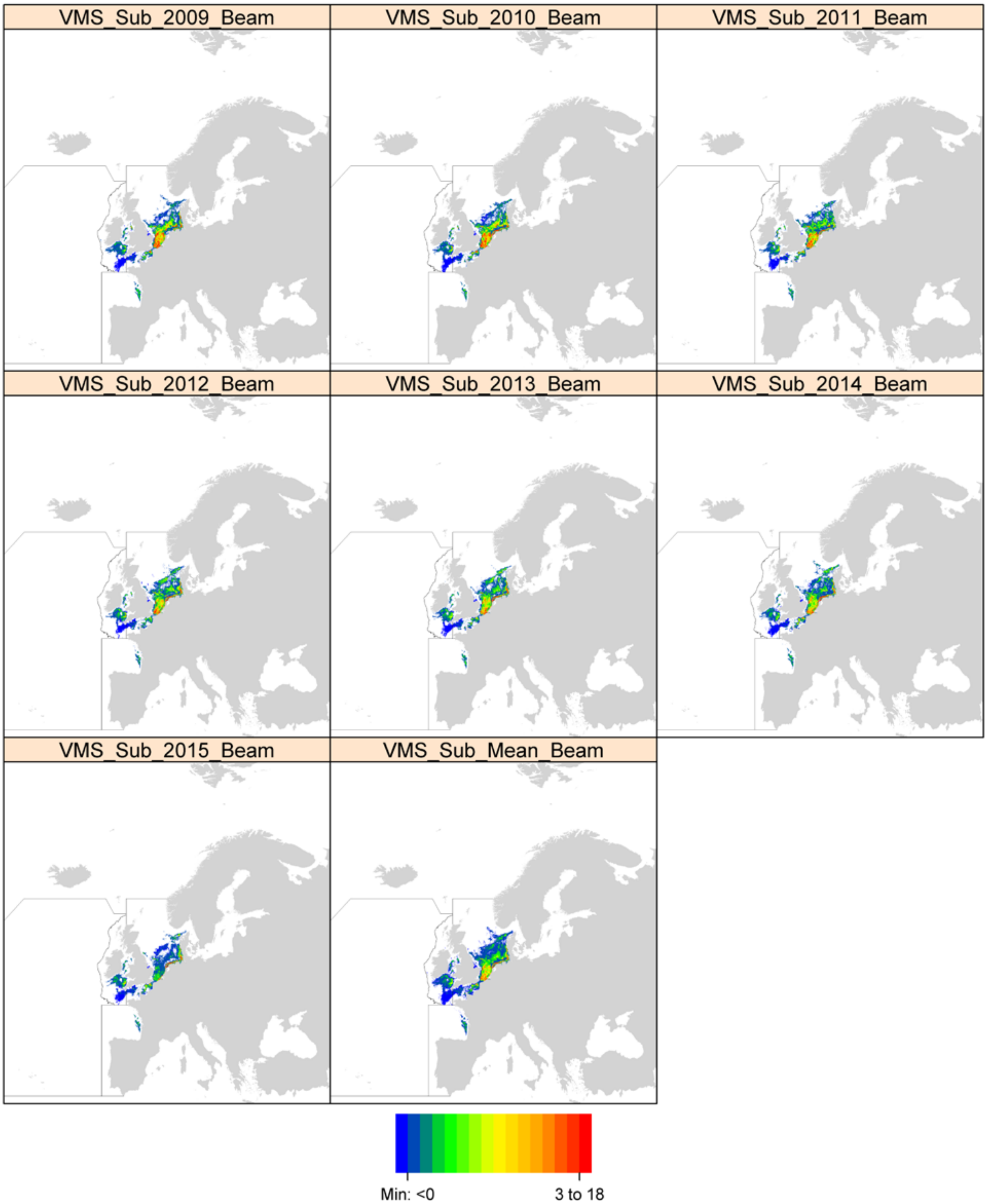
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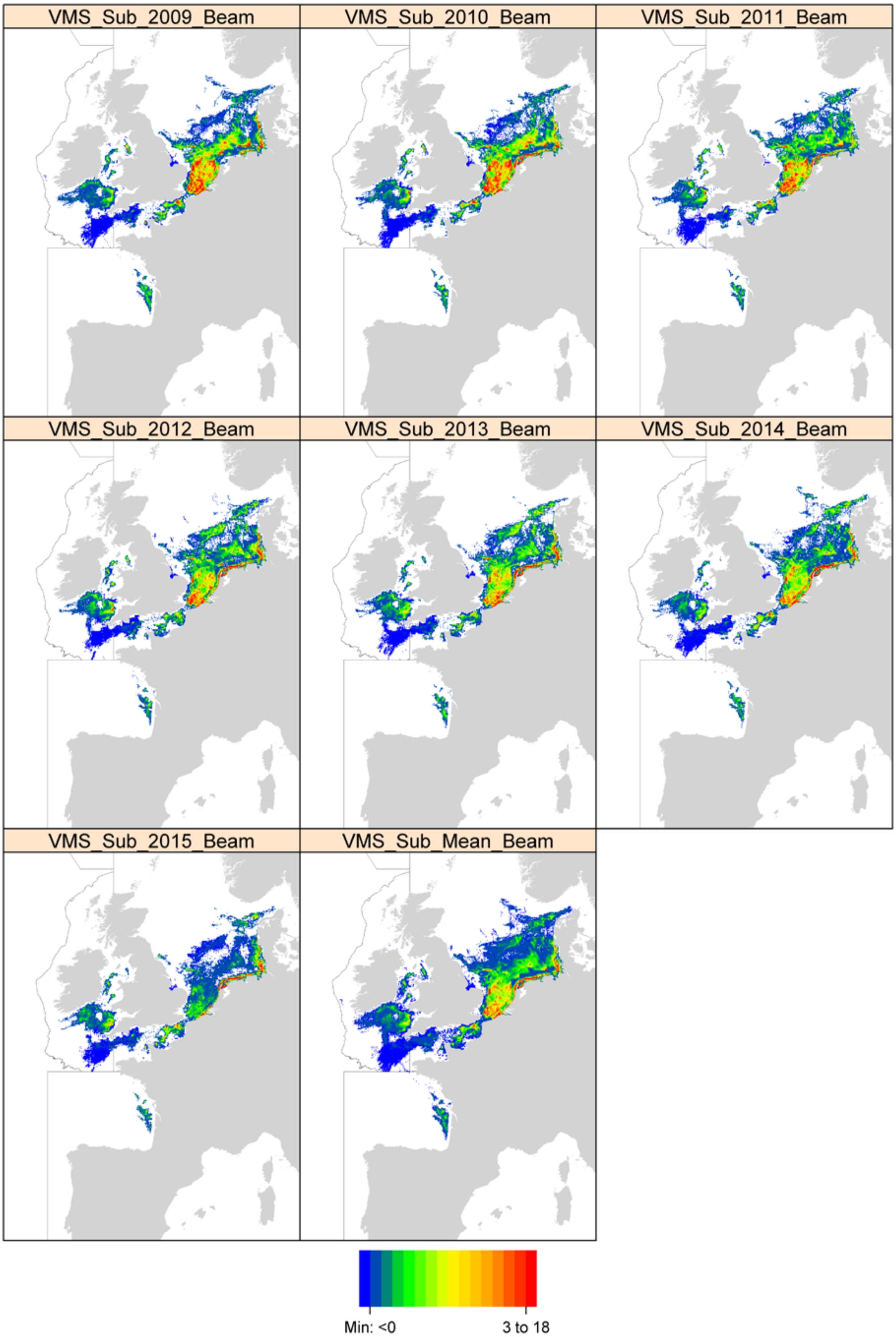
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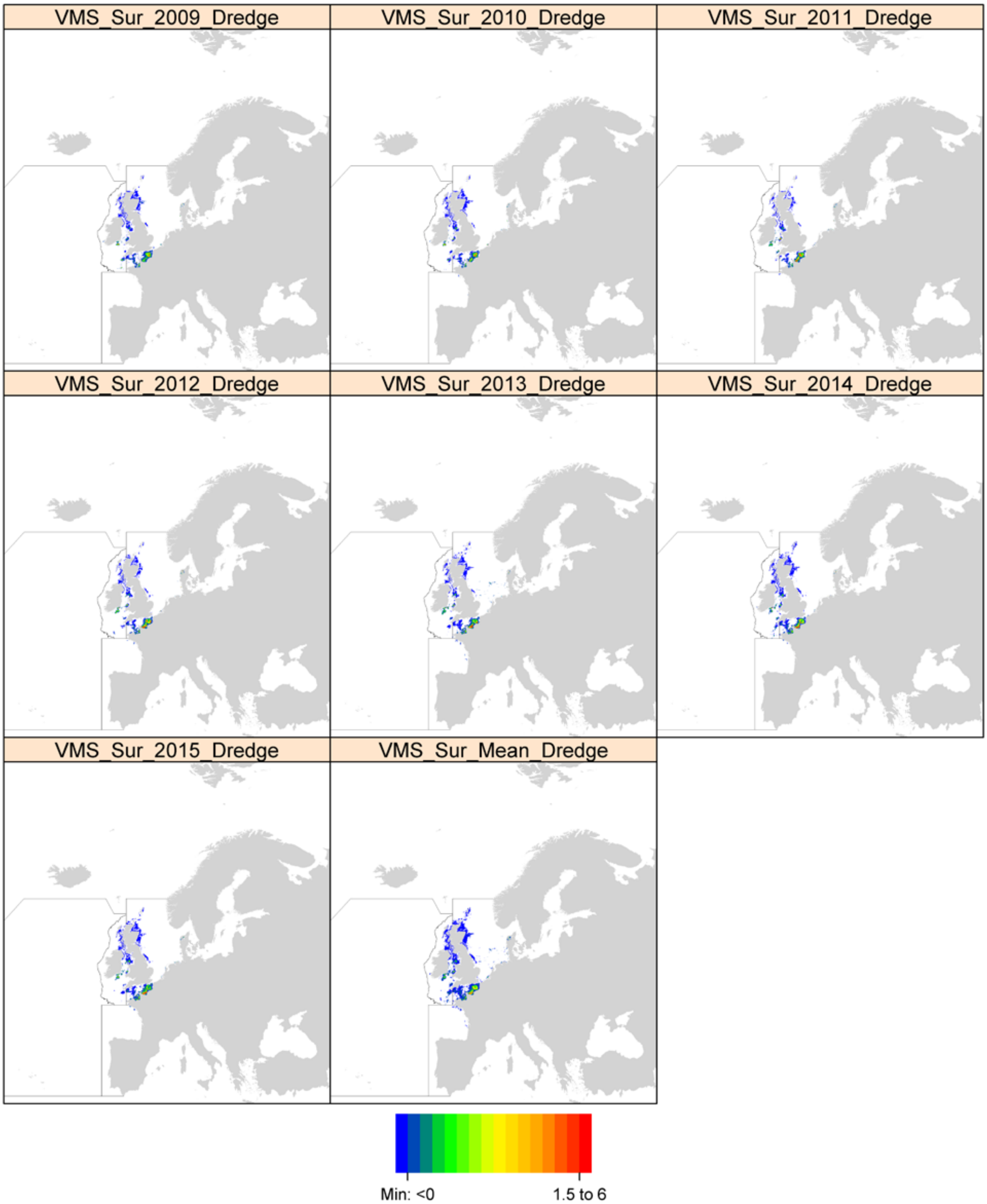
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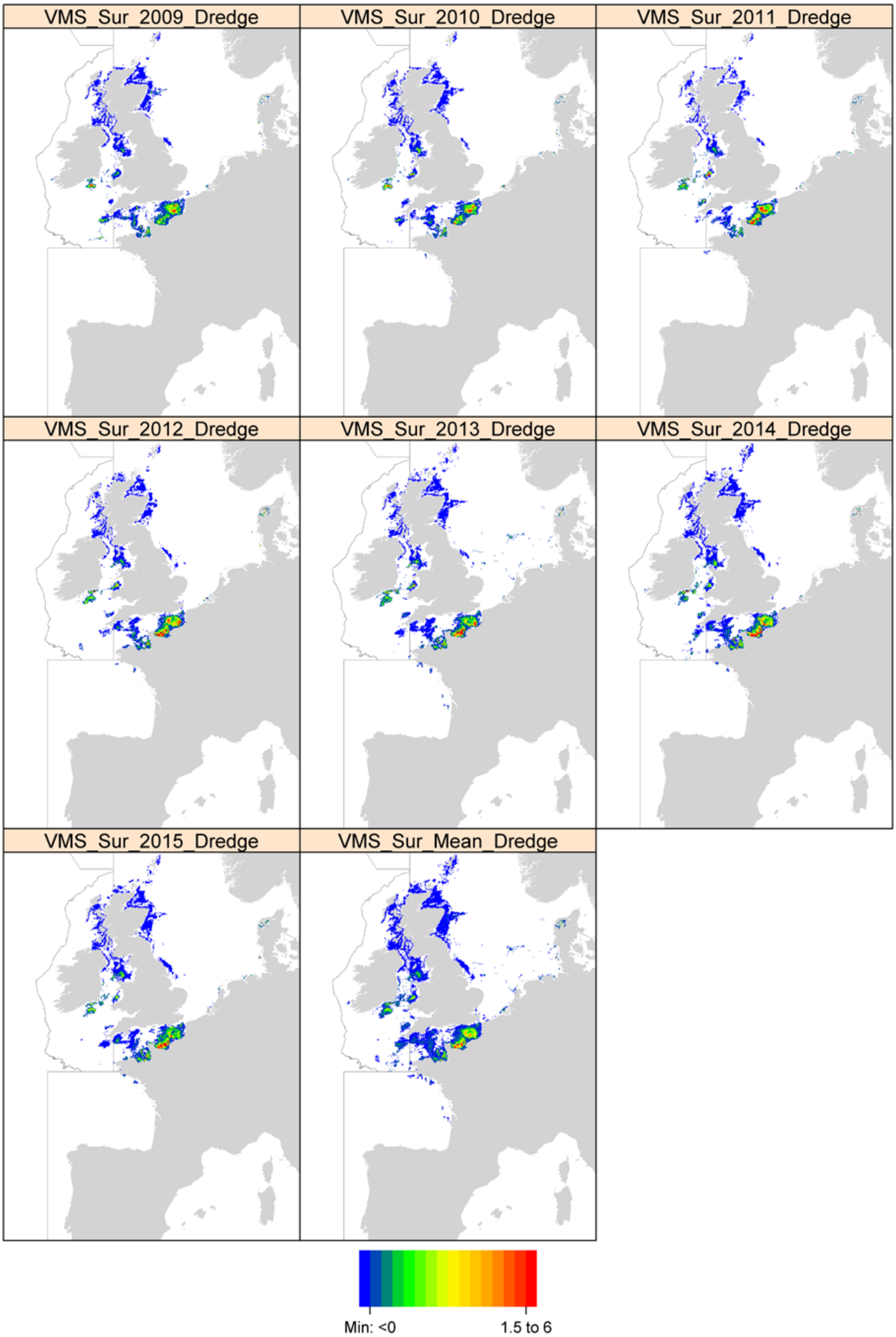
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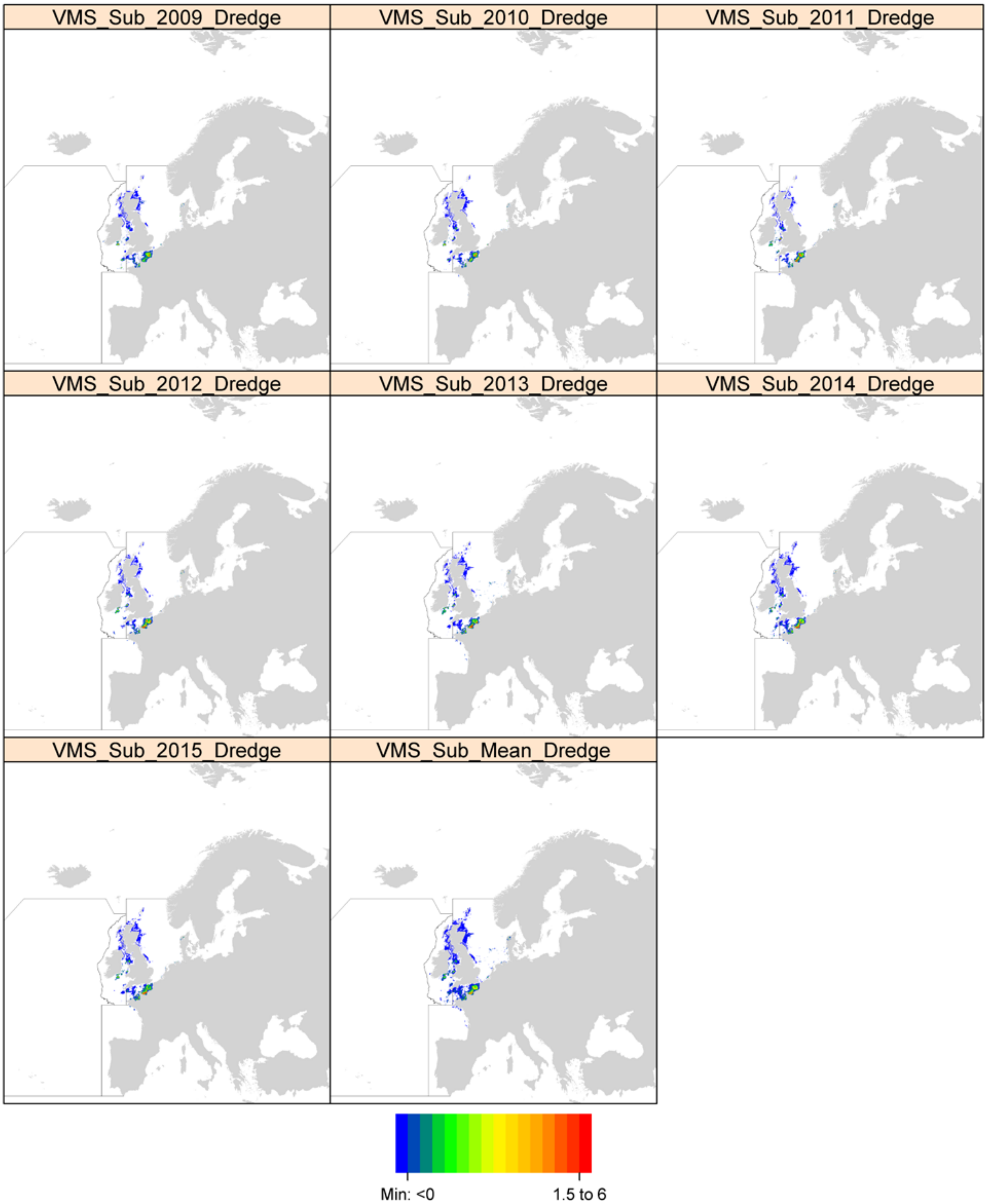
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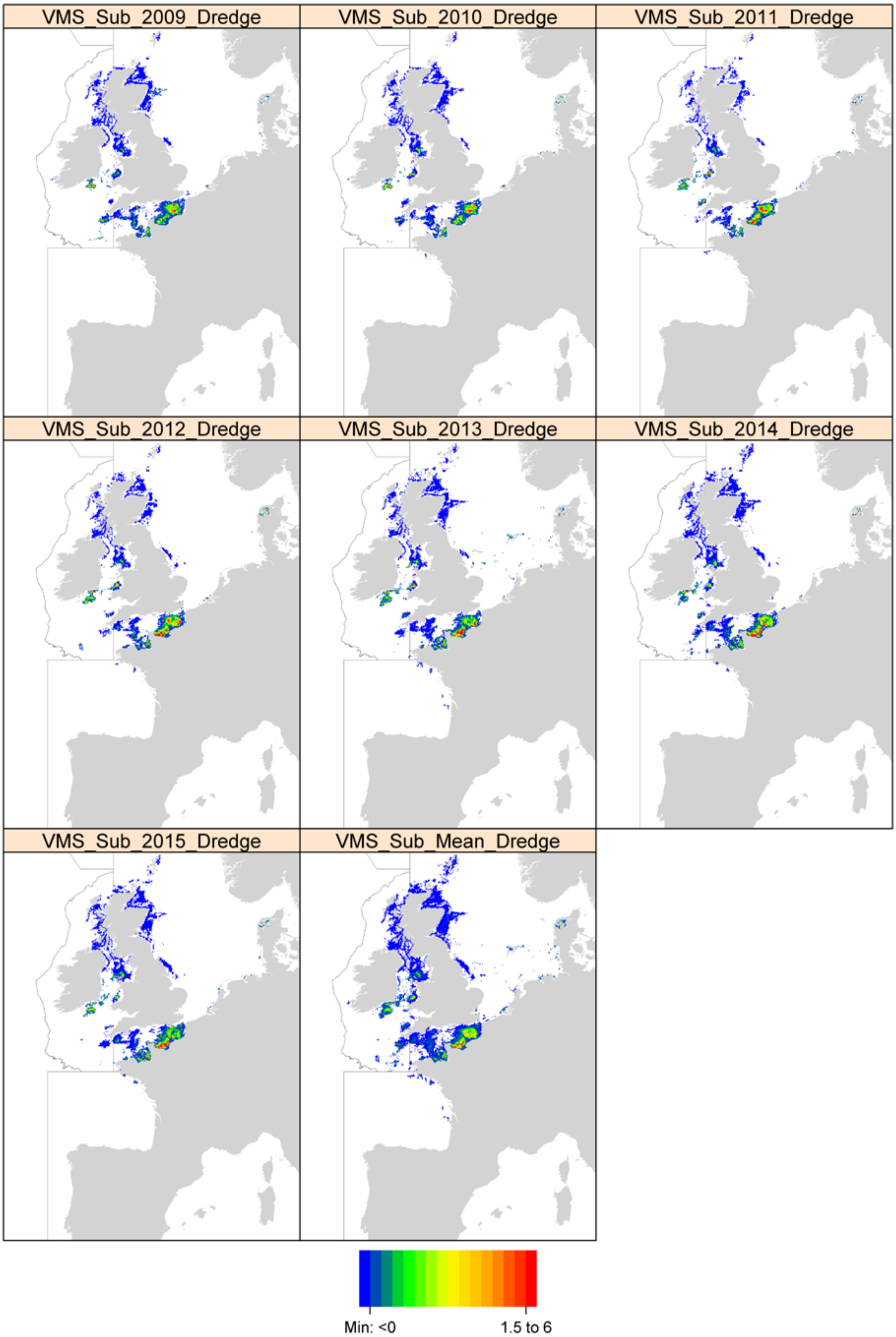
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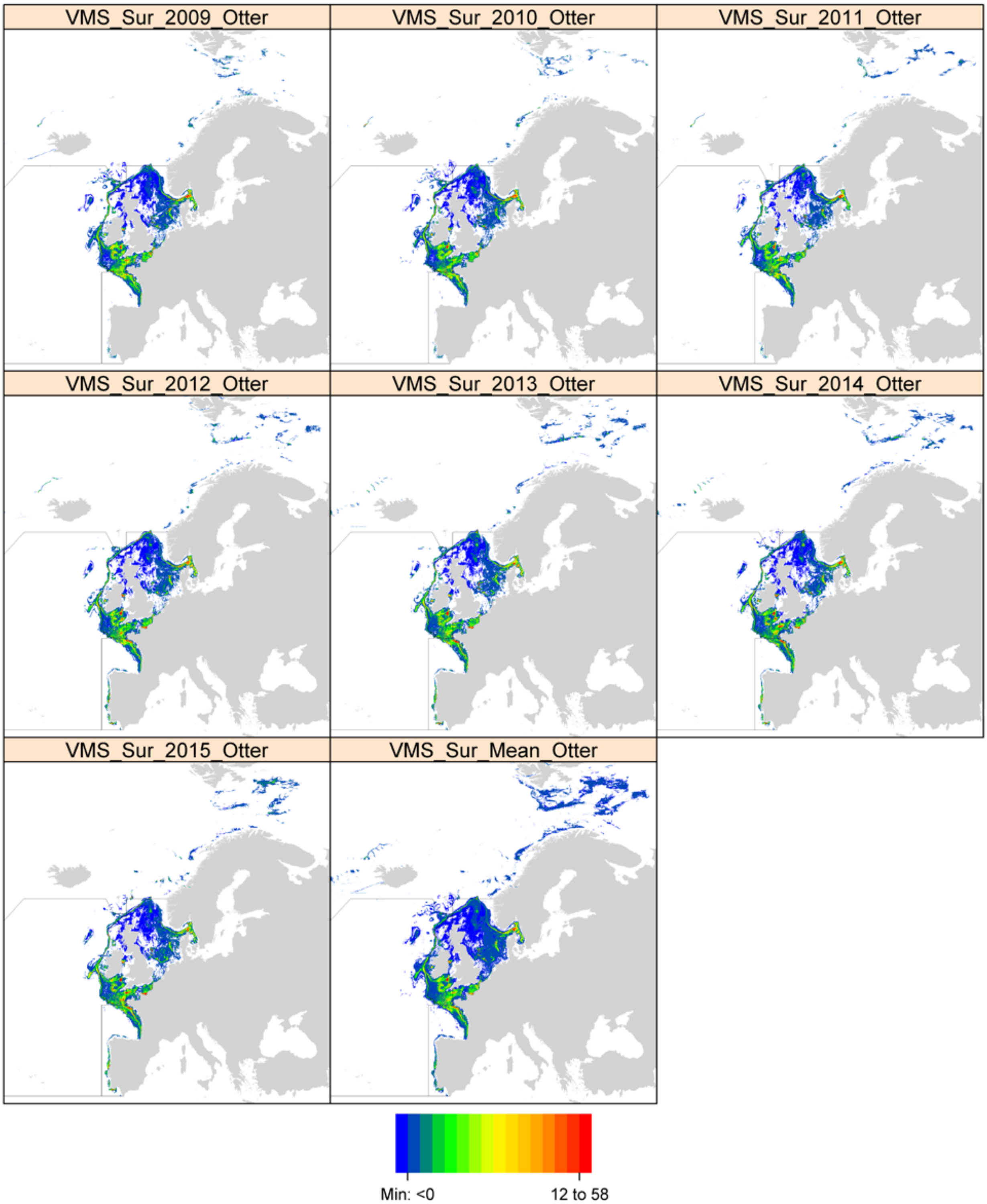
