Appendix 1. Cod in the Kattegat – stock identity

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Introduction

Inference about population structure is to understand how groups of spawning fish are connected and to what degree. For instance, it has become increasingly evident that cod (*Gadus morhua*) across the North Atlantic are found in separated population units.

Population divisions demonstrated with population genetic methods are in general considered as robust (Palsbøll et al. 2006). Recent studies have also indicated the existence of divergent cod subpopulations (e.g. Hutchinson et al. 2001, Ruzzante et al. 2001, Knutsen et al. 2003). It is worth noticing the “iceberg” phenomenon concerning the detectability of ecologically relevant population structures, using genetic markers (Hauser & Carvalho 2008); many ecologically relevant population units will remain unrevealed merely due to their interrelated migration rates or due to a recent population divergence. In order to investigate subpopulation structures also other methods should be deployed such as otolith chemistry (Gibb et al. 2007, Svedäng et al. 2010a), location of spawning grounds (Vitale et al. 2008), migratory studies (Pihl & Ulmestrand, 1993; Svedäng et al. 2007), and simple deduction from series of events in abundance of different life stages (Stenseth et al. 2006, Svedäng & Svenson 2006).

Spatially separate stocks need individual, spatially sensitive management, or at least recognition and a lowering of the general exploitation rate to levels where there the survival of the least productive stock elements is secured (Stephenson 1999). Failure to account for such a complexity in fishery management will lead severe weakening of the productivity of the whole stock (Frank & Brickman 2001). The decline and deteriorated gadoid population structure in the Kattegat spells this out eloquently: haddock and pollack have almost become obliterated (Cardinale et al. 2012).

The Kattegat cod population structure

The cod population structure in the Kattegat and Öresund has been studied by five different methods: fishery independent surveys, genetic surveys, tagging experiments, egg surveys and otolith chemistry studies. The biological Kattegat stock is defined as cod spawning in the Kattegat area. However, the Kattegat management unit is composed of cod caught in the Kattegat and may comprise a mixture of cod originating from different areas (the Kattegat, North Sea and Western Baltic including the Belt Sea and the Öresund). It is a challenge to separate between these stock units.

Cod spawning aggregations have been observed in the central and southern part of the Kattegat (Hagström et al. 1990, Bagge et al. 1994, Svedäng & Bardon 2003, Vitale et al. 2008, Svedäng et al. 2010a,b). Egg surveys have indicated spawning activities in the same areas (Selma Pacariz in. prep.). Genetic surveys indicate Kattegat cod as separated from stock units in the North Sea and Skagerrak (Knutsen et al. 2004), however yet no genetic evidence of separation between cod in the Kattegat and the Öresund has been obtained (Svedäng et al. 2010a).

There are indications of a significant transportation of cod larvae from the North Sea stocks into the Kattegat (Munk et al. 1999, Cardinale & Svedäng 2004). Tagging studies suggest that the northern Kattegat may also function as a nursery area for North Sea cod, and that return migration to the North Sea is common (Svedäng & Svenson 2006, Svedäng et al. 2007). The principal age when most return migrations from the Kattegat towards the North Sea take place is at age 2 to 3 (Svedäng et al. 2007).

A large proportion of cod in the Kattegat are resident (Svedäng et al. 2007). Tagging of cod have discerned three putative spawning groups in the Kattegat and Öresund, indicating spawning activity in the middle of the Öresund and in the south-eastern part of the Kattegat, as well as a spawning ground in between in the Kullen area. At the latter spawning site fish aggregate only at spawning: coming from the central Öresund, the Kattegat as well as the Skagerrak. The phenomenon that cod temporarily aggregate in the Kullen area during the spawning season but abandon this location for the rest of the year, is also reflected in the fishing pattern by Danish fishers (Anon. 2009).

Asynchronous population dynamics is also evident in monitoring fishing surveys, as depleted areas, such as the ones in Skälderviken and Laholmsbukten, show no signs of recovery in spite of stringent protective measures taken (Svedäng et al. 2010b). In other words, the putative subpopulations are not replenished from adjacent areas (in spite of the occurrence of juvenile fish in those areas), which lends support to the theory that cod in the Kattegat constitute a heterogeneous agglomeration of subpopulations. A homogeneous population would have rapidly redistributed in response to local variability in exploitation according to the theory that cod populations are structured by hydrodynamic retention mechanisms (Nielsen et al. 2005).

The present knowledge about the biological Kattegat stock can be summarised as follows:

- The biological Kattegat cod have limited migration (Svedäng et al. 2007, 2010a)
- There is a small but significant genetic differentiation between spawning aggregations in the Kattegat and the North Sea/ Skagerrak area (Carl André in prep.), i.e. the biological Kattegat stock is unlikely to be replenished from elsewhere in at least mid-term perspective, given that new population behavioural patterns need to evolve.
- The historical spawning grounds in the Kattegat are well documented (Pihl & Ulmestrand 1988, Hagström et al. 1990, Svedäng & Bardon 2003, Svedäng et al. 2010a).
- Spawning still occurs at these particular grounds (Vitale et al. 2008).
- The distribution of cod eggs is concentrated to these putative spawning grounds, confirming local spawning and indicating local retention of eggs and larvae (Selma Pacariz, in. prep).

Additional studies: Genetic characterisation of cod year class in the Kattegat in 2011

Abundance of 0-group cod in the Kattegat and Skagerrak, i.e. belonging to the year class of 2011, was at the highest level since 2003 (IBTS-data). Naturally, it was of interest to investigate whether the closure of spawning areas in the Kattegat has resulted in a better recruitment, as is the prime aim of this regulation, or if the enhanced recruitment is due to a inflow of recruits from spawning areas in the North Sea.

Thus, samples have been taken for genetic analysis during IBTS cruise in the third quarter of 2011 from the southern Kattegat, and, for comparisons reasons, from the Skagerrak close to the Swedish coast. These samples have been analysed in Norway, screening the frequency of the following micro-satellites: gmo2, gmo3, gmo8, gmo19, gmo34, gmo35, GMO37, GMO132, tch5, tch13, tch22. GMO36 and TCH5. The samples have been compared to reference populations in the Öresund, Kattegat and in the North Sea/ western Skagerrak. The analysis showed that juvenile cod in the Kattegat were genetically similar to spawning populations in the North Sea/ western Skagerrak, i.e. most of the juveniles in the Kattegat 2011 were not spawn from the local population. In addition, the juvenile cod in the Kattegat were almost identical to juvenile cod in the Skagerrak, implying that most juvenile cod in the Skagerrak-Kattegat area in 2011 were recruited from the same source (i.e. the North Sea/ western Skagerrak). These results thus show that no major improvement in recruitment of the Kattegat cod stock has occurred.

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Appendix 2. Data on cod catch per unit of effort by stations from different surveys available in the Kattegat.

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Dataa on cod CPUE were available from six surveys:

i) International Bottom Trawl Survey (IBTS),in the 1st and 3rd quarter

ii) Baltic International Trawl survey (BITS) in the 1st and 4th quarter

iii) Joint Swedish-Danihs cod survey, in the 4th quarter

iv) Danish sole survey in the 4th quarter

The figures below show raw data on cod CPUE by station from these surveys, for different age-groups of cod. The size of the bobbles in the plots are comparable between years within a given survey and age-group, but not between age-groups or surveys.

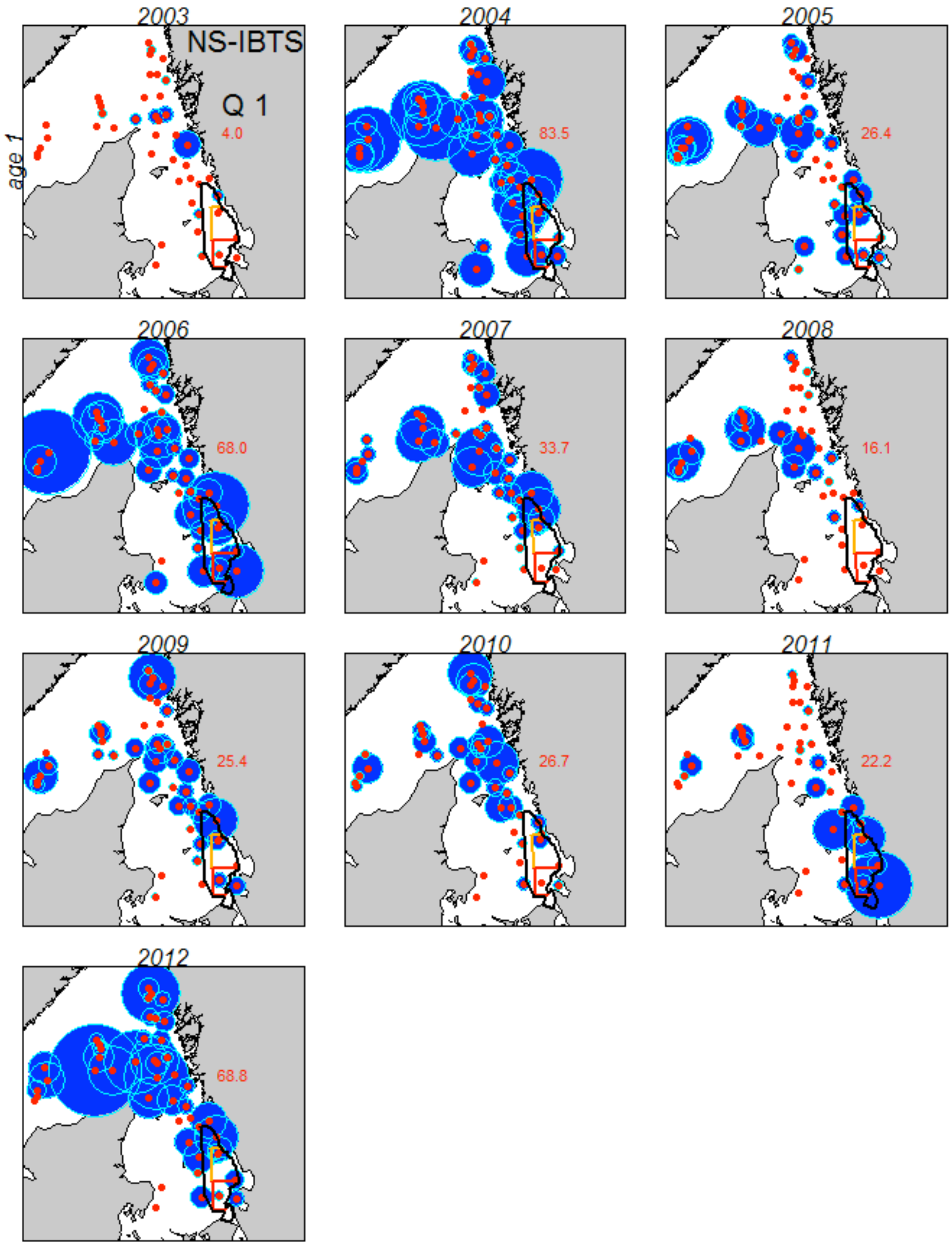

Fig. 1a. CPUE of cod from IBTS Q1 survey for age 1.

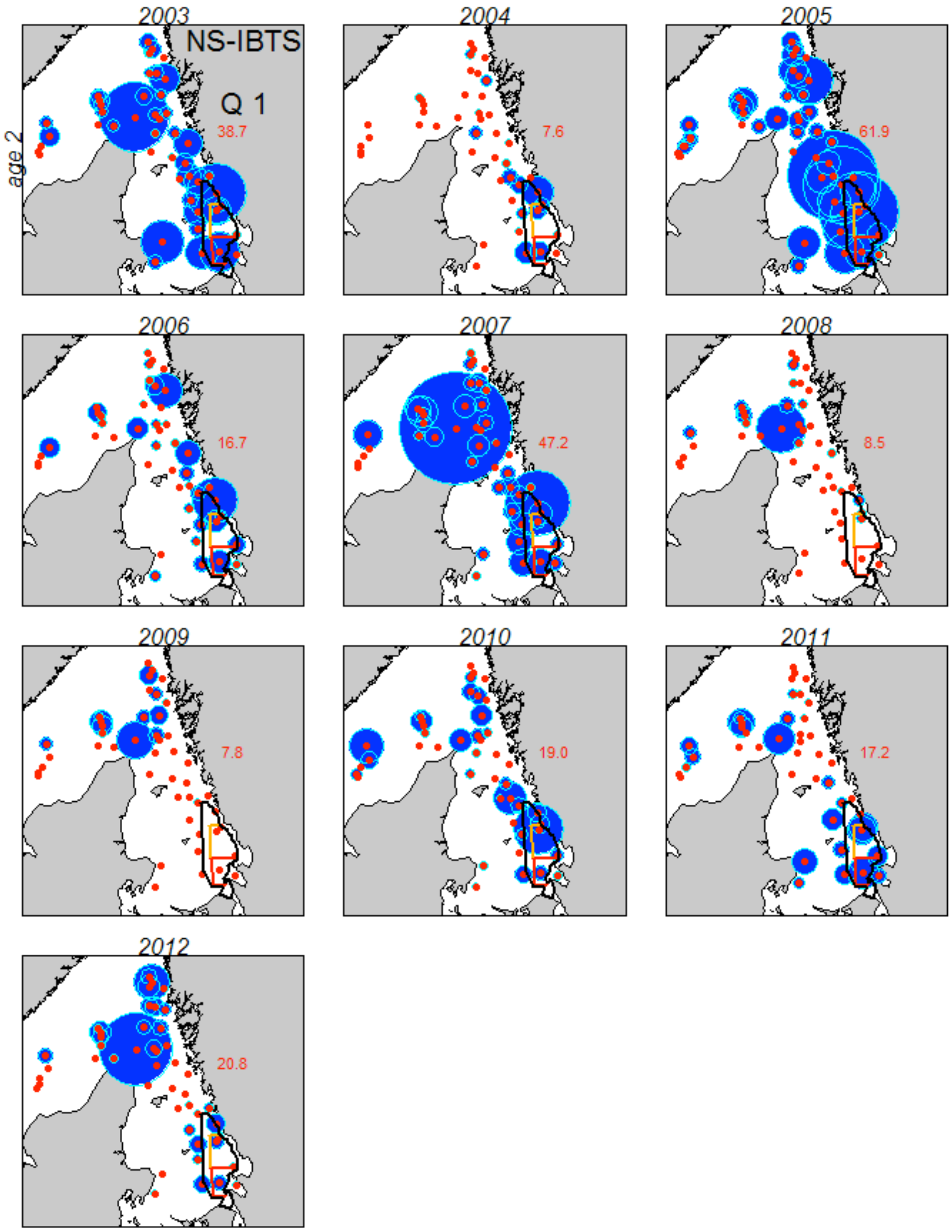

Fig.1b CPUE of cod from IBTS Q1 survey for age 2.

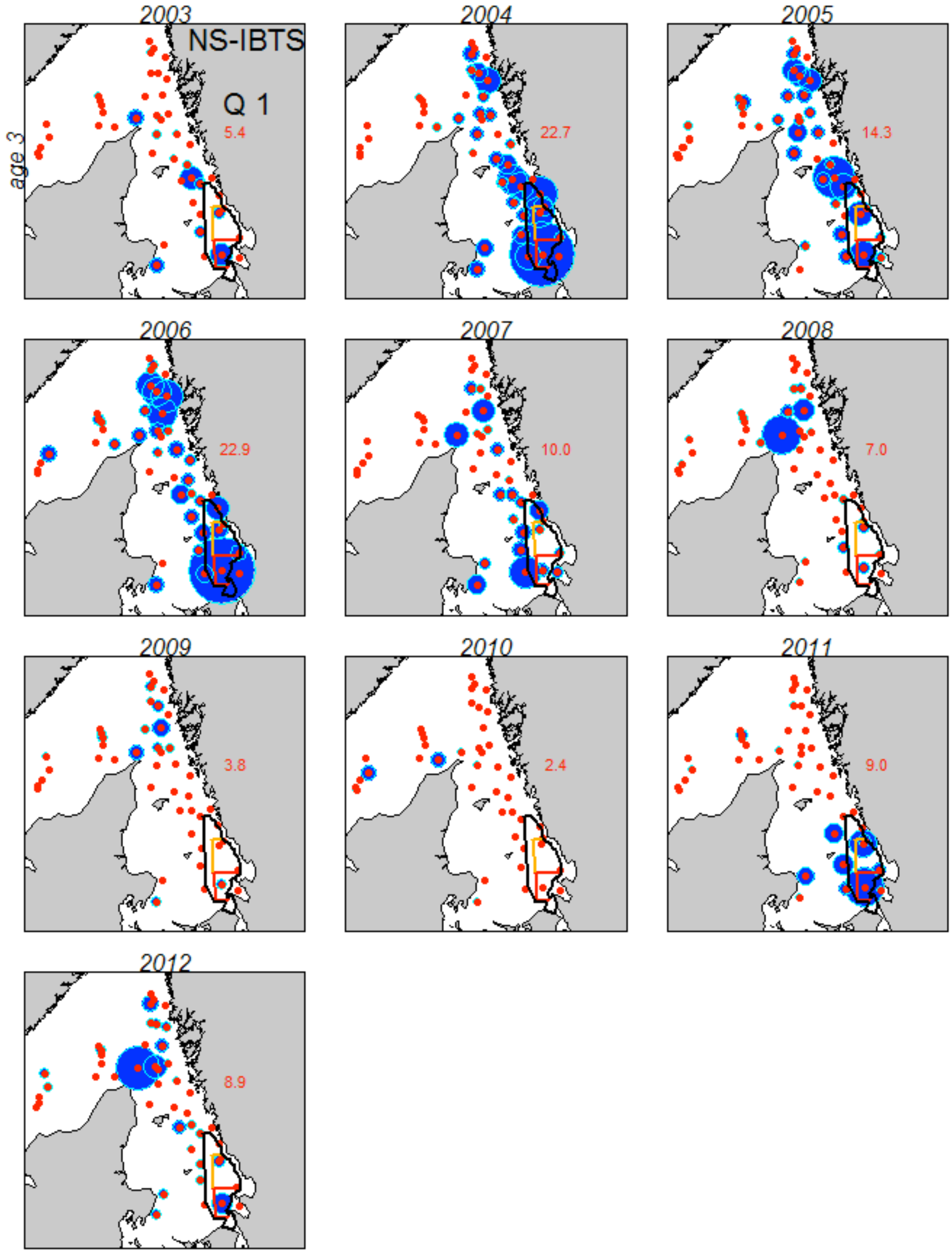

Fig. 1c. CPUE of cod from IBTS Q1 survey for age 3+.

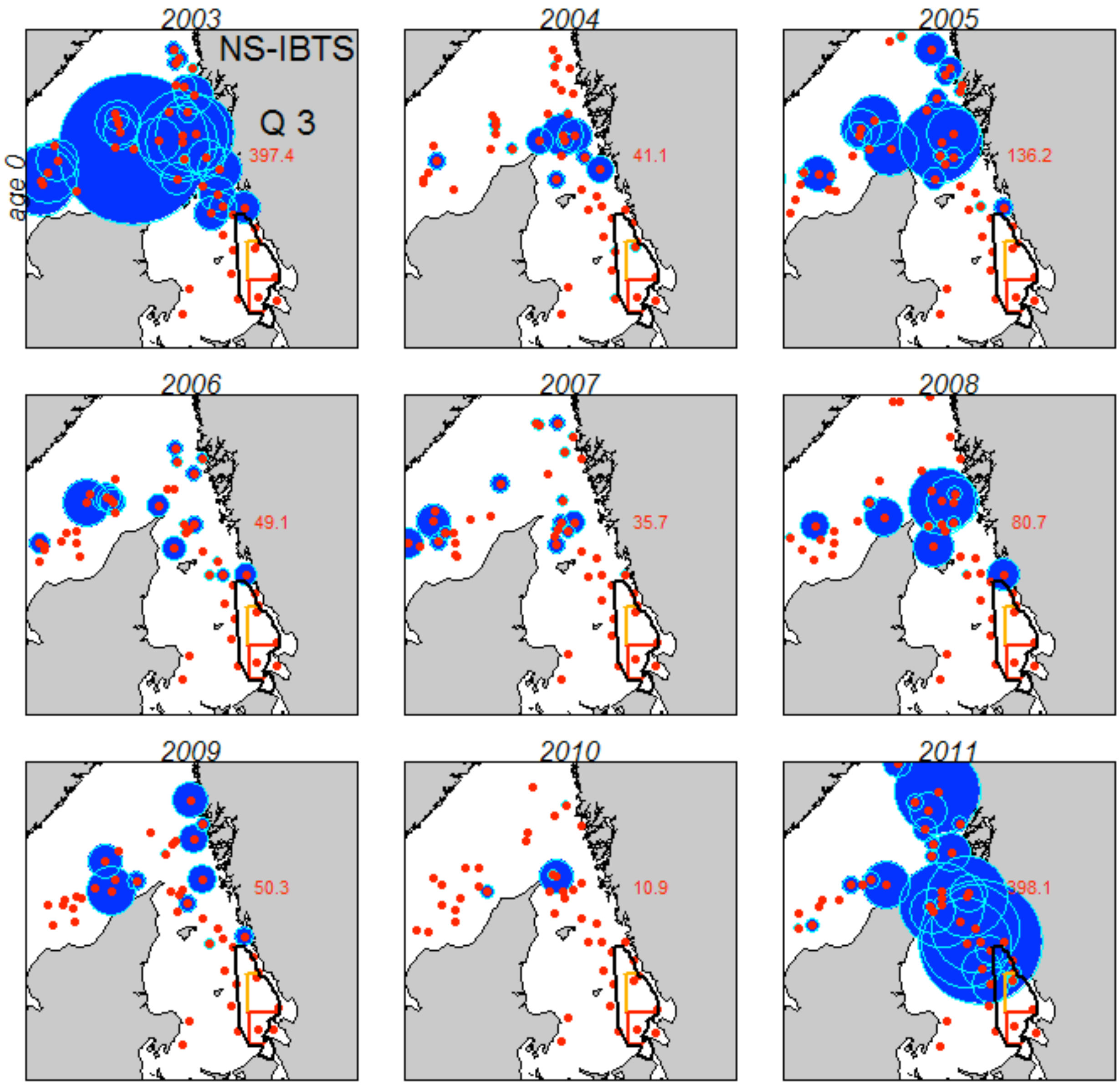

Fig. 2a. CPUE of cod from IBTS Q3 surveys for age 0.

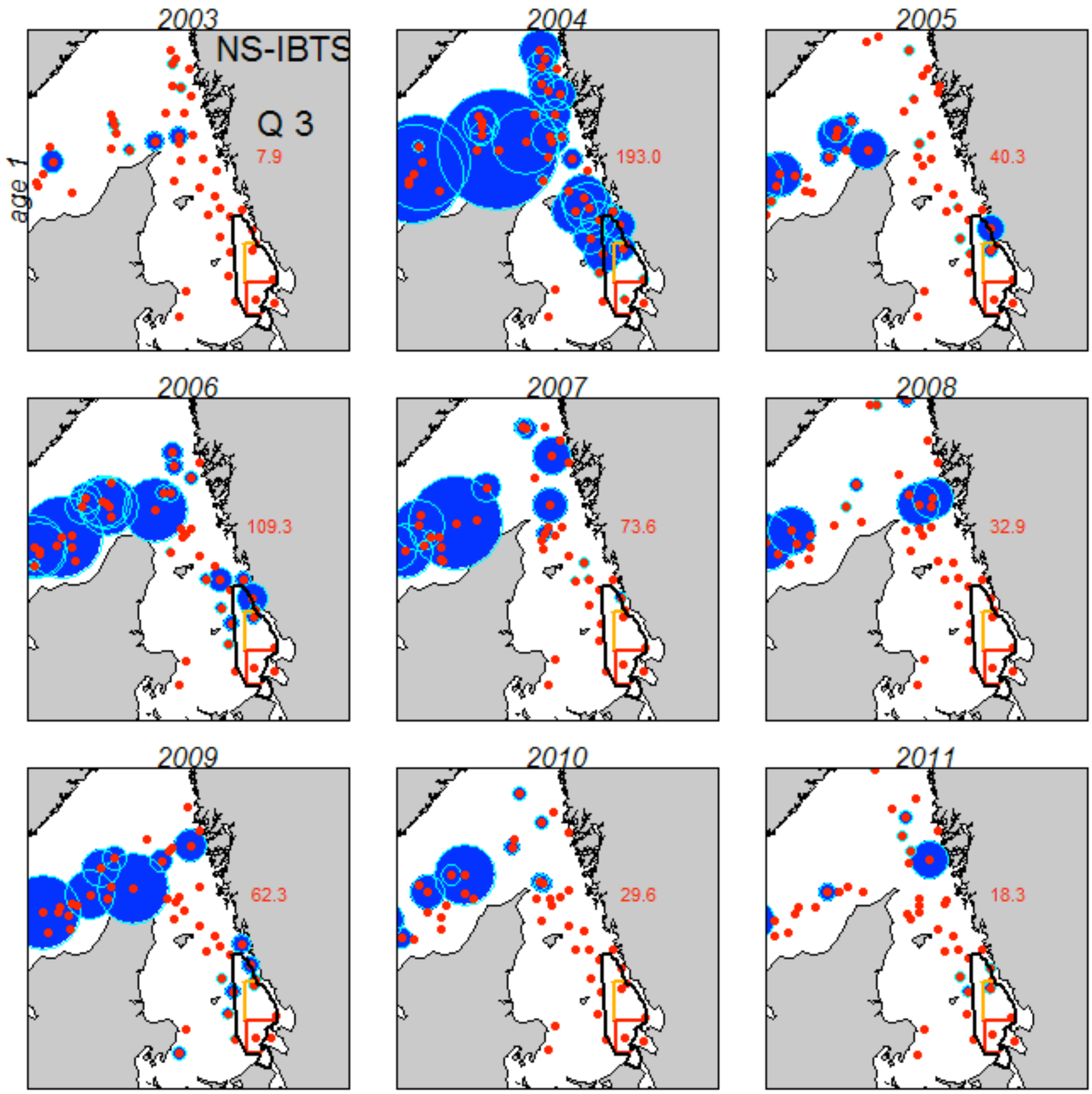

Fig. 2b.CPUE of cod from IBTS Q3 survey for age 1.

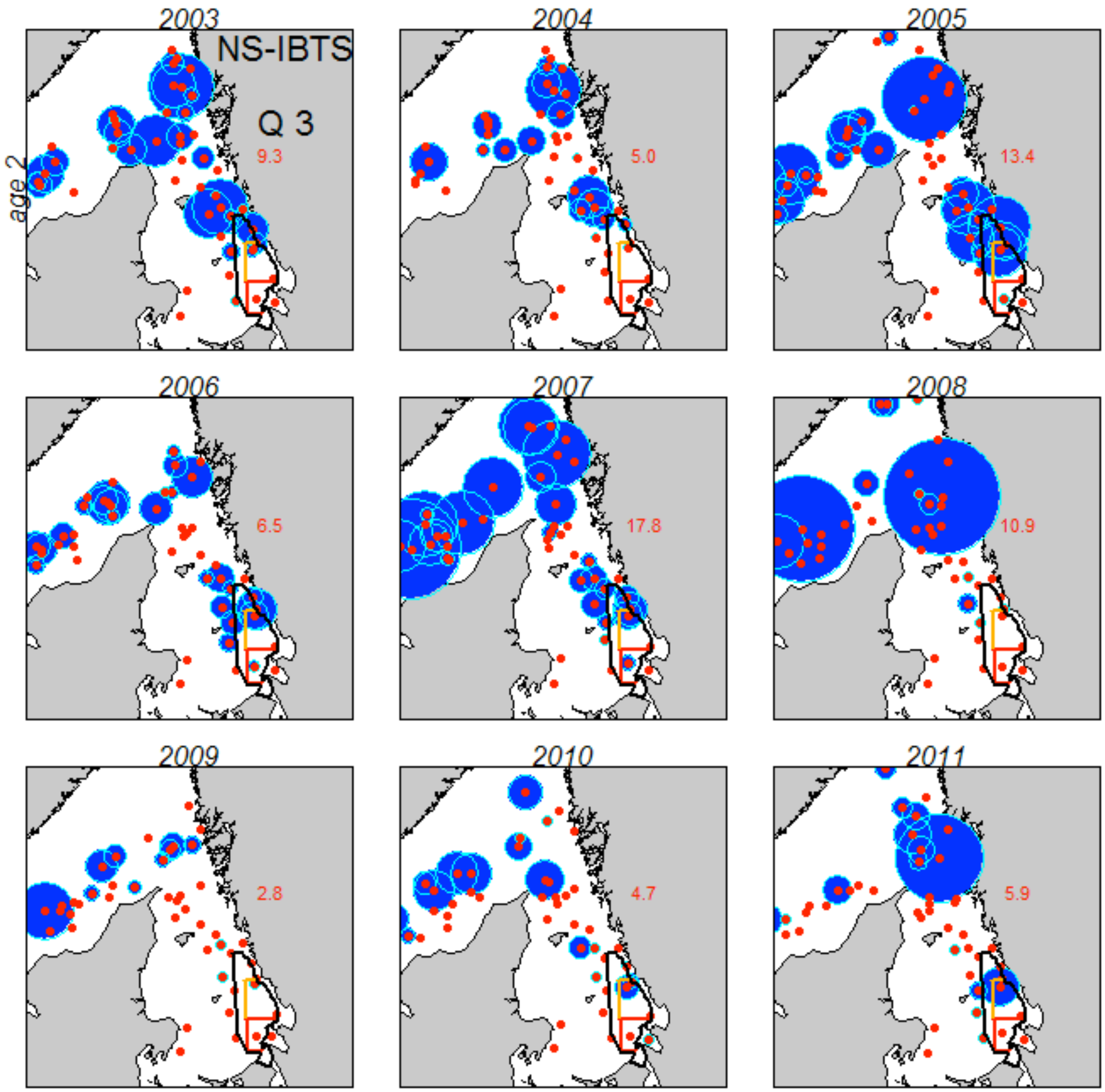

Fig. 2c. CPUE of cod from IBTS Q3 surveys for age 2.

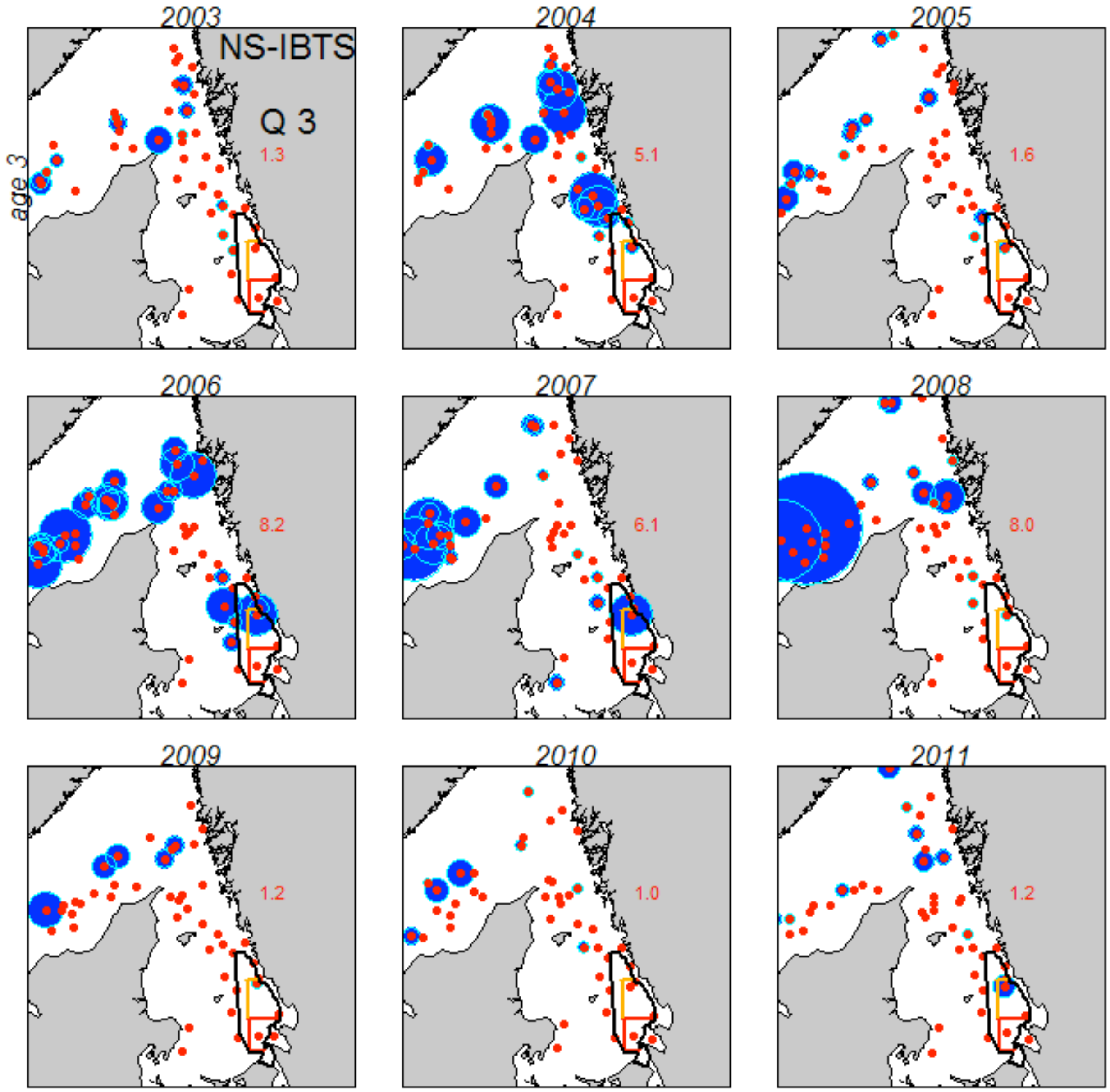

Fig. 2d. CPUE of cod from IBTS Q3 survey for age 3+.

