FIS005 - Reconsideration of European Relative Stability Quota Shares and Implications for the Landings Obligation

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AND PREPARED BY

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Reconsideration of European Relative Stability Quota Shares and Implications for the Landings Obligation

Fisheries Innovation Scotland Contract FIS05: Final Report

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October 9, 2015

1 Project outline

Project title Reconsideration of European Relative Stability Quota Shares and Implications for the Landings Obligation.

Project code FIS05

Purpose For several years, the Scottish demersal fishing industry have been reporting an increasing discrepancy between their perceptions of the abundance of key stocks (particularly cod, hake and saithe) and the overall stock estimates produced by ICES. The stock estimates generally refer to the entire North Sea, while the Scottish demersal fleet operates principally in the northern part only, and it is hypothesised that changes in the spatial distribution of stocks may be contributing to these discrepancies. More generally, we hypothesise that the relative distributions of fish and fishing effort that were in place when the Relative Stability shares were specified (during the 1980s) may no longer be extant, and that the shares may therefore no longer be fully relevant. If this is the case, then it may prove impossible to allocate national quotas in such a way as to facilitate the forthcoming EU Landings Obligation.

Research context ICES stock assessments generally assume that the stock in question is evenly distributed over the notional stock area, and do not take full cognisance of the fact that distribution within the area may be patchy and changing through time. Similarly, while countries are allocated quota shares on the basis of a historical perception of stock accessibility, there is no allowance for the fact that fishing effort distributions also change through time. In this project, we will collate information on stock distribution (from *inter alia* research-vessel survey data) and national fishing effort distribution (from *inter alia* the STECF effort database). We will use these data to generate an index of the likelihood of the fishing fleets of each country encountering different stocks by considering the extent of overlap between fishing effort and fish stock distributions. We will then repeat this process for each available year (from 1990 onwards) to generate time-series of the estimated resource-allocation share, and compare these with the currently-applied relative stability shares to determine if these remain valid. Finally, we will consider the implications for fisheries managers of our findings, if appropriate, and suggest potential courses of action.

2 Contacts schedule

1. Fisheries Innovation Scotlands Representative will be: Richard Slaski.
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3 Project dates

Date of commencement 15th January 2015.

Date of completion 31st August 2015.

4 Project costs and staff input

The full project costs for FIS were 14,186.00 inclusive of VAT. The total staff input by grade was 28 half-day units (HDUs) at C1 grade, and 11 HDUs at C2 grade.

5 Project objectives and milestones

Milestones are listed in Table 1. The project objectives were as follows:

1. Collate fishery effort data and stock distribution data from the relevant public databases.

2. Develop relative share indices for each year, country and stock, based on the extent of overlap between effort and stock distributions.

3. Generate reports, presentations and papers based on the outcomes of the analysis and disseminate appropriately.

4. Following stakeholder feedback, revisit and revise data and methodology as appropriate.

It should be noted that the fourth objective, relating to stakeholder feedback, was removed during the project kick-off meeting on 27th January 2015: the project Board concluded that such feedback may not be constructive and could in fact be counter-productive.

Milestone	Target date	Title
M1	End of 2nd month	Completed data collation, including (if necessary) effort data at a finer scale than national (gear types, for example).
M2	End of 5th month	Completion of analysis methodology and initial progress report.
M3	End of 8th month	Completion of initial dissemination and iterative collation of stakeholder feedback.

Table 1: Milestones for project FIS05.

6 Executive summary

The aim of project FIS05 was to determine whether the existing EU relative-stability quota allocations between different countries in the North Sea could be considered to be representative of the likely catches of national fishing fleets. The advent of the EU Landings Obligation in 2016 meant that this was a highly relevant study.

Most North Sea fishing vessels operate in a mixed fishery in which they will be granted quota for a number of different species. Previously, if the proportions of different species caught did not match the species quota proportions allocated to a vessel, the skipper would be legally obliged to discard over-quota fish but could continue to land species for which quota remained. The Landings Obligation removes the discard option, and if the allocated quota mix is not representative of the encountered species mix, vessels may be forced to stop fishing as soon as their smallest quota is exhausted. Quota allocations were specified in 1983, based on species and fishing effort distribution at the time, and have not changed to reflect changes in stock and effort distribution.

This study used data on fishing effort (from EU databases) and fish distribution (from survey data) to generate indices of the likely catch (called the *implied catch*) of each country fishing in the North Sea, accounting for the *possibility* of gear catchability differences (although we emphasise that data on gear catchability parameters have not yet been collated, and the results currently assume that all gear catch all species equally well). The national implied catch was then expressed as a proportion of the total international implied catch. Finally, we compared implied catch with the national proportions of catches and landings, along with the fixed relative-stability quota allocation proportion used by the EU since 1983. Our conclusions were:

- Stock distributions have changed significantly over time, particularly for species such as cod, saithe and hake which are now distributed further north than was the case when relative-stability quota allocations were determined.
- Fishing-effort distributions have remained roughly constant since 2003 (the first year for which comprehensive effort data are available).
- The national proportions of estimated implied catch (assuming equal catchability for all gears for the time being) are often very different from either the relative-stability quota

allocation, or the historical landings (or catches).

- The most strongly affected countries are those which fish predominantly in the northern North Sea, due to the concentration of distribution of several species in that area.
- If found to still pertain once appropriate gear catchability parameters are factored in, such significant discrepancies between the quota allocation key and the fish available to national fleets will hinder the successful implementation of the EU Landings Obligation, unless a mechanism is in place to transfer quota to the areas and fleets where it is most required.

In the time available, we were unable to locate suitable gear catchability parameters, and the results presented assume that all species are equally vulnerable to all gears. This is clearly a poor approximation, and future work must include the development of representative parameters to allow for more realistic estimates of implied catch.

7 Methods

7.1 Introduction

The purpose of this project was to consider the relative distributions of fish stocks and national fishing effort in the North Sea, and determine what might be appropriate relative shares of available fishing quota based on fish availability to national fleets. Initial approaches assumed that all fish were equally available to all gear and vessel types, although this was later modified to enable the accounting of potentially different catchability characteristics of different gears (although we emphasise that data on gear catchability parameters has not yet been collated, and the results currently assume that all gear catch all species equally well). In brief, we assumed that the available research-vessel survey catches could be considered a valid representation of the actual stock in an ICES statistical rectangle, and then divided this stock between the relevant fishing nations on the basis of the proportion of total international effort that was expended by vessels of each nation (to be modified in future work by a consideration of gear catchability at length). The implied national catches were then summed over the whole North Sea to generate an estimate of the proportion of the total catch that should be granted to each country, on the basis of *availability*.

We consider first a simple illustrative case to specify the method. Suppose we have a sea divided into three zones $Z1$ (north), $Z2$ (central) and $Z3$ (south); and that we have research-vessel survey data for a particular species from these three zones. Denote the number of fish caught by the survey in zone $Z1$ by N_{Z1}, that for zone $Z2$ by N_{Z2}, and that for zone $Z3$ by N_{Z3}. Suppose initially that these abundances are all the same, so that:

$$\begin{aligned} N_{Z1} &= 100 \quad (1) \\ N_{Z2} &= 100 \\ N_{Z3} &= 100 \end{aligned}$$

As mentioned above, we assume that these survey indices are a good representation of the actual number of fish in the sea. We also allow that there are three countries fishing in this sea, denoted A, B and C. In the first instance, we suppose that fishing effort E by zone and country is evenly distributed, so that (for some unit of effort):

$$\begin{array}{llll} & A & B & C \\ Z1 & E_{Z1,A} = 10 & E_{Z1,B} = 10 & E_{Z1,C} = 10 \\ Z2 & E_{Z2,A} = 10 & E_{Z2,B} = 10 & E_{Z2,C} = 10 \\ Z3 & E_{Z3,A} = 10 & E_{Z3,B} = 10 & E_{Z3,C} = 10 \end{array} \tag{2}$$

To determine the proportion of fishing effort expended by each country in each zone, we divide each E by the total effort $\sum E = 90$ to get scaled effort E':

$$\begin{array}{llll} & A & B & C \\ Z1 & E'_{Z1,A} = 0.11 & E'_{Z1,B} = 0.11 & E'_{Z1,C} = 0.11 \\ Z2 & E'_{Z2,A} = 0.11 & E'_{Z2,B} = 0.11 & E'_{Z2,C} = 0.11 \\ Z3 & E'_{Z3,A} = 0.11 & E'_{Z3,B} = 0.11 & E'_{Z3,C} = 0.11 \end{array} \tag{3}$$

We assume for the time being that all fish are equally available to the vessels of all countries (so that there are no catchability effects). Then the number of fish caught by each country in each area can be determined by multiplying the survey abundance index N by the scaled effort E':

$$\begin{array}{llll} & A & B & C \\ Z1 & N_{Z1} \times E'_{Z1,A} = 11.11 & N_{Z1} \times E'_{Z1,B} = 11.11 & N_{Z1} \times E'_{Z1,C} = 11.11 \\ Z2 & N_{Z2} \times E'_{Z2,A} = 11.11 & N_{Z2} \times E'_{Z2,B} = 11.11 & N_{Z2} \times E'_{Z2,C} = 11.11 \\ Z3 & N_{Z3} \times E'_{Z3,A} = 11.11 & N_{Z3} \times E'_{Z3,B} = 11.11 & N_{Z3} \times E'_{Z3,C} = 11.11 \end{array} \tag{4}$$

The proportion P of the total number of fish available to each country can then be determined by summing these quantities across zones and expressing as a proportion:

$$\begin{aligned} P_A = \frac{1}{\sum P} \sum_{z=Z1,Z2,Z3} N_z \times E'_{z,A} &= 33.33\% \\ P_B = \frac{1}{\sum P} \sum_{z=Z1,Z2,Z3} N_z \times E'_{z,B} &= 33.33\% \\ P_C = \frac{1}{\sum P} \sum_{z=Z1,Z2,Z3} N_z \times E'_{z,C} &= 33.33\% \end{aligned} \tag{5}$$

In this example, fishing effort and fish abundance are both evenly distributed across countries and zones, so the proportion available is constant for each country.