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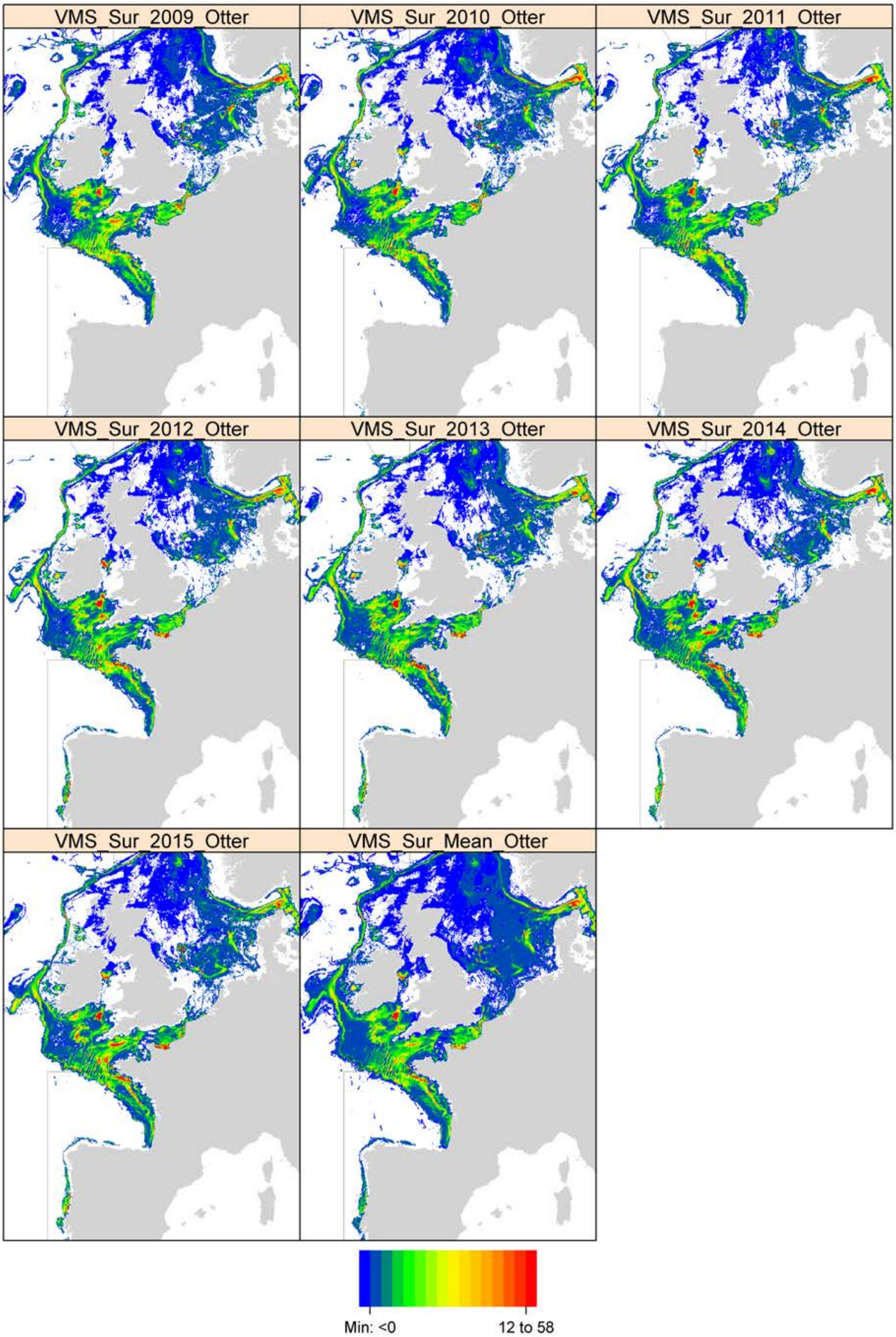
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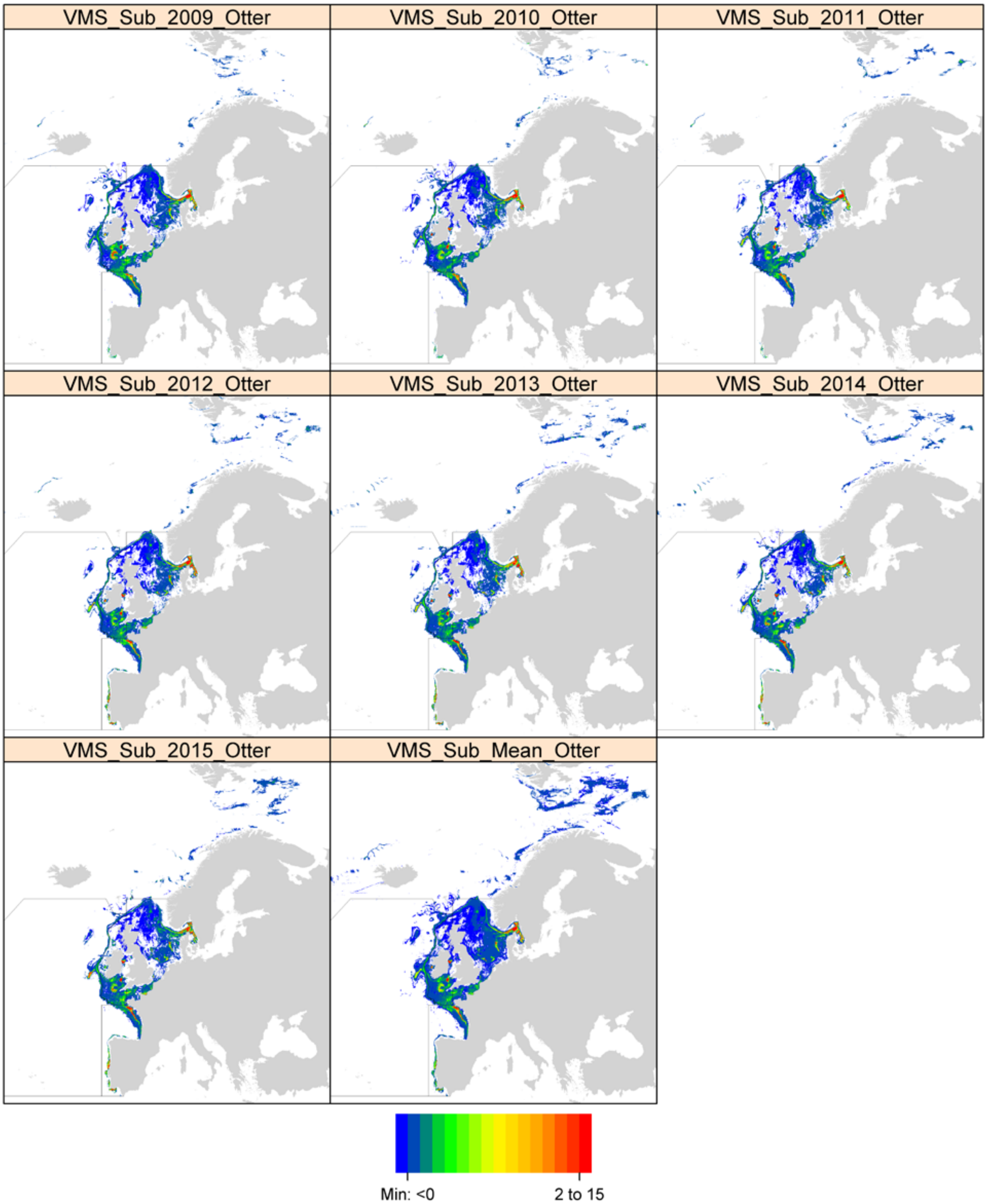
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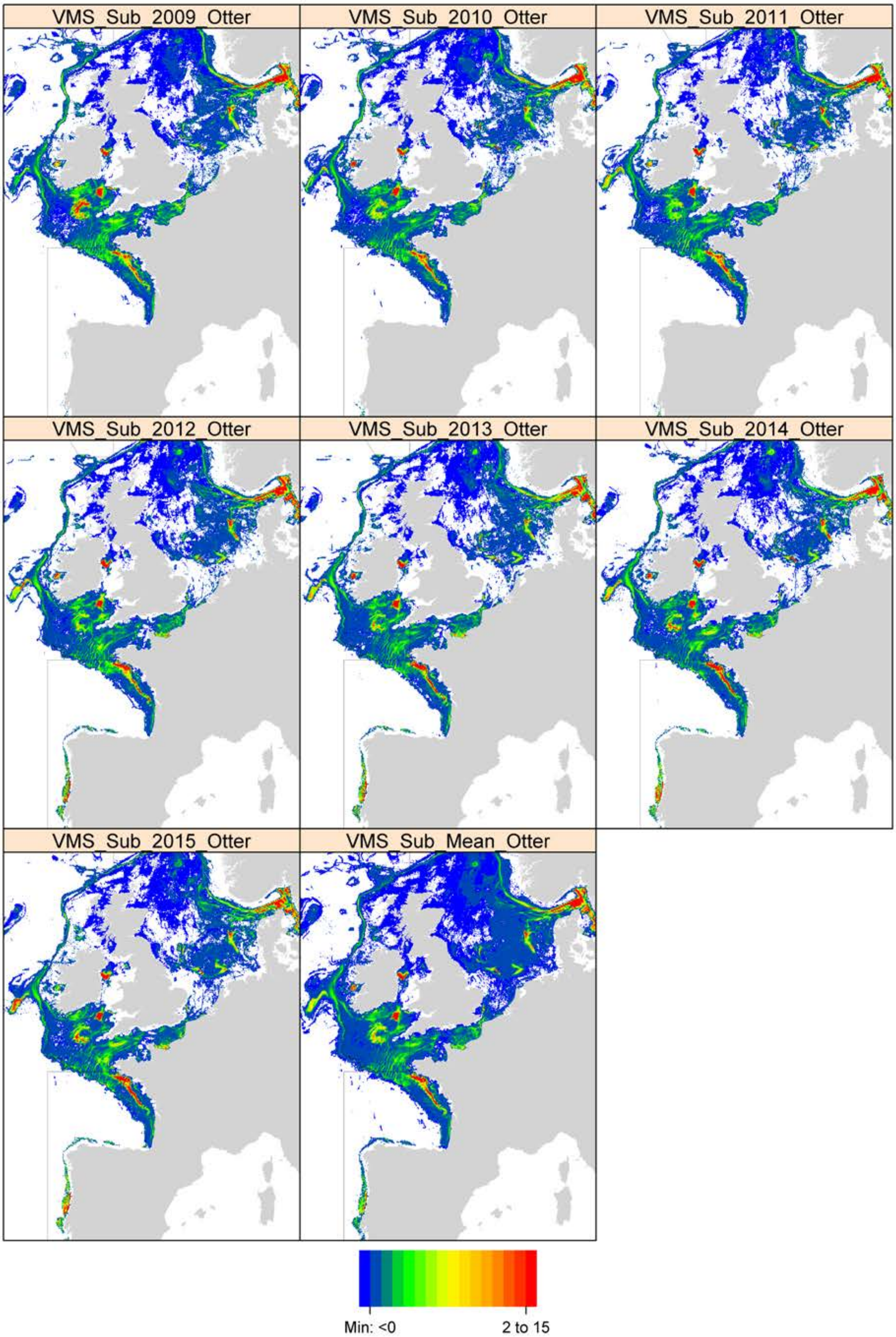
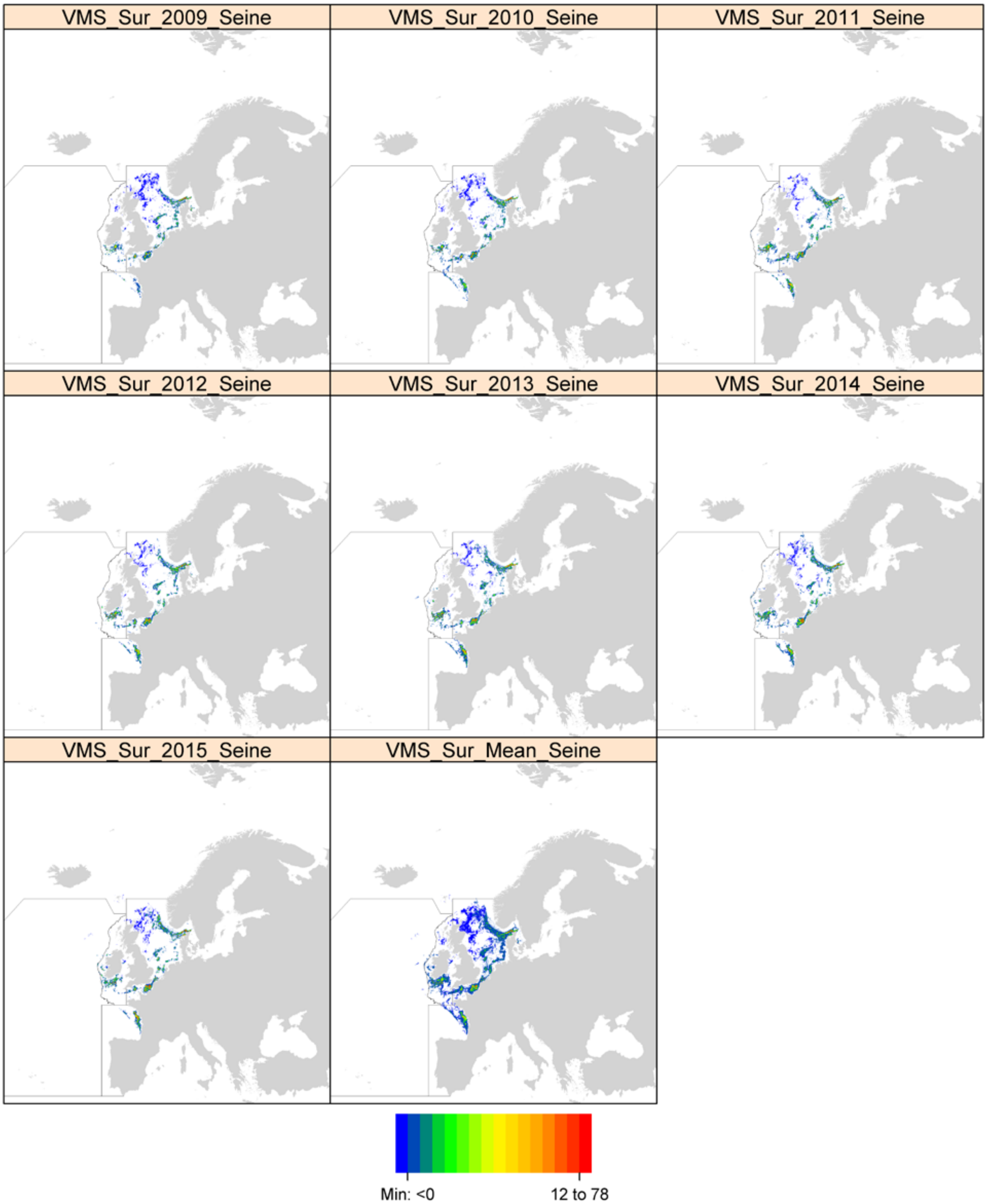
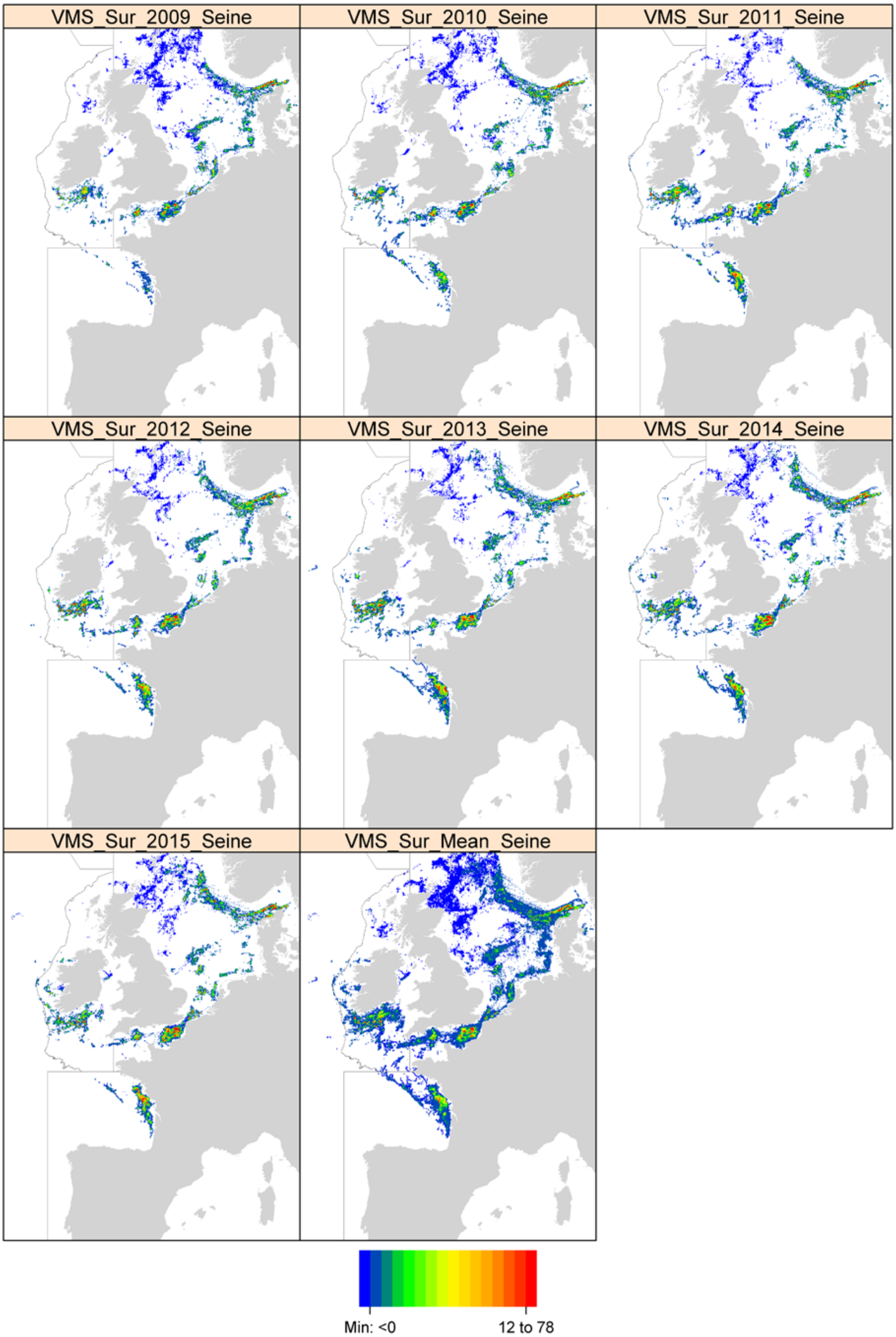
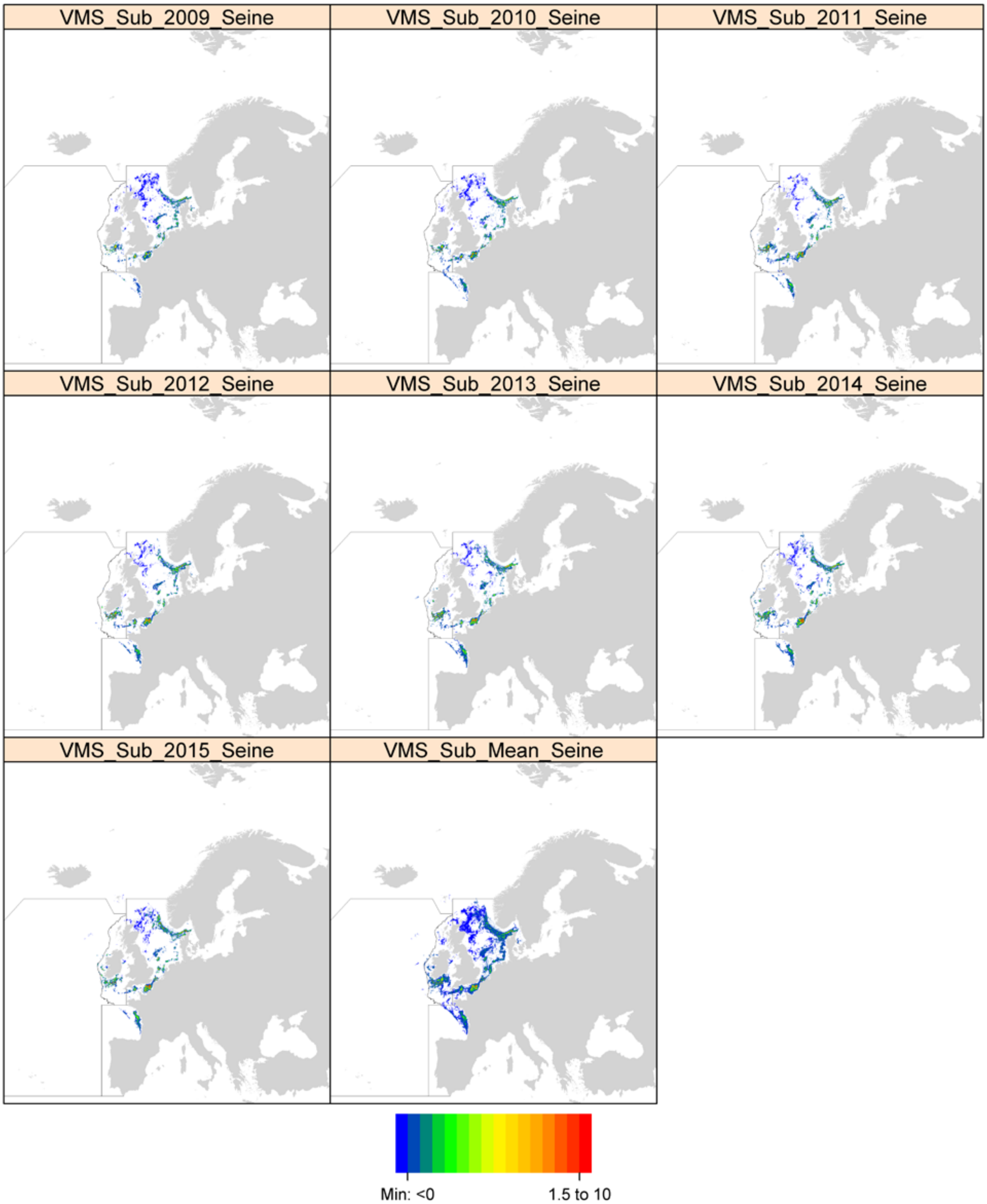
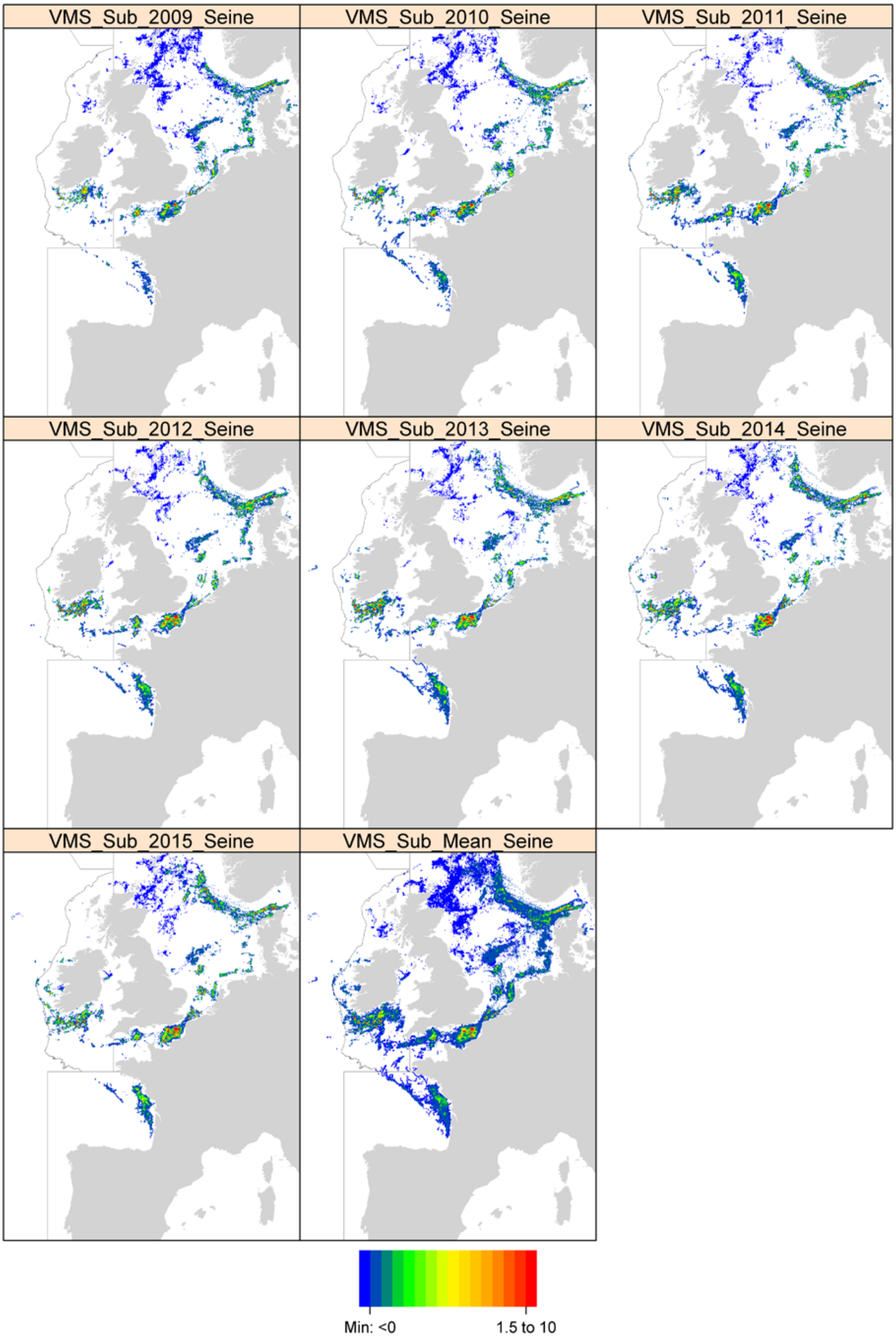
VMS_Sub_2013_Otter
VMS_Sub_2014_Otter
VMS_Sub_2015_Otter
VMS_Sub_Mean_Otter
Min: <0
2 to 15


