Variations in North Sea sole distribution

Variation in North Sea sole distribution with respect to the 56°N parallel perceived through scientific survey and commercial fisheries

Author(s): Thomas Brunel & Ruben Verkempynck

Wageningen University & Research report C087/18

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Summary

The Dutch commercial fisheries report that sole (*Solea solea*) catches in the north of the North Sea have been increasing over the past years. While the large majority of North Sea sole catches are taken by beam trawl with 80mm mesh size, fishing with this gear is currently not allowed north of 56°N. In order to be able to get permission for a dedicated sole fishery (80 mm) in that area, scientific proof is needed for the increase in sole in the area north of 56°N.

This study analyses data collected during the Beam Trawl Survey and STECF landing and effort data to investigate whether the spatial distribution of North Sea sole has changed over the last two decades. The study focusses in particular on the part of the North Sea to the north of the 56°N parallel where the main sole targeting fishery (beam trawl with 80mm mesh size) is currently not allowed to fish.

Results based on the survey data show that the abundance and the extent of the distribution of sole in the area north of 56°N has increased (nearly doubled) since 2010. The proportion of the stock distributed north of 56°N also increased, but remains overall low (less than 7.5%). Over the same period, the centre of gravity of the stock has remained at a similar location.

The only fleet operating at a scale large enough to provide information on sole at the scale of the North Sea was the Danish gillnet fishery. The proportion of landings of this fleet taken north of 56°N (in front of northern Denmark) has increased markedly since 2012, even when potential changes in the spatial distribution of the effort are taken into account.

These results suggest an expansion of the stock at the margin of the distribution, while the core of the distribution of the stock has remained in the southern and central part of the North Sea (south of 54°N).

1 Introduction

The Dutch commercial fisheries report that sole (*Solea solea*) catches in the north of the North Sea have been increasing over the past years. While the large majority of North Sea sole catches are taken by beam trawl with 80mm mesh size, fishing with this gear is currently not allowed north of 56°N. In order to be able to get permission for a dedicated sole fishery (80 mm) in that area, scientific proof is needed for the increase in sole in the area north of 56°N.

The present study (a) describes the sole distribution in the North Sea over recent years and (b) calculates a number indicators to measure the changes in distribution. The analyses were based on data from two sources: (1) the Beam Trawl Survey in the North Sea (the Netherlands, Germany, Belgium), and 2) the STECF data on landing and effort per metier. Both sources of data provide spatial information on sole density (catch rates).

Both data sources were analysed separately, as they have different proprieties. The survey data provides a complete synoptic coverage of the stock for standardised fishing operations, but is representative only of one part of the year (third quarter). The fisheries data does not provide a complete coverage of the stock, but provides a coverage throughout the year.

2 Materials and Methods

2.1 Data

2.1.1 Scientific Survey data

The most suitable survey to provide information on North Sea sole is the North Sea beam trawl survey (BTS), carried out annually in the 3rd quarter (July-September) by Belgium, Germany and the Netherlands. The gear used for sampling is a beam trawl of width 4m, 7m and 8m respectively for these three countries. The data for the surveys carried out between 1987 and 2017 were extracted from the ICES database DATRAS (http://datras.ices.dk).

The data available in DATRAS cover the period 1987-2017 for the Dutch part of the survey (1987-1996: only south-eastern North Sea), 1995-2017 for German part of the survey, and 2010-2017 for the Belgian part of the survey. This implies that the spatial coverage from the data available has changed over the years. Until 1995, the area north of 56°N was not covered by the survey (see annex 1). Between 1996 and 1998, the coverage has further expanded to the north and the survey area has remain roughly identical since then. Likewise, the data for the area covered by Belgium are not available before 2010, resulting in a gap in the coverage in the southern part of the North Sea prior to 2010.

2.1.2 Fisheries data

Fisheries dependent information was derived from the STECF FDI database (https://stecf.jrc.ec.europa.eu/dd/effort/graphs-quarter). This database contains the results of the DCF data calls to support fishing effort regime evaluations. The data is provided by Member States and is analysed during the STECF Expert Working Group on Fisheries Dependent Information (most recent event: EWG-17-05, https://stecf.jrc.ec.europa.eu/ewg1705). Information about the scope of the data in each annex, the relationship of data to management regimes and the meanings of the codes used can be found in the description of the data (https://stecf.jrc.ec.europa.eu/dd/effort/graphs-quarter).

For this study the effort off all fleets active in the North Sea and landings of sole by rectangle was derived from the STECF FDI database:

- (EU) management regime (or management area): Annex IIa
- Regulated area: 3B2
- Years: 2003 – 2016

2.2 Methods

2.2.1 Analyses of survey data

Sole abundance indices

Sole density (individuals/km2) is calculated by year and by ICES statistical rectangle by, first, calculating the catch rates for each station (number of fish divided by area trawled), and then averaging the catch rate per ICES statistical rectangle. Then, an abundance index was obtained by summing this mean density per statistical rectangle across rectangles. The index was calculated each year both for the whole survey area, and for the part of the survey area located north of the 56°N parallel. The annual proportion of the stock located north of the 56°N parallel was also calculated based on these abundance indices.

These calculations were made for different length categories: 1) including fish of all lengths, 2) including only marketable sizes (sole larger than 24cm), and 3) including only undersized fish (smaller than 24cm).

The abundance index and proportion of stock north of the 56°N parallel were then plotted against the years to look for potential temporal changes in the distribution.

Centre of gravity

The centre of gravity of the distribution area was calculated for each year to describe overall changes in the sole distribution. The centre of gravity is calculated as the mean of the coordinates of the centre of the ICES rectangles covered by the survey, weighted by the average catch rate in each rectangle. Looking at changes in the position of the centre of gravity from year to year can provide indication of an overall shift or directional expansion of the distribution.

Probability of occurrence north of the 56°N parallel

The probability of occurrence was calculated annually as the proportion of the ICES rectangles visited by the survey north of the 56°N parallel in which sole was caught.

Variations in survey coverage and selection of the data used

The changes in the extent of the survey coverage over the period studied could potentially introduce a bias in the analyses. In order to avoid such a bias, the analyses requiring a complete coverage of the stock were carried out only for the period 2010-2017. This was the case for the analysis of the proportion of the stock distributed north of 56°N based on abundance index, and for the analyses of the centre gravity.

The calculation of an abundance index and of the probability of occurrence for the northern area is not influenced by the Belgian part of the survey and was therefore conducted for the period 2000-2017 for which there was a consistent coverage of the northern North Sea.

2.2.2 Fisheries data

The STECF data was used to look at the percentage of the sole landings occurring north of 56°N. Since the distribution of the fishing effort varies between years, the calculation of percentage landings includes correction for potential changes in effort distribution. This was done by calculating the ratio of the proportion of the landings taken above 56°N divided by the proportion of the effort deployed above 56°N.

This analysis was carried out separately for different metiers. The data analysed here is based on landings, and therefore assumed to be representative of the fraction of catches above the minimum marketable size of 24cm.

3 Results

3.1 Analyses of survey data

3.1.1 Abundance index

The abundance index calculated from the survey stations carried out north of 56°N shows a period of slight decrease (from 2000 to 2010) followed by a sharp increase after 2010 (figure 1). This pattern is found for the index based on fish of all sizes and for the index based on fish above 24cm. It is also found for sole <24cm, except in two recent years (2014 and 2015) for which the index was lower.

The proportion of the stock above 56°N shows a similar trend as the abundance for the period after 2010, with an increase by around 100% (from around 2.5% to around 7.5% for the index based on all sizes and from 4% to 8% for the index for marketable sole, figure 2). No particular trend was found for the proportion of the sole <24cm north of 56°N.