Suppose now that effort by country is *not* evenly distributed, so that country A only fishes in zone $Z1$, country B in zone $Z2$, and country C in zone $Z3$:

$$\begin{array}{llll} & A & B & C \\ Z1 & E_{Z1,A} = 30 & E_{Z1,B} = 0 & E_{Z1,C} = 0 \\ Z2 & E_{Z2,A} = 0 & E_{Z2,B} = 30 & E_{Z2,C} = 0 \\ Z3 & E_{Z3,A} = 0 & E_{Z3,B} = 0 & E_{Z3,C} = 30 \end{array} \tag{6}$$

If fish are still distributed evenly across zones, then the fish catch is:

$$
\begin{array}{llll}
 & A & B & C \\
Z1 & N_{Z1} \times E'_{Z1,A} = 33.33 & N_{Z1} \times E'_{Z1,B} = 0.0 & N_{Z1} \times E'_{Z1,C} = 0.0 \\
Z2 & N_{Z2} \times E'_{Z2,A} = 0.0 & N_{Z2} \times E'_{Z2,B} = 33.33 & N_{Z2} \times E'_{Z2,C} = 0.0 \\
Z3 & N_{Z3} \times E'_{Z3,A} = 0.0 & N_{Z3} \times E'_{Z3,B} = 0.0 & N_{Z3} \times E'_{Z3,C} = 33.33
\end{array} \tag{7}
$$

And the availability proportion is, as before:

$$
\begin{aligned}
P_A = \frac{1}{\sum P} \sum_{z=Z1,Z2,Z3} N_z \times E'_{z,A} &= 33.33\% \\
P_B = \frac{1}{\sum P} \sum_{z=Z1,Z2,Z3} N_z \times E'_{z,B} &= 33.33\% \\
P_C = \frac{1}{\sum P} \sum_{z=Z1,Z2,Z3} N_z \times E'_{z,C} &= 33.33\%
\end{aligned} \tag{8}
$$

Finally, consider the case where effort is unevenly distributed as above, *and* fish are more concentrated towards the north (zone $Z1$), a situation analogous to what has been observed for North Sea cod (ICES-WGNSSK 2014):

$$
\begin{aligned}
N_{Z1} &= 150 \\
N_{Z2} &= 100 \\
N_{Z3} &= 50
\end{aligned} \tag{9}
$$

Then application of the preceding method results in:

$$
\begin{array}{llll}
 & A & B & C \\
Z1 & N_{Z1} \times E'_{Z1,A} = 50.0 & N_{Z1} \times E'_{Z1,B} = 0.0 & N_{Z1} \times E'_{Z1,C} = 0.0 \\
Z2 & N_{Z2} \times E'_{Z2,A} = 0.0 & N_{Z2} \times E'_{Z2,B} = 33.33 & N_{Z2} \times E'_{Z2,C} = 0.0 \\
Z3 & N_{Z3} \times E'_{Z3,A} = 0.0 & N_{Z3} \times E'_{Z3,B} = 0.0 & N_{Z3} \times E'_{Z3,C} = 16.67
\end{array} \tag{10}
$$

And thus:

$$
\begin{aligned}
P_A = \frac{1}{\sum P} \sum_{z=Z1,Z2,Z3} N_z \times E'_{z,A} &= 50.00\% \\
P_B = \frac{1}{\sum P} \sum_{z=Z1,Z2,Z3} N_z \times E'_{z,B} &= 33.33\% \\
P_C = \frac{1}{\sum P} \sum_{z=Z1,Z2,Z3} N_z \times E'_{z,C} &= 16.67\%
\end{aligned} \tag{11}
$$

Not surprisingly, the focus of the fishing effort of country A in the northern area $Z1$ combines with the concentration of fish in the northern area to result in a quota-share allocation which is skewed towards country A. The allocation therefore reflects the relative distribution of fishing effort and the fish stock.

7.2 Implementation

The simple example given above demonstrates the approach taken in this project, which can be outlined more generally as follows. Denote ICES statistical rectangle (“stat square”) by s, gear type by g, country by c, and year by y. Data on reported fishing effort (days at sea) by gear, country and stat square were taken from the relevant EU STECF database (STECF 2014), and are denoted by $E_{s,g,c,y}$. The total international effort for year y is given by

$$\mathbf{E}_y = \sum_{s,g,c} E_{s,g,c,y} \tag{12}$$

and we determine the annual proportion $E^p_{s,g,c,y}$ as:

$$E^p_{s,g,c,y} = \frac{E_{s,g,c,y}}{\mathbf{E}_y} \tag{13}$$

Note that 2003 effort data was used for 1990-2002, as there were no data in the STECF database for the earlier period.

To model the effect of different fishing gears, a catchability function $q_{l,f,g,c}$ was generated for each length l, fish stock f, gear type g and country c, such that:

$$\alpha_{f,g,c} = \mathrm{L50}_{f,g,c} \tag{14}$$

$$\beta_{f,g,c} = \frac{-\log\left(\frac{1}{3}\right)}{0.5 \times \mathrm{SR}_{f,g,c}} \tag{15}$$

$$q_{l,f,g,c} = \frac{1}{1 + \exp(-\beta_{l,f,g,c}(l - \alpha_{l,f,g,c}))} \tag{16}$$

where $\mathrm{L50}_{f,g,c}$ is the length (in cm) at which 50% of stock f are retained by gear g, and $\mathrm{SR}_{f,g,c}$ is the distance (in cm) between $\mathrm{L25}_{f,g,c}$ and $\mathrm{L75}_{f,g,c}$ (the length at which 25% and 75% of the fish are retained, respectively). Ideally, each $\mathrm{L50}_{f,g,c}$ and $\mathrm{SR}_{f,g,c}$ parameter would determined experimentally, but for most gears, countries and stocks these estimates are not currently available. Due to the short duration of the project, we proceeded with method development assuming the catchability parameters are the same across all cases, which results in the same output as would arise were the catchability aspect to be ignored completely, but the code is intentionally general and can readily be modified to allow for case-specific catchability parameters. The issue is considered further in Section 9.

Research-vessel survey data were downloaded from the ICES DATRAS database (ICES 2014), for the third-quarter beam-trawl survey BTS Q3 (used for plaice and sole) and the first-quarter demersal-trawl survey IBTS Q1 (used for all other stocks). These data are imported in the Exchange data format. For each year y and stock f, the addSpectrum function from the R DATRAS library (Kristensen & Berg 2015) was used to convert Exchange data to numbers-at-length distributions (in one-cm length classes l from 0 cm to 150 cm) for each stock f, stat square s, and year y, denoted by $N_{l,f,s,y}$ (the full R code for the analyses is given in the Appendix).

Given catchability $q_{l,f,g,c}$, effort $E_{s,g,c,y}$ and survey-derived abundance $N_{l,f,s,y}$, we estimate an index of the implied catch of fish of length l for stock f, gear g, country c in stat square s

and year y as

$$C_{l,f,g,c,s,y} = q_{l,f,g,c} \times N_{l,f,s,y} \times E_{r,g,c,y}. \tag{17}$$

In other words, this is the catch at length that a given gear would be *expected* to take for a given expenditure of effort, assuming that the survey index is an exact measurement of the number of fish available. We then sum $C_{l,f,g,c,s,y}$ across all gear types for a given country and statistical rectangle, and then across all statistical rectangles. We refer to this quanitity hereafter as the *implied catch*. Expressing this number as a proportion of the total international catch enables us finally to estimate the proportion $P_{f,c,y}$ of the available fish of stock f that each country c could be expected to catch in year y.

We can then compare this with the actual relative quota share available to each country during the study period, and the resultant reported landings. Data on quotas were taken from the relevant EU quota regulation document for 2014 (European Commission 2014) and converted to proportions available to each country for each stock (these proportions have not changed since relative stability was first implemented in 1983, so it is sufficient to consider data from one year only). EU landings data were taken from the datasets provided for ICES assessment working groups, and summarised in ICES-WGNSSK (2014); while EU catch and discards data were taken from the relevant STECF database (see the link to Appendix 5 at `http://stecf.jrc.ec.europa.eu/ewg1406`). The results were summarised by time-series plots comparing the relative national proportions of implied catch, historical landings and catches, and the relative-stability quota allocations.

8 Results

The STECF database includes landings information for a total of 32 discrete fishing gears. Figure 1 illustrates the shape of the assumed catchability curves for each of these gears in the analysis reported here, along with observed and catchability-modified survey abundance-at-length. We note again that, in this example, all the catchability curves are identical as sufficient information on gear parameters has not yet been identified - this is intended to be addressed (to the extent possible) shortly after the conclusion of the FIS project (see Section 9). The simple catchability curves shown here assume an L_{50} of 20 cm and a selection range of 10 cm, but these must be considered as interim values only to illustrate the method.

Figure 2 shows the observed abundance distribution for haddock (summed across all lengths), scaled in each case by the appropriate assumed catchability curve for the gear in question. We therefore have a potentially different version of the survey data for each commerical gear considered. However, as before, we have not yet obtained the correct catchability parameters for each gear type, so here all the catchability-modified survey distributions are identical. It is appropriate to include all lengths in this analysis, as the very small fish which would not be retained in commercial fishing gears (but which are caught by the survey) are in any case removed from the calculation by the catchability considerations.

We illustrate an example of the effort data available in the STECF database in Figure 3, which shows the spatial distribution of recorded Scottish fishing effort across the North Sea for the 32 gears available in the database. The bulk of the Scottish effort was due to bottom trawls, although there were also significant concentrations of dredge and pot effort along the eastern coast of the UK, as well as lighter exploitation by pelagic trawls (in the north) and beam trawls (in the south). Figure 4 summarises the effort distribution by country for 2013, summed across all gears. Figure 5 gives the corresponding effort distributions for 2003 for comparison: we can see that the distributions of national fishing effort have not changed significantly over the last ten years.