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
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
12 to 78

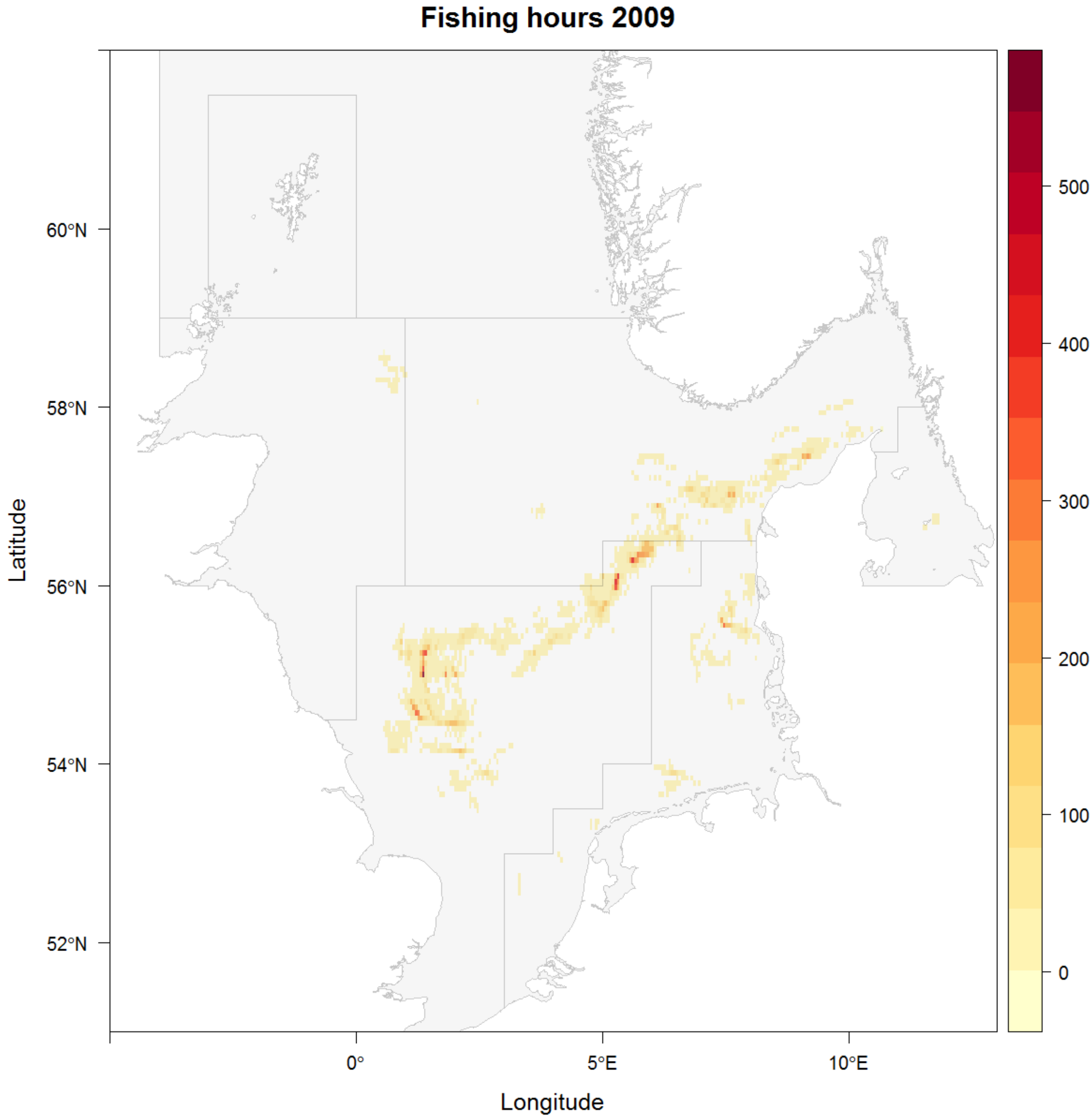

VMS_Sur_2009_Seine
VMS_Sur_2010_Seine
VMS_Sur_2011_Seine
VMS_Sur_2012_Seine
VMS_Sur_2013_Seine
VMS_Sur_2014_Seine
VMS_Sur_2015_Seine
VMS_Sur_Mean_Seine
Min: <0
12 to 78

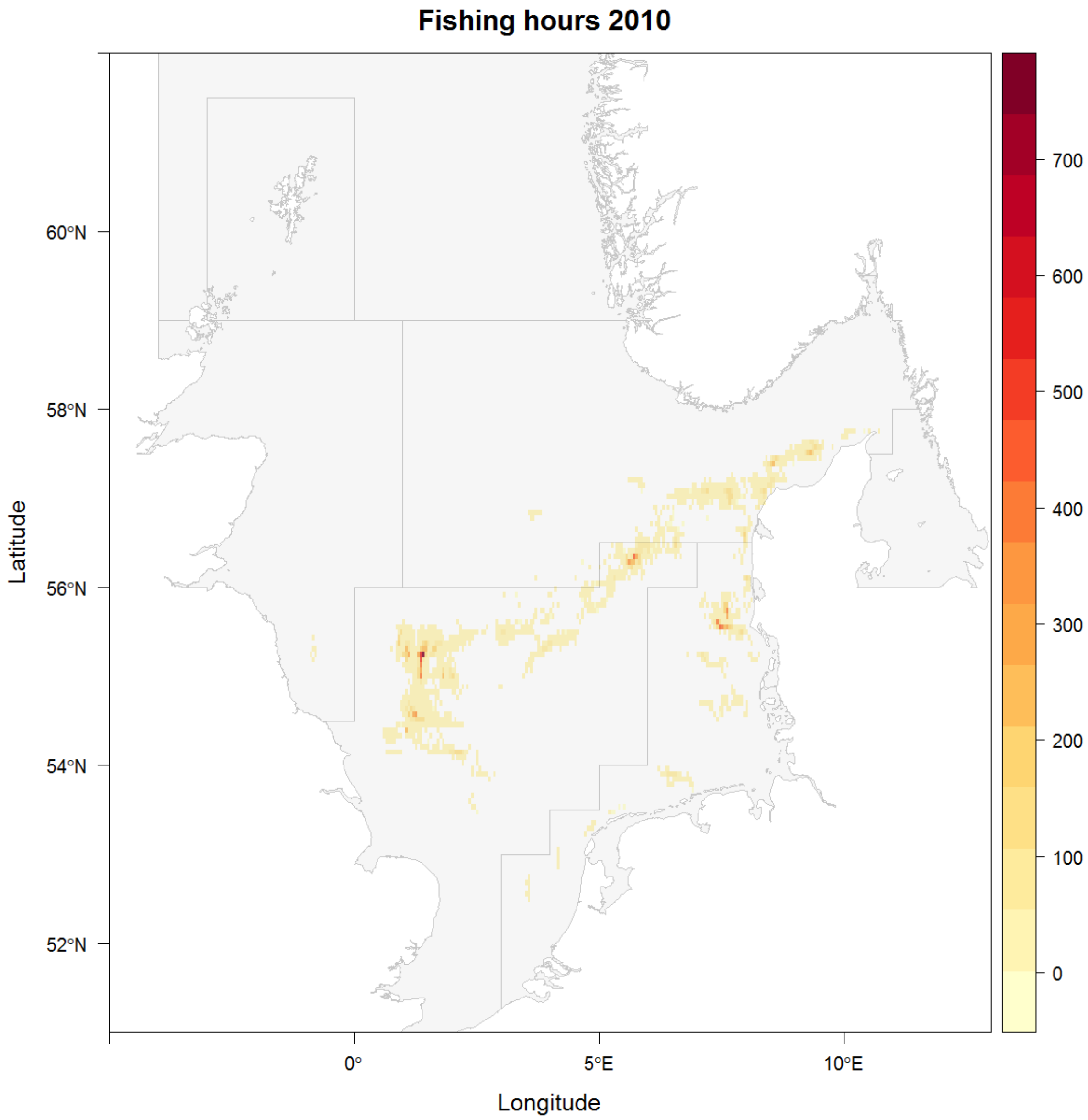

VMS_Sub_2009_Seine
VMS_Sub_2010_Seine
VMS_Sub_2011_Seine
VMS_Sub_2012_Seine
VMS_Sub_2013_Seine
VMS_Sub_2014_Seine
VMS_Sub_2015_Seine
VMS_Sub_Mean_Seine
Min: <0
1.5 to 10

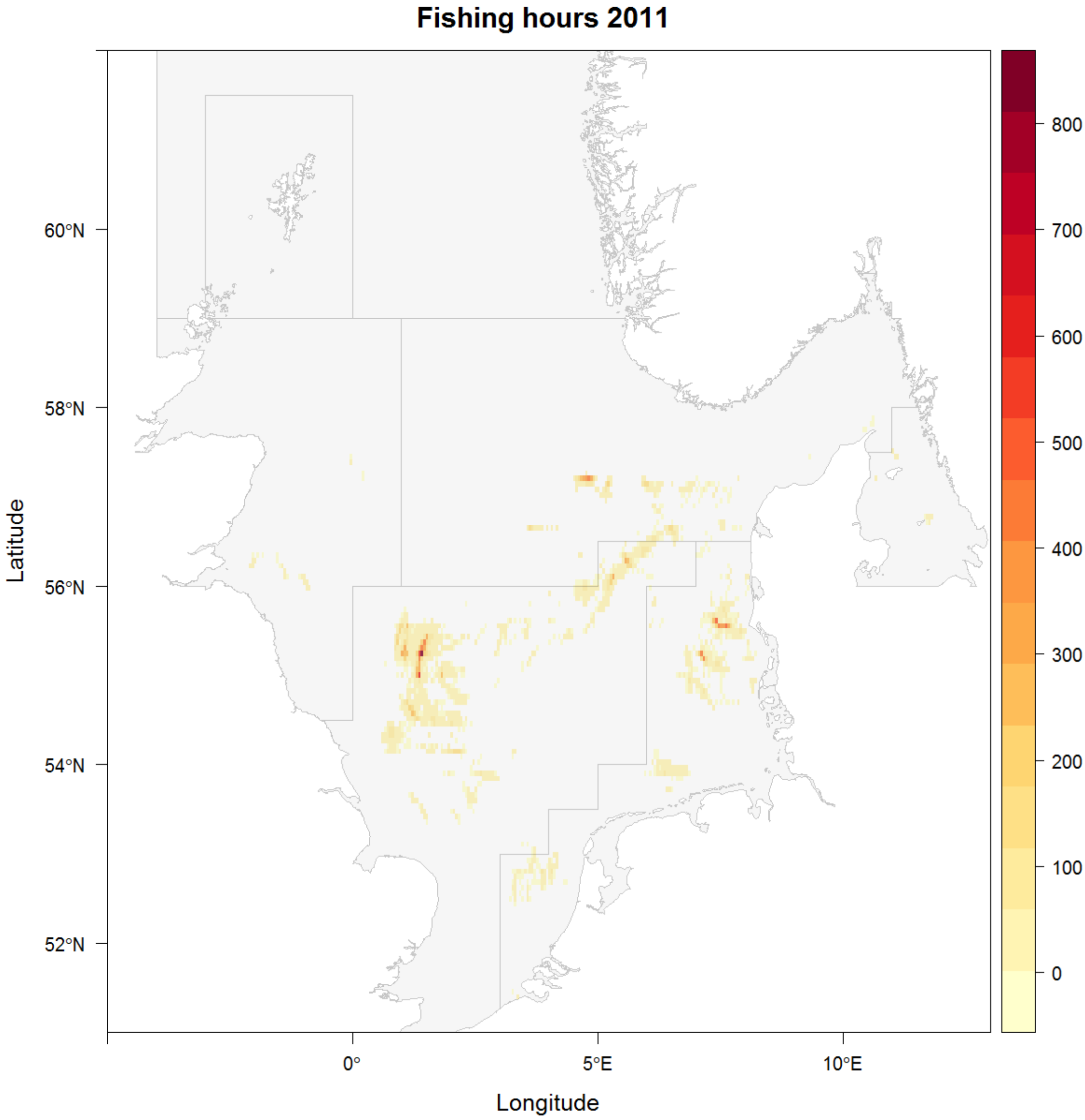

VMS_Sub_2009_Seine
VMS_Sub_2010_Seine
VMS_Sub_2011_Seine
VMS_Sub_2012_Seine
VMS_Sub_2013_Seine
VMS_Sub_2014_Seine
VMS_Sub_2015_Seine
VMS_Sub_Mean_Seine
Min: <0
1.5 to 10

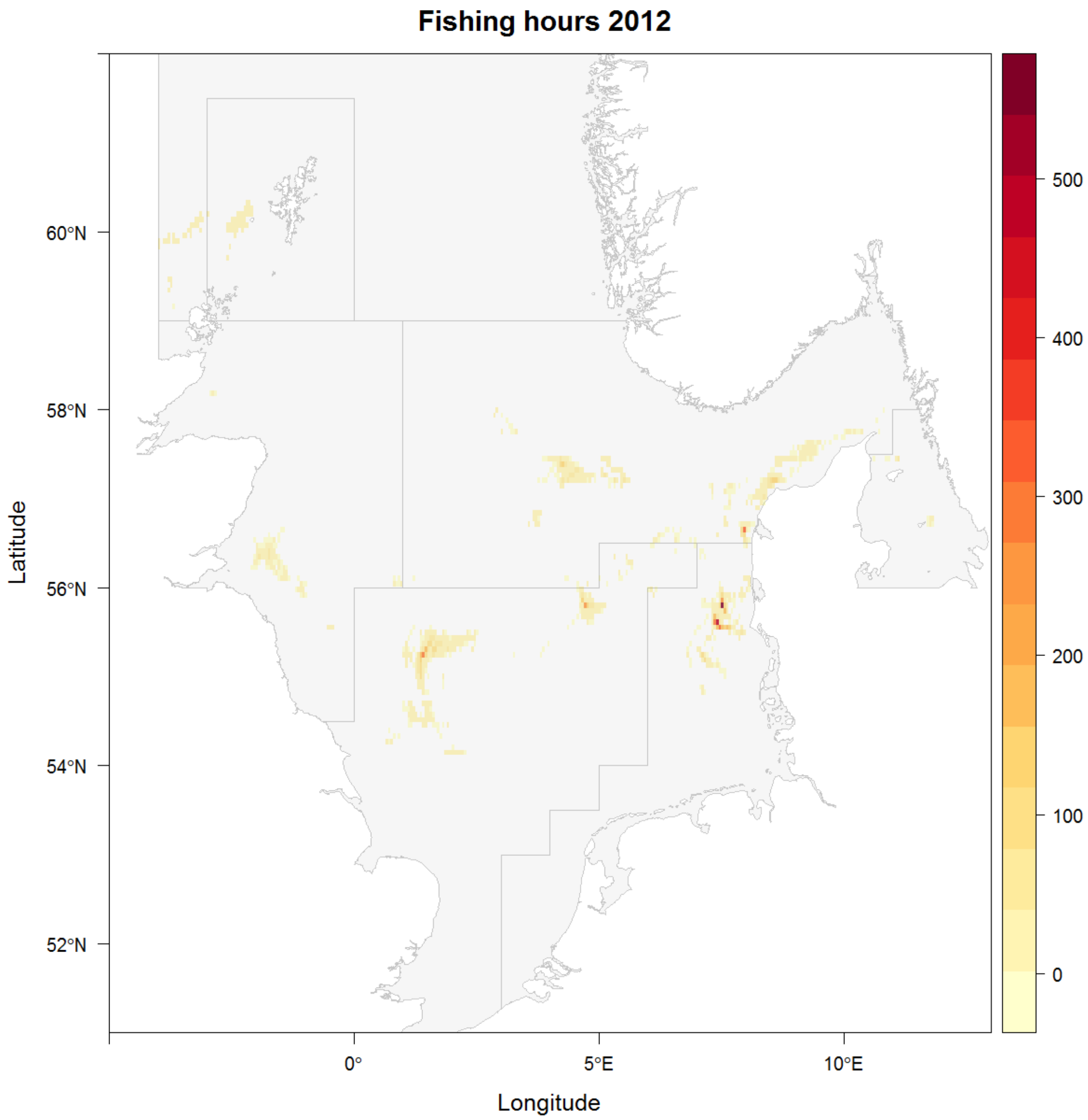
Annex 5: Maps produced for ToR f: Request from WKSand on the sandeel fishery

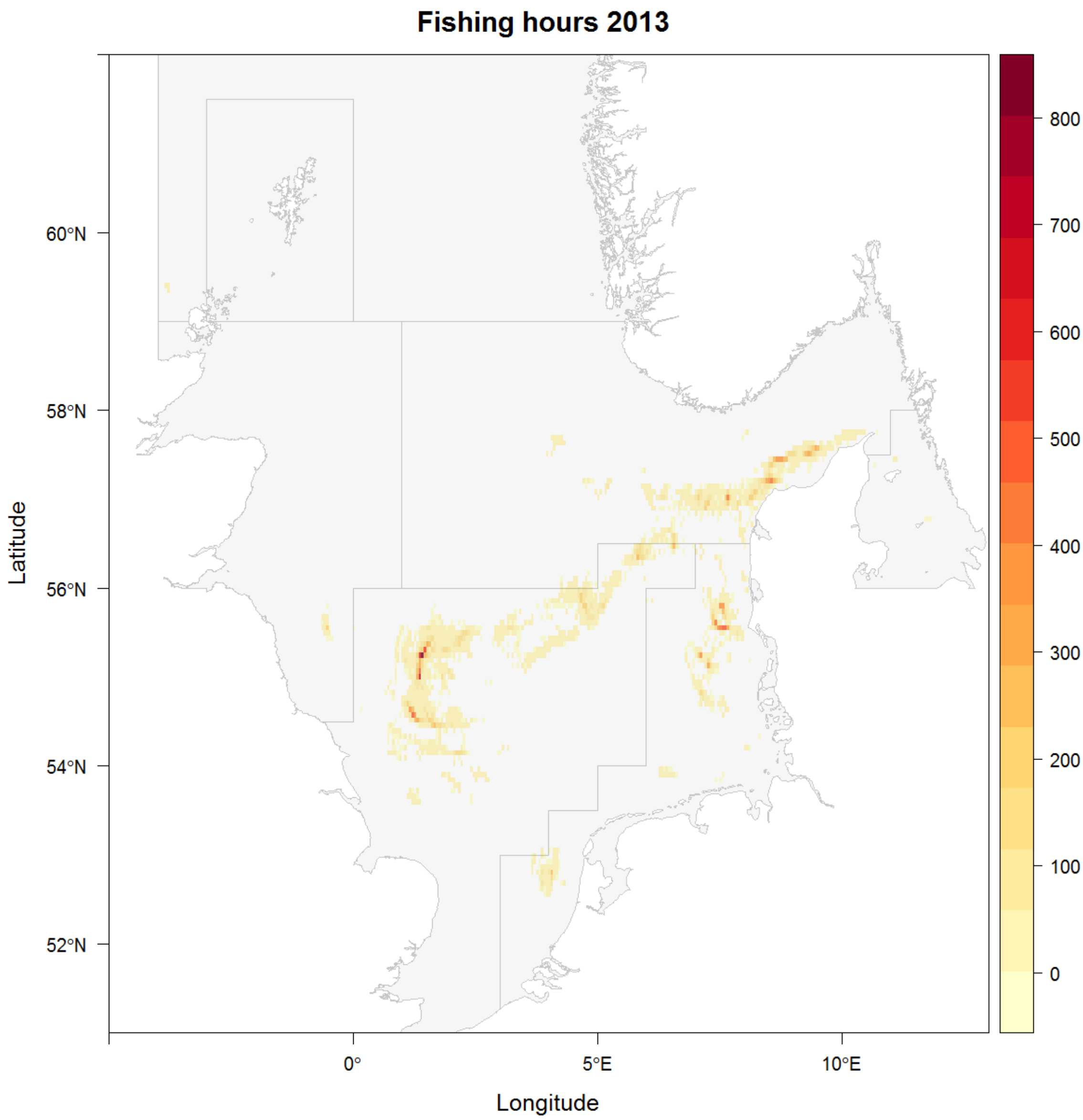
Yearly effort in fishing hour 2009 – 2015

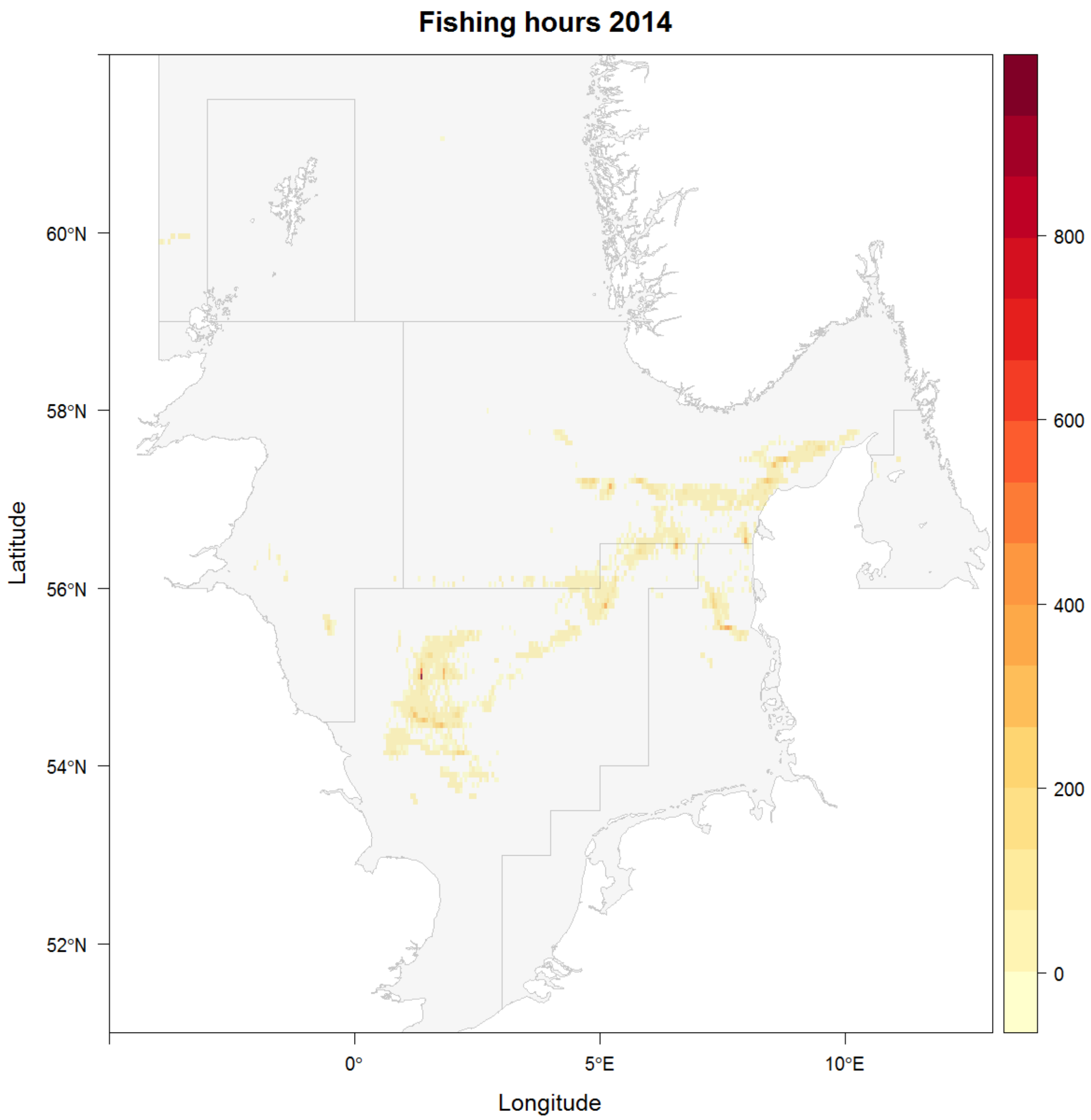


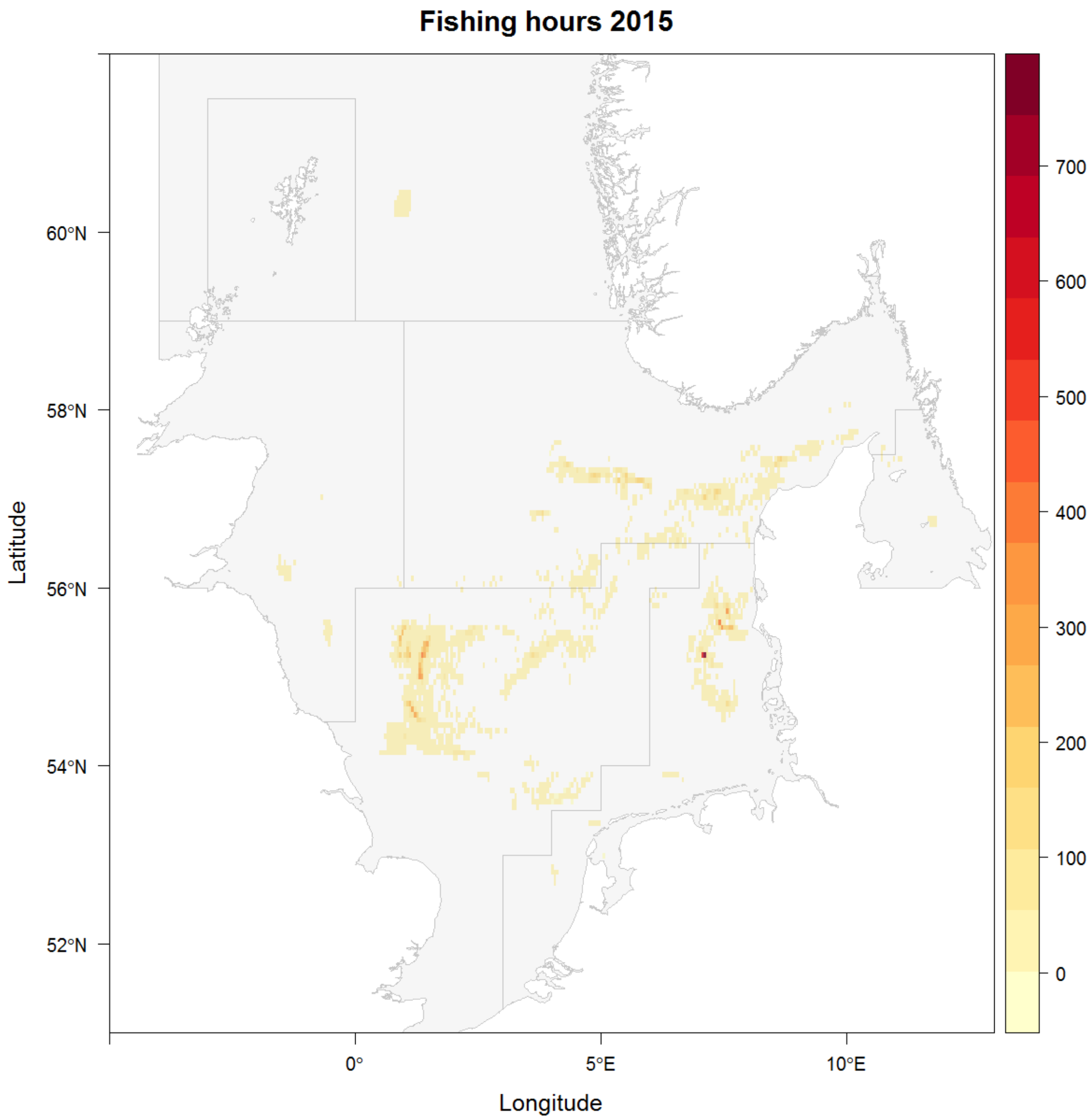

Fishing hours 2010
Latitude
Longitude
60°N
58°N
56°N
54°N
52°N
0°
5°E
10°E
700
600
500
400
300
200
100
0