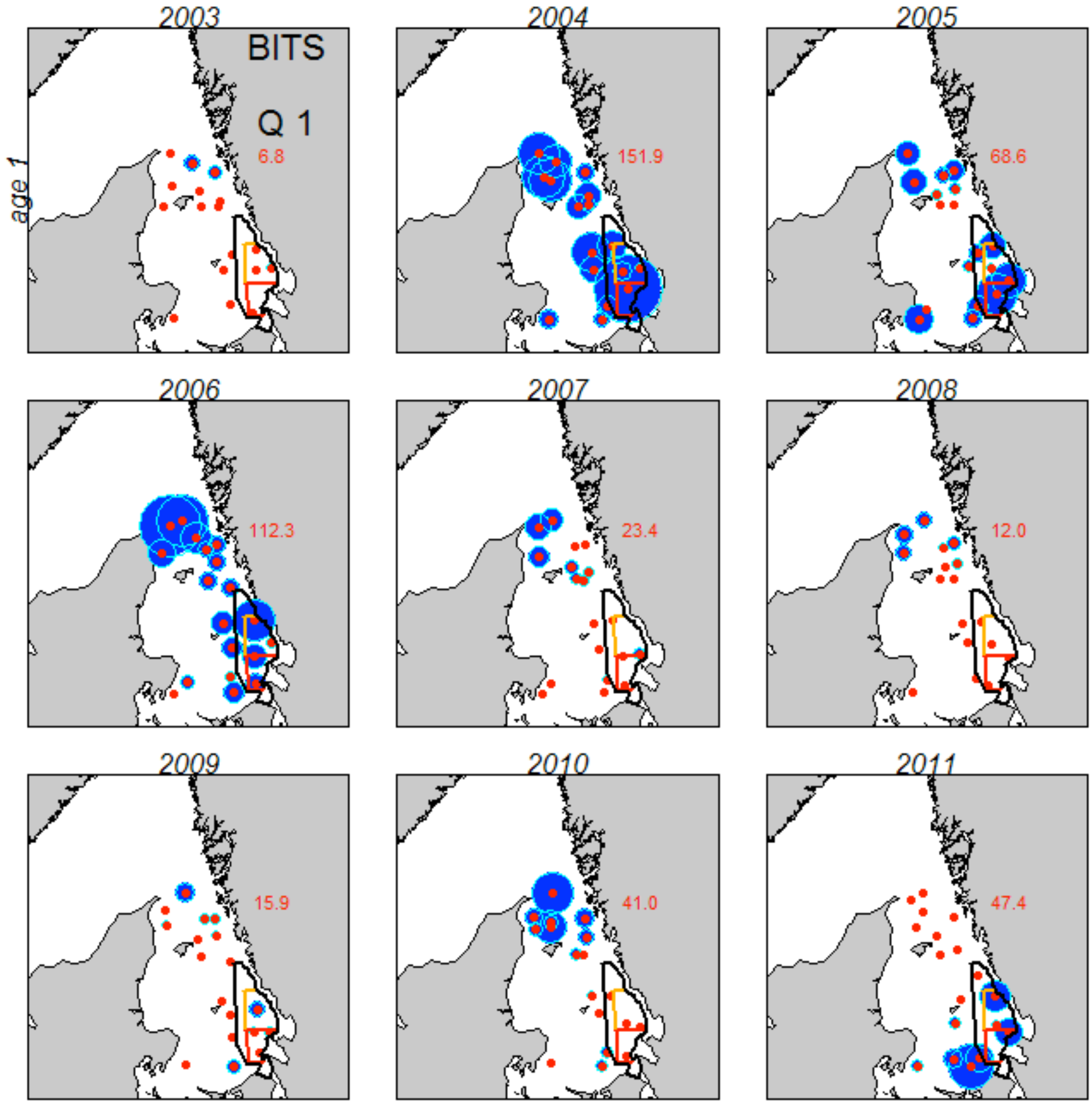

Fig. 3a. CPUE of cod from BITS Q1 survey for age 1.

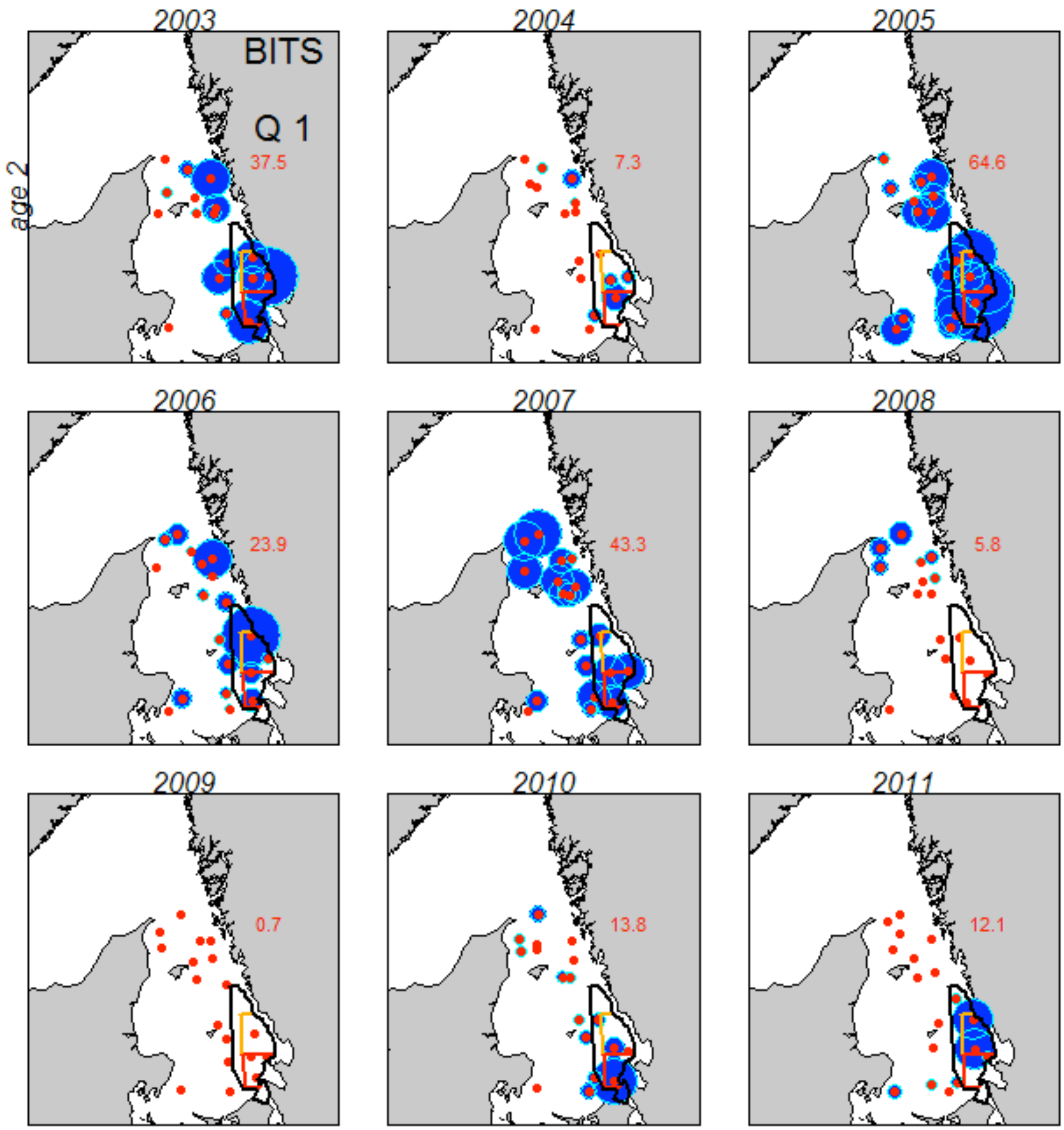

Fig. 3b. CPUE of cod from BITS Q1 survey for age 2.

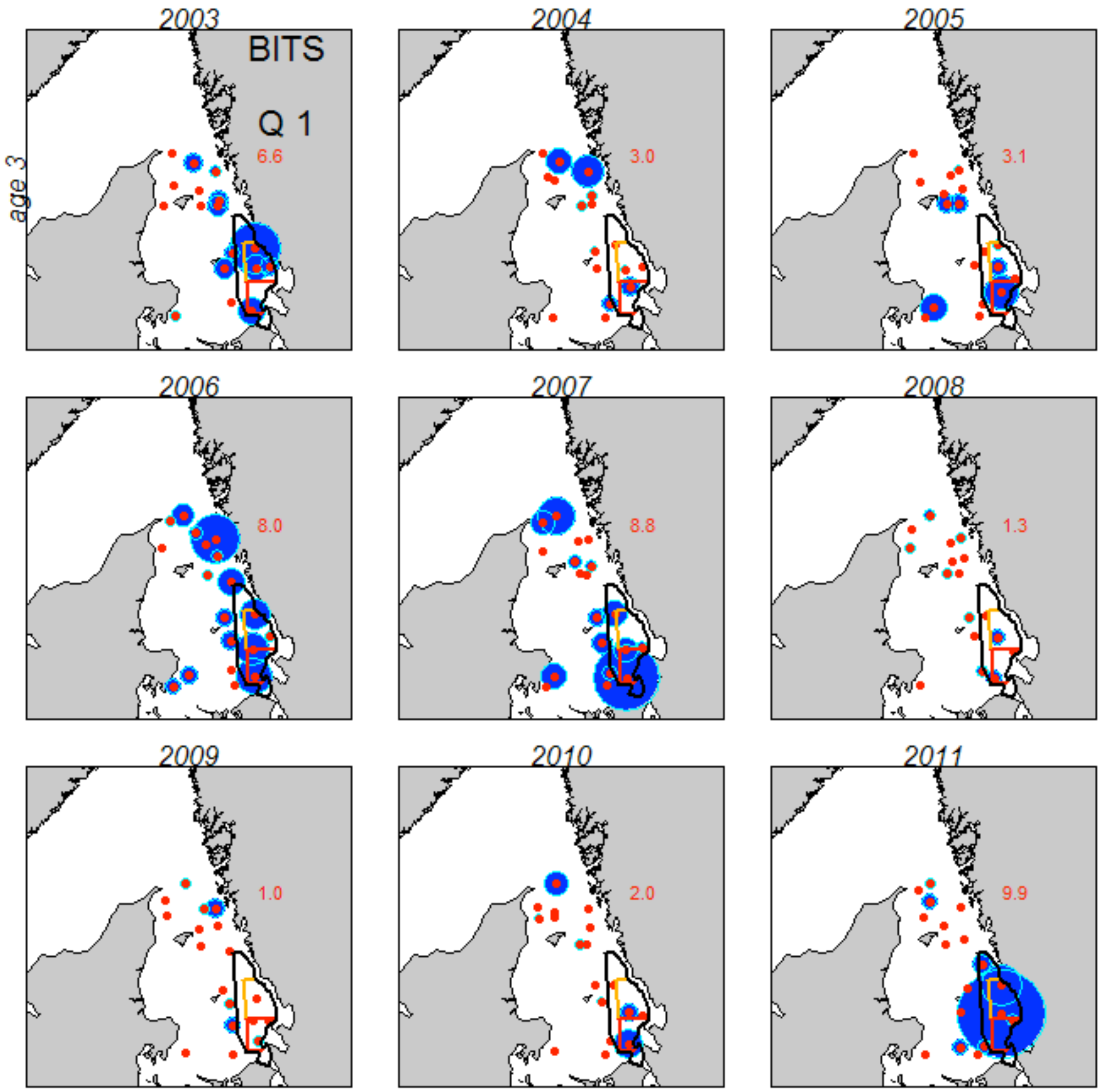

Fig. 3c. CPUE of cod from BITS Q1 survey for age 3+.

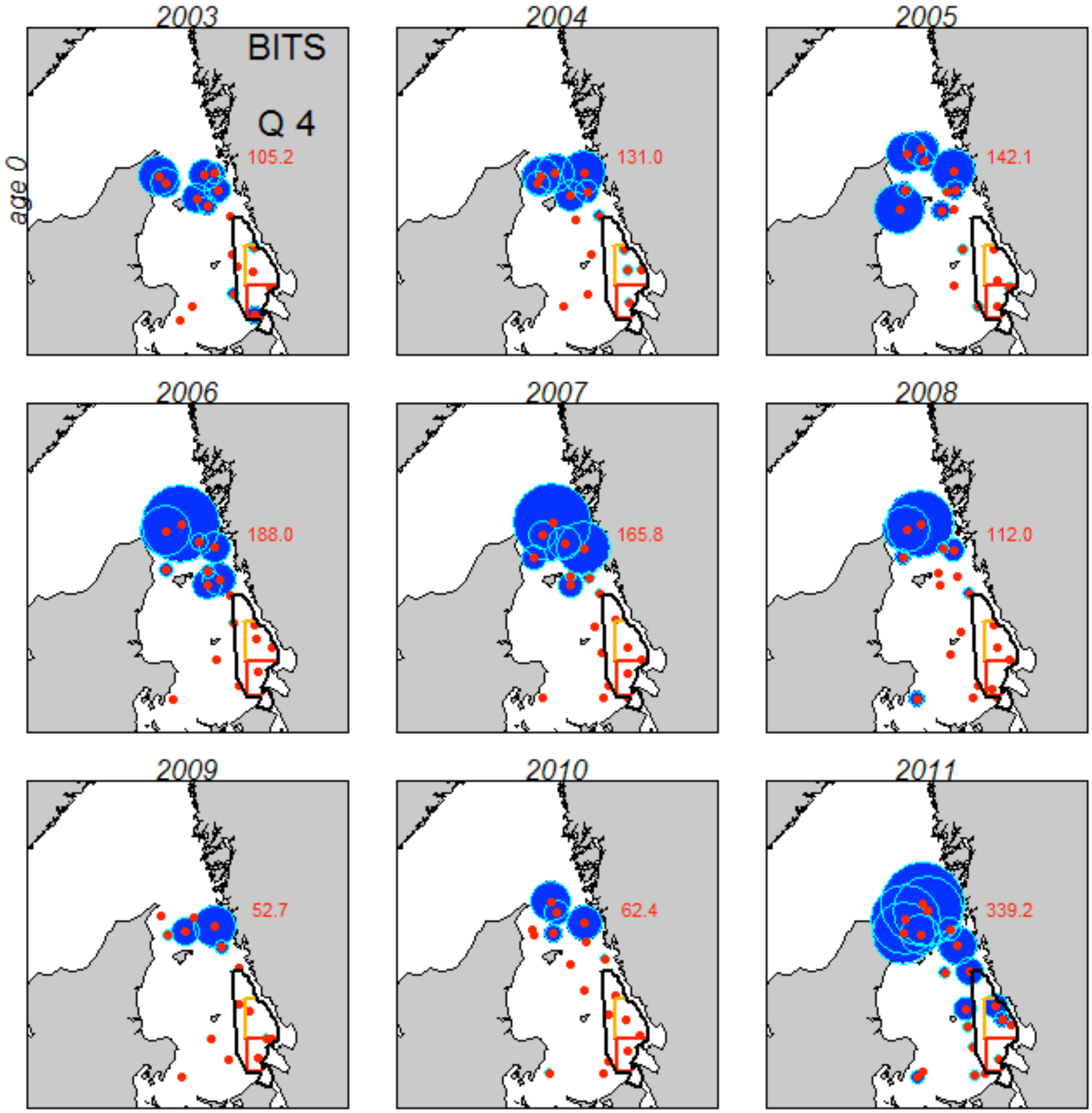

Fig. 4a. CPUE of cod from BITS Q4 survey for age 0.

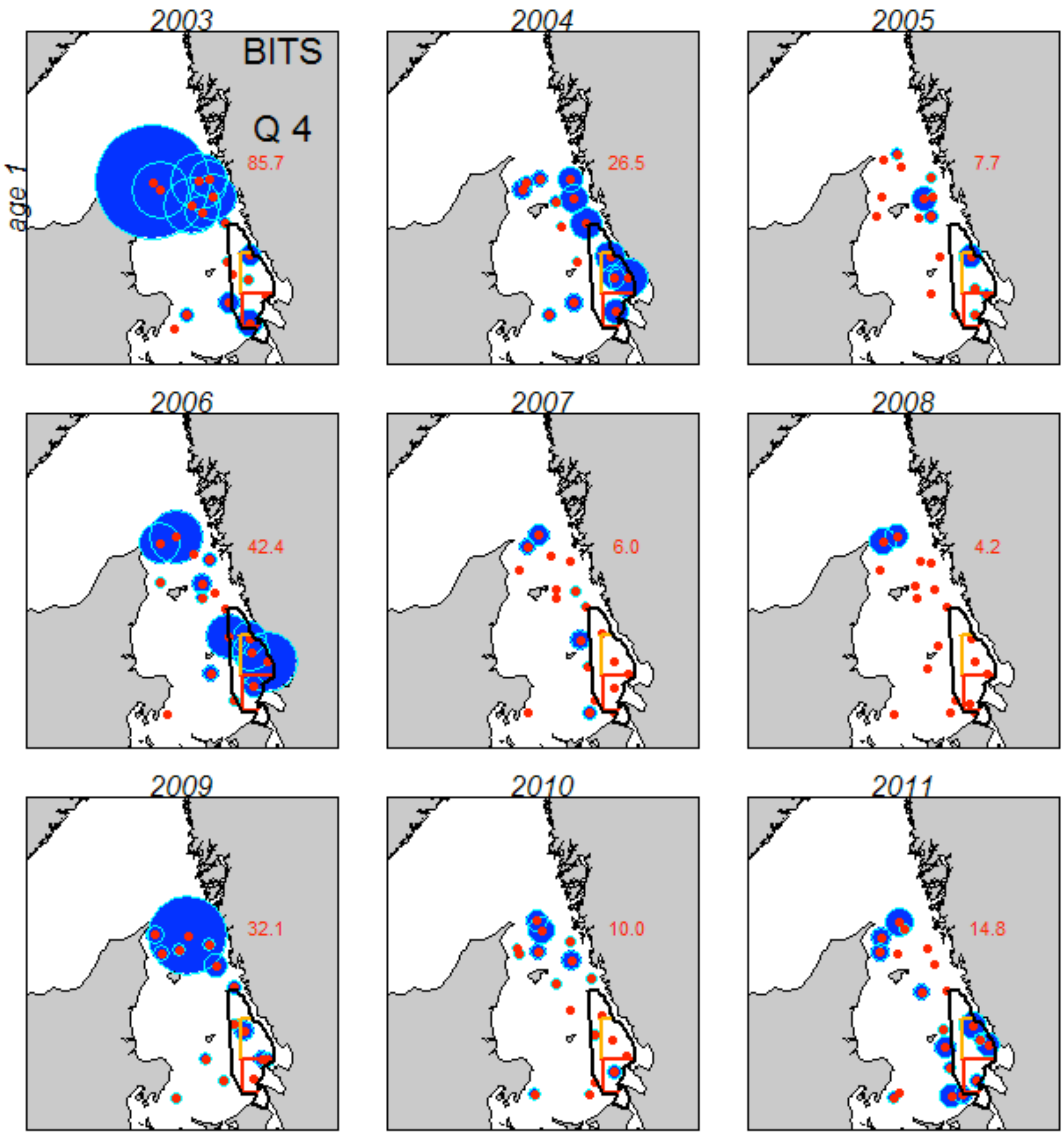

Fig. 4b. CPUE of cod from BITS Q4 survey for age 1.

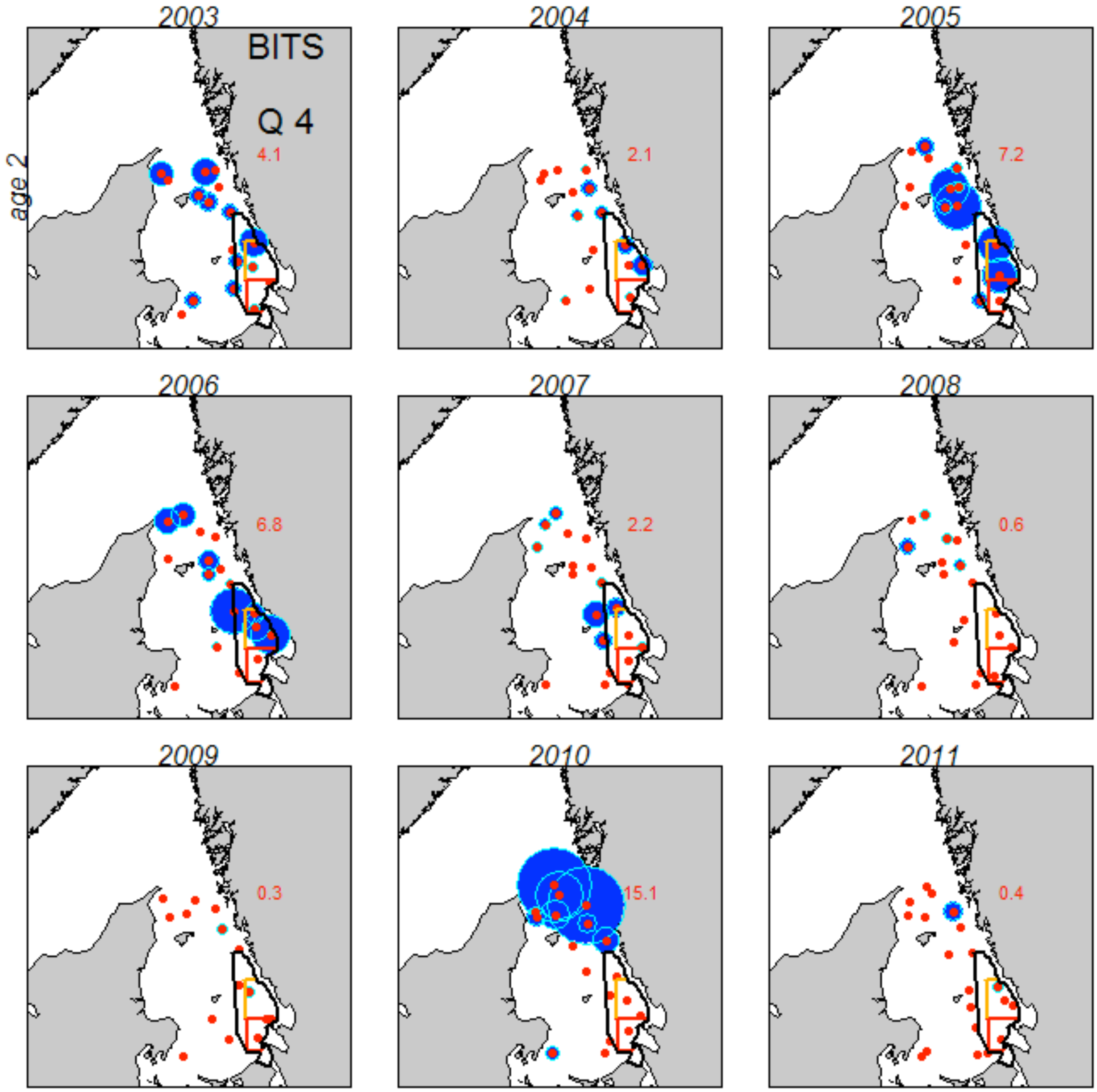

Fig. 4c. CPUE of cod from BITS Q4 survey for age 2.

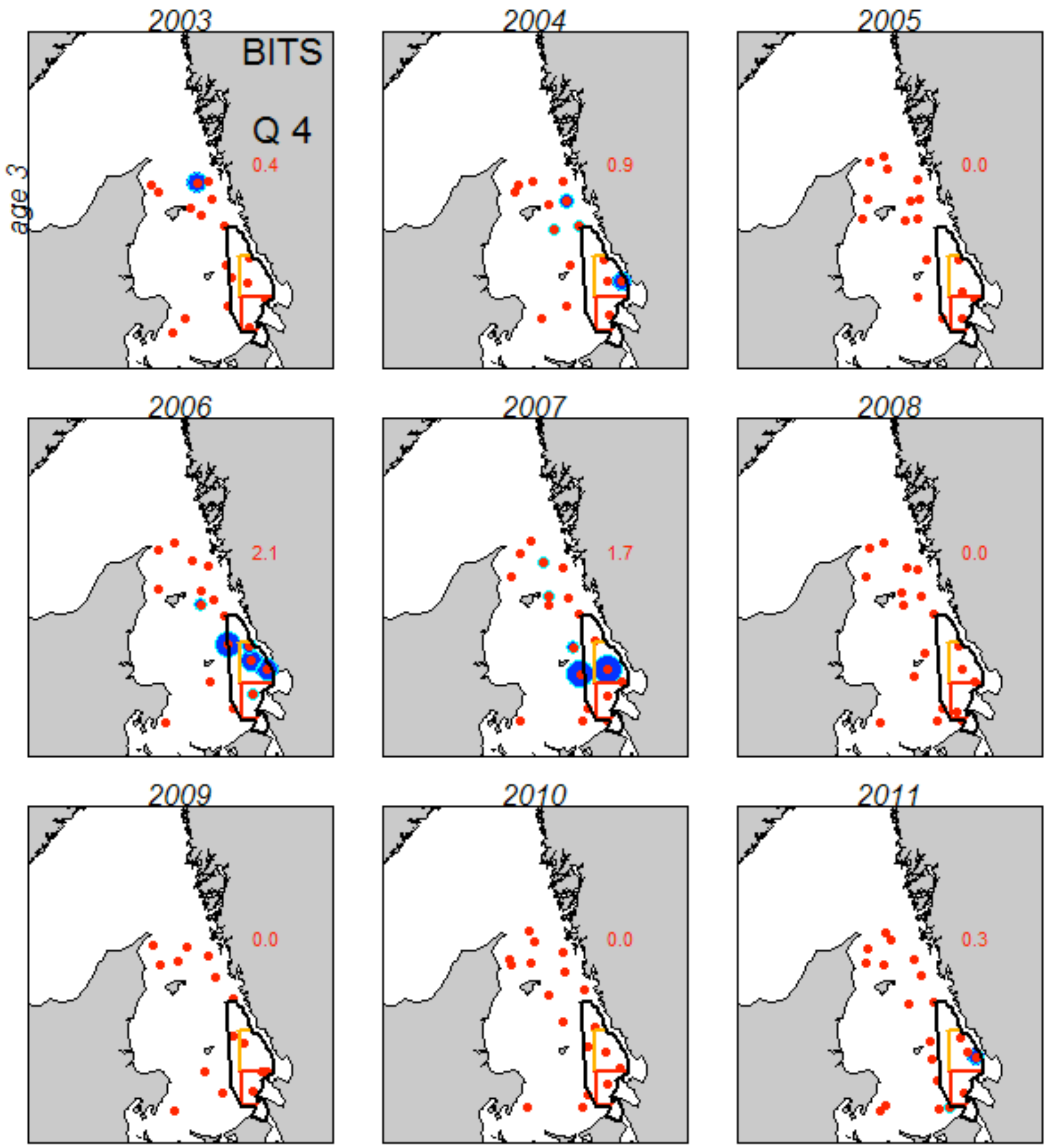

Fig. 4d. CPUE of cod from BITS Q4 survey for age 3+.

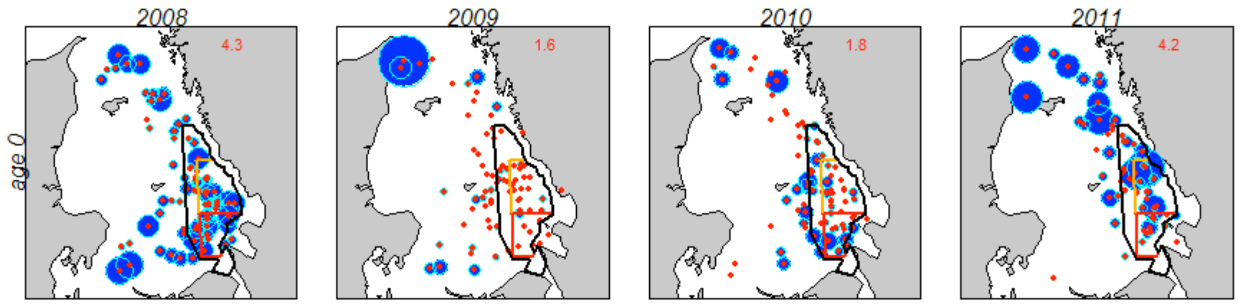

Fig. 5a. CPUE of cod from Cod survey Q4 for age 0.

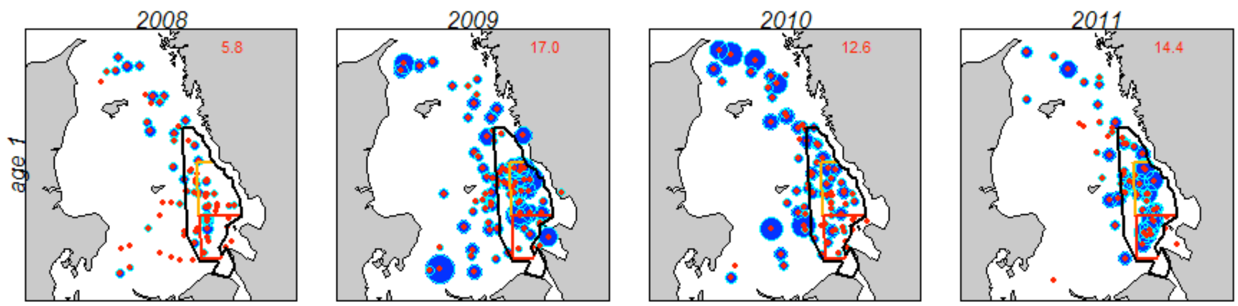

Fig. 5b. CPUE of cod from Cod survey Q4 for age 1.

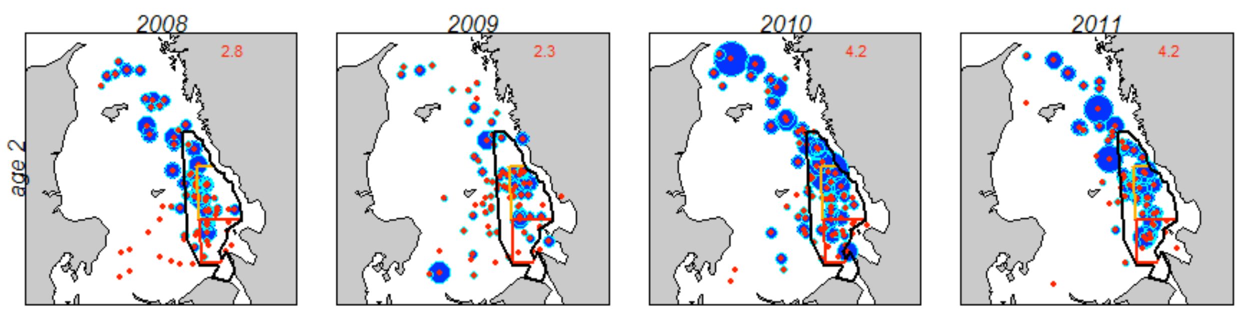

Fig. 5c. CPUE of cod from Cod survey Q4 for age 2.

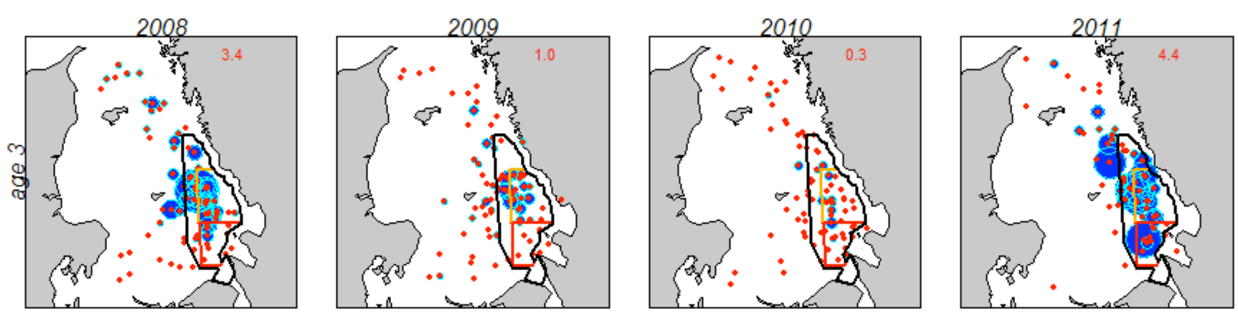

Fig. 5d. CPUE of cod from Cod survey Q4 for age 3+.