The next stage of the analysis is to multiply the catchability-modified survey index by the appropriate national effort, by gear, year and ICES statistical rectangle, to give an estimate of *implied catch*. The results for Scotland are shown in Figure 6. As before, we note that these results do not yet account for the likely different catchabilities between gears - for example, it is unlikely that dredges, pelagic trawls or pots would catch much haddock, but they are shown in Figure 6 as contributing significantly to the Scottish total.

The results given thus far have focussed on 2013 as an illustrative year. However, with the method implemented, it is straightforward to apply it to each of the years 1990-2013. Figure 7 shows the results for haddock, for each of the countries considered. Note that the UK results are given here as the sum of the results for England and Scotland - the proportions across all countries add to 1 when the UK is not included. The implied relative shares are shown for each year, along with the fit of a loess smoother (span = 1.0) and its associated approximate 95% confidence interval. The plots also show the fixed relative-stability EU quota share for each country, along with the proportional share of the landings and catch. For this stock, the clear implication is that the historical relative-share allocation of haddock for Scotland (around 66%) does not reflect the implied quota share on the basis of relative distributions of haddock and fishing effort, nor the historical share of landings and discards: all of these measures are considerably higher than the relative-share allocation. The allocation for England is considerably higher than would appear to be required, and much of this discrepancy is addressed through internal quota movement within the UK, but even so the allocation for the UK as a whole would appear to be insufficient for the implied catch for UK vessels. We note again, however, that the analysis does not yet account for potential differences in gear catchability for haddock, and that therefore the conclusions should be considered to be interim only.

The same approach was applied to data for five other stocks: cod, whiting, saithe and hake (all using IBTS Q1 survey data), along with plaice (using BTS Q3 survey data, as that is the directed flatfish survey which is used in the ICES plaice assessment). The results are summarised in Figures 8 to 12. For cod (Figure 8), the discrepancy between implied catch and quota share for Scotland has become particularly marked in recent years as the North Sea cod stock has become concentrated in the northern North Sea where the Scottish fleet operates (see Figure 9). For the same reason, the quota allocation for Denmark has become high in relation to the implied catch of the Danish fleet. The opposite is true for whiting (Figure 10), for which the Scottish allocation looks to be too large - in this case, it is the English fleet which has a much higher implied catch than the allocated quota would suggest. We note also that the French allocation appears to be too large for the implied catch, but the French whiting fishery is located at the very southern extreme of the IBTS survey area and the outcome may be biased by boundary effects. The use by the French fleets of smaller mesh than would be usual in the north has not yet been addressed in this method (due to the current lack of suitable catchability parameters), and it may be that this would also affect the estimates of implied catch.

The results for saithe (Figure 11) show that the allocated quota for Scotland appears to be low in relation to the implied catch. This was also the case historically for Denmark, although the Danish implied catch and quota allocation seem to have converged in recent years. The French and German quota allocations for saithe are much higher than the implied catch of those countries. The conclusions for hake are very similar (Figure 12). Saithe and hake are both stocks for which the UK (and hence Scotland) has a relatively low quota allocation, but which are now distributed principally in the northern North Sea where the Scottish fleet are based. Finally, the results for plaice (Figure 13) show that the implied catch is close to the quota allocation in the majority of cases: the only country with a significant discrepancy for this stock is probably Germany.

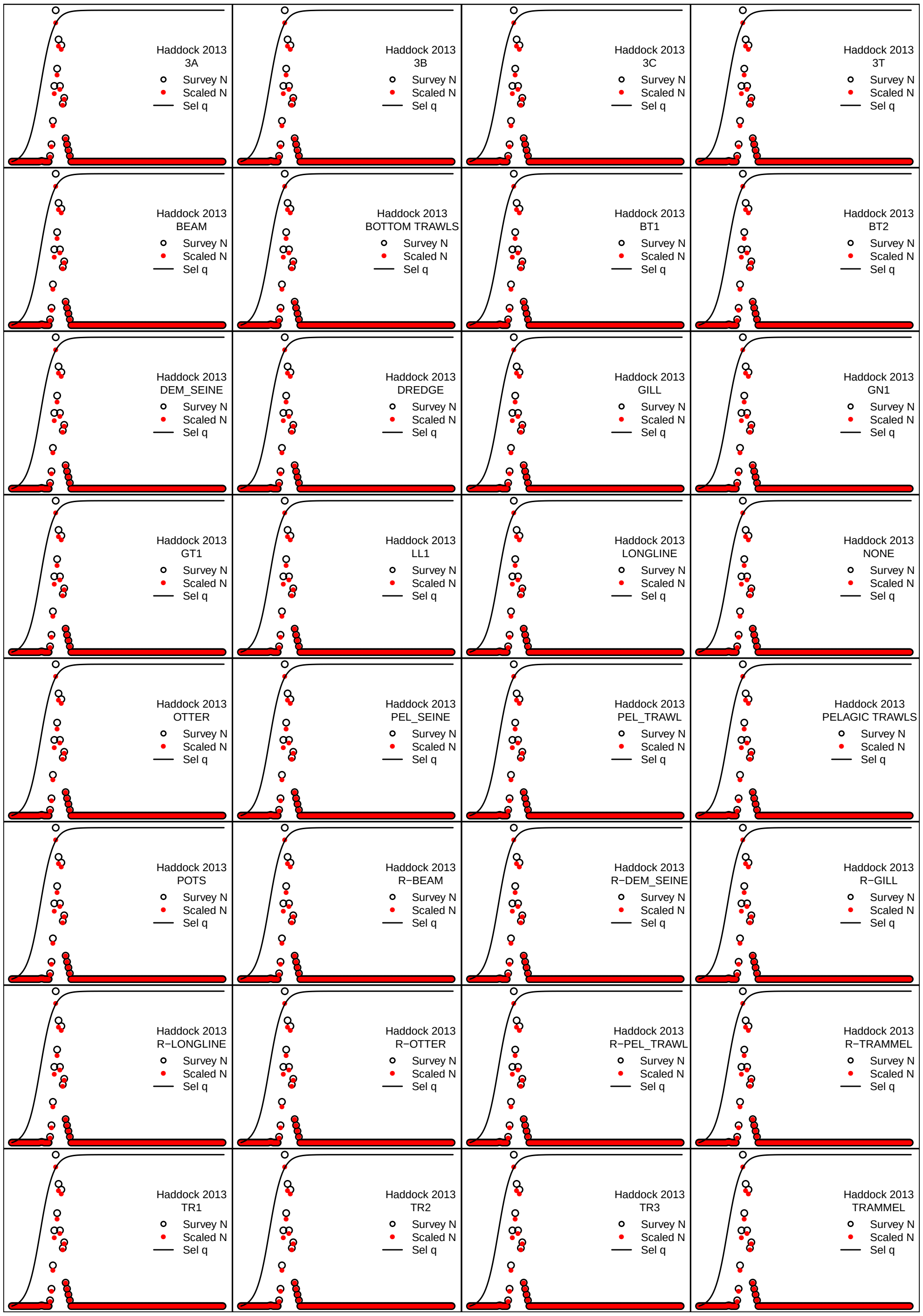

Figure 1: Assumed catchability curves q for the 32 gears available in the STECF effort database (lines). Points give the observed abundance N at length for the haul in the 2013 IBTS Q1 survey with the highest haddock abundance (open black points), and the product $q \times N$ of the observed abundance and the assumed gear catchability (closed red points). The notation here follows that of Equation 17.