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

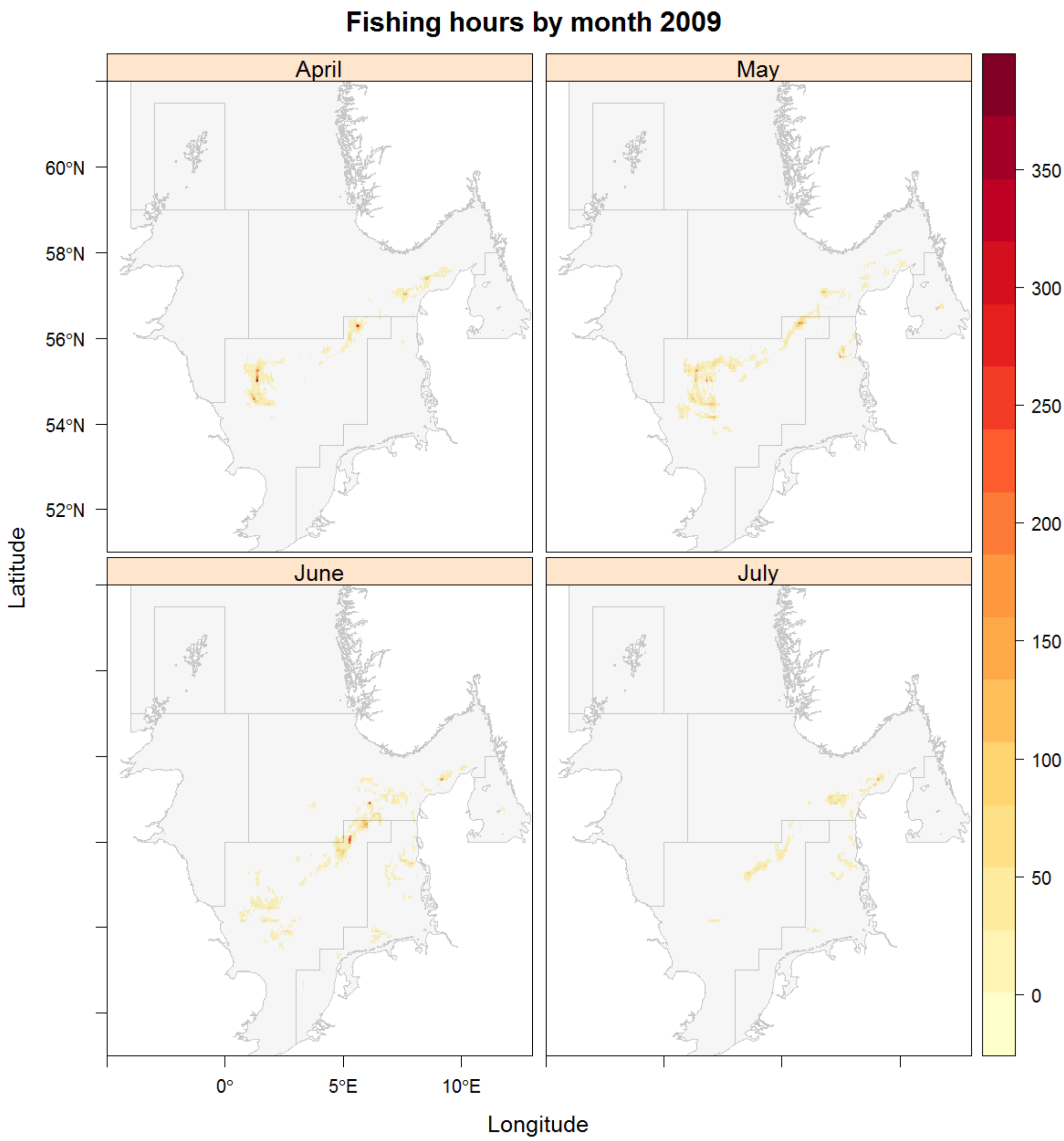

Fishing hours 2013
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
800
700
600
500
400
300
200
100
0

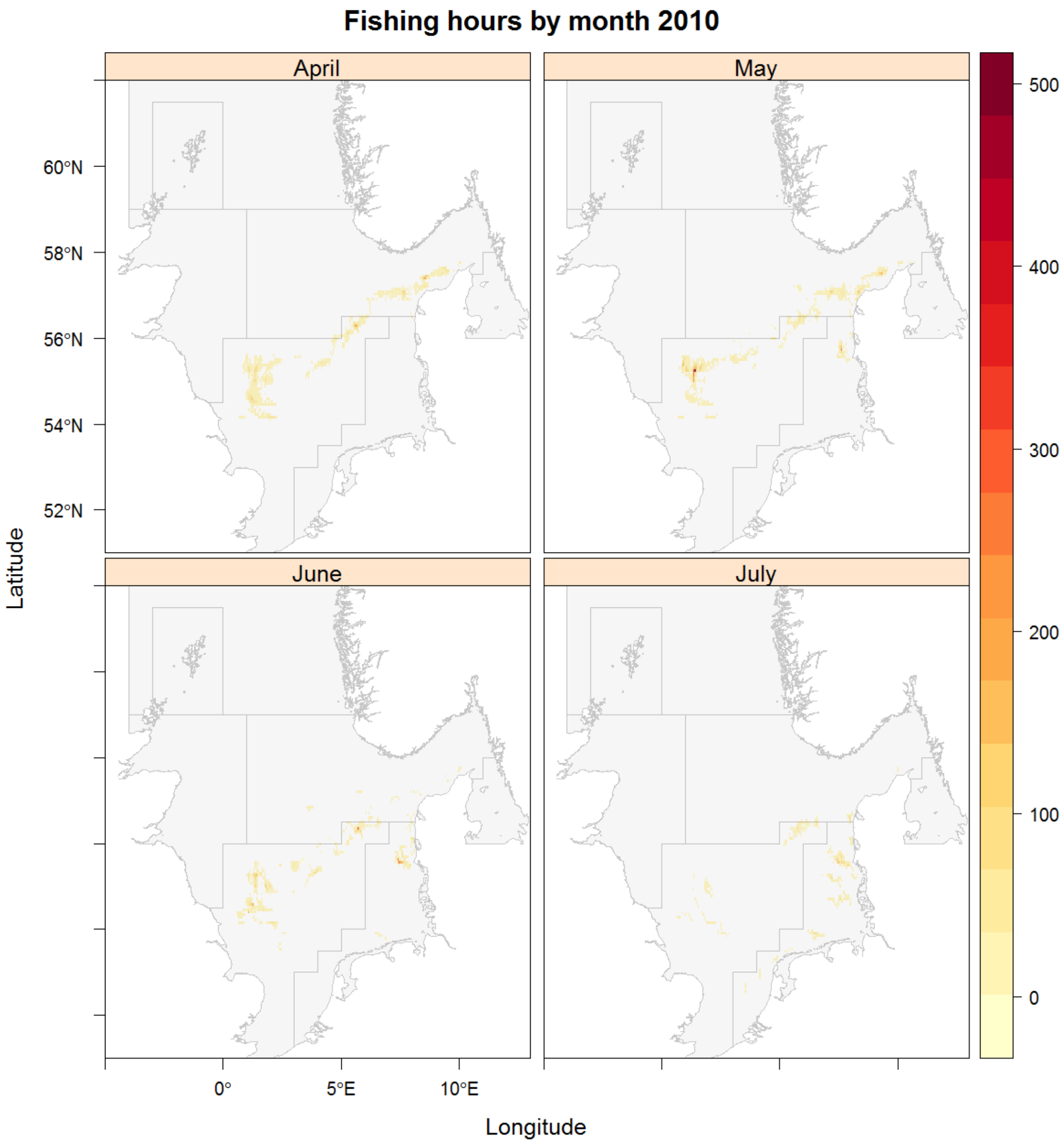

Fishing hours 2014
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
800
600
400
200
0

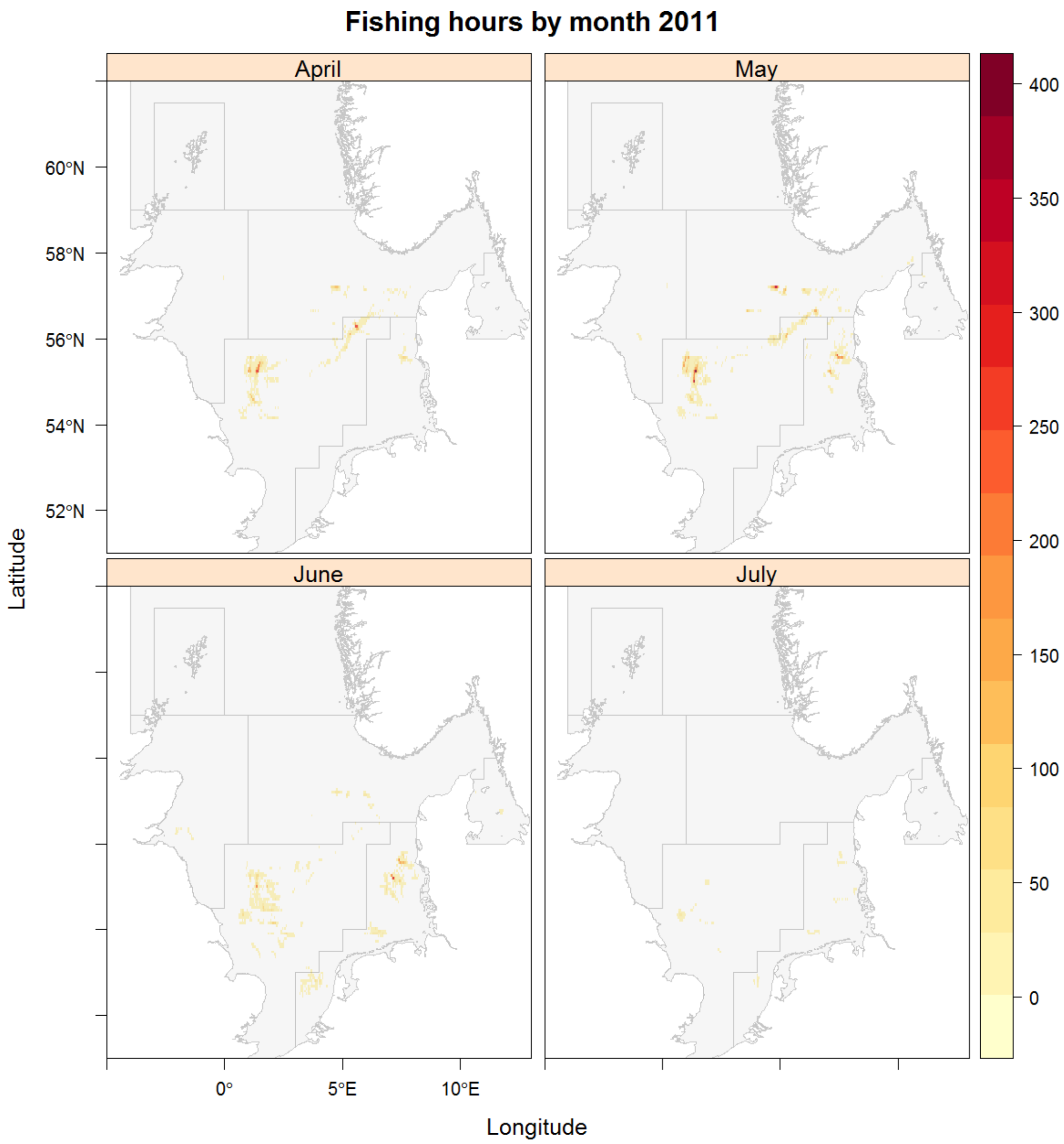


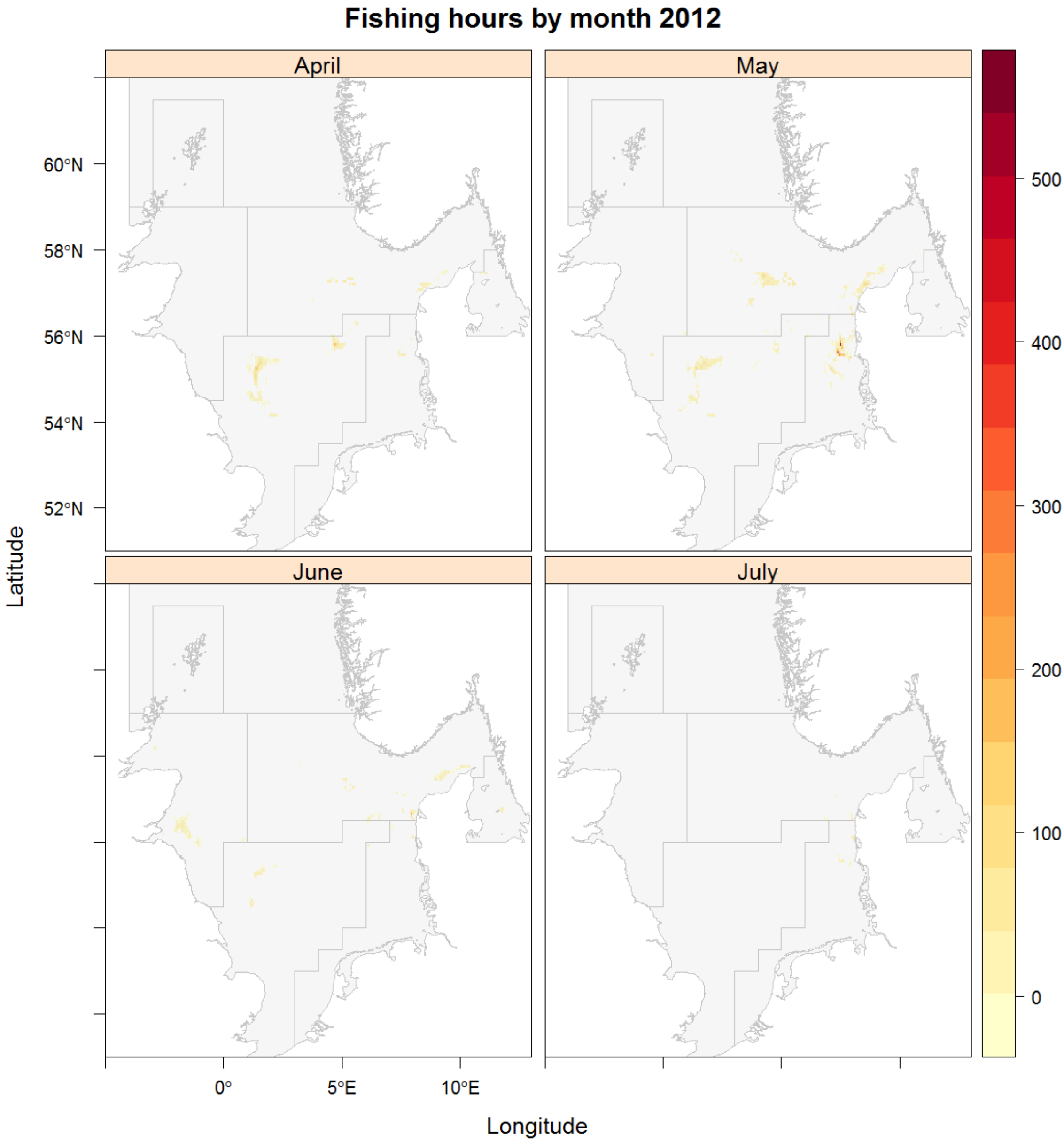
Fishing hours 2015
Latitude
Longitude
60°N
58°N
56°N
54°N
52°N
0°
5°E
10°E
700
600
500
400
300
200
100
0

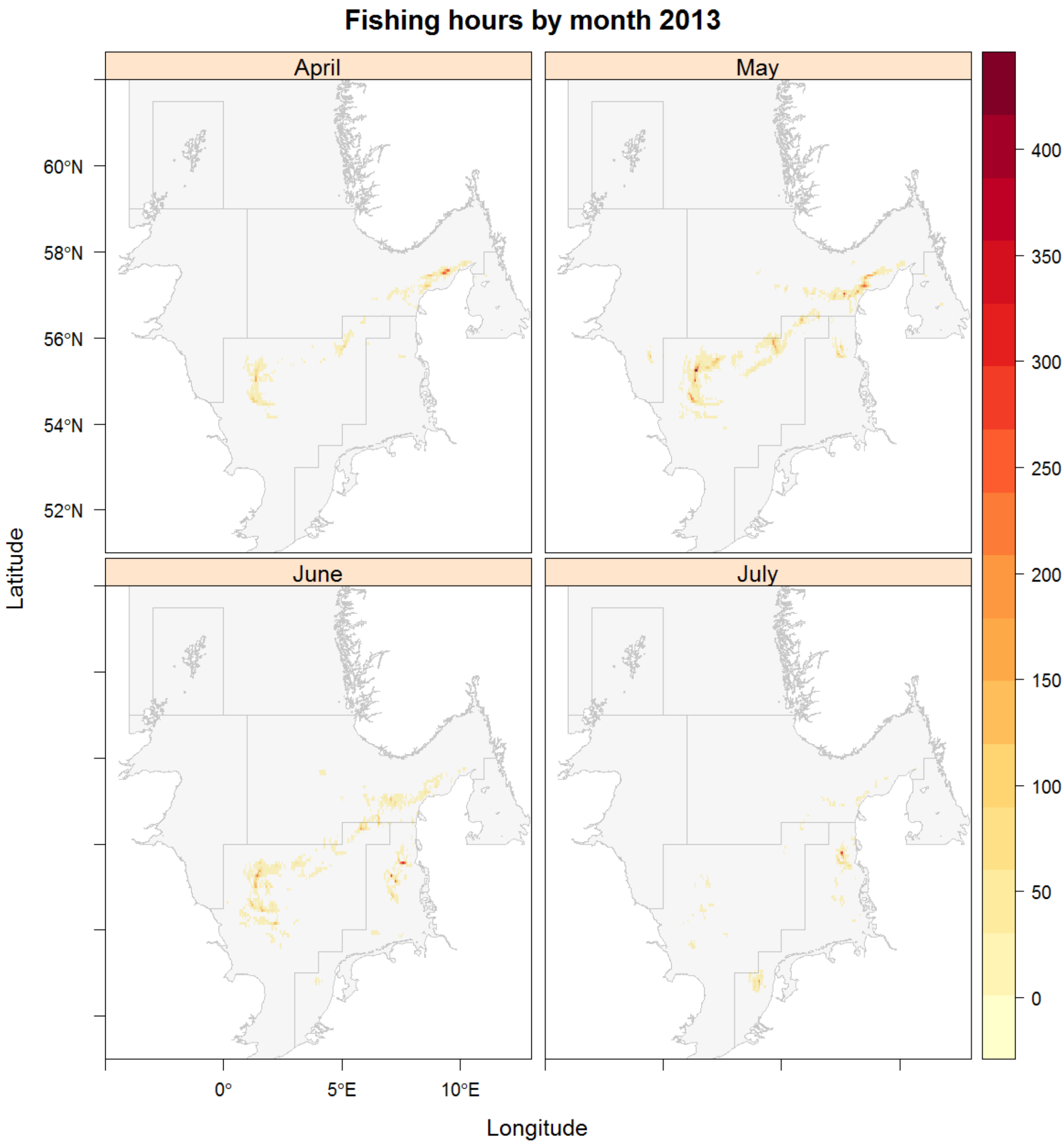
Monthly fishing effort

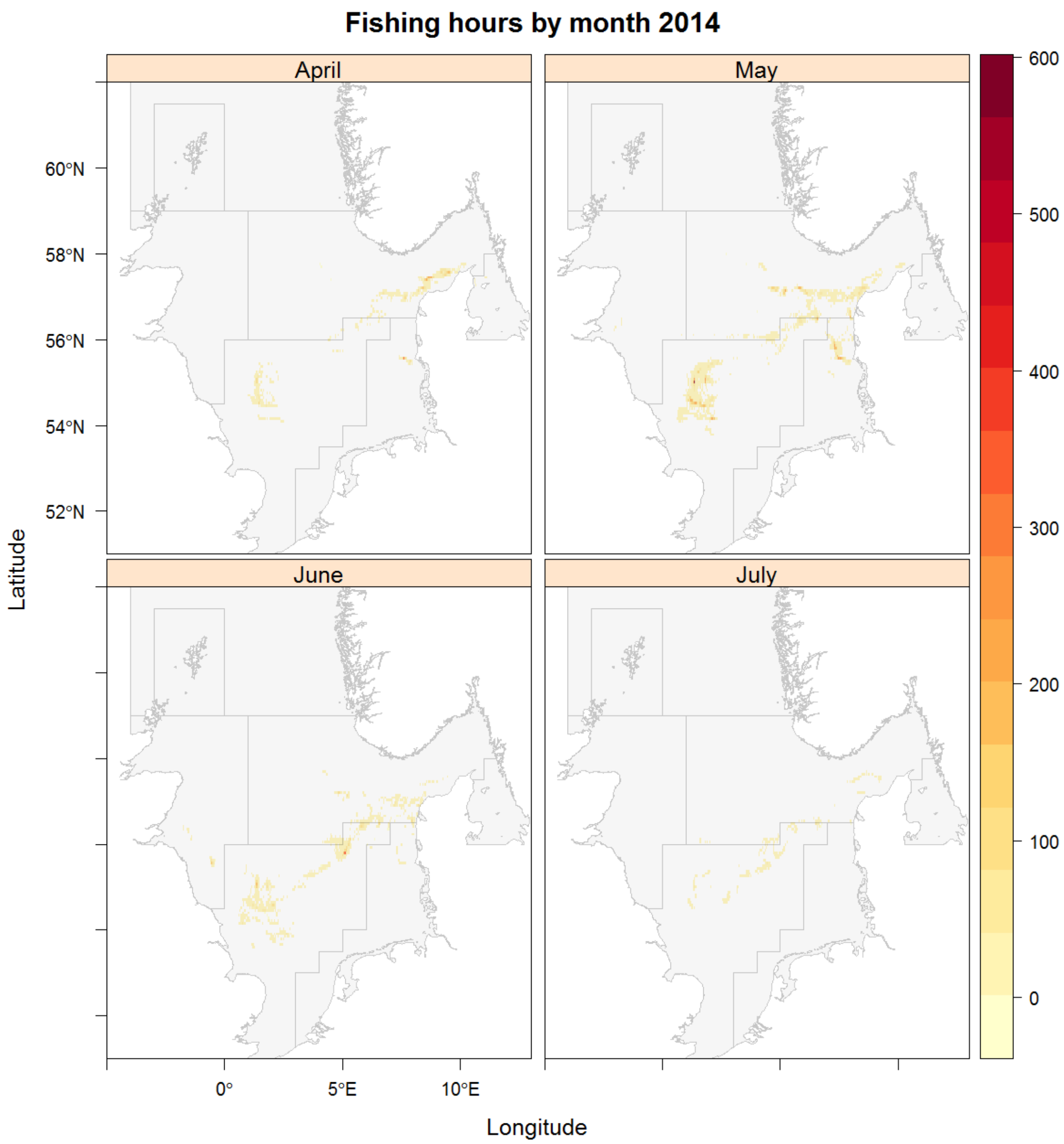



Fishing hours by month 2010
April
May
June
July
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
500
400
300
200
100
0