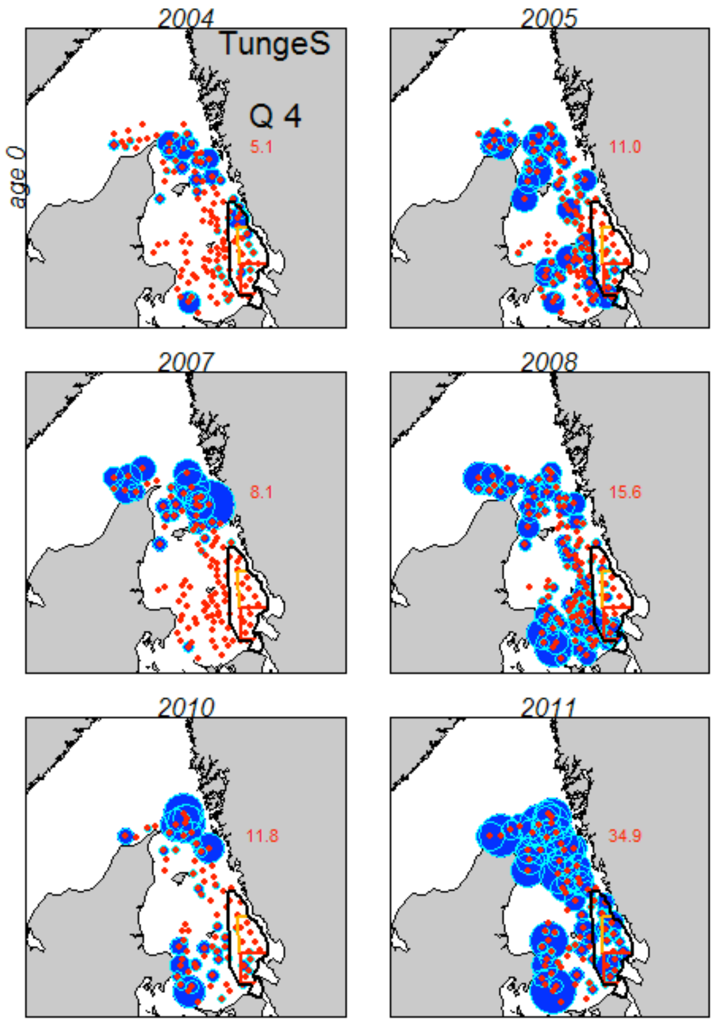

Fig. 6a. CPUE of cod from Sole survey Q4 for age 0.

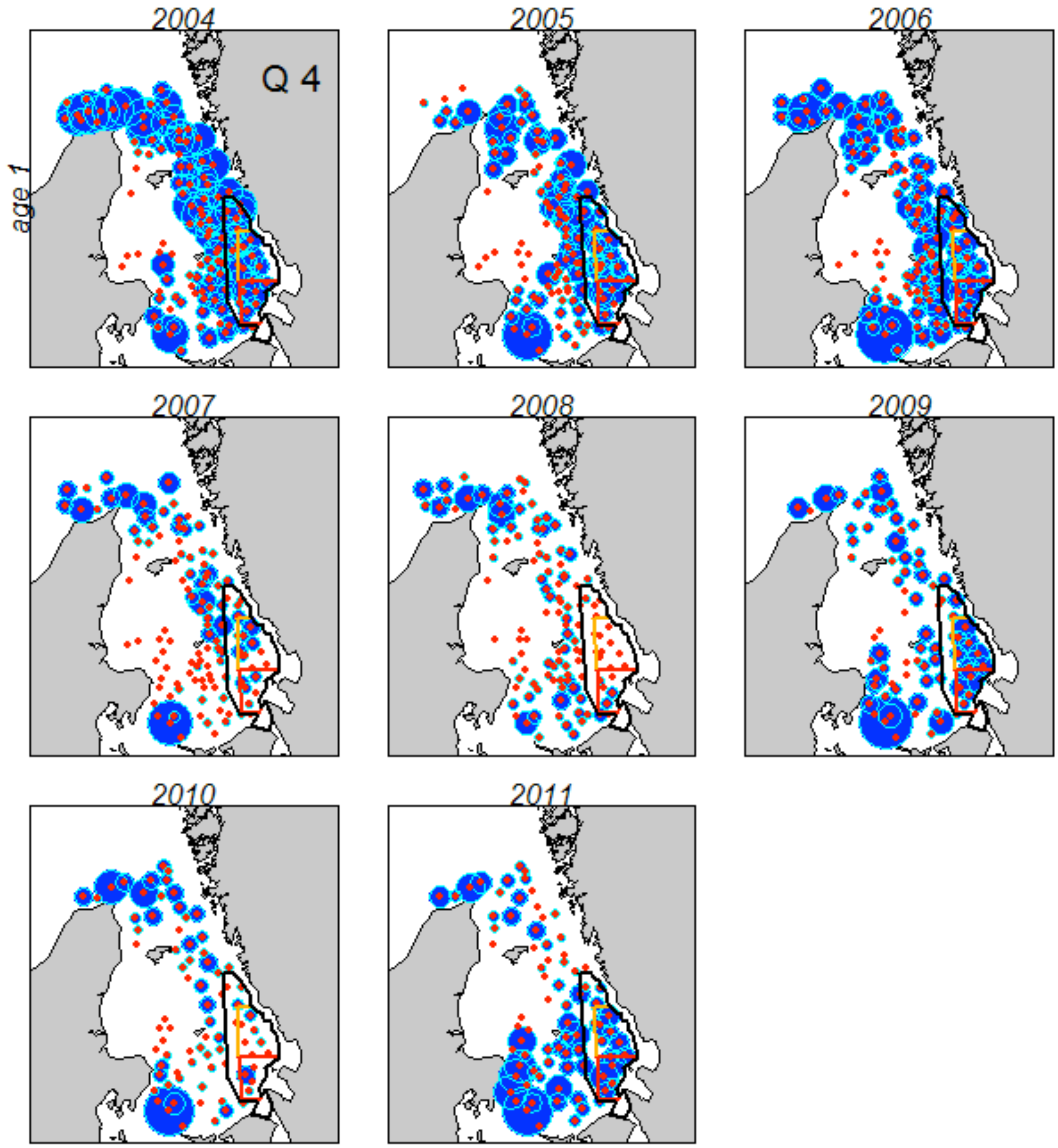

Fig. 6b. CPUE of cod from Sole survey Q4 for age 1.

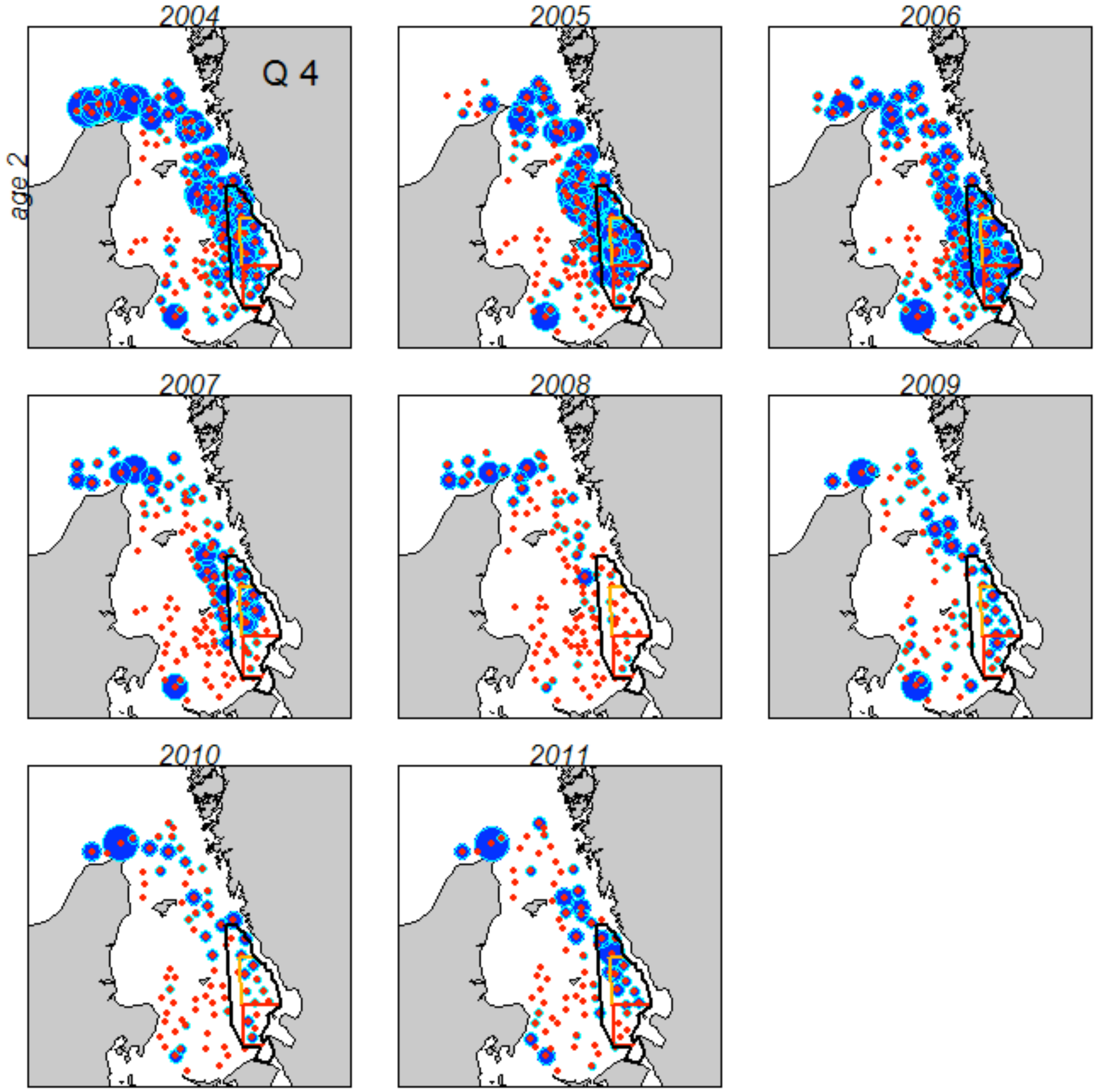

Fig. 6b. CPUE of cod from Sole survey Q4 for age 2.

Appendix 3. 18 June 2012

Changes in fishing mortality of Kattegat cod due to the introduction of closed areas and other management measures.

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Summary

Statistical spatial/temporal analysis of survey catches of cod shows that the distribution of young and older cod is different and that the distribution changes within a year. Older cod is mainly found in the deeper part of the eastern and southern Kattegat, while the distribution of younger cod is more disperse with the highest concentrations in the north western and south western Kattegat. All the closed areas in quarter 1 contain a large proportion of older cod. The permanently closed areas in the southern Kattegat and in Kilen do include a substantial proportion the large cod in quarter 1 (at spawning time), but the cod density is low in the area in other quarters. The partially closed area where fishery with selective gears is allowed includes a large proportion of cod at age 2 and older in all quarters. The statistical analysis shows an increase in cod abundance for all ages since the closures were implemented in 2009.

The introduction of closed areas in Kattegat has, as intended, given a very low effort in the closed areas in the **first quarter** of 2009 to 2011. In quarter 1, the effort was reallocated outside the closed areas, mainly to the more eastern grounds. In the **second quarter** of 2009, a very low Danish effort was allocated to the partially closed area where fishery with gears with low cod catch (SELTRA 300 or sorting grid)is allowed from the 1st April to the 31th December. The Swedish effort in the area was however maintained due to the use of sorting grid. This pattern changed significantly in 2010 when this area had the highest concentration of international effort in the time series (2007-2011). Limited information is available on the actual use of SELTRA 300 or grid in these areas. In 2011, almost no fishing activity was registered in the area. The change in effort distribution in **quarter 3**, with an increase of effort in the area where the use of selective gears is mandatory, is similar to the changes observed for quarter 2. **In quarter 4**, the effort in the partially closed area was lowest in the first year of closure (2009) followed by a small increase in the following years.

Some VMS fishing activity has been recorded in the permanently closed area in May-August of 2010, while VMS activity in this area in other periods has been insignificant.

The temporal closure of the northern Sound (“Kilen”) and a later permanent ban on the use of Danish seine in this area have almost entirely removed VMS activity and cod catches by segment TR1 and TR2 in the area.

The estimated fishing impact on cod in Kattegat from the TR2 segment has decreased in the period 2008-2011 as shown in the table below.

Relative fishing impact on Kattegat cod from the Danish and Swedish TR2 segment.

Year	Age 1	Age 2	Age 3+
2008	100%	100%	100%
2009	53%	46%	44%
2010	51%	40%	42%
2011	56%	37%	32%

The fishing impact on cod in 2011 was estimated to be 56%, 37% and 32% of the level in 2008 (i.e. before the closures were implemented), for age 1, age 2 and age 3 plus, respectively. The reduction in fishing impact was highest in the first year of closure, followed by a modest further reduction in succeeding years. Fishing impact has been reduced both inside and outside the closed areas indicating that the reduction in fishing impact is not due to the closed areas alone. The relative reduction in fishing impact was estimated lower for Denmark compared to Sweden. However, in absolute terms, the Swedish fishing impact is larger for age 1 and 2 cod, even though the Swedish nominal effort (kW days) is considerably smaller compared to the Danish effort.

The reduction in fishing impact relies heavily on the assumed size selection for the applied gears. For the trawl equipped with 120 mm square mesh panel there exist two rather different estimates of the selection. The results presented above are based on as study that shows a very low retention of small cod. When the selection curves from another study with higher retention is used, the absolute fishing impact becomes higher, but the relative impact is actually estimated to be smaller in 2011. This is due the fact that the gain of a later shift to a gear with an even lower retention of cod becomes bigger when the first gear had a higher retention.

Separating the effects of different measures, i.e. closed areas, use of more selective gears, and reduction in overall effort, is not possible due to some of them being connected. The use of selective gears has increased, at least partly, to get access to the partially closed areas. Further, Denmark has of obtained additional fishing effort (article 13 in the cod recovery plan) due to implementation of the closures. In an attempt to estimate the effect of area closures alone, a calculation was made where the spatial distribution of effort was assumed as observed in the period 2008-2011, but the total effort and gears used were assumed constant. This calculation shows only a modest effect of the closure. In this scenario, for age 1 the fishing impact in 2011 is estimated to be 107% of what is was in 2008. For age 2 (and 3 plus the impact is s reduced by 6 and 12 %, respectively. In the analyses estimating the effect of closure alone, the relative reduction in fishing impact was larger for the Danish fishery probably due to the fact that the permanently closed area was hardly fished by Sweden in 2008 and the Swedish effort continued in the partially closed area after the implementation of closures due to the use of sorting grid.

The present cod management plan includes a target F_{3-5} at 0.4. Fishing impact on age 3 plus (equivalent to ages 3-5) in 2011 is estimated to be 32% of the value in 2008. Therefore, the absolute F_{3-5} is at present likely below target F at 0.40 (for SSB > Bpa), however, SSB is low and most likely below Blim. In such cases the management plan dictates that F shall be reduced by 25% per year (equivalent to (1-0.25)^3=42% of the F level remaining after a period of 3 years) which is actually less than the estimated realized reduction in fishing impact. These analyses indicate that the aim of the management plan to reduce F_{3-5} has worked, but the objective to rebuild SSB to above Bpa has not yet been reached, even though an increase in SSB is detected.

Background

The very low cod TAC and even lower reported landings in the most recent years have given a very uncertain ICES stock assessment with respect to estimation of fishing mortality (F). Consequently, the assessment cannot be used as a basis for evaluating the most recent F in relation to any F reference point given in the management plan.

Several management measures have been applied to decrease F on cod, and to maintain the present level of fishing effort for the economically important fisheries targeting *Nephrops* and sole. The most important measures include the introduction of closed areas and use of gears with lower catchability of cod.

1) Closed areas for protection of cod were established in 2009 in Kattegat (see Figure 1):
   a) Area 1 (the “black” or seasonal closed area) is closed 1st January- 31th March (cod spawning season) except for fishery with selective gears with a very low catch of cod (i.e. SELTRA 300 or sorting grid). In area 1 the Northern Sound is closed 1st February -31th March, except for fishery with selective gears. This area is named “Kilen” (the Triangle) ;
   b) Area 2 (the “orange” or partial closed area) is closed for bottom trawling 1st January- 31th March and all year for all fisheries except fisheries with selective gears with a low catch of cod;
   c) Area 3 (the “red” or permanently closed area) is closed for all fisheries, including recreational fisheries.
2) Application of selective gears:
   a) Mandatory use in the Danish fishery, since 1st February 2008, of an exit-panel with square-meshes at a minimum 120 mm.
   b) Mandatory use of SELTRA 300 or sorting grid, since 1st January 2009 in the closed areas in the period when selective gears are required.
   c) Use of the Swedish sorting grid (as part of article 11 derogation)
   d) Mandatory use in the Danish fishery, since 15th July 2011 of one the selective gears listed below in the period 1st January -14t^{h} October (1st January- 30th September in 2012) :
      i) 4-panel codend with a 180 mm square mesh panel installed 4 - 7 meter from the codline.
      ii) 4-panel codend with a diamond mesh panel with a minimum mesh size of 270 mm installed 4- 7 meter from the codline.
      iii) 2-panel codend with a 180 mm square mesh panel installed 4 -7 meters from the codline.
      iv) Trawl gear with a Swedish Nephrops-grid installed.
      v) Codend with a 300 mm square mesh panel installed 3 – 6 meters from the codline.
      vi) Topless trawl in with a codend with a minimum 175 mm square mesh panel installed 3-6 meters from the codline

Other initiatives to reduce discards have also been introduced; however it is difficult to quantify the effects of individual management measures. In this paper we disregard landings and discard information, but investigate changes in fishing pressure for the main trawl segment TR2,based on VMS data and the selectivity of the gear used. Fishing impact (proxy for fishing mortality) on cod is estimated by overlaying the spatial and temporal distribution of fishing pressure with the predicted distribution of cod.

Method

The fishing impact on the cod population in the period 2008-2011 is analysed from the temporal and spatial distribution of the cod stock and the fishery, as outlined below:

1. Map the stock distribution of cod.
   a. Use survey CPUE to model cod density at age by quarter as a function of catch position (longitude, latitude), depth, year and survey

    b. Predict stock distribution of Kattegat cod from the fitted model and a bathymetric map of Kattegat.
2. Map the distribution of fishing pressure.
    a. Use VMS recordings assigned to fishing to map the distribution of effort for the Danish and Swedish fishing fleet.
    b. Estimate relative catchability by gear type used from size election curves of the gears.
    c. Assume that fishing pressure is proportional to vessel engine size (kW)
    d. Estimate local fishing pressure from the sum of product of effort, catchability and engine size (kW) for the individual gear segments.
    e. Raise the fishing pressure by the proportion of the total national kW-days included in VMS data.
3. Estimate the fishing impact (proxy for fishing mortality) on cod
    a. Assume that local fishing impact is proportional to the product of local fishing pressure and local cod density.
    b. Overlay the spatial distribution (0.01^{o} longitude x 0.01^{o} latitude) of fishing pressure and temporal distribution (quarter of the year) of the cod stock to obtain the local fishing impact.
    c. Integrate over all local impact (all VMS positions) to obtain the total impact from the fleet segment.

The following text elaborates the approach.

1. Distribution of cod in Kattegat

Available data

Survey coverage in Kattegat is relatively good, however most often covered by multi-purposed surveys. CPUE data for analysis of cod distribution were taken from the Kattegat area and a limited area adjacent to Kattegat (Figure 1). By including the areas bordering Kattegat, the density of cod in the border areas of Kattegat can be estimated with less statistical uncertainty and minimise the edge effect in the abundance estimate.

For the first quarter of the year, data from two surveys are available. The ICES coordinated International Bottom Trawl Survey, (IBTS) provided around 20 stations by year in Kattegat and around 2-3 stations per year in the Skagerrak bordering Kattegat were used. In some years, the IBTS is extended south of the borderline between Kattegat and the Sound. Data from these 0-2 stations per year were included as well. IBTS covers mainly depths above 20 m. The Danish Havfisken survey (part of the Baltic International Trawl Survey (BITS)) covers also the more shallow waters. Data from this survey include around 22 stations per year for Kattegat, 1-3 for the Sound and 1-3 stations for the neighbouring area in the Belt Sea were included in the analyses. For both surveys, data for the period 1996-2012 were used for modelling stock distribution (Figure 2).

No up to date time series is available for the second quarter.

For the third quarter the IBTS Quarter 3 data, 1991-2011 are available including around 20 stations per year in Kattegat. Data for the period 2001-2011 were used as the analyses of centre of gravity indicated a shift in the cod distribution around 2001 (Vinther et al 2011) (Figure 7).

For the 4th quarter, data from three surveys were available. The Danish/Swedish cod survey initiated in December 2008 covers the full distribution area of cod in Kattegat, with 80 trawl haul per year for the period 2008 – 2011. The Danish "sole survey" targets sole, but smaller cod are also caught in relative high numbers. At least 70 hauls per year are made covering both Kattegat and adjacent areas in Skagerrak. These data and data from the Danish Havfisken survey (part of the BITS Quarter 4 survey) were used to model the cod distribution in quarter 4 (Figure 10). For a more balanced model design, only the data since 2008 were used for all three surveys.

IBTS and BITS data were extracted from the ICES DATRAS database as catch at age per haul. Data from the Danish/Swedish cod survey and the Sole survey were extracted from the "final-international" (as described in Jørgensen *et. al*, 2011) catch at age data set.

Statistical analysis

The relative cod density was modelled using a Generalized Additive Model (GAM) of the CPUE at age by haul as a function of position, depth, year and survey:

$$CPUE \sim \alpha + f1(latitude \times longitude) + f2(depth) + f3(year) + survey + \varepsilon$$

where f1, f2 and f3 are smoothing functions and survey is a factor. Smooth terms are using penalized regression splines with the number of smoothing parameters selected as part of the model fitting. See Wood (2006) and Wood (2008) for more information. The R-package "mgcv" was used for analysis. For quarter 4 with only four years data, the year effect was modelled as a factor. For all analyses, non-significant model terms were removed from the final model.

The negative binomial distribution and log-link function was used to model CPUE.

Results

Stock distribution

The results for the **quarter 1** regressions are shown in Table 2 and Figure 3 to Figure 6. Catch position, depth and year are highly significant model terms for ages 1, 2 and 3 plus. The Survey effect was not significant for age 2. Compared to the Havfisken survey, IBTS has lower catch rates of age 1 and 2, and higher catch rates for age 3 plus. The year effects (Figure 3) for age 1, age 2 and 3plus show a downward trend for whole time series 1996-2011. However, the "year effect" (stock abundance) of all ages has increased significantly since 2009. The predicted stock distribution (Figure 5) is rather dispersed for the 1 group cod with the highest concentration in the North-western Kattegat. Age 2 is mainly concentrated in the deeper eastern Kattegat and predominately in Kilen. The age 3 plus, which includes most of the spawning stock, is concentrated in the permanently closed areas and in Kilen. Due to the high density of cod the northern Sound (Kilen), it is difficult to see the actual distribution within the Kattegat area. Distribution maps without the high concentration in Kilen give a better overview of the stock distribution in Kattegat (Figure 6). As an example, Figure 4 shows the uncertainties for the stock distribution. The Coefficient of Variation is, as expected, highest close to the coast and in areas with few observations, e.g. the shallow water.

The depth effect was not significant in the analyses **for quarter 3** for age 1-2+ (Table 3). The pattern in year effect (Figure 8) for Age 2 and 2 plus in quarter 3 is very similar to the pattern estimated for quarter 1 (Figure 3) with an increase in year effect (abundance) for age 2, age 2+ and age 3+. Age 2 plus cod is mainly concentrated in the north-eastern Kattegat, with part of the high concentration area within the “orange” area, where selective gears are mandatory (Figure 9). Depth effect is significant for age 3+, which probably adds to a slightly different distribution than the age 2+. However, as for the age 2+, high concentrations of age 3+ are found in the “orange” area.

The **quarter 4** analysis (Table 2 to Table 5) shows that abundance has increased since 2009 for all ages. The predicted concentrations (Figure 12) of age 0 and 1 are highest in the north-western Kattegat and in the south western Kattegat close to Skagerrak and the Belt Sea respectively. Age 2 and older are distributed in the deeper parts of Kattegat with high concentrations in or just north of the “orange” area, which is quite similar to the quarter 3 distribution.

The density of cod age 0-1 is general lower within the closed areas. For cod age 2, most of the population is within the closed areas in quarter 1. For quarter 3 and 4 age 2 cod is mainly found northern Kattegat and in the partially closed area where fishery with selective gears is allowed. Age 3 and older cod in quarter1 are mainly found in Kilen and in the permanently closed area in the southern Kattegat. In quarter 3 and 4, age 3 plus cod is mainly found in the partially closed area where fishery with selective gears is allowed.

All the closed areas in quarter 1 contain a large proportion of older cod. The permanently closed areas in the southern Kattegat and in Kilen do include a larger proportion of large cod in quarter 1 (at spawning time), but the cod density is low in this area for other quarters. The partially closed area where fishery with selective gears is allowed includes a large proportion of the age 2 and older cod in all quarters.

2. Distribution of fishing effort from VMS

VMS records from fishing vessels with speed 2-4 knots (Denmark) or 1.5-3.5 knots (Sweden) were classified as “fishing” activity and afterwards merged with Logbook data by trip to allocate each trip to the fleet segments TR1, TR2 or “other” based on gear and mesh size information. In this process, misclassification of both vessel activity and segment might occur.

Figure 13 and Figure 14 present the basic VMS data classified as “fishing” for the TR1 and TR2 segment for the period 2007-2011. The main part of the fisheries takes place on fishing grounds in the deeper parts of central and eastern Kattegat.

Effort of the TR1 segment has decreased significantly since 2007 with the highest density in Kilen before the closure in 2009 (Figure 15). From 2010, TR1 VMS effort was less than 1% of the TR2 effort. VMS recordings for the TR2 segment show a rather stable level for the years considered. The effect of the box closures in 2009 is clearly seen for the first year of closure where mainly the Danish fishery was absent from the area. The second year of closure (2010) had a high activity in the “orange” area where fisheries with selective gears are permitted in quarter 2-4, and some activity in the “red” box where fishery is illegal. In 2011, the activity in the “orange” area decreased significantly compared to 2010 level, and there is almost no activity in the “red” area.

The different spatial distribution of the Danish and Swedish fishery is clearly seen from Figure 16. The Swedish fishery is mainly in the deeper parts of Kattegat closer to the Swedish coastline, while the Danish fishery covers the same area and areas closer to Denmark. Sweden had almost no fishery in the “red” area before the closure while Denmark had some activity in the area. The response to the closure of the “orange” area is also different. Sweden maintained the activity in the area after the closure due to the use of sorting grid, while the Danish activity in the area was limited in 2009. In 2010, the

Danish fishery was concentrated in the "orange" area, where the use of SELTRA 300 is allowed, , whereas in 2011 both the Danish and Swedish effort in this area decreased.

The effect of the box closures in 2009 is clearly seen for the effort distribution in the first quarter (Figure 17) with almost no activity in the closed areas. Effort seems redistributed more westerly (rather than northerly) after the closure. In the second quarter, (illegal) effort in the "red" area was at a significant level in 2010. Effort in the "orange" area increased significantly in 2010 and this area seems to be the most important fishing area in the second quarter in that year. A similar increase in effort in 2010 in the "orange" area is also seen for quarter 3 (Figure 18). In 2011 the activity in the area was close to nothing.

Effort distribution in 2010 by month (Figure 19) shows very limited activity in the closed areas in January-March. From April onwards, there is no restriction for the "black" area which is also reflected in the effort distribution. Fishery in the "orange" area is allowed in the period 1st April – 31th December with selective gears (SELTRA 300 and sorting grid), and activity in this area was especially high in May-September. There is no log book information available to DTU Aqua about the actual use of SELTRA 300 to confirm the application of that gear in the area. The "red" area, closed for all fisheries, contains some VMS "fishing activity" in April-August which seems unlikely to be misclassification of vessel activity. Almost no VMS "fishing activity" is recorded from September onwards. This may be linked to the press release of the Greenpeace campaign the 22. August 2010, that showed clear evidence of illegal fishery in the "red" area by Danish vessels.

In 2011, the VMS recordings (and the fishery) were at a low level in February-June, while the activity was at the same level as in 2010 for the other months (Figure 20). Compared to 2010 the activity in the "orange" area is now much lower, and there is almost no activity in the "red" area.

Based on the calculated centre of gravity of the fishing effort by year and quarter (Figure 21), large scale changes in effort distribution since 2007 are not apparent. The largest variation is seen for quarter 2 where the introduction of the "orange" area in 2009 is giving a more northerly distribution of the Danish fishery, followed by the large activity in the area in 2010, which gave a very southerly centre of gravity for that year. In 2011 the fishery shifted further north in quarter 2-4.

An overview of the VMS activity assigned to fishing is provided in Table 8. Comparing the nominal effort (Table 1) with the VMS activity raised to the nominal effort, it seems as the ratio between VMS activity and nominal effort varies slightly by year and nation, but is rather constant over the years and between nations.

Summary: The introduction of closed Kattegat areas in 2009 has, as intended, given a very low effort in the closed areas in the **first quarter** of 2009 to 2011. Quarter 1 effort was reallocated outside the closed areas, mainly to the more eastern grounds. The **second quarter** of 2009 had a very low Danish effort in the partial closed area where fishery is allowed, 1st April to 31th December with gears with low catch of cod (SELTRA 300 or sorting grid). The Swedish effort in the area was however maintained due to the use of sorting grid. This pattern changed significantly in 2010 where this area had the highest concentration of international effort in the time series (2007-2011). The reason for this change is not investigated further, but it might be linked to a higher CPUE of especially larger Nephrops in the area due to the area closure the year before. Limited information is available on the actual use of SELTRA 300 or grid in the areas. In 2011 there was almost no fishing activity in the area. The change in effort distribution for **quarter 3**, with an increase of effort in the area with mandatory use of selective gears, seems similar to the changes observed for quarter 2. **For quarter 4**, effort in the partially closed area was lowest in the first year of closure followed by a small increase.

Some fishing activity has been recorded in the permanently closed area in May-August of 2010, while VMS activity in this closed area in other periods has been insignificant and might as well be due to misclassification of fishing activity.

The temporal closure of the northern Sound ("Kilen") and a later permanent ban on the use of Danish seine in the area have almost entirely removed VMS activity by segment TR1 and TR2 in the area.

3. Fishing impact on cod for the period 2007–2011

The TR2 segment is by far the most important with respect to effort (Tables 1) and cod landings (ICES 2012) in Kattegat. Consequently this analysis focuses on the TR2 segment.

Method

Fishing impact (proxy for Fishing mortality) is here defined as

$$\text{Impact}_{lon,lat,year,quarter,gear,age} = \text{density}_{lon,lat,quarter,age} * \text{effort}_{lon,lat,year,quarter,gear} * \text{Retension}_{gear,age}$$

where

density is the proportion of the cod stock (at age) in Kattegat within a given position (longitude, latitude grid, 0.01 x 0.01 degree) for a given quarter and age.

effort is the fishing activity given by the number of VMS "fishing" records times engine power (kW) raised to the total nominal effort for the segment.

Retention is the retention likelihood of cod at age (see Figure 24) derived from gear specific selection curves (see Krag and Herrmann 2012; Madsen and Valentinsson 2010) and age-length distribution of the cod population.

The effort of the fleet equipped with VMS is raised to the total effort of the segment (with and without VMS information). It is thereby assumed that large and small vessels have the same use of selective gears and the same exploitation pattern.

"density" is derived from the predicted quarterly cod distribution within Kattegat, (e.g. Figure 5). Both "effort" and "density" are used on a 0.01 x 0.01 degree grid.

The estimated effort can be seen a proxy for swept area. There is a tendency that the Danish vessels use a slightly higher trawling speed than the Swedish. To take that into account when the "swept area" is calculated Danish effort was raised by 20% for a sensitivity analysis. Another sensitivity analysis was made with the assumed retention for the trawls used. For trawl with an exit-panel with square-meshes at a minimum 120 mm two rather different estimate of the retention exist, one from 2009 (Frandsen et al 2009) and one from 2011. The newest estimate has a much smaller retention of smaller fish, and this estimate is used as the default choice. For a sensitivity analysis, the estimate of fishing impact was also calculated using the 2009 retention estimate.

Information on the actual type of trawl has not been mandatory to write in the logbook before August 2011 for the Danish fishery. After that period, information on the type of gear is however missing for a large proportion of the fishing effort (Table 7). Information from the industry and fishery control unit indicates that the selective gears actually have been applied in the mandatory period. The “missing” gear information was therefore estimated proportionally to the recorded choice of gear in the mandatory period. After that period, the recorded choice of gear was used, even though there is information that the use of the more selective gears continued to a large degree throughout 2011.

There is no logbook information available to DTU Aqua about the use of the SELTRA 300 trawl before August 2011 in the Danish fishery. SELTRA 300 has been mandatory for fishing in the “orange” area in the period 1st April to 31th December, and in the ”black” area 1st Jan to 31th March. In the calculations, it has been assumed that the mandatory gear has actually been used in the areas. Vessels fishing (illegally) in the permanently closed “red” area are assumed to have used the default gear (120 mm exit window) or the gear type noted in the log book if such information exist.

The use of trawl with an exit-panel with square-meshes at a minimum 120 mm has been mandatory since 1st February 2008 in the Danish fishery. However in 2007 the fishermen were allocated additional fishing days at sea when using such gear, so the exit window has been used since 2007 for part of the fleet. The exact use of the gear is not known to DTU Aqua, but it is assumed that the standard gear was applied in January 2008 and that 120 mm square meshes exit-panel has been the standard gear since 1st February 2008.

Total effort at various levels of details is presented in Table 9 to Table 11.