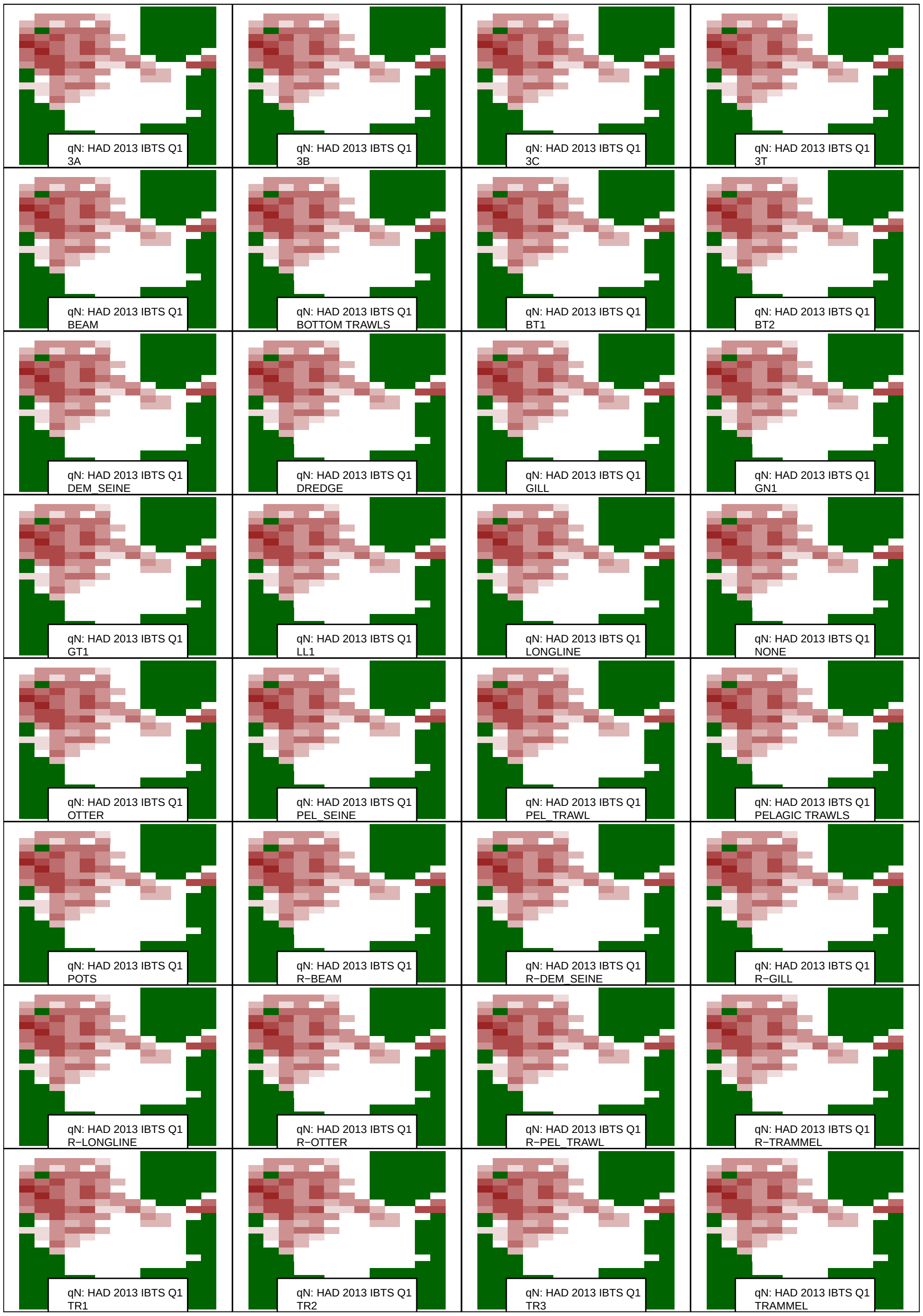

Figure 2: Haddock distribution for 2013 from the IBTS Q1 survey, scaled by the appropriate assumed catchability for each of 32 gear types. Following the notation of Equation 17, this figure summarised $q \times N$.

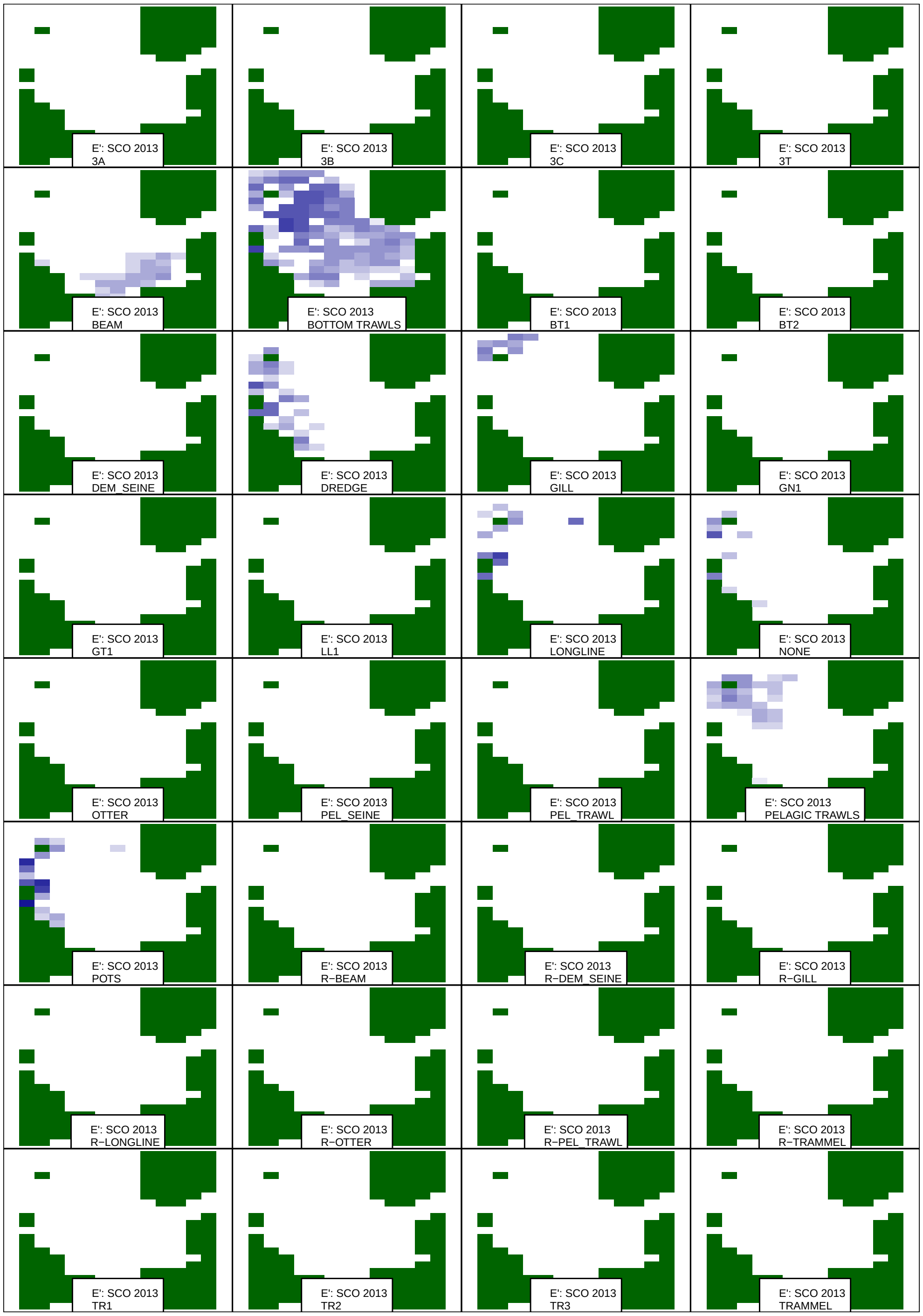

Figure 3: Spatial distribution of Scottish fishing effort in 2013 for each of the 32 gears recorded in the STECF database. Relative effort E' is shown on a log scale and collated by ICES statistical rectangle, and is colour coded (with darker shading indicating more effort).

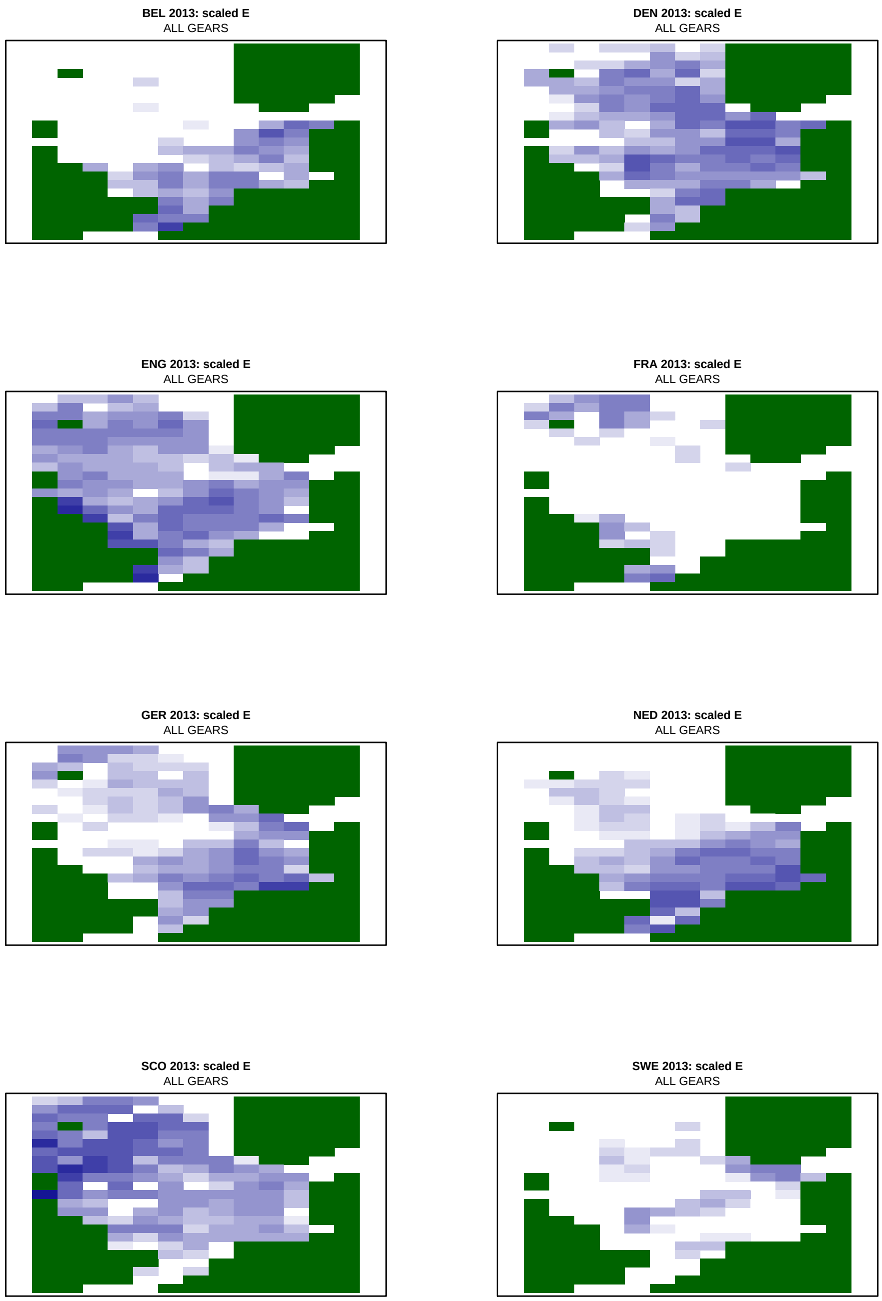

Figure 4: Spatial distribution of fishing effort in 2013 for each of the main fishing countries in the North Sea, summed across gears. Relative effort E' is shown on a log scale and collated by ICES statistical rectangle, and is colour coded (with darker shading indicating more effort).