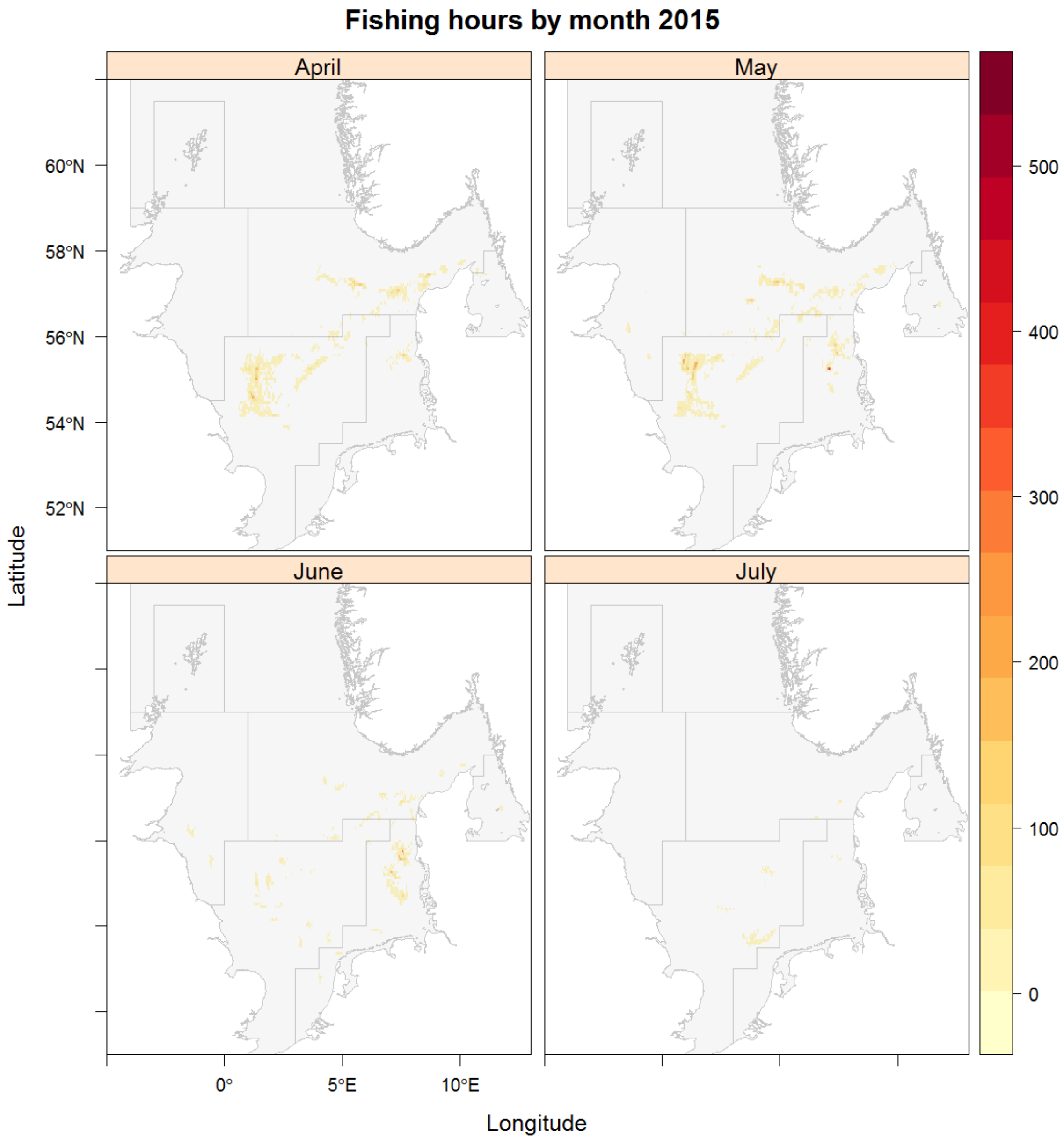

Fishing hours by month 2011
April
May
June
July
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
400
350
300
250
200
150
100
50
0


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

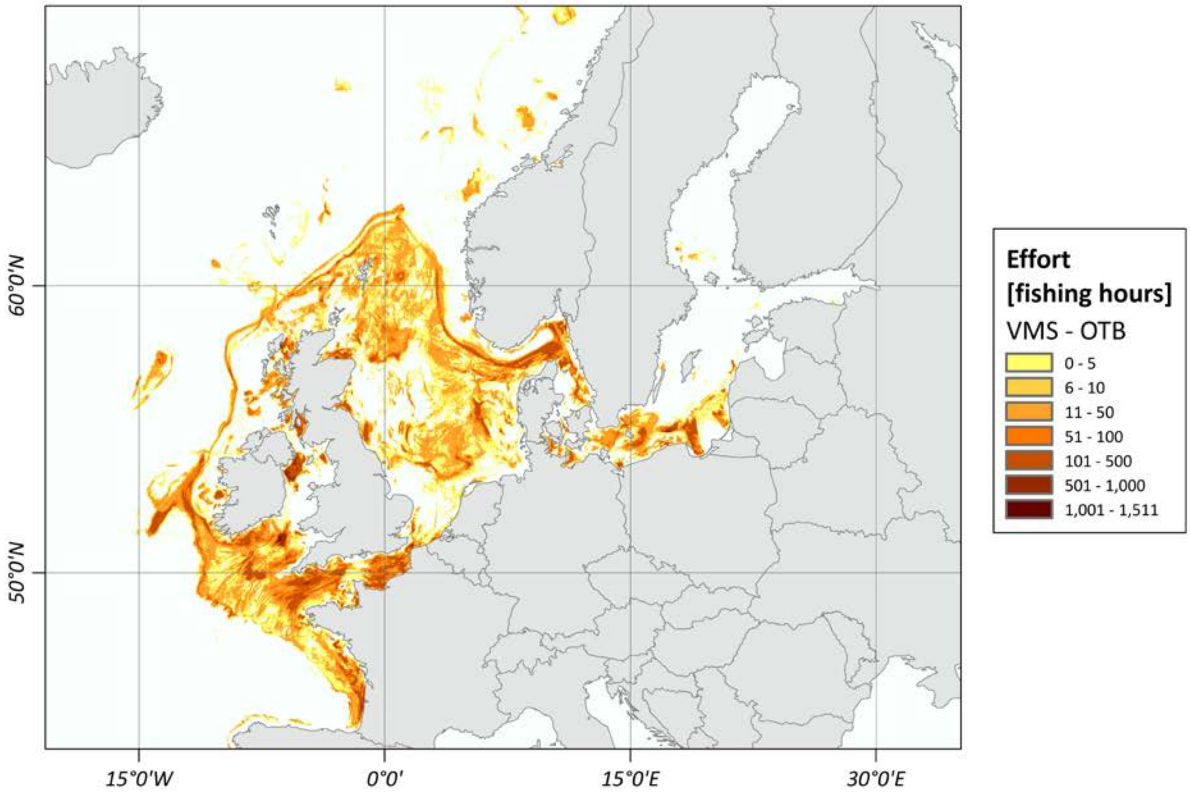

Fishing hours by month 2013
April
May
June
July
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
400
350
300
250
200
150
100
50
0

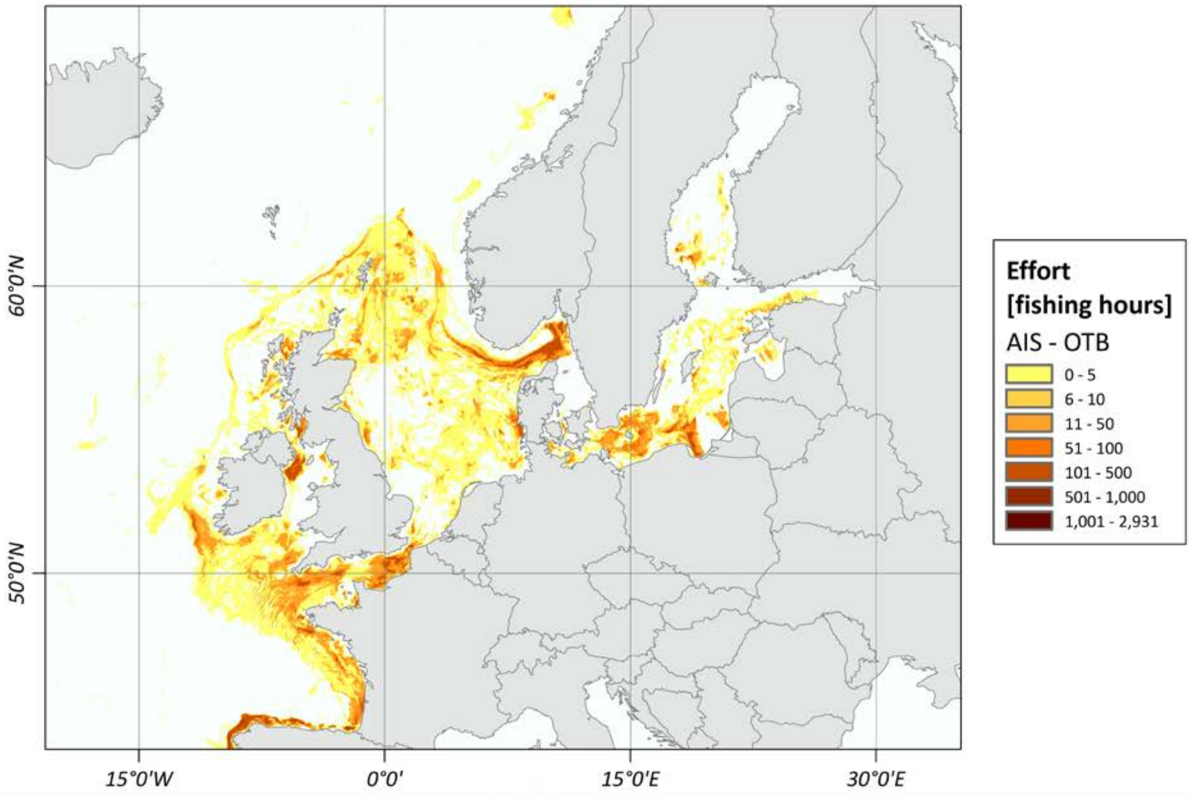


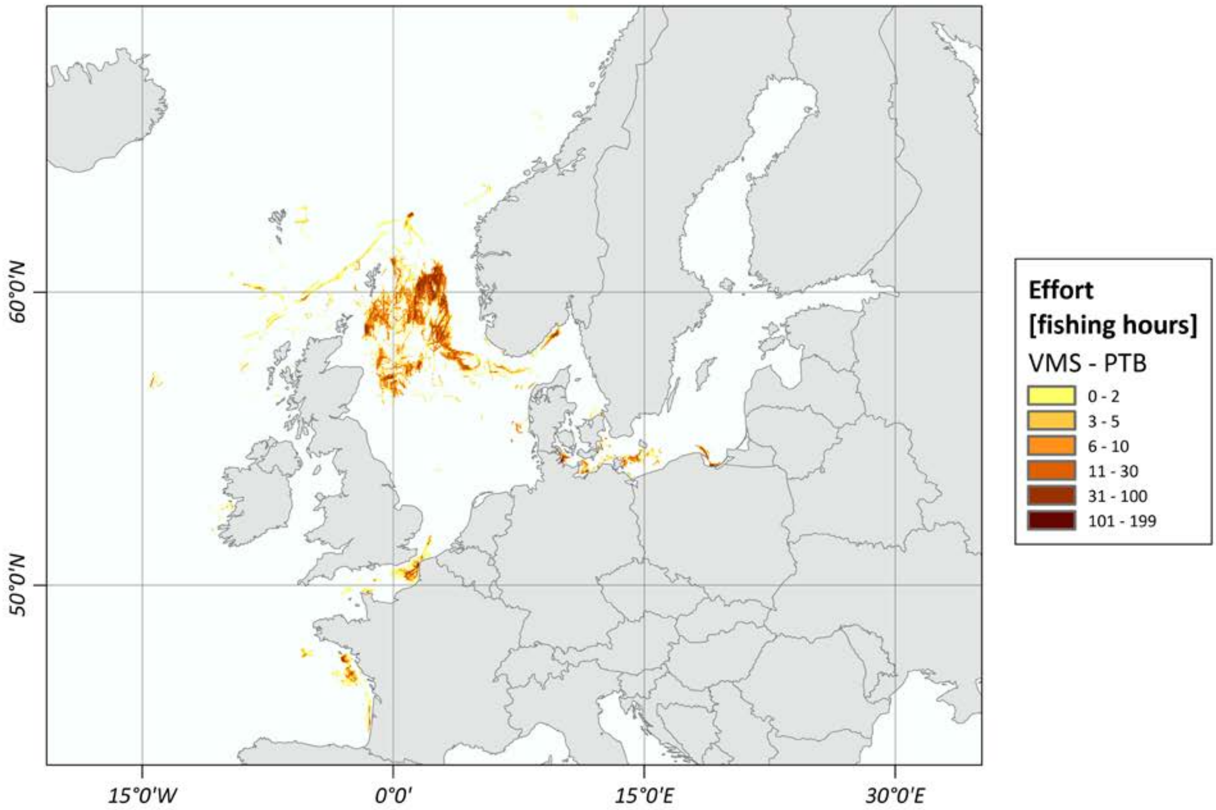
Fishing hours by month 2014
April
May
June
July
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
600
500
400
300
200
100
0


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

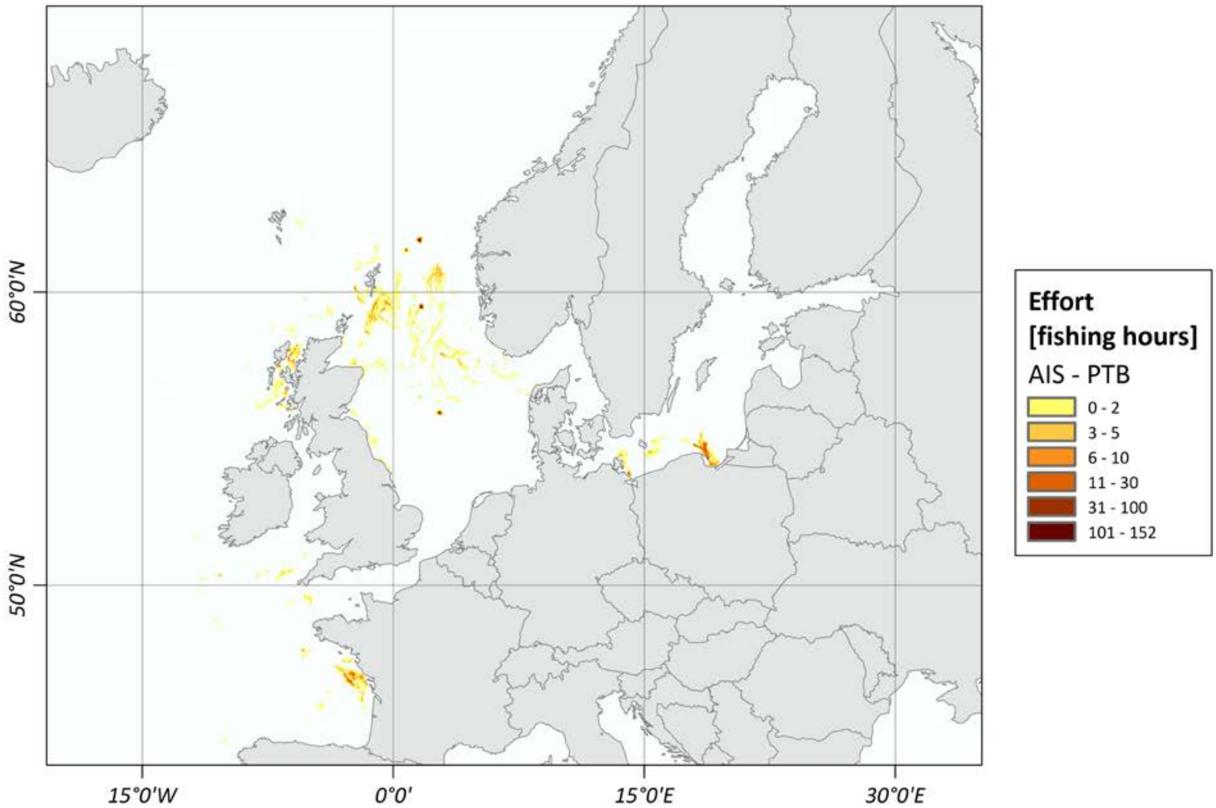
Annex 6: Maps comparing VMS and AIS data outputs



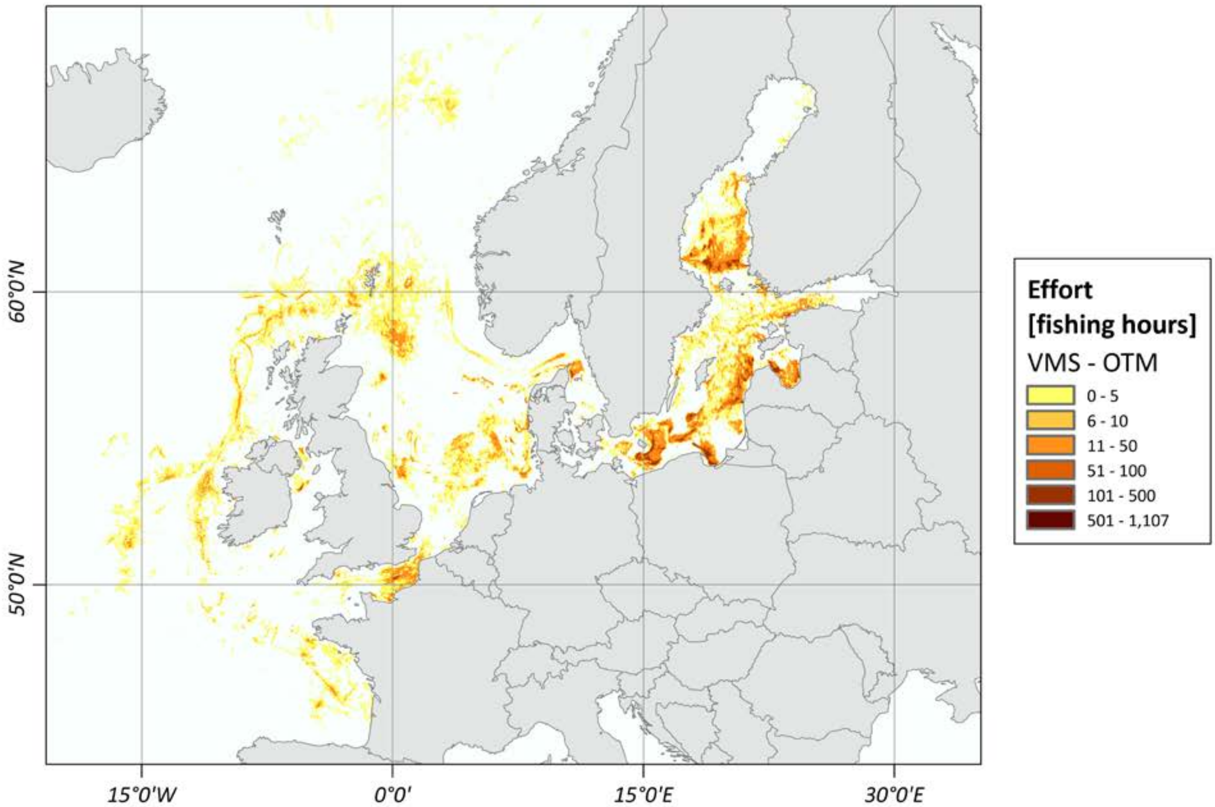


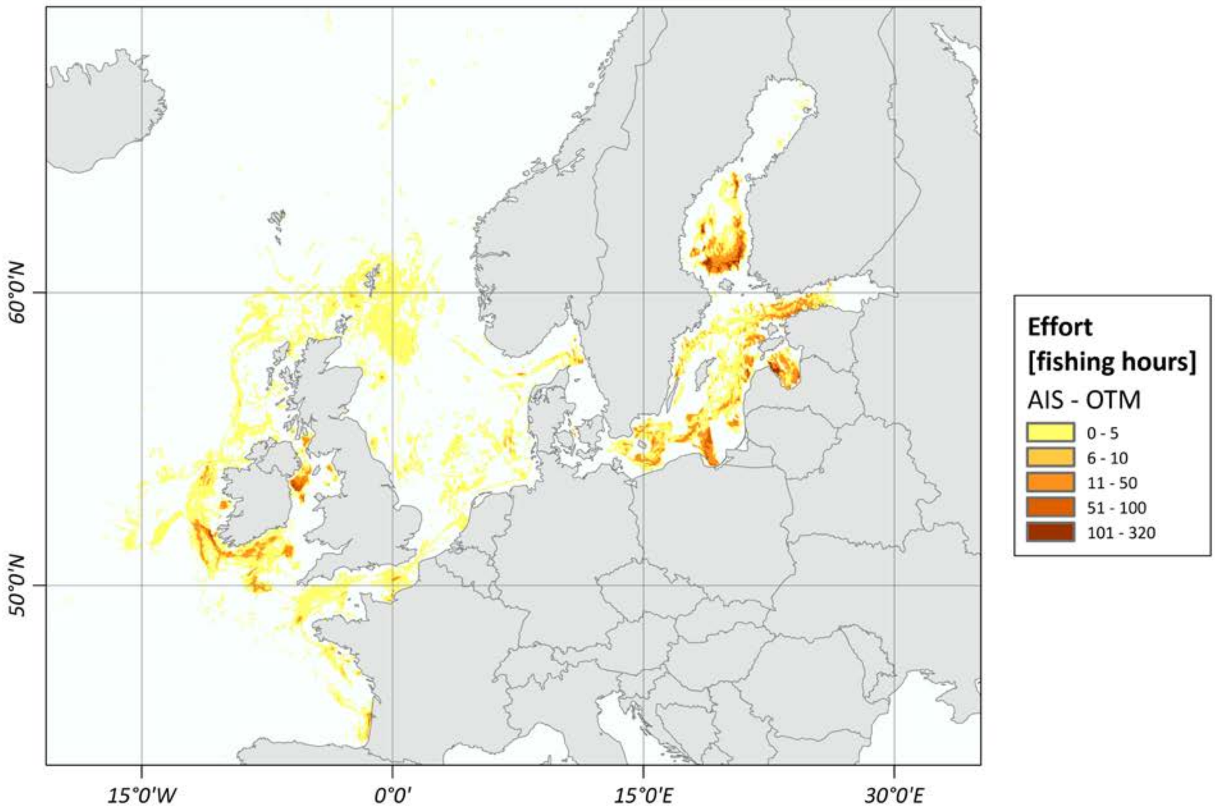


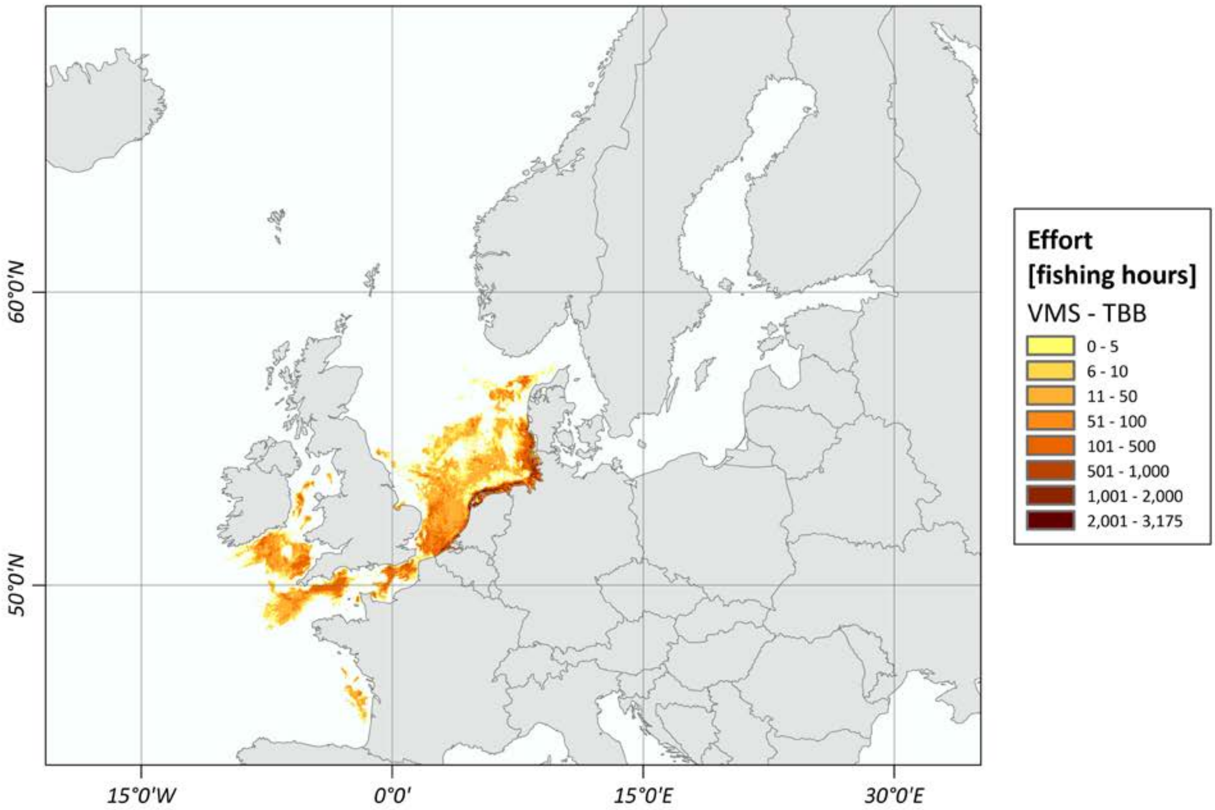
60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E
Effort
[fishing hours]
VMS - PTB
0 - 2
3 - 5
6 - 10
11 - 30
31 - 100
101 - 199

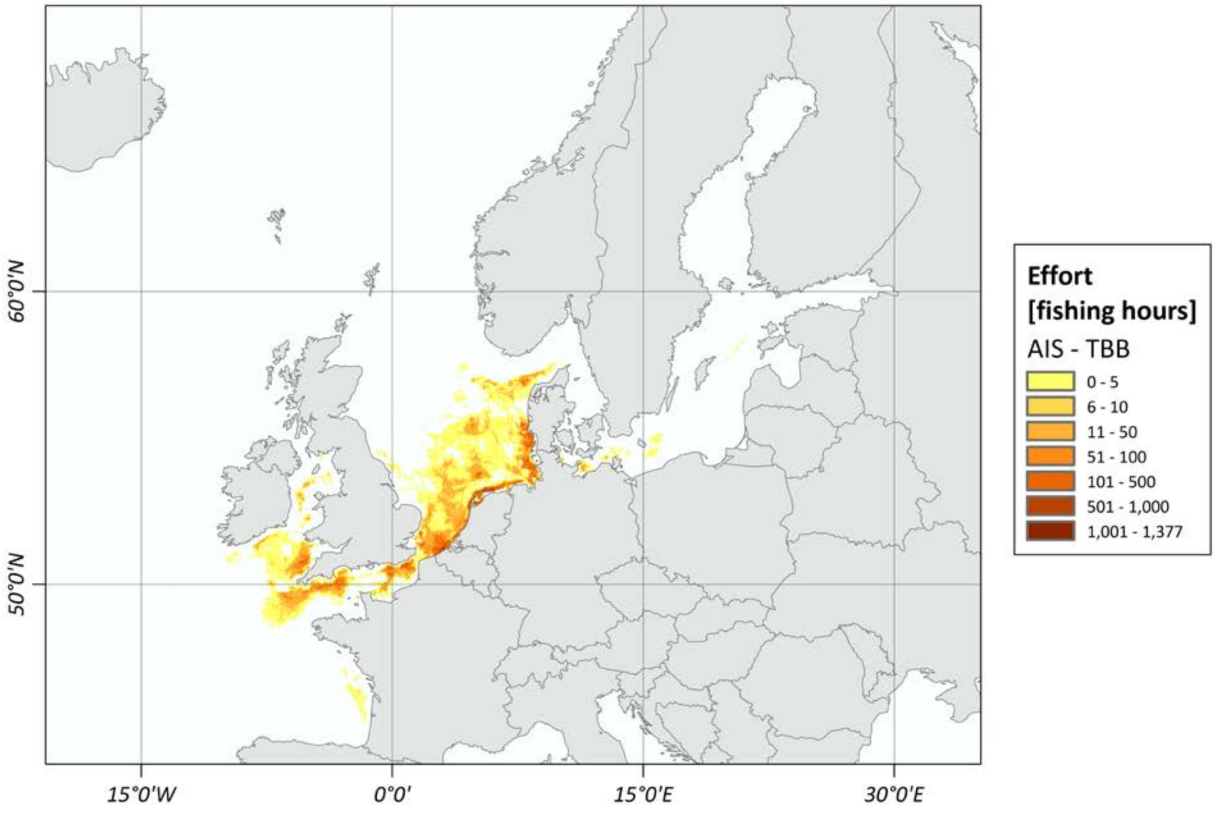


60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E
Effort
[fishing hours]
AIS - PTB
0 - 2
3 - 5
6 - 10
11 - 30
31 - 100
101 - 152