Results

Fishing impact on Kattegat cod from the TR2 segment has decreased for all ages during the period of box closures (Table 12). Relative to the period before closure (2008) the fishing impact in 2011 was 56% for age 1, 37% for age 2 and 32% for age 3 plus. The reduction in fishing impact is highest in the first year of closure, followed by a modest reduction in the succeeding years. Fishing impact has been reduced both inside and outside the closed areas indicating that it is not the closures alone that have reduced the fishing impact.

The relative reduction in fishing impact is lower for Denmark (Table 13) than for Sweden (Table 14). In absolute terms the impact from Sweden is however larger for age 1 and 2, even though the Swedish nominal effort (kW days) is considerably smaller.

In an attempt to dis-entangle the effect of box closures from the effect of more selective gears and effort reduction, a calculation was made where the spatial distribution of effort is assumed as observed in the period 2008-2011, but the total effort and gear used are assumed constant. This calculation (Table 15) shows a rather modest effect of the closure. For age 1 the impact in 2011 is estimated to be 107% of what is was in 2008. For age 2 (94%) and 3 plus (88%) the impact is reduced, but the reduction is low. The relative reduction is highest for the Danish fishery (Table 15) probably due to the fact that the “red” area was hardly fished by Sweden in 2008 and the Swedish effort in the “orange” area continued after the closures due to the use of sorting grid.

To eliminate the effect of the general decrease in nominal effort of both countries a calculation was made using the observed spatial distribution of the fishery and the gear used, but the total nominal effort was kept constant. The results (Table 16) show a substantial reduction for all ages (77% of the impact in 2008 for age 1, 49% for age 2 and 41% for age 3 plus). The relative reduction is highest for Sweden.

The calculation made based on real and hypothetical changes in the fishery clearly show that the high reduction in fishing impact is due to both area closures, the use of more selective gears and reduction in effort. Some of the changes towards greater use of selective gears have been made to get access to the closed areas, such that the effect of closures cannot be isolated. However, the analysis shows that the box closures alone have had a rather modest direct effect compared to the effect of gear changes and effort reductions.

The sensitivity analysis with respect to choice of selection curve for the 120 mm square mesh panel shows that the relative fishing impact has decreased even more from 2008 to 2011 when the selection pattern from 2009 (Frandsen et al. 2009) was applied (Table 17). For age 2, as an example, fishing impact in 2011 is now estimated to 34% of what it was in 2008, while the default configuration gave 32 % (Table 12). The reason is simple that the gain of shifting from the 120mm square mesh panel to a more selective gear is estimated higher when the retention of the 120 mm gear is estimated to higher. In absolute terms the fishing impact for the Danish TR2 segment increases (Table 18) and reaches the level as estimated for the Swedish TR2 segment (Table 14).

The sensitivity analysis with respect to the difference in national fishing speed shows that the effect of a 20% larger swept area per ping for the Danish fleet result in around 1% less reduction in fishing impact from 2008 to 2011 (Table 19). The reason is that the impact per ping is quite similar for the two nations, such that a consistent increase in one nation's effort for all years does not influence the trend in impact. The absolute fishing impact does however increase for the Danish TR2 segment.

The results (Table 20 and Table 21) of applying both the 2009 estimate of the 120 mm square mesh panel and the 20% larger swept area for the Danish fleet show a relative fishing impact very close to the impact estimated with just the more conservative selection for 120 SMP (Table 17) but the absolute impact is naturally higher. Given the high estimate of absolute fishing impact from the Danish TR2 segment (Table 21) and the Swedish (Table 14), the impact in 2011 from the Danish TR2 was 22% lower than the Swedish for age 1 cod. For age 2 and 3 the absolute impact from the Danish TR2 are higher (34% and 62% higher respectively).

Discussion

The uncertainty of the estimated fishing impact cannot be ignored. Around 40% of the effort in Kattegat is from small vessels without VMS. It is assumed that the smaller vessels have the same exploitation pattern of cod with respect to fishing ground, time of the year and use of selective gears. This might not be the case, and might bias the result.

It is also assumed, that selective gears are used when noted in the logbook or during fishery in the closed areas where such gears are mandatory. We have information from the Danish fishery that SELTRA 300 was used, both inside and outside the closed areas, and that the mandatory selective gears have been applied since August 2011 outside the closures. Logbook data documenting the use of the mandatory gear, complemented with statistics from enforcement, are however necessary. The mandatory recording of the gear type in the Danish logbook introduced August 2011 seems not fully implemented, as data are missing from a large proportion of the fleet, which adds to the uncertainty.

The selection curve for trawl with 120 mm exit window gear is highly uncertain (see Kragh and Herrmann, 2012). We have used a selection curve that might underestimate the retention of smaller fish. This means that the catch reduction due to a shift to a more selective gear (e.g. SELTRA 300) will be underestimated, such that the reduction in fishing impact also will be underestimated.

A similar calculation as presented in this document was made last year (Vinther et al 2011). The results this year show a steeper decline in the fishing impact. The difference is mainly due to the use of better information on gear selection by cod size. Last year it was assumed that size selection was the same for all size. The addition of the 2011-12 survey data changed the predicted stock distribution marginally.

The present management plan includes targets for F at 0.4, which is defined as "fishing mortality on cod on appropriate age groups". This age range is interpreted as ages 3-5, which was used to by ICES to calculate mean F. Fishing impact of age 3 plus (equivalent to ages 3-5) in 2011 is estimated to be 32% of the value in 2008. Such reduction makes it likely that the absolute F (for age 3-5) is below target F at 0.40 (for SSB > Bpa), however, SSB is low and probably below Blim. In such cases F shall be reduced by 25% per year, which is equivalent to 0.75^3=42% of the F value after the period of 3 years. This reduction is actually less than the estimated realized reduction in fishing impact, which shows that the aim of the management plan to reduce F has worked, but the objective to rebuild SSB to above Bpa has most likely not been reached yet, even though an increase in SSB is visible.

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Table 1. Nominal effort (mega Watt days) by segment and year for the Kattegat and the Sound fisheries as used in the analysis.

DENMARK

Area	Year	NA	GN	GT	LL	TR1	TR2	TR3
The Kattegat	2007	376	73	12	NA	184	2026	301
	2008	288	66	12	NA	156	2147	146
	2009	333	82	23	0	102	2214	93
	2010	327	67	14	NA	70	2384	36
	2011	431	49	12	0	51	1891	34
The Sound	2007	132	315	38	25	185	36	1
	2008	181	315	36	7	179	27	NA
	2009	149	290	30	4	24	12	0
	2010	166	223	44	4	16	18	0
	2011	144	256	42	3	12	22	NA

SWEDEN, Kattegat

Gear segment	2007	2008	2009	2010	2011
TR1	20	58	7	14	1
TR2 (% SPECON)	1275 (18)	1228 (25)	852 (49)	767 (63)	731 (59)
TR3	1	0	1	0	0
GN	15	33	33	33	39
GT	34	29	18	27	-
LL	38	25	0	0	-

Table 2. Regression results of GAM analysis of CPUE at age as function of trawl position(x,y), depth and survey, Quarter 1.

Age 1

```
Family: Negative Binomial(0.749) Link function: log
Formula: Age_1 ~ s(x, y) + s(Depth) + s(Year) + Survey

Parametric coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  3.78108    0.07839  48.231  < 2e-16 ***
SurveyIBTS  -0.75777    0.11217  -6.756 1.42e-11 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
            edf Ref.df Chi.sq  p-value
s(x,y)   15.733 20.465  46.89 0.000757 ***
s(Depth)  7.412  8.309  22.73 0.004529 **
s(Year)   8.332  8.876 174.81  < 2e-16 ***
---
R-sq.(adj) =  0.249   Deviance explained = 33.1%
UBRE score = 0.30761  Scale est. = 1         n = 593
```

Age 2

```
Family: Negative Binomial(0.81) Link function: log
Formula:Age_2 ~ s(x, y) + s(Depth) + s(Year)

Parametric coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)   2.8950     0.0478   60.56   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
            edf Ref.df Chi.sq p-value
s(x,y)   24.655 27.773 232.18  <2e-16 ***
s(Depth)  6.520  7.643  17.68  0.0196 *
s(Year)   8.867  8.994 434.67  <2e-16 ***
---
R-sq.(adj) =  0.121   Deviance explained = 47.2%
UBRE score = 0.29358  Scale est. = 1         n = 593
```

Age 3+

```
Family: Negative Binomial(1.105) Link function: log
Formula:Age_3Plus ~ s(x, y) + s(Depth) + s(Year) + Survey

Parametric coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  1.32050    0.08003  16.501  < 2e-16 ***
SurveyIBTS   0.60292    0.11201   5.383 7.34e-08 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
            edf Ref.df Chi.sq  p-value
s(x,y)   24.768 27.780 401.92  < 2e-16 ***
s(Depth)  8.023  8.713  42.91 1.75e-06 ***
s(Year)   8.549  8.941 315.96  < 2e-16 ***
---
R-sq.(adj) =   0.23   Deviance explained = 57.3%
UBRE score = 0.2649  Scale est. = 1         n = 593
```

Table 3. Regression results of GAM analysis of CPUE at age as function of trawl position(x,y) year and depth, Quarter 3.

Age 1

```
Family: Negative Binomial(1.211) Link function: log
Formula:Age_1 ~ s(x, y) + s(Year)

Parametric coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  1.21479    0.07688    15.8   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
           edf Ref.df Chi.sq p-value
s(x,y)  17.860  21.75  150.5  <2e-16 ***
s(Year)  8.979   9.00  185.9  <2e-16 ***
---
R-sq.(adj) =  0.438   Deviance explained = 64.7%
UBRE score = 0.32721  Scale est. = 1         n = 247
```

Age 2

```
Family: Negative Binomial(2.081) Link function: log
Formula: Age_2 ~ s(x, y) + s(Year)

Parametric coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  -1.1575     0.2111  -5.483 4.18e-08 ***
---
Approximate significance of smooth terms:
           edf Ref.df Chi.sq  p-value
s(x,y)  16.460 19.679 166.71  < 2e-16 ***
s(Year)  8.733  8.973  72.44 4.91e-12 ***
---
R-sq.(adj) =  0.524   Deviance explained = 73.9%
UBRE score = -0.069708  Scale est. = 1         n = 247
```

Age 2+

```
Family: Negative Binomial(1.871) Link function: log

Formula: Age_2Plus ~ s(x, y) + s(Year)

Parametric coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  -0.8137     0.1556   -5.23 1.69e-07 ***
---
Approximate significance of smooth terms:
           edf Ref.df Chi.sq  p-value
s(x,y)  18.326 21.291 207.50  < 2e-16 ***
s(Year)  8.085  8.758  92.16 4.44e-16 ***
---
R-sq.(adj) =  0.485   Deviance explained = 75.8%
UBRE score = -0.049076  Scale est. = 1         n = 247
```

Age 3+

```
Family: Negative Binomial(1.323) Link function: log
Formula: Age_3Plus ~ s(x, y) + s(Year) + s(Depth)

Parametric coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  -2.7154     0.3726  -7.287 3.16e-13 ***
---
Approximate significance of smooth terms:
           edf Ref.df Chi.sq  p-value
s(x,y)   9.336 12.147  30.19  0.00283 **
s(Year)  8.332  8.862  47.02 3.43e-07 ***
s(Depth) 3.152  3.765  14.04  0.00587 **
---
R-sq.(adj) =  0.414   Deviance explained = 70.6%
UBRE score = -0.38285  Scale est. = 1         n = 247
```

Table 4. Regression results of GAM analysis of CPUE at age as function of trawl position(x,y), depth and year, Quarter 4.

Age 0

```
Family: Negative Binomial(0.889) Link function: log
Formula: Age_0 ~ s(x, y) + factor(Year) + s(Depth) + Survey

Parametric coefficients:
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)        1.3661     0.1037  13.170  < 2e-16 ***
factor(Year)2009  -1.2226     0.1300  -9.405  < 2e-16 ***
factor(Year)2010  -0.8294     0.1255  -6.611 3.82e-11 ***
factor(Year)2011   0.4788     0.1204   3.975 7.04e-05 ***
SurveyHavF         2.4266     0.1532  15.838  < 2e-16 ***
SurveySoleS        1.1725     0.1073  10.924  < 2e-16 ***
---
Approximate significance of smooth terms:
            edf Ref.df  Chi.sq p-value
s(x,y)   19.969 24.698 249.895  <2e-16 ***
s(Depth)  2.619  3.331   7.422  0.0757 .
---
R-sq.(adj) =  0.492   Deviance explained = 62.1%
UBRE score = 0.21277  Scale est. = 1         n = 693
```

Age 1

```
Family: Negative Binomial(1.885) Link function: log
Formula: Age_1 ~ s(x, y) + factor(Year) + s(Depth) + Survey

Parametric coefficients:
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)       1.74828    0.07364  23.739  < 2e-16 ***
factor(Year)2009  1.02268    0.08723  11.724  < 2e-16 ***
factor(Year)2010  0.53652    0.08814   6.087 1.15e-09 ***
factor(Year)2011  1.09666    0.08741  12.546  < 2e-16 ***
SurveyHavF       -0.42632    0.11194  -3.809  0.00014 ***
SurveySoleS      -0.10007    0.07304  -1.370  0.17066
---
Approximate significance of smooth terms:
           edf Ref.df Chi.sq  p-value
s(x,y)   21.44 25.902 125.02 6.02e-15 ***
s(Depth)  7.44  8.338  18.93   0.0183 *
---
R-sq.(adj) =  0.186   Deviance explained = 33.3%
UBRE score = 0.21794  Scale est. = 1         n = 693
```

Age 2

```
Family: Negative Binomial(3.103) Link function: log
Formula: Age_2 ~ s(x, y) + s(Depth) + factor(Year) + Survey

Parametric coefficients:
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)       0.59906    0.08663   6.915 4.67e-12 ***
factor(Year)2009  0.26207    0.10710   2.447   0.0144 *
factor(Year)2010  0.53232    0.10211   5.213 1.86e-07 ***
factor(Year)2011  0.49357    0.10444   4.726 2.29e-06 ***
SurveyHavF       -0.96508    0.14614  -6.604 4.01e-11 ***
SurveySoleS      -0.70849    0.08548  -8.288  < 2e-16 ***
---
Approximate significance of smooth terms:
            edf Ref.df Chi.sq  p-value
s(x,y)   22.602 26.626 132.49 5.21e-16 ***
s(Depth)  4.543  5.597  22.72 0.000644 ***
---
R-sq.(adj) =  0.313   Deviance explained = 41.9%
UBRE score = 0.17992  Scale est. = 1         n = 693
```

Table 4 (continued). Regression results of GAM analysis of CPUE at age as function of trawl position(x,y), depth and year, Quarter 4.

Age 2+

```
Family: Negative Binomial(2) Link function: log
Formula:Age_2Plus ~ s(x, y) + s(Depth) + factor(Year) + Survey

Parametric coefficients:
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)       1.00554    0.08816  11.406  < 2e-16 ***
factor(Year)2009  0.19652    0.10950   1.795  0.07271 .
factor(Year)2010  0.28697    0.10735   2.673  0.00751 **
factor(Year)2011  0.55042    0.10644   5.171 2.33e-07 ***
SurveyHavF       -0.93950    0.14611  -6.430 1.28e-10 ***
SurveySoleS      -0.82641    0.08940  -9.244  < 2e-16 ***
---
Approximate significance of smooth terms:
            edf Ref.df Chi.sq  p-value
s(x,y)   21.002 25.517 144.81  < 2e-16 ***
s(Depth)  7.272  8.225  33.41 6.21e-05 ***
---
R-sq.(adj) =  0.362   Deviance explained = 46.7%
UBRE score = 0.21679  Scale est. = 1         n = 693
```

Age 3+

```
Family: Negative Binomial(2.467) Link function: log
Formula:  Age_3Plus ~ s(x, y) + s(Depth) + factor(Year) + Survey

Parametric coefficients:
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)       0.13037    0.13357   0.976   0.3290
factor(Year)2009 -0.70178    0.16937  -4.144 3.42e-05 ***
factor(Year)2010 -1.96065    0.21825  -8.983  < 2e-16 ***
factor(Year)2011  0.07518    0.15680   0.479   0.6316
SurveySoleS      -0.40704    0.15490  -2.628   0.0086 **
---
Approximate significance of smooth terms:
           edf Ref.df Chi.sq p-value
s(x,y)   20.60  24.94 163.51  <2e-16 ***
s(Depth)  5.03   6.13  15.76  0.0164 *
---
R-sq.(adj) =  0.528   Deviance explained = 63.2%
UBRE score = -0.033664  Scale est. = 1         n = 516
```

Table 5 Estimates of year effects (log and response) from GAM analysis, Quarter 4.

Log values	age 0	age 1	age 2	age 2+	age 3+
2008	0	0	0	0	0
2009	-1.22	1.02	0.26	0.20	-0.70
2010	-0.83	0.54	0.53	0.29	-1.96
2011	0.48	1.10	0.49	0.55	0.08

Response	age 0	age 1	age 2	age 2+	age 3+
2008	1.00	1.00	1.00	1.00	1.00
2009	0.29	2.78	1.30	1.22	0.50
2010	0.44	1.71	1.70	1.33	0.14
2011	1.61	2.99	1.64	1.73	1.08

Table 6. Percentage of nominal effort for which VMS data exist for the Kattegat TR2 segment by country and month.

Country	Year	1	2	3	4	5	6	7	8	9	10	11	12
DNK	2007	81	55	50	48	52	53	44	59	66	59	60	55
	2008	84	58	43	53	54	55	52	59	57	65	64	53
	2009	66	56	52	52	57	54	54	54	59	57	60	53
	2010	72	76	66	61	59	57	60	63	63	60	59	56
	2011	64	67	52	52	56	56	52	62	55	62	58	73
SWE	2007	58	58	58	64	64	64	67	67	67	58	58	58
	2008	54	54	54	50	50	50	60	60	60	48	48	48
	2009	68	68	68	70	70	70	72	72	72	62	62	62
	2010	72	72	72	74	74	74	78	78	78	68	68	68
	2011	72	72	72	68	68	68	74	74	74	68	68	68

Table 7. Number of pings for the Danish Kattegat TR2 segment in 2011 by gear type and month as extracted from logbooks and VMS, and as adjusted for missing Gear type* specification.

Observed

Gear type \ Month	1	2	3	4	5	6	7	8	9	10	11	12
0	3917	1032	1008	1164	1704	2439	2092	2790	1069	1692	855	1112
1	.	.	.	.	.	.	108	208	390	517	142	140
2	.	.	.	.	.	.	693	2848	2141	1846	2499	909
3	.	.	.	.	.	.	.	.	.	.	.	4
5	.	.	.	.	.	.	96	906	1356	579	920	25

Adjusted

Gear type	1	2	3	4	5	6	7	8	9	10	11	12
0	3917	1032	1008	1164	1704	2439	.	.	.	.	855	1112
1	.	.	.	.	.	.	179	322	472	742	142	140
2	.	.	.	.	.	.	2498	4885	2879	2931	2499	909
3	.	.	.	.	.	.	79	126	32	54	.	4
5	.	.	.	.	.	.	233	1419	1569	907	920	25

*The Gear type 1-5 refers to gear type i) to v) mention in the Background section

Table 8. Number of VMS recordings assigned to fishing activity for the Kattegat TR2 segment as observed and raised to full segment effort. Gear Type 0 refers to no specification of gear type.

OBSERVED

Country	Year	Gear.type 0	1	2	3	4	5
DNK	2007	40570	NA	NA	NA	NA	NA
	2008	40820	NA	NA	NA	NA	NA
	2009	36306	NA	NA	NA	NA	NA
	2010	45360	NA	NA	NA	NA	NA
	2011	13230	1997	16601	294	4	5074
SWE	2007	19496	NA	NA	NA	3170	NA
	2008	15453	NA	NA	NA	4778	NA
	2009	9840	NA	NA	NA	9910	NA
	2010	7671	NA	NA	NA	12564	NA
	2011	6644	NA	NA	NA	10104	NA

RAISED TO FULL SEGMENT EFFORT

Country	Year	Gear.type 0	1	2	3	4	5
DNK	2007	68890	NA	NA	NA	NA	NA
	2008	68799	NA	NA	NA	NA	NA
	2009	64325	NA	NA	NA	NA	NA
	2010	72740	NA	NA	NA	NA	NA
	2011	22212	3366	28238	505	7	8694
SWE	2007	31298	NA	NA	NA	5020	NA
	2008	28546	NA	NA	NA	8930	NA
	2009	14374	NA	NA	NA	14296	NA
	2010	10597	NA	NA	NA	16742	NA
	2011	9359	NA	NA	NA	14136	NA

Table 9 Fishing effort (arbitrary unit *no of VMS pings * kW * scaling) by country, year area (box*) and gear derived from VMS data raised to nominal effort for the Kattegat TR2 segment.**

			year					
			2007	2008	2009	2010	2011	All
Country	Box							
DNK	0	D90	12386	1508	.	.	.	13894
		D90S120	.	11796	13187	11719	4755	41457
		SELTRA300	.	.	.	.	886	886
		fourPanel180	.	.	.	.	522	522
		fourPanel270	.	.	.	.	5889	5889
		All	12386	13304	13187	11719	12052	62648
	1	D90	1549	62	.	.	.	1611
		D90S120	.	1191	2177	1988	351	5707
		SELTRA300	.	.	115	111	439	664
		fourPanel180	.	.	.	.	110	110
		fourPanel270	.	.	.	.	670	670
		All	1549	1253	2292	2098	1570	8762
	2	D90	2313	49	.	.	.	2362
		D90S120	.	2021	19	1	.	2040
		SELTRA300	.	.	720	3578	969	5267
		All	2313	2069	739	3578	969	9669
	3	D90	1762	89	.	.	.	1851
		D90S120	.	1492	152	492	53	2188
		SELTRA300	.	.	.	.	7	7
		fourPanel180	.	.	.	.	34	34
		fourPanel270	.	.	.	.	19	19
		All	1762	1580	152	492	113	4099
	All	D90	18010	1707	.	.	.	19717
		D90S120	.	16500	15534	14200	5158	51392
		SELTRA300	.	.	836	3688	2300	6824
		fourPanel180	.	.	.	.	666	666
		fourPanel270	.	.	.	.	6578	6578
		All	18010	18207	16370	17888	14703	85178

Table 9 (continued) Fishing effort (arbitrary unit *no of VMS pings * kW * scaling) by country, year, area (box*) and gear derived from VMS data raised to nominal effort for the Kattegat TR2 segment.**

			year					
			2007	2008	2009	2010	2011	All
Country	Box							
SWE	0	D90	5271	3906	3536	2460	2250	17423
		Grid	1141	1904	2081	2082	2507	9715
		All	6412	5810	5617	4542	4757	27138
	1	D90	3004	2363	1322	1230	1037	8956
		Grid	254	691	966	1241	1452	4605
		All	3258	3054	2289	2472	2489	13561
	2	D90	1871	3171	64	71	121	5298
		Grid	102	87	1537	2306	941	4974
		All	1973	3258	1601	2377	1063	10272
	3	D90	18	49	.	.	.	68
		Grid	8	.	.	.	0	9
		All	26	49	.	.	0	76
	All	D90	10164	9490	4923	3761	3409	31746
		Grid	1505	2682	4584	5629	4900	19302
		All	11669	12172	9507	9390	8309	51048

*See Figure 1 for definitions of boxes. Box 0 in this table refers to the Kattegat area outside the closed areas, Box 1 to area 1 (the black box) in Figure 1, Box 2 to area 2 (the orange box) and box 3 to area 3 (the red box).

** The gear codes applied:

- D90: Trawl with 90 mm diamond mesh in the codend
- D90S120: Trawl with 90 mm and above diamond mesh in the codend and a 120 mm square meshed panel as defined in the Council Regulation (EC) no.4 41/2006, Annex IIA,8.1
- fourPanel180: 4-panel codend with a 180 mm square mesh panel installed 4 - 7 meter from the codline. The code is also used for a few observations of a trawl with 2-panel codend with a 180 mm square mesh panel installed 4 -7 meters from the codline.
- Grid: Swedish sorting grid
- fourPanel270: 4-panel codend with a diamond mesh panel with a minimum mesh size of 270 mm installed 4- 7 meter from the codline.
- SELTRA300: Codend with a 300 mm square mesh panel installed 3 – 6 meters from the codline.

Table 10 Fishing effort (arbitrary unit *no of VMS pings * kW * scaling) by country, year, area (box*) and gear derived from VMS data raised to nominal effort for the Kattegat TR2 segment.**

		year					
		2007	2008	2009	2010	2011	All
Box	Gear						
0	D90	17657	5414	3536	2460	2250	31317
	D90S120	.	11796	13187	11719	4755	41457
	Grid	1141	1904	2081	2082	2507	9715
	SELTRA300	.	.	.	.	886	886
	fourPanel180	.	.	.	.	522	522
	fourPanel270	.	.	.	.	5889	5889
	All	18798	19114	18804	16261	16809	89787
1	D90	4553	2425	1322	1230	1037	10567
	D90S120	.	1191	2177	1988	351	5707
	Grid	254	691	966	1241	1452	4605
	SELTRA300	.	.	115	111	439	664
	fourPanel180	.	.	.	.	110	110
	fourPanel270	.	.	.	.	670	670
	All	4807	4307	4580	4570	4059	22323
2	D90	4184	3220	64	71	121	7660
	D90S120	.	2021	19	1	.	2040
	Grid	102	87	1537	2306	941	4974
	SELTRA300	.	.	720	3578	969	5267
	All	4286	5328	2340	5955	2032	19941
3	D90	1780	138	.	.	.	1918
	D90S120	.	1492	152	492	53	2188
	Grid	8	.	.	.	0	9
	SELTRA300	.	.	.	.	7	7
	fourPanel180	.	.	.	.	34	34
	fourPanel270	.	.	.	.	19	19
	All	1788	1629	152	492	113	4175
All	D90	28173	11197	4923	3761	3409	51463
	D90S120	.	16500	15534	14200	5158	51392
	Grid	1505	2682	4584	5629	4900	19302
	SELTRA300	.	.	836	3688	2300	6824
	fourPanel180	.	.	.	.	666	666
	fourPanel270	.	.	.	.	6578	6578
	All	29679	30379	25876	27279	23012	136225

Table 11 Fishing effort (arbitrary unit *no of VMS pings * kW * scaling) by country, year, month, area (box*) and gear derived from VMS data raised to nominal effort for the Kattegat TR2 segment.**

country DNK

			month												All
			1	2	3	4	5	6	7	8	9	10	11	12	
Year	Box														
2008	0	D90	1508	.	.	.	.	.	.	.	.	.	.	.	1508
		D90S120	.	423	381	596	1154	867	806	2051	1606	1764	1124	1023	11796
		All	1508	423	381	596	1154	867	806	2051	1606	1764	1124	1023	13304
	1	D90	62	.	.	.	.	.	.	.	.	.	.	.	62
		D90S120	.	12	13	54	215	117	67	359	177	67	63	49	1191
		All	62	12	13	54	215	117	67	359	177	67	63	49	1253
	2	D90	49	.	.	.	.	.	.	.	.	.	.	.	49
		D90S120	.	2	.	15	88	46	322	463	396	171	224	293	2021
		All	49	2	.	15	88	46	322	463	396	171	224	293	2069
	3	D90	89	.	.	.	.	.	.	.	.	.	.	.	89
		D90S120	.	3	3	26	156	172	112	193	428	113	129	156	1492
		All	89	3	3	26	156	172	112	193	428	113	129	156	1580
	All	D90	1707	.	.	.	.	.	.	.	.	.	.	.	1707
		D90S120	.	440	397	692	1613	1202	1307	3065	2607	2116	1540	1521	16500
		All	1707	440	397	692	1613	1202	1307	3065	2607	2116	1540	1521	18207
2009	Box														
	0	D90S120	1361	689	572	953	1034	1133	915	1484	1737	1250	1274	785	13187
		All	1361	689	572	953	1034	1133	915	1484	1737	1250	1274	785	13187
	1	D90S120	.	.	.	216	81	234	188	722	273	226	121	116	2177
		SELTRA300	21	21	73	.	.	.	.	.	.	.	.	.	115
		All	21	21	73	216	81	234	188	722	273	226	121	116	2292
	2	D90S120	.	7	12	.	.	.	.	.	.	.	.	.	19
		SELTRA300	.	.	.	19	79	45	13	176	201	128	20	40	720
		All	.	7	12	19	79	45	13	176	201	128	20	40	739
	3	D90S120	7	.	4	4	2	1	.	2	39	41	19	32	152
		All	7	.	4	4	2	1	.	2	39	41	19	32	152
	All	D90S120	1369	696	588	1174	1117	1368	1103	2208	2049	1516	1414	933	15534
		SELTRA300	21	21	73	19	79	45	13	176	201	128	20	40	836
		All	1390	717	661	1193	1196	1412	1116	2384	2250	1644	1434	973	16370

country DNK

			month												All
			1	2	3	4	5	6	7	8	9	10	11	12	
2010	Box														
	0	D90S120	1174	943	1873	902	562	797	679	867	1532	941	765	684	11719
		All	1174	943	1873	902	562	797	679	867	1532	941	765	684	11719
	1	D90S120	.	.	.	654	105	134	60	265	340	163	128	138	1988
		SELTRA300	41	27	42	.	.	.	.	.	.	.	.	.	111
		All	41	27	42	654	105	134	60	265	340	163	128	138	2098
	2	D90S120	1	.	.	.	.	.	.	.	.	.	.	.	1
		SELTRA300	.	.	.	186	675	672	137	757	666	333	138	15	3578
		All	1	.	.	186	675	672	137	757	666	333	138	15	3578
	3	D90S120	5	11	.	30	136	143	15	114	13	16	4	6	492
		All	5	11	.	30	136	143	15	114	13	16	4	6	492
	All	D90S120	1180	954	1873	1586	803	1073	755	1245	1885	1120	897	828	14200
		SELTRA300	41	27	42	186	675	672	137	757	666	333	138	15	3688
		All	1221	982	1916	1772	1478	1745	892	2002	2551	1453	1035	843	17888
2011	Box														
	0	D90S120	1436	348	419	405	636	864	.	.	.	.	286	360	4755
		SELTRA300	.	.	.	.	.	.	71	294	240	186	93	4	886
		fourPanel180	.	.	.	.	.	.	54	77	121	213	33	24	522
		fourPanel270	.	.	.	.	.	.	1089	1617	1006	1050	878	249	5889
		All	1436	348	419	405	636	864	1214	1988	1367	1448	1289	637	12052
	1	D90S120	.	.	.	61	43	131	.	.	.	.	80	35	351
		SELTRA300	57	22	8	.	.	.	19	175	92	22	42	1	439
		fourPanel180	.	.	.	.	.	.	4	8	50	39	9	.	110
		fourPanel270	.	.	.	.	.	.	99	278	148	69	69	8	670
		All	57	22	8	61	43	131	122	461	290	130	200	44	1570
	2	SELTRA300	.	.	.	11	2	5	14	141	344	199	237	16	969
		All	.	.	.	11	2	5	14	141	344	199	237	16	969
	3	D90S120	1	1	.	5	3	7	.	.	.	.	23	12	53
		SELTRA300	.	.	.	.	.	.	0	3	2	1	.	.	7
		fourPanel180	.	.	.	.	.	.	0	0	11	14	9	.	34
		fourPanel270	.	.	.	.	.	.	2	7	1	7	2	.	19
		All	1	1	.	5	3	7	2	10	14	22	34	12	113
	All	D90S120	1437	349	419	471	683	1003	.	.	.	.	390	407	5158
		SELTRA300	57	22	8	11	2	5	104	613	679	408	372	21	2300
		fourPanel180	.	.	.	.	.	.	59	86	182	266	50	24	666
		fourPanel270	.	.	.	.	.	.	1190	1901	1155	1126	949	257	6578
		All	1494	371	427	481	684	1008	1353	2600	2016	1799	1760	708	14703

Table 11 (continued) Fishing effort (arbitrary unit *no of VMS pings * kW * scaling) by country, year, month, area (box*) and gear derived from VMS data raised to nominal effort for the Kattegat TR2 segment.**

country SWE

			month												
			1	2	3	4	5	6	7	8	9	10	11	12	All
Year	Box														
2008	0	D90	417	105	105	105	625	307	244	556	353	432	340	316	3906
		Grid	24	245	322	357	278	207	126	276	44	.	9	17	1904
		All	441	351	427	462	902	514	370	832	397	432	350	333	5810
	1	D90	249	46	36	21	245	75	138	587	379	109	189	288	2363
		Grid	.	277	75	57	62	62	35	73	49	.	.	1	691
		All	249	323	111	78	307	137	174	660	428	109	189	288	3054
	2	D90	405	40	36	112	162	475	508	469	571	98	169	127	3171
		Grid	.	3	3	34	.	15	22	5	4	.	.	1	87
		All	405	42	39	146	162	490	530	475	575	98	169	127	3258
	3	D90	1	6	11	1	2	.	6	5	1	.	.	17	49
		All	1	6	11	1	2	.	6	5	1	.	.	17	49
	All	D90	1072	197	188	239	1033	857	897	1617	1305	639	698	747	9490
		Grid	24	525	401	449	340	285	183	354	96	.	9	18	2682
		All	1096	722	589	688	1373	1142	1080	1971	1400	639	708	765	12172
2009	Box														
	0	D90	580	372	224	293	228	513	53	283	382	191	216	203	3536
		Grid	198	147	42	96	101	385	154	358	243	135	114	108	2081
		All	779	519	266	389	328	898	207	641	624	326	330	311	5617
	1	D90	6	6	3	181	162	153	148	190	124	152	60	138	1322
		Grid	118	63	48	19	81	103	130	178	37	91	58	40	966
		All	124	69	51	200	243	256	278	368	161	243	117	178	2289
	2	D90	0	.	.	4	2	7	5	7	24	6	4	4	64
		Grid	.	.	.	47	10	128	305	547	388	55	20	37	1537
		All	0	.	.	51	13	135	310	555	412	61	23	41	1601
	All	D90	587	378	227	478	392	673	205	480	530	348	279	345	4923
		Grid	316	210	90	162	192	616	589	1084	667	281	192	185	4584
		All	902	588	317	640	584	1289	794	1564	1198	630	471	530	9507

country SWE

			month												All
			1	2	3	4	5	6	7	8	9	10	11	12	
2010	**Box**														
	0	**D90**	411	89	387	139	211	65	12	292	247	120	301	186	2460
		Grid	150	27	220	228	318	140	102	256	377	177	47	40	2082
		All	561	116	607	368	530	204	114	548	623	298	348	226	4542
	1	**D90**	5	4	5	88	29	40	80	244	109	144	344	138	1230
		Grid	64	12	119	135	53	71	234	229	196	104	18	6	1241
		All	68	16	123	224	82	111	314	474	305	249	362	145	2472
	2	**D90**	.	1	.	1	0	2	4	8	9	14	21	10	71
		Grid	.	.	2	253	315	394	197	602	417	116	2	8	2306
		All	.	1	2	254	316	396	201	610	426	130	23	18	2377
	All	**D90**	415	94	391	229	240	107	96	544	364	279	667	334	3761
		Grid	214	39	341	617	687	604	532	1088	990	398	66	55	5629
		All	629	132	732	846	928	711	629	1632	1355	676	733	389	9390
2011	**Box**														
	0	**D90**	238	144	253	118	151	205	65	451	189	194	163	80	2250
		Grid	16	12	145	66	250	409	253	638	330	141	150	97	2507
		All	253	156	398	184	401	614	318	1089	519	335	313	177	4757
	1	**D90**	2	3	1	95	42	137	78	211	178	132	93	66	1037
		Grid	5	8	4	71	133	256	239	360	242	79	54	1	1452
		All	7	11	5	166	175	393	318	571	420	210	147	67	2489
	2	**D90**	.	.	0	2	.	8	6	17	30	51	.	7	121
		Grid	.	.	.	39	3	17	102	141	327	107	206	.	941
		All	.	.	0	41	3	25	108	158	356	158	206	7	1063
	3	**Grid**	.	.	.	.	.	.	.	.	0	.	.	.	0
		All	.	.	.	.	.	.	.	.	0	.	.	.	0
	All	**D90**	240	147	254	215	193	350	149	679	397	376	256	152	3409
		Grid	20	20	149	176	386	682	595	1139	899	327	410	98	4900
		All	260	166	403	391	579	1032	744	1818	1296	704	666	251	8309

Table 12 Danish and Swedish fishing impact (absolute and relative) from the Kattegat TR2 segment by cod age, year and area.