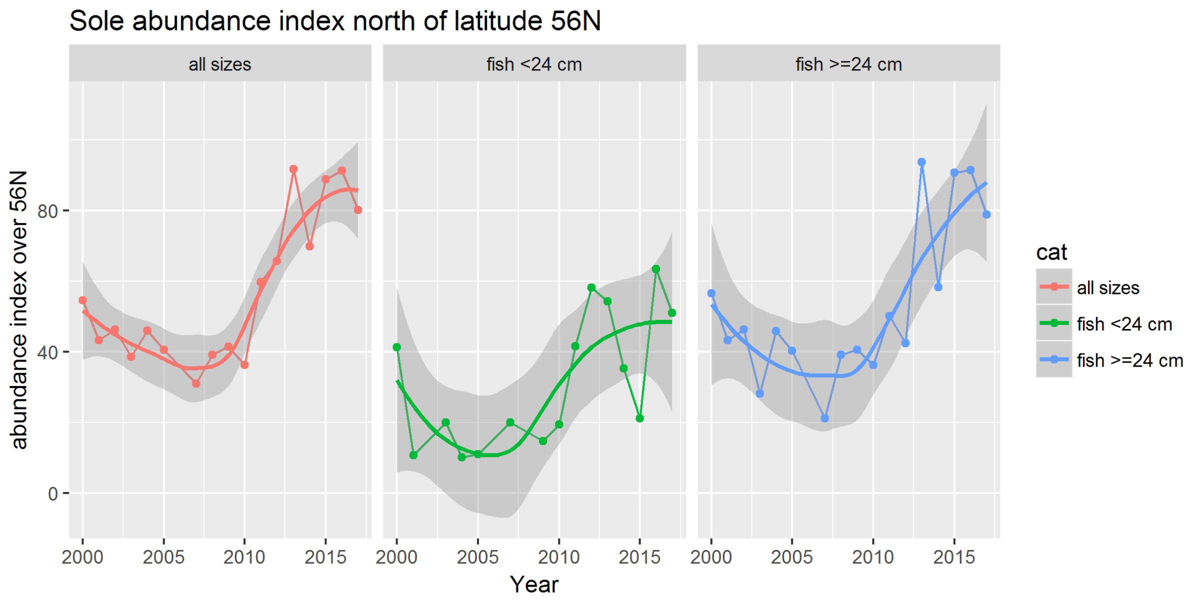


Figure 1: sole abundance index calculated based on survey stations carried out north of the 56°N parallel, for fish all sizes, for fish under 24cm, and for fish larger than 24cm.

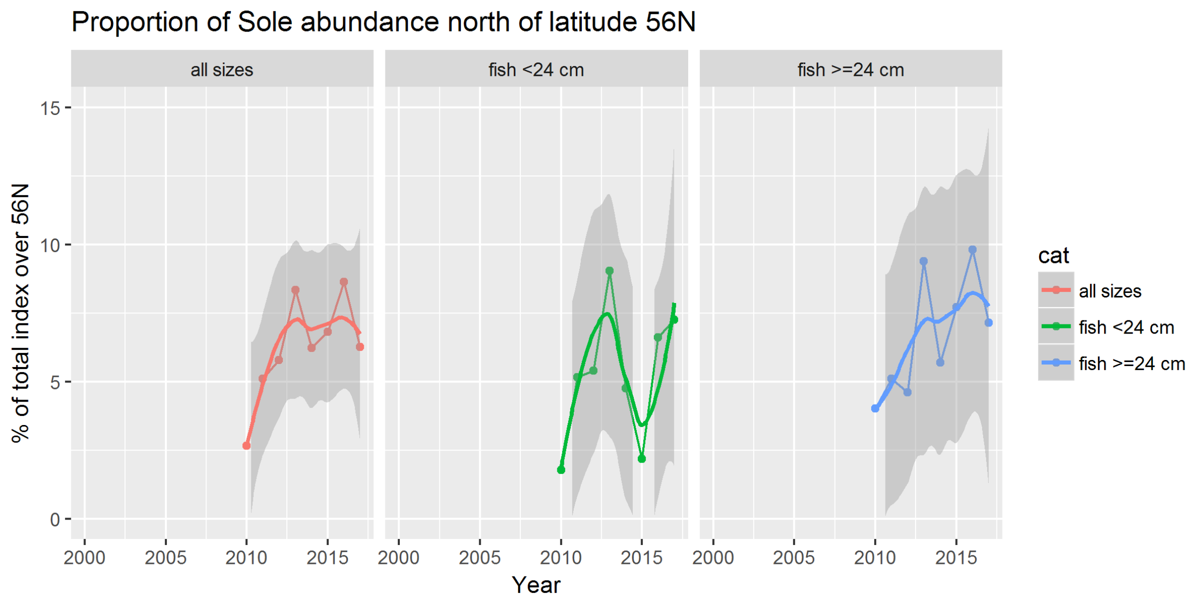


Figure 2: percentage of the sole stock (based on survey abundance index) distributed north of the 56°N parallel, for all fish sizes, for fish under 24, and for fish larger than 24cm. Prior to 2010 the spatial coverage of the survey differed too much to calculate the proportion for a longer time-span.

3.1.2 Centre of gravity

Over the period 2010-2017, the centre of gravity of sole distribution has varied slightly, with a northwards movement of about 0.5 degree between 2010 and 2015 (both for data on all size-classes and data on fish larger than 24cm), followed by a southwards displacement of the same magnitude (figure 3). Part of this pattern is also visible in the average latitude of the survey position (e.g. latitude increasing by 0.5 degree between 2010 and 2015) which suggest that the change in the centre gravity partially reflect changes in survey coverage. There was no clear pattern for the latitude of the centre of gravity of the sole under 24cm.

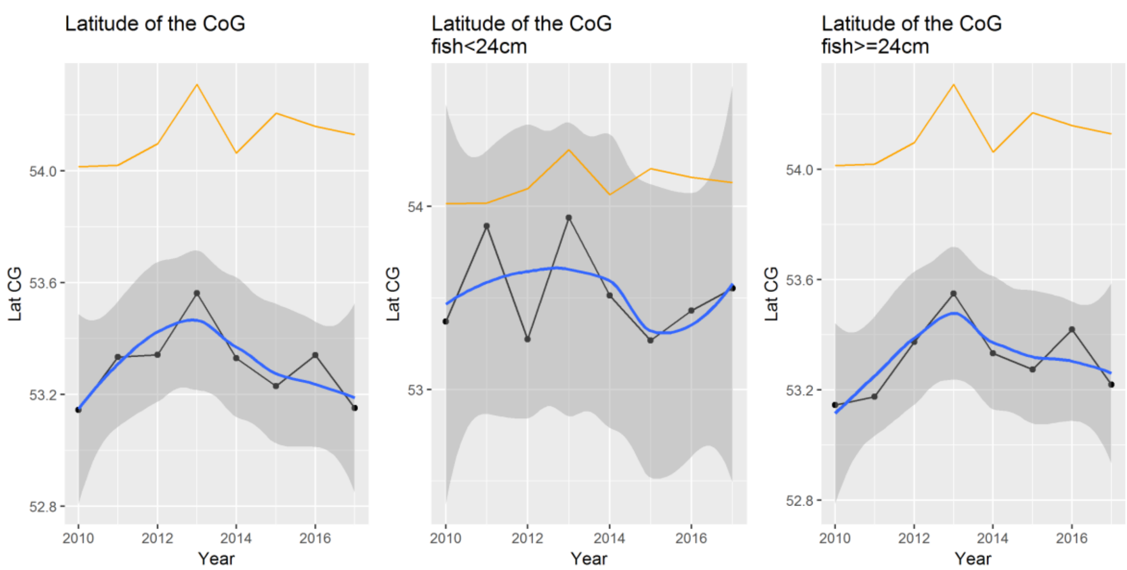


Figure 3: latitude of the centre of gravity (CoG) of sole distribution (black line, with smoother in blue) in the BTS survey for fish of all size, fish under 24cm and fish above 25cm and average latitude of the survey stations (orange line).

3.1.3 Probability of occurrence in the survey area located in the north of 56°N

The number of ICES rectangles covered by the survey in the area north of 56°N has varied between 31 and 46 over the period 2000-2017. No specific trend (figure 4) is visible in the number of rectangles covered, as the planned station grid is stable over the years and modifications only occur due to technical problems or bad weather conditions. The probability of occurrence of sole in the survey for this area has been increasing since around 2006, from around 10% to around 22%. The occurrence of sole under 24cm in the north of 56°N is lower than for sole larger than 24cm and has in general also increased over the same period, from around 2% to 12%.

The raw survey data (annex 1) indicates that this increase in sole occurrence is mainly due to sole being increasingly found in the survey stations close to the Danish coast, while occurrence more to the west (of the area surveyed north of 56°N) does not seem to have changed.