60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E
Effort
[fishing hours]
VMS - 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

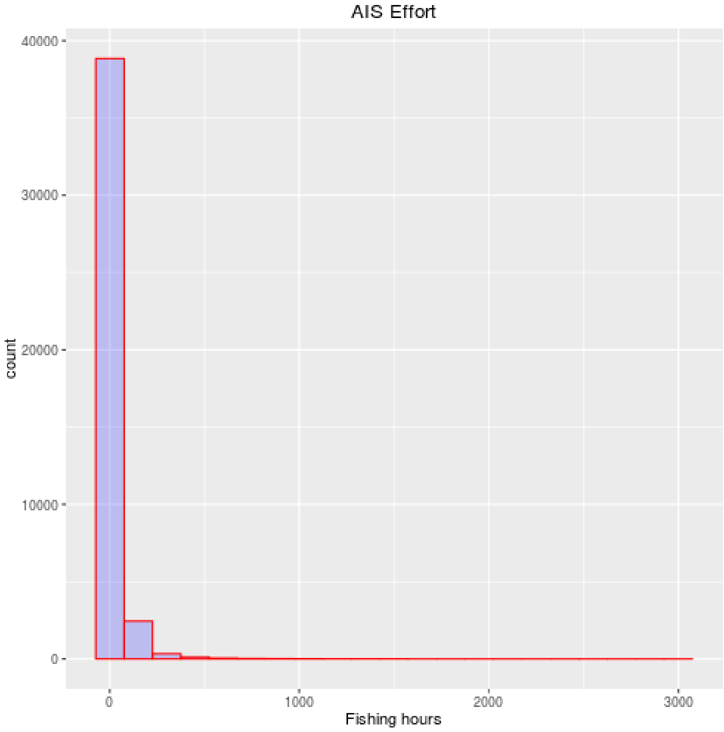

60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E
Effort
[fishing hours]
VMS - TBB
0 - 5
6 - 10
11 - 50
51 - 100
101 - 500
501 - 1,000
1,001 - 2,000
2,001 - 3,175


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

Annex 7: Statistical analysis comparing VMS and AIS data

AIS OTB SUMMARY

Original Values



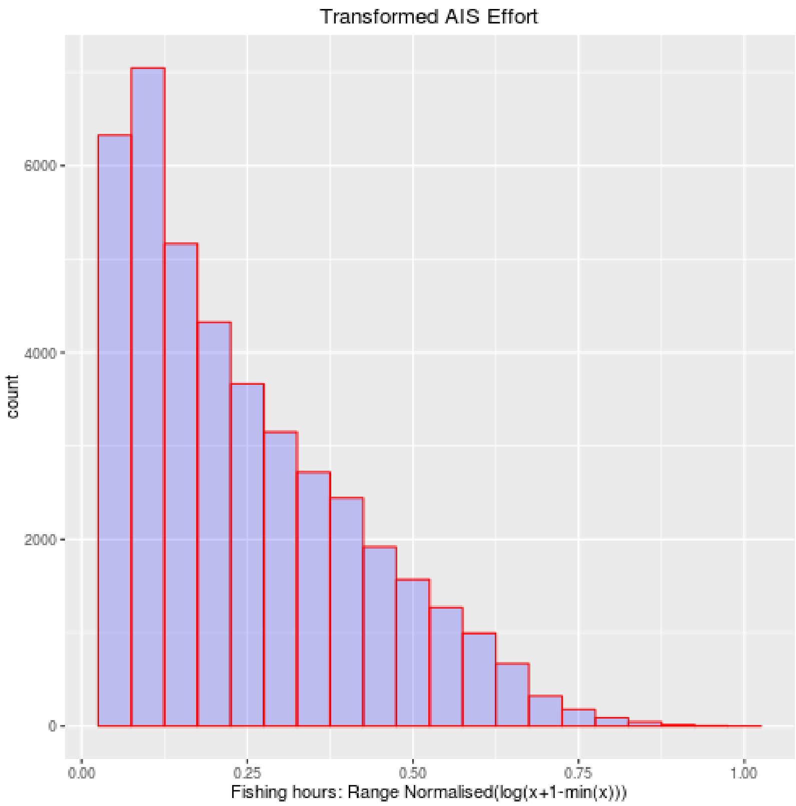
Summary statistics

	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

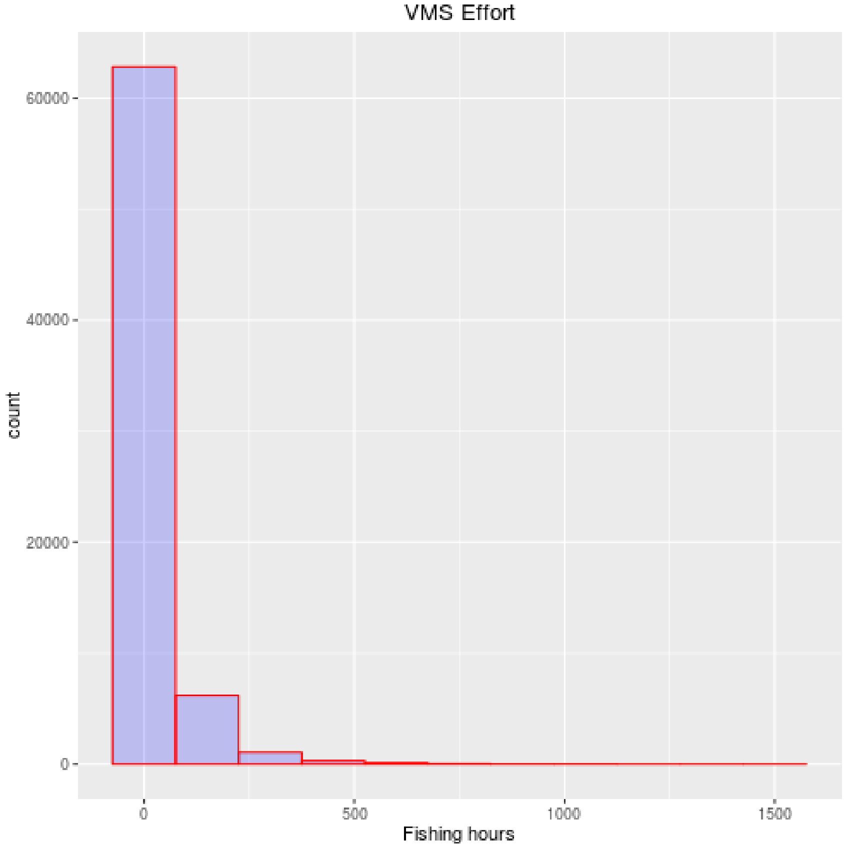
	AIS OTB Transformed Fishing Hours
Values	41930.00000
NULL	0.00000
NA	0.00000
min	0.04363
max	1.00000
range	0.95637
sum	10314.09337
median	0.20160
mean	0.24598
SE.mean	0.00084
CI.mean.0.95	0.00165
var	0.02957
std.dev	0.17196
coef.var	0.69908

Quartiles

0%	25%	50%	75%	100%
0.044	0.102	0.202	0.356	1.000

VMS OTB SUMMARY

Original Values



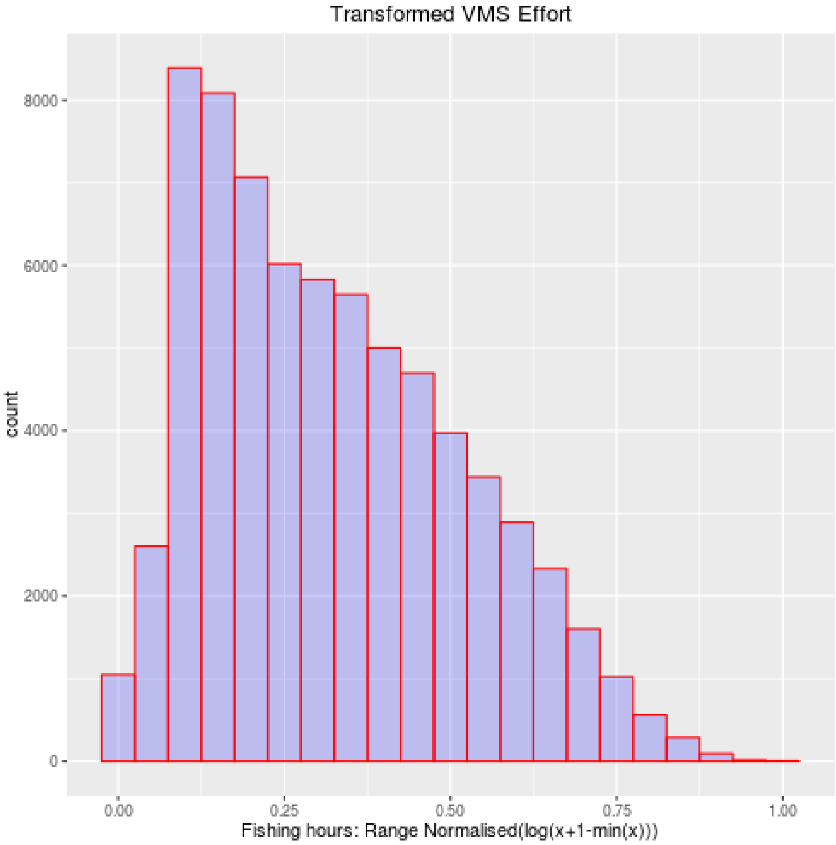
Summary statistics

	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



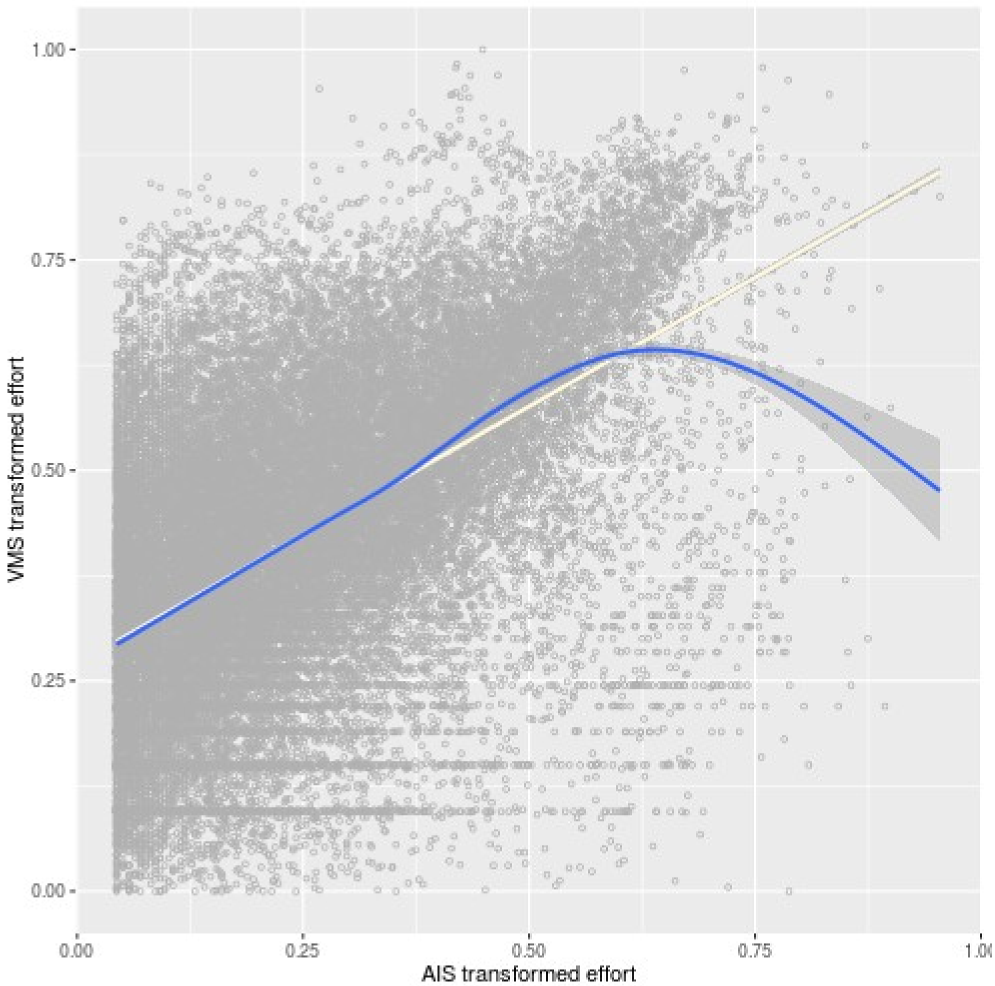
Summary statistics

	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:

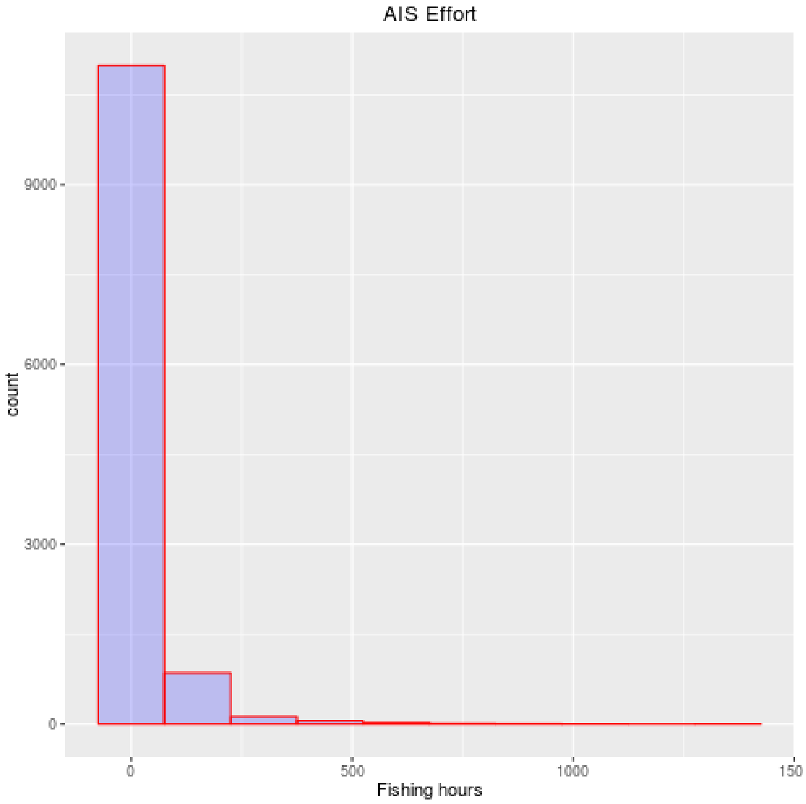
true ratio of variances is not equal to 1 95 percent confidence interval: [0.79 ;0.82]

sample estimates:

ratio of variances 0.81

AIS TBB SUMMARY

Original Values



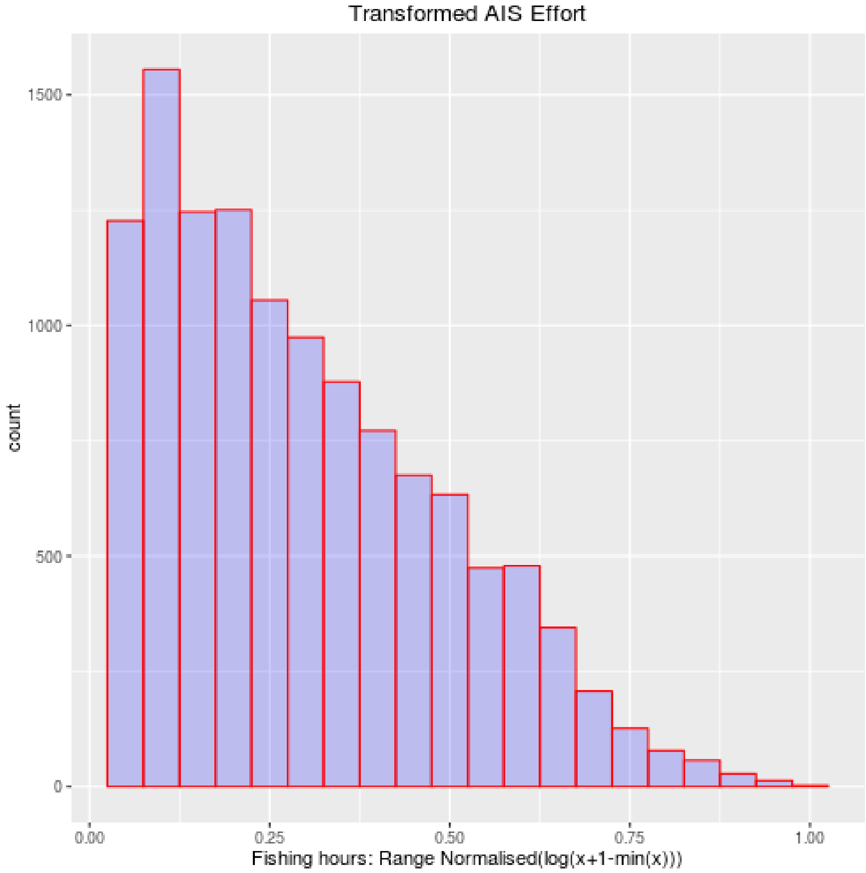
Summary statistics

	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

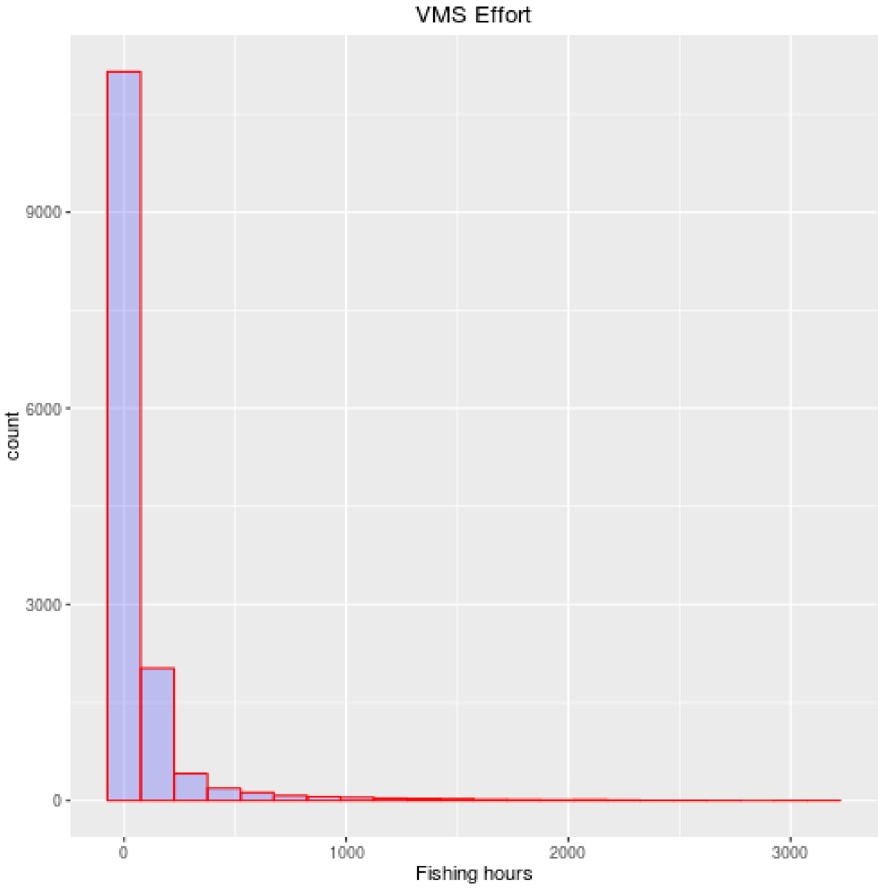
	AIS TBB Transformed Fishing Hours
Values	12075.0000
NULL	0.0000
NA	0.0000
min	0.0482
max	1.0000
range	0.9518
sum	3611.0166
median	0.2590
mean	0.2990
SE.mean	0.0018
CI.mean.0.95	0.0035
var	0.0378
std.dev	0.1944
coef.var	0.6500

Quartiles

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

VMS TBB SUMMARY

Original Values



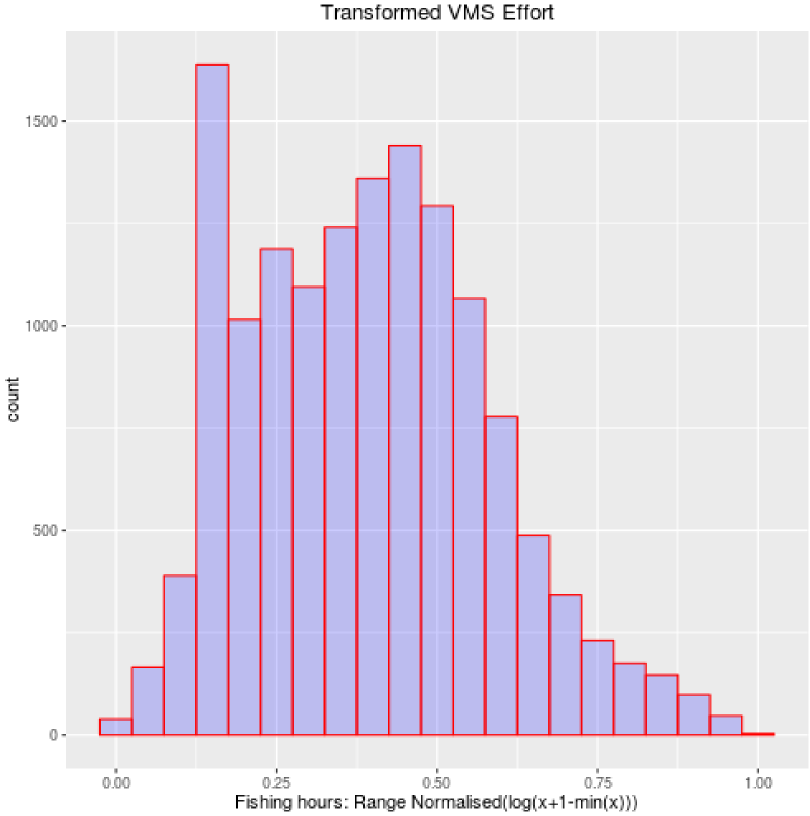
Summary statistics

	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



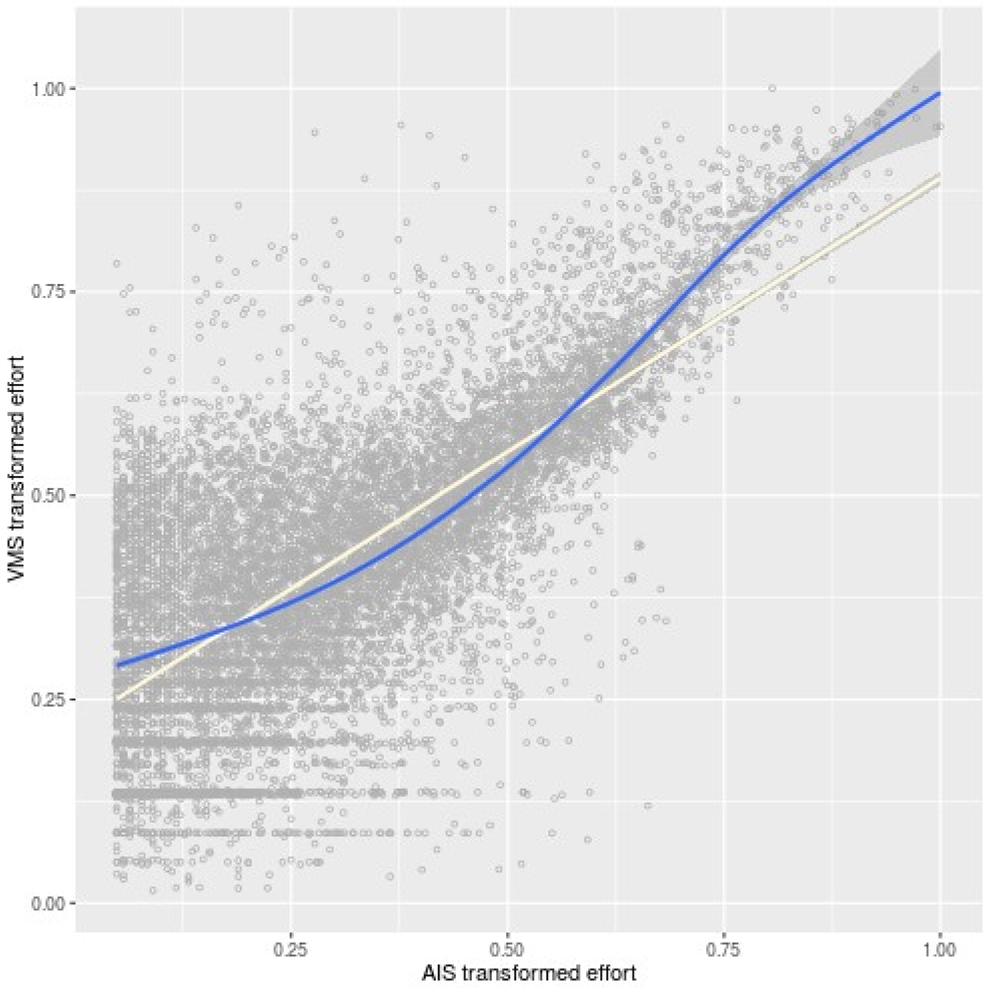
Summary statistics

	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

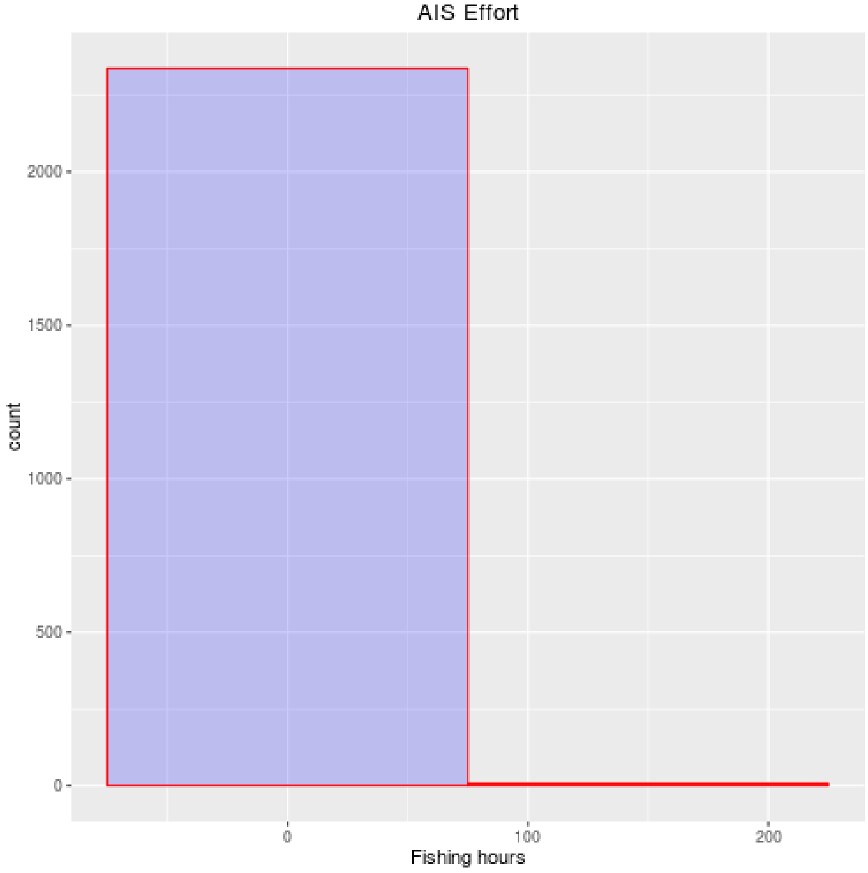
95 percent confidence interval: [1.1 ;1.2]