ABSOLUTE (arbitrary unit)

Age	Year	Box 0 Outside	Box 1 Black	Box 2 Orange	Box 3 Red	All All
Age 1	2008	127	95	98	4	324
	2009	92	58	22	0	172
	2010	73	62	30	1	166
	2011	100	61	19	0	181
Age 2	2008	502	328	602	44	1475
	2009	407	232	41	2	682
	2010	310	200	67	15	593
	2011	333	169	39	1	542
Age 3+	2008	794	498	1348	139	2779
	2009	732	419	66	7	1223
	2010	535	362	197	60	1154
	2011	528	266	83	4	880

RELATIVE TO 2008

Age	Year	Box 0	Box 1	Box 2	Box 3	All
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.73	0.61	0.22	0.09	0.53
	2010	0.57	0.66	0.31	0.14	0.51
	2011	0.79	0.65	0.19	0.05	0.56
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.81	0.71	0.07	0.04	0.46
	2010	0.62	0.61	0.11	0.35	0.40
	2011	0.66	0.52	0.06	0.03	0.37
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.92	0.84	0.05	0.05	0.44
	2010	0.67	0.73	0.15	0.44	0.42
	2011	0.66	0.53	0.06	0.03	0.32

Table 13 Danish fishing impact (absolute and relative) from the Kattegat TR2 segment by cod age, year and area.

ABSOLUTE (arbitrary unit)

	Box	Box 0	Box 1	Box 2	Box 3	All
		Outside	Black	Orange	Red	All
Age	Year					
Age 1	2008	43	4	8	3	58
	2009	32	9	2	0	43
	2010	23	6	7	1	37
	2011	39	7	2	0	48
Age 2	2008	297	45	101	41	484
	2009	225	86	8	2	321
	2010	171	65	33	15	284
	2011	196	39	8	1	245
Age 3+	2008	558	95	475	132	1260
	2009	511	216	44	7	778
	2010	366	154	177	60	757
	2011	355	84	50	4	491

RELATIVE TO 2008

	Box	Box 0	Box 1	Box 2	Box 3	All
Age	Year					
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.75	2.17	0.24	0.11	0.75
	2010	0.54	1.40	0.93	0.17	0.63
	2011	0.91	1.64	0.31	0.06	0.83
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.76	1.91	0.08	0.05	0.66
	2010	0.57	1.45	0.32	0.37	0.59
	2011	0.66	0.87	0.08	0.03	0.51
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.91	2.28	0.09	0.05	0.62
	2010	0.66	1.62	0.37	0.46	0.60
	2011	0.63	0.88	0.10	0.03	0.39

Table 14 Swedish fishing impact (absolute and relative) from the Kattegat TR2 segment by cod age, year and area.

ABSOLUTE (arbitrary unit)

Age	Year	Box 0 Outside	Box 1 Black	Box 2 Orange	Box 3 Red	All All
Age 1	2008	84	90	91	1	266
	2009	61	49	20	NA	129
	2010	50	56	23	NA	129
	2011	61	54	17	0	132
Age 2	2008	204	283	501	3	991
	2009	182	146	32	NA	361
	2010	140	135	35	NA	309
	2011	137	130	31	0	298
Age 3+	2008	236	403	872	7	1519
	2009	222	203	21	NA	446
	2010	168	208	21	NA	397
	2011	173	183	33	0	389

RELATIVE TO 2008

Age	Year	Box 0	Box 1	Box 2	Box 3	All
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.72	0.54	0.22	NA	0.48
	2010	0.59	0.62	0.25	NA	0.49
	2011	0.73	0.60	0.18	0.00	0.50
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.89	0.52	0.06	NA	0.36
	2010	0.68	0.48	0.07	NA	0.31
	2011	0.67	0.46	0.06	0.00	0.30
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.94	0.50	0.02	NA	0.29
	2010	0.71	0.52	0.02	NA	0.26
	2011	0.73	0.45	0.04	0.00	0.26

Table 15 Estimates of relative fishing impact due to box-closures alone (assumption of fixed total effort and fixed gear use, but change in spatial distribution), from the Kattegat TR2 segment by cod age, year and area.

Denmark

Age	Year	Box 0 Outside	Box 1 Black	Box 2 Orange	Box 3 Red	All All
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.09	2.34	0.46	0.11	1.06
	2010	0.85	1.61	1.67	0.35	0.98
	2011	1.11	1.78	0.63	0.08	1.04
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.98	2.24	0.50	0.06	0.93
	2010	0.74	1.62	1.90	0.45	1.05
	2011	1.04	1.63	0.54	0.05	0.91
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.06	2.64	0.42	0.06	0.83
	2010	0.71	1.72	1.57	0.47	1.09
	2011	0.99	1.72	0.54	0.04	0.78

Sweden

Age	Year	Box 0	Box 1	Box 2	Box 3	All
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.11	0.89	0.73	NA	0.93
	2010	0.95	1.08	0.97	NA	1.00
	2011	1.30	1.30	0.60	0.01	1.09
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.24	0.90	0.83	NA	0.95
	2010	1.06	1.02	0.99	NA	1.01
	2011	1.41	1.22	0.55	0.01	0.95
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.27	0.92	0.90	NA	0.97
	2010	1.08	1.14	0.94	NA	1.02
	2011	1.53	1.29	0.56	0.02	0.94

Both

Age	Year	Box 0	Box 1	Box 2	Box 3	All
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.10	1.12	0.67	0.10	0.98
	2010	0.90	1.16	1.14	0.33	0.99
	2011	1.19	1.37	0.61	0.07	1.07
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.09	1.11	0.77	0.06	0.94
	2010	0.87	1.11	1.18	0.43	1.02
	2011	1.19	1.28	0.55	0.05	0.94
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.15	1.16	0.76	0.06	0.92
	2010	0.87	1.22	1.13	0.44	1.04
	2011	1.22	1.35	0.55	0.04	0.88

Table 16 Estimates of relative fishing impact due to box-closures and gear change (assumption of fixed total effort, but change in spatial distribution and gear), from the Kattegat TR2 segment by cod age, year and area.

Denmark

		Box 0 Outside	Box 1 Black	Box 2 Orange	Box 3 Red	All All
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.83	2.41	0.27	0.12	0.83
	2010	0.55	1.43	0.94	0.18	0.64
	2011	1.12	2.03	0.38	0.08	1.03
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.84	2.12	0.09	0.05	0.74
	2010	0.58	1.48	0.33	0.38	0.60
	2011	0.82	1.07	0.10	0.04	0.62
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.02	2.53	0.10	0.06	0.69
	2010	0.67	1.65	0.38	0.47	0.61
	2011	0.78	1.09	0.13	0.03	0.48

Sweden

Age	Year	Box 0	Box 1	Box 2	Box 3	All
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.92	0.69	0.28	NA	0.62
	2010	0.77	0.80	0.33	NA	0.63
	2011	1.06	0.88	0.27	0.00	0.73
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.14	0.66	0.08	NA	0.47
	2010	0.89	0.62	0.09	NA	0.40
	2011	0.98	0.67	0.09	0.00	0.44
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.20	0.64	0.03	NA	0.38
	2010	0.92	0.67	0.03	NA	0.34
	2011	1.07	0.66	0.06	0.00	0.38

Both

Age	Year	Box 0	Box 1	Box 2	Box 3	All
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.90	0.74	0.28	0.09	0.65
	2010	0.71	0.82	0.36	0.13	0.63
	2011	1.08	0.91	0.28	0.06	0.77
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.99	0.80	0.08	0.05	0.53
	2010	0.74	0.70	0.12	0.34	0.45
	2011	0.90	0.71	0.09	0.03	0.49
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	1.09	0.90	0.05	0.05	0.49
	2010	0.77	0.80	0.12	0.43	0.44
	2011	0.90	0.72	0.08	0.03	0.41

Table 17 Sensitivity analysis using selection curves from the 120 mm Square mesh panel as estimated by Frandsen et al, 2009. Danish and Swedish fishing impact (absolute and relative) from the Kattegat TR2 segment by cod age, year and area.

ABSOLUTE (arbitrary unit)

Age	Box Year	Box 0 Outside	Box 1 Black	Box 2 Orange	Box 3 Red	All All
Age 1	2008	266	111	126	16	519
	2009	233	94	22	2	350
	2010	182	87	30	4	303
	2011	135	64	19	1	219
Age 2	2008	714	364	681	73	1833
	2009	618	304	41	4	968
	2010	486	259	68	31	843
	2011	412	178	39	2	631
Age 3+	2008	872	512	1421	155	2960
	2009	824	452	66	8	1350
	2010	606	384	197	69	1257
	2011	558	269	83	4	914

RELATIVE TO 2008

Age	Box Year	Box 0	Box 1	Box 2	Box 3	All
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.88	0.85	0.17	0.11	0.67
	2010	0.68	0.78	0.24	0.25	0.58
	2011	0.51	0.58	0.15	0.04	0.42
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.87	0.84	0.06	0.05	0.53
	2010	0.68	0.71	0.10	0.42	0.46
	2011	0.58	0.49	0.06	0.03	0.34
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.94	0.88	0.05	0.05	0.46
	2010	0.70	0.75	0.14	0.44	0.42
	2011	0.64	0.53	0.06	0.03	0.31

Table 18 Sensitivity analysis using selection curves from the 120 mm Square mesh panel as estimated by Frandsen et al, 2009. Danish fishing impact (absolute and relative) from the Kattegat TR2 segment by cod age, year and area.

ABSOLUTE (arbitrary unit)

	Box	Box 0 Outside	Box 1 Black	Box 2 Orange	Box 3 Red	All All
Age	Year					
Age 1	2008	182	21	36	15	253
	2009	172	46	2	2	221
	2010	132	31	7	4	174
	2011	74	10	2	1	86
Age 2	2008	510	81	180	70	841
	2009	436	158	9	4	607
	2010	346	124	33	31	534
	2011	275	48	8	2	333
Age 3+	2008	636	108	548	149	1442
	2009	602	249	45	8	904
	2010	438	176	177	69	860
	2011	385	87	50	4	526

RELATIVE TO 2008

	Box	Box 0	Box 1	Box 2	Box 3	All
Age	Year					
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.95	2.21	0.05	0.11	0.87
	2010	0.72	1.50	0.20	0.26	0.69
	2011	0.41	0.47	0.07	0.04	0.34
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.85	1.94	0.05	0.05	0.72
	2010	0.68	1.52	0.18	0.44	0.63
	2011	0.54	0.59	0.05	0.03	0.40
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.95	2.30	0.08	0.05	0.63
	2010	0.69	1.63	0.32	0.46	0.60
	2011	0.61	0.80	0.09	0.03	0.36

Table 19 Sensitivity analysis assuming that Danish fishing speed (and swept area) is 20% higher than the Swedish. Danish and Swedish fishing impact (absolute and relative) from the Kattegat TR2 segment by cod age, year and area.

ABSOLUTE (arbitrary unit)

	Box	Box 0	Box 1	Box 2	Box 3	All
		Outside	Black	Orange	Red	All
Age	Year					
Age 1	2008	135	96	100	5	336
	2009	99	60	22	0	181
	2010	78	63	32	1	173
	2011	108	63	20	0	190
Age 2	2008	561	337	623	52	1572
	2009	452	249	42	2	746
	2010	345	213	74	18	650
	2011	373	177	40	1	591
Age 3+	2008	906	517	1443	165	3031
	2009	834	462	74	8	1379
	2010	608	393	233	73	1306
	2011	599	283	93	4	979

RELATIVE TO 2008

	Box	Box 0	Box 1	Box 2	Box 3	All
Age	Year					
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.73	0.62	0.22	0.09	0.54
	2010	0.57	0.66	0.32	0.15	0.52
	2011	0.79	0.66	0.20	0.05	0.57
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.81	0.74	0.07	0.04	0.47
	2010	0.61	0.63	0.12	0.35	0.41
	2011	0.66	0.53	0.06	0.03	0.38
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.92	0.89	0.05	0.05	0.45
	2010	0.67	0.76	0.16	0.44	0.43
	2011	0.66	0.55	0.06	0.03	0.32

Table 20 Sensitivity analysis assuming that Danish fishing speed (and swept area) is 20% higher than the Swedish and using selection curves from the 120 mm Square mesh panel as estimated by Frandsen et al, 2009. Danish and Swedish fishing impact (absolute and relative) from the Kattegat TR2 segment by cod age, year and area.

ABSOLUTE (arbitrary unit)

	Box	Box 0	Box 1	Box 2	Box 3	All
		Outside	Black	Orange	Red	All
	Box	Box 0	Box 1	Box 2	Box 3	Xbox
Age	Year					
Age 1	2008	302	115	134	19	570
	2009	267	103	22	2	394
	2010	208	93	32	5	337
	2011	149	66	20	1	236
Age 2	2008	816	380	717	87	2001
	2009	706	336	43	4	1089
	2010	555	283	74	37	950
	2011	467	187	40	3	697
Age 3+	2008	1000	534	1531	185	3249
	2009	944	501	75	10	1531
	2010	694	420	233	83	1429
	2011	635	287	93	5	1020

RELATIVE TO 2008

		Box	Box 0	Box 1	Box 2	Box 3	All
Age	Year						
Age	Year						
Age 1	2008		1.00	1.00	1.00	1.00	1.00
	2009		0.88	0.90	0.16	0.11	0.69
	2010		0.69	0.81	0.24	0.25	0.59
	2011		0.49	0.57	0.15	0.04	0.41
Age 2	2008		1.00	1.00	1.00	1.00	1.00
	2009		0.86	0.88	0.06	0.05	0.54
	2010		0.68	0.75	0.10	0.43	0.47
	2011		0.57	0.49	0.06	0.03	0.35
Age 3+	2008		1.00	1.00	1.00	1.00	1.00
	2009		0.94	0.94	0.05	0.05	0.47
	2010		0.69	0.79	0.15	0.45	0.44
	2011		0.64	0.54	0.06	0.03	0.31

Table 21 Sensitivity analysis assuming that Danish fishing speed (and swept area) is 20% higher than the Swedish and using selection curves from the 120 mm Square mesh panel as estimated by Frandsen et al, 2009. Danish fishing impact (absolute and relative) from the Kattegat TR2 segment by cod age, year and area.

ABSOLUTE (arbitrary unit)

	Box	Box 0	Box 1	Box 2	Box 3	All
		Outside	Black	Orange	Red	All
	Box	Box 0	Box 1	Box 2	Box 3	Xbox
Age	Year					
Age 1	2008	218	25	43	18	304
	2009	206	55	2	2	266
	2010	158	37	9	5	208
	2011	88	12	3	1	104
Age 2	2008	612	97	216	84	1010
	2009	523	190	11	4	728
	2010	415	149	40	37	640
	2011	330	57	10	3	399
Age 3+	2008	764	130	658	179	1730
	2009	723	299	54	10	1085
	2010	526	212	212	83	1032
	2011	462	104	60	5	631

RELATIVE TO 2008

	Box	Box 0	Box 1	Box 2	Box 3	All
Age	Year					
Age 1	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.95	2.21	0.05	0.11	0.87
	2010	0.72	1.50	0.20	0.26	0.69
	2011	0.41	0.47	0.07	0.04	0.34
Age 2	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.85	1.94	0.05	0.05	0.72
	2010	0.68	1.52	0.18	0.44	0.63
	2011	0.54	0.59	0.05	0.03	0.40
Age 3+	2008	1.00	1.00	1.00	1.00	1.00
	2009	0.95	2.30	0.08	0.05	0.63
	2010	0.69	1.63	0.32	0.46	0.60
	2011	0.61	0.80	0.09	0.03	0.36

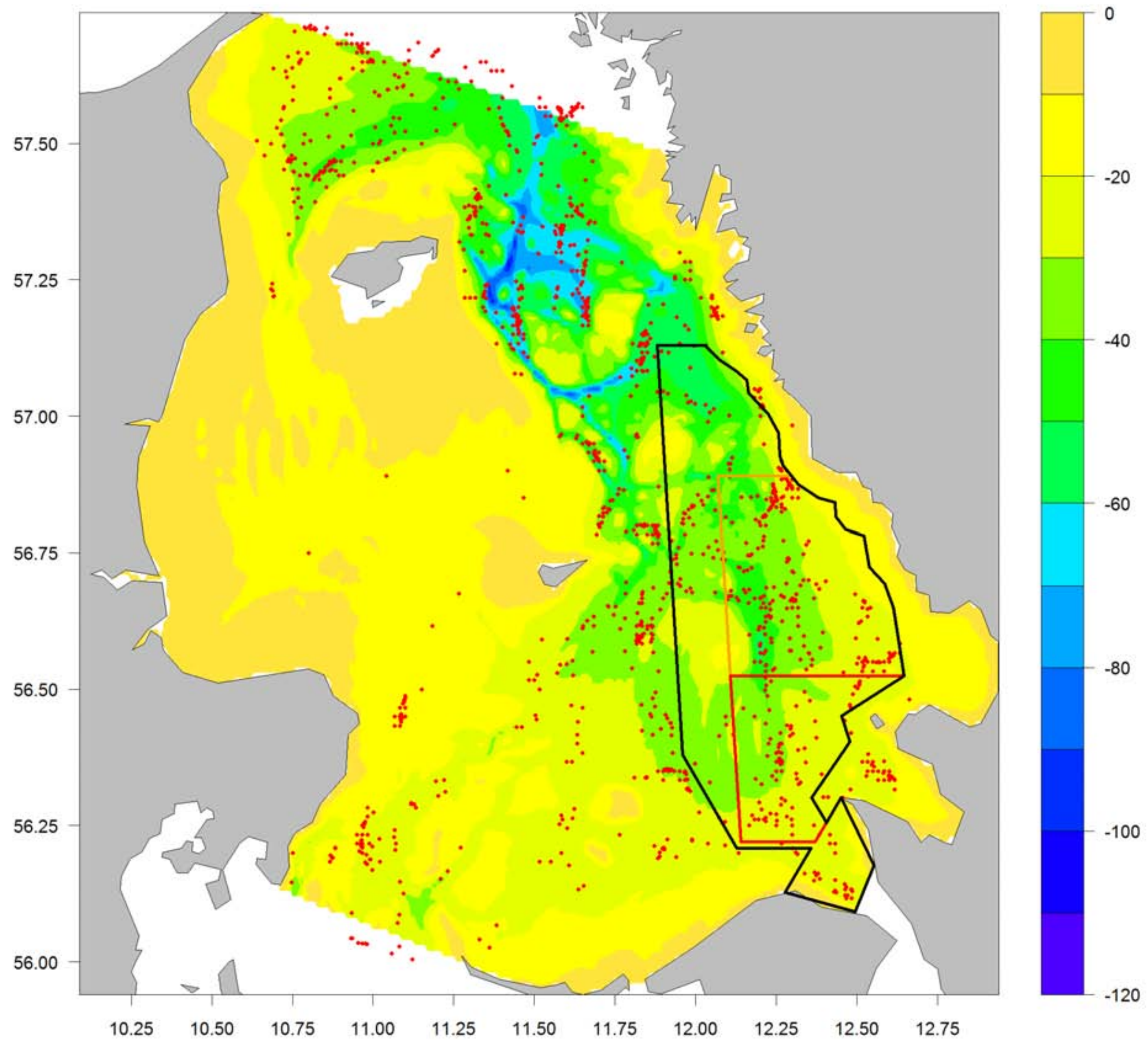

Figure 1. Bathymetry of Kattegat and the northern Sound (Kilen). The red dots show the location of trawl stations used for modelling stock distribution.

Closed areas:

- **Area 1: The "black" area is closed during the period 1st January-31th March, except for fishery with selective gears; The "black" area in the Northern Sound ("Kilen" or the Triangle) is closed 1st February -31th March, except for fishery with selective gears;**
- **Area 2. The "orange" area is closed for all fisheries in the period 1st January-31th March. Fisheries with selective gears is allowed 1st April - 31th December;**
- **Area 3: The "red" area is closed for all fisheries, including recreational fisheries;**

"Selective gears" refers to trawls equipped with sorting grid or SELTRA 300;

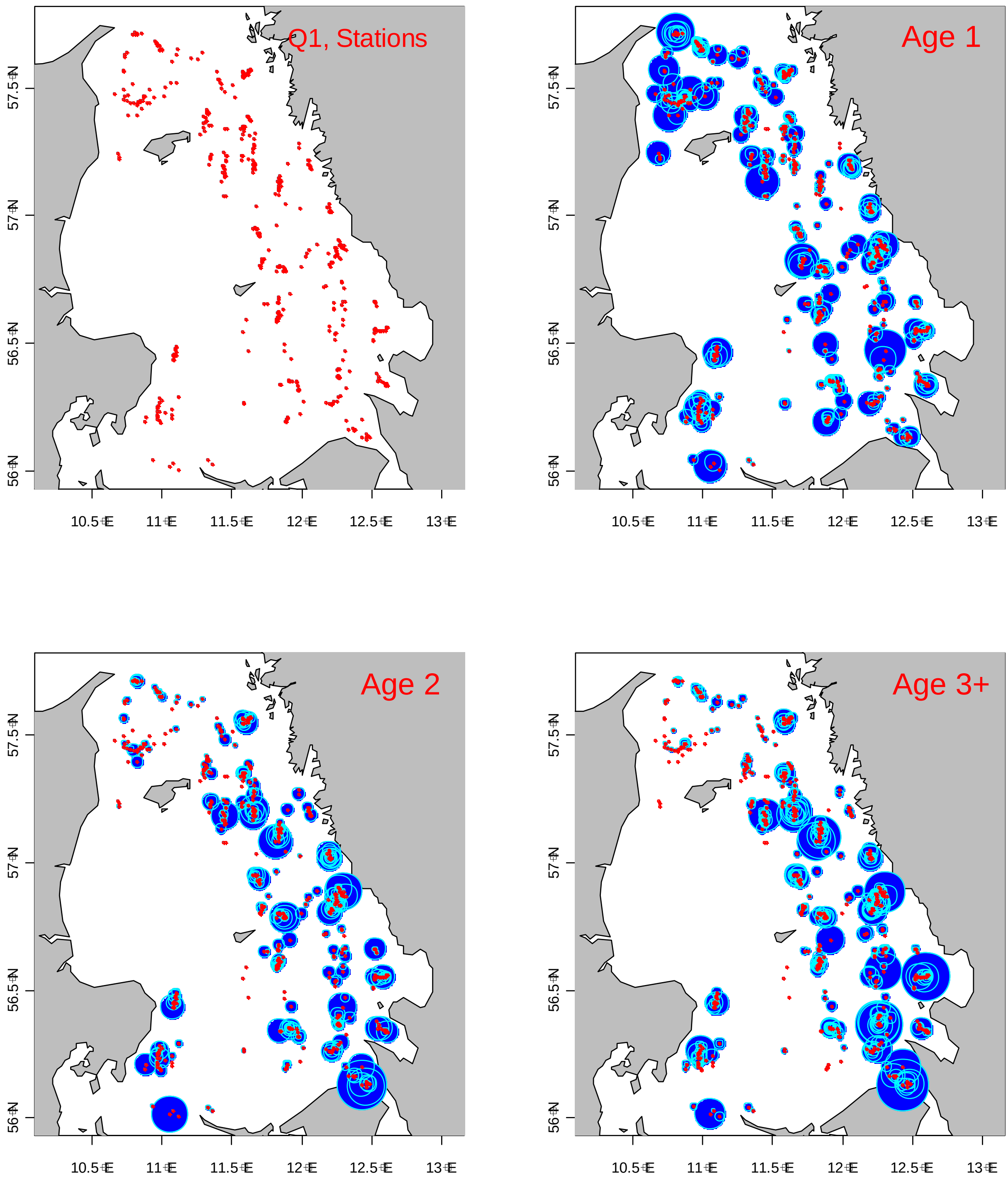

Figure 2. Distribution of trawl stations (red points) and CPUE at age by station from Quarter 1, IBTS and Havfisken surveys, 1996-2011. The area of the blue dots is proportional to CPUE. The scaling of CPUE~dot size is different between ages.

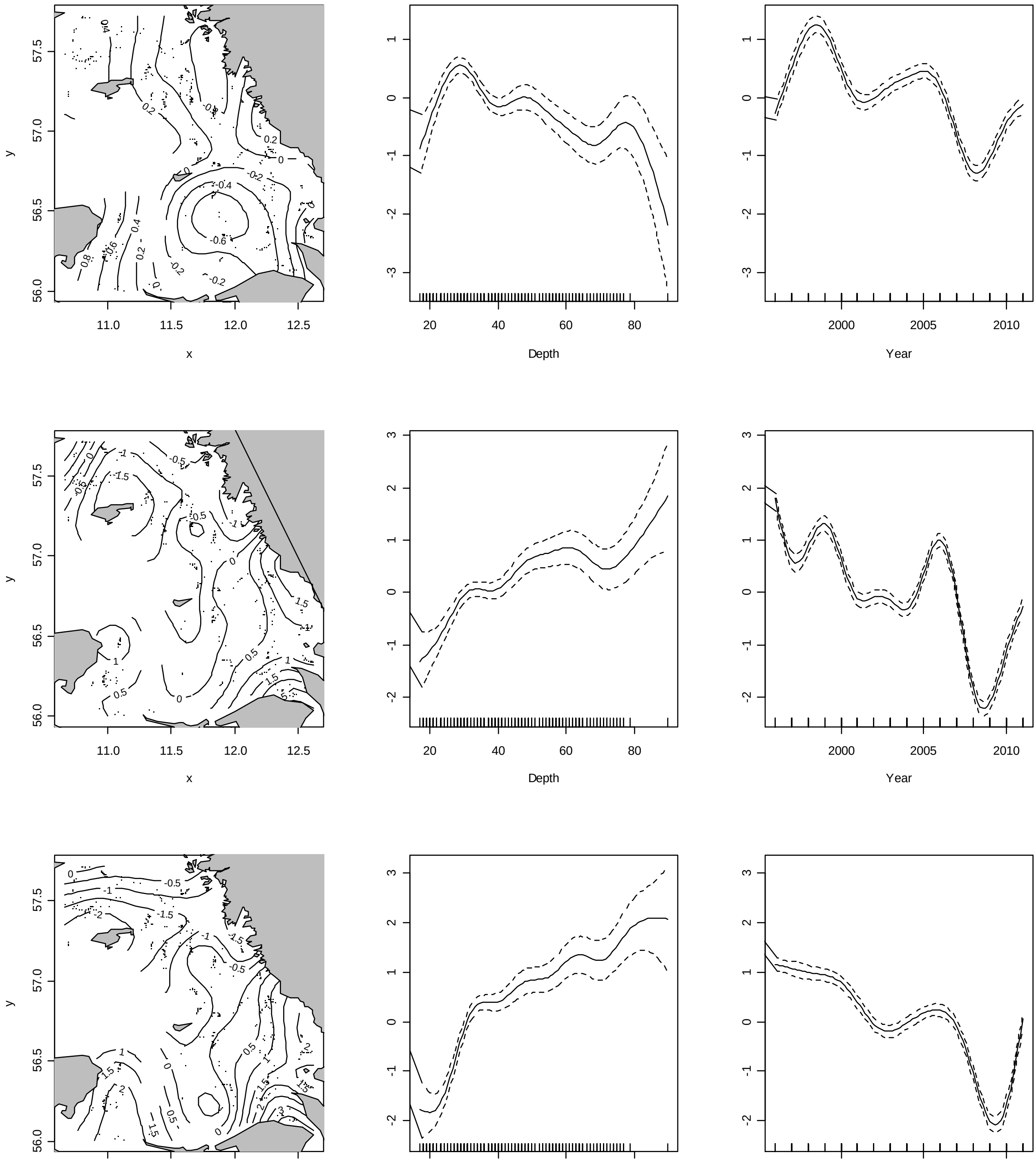

Figure 3. Predicted effect of position (latitude, longitude), depth and year as estimated by GAM models on CPUE (number) at age in Quarter 1 surveys. Top row presents results for age 1, second row for age 2 and bottom row for age 3+. For depth and year effects, the mean values and 95% confidence interval are shown.

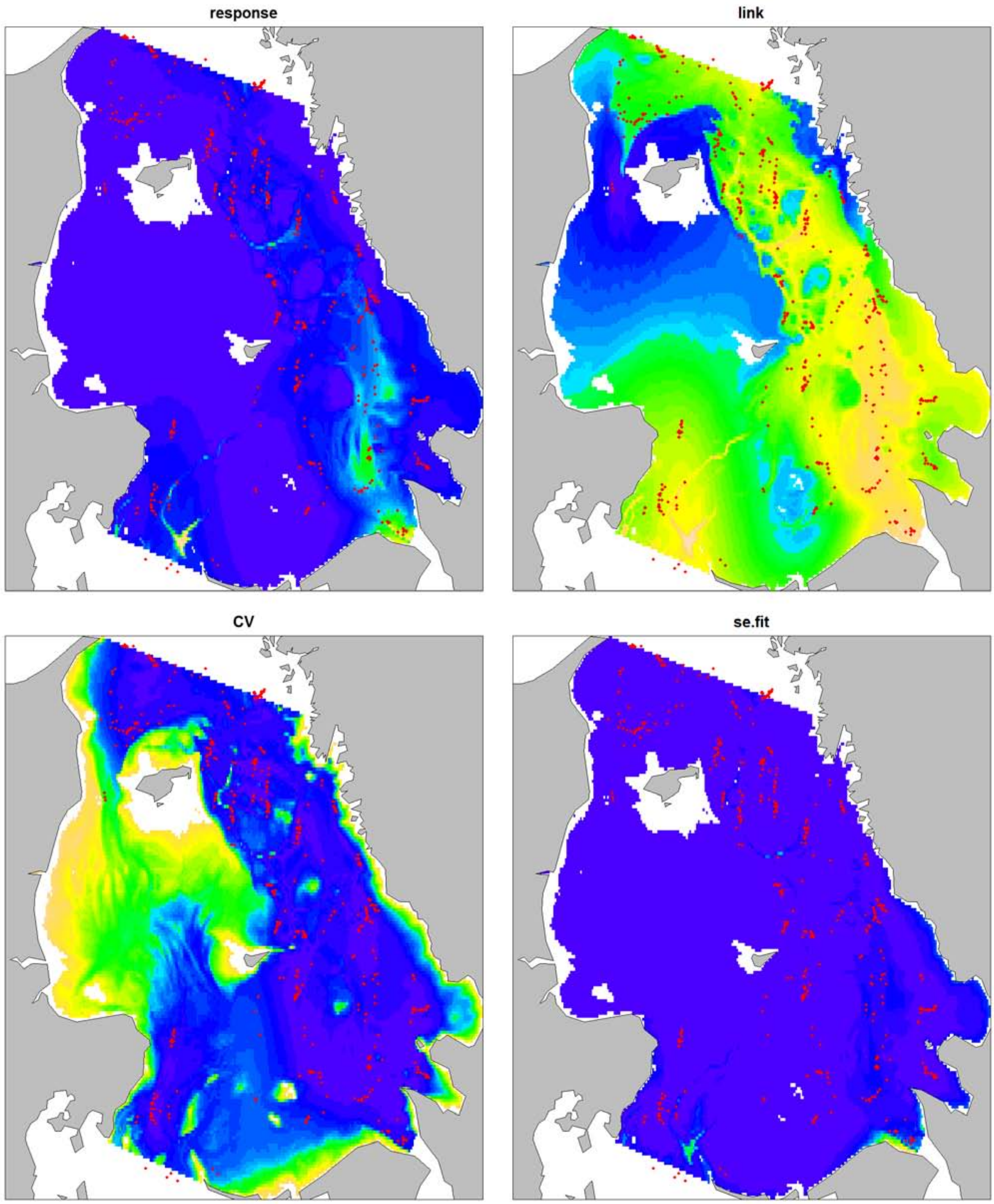

Figure 4. Predicted stock distribution and uncertainties, quarter 1. Age 3 plus. "Response" is the predicted value, "link" is the log (linked) value, CV is the coefficient of variation and se.fit is the standard deviation of the predicted value. Blue show low value, green medium and yellow – orange the highest values. White areas are outside the Kattegat or on depth less than 5 m.