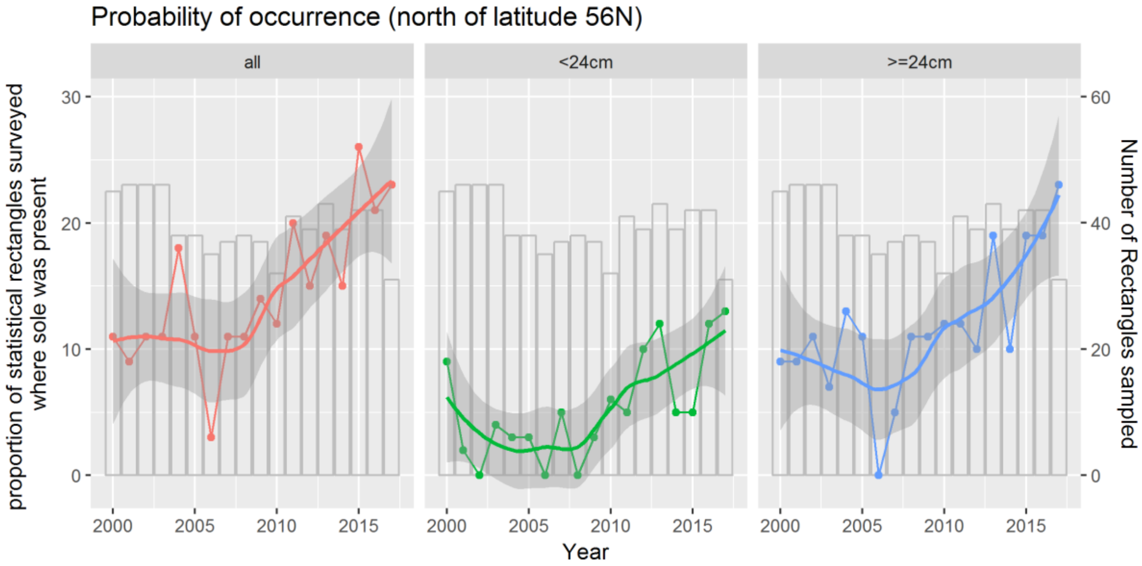


Figure 4: variations of the probability of occurrence of sole in the survey for ICES rectangles located north of 56°N (broken line with dots, and smoother) for all sizes of sole, sole under 24cm and sole above 24cm and number of ICES rectangles surveyed north of 56°N (bars).

3.2 Analyses of fisheries data

Most of the landings of sole are taken by beam trawlers (BT2), with the Dutch fleet representing the main contributor to the total landings (figure 5). Among the beam trawlers, almost the totality of the landings are vessels operating with a 80-89mm mesh size trawl, taking on average 66% of the total sole landings. This metier is not allowed to operate above the 56°N parallel so its landings and effort data cannot be used to analyse the changes in spatial distribution of commercial landings or catch rates with respect to the 56°N parallel. Therefore, for the beam trawlers, the analysis was carried out using only data from vessels operating with 100-119mm mesh size, representing only 0.5% of the annual sole landings. Part of the effort corresponding to this gear is deployed north of 56°N (annex 2).

Among the fleets using other gears, the French trammel net (GT1) fleet is the largest contributor to the landings of sole (4% of annual landings), but operates only in the southern or central North Sea, south of 56°N. The Danish gillnet (GN1) fishery represents on average 3% of annual sole landings and operates over the whole North Sea (see annex 3). Changes in the distribution of the landings and LPUE from this fleet were also analysed.

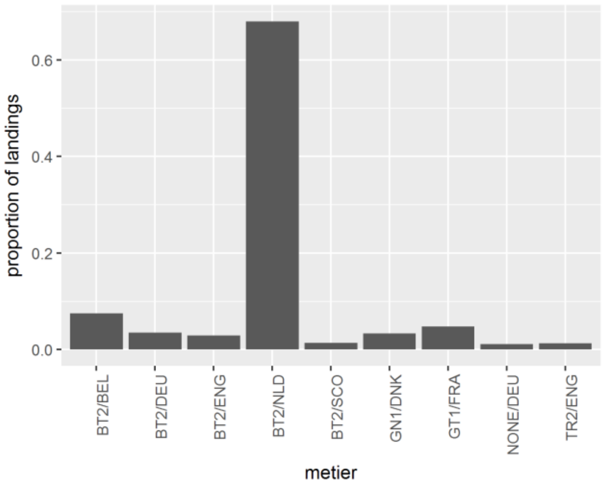


Figure 5: average annual percentages of landings per "metier".

Overall, sole landings from beam trawls with 100-119mm mesh size are low, varying between 2 and 37 tonnes per quarter. The landings for the area north of 56°N are very low (figure 6), mainly varying between 0 and 0.15 tonnes per quarter, except for the 3rd quarter (Q3) in 2016, when they reached 1.6 tonnes. Similarly, the proportion of the sole landings taken north of 56°N is very low for all quarters, with a substantially higher -but still remaining low- value for 2016 Q3. The same pattern is observed when the proportion of landings is corrected for the proportion of effort north of 56°N. Apart from the higher value in 2016 Q3, there is no particular trend in landings of the beam trawls with 100-119mm mesh size with respect to the 56°N parallel.

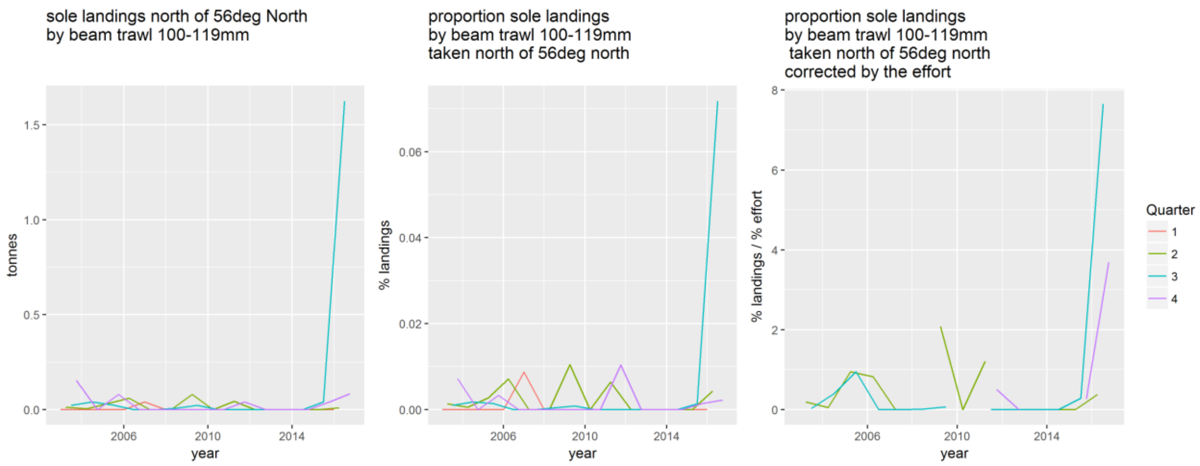


Figure 6: beam trawlers using a 100-119mm mesh size : sole landings taken north of 56°N by quarter, proportion of the landings taken north of 56°N by quarter and ratio of the proportion of the landings by the proportion of the effort north of 56°N.

The sole landings of the Danish gillnet fishery ranged from 4 to 430 tonnes per quarter (Q), of which less than 1 to 200 tonnes taken north of 56°N (figure 7). There is a strong seasonality in the fishery, with landings mainly in Q2 and Q3 (annex 3). Landings in Q2 are caught close to the Danish coast and Dutch coast, while landings in Q3 are almost exclusively taken in front of the Netherlands (annex 3 and figure 7). Landings taken north of 56°N in Q2 have decreased from 2003 to 2012, and increased quickly after 2012. Landings north of 56°N from the Q1 have been low prior to 2012, and have increased substantially after 2012. The proportion of the landings taken north of 56°N (with or without correction for effort distribution relative to 56°N) has changed similarly for Q1 and Q2, decreasing from 2003 to 2012, followed by a steep increase.