sample estimates:

ratio of variances 1.2

AIS PTB SUMMARY

Original Values



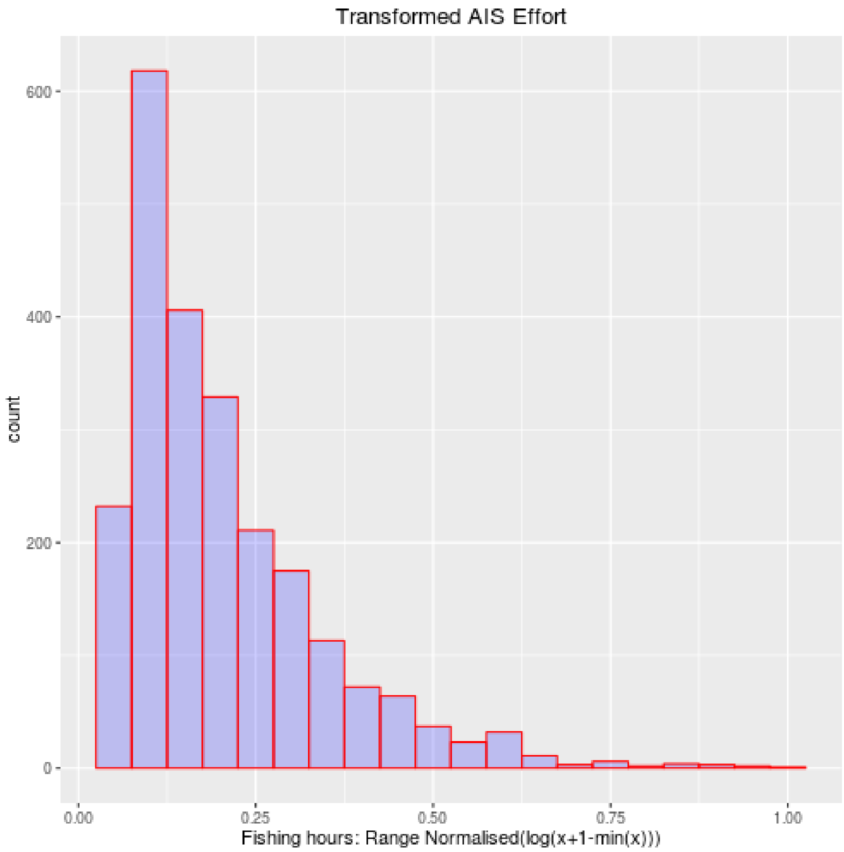
Summary statistics

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

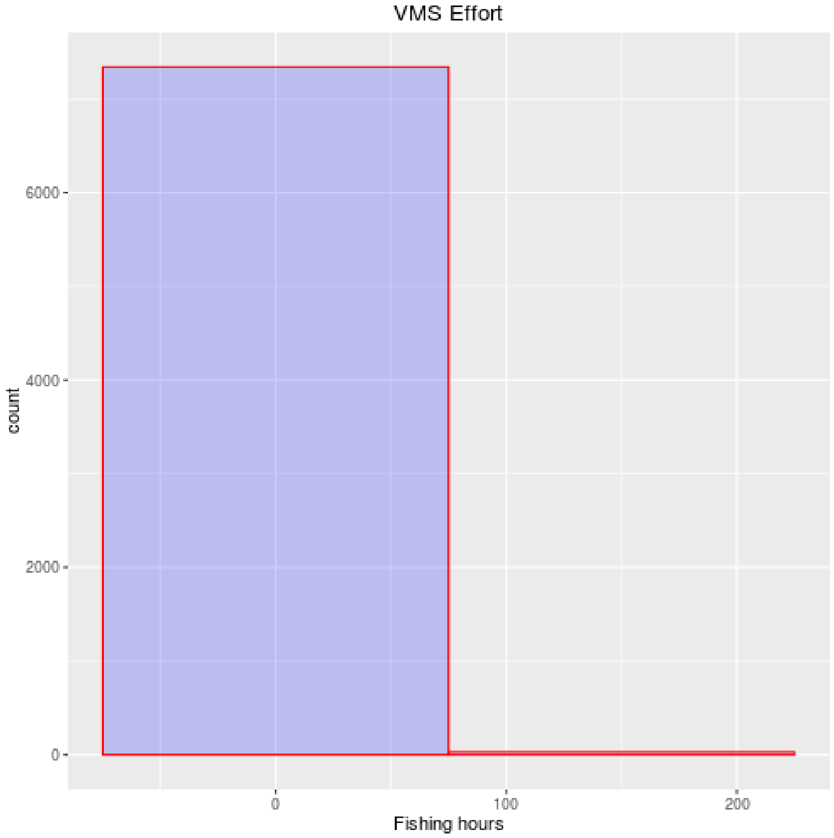
	AIS PTB Transformed Fishing Hours
Values	2344.0000
NULL	0.0000
NA	0.0000
min	0.0693
max	1.0000
range	0.9307
sum	479.1515
median	0.1613
mean	0.2044
SE.mean	0.0029
CI.mean.0.95	0.0056
var	0.0192
std.dev	0.1387
coef.var	0.6787

Quartiles

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

VMS PTB SUMMARY

Original Values



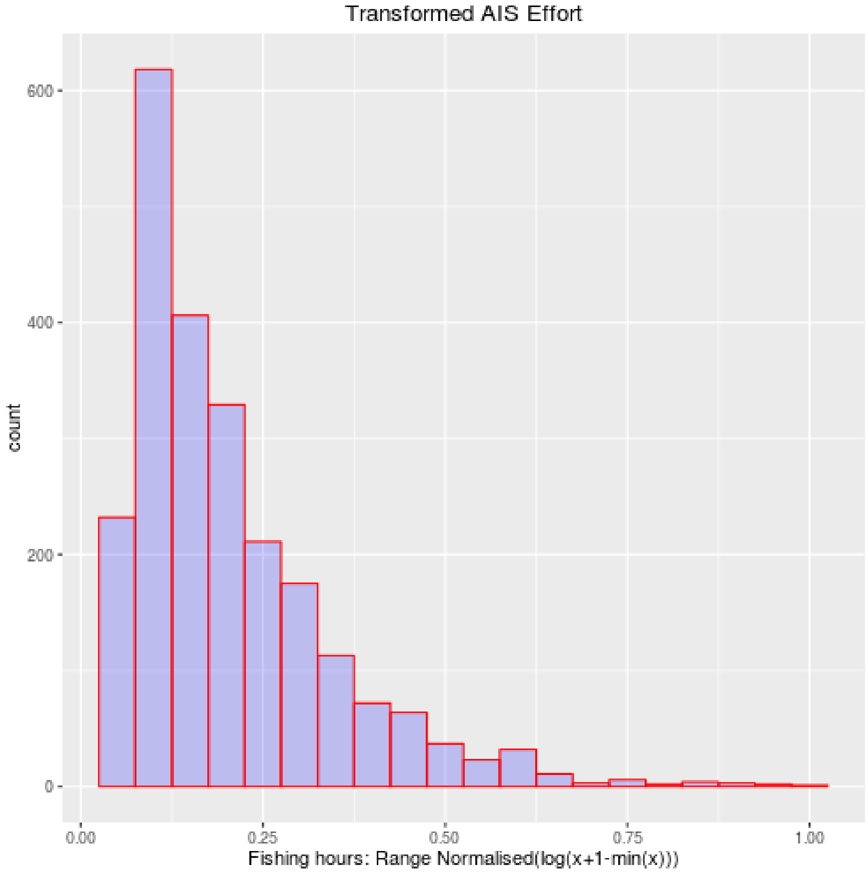
Summary statistics

	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



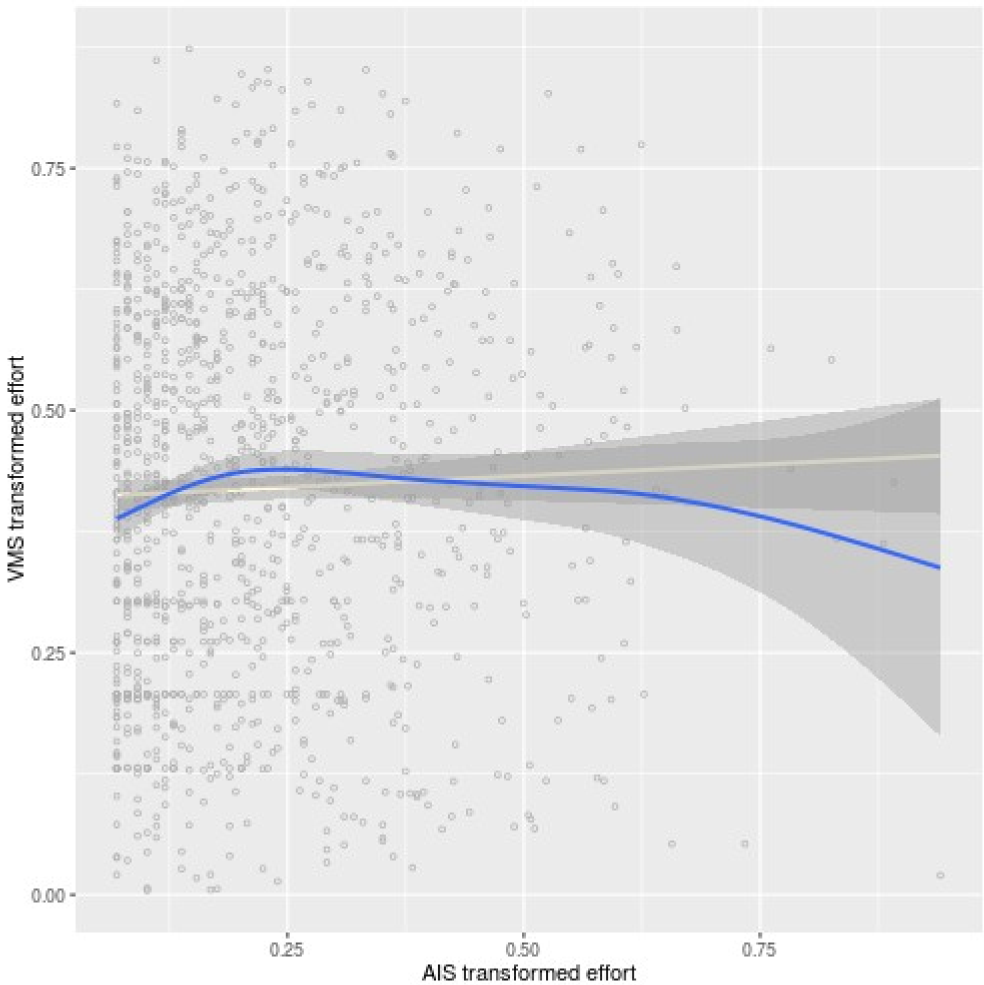
Summary statistics

	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

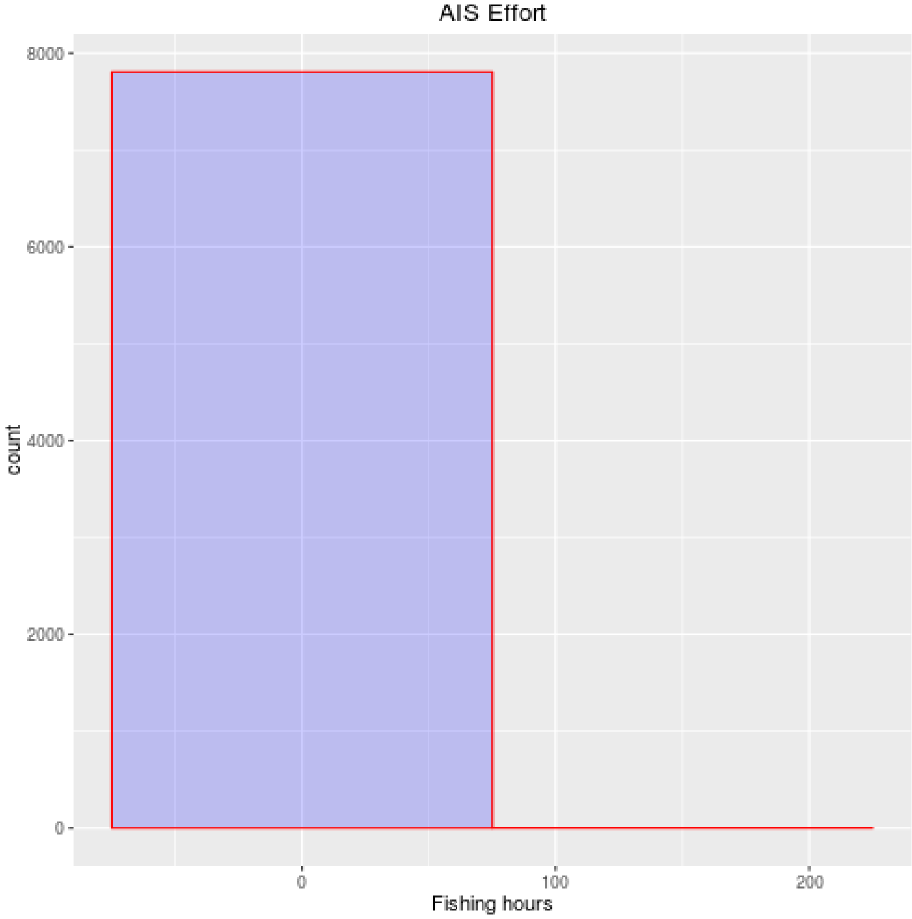
95 percent confidence interval: [0.45 ;0.57]

sample estimates:

ratio of variances 0.51

AIS OTT SUMMARY

Original Values



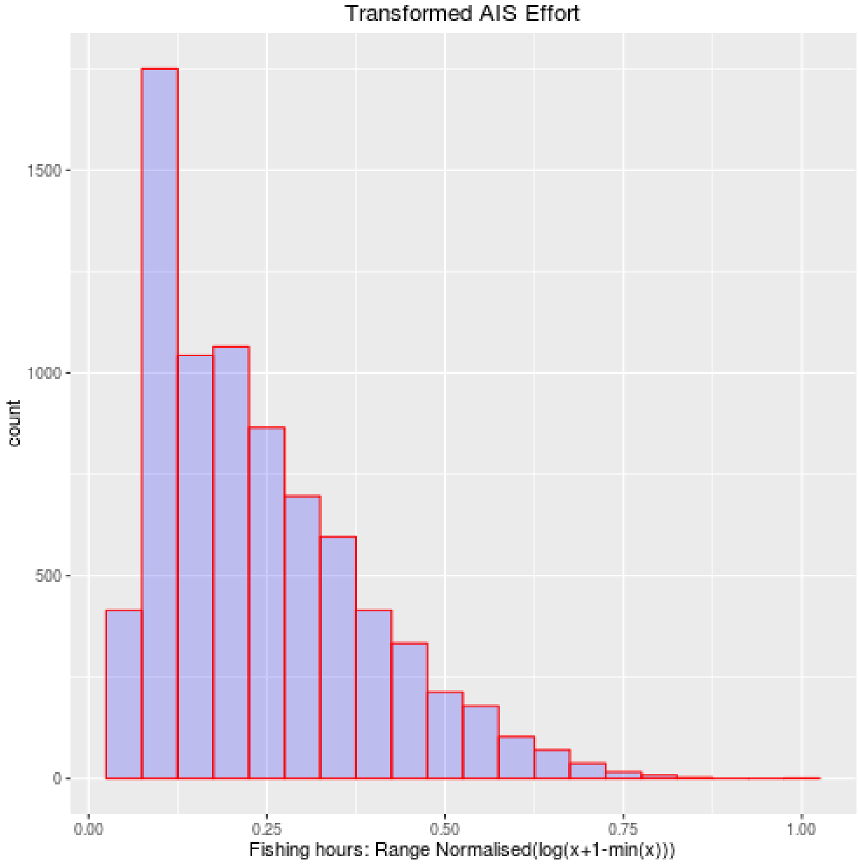
Summary statistics

	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



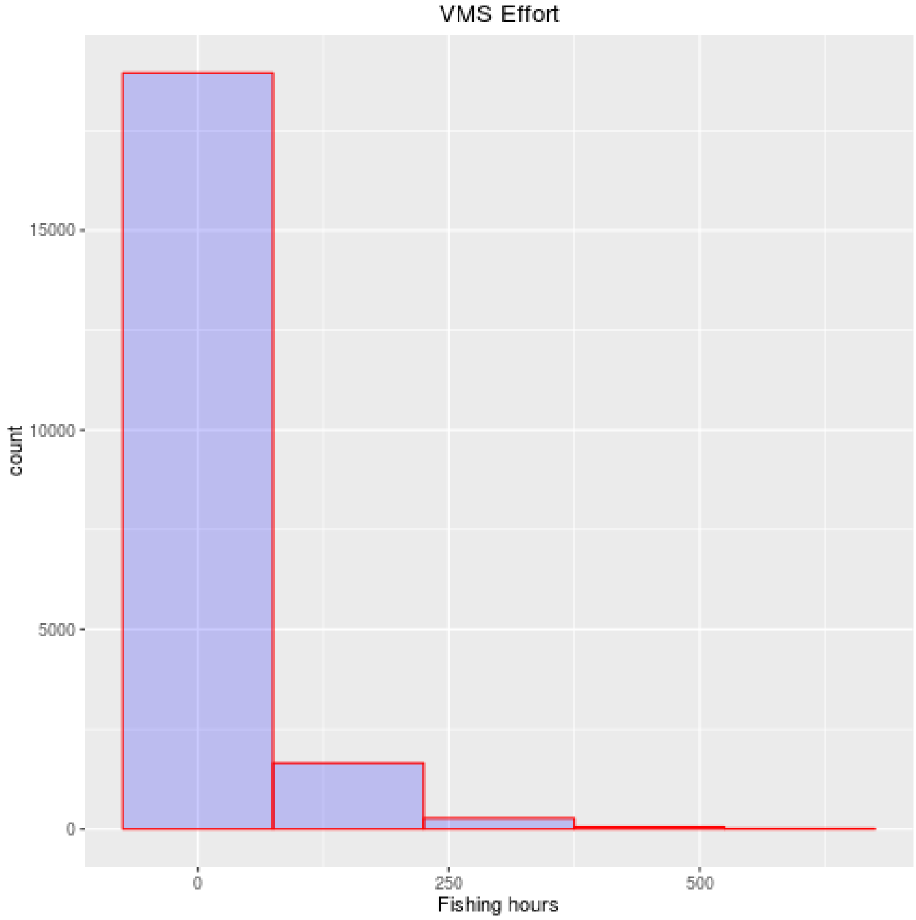
Summary statistics

	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



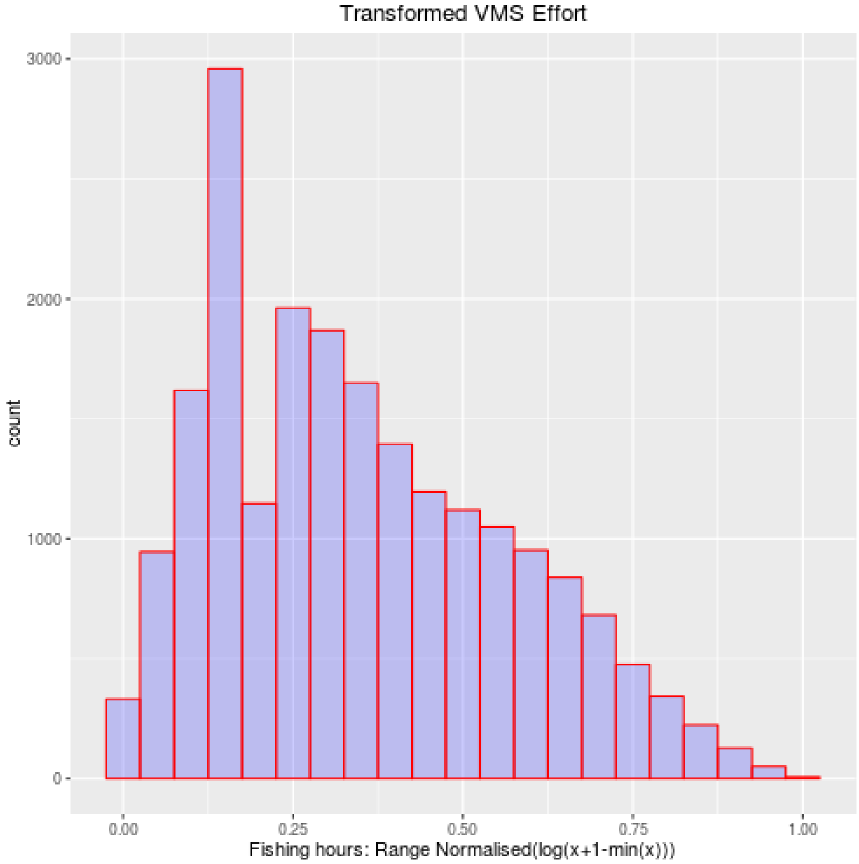
Summary statistics

	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



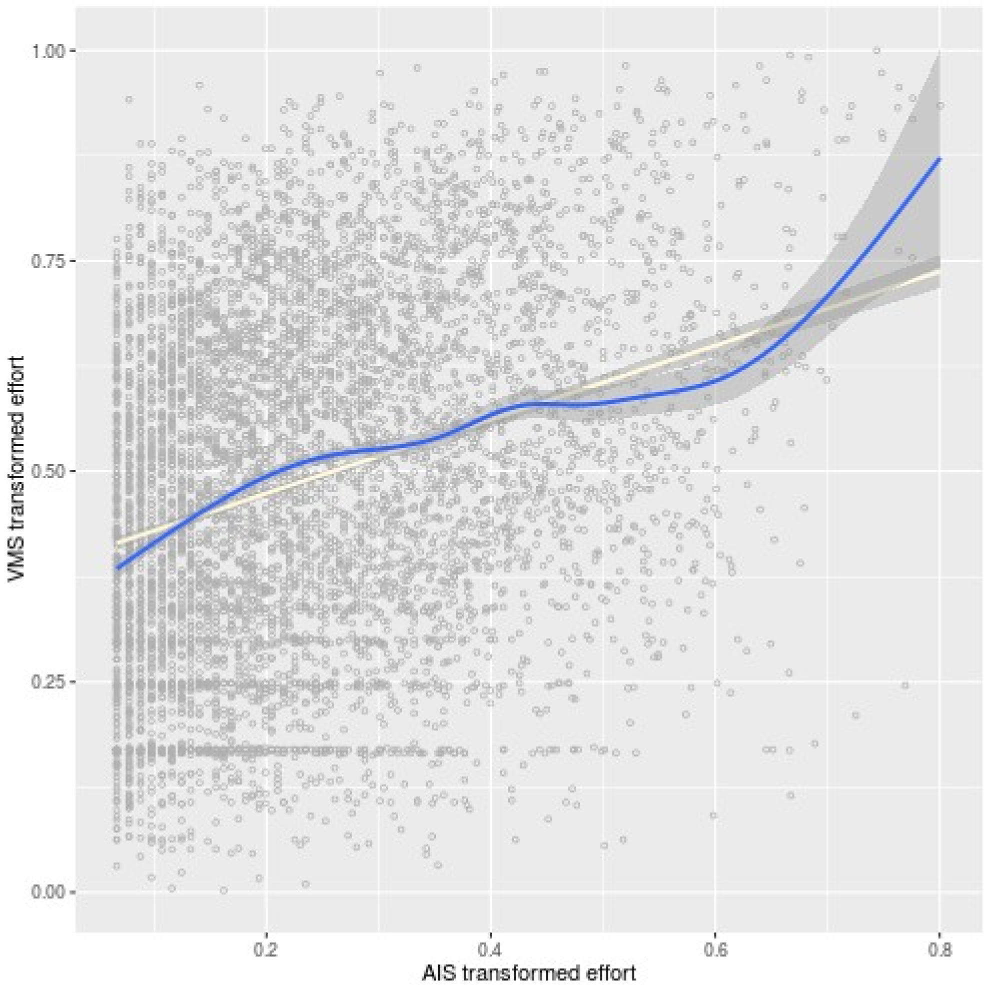
Summary statistics

	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

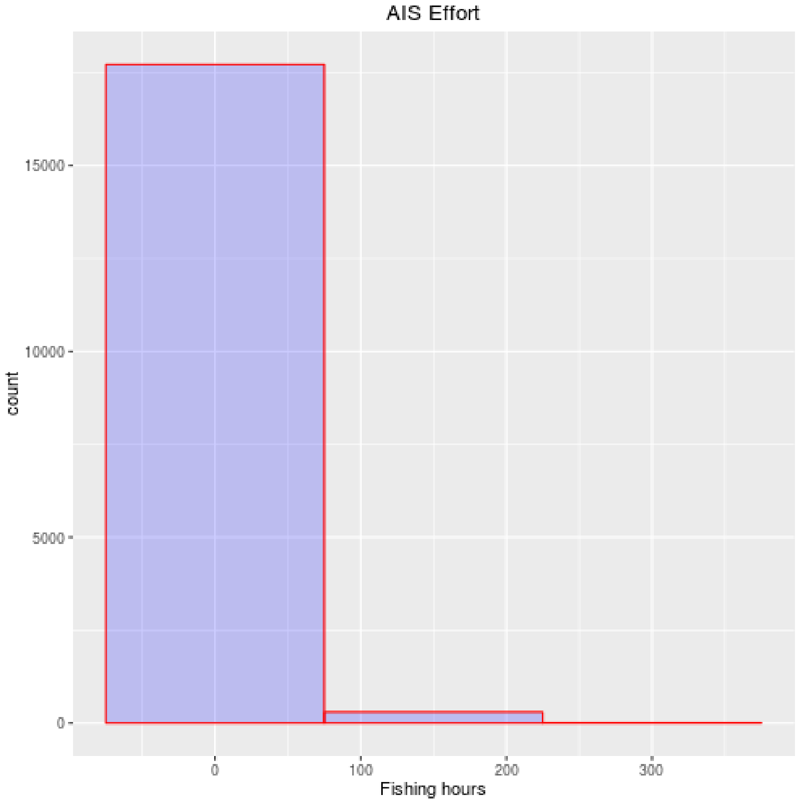
95 percent confidence interval: [0.45 ;0.49]