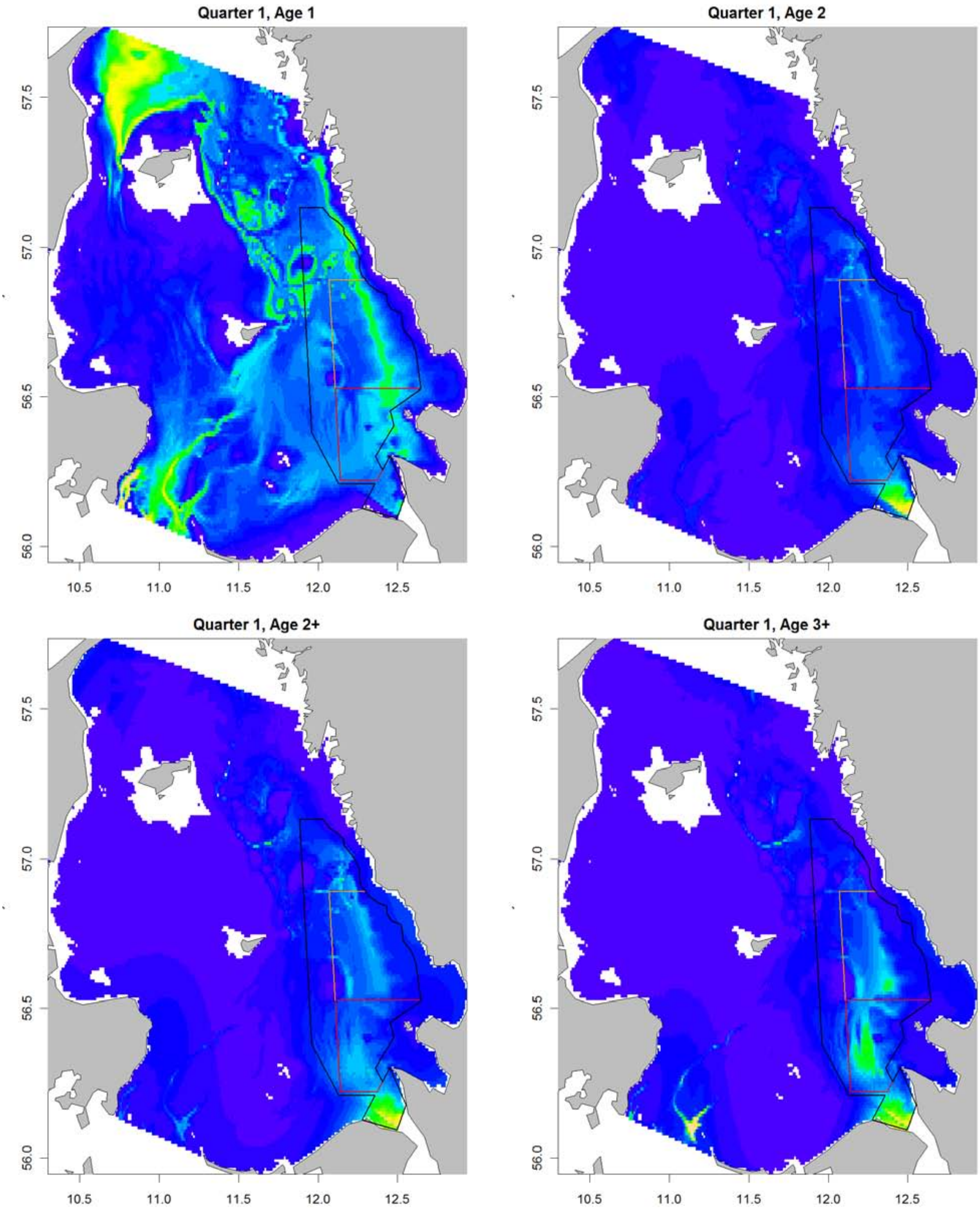

Figure 5. Predicted stock distribution, quarter 1. Blue show low density, green medium and yellow – orange the highest densities. White areas are outside the Kattegat or on depth less than 5 m.

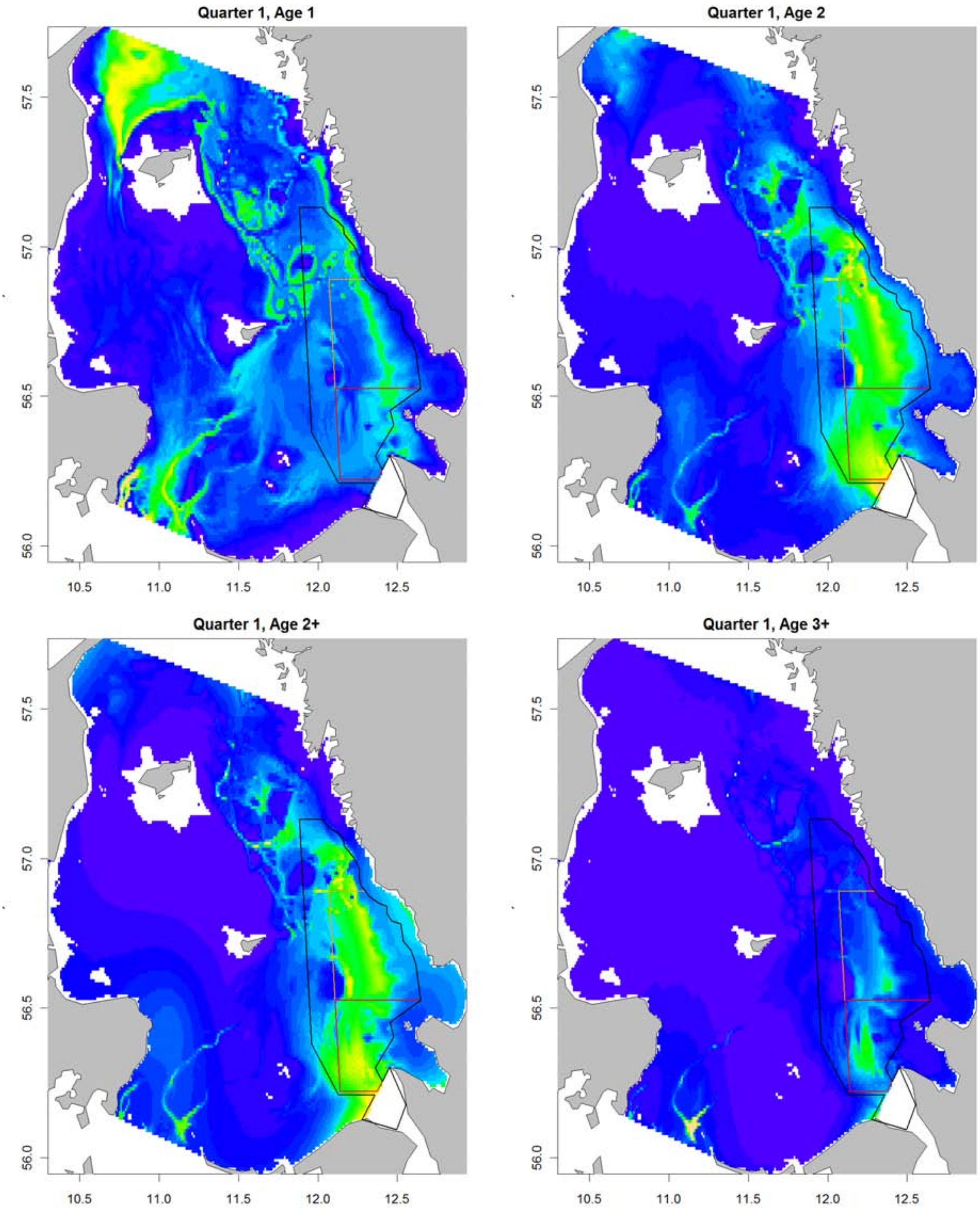

Figure 6. Predicted stock distribution, quarter 1 WITHOUT "KILEN" AREA. Blue show low density, green medium and yellow – orange the highest densities. White areas are outside the Kattegat or on depth less than 5 m.

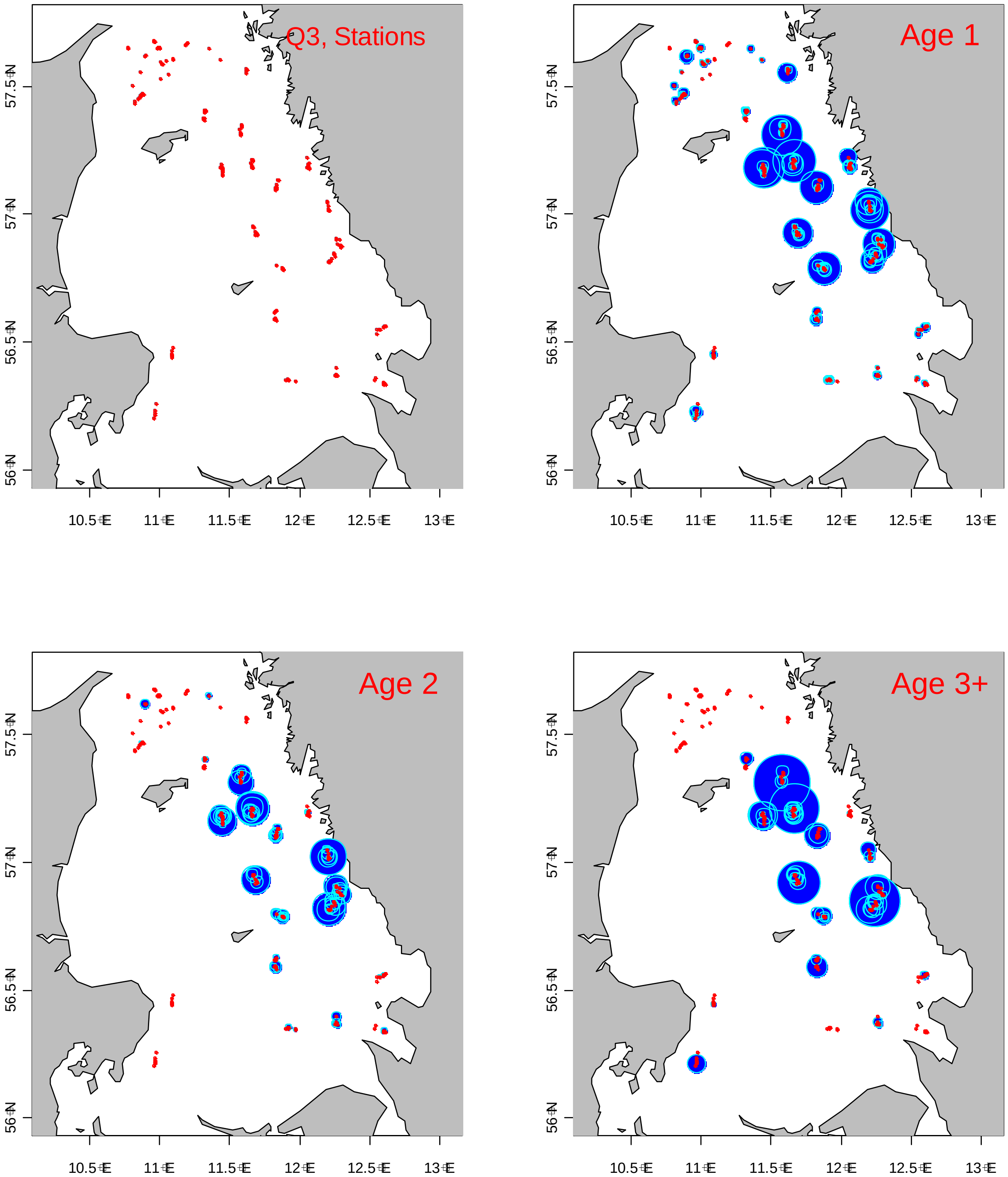

Figure 7. Distribution of trawl station (red points) and CPUE at age by station from Quarter 3, IBTS, 2001-2010. The area of the blue dots is proportional to CPUE. The scaling of CPUE~dot size is different between ages.

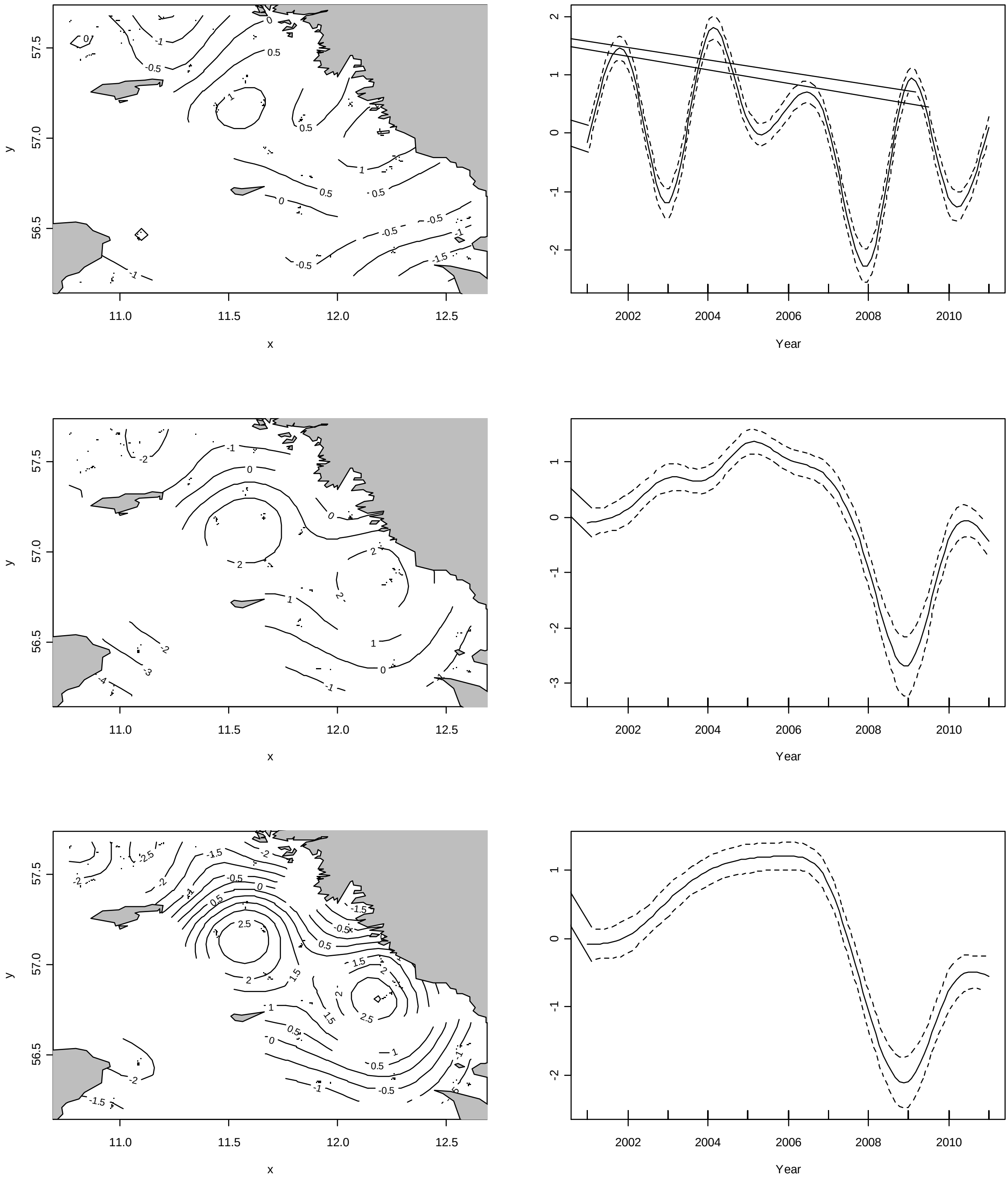

Figure 8. Predicted effect of position (latitude, longitude), depth and year as estimated by GAM models on CPUE (number) at age in Quarter 3 survey. Top row presents results for age 1, second row for age 2 and bottom row for age 2+. For depth and year effect, the mean value and 95% confidence interval are shown.

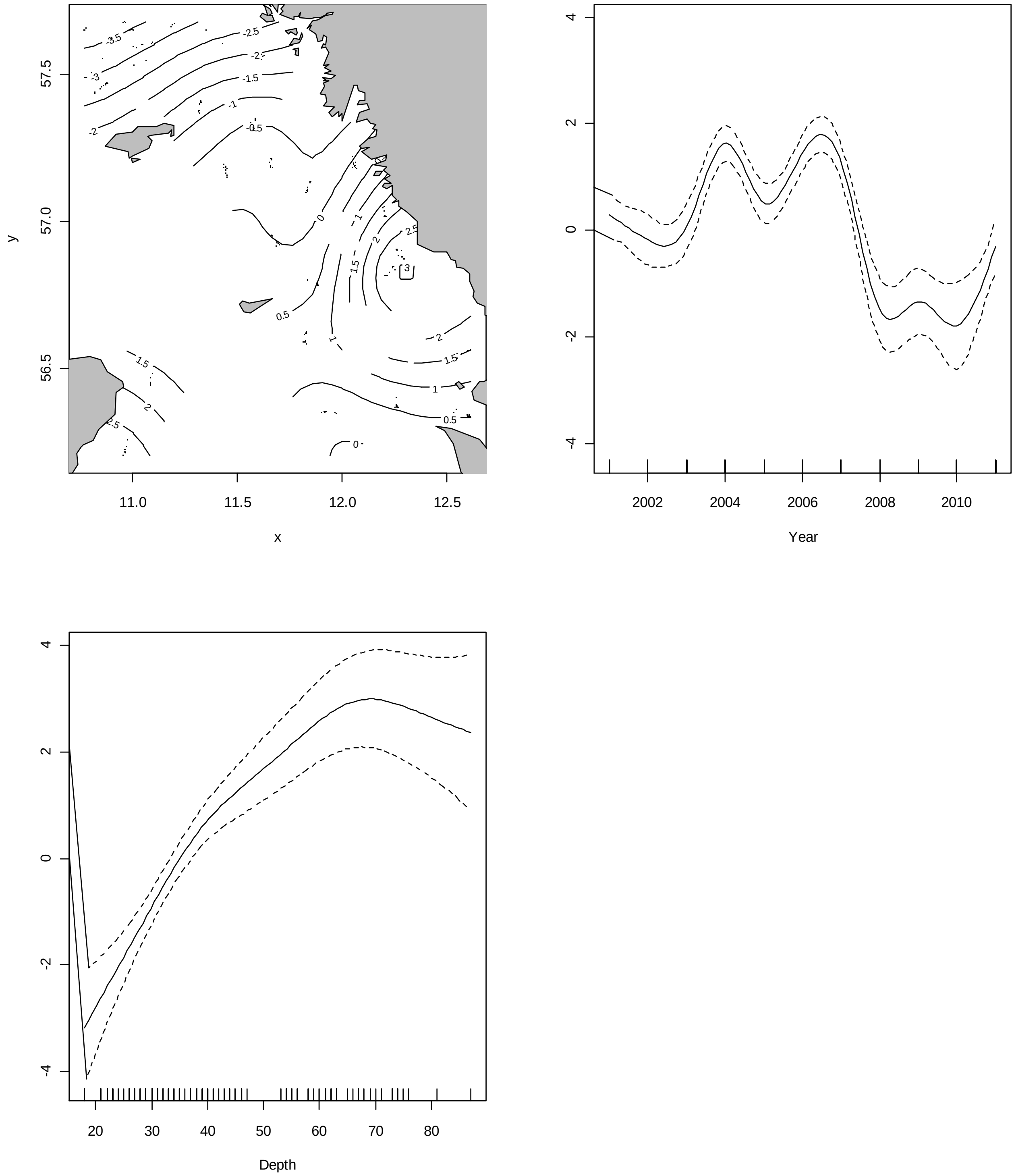

Figure 8 (continued) Plots of predicted effect of position (latitude, longitude), depth and year as estimated by GAM models on CPUE (number) at age in Quarter 3 survey, age 3+. For depth and year effect, the mean value and 95% confidence interval are shown.

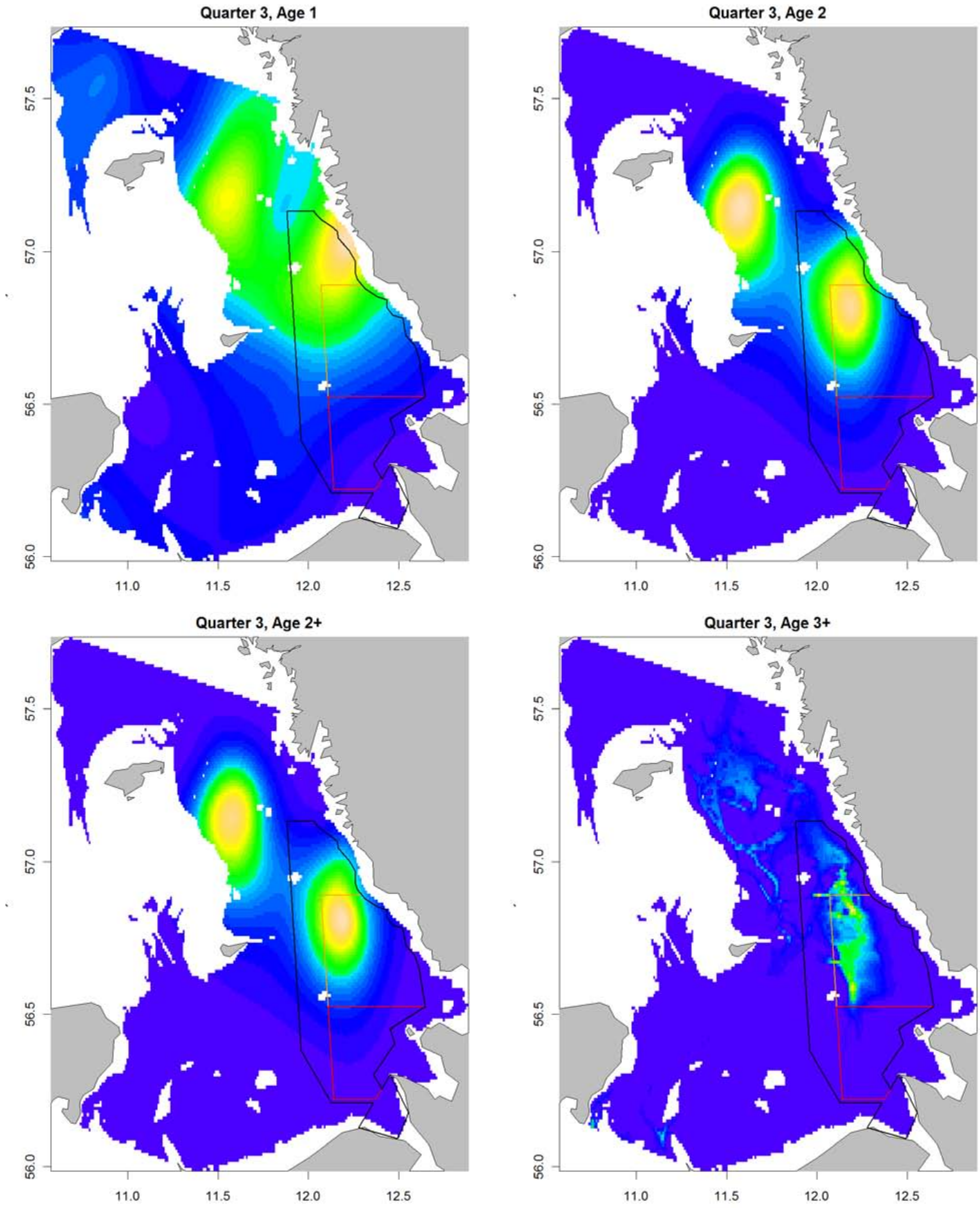

Figure 9. Predicted stock distribution, quarter 3. Blue show low density, green medium and yellow – orange the highest densities. White areas are outside the Kattegat or on depth less than 15 m.

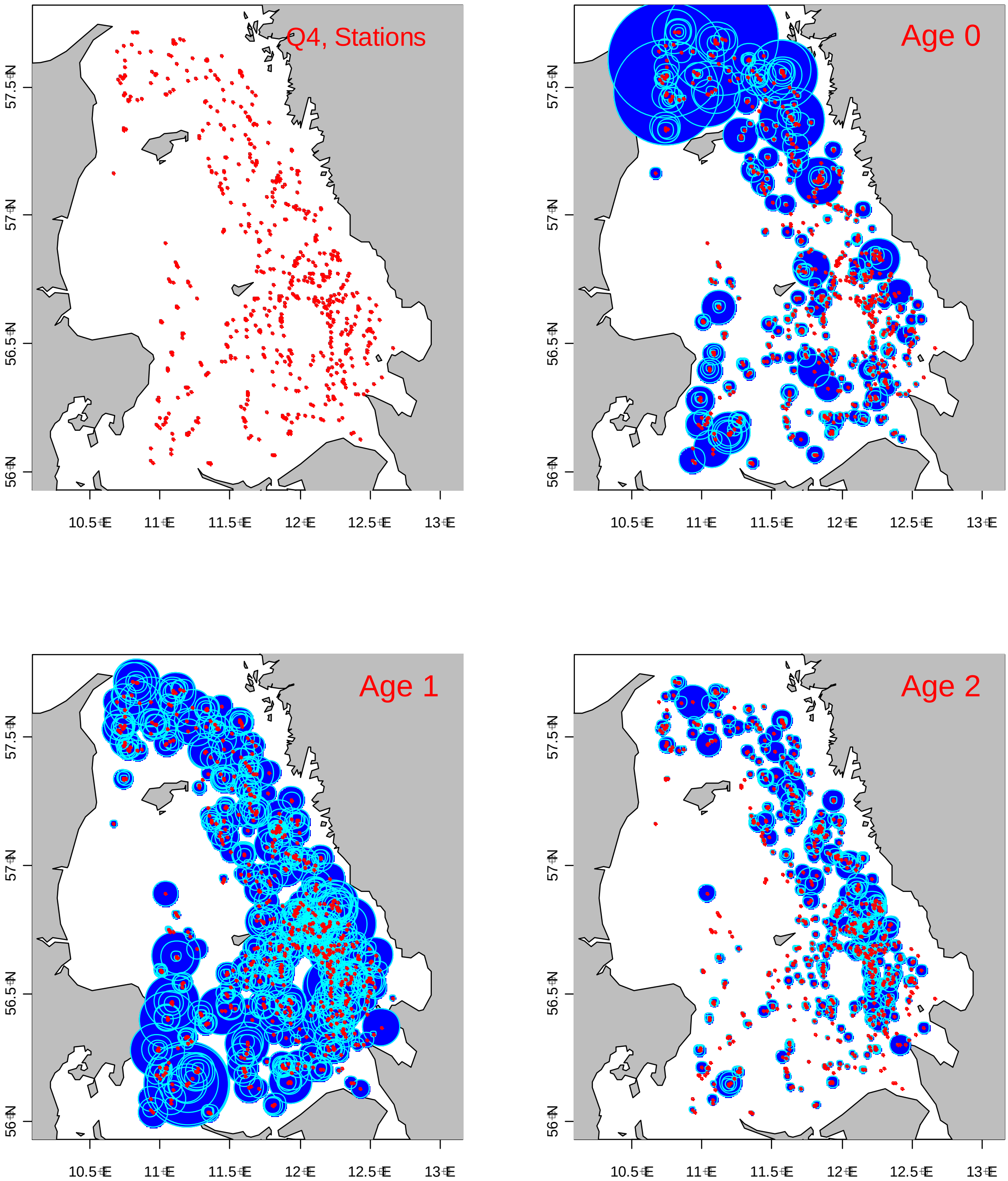

Figure 10. Distribution of trawl stations (red points) and CPUE at age by station from Quarter 4, 2008-2011, Danish-Swedish cod survey, Sole survey and Havfisken survey. The area of the blue dots is proportional to CPUE. The scaling of CPUE~dot size is different between ages.

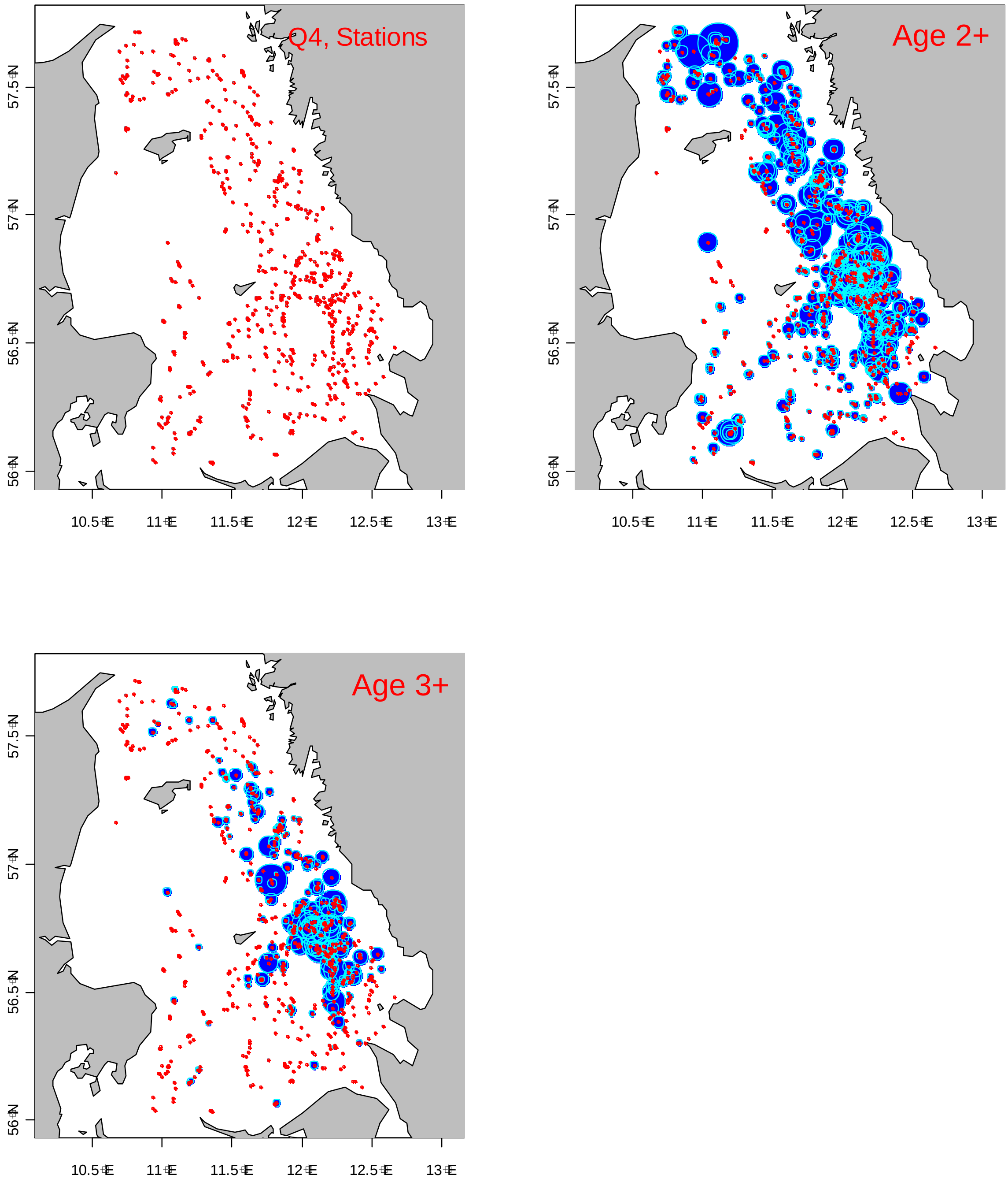

Figure 10 (continued). Distribution of trawl stations (red points) and CPUE at age by station from Quarter 4, 2008-2011, Danish-Swedish cod survey, Sole survey and Havfisken survey. The area of the blue dots is proportional to CPUE. The scaling of CPUE~dot size is different between ages.