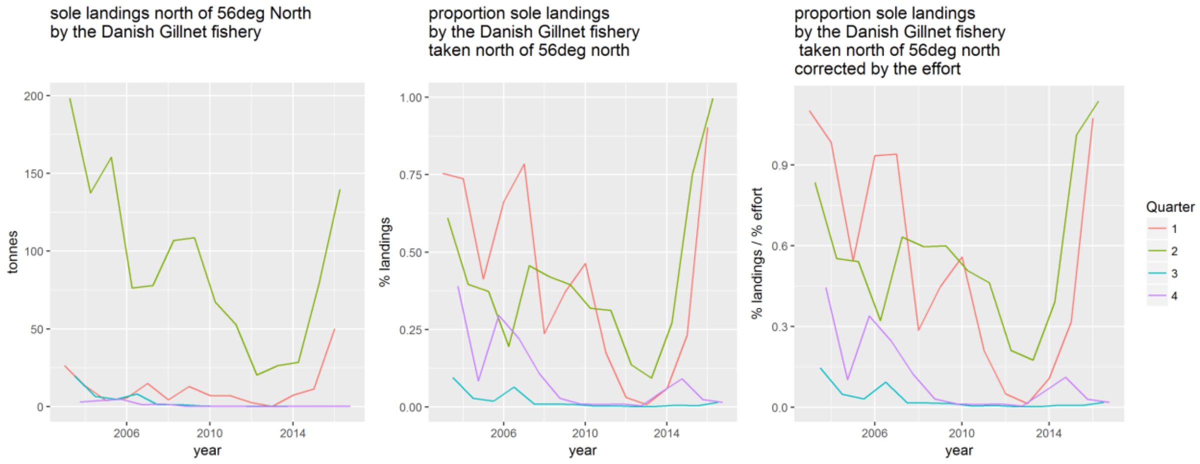


Figure 7: Danish gillnet: sole landings taken north of 56°N by quarter, proportion of the landings taken north of 56°N by quarter and ratio of the proportion of the landings by the proportion of the effort north of 56°N.

4 Conclusions

The analysis of the BTS survey data over the period 2000-2017 shows that both the probability of occurrence (i.e. the chance of finding sole in the survey), and the abundance of sole north of 56°N have increased –nearly doubled- since 2010. This increasing trend is particularly clear for sole above 24cm. It is also found for sole under 24cm, with the same overall magnitude, but with more variability. The proportion of the stock distributed north of 56°N also increased between 2010 and 2017, which indicates that the abundance of sole south of 56°N increased at a slower rate than north of 56°N. The centre of gravity of the stock has not moved substantially during the period 2010-2017, when a northwards displacement could have been expected given the observed increase in the north. This indicates that the distribution of the stock has not shifted northwards, but rather that the margin of the stock's distribution, with lower local densities and representing a small proportion of the population (figure 2), has expanded further north, mainly in front of the west coast of Denmark.

Less insight could be gained from the analysis of the fisheries data. The only fleet operating both south and north of 56°N and taking a non-negligible percentage of the sole landings was the Danish gillnet fleet (targeting principally cod *Gadus morhua* and plaice *Pleuronectes platessa*). The fact that a similar pattern is observed both in the landings and in the landing proportion taken north of 56°N indicates that these changes are not reflecting variations of the overall level of the catches, but a local increase in the catches in front of the Danish west coast. Furthermore, as the same pattern is still visible when potential changes in the distribution of the effort are taken into account, the increase in the catches in front of Denmark is more likely to be reflecting changes in local abundance, than changes in fishing activity.

Both survey and fisheries data point towards an expansion of the stock towards the north. These changes in distribution have occurred in a period during which the size of the North Sea sole stock –as estimated by stock assessment- has increased (by about 100% between the period 2006-2008 and the period 2015-2017, ICES 2018).

Different conceptual models have been proposed to explain the link between population spatial distribution and population size (Petitgas, 1998). In the basin model (figure 8), an increase in population size will result in an expansion of the area occupied to less suitable habitat, combined with a general increase in density. An alternative is the constant model, where density in the core area cannot exceed a given maximum value, and an increase in abundance results in an expansion of the area covered by the stock and an increased density in the peripheral areas, but not in the core area. The third model corresponds to a situation where a geographical expansion of the population is impossible, and local abundance increases by a constant proportion throughout the distribution area.

The situation observed for North Sea sole could correspond to a constant or a basin type of relationship.

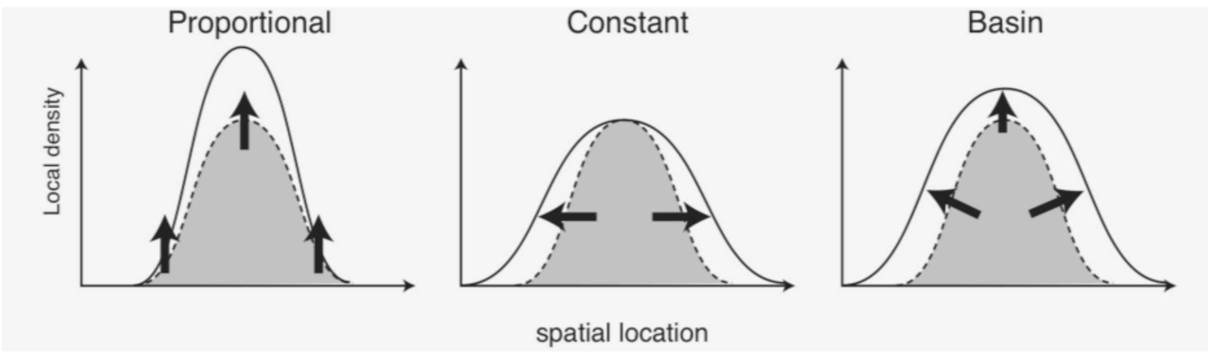


Figure 8: conceptual models for the relationship between population size and its geographical distribution (after Petitgas, 1998).

References

ICES. 2018. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 24 April - 3 May 2018, Oostende, Belgium. ICES CM 2018/ACOM:22. 27 pp

Petitgas, P. (1998). Biomass-dependent dynamics of fish spatial distributions characterized by geostatistical aggregation curves. ICES Journal of Marine Science, 55, 443–453.

Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. This certificate is valid until 15 December 2018. The organisation has been certified since 27 February 2001. The certification was issued by DNV GL.

If the quality cannot be guaranteed, appropriate measures are taken.

Justification

Report C087/18

Project Number: 4316100162

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: Ingeborg J. de Boois

Researcher

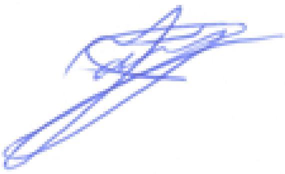
Signature:

Date: 26 November 2018

Approved: Jakob Asjes

Manager Integration

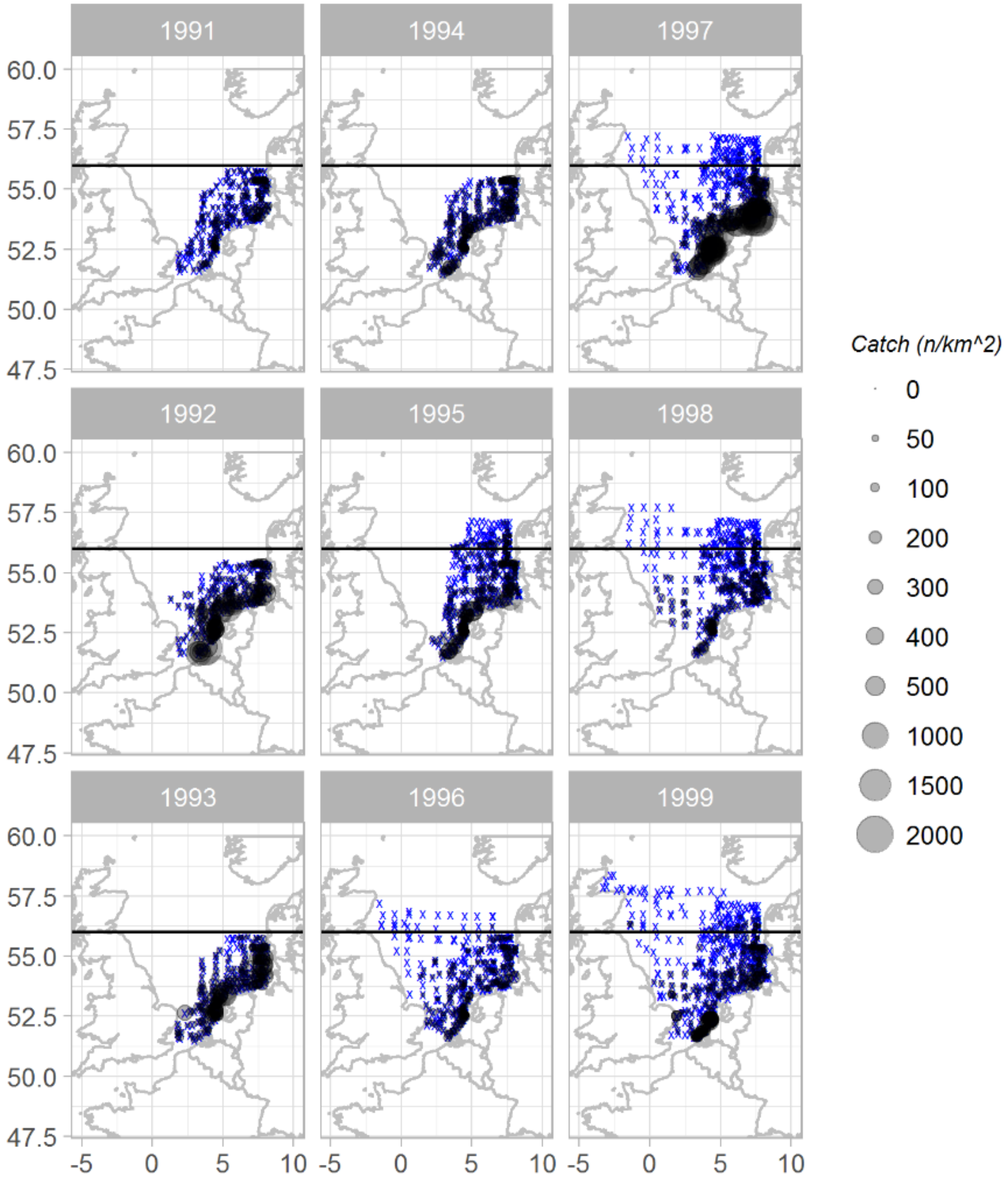
Signature:



Date: 26 November 2018

Annex 1

location of BTS survey station (blue crosses) and sole catch rates per station (circles) for the years 1991-2017.



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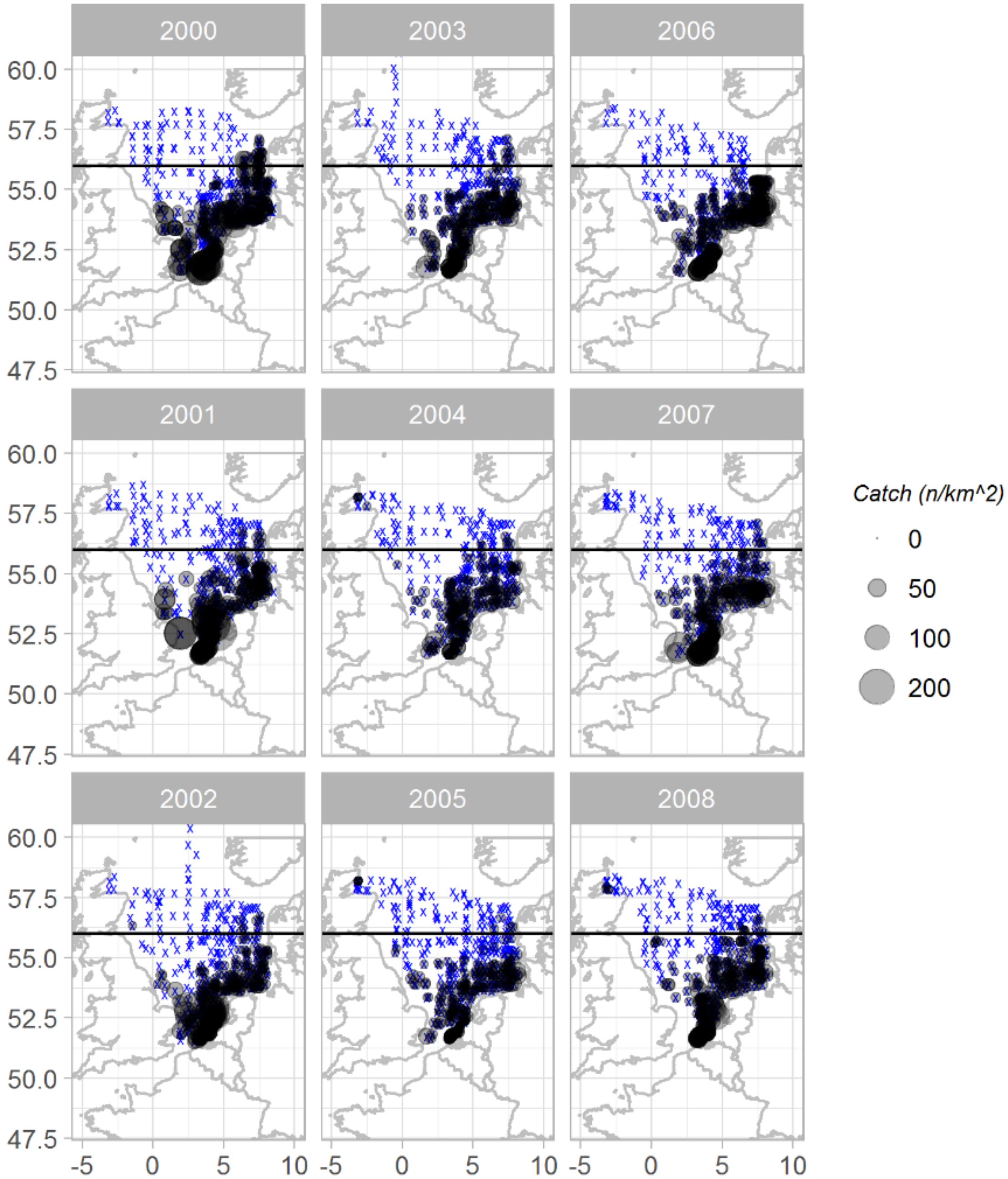
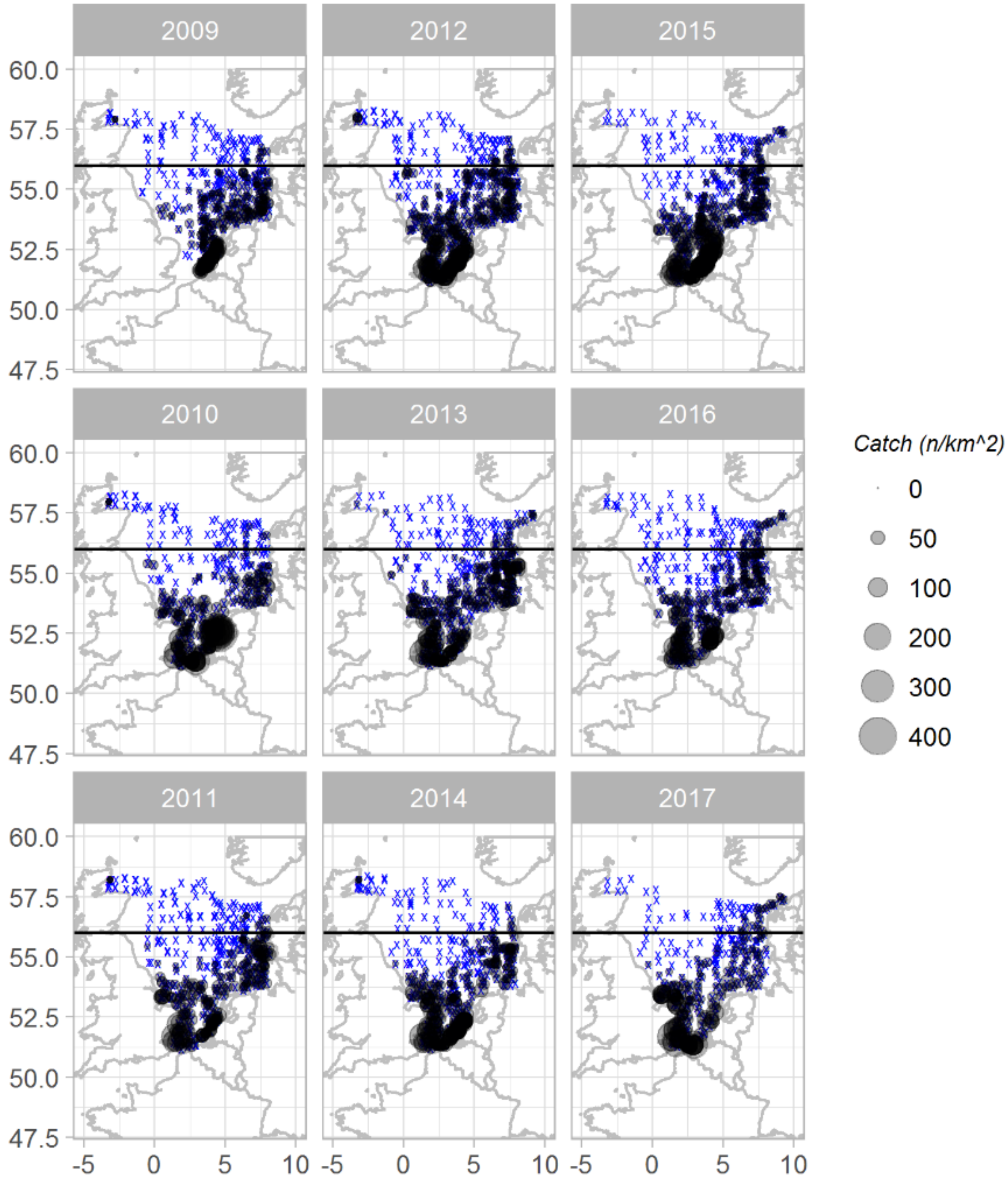