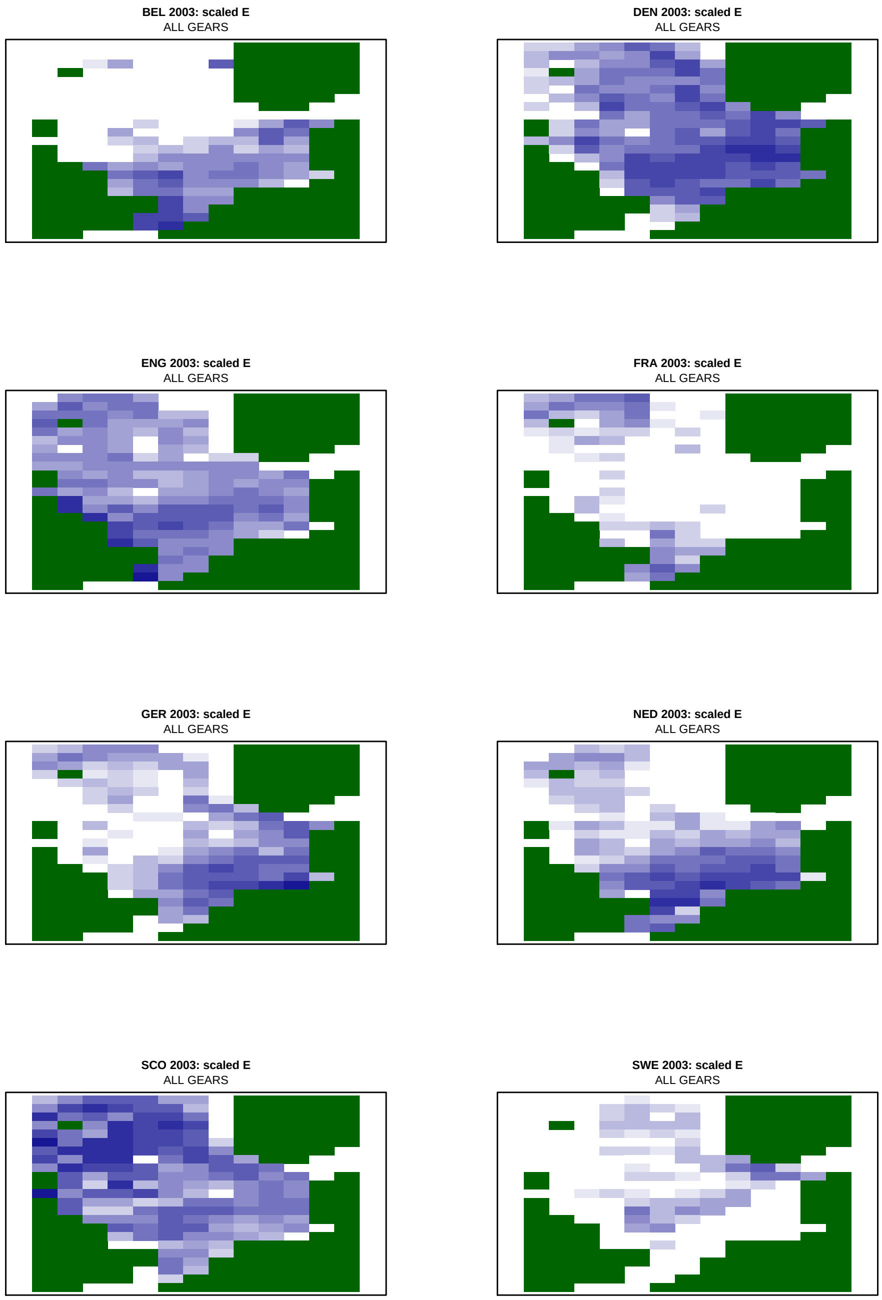

Figure 5: Spatial distribution of fishing effort in 2003 for each of the main fishing countries in the North Sea, summed across gears. Relative effort E' is shown on a log scale and collated by ICES statistical rectangle, and is colour coded (with darker shading indicating more effort).

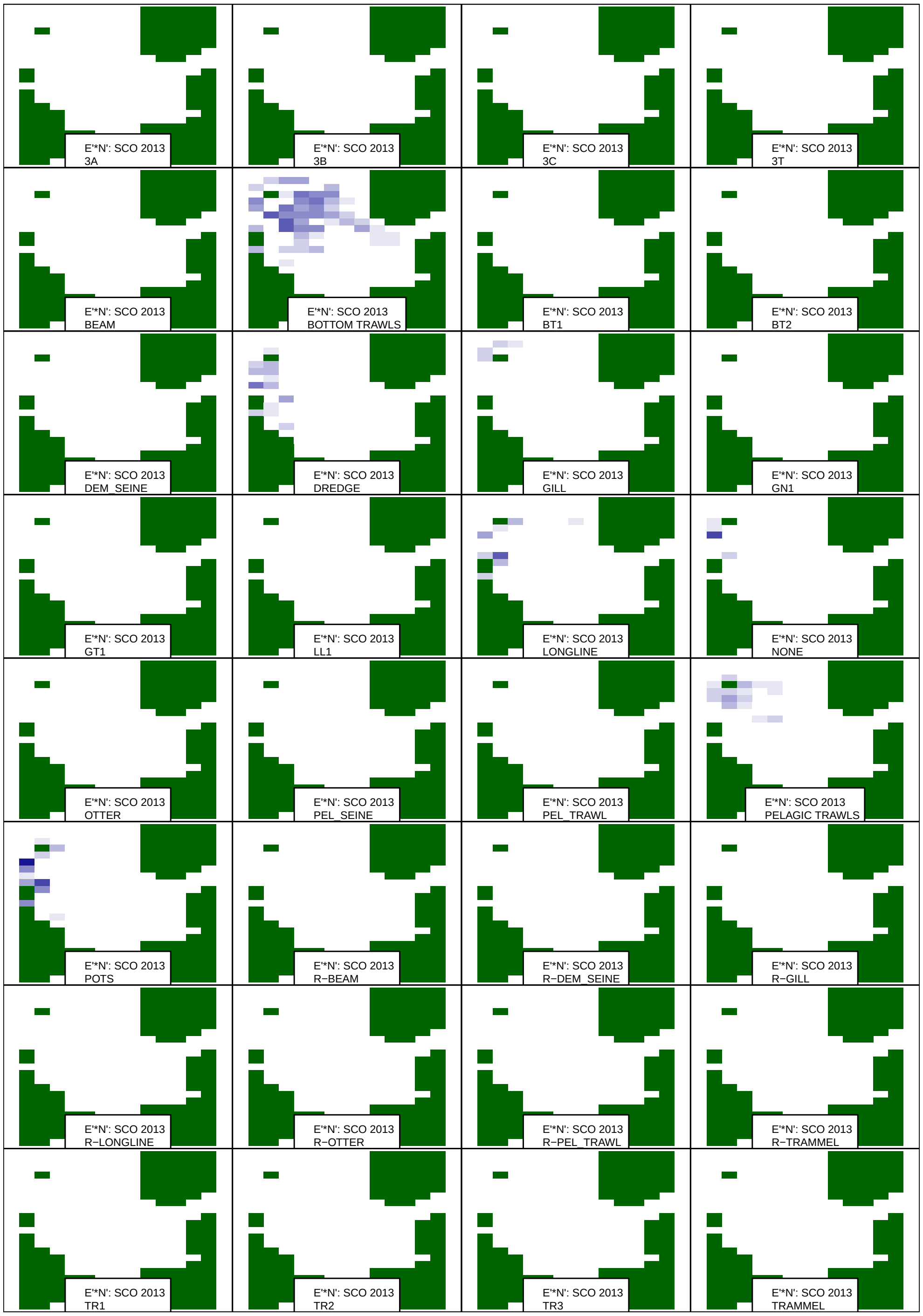

Figure 6: Spatial distribution of the Scottish implied catch C (see Equation 17) for 2013. The implied catch (shown here on a log scale as $\ln(C + 1)$) is colour-coded, with darker shading indicating a higher C.