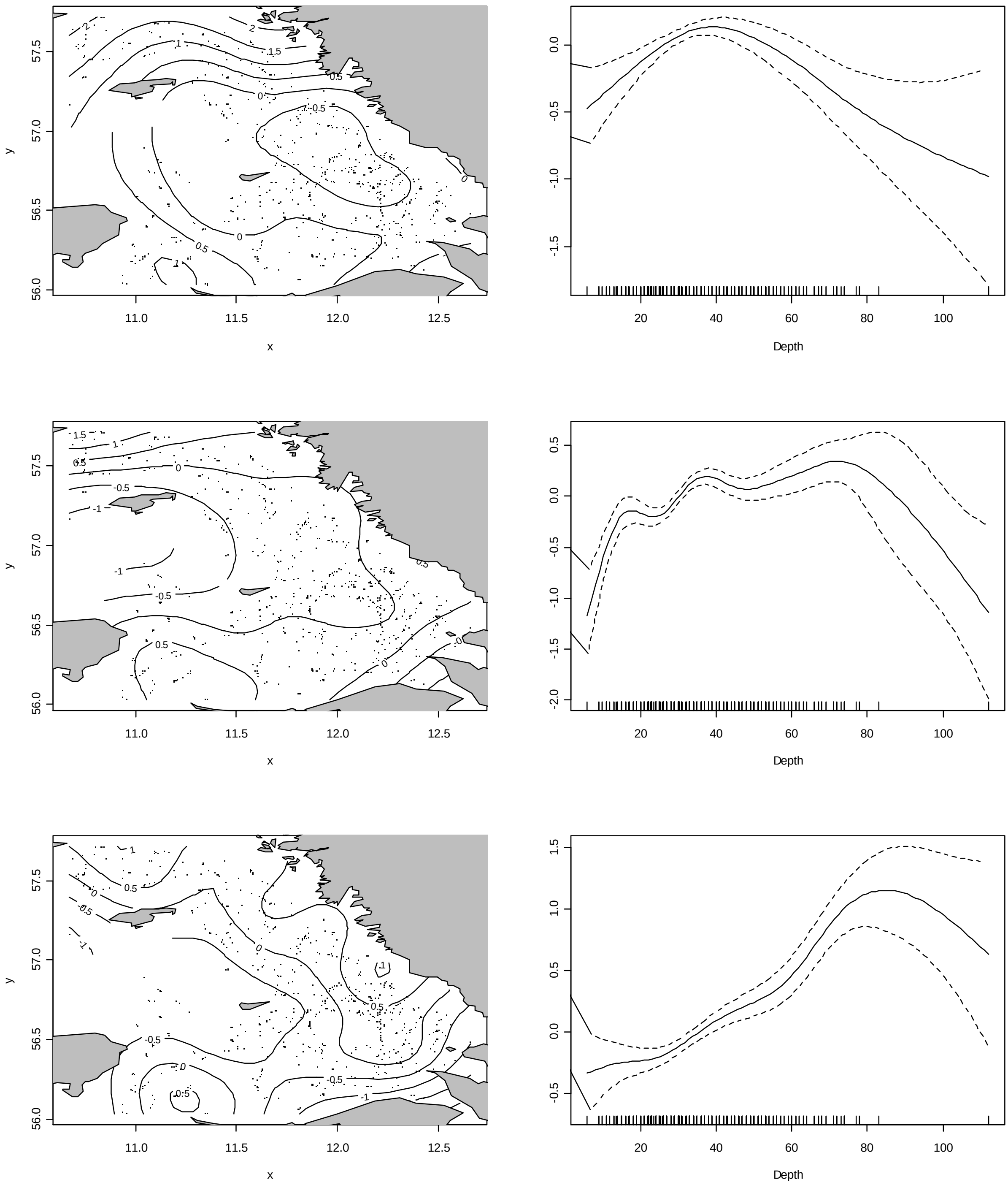

Figure 11. Predicted effect of position (latitude, longitude), depth and year as estimated by GAM models on CPUE (number) at age in Quarter 4 survey, age 0 (top), age 1 and age 2 (bottom row). For depth and year effect, the mean value and 95% confidence interval are shown.

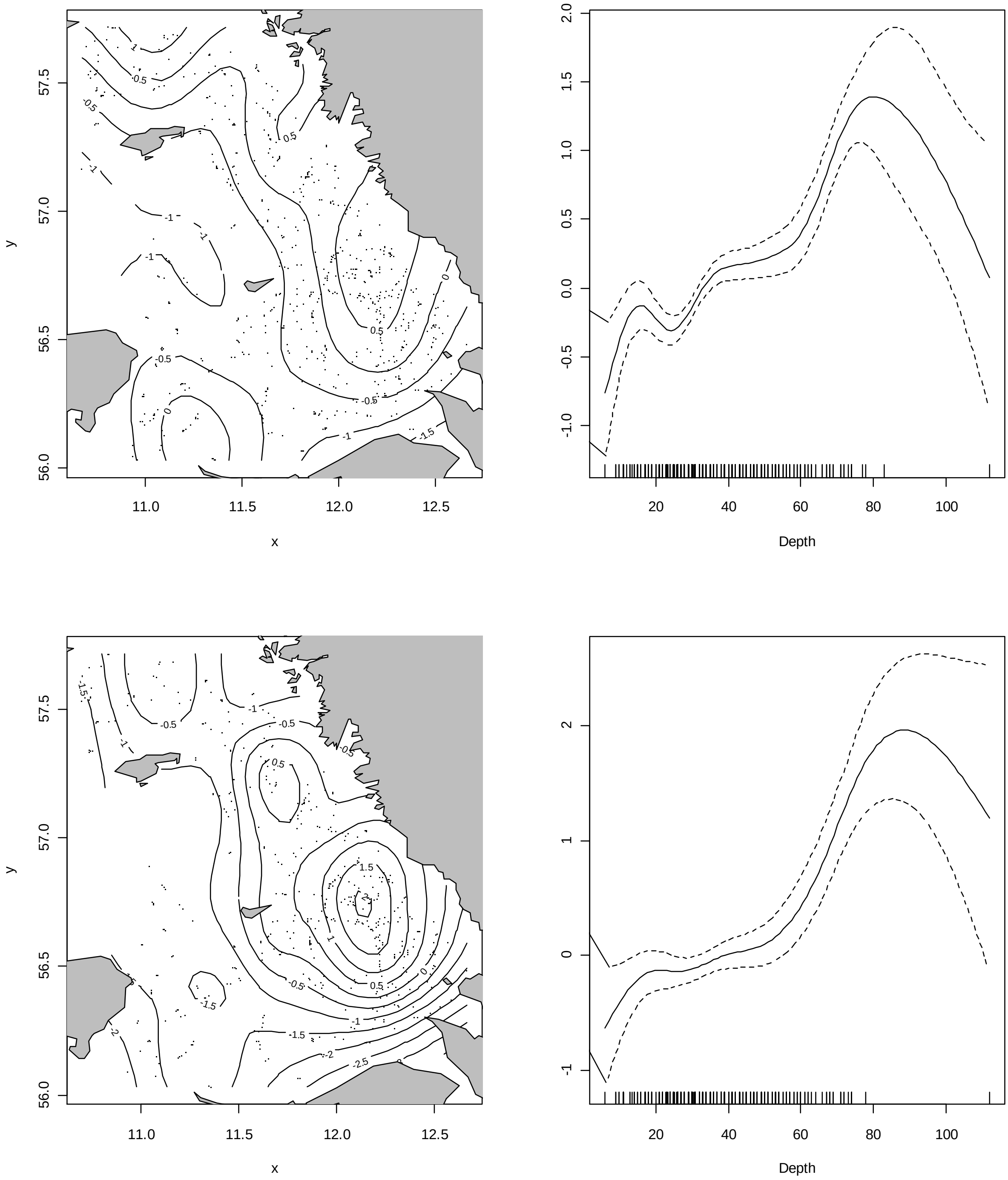

Figure 10 (continued). Plots of predicted effect of position (latitude, longitude), depth and year as estimated by GAM models on CPUE (number) at age in Quarter 4 survey, age 2+ (top) and age 3+ (bottom row). For depth effect, the mean value and 95% confidence interval are shown.

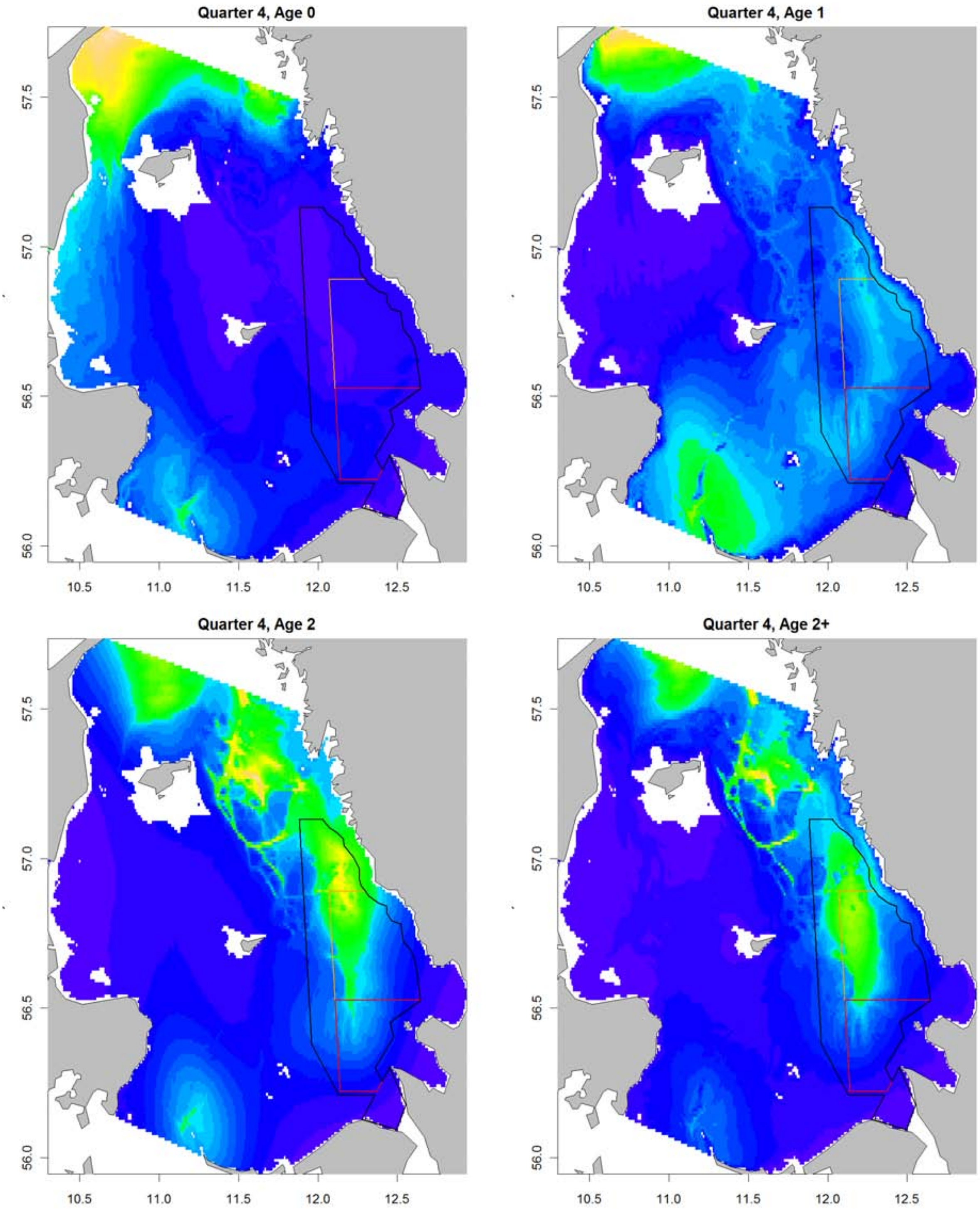

Figure 12. Predicted stock distribution, quarter 4. Blue show low density, green medium and yellow – orange the highest densities. White areas are outside the Kattegat or on depth less than 5 m.

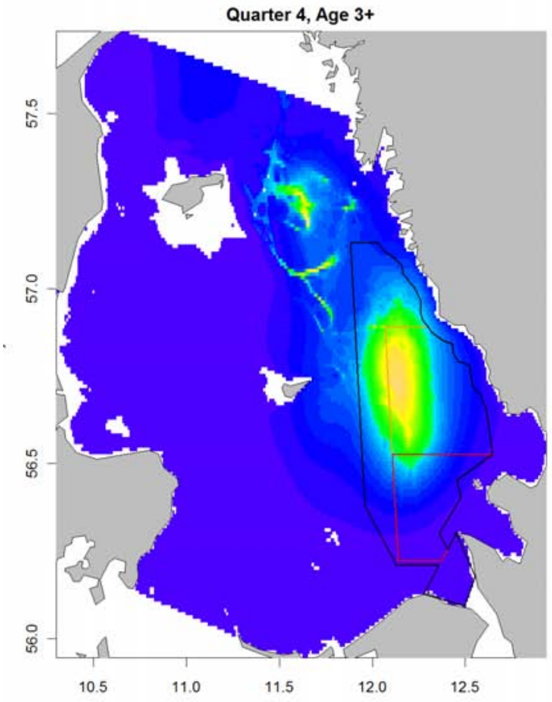

Figure 12 (continued). Predicted stock distribution, quarter 4. Blue show low density, green medium and yellow – orange the highest densities. White areas are outside the Kattegat or on depth less than 5 m.

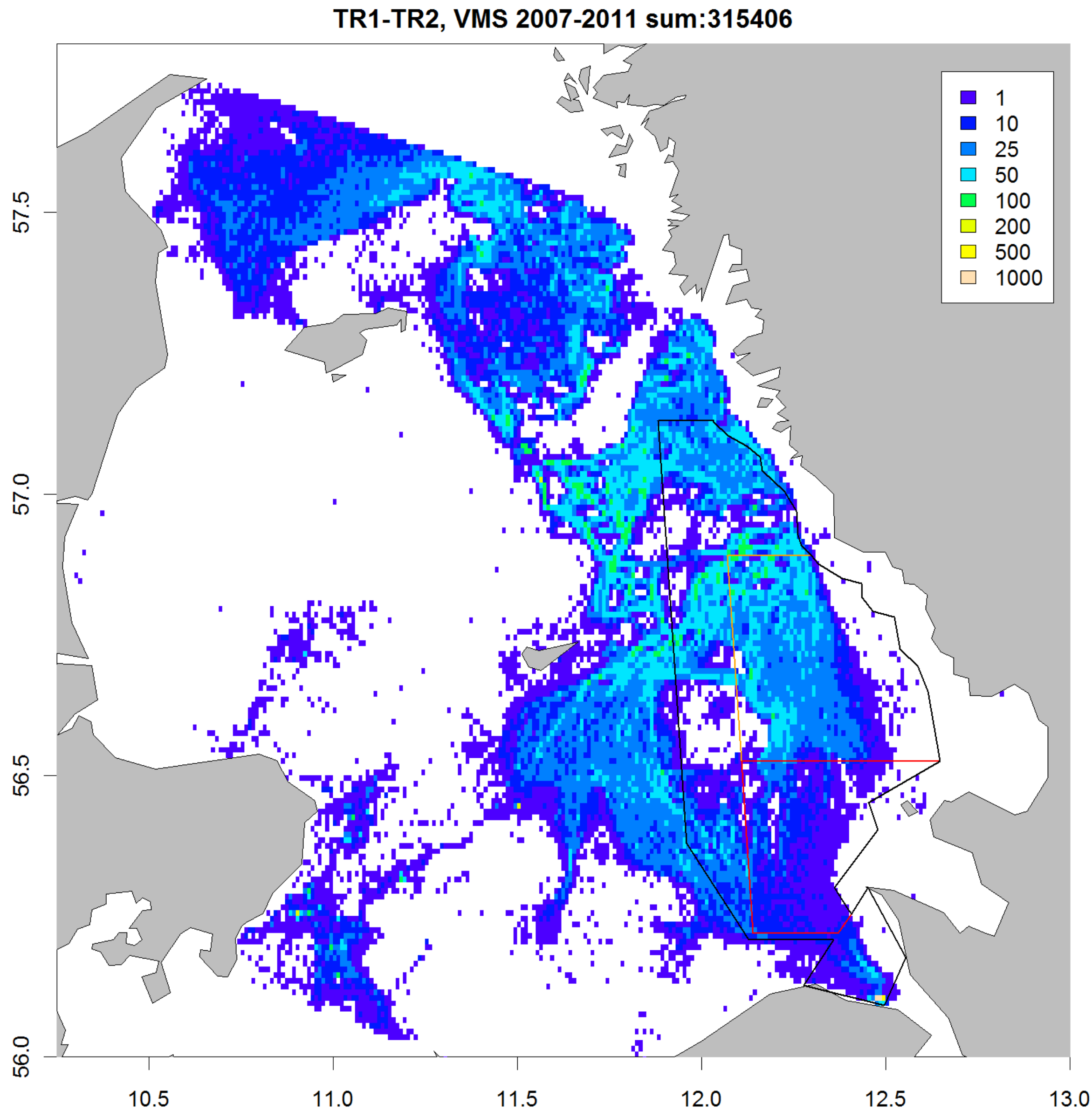

Figure 13. Distribution of Danish and Swedish fishing effort (sum of VMS hourly ping assigned to fishery) for segment TR1 and TR2 combined in Kattegat and the Sound. Spatial resolution is 0.01 degree. The scale shows the lower limit of the range, e.g. "1" denotes the range 1-9 pings, "10" the range 10-24 pings etc.

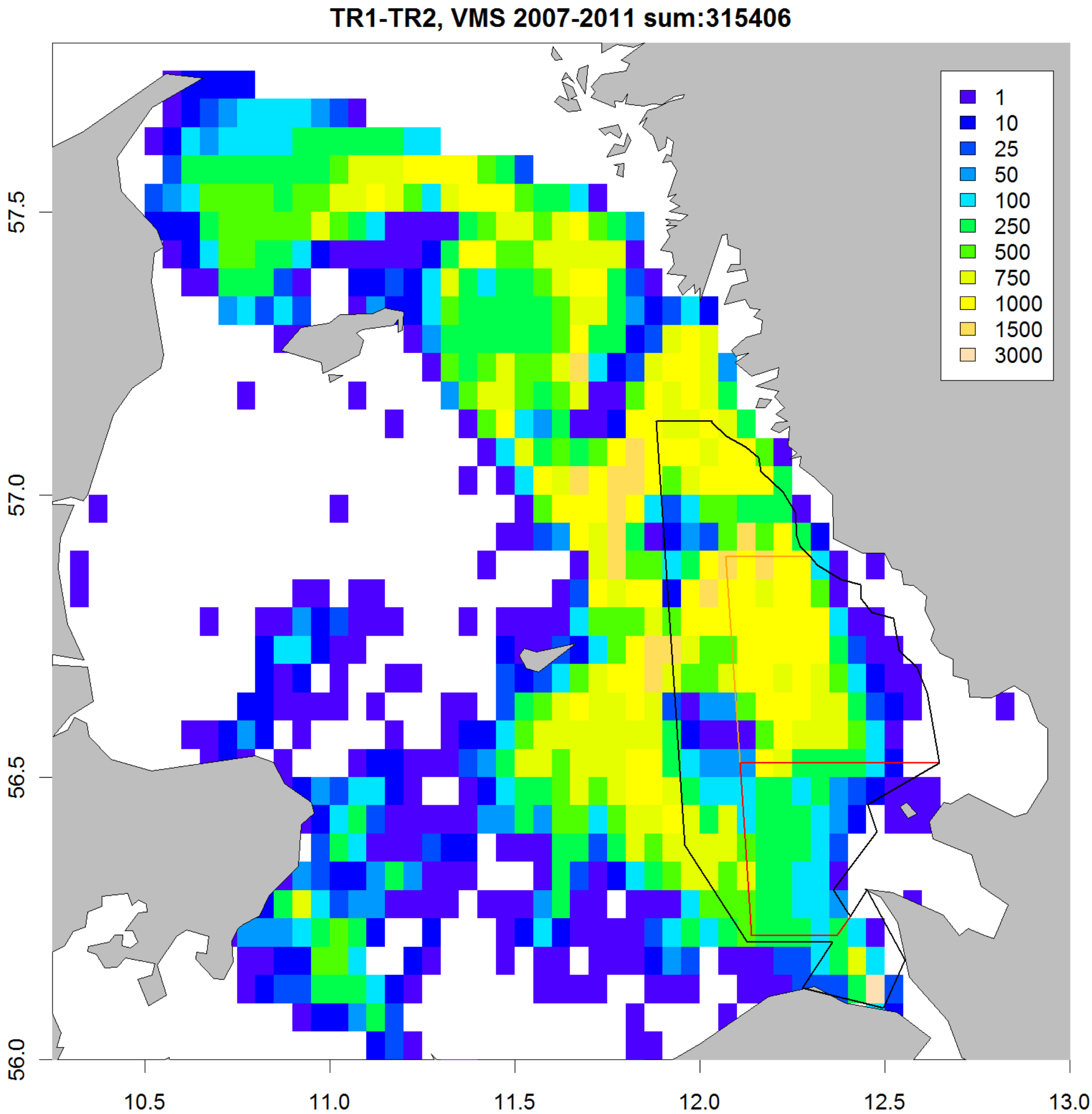

Figure 14. Distribution of Danish and Swedish fishing effort (sum of VMS hourly ping assigned to fishery) for segment TR1 and TR2 combined. Spatial Resolution is 0.05 degree.

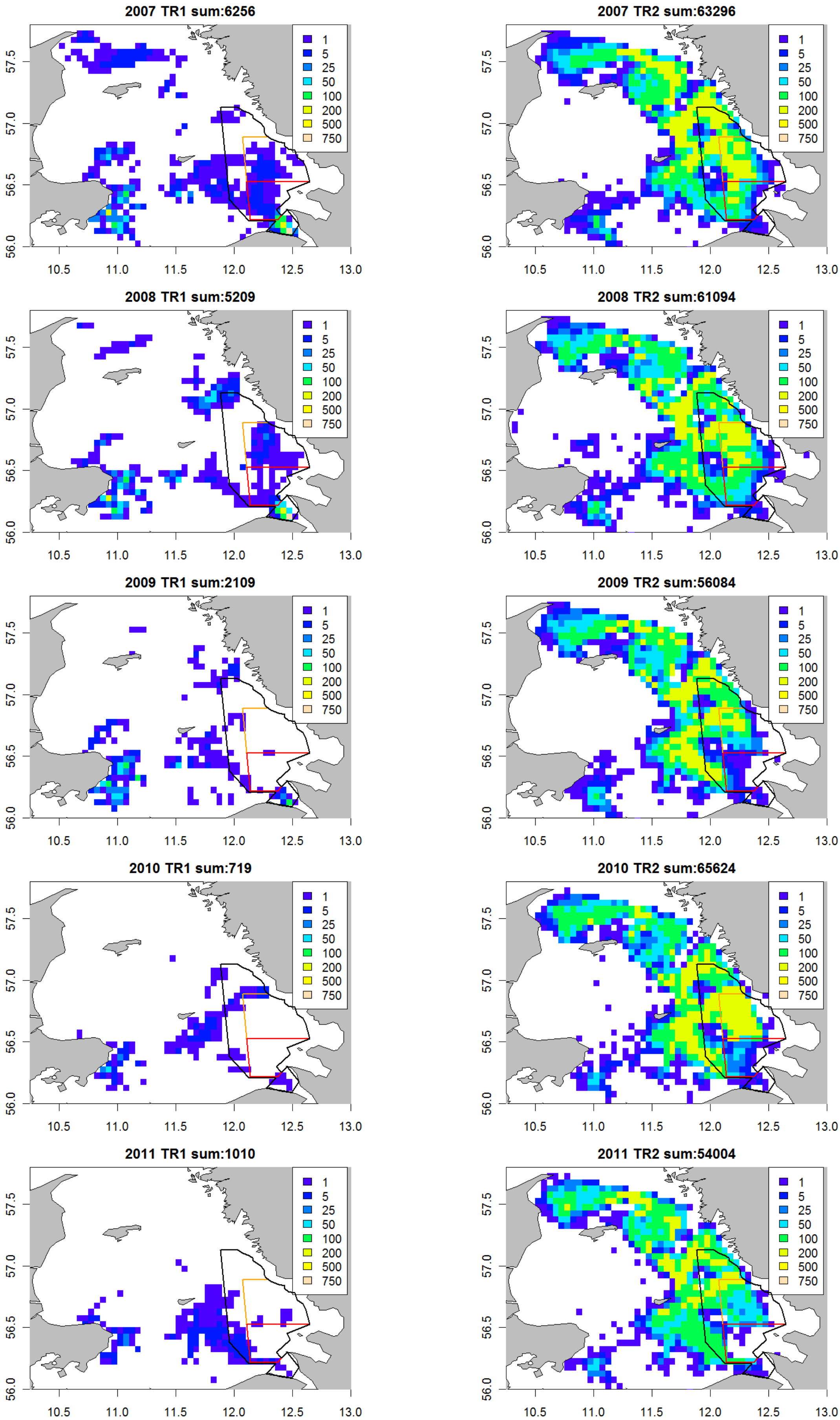

Figure 15. Distribution fishing effort (sum of VMS hourly ping assigned to fishery) for segment TR1 and TR2.

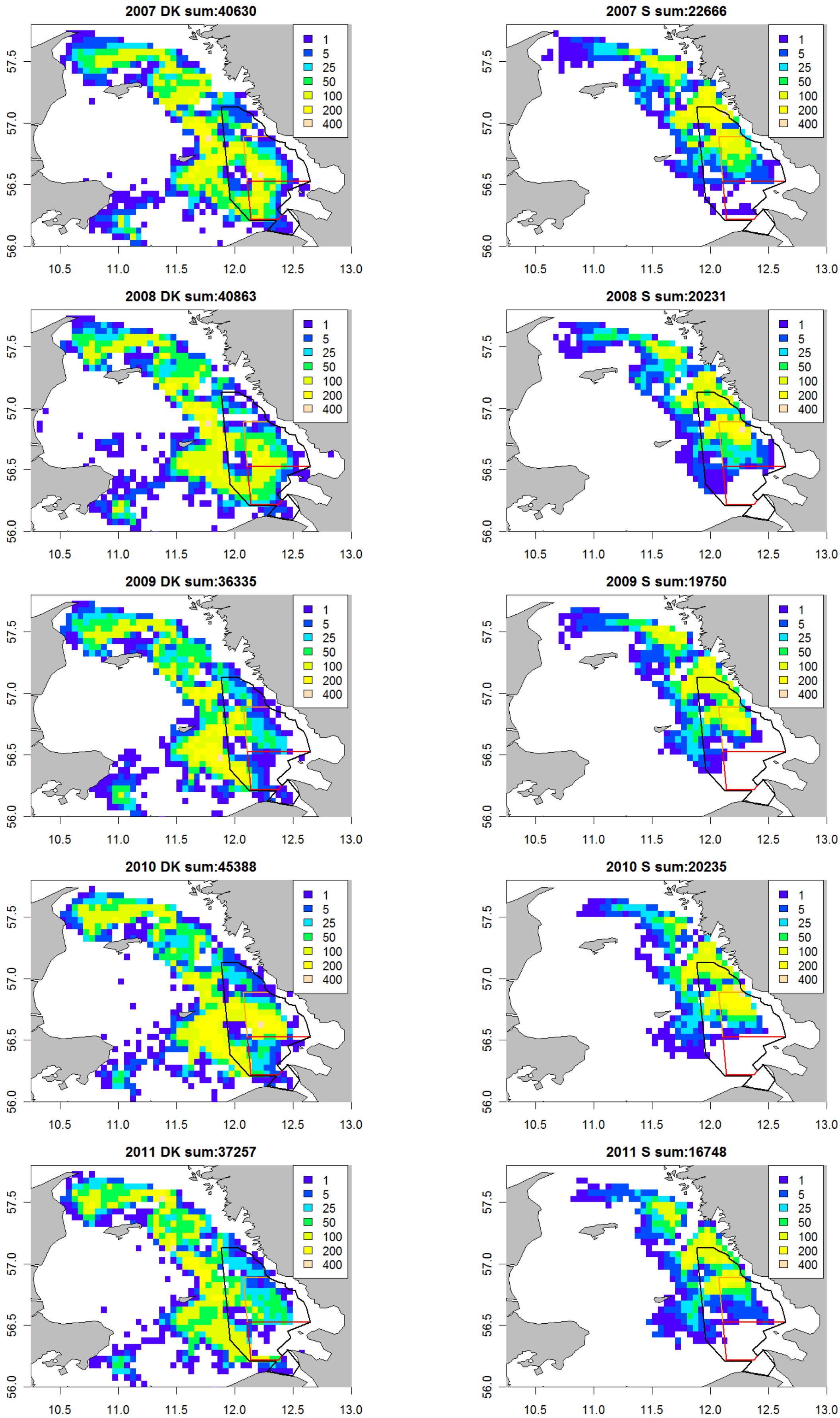

Figure 16. Distribution fishing effort (sum of VMS hourly ping assigned to fishery) Danish and Swedish TR2 segment.

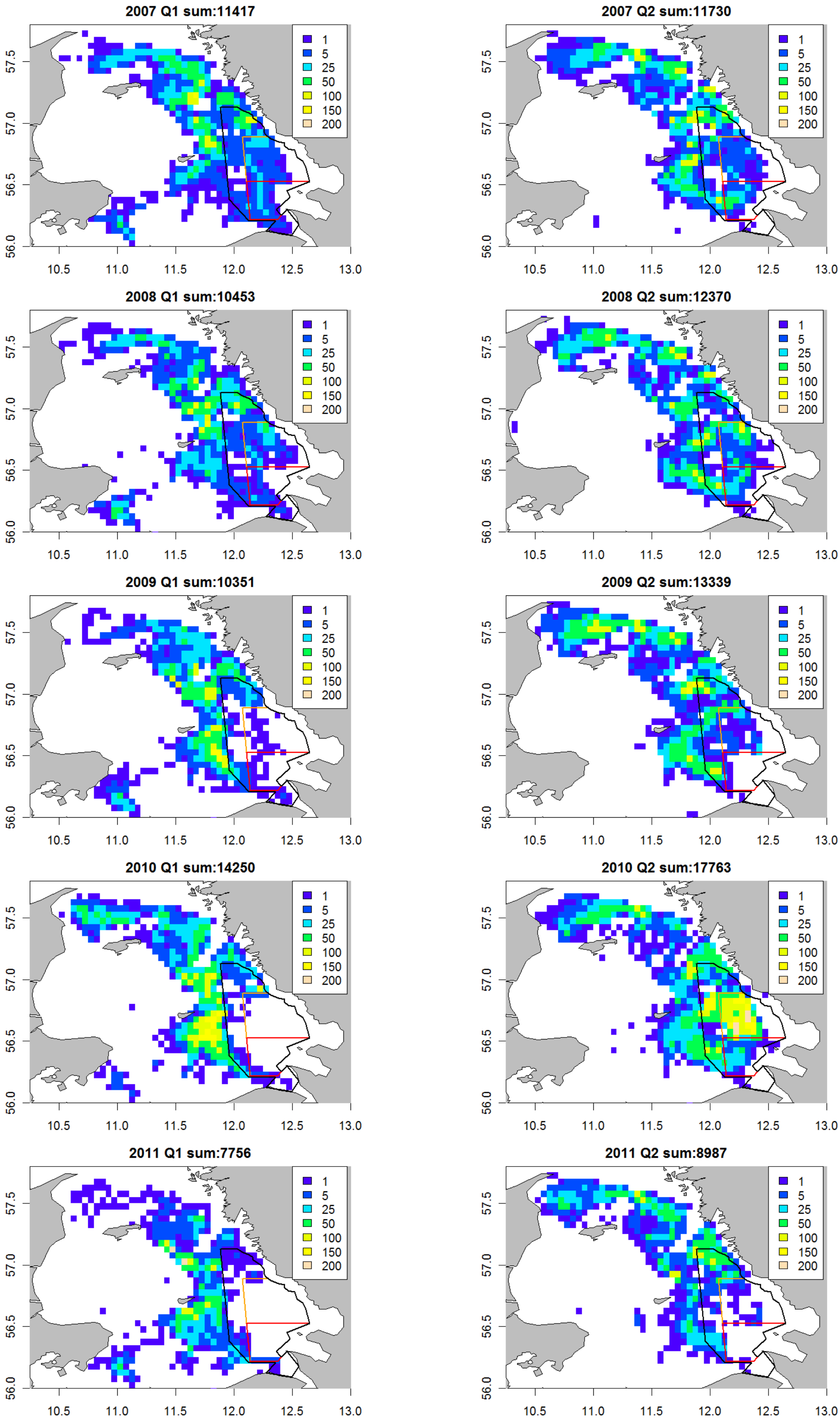

Figure 17. Distribution fishing effort (sum of VMS hourly ping assigned to fishery) for TR2 segment by year and quarter.