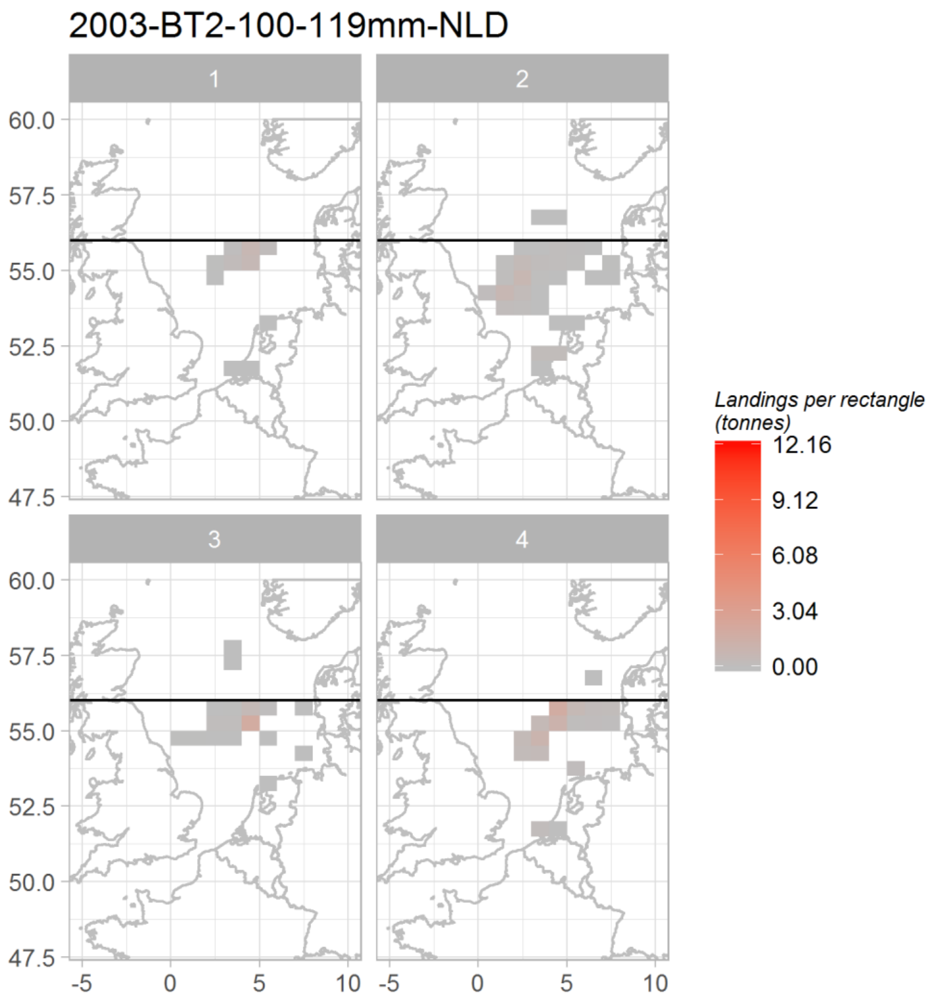
2000
2003
2006
2001
2004
2007
2002
2005
2008
60.0
57.5
55.0
52.5
50.0
47.5
-5
0
5
10
Catch (n/km^2)
0
50
100
200

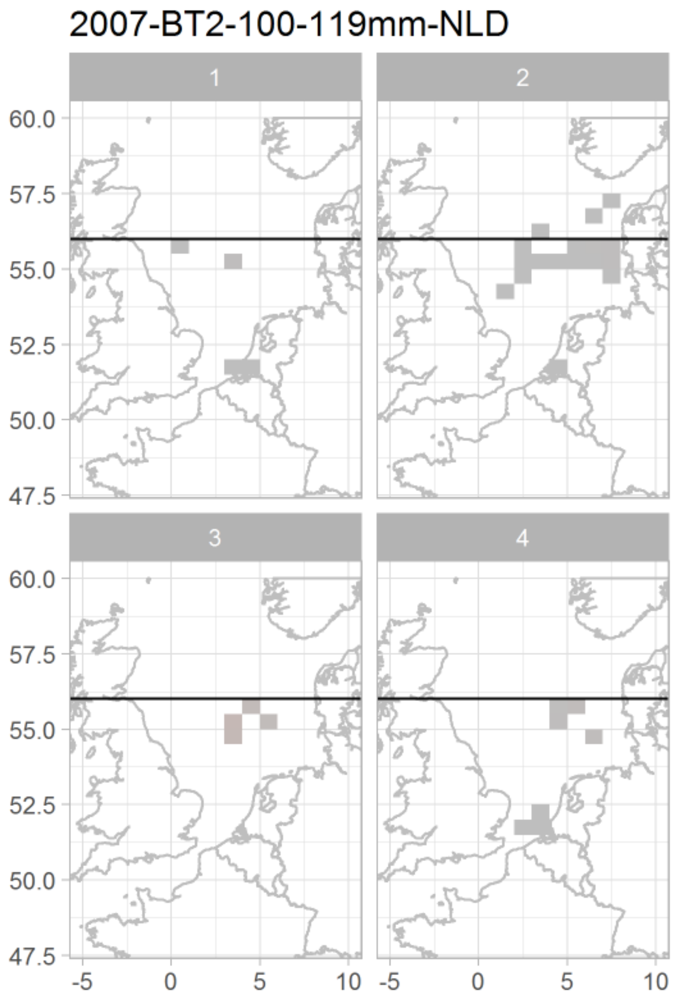
Annex1 (cont)

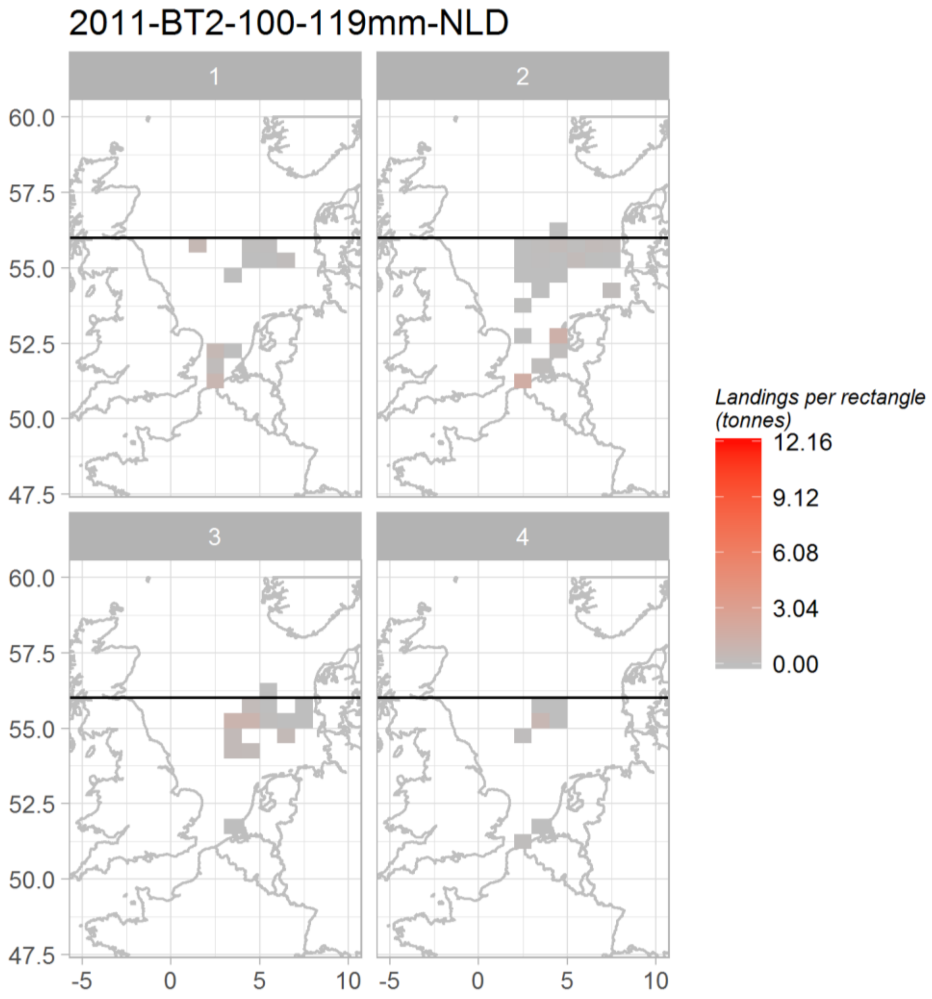

2009
2012
2015
2010
2013
2016
2011
2014
2017
60.0
57.5
55.0
52.5
50.0
47.5
-5
0
5
10
Catch (n/km^2)
0
50
100
200
300
400