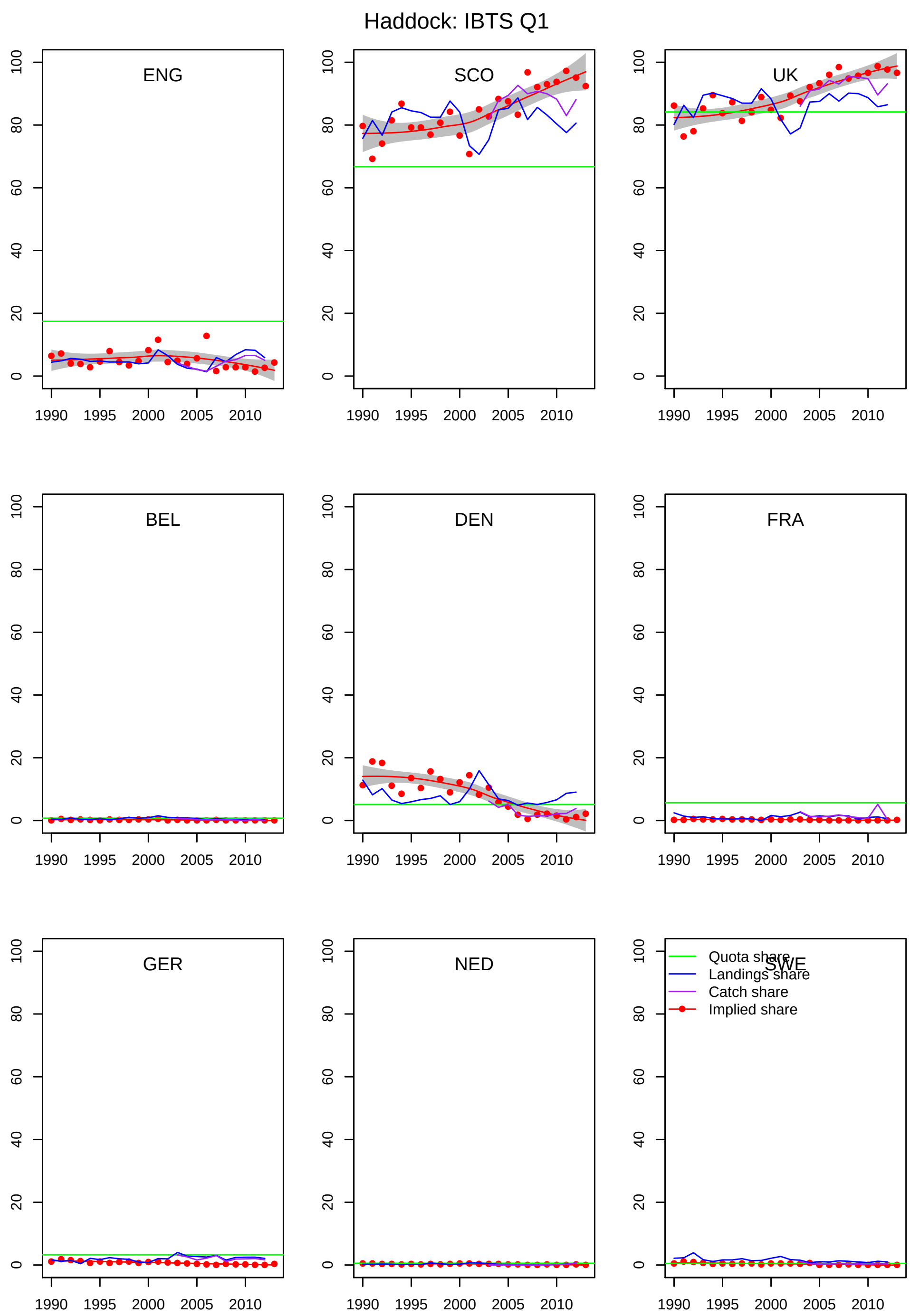

Figure 7: Summary of relative-share analysis for North Sea haddock. In each plot, the red points give the annual national share of the implied international catch (estimated using the distribution of fishing effort and catchability-modified survey-based fish abundance). The red line gives a loess smoother through these points, with the grey band showing the approximate 95% confidence interval. Green lines give the national share of the EU relative-stability quota allocation, while blue and purple lines give the national shares of the total EU landings and catches respectively.

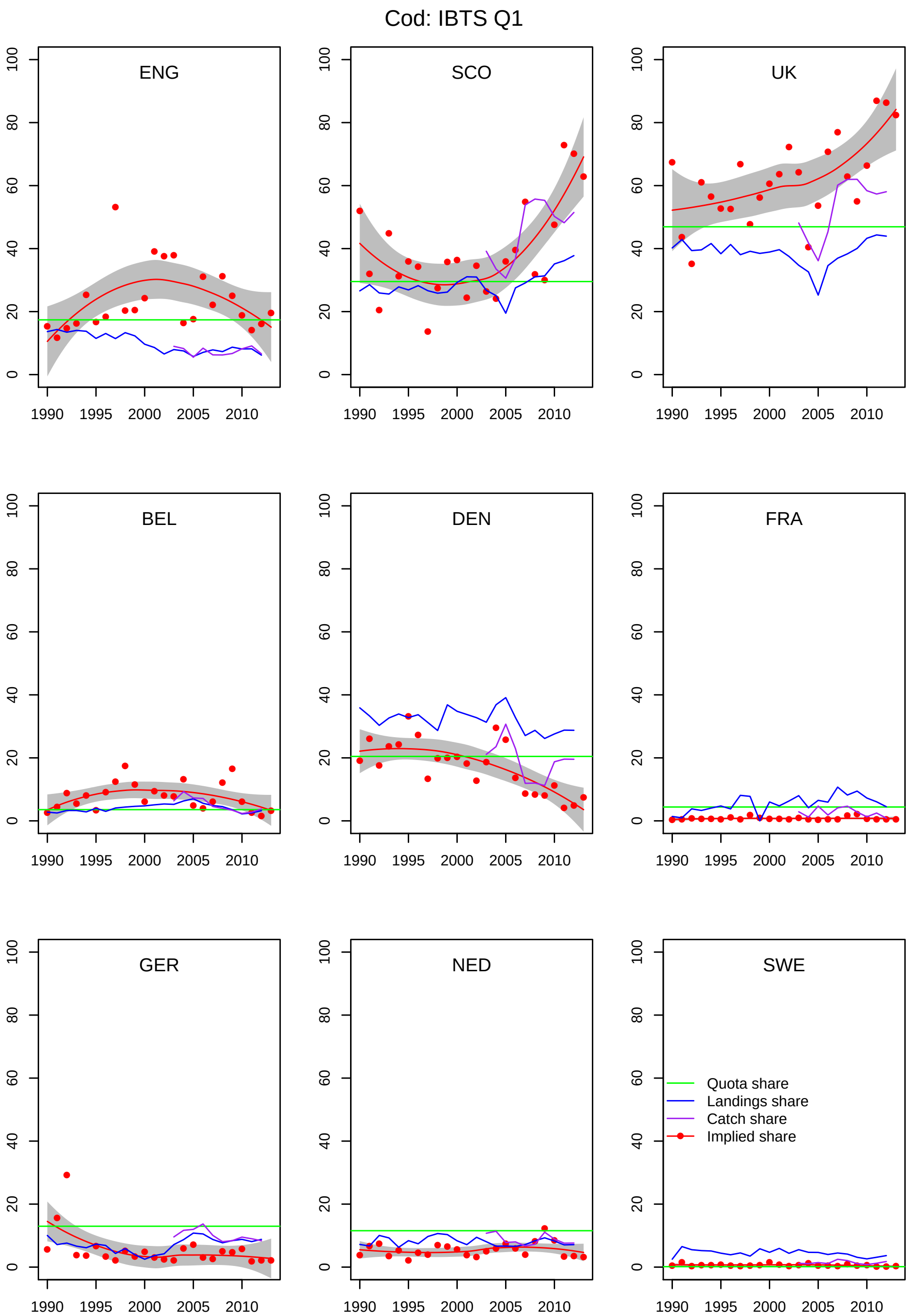

Figure 8: Summary of relative-share analysis for North Sea cod. See caption for Figure 7 for an explanation of the plot format.

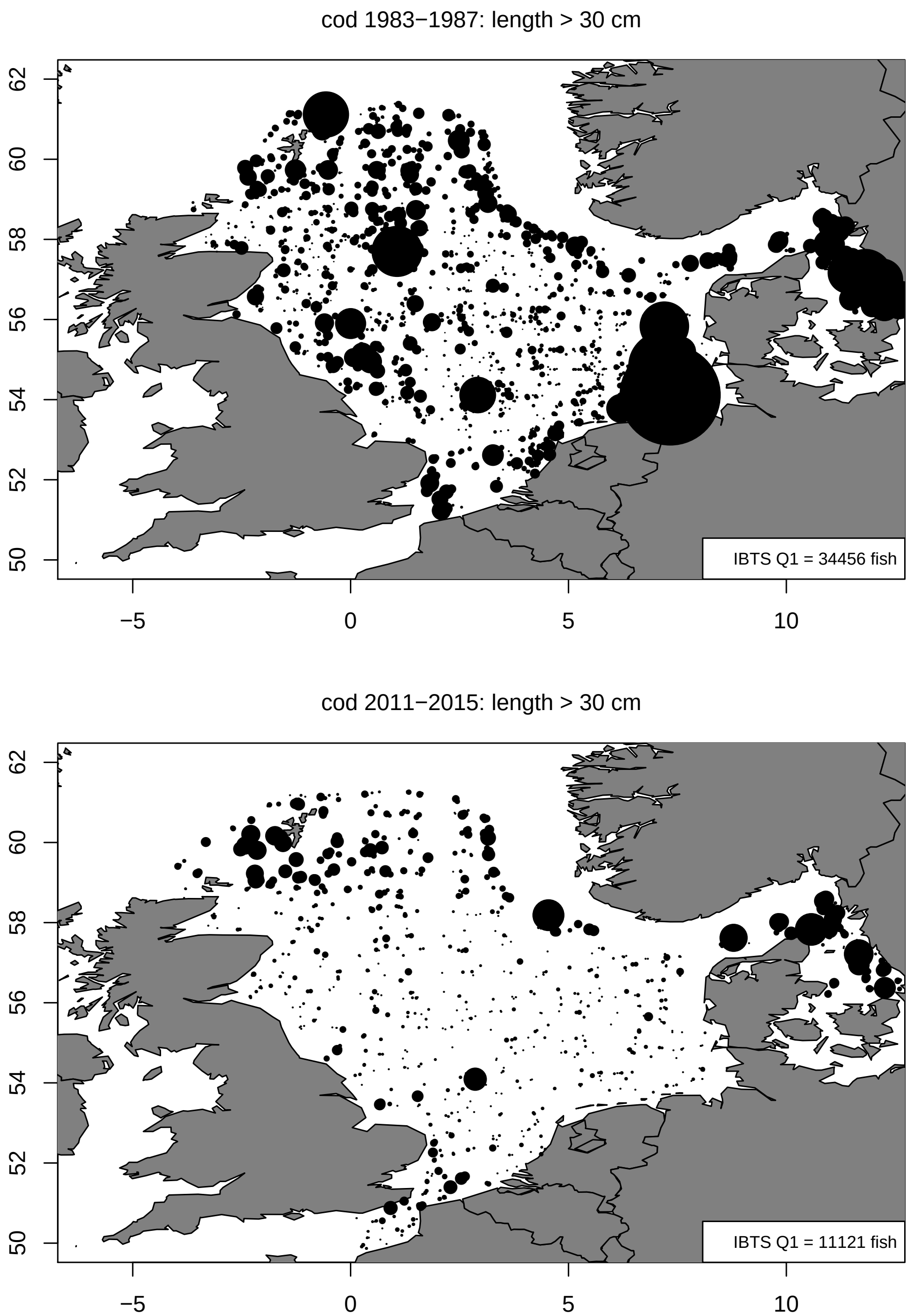

Figure 9: Changes in North Sea cod distribution from 1983-1987 (upper) to 2011-2014 (lower). Circles give the locations of IBTS Q1 hauls, and the sizes of the circles are proportional to the abundance of cod greater than 30 cm caught in those hauls. Form the upper plot, we can see that cod used to be widely distributed throughout the North Sea, while the lower plot shows that the remaining cod are concentrated in the northern area.