sample estimates:

ratio of variances 0.47

AIS OTM SUMMARY

Original Values



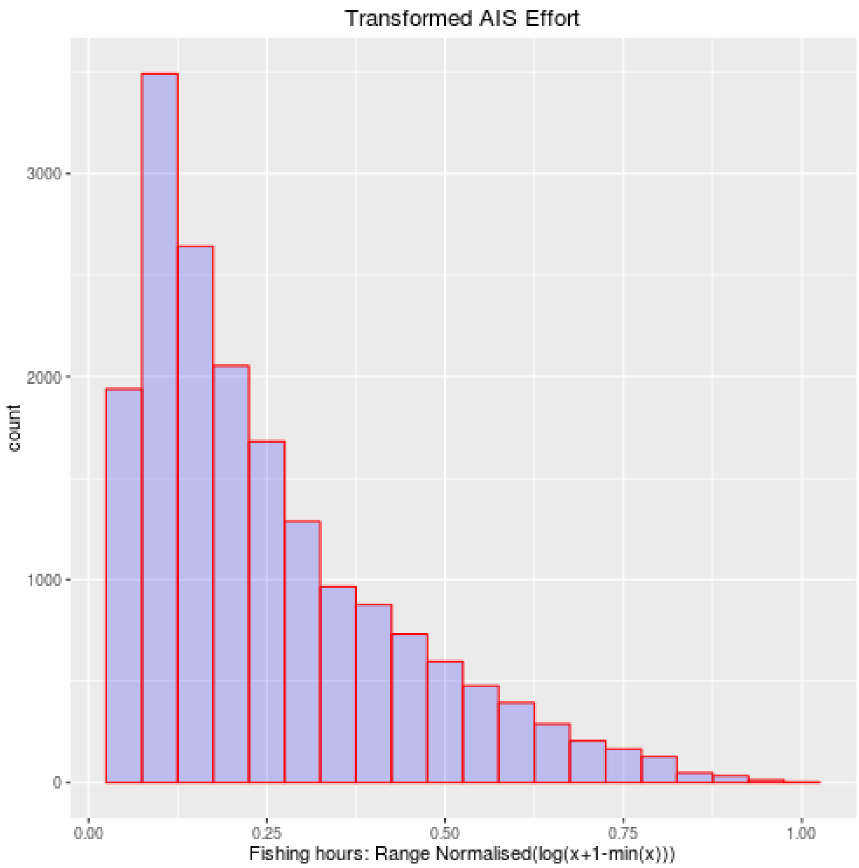
Summary statistics

	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

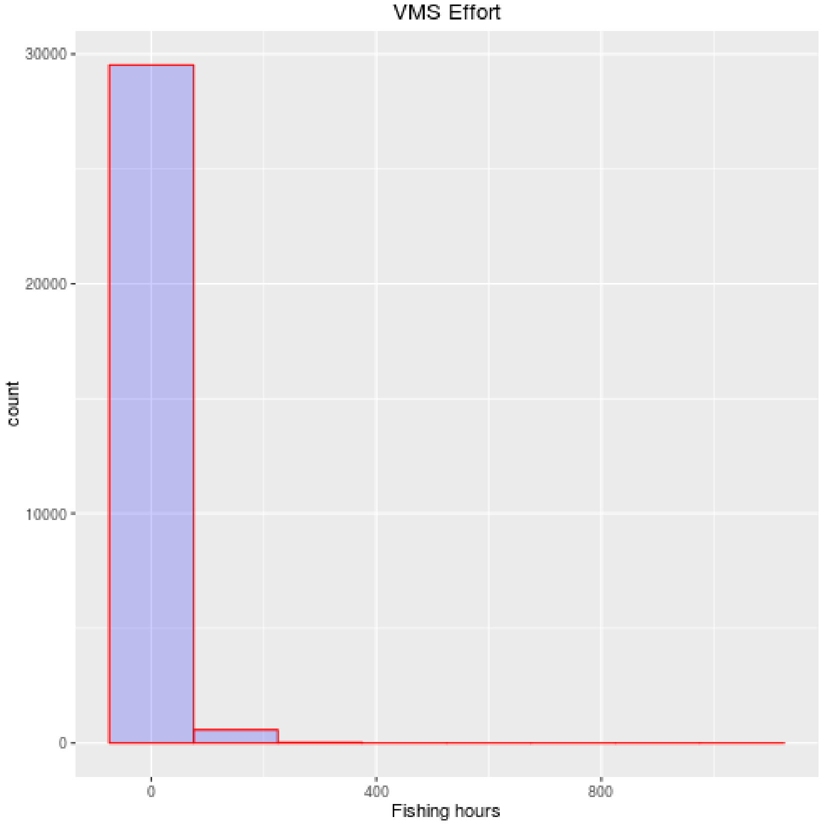
	AIS OTM Transformed Fishing Hours
Values	18024.0000
NULL	0.0000
NA	0.0000
min	0.0604
max	1.0000
range	0.9396
sum	4517.6656
median	0.1951
mean	0.2506
SE.mean	0.0013
CI.mean.0.95	0.0026
var	0.0322
std.dev	0.1794
coef.var	0.7156

Quartiles

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

VMS OTM SUMMARY

Original Values



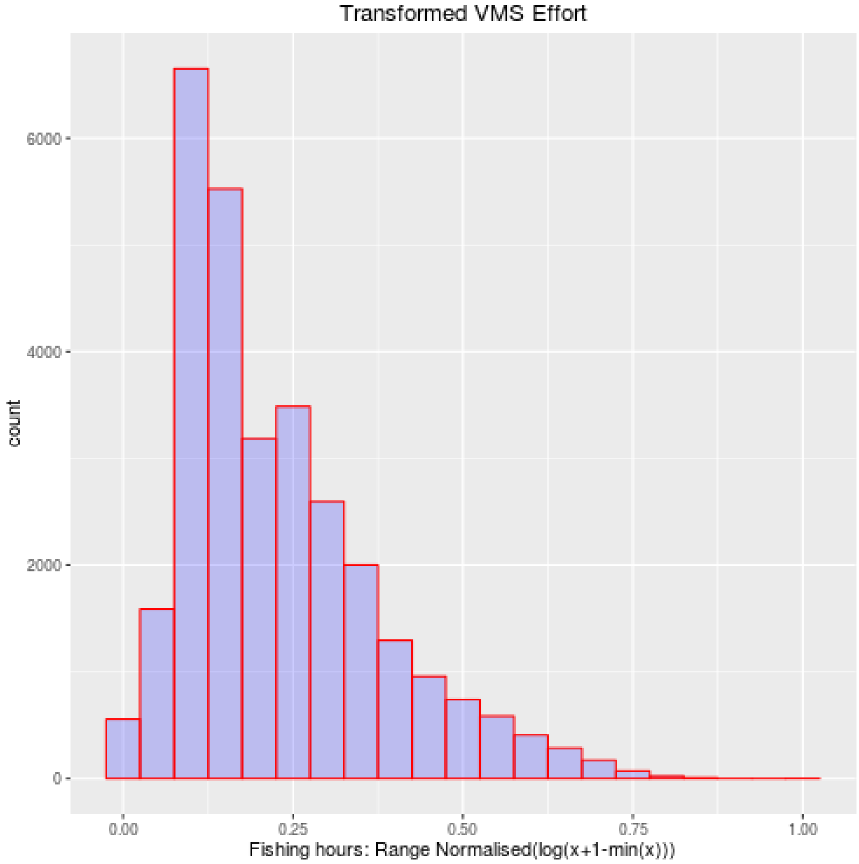
Summary statistics

	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



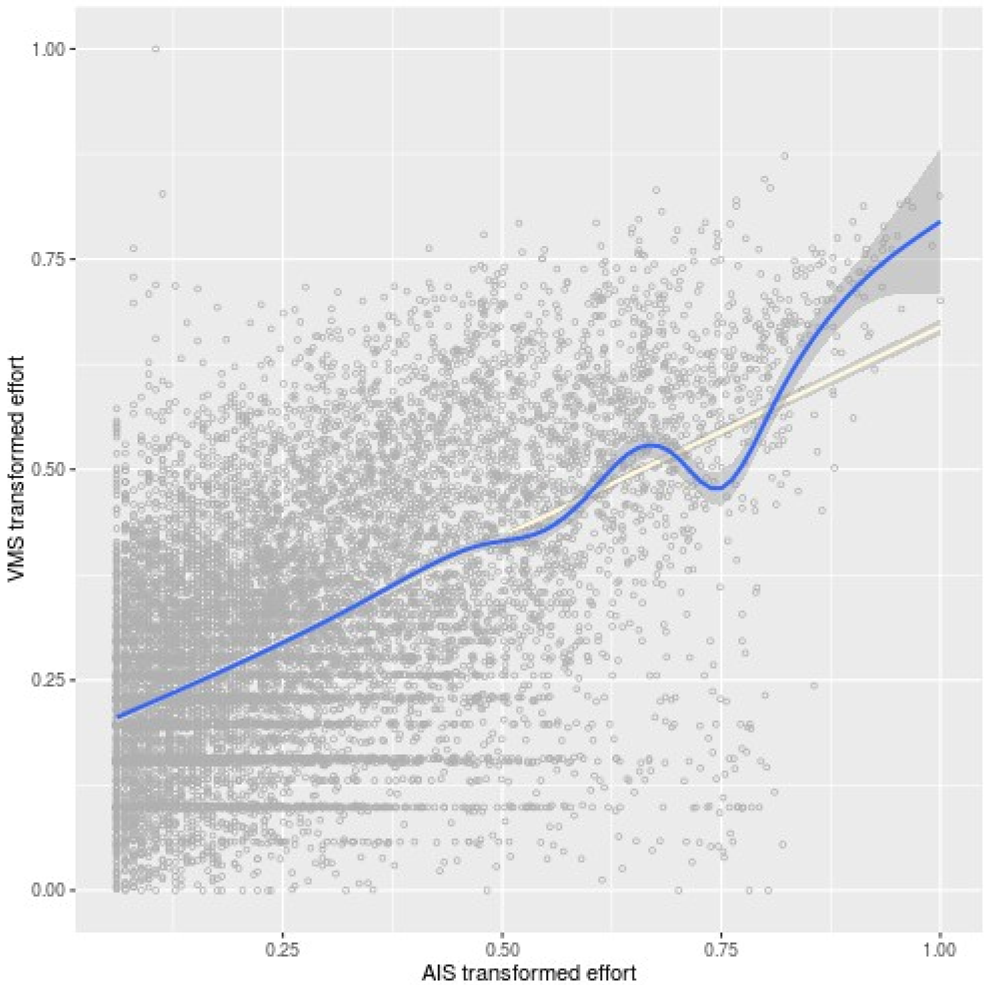
Summary statistics

	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%
0.00	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

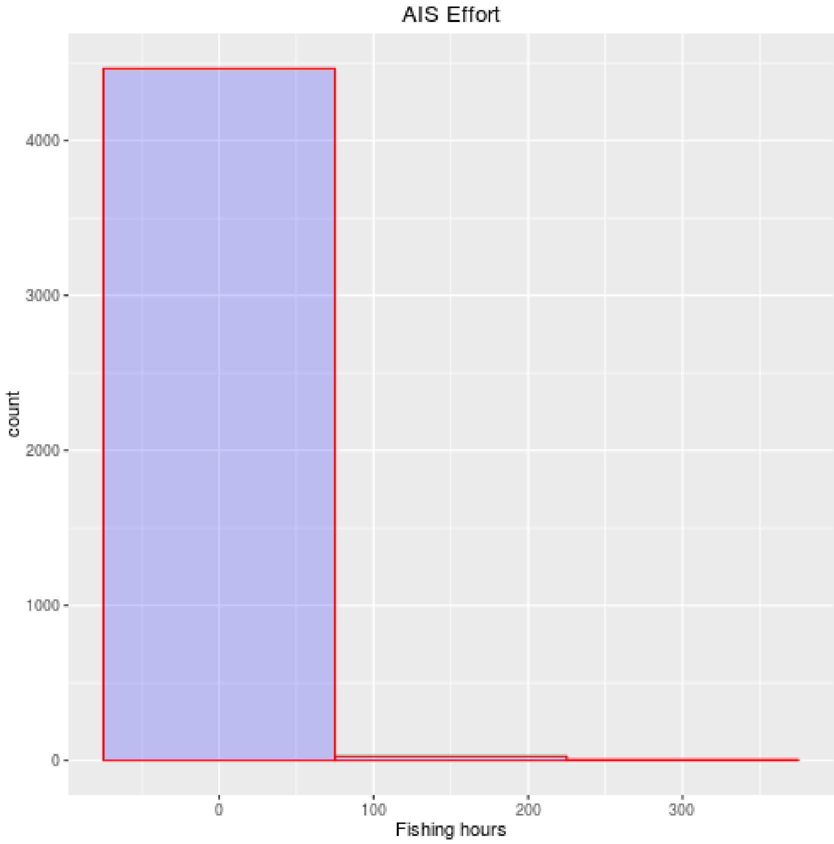
95 percent confidence interval: [1.3 ;1.4]

sample estimates:

ratio of variances 1.3

AIS PTM SUMMARY

Original Values



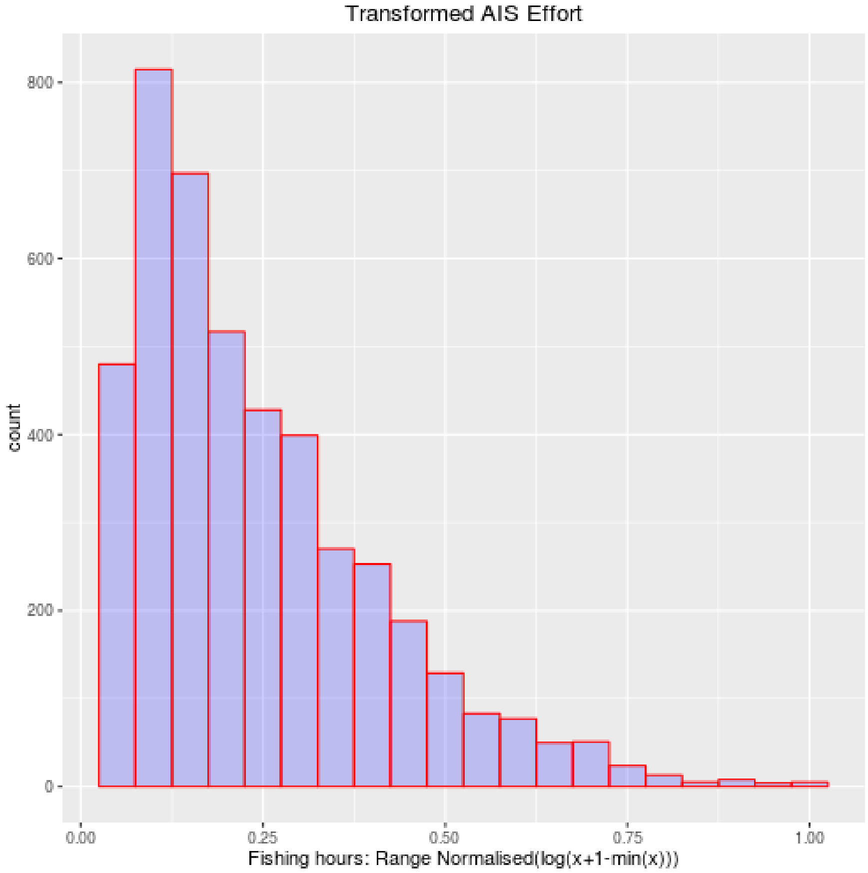
Summary statistics

	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%
).50	0.92	2.00	5.33	249.67

Transformed values



Summary statistics

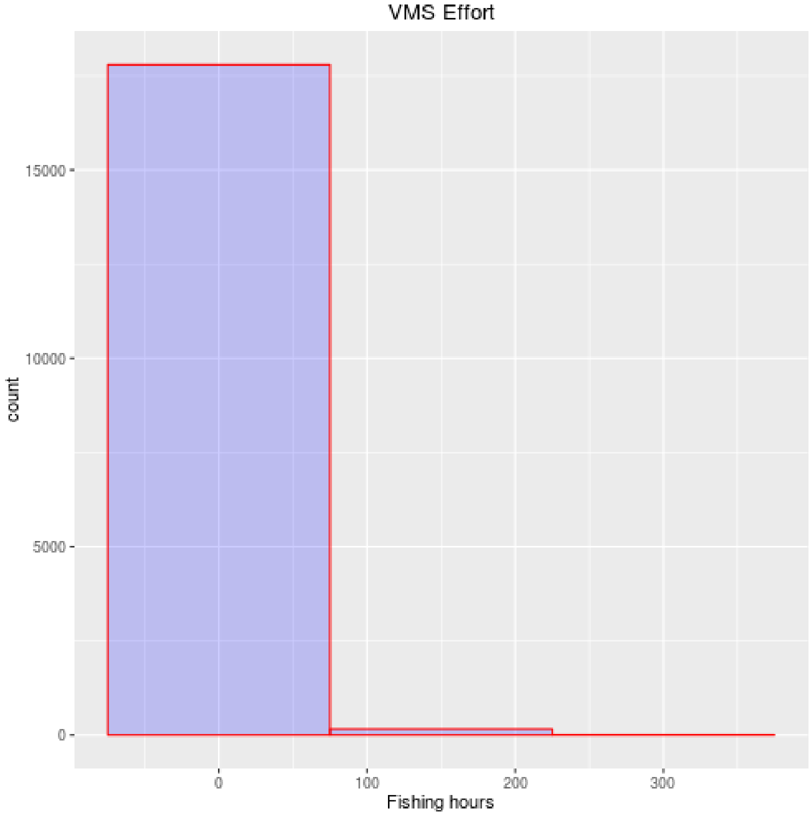
	AIS PTM Transformed Fishing Hours
Values	4496.0000
NULL	0.0000
NA	0.0000
min	0.0631
max	1.0000
range	0.9369
sum	1095.1526
median	0.1938
mean	0.2436
SE.mean	0.0025
CI.mean.0.95	0.0049
var	0.0275
std.dev	0.1659
coef.var	0.6812

Quartiles

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

VMS PTM SUMMARY

Original Values



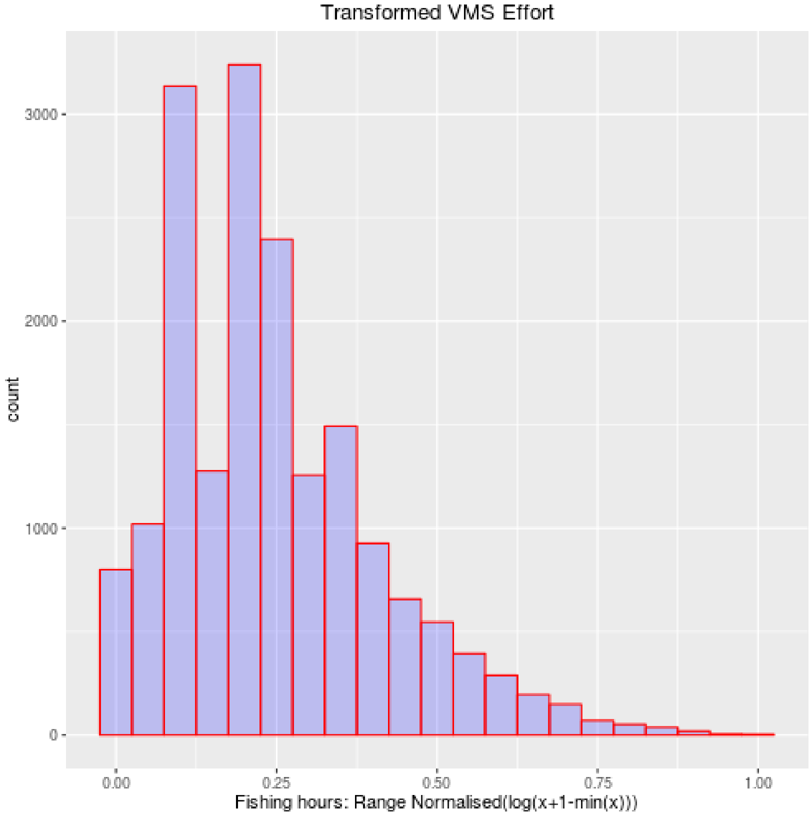
Summary statistics

	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



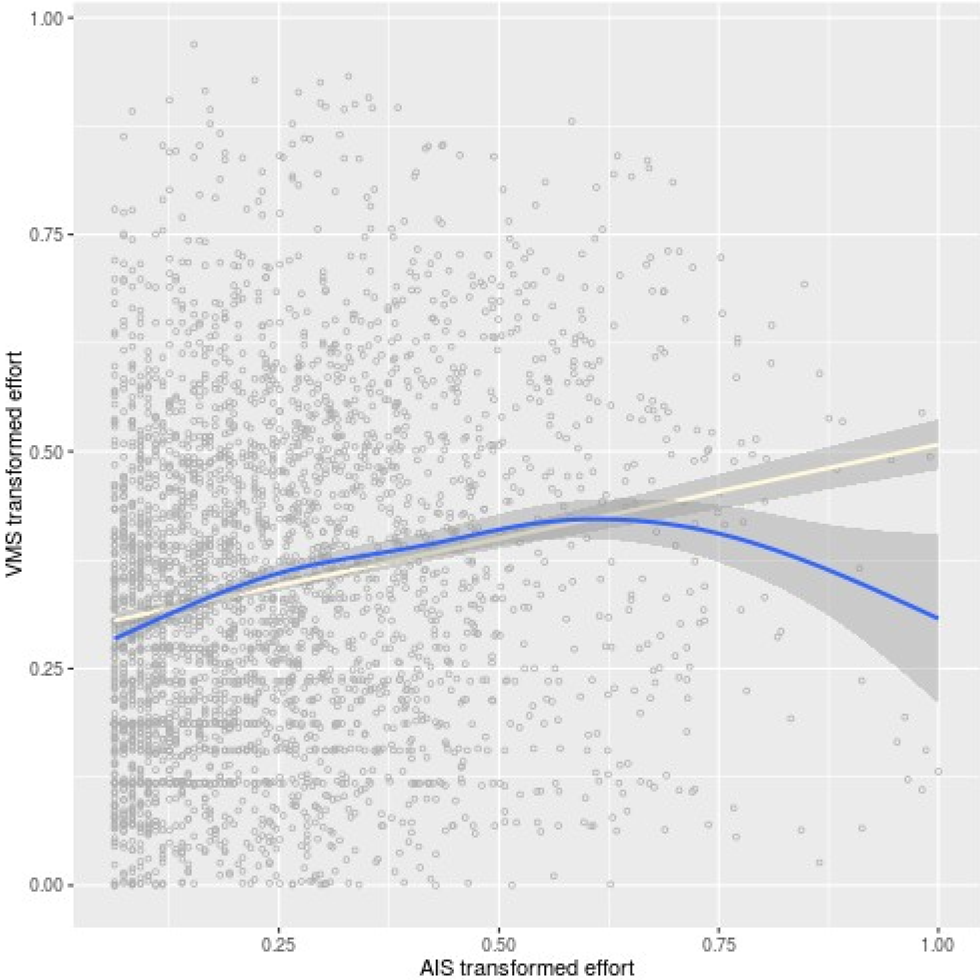
Summary statistics

	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