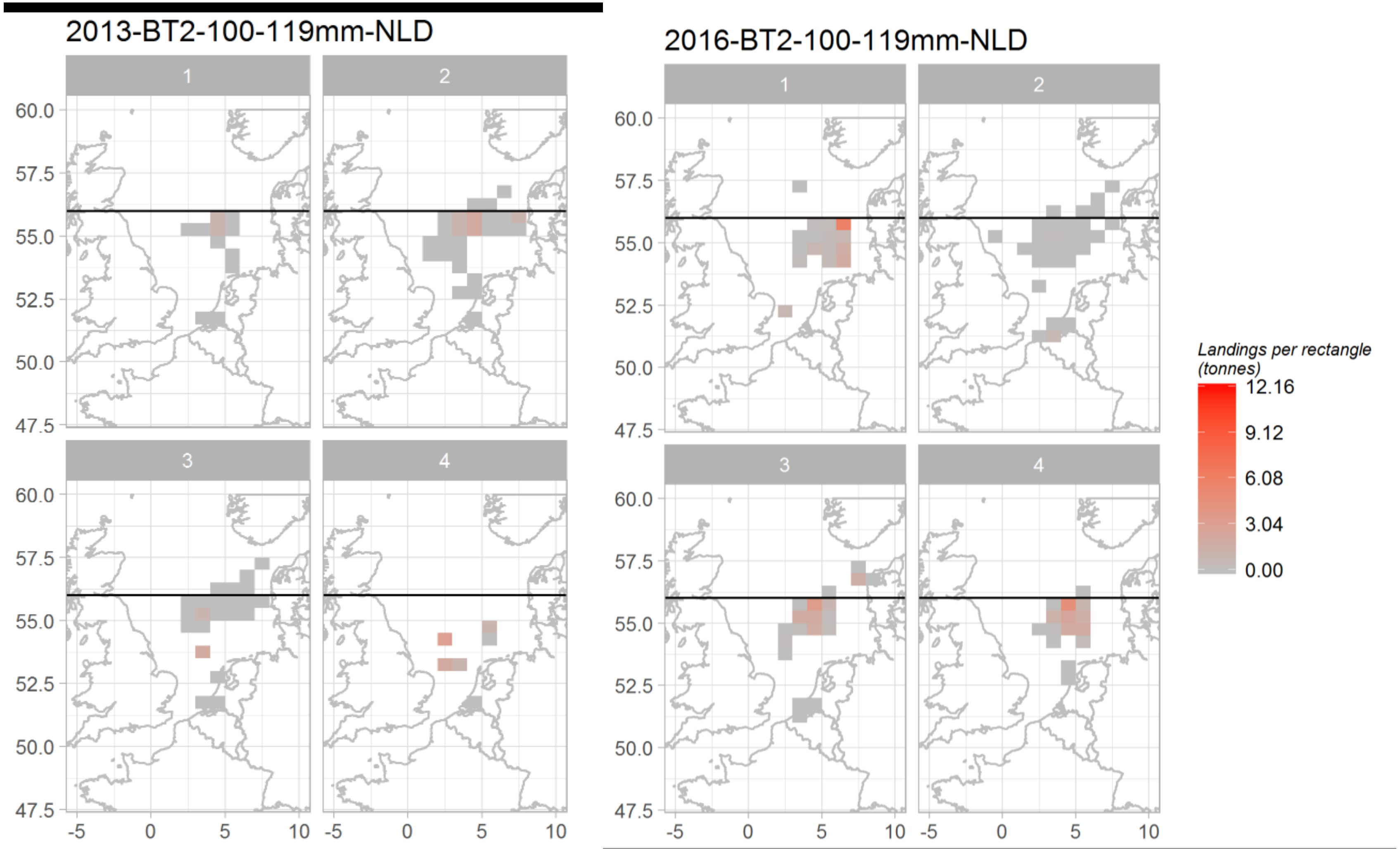
Annex 2

Example of quarterly distribution of sole landings for the beam trawler fishery with 100-119mm mesh size