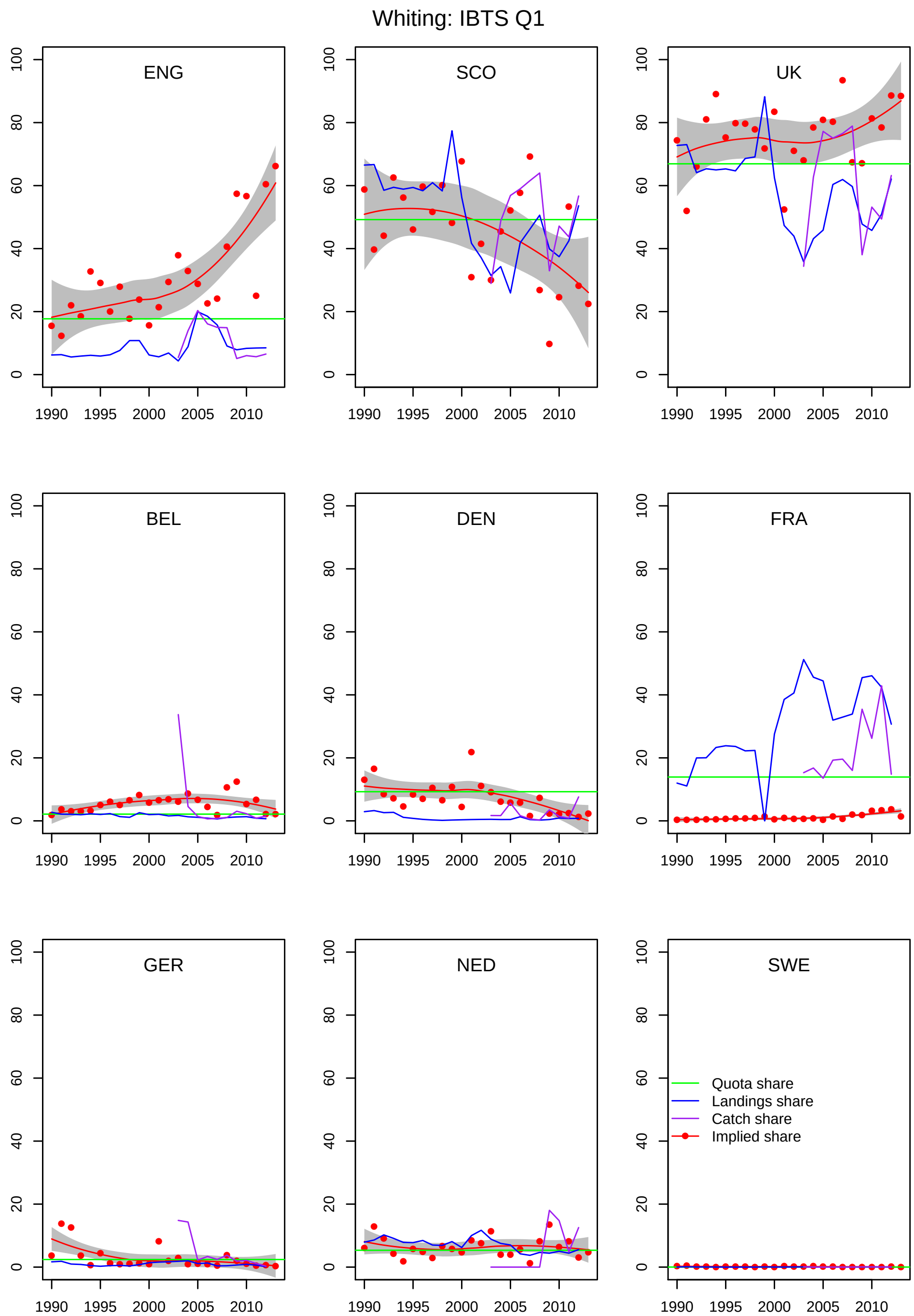

Figure 10: Summary of relative-share analysis for North Sea whiting. See caption for Figure 7 for an explanation of the plot format.

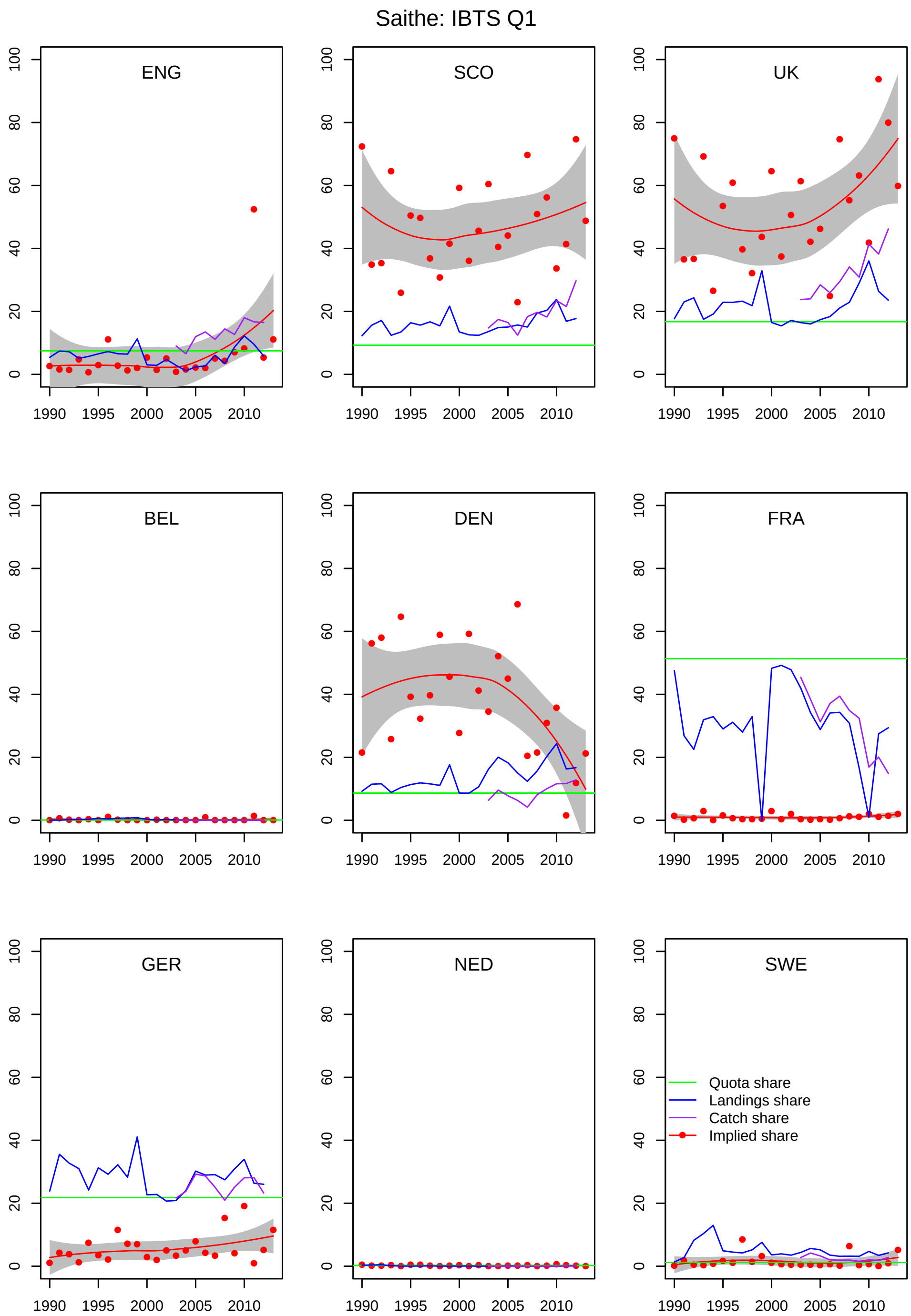

Figure 11: Summary of relative-share analysis for North Sea saithe. See caption for Figure 7 for an explanation of the plot format.