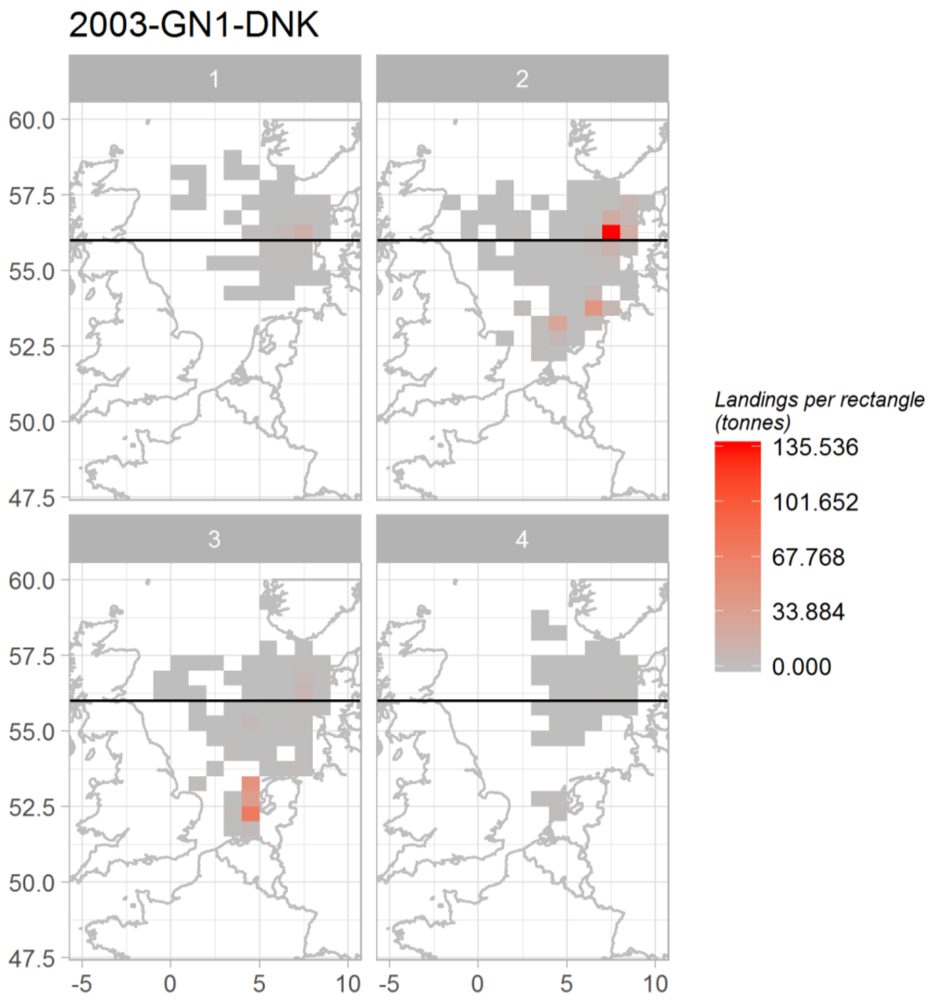

2007-BT2-100-119mm-NLD
1
2
3
4
60.0
57.5
55.0
52.5
50.0
47.5
-5
0
5
10

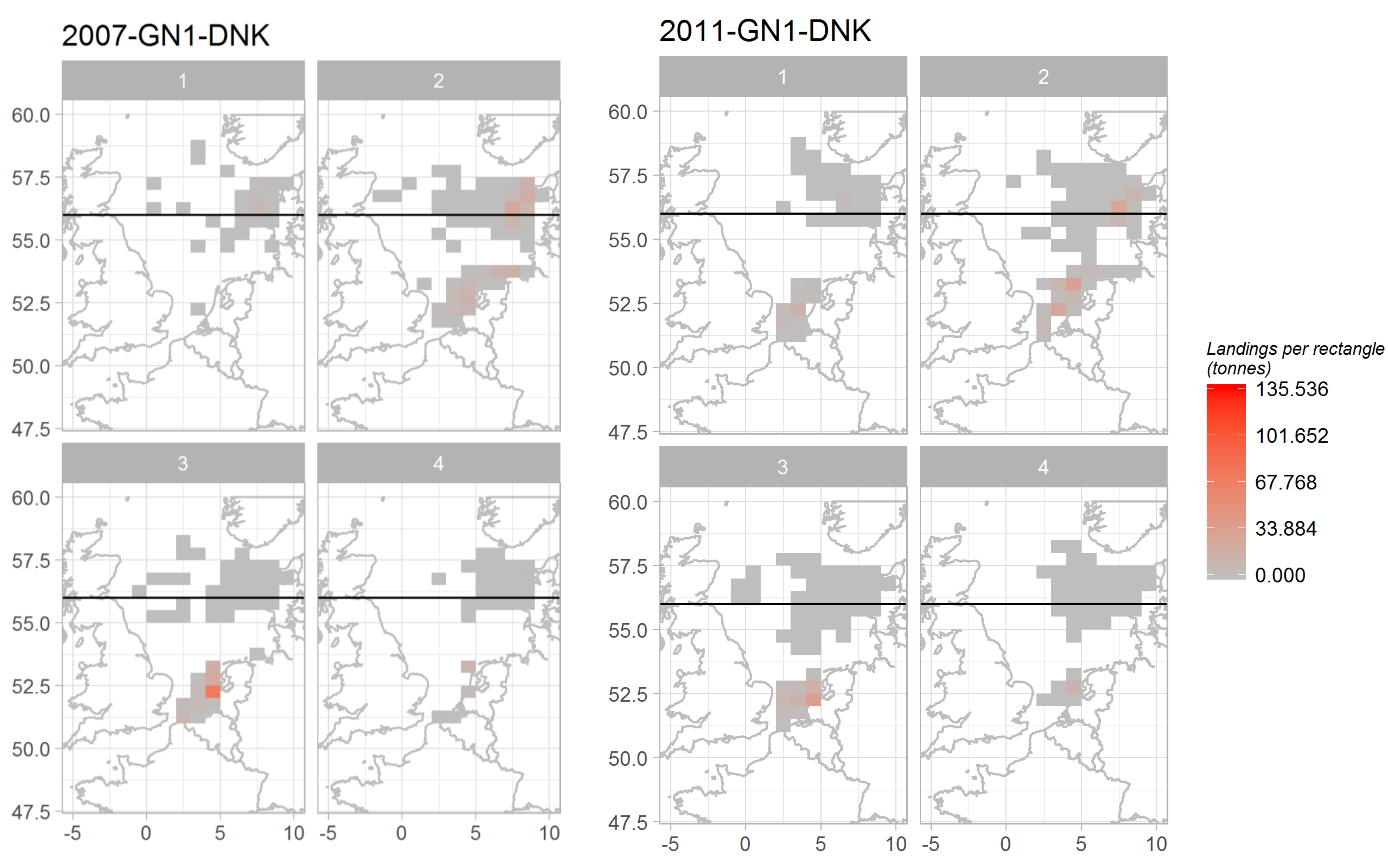

2011-BT2-100-119mm-NLD
1
2
3
4
60.0
57.5
55.0
52.5
50.0
47.5
-5
0
5
10
Landings per rectangle
(tonnes)
12.16
9.12
6.08
3.04
0.00

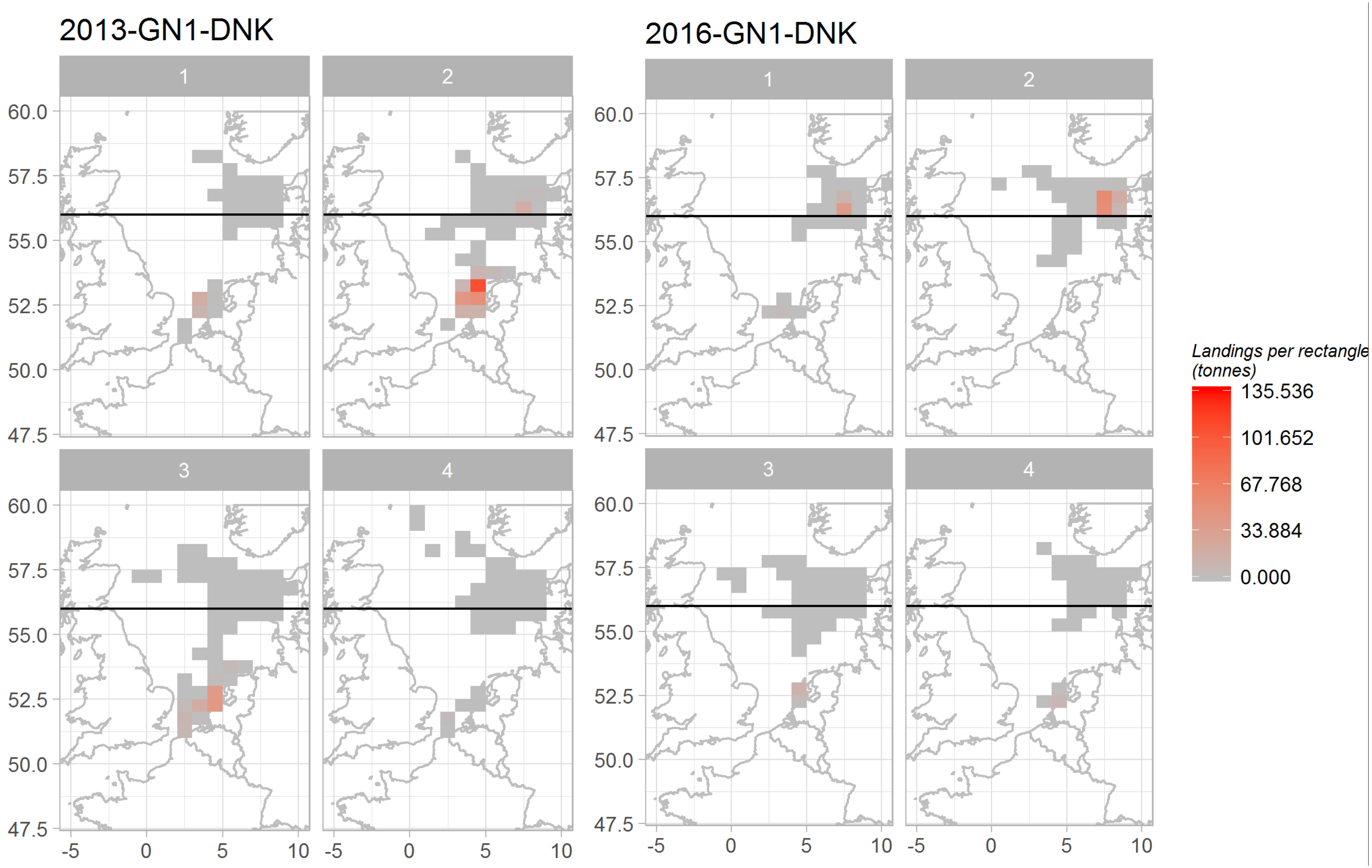

2013-BT2-100-119mm-NLD
2016-BT2-100-119mm-NLD
1
2
3
4
60.0
57.5
55.0
52.5
50.0
47.5
-5
0
5
10
Landings per rectangle (tonnes)
12.16
9.12
6.08
3.04
0.00

Annex 3

Example of quarterly distribution of sole landings for the Danish Gillnet fishery




2007-GN1-DNK
2011-GN1-DNK
1
2
3
4
60.0
57.5
55.0
52.5
50.0
47.5
-5
0
5
10
Landings per rectangle (tonnes)
135.536
101.652
67.768
33.884
0.000


2013-GN1-DNK
1
2
3
4
60.0
57.5
55.0
52.5
50.0
47.5
-5
0
5
10
2016-GN1-DNK
Landings per rectangle (tonnes)
135.536
101.652
67.768
33.884
0.000

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