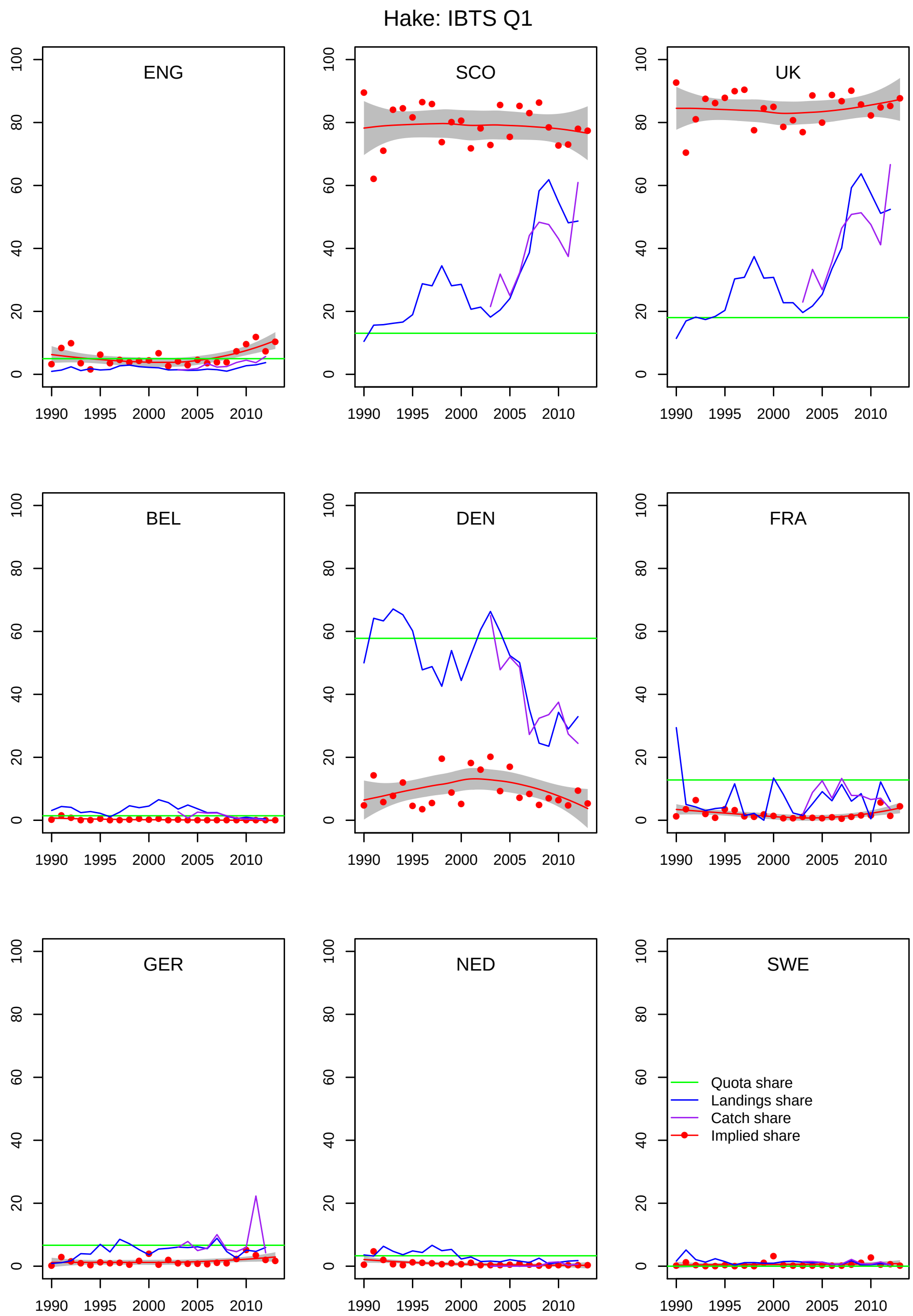

Figure 12: Summary of relative-share analysis for North Sea hake. See caption for Figure 7 for an explanation of the plot format.

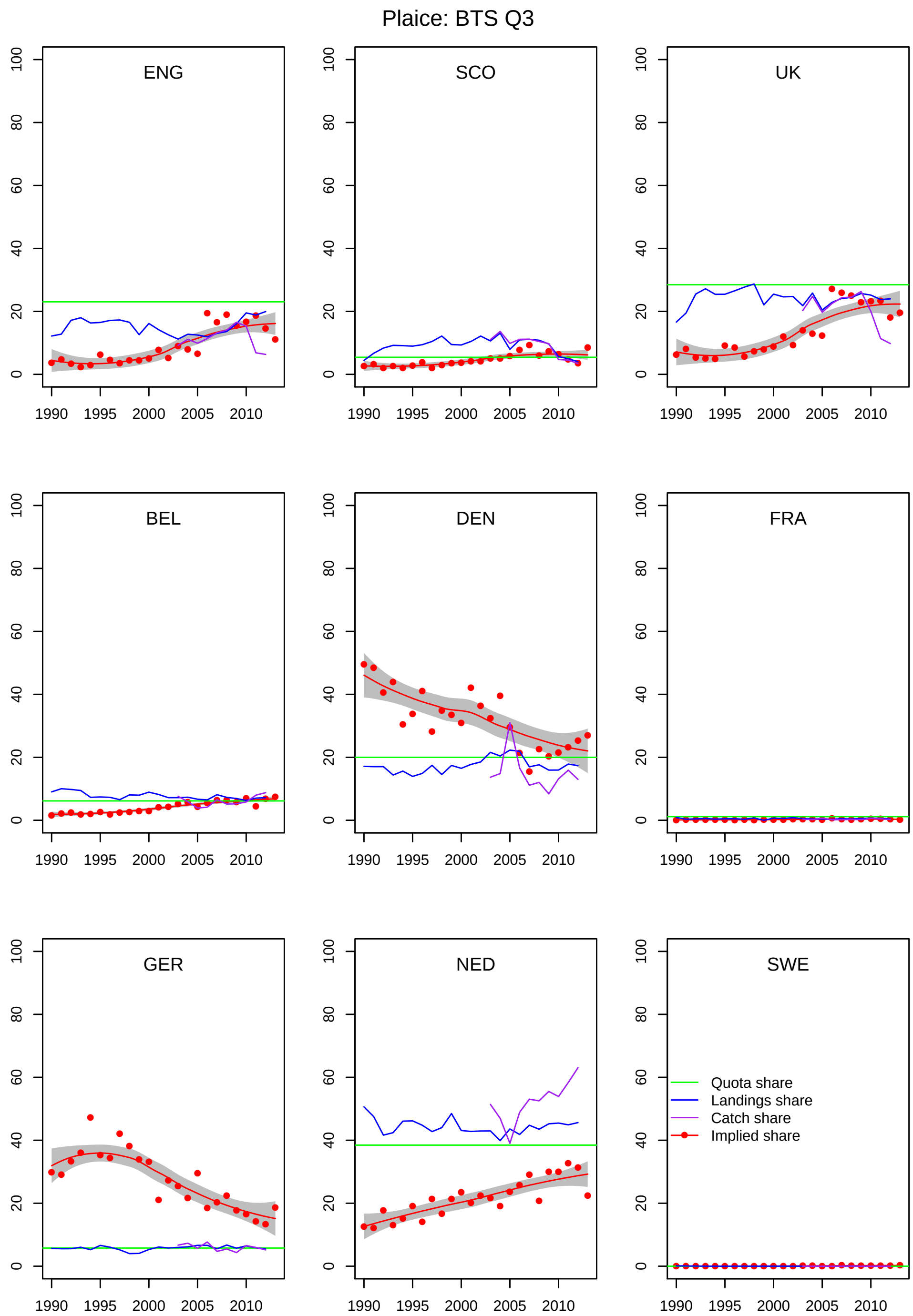

Figure 13: Summary of relative-share analysis for North Sea plaice. See caption for Figure 7 for an explanation of the plot format.

9 Discussion and conclusions

In this short project, we have applied a relatively simple methodology to estimate the implied catch of different species for different fishing nations in the North Sea, *assuming* that the available survey data provide a good representation of stock abundance. The results indicate that, in many cases (and under the interim assumption that all gears catch all species equally well), the relative-share quota allocations do not correspond well with the implied-catch proportion. The principal discrepancies arise with stocks for which the abundance distribution has moved northwards since the relative-share allocations were determined in 1983, and in particular for those countries which fish predominantly in the northern North Sea.

The relevance of this conclusion lies in the potential effect of the forthcoming EU Landing Obligation regulation, under which vessels will be compelled to land all fish they catch of a set number of species. This is due to begin to be phased in for demersal species (such as those considered here) from 2016 onwards. If the quota allocations remain constant, then it is likely that vessels fishing in the northern North Sea will catch fish for which they have no (or very little) quota allocation. This is a common occurrence at the time of writing, but currently skippers have the option (and indeed the legal obligation) to discard such overquota fish and can thus remain within their quota allocation. With the implementation of the Landing Obligation, this option will no longer pertain and vessels may have to cease fishing early in the year once any of their species quotas are exhausted.

A number of approaches have been suggested to attempt to ameliorate these difficulties. One of the most direct would be to apply regular revisions of the quota allocation keys, using *inter alia* methods such as those described here, but there are considerable political difficulties involved in this and it seems unlikely to be applied. Several possibilities exist for developing multi-species quotas, although all of these also have methodological and political difficulties that would need to be overcome. It may be that existing quota-transfer mechanisms could be sufficient to achieve the required re-distribution of quota to match the relative distributions of effort and stock. The important point is that, unless some form of re-distribution is implemented, the change over the years in fish stock distributions will make the appropriate application of the Landings Obligation very difficult to achieve.

As frequently mentioned throughout, one element currently missing from the analysis is the consideration of the different catchabilities of commercial fishing gears. Due to a lack of readily-available gear catchability parameters, the analysis presented here has assumed that all gears have the same catchability characteristics for all species and in all areas. However, this is clearly not true - we have mentioned the difference in catchability for haddock between bottom trawls and pots, for example, and there are similar differences between gears for all the stocks considered here. A key element of future work, therefore, is to seek to apply suitable catchability parameters to the analysis. The EU H2020 DiscardLess project is currently compiling such parameters from fisheries institutes across Europe, and once complete these parameters will be incorporated into the analyses presented here. The DiscardLess website is still in preparation, but the project summary can be accessed at:

`http://www.nsrac.org/wp-content/uploads/2015/02/DiscardLess-intro-leaflet.pdf`

Finally, we consider the objectives of the project as specified in the original proposal:

1. *Collate fishery effort data and stock distribution data from the relevant public databases.* This has been achieved, as reported in Section 7.2.

2. *Develop relative share indices for each year, country and stock, based on the extent of overlap between effort and stock distributions.* This has been achieved, as reported in Section 7.2.

3. *Generate reports, presentations and papers based on the outcomes of the analysis and disseminate appropriately.* During the project kick-off meeting on 27th January 2015, the project Board indicated that the results of the project should not be disseminated before the project report had been approved by the FIS Board. Accordingly, presentations and papers based on the project have not yet been given. However, the project methodology and results are fully written up in the current report, and the production of a summary paper (along with suitable presentations) should be achieved quickly following completion.

4. *Following stakeholder feedback, revisit and revise data and methodology as appropriate.* The fourth objective was removed during the project kick-off meeting: the project Board concluded that such feedback may not be constructive and could in fact be counter-productive.

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Appendix: R code

The full data analysis and result output code for the FIS05 project is available from the author at `needlec@marlab.ac.uk`. We used R version 3.0.2 running on a 32-bit PC (R Development Core Team 2015), along with the `DATRAS` library version 1.0 (Kristensen & Berg 2015) and the `mapdata` library version 2.2-2.

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