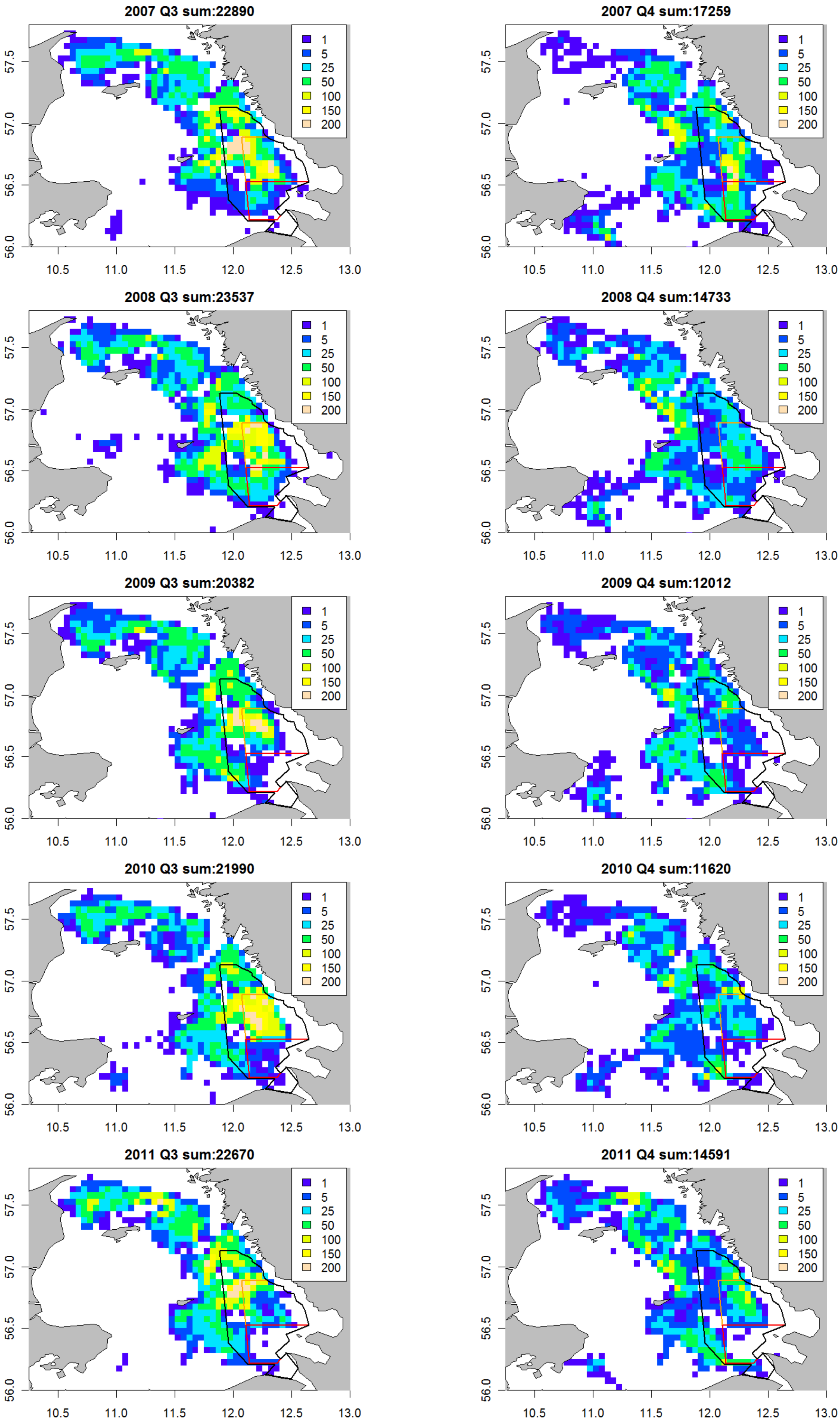

Figure 18 Distribution fishing effort (sum of VMS hourly ping assigned to fishery) for TR2 segment by year and quarter, Danish and Swedish data combined

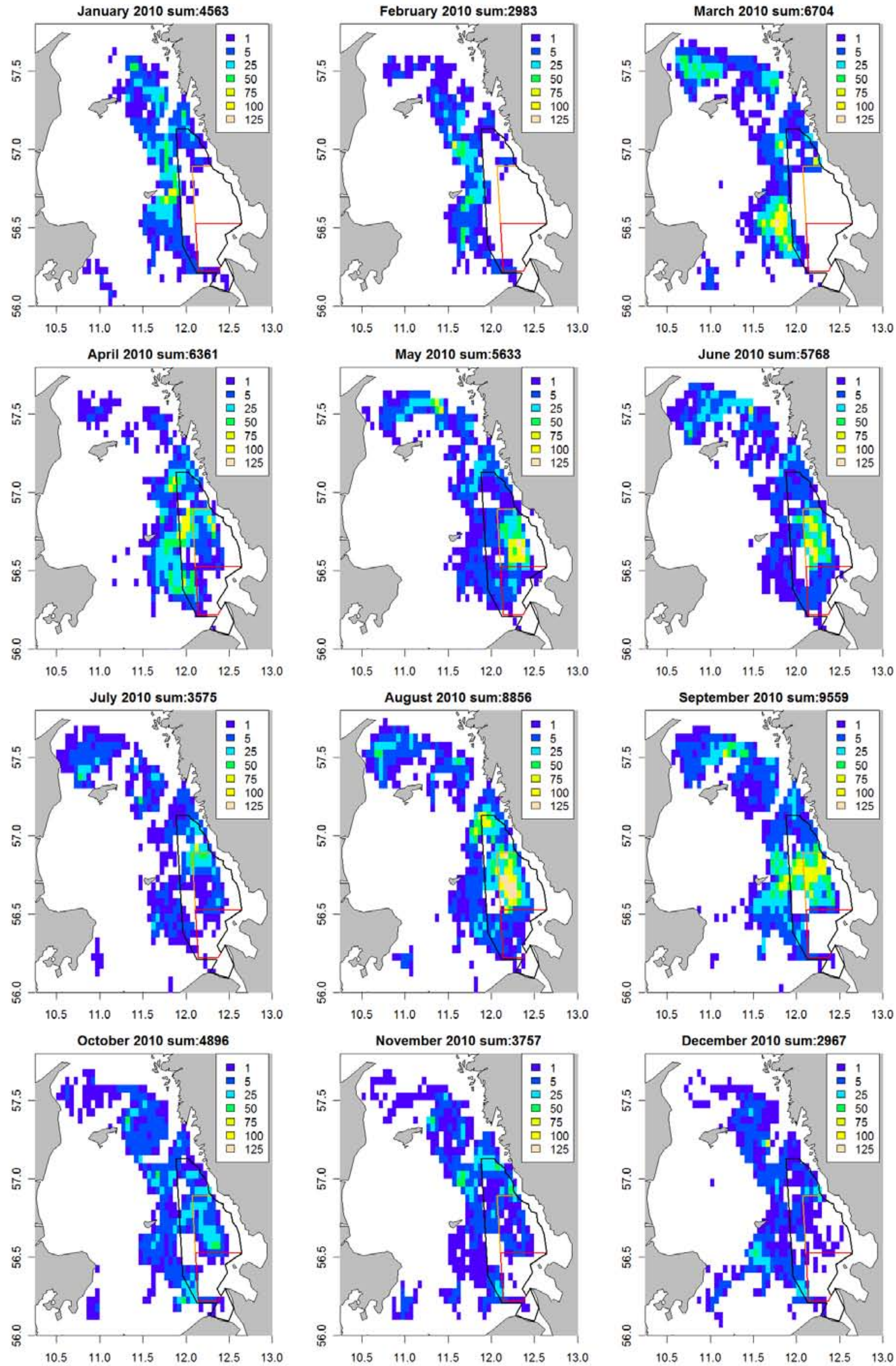

Figure 19. Distribution monthly fishing effort (sum of VMS hourly ping assigned to fishery) for TR2 segment in 2010.

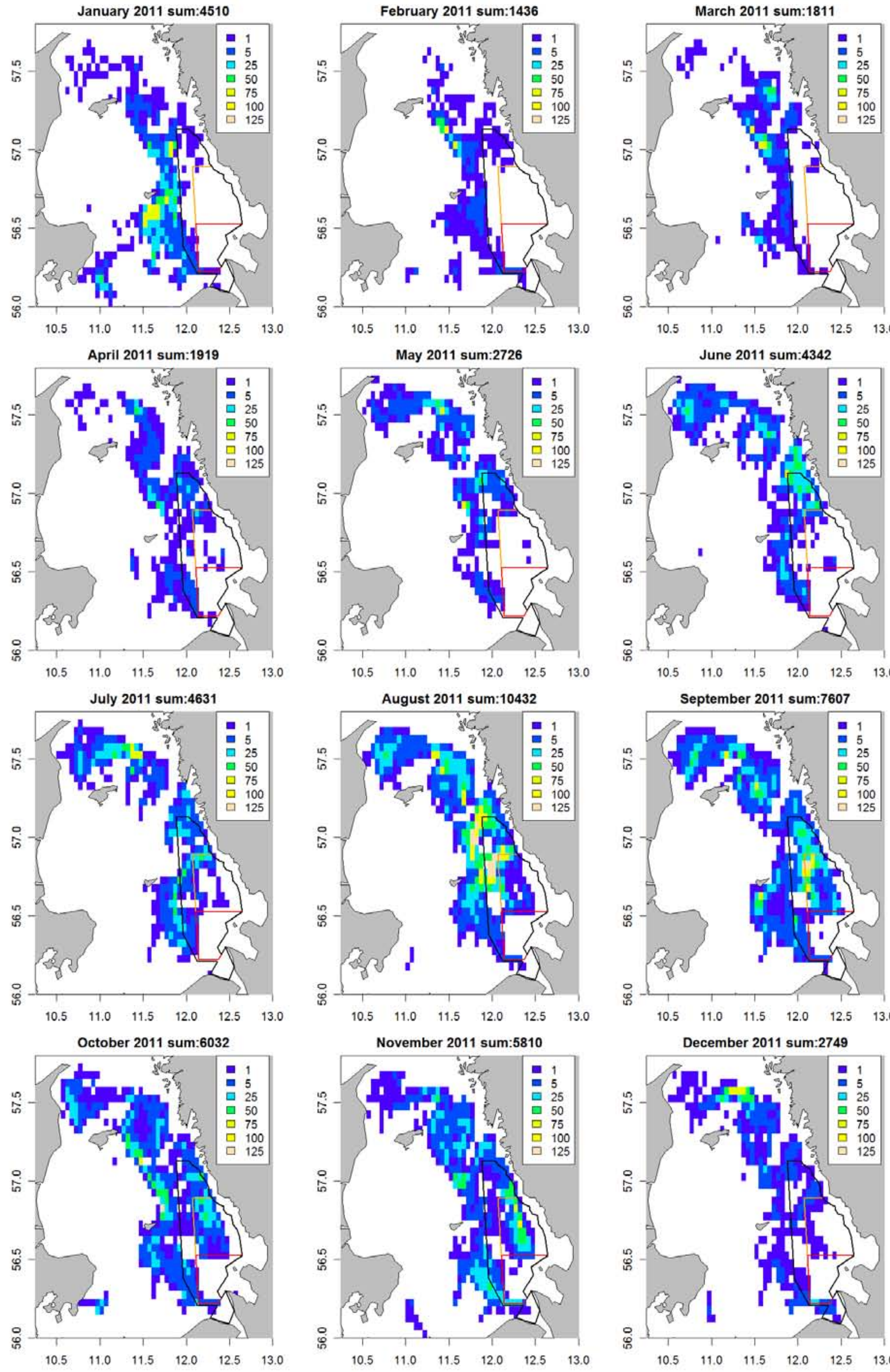

Figure 20. Distribution monthly fishing effort (sum of VMS hourly ping assigned to fishery) for TR2 in 2011.

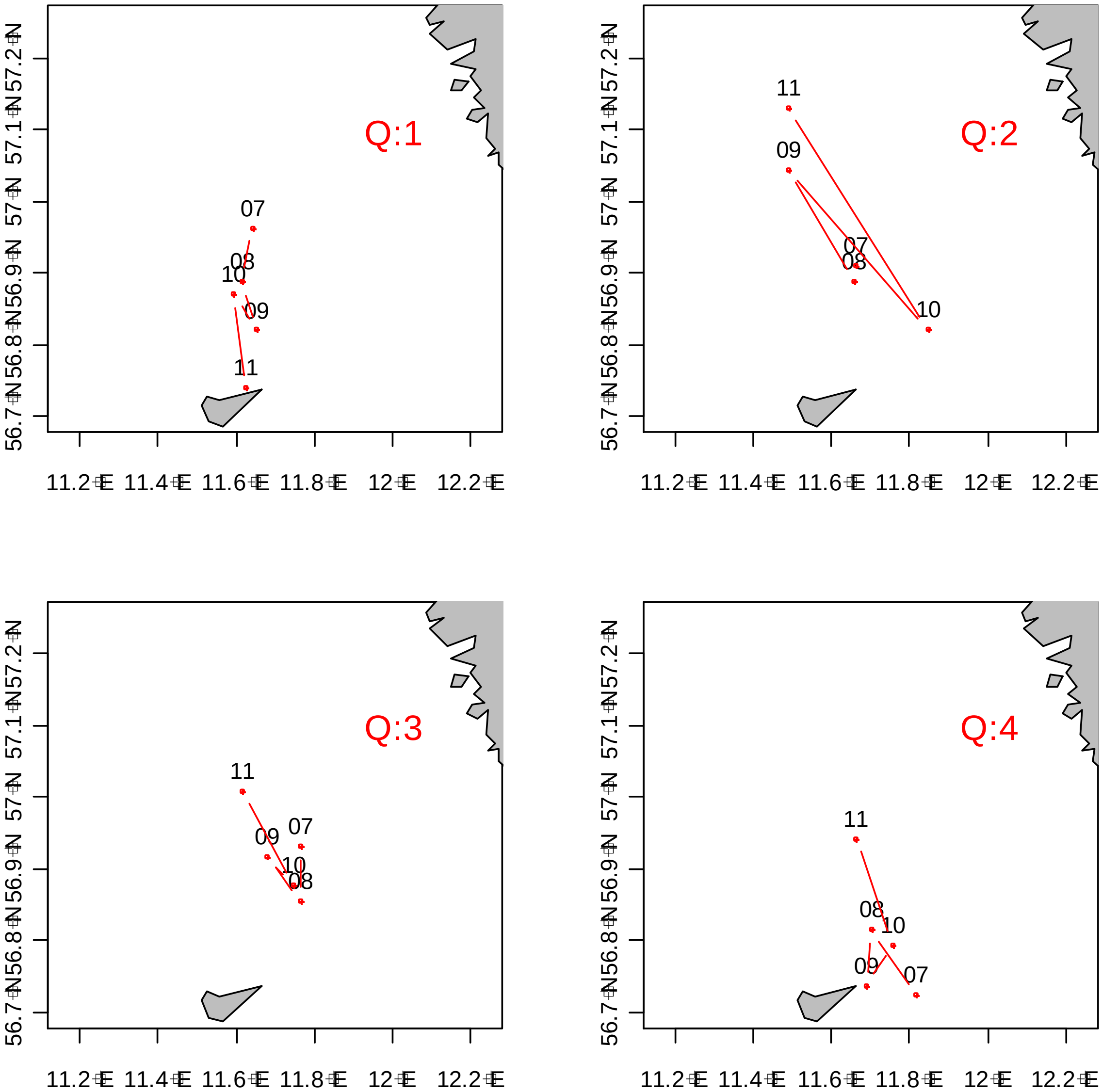

Figure 21. Centre of gravity of VMS recordings by year and quarter for the Kattegat TR2 segment.

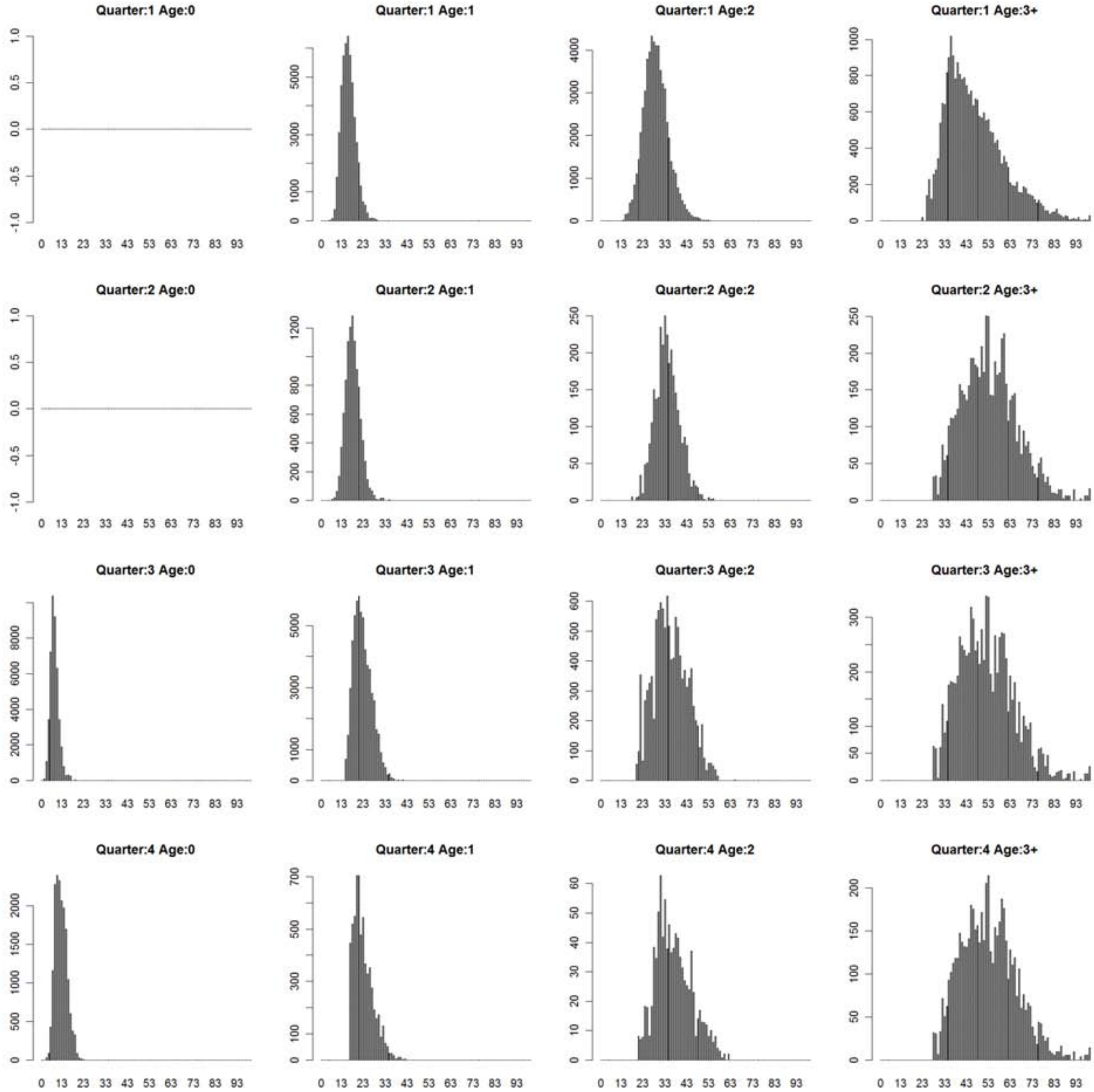

Figure 22. Age length distribution of Kattegat cod derived from a simple sum of all ICES IBTS (since 1982) and BITS (since 1996) CPUE at length and age data downloaded from ICES DATRAS database. Some data manipulations have been made to correct for obvious errors (e.g. large proportion of age 1 cod less than 15 cm in the fourth quarter). Length of Age 4+ cod was assumed independent of quarter to obtain sufficient observations for the second and fourth quarter.

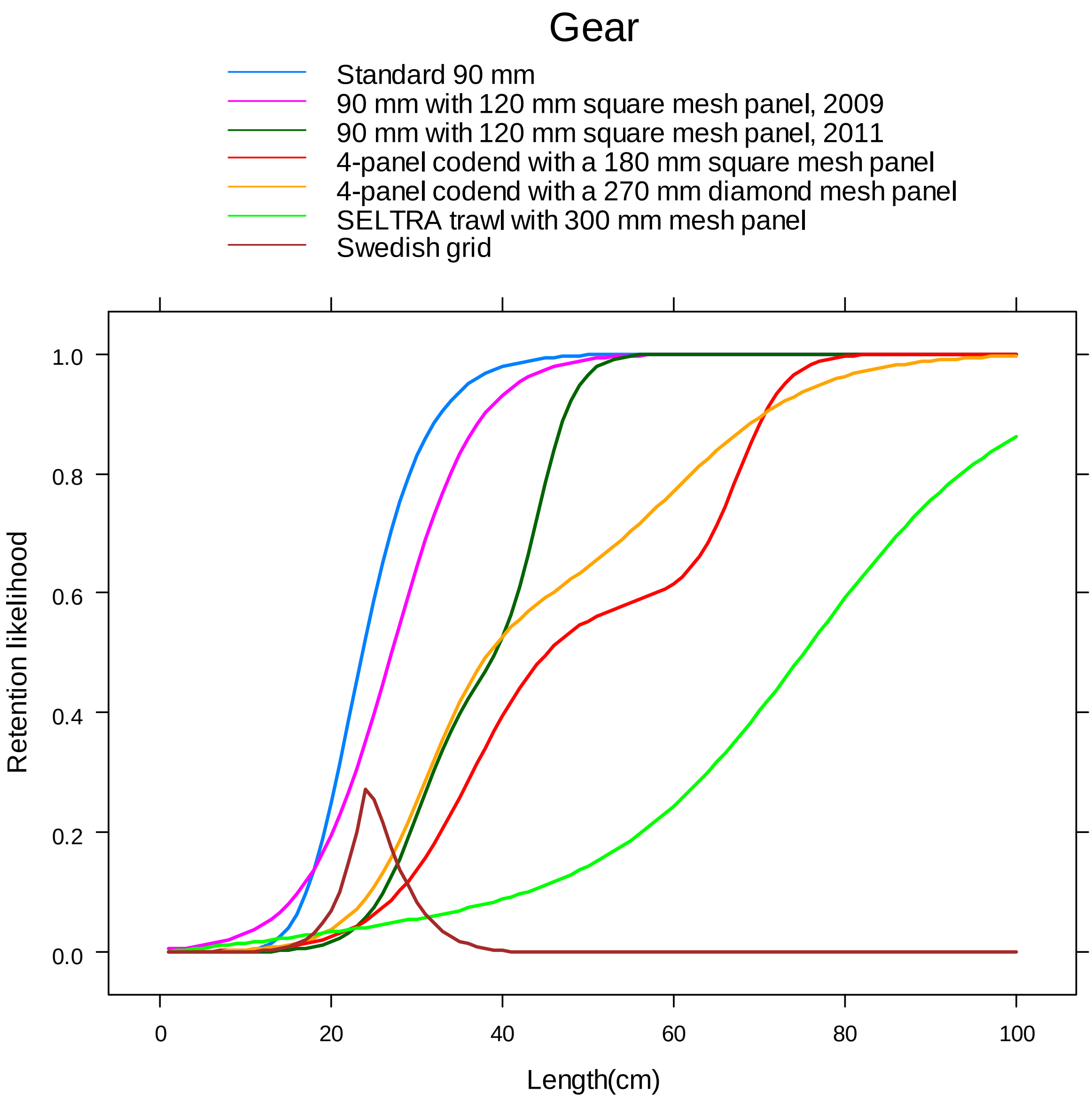

Figure 23 Selection curves by length for selected gears. Selection by length information was obtained from "Documentation of selective effect by length" (Krag & Herrmann, 2012) , Frandsen et al, 2009 and Madsen and Valentinsson, 2010 and age length distribution (Figure 22).

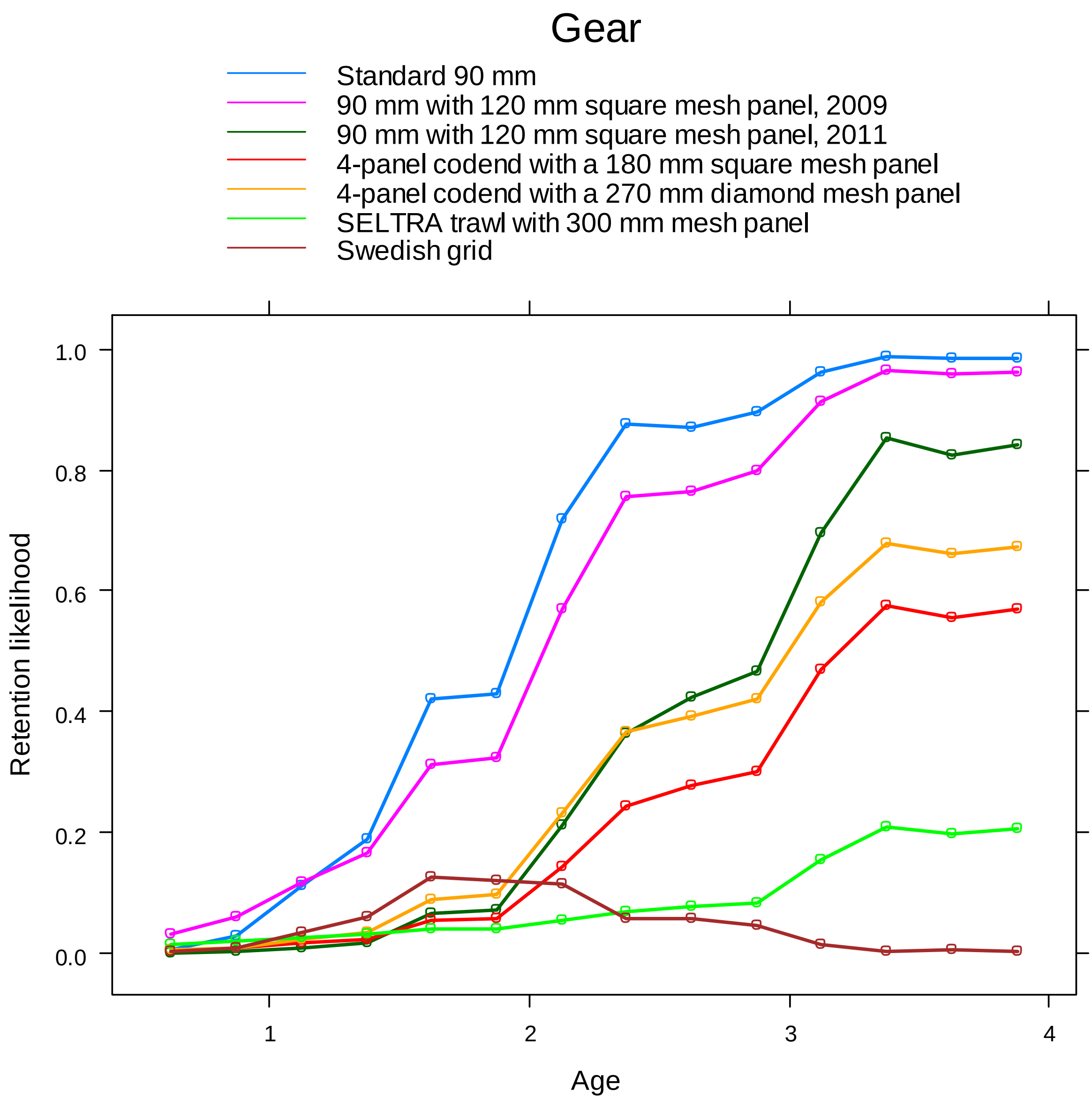

Figure 24. Selection curves by age for selected gears. Selection by length information was obtained from "Documentation of selective effect by length" (Krag & Herrmann, 2012) , Frandsen et al, 2009 and Madsen and Valentinsson, 2010 and age length distribution (Figure 22). Age 3 on the selection curve is a plus group.

Appendix 4. Statistical evaluation of the cod closures in Kattegat

Johan Lövgren, Institute of Marine Research, Department of Marine Resources, Swedish University of Agriculture

The cod closures in Kattegat has been in place since 2009, and there are three different types of closed areas defined by when they are closed and gear allowed

The areas are as follows:

The “black” seasonally closed area is closed during the period 1st January to 31th March, except for fishery with selective gears; The “black” area in the Northern Sound (”Kilen” or the Triangle) is closed 1st February to 31th March, except for fishery with selective gears;

•The “orange” partially closed area is closed for all fisheries in the period 1st January to31th March. Fisheries with selective gears are allowed 1st April to 31th December;

• The “red” permanently closed area is closed for all fisheries, including recreational fisheries-The

• The Kattegat area=the area surrounding the above defined areas.

There is no survey in place that has been specifically designed to evaluate the effect of the closures. The different surveys in place in the Kattegat are to different degrees covering the different areas and targeting different species. The only two surveys that covered all the areas in the cod box with more than one haul, was the Sole survey (Tab.3) and the Cod survey (Tab.6).These two surveys were consequently the only two that was analyzed statistically.

<u>The surveys in place in Kattegat are as follows:</u>

-IBTS (1th and 3rd quarters)

-The sole survey (4^{th} quarter)

-The cod survey (4^{th} quarter)

-The Havfisken survey (1th and 4^{th} quarter)

Table 1- Table 6 shows the number of hauls by area and year from 2008-2011.

Table1 IBTS quarter 1. Number of hauls by area and year

	2008	2009	2010	2011
Kattegat	17	17	16	14
Orange	2	3	2	3

Red	1	1	1	1
Area Black	1		1	

Table2 IBTS quarter 3. Number of hauls by area and year

	2008	2009	2010	2011
Kattegat	19	19	19	20
Orange	2	2	3	2
Red	1	1	1	4
Black	1	1		1

Table3 Sole survey quarter 4. Number of hauls by area and year

	2008	2009	2010	2011
Kattegat	83	54	53	55
Orange	10	8	7	8
Red	5	4	4	4
Black	4	3	5	4

Table4.Havfisken quarter 1 Number of hauls by area and year

	2008	2009	2010	2011
Kattegat	13	13	14	15
Orange	1	1	2	3
Red	2	3	1	1
Black	1		1	1

Table5. Havfisken quarter 4 Number of hauls by area and year

	2008	2009	2010	2011
Kattegat	13	11	14	15
Orange	3	2	2	3
Red	1	2	1	1
Black	1	1	2	0

Table6. Cod survey quarter 4 Number of hauls by area and year

	2008	2009	2010	2011
Kattegat	38	44	37	39
Orange	19	21	19	19
Red	8	4	9	8

Black	15	11	15	14

Statistical approach

A two way ANOVA with time and Area as factors was used to evaluate the response variable Catch per unit of effort (CPUE) on Adult cod (2+) and on juvenile cod (age 0 and1) using survey data from the Sole survey and the Cod survey. In addition a similar analysis was performed on cod survey data using length above and under minimal landing size (MLS=30 cm) as a proxy for large and small cod.

Levenes test for homogeneity of variances was significant in spite of the different data transformations used (square root +1 and log+1). Due to the lack of homogeneity of variances a non-parametric approach using ranks transformation tests was used. The data are transformed to ranks and then these ranks are analyzed using the appropriate parametric test. All data are ranked from 1-N and a two way ANOVA are computed on the ranks (Conver and Iman 1981, Quinn and Keough 2002).

However, for comparison of methods, F-values and p-values from two way ANOVA s with log +1transformed data and F and P-values from Permanova (Permutational ANOVA) are also presented for adult cod in the Sole and Cod survey. Permanova was done using the programme PRIMER 6 with PERMANOVA (Anderson, 2001, 2005; McArdle and Anderson, 2001). Permutation of residuals was under a reduced model with 999 permutations. Significant interactions or main effects were post hoc analyzed using pair wise tests and permutation of residuals was under a reduced model with 999 permutations.

The ANOVA with the log +1 transformed data are however performed on all analyses.

To account for the unbalanced design (with unequal replicates in the different areas) it is advisable to use type III sums of squares (SS) (Underwood 1998). The Type II SS and a Type III approach are rather similar except that the main effects (in this case Time and Area) are interpreted without controlling for the overlap with the interaction term. So if an interaction is present (Time*Area) it is inappropriate to use the type II SS while type III SS still can be used. In this analyses both the ANOVA using type II and type III SS are presented and discussed.

If the interaction term was significant (Year*Area), the main terms (Area ,Year) are not evaluated. Instead simple main effects are evaluated. Simple main effects do not really examine the interaction, just separate effects of one factor for each level of the other factor. Simple main effects tests are basically a single factor ANOVAS at each level of the other factor but are best viewed as a set of particular contrasts and a part of the two factors ANOVA. If the one way ANOVA of the simple main effects is significant a pairwise t-test with Bonnferoni adjustments of p-values was used to evaluate the interaction.

If the interaction term is insignificant each significant main factor factors are evaluated using a pairwise t-test with Bonnferoni adjustments of p-values are used in order to evaluate in between which areas and years the significant effects were found.

The boxplots presented in the paper follows the standardized way to describe the distribution of data. The box cover the 1 and the third quartile of the data, the interquartile range(IQR) . The box is divided by the median of the distribution of data. The whiskers in this case represents 1.5*IQR (the inner fence).

Tab 6.Levenses test of homogeneity of variances for two types of data transformations square root+1 and log +1

Square root transformed +1

Survey	Response variable	factor	p-value
Sole survey	Adult cod	Area	0.03
		Year	0.0001
		Area*Year	0.01
Sole survey	juvenile cod	Area	0.28 (n.s)
		Year	0.0024
		Area*Year	0.0001
Cod survey	Adult cod	Area	0.06 (n.s)
		Year	0.001
		Area*Year	0.01
Cod survey	juvenile cod	Area	0.003
		Year	0.09 (n.s)
		Area*Year	0.03

Log +1 transformed

Survey	Response variable	factor	p-value
Sole survey	Adult cod	Area	0.15 (n.s)
		Year	0.0001
		Area*Year	0.007
Sole survey	juvenile cod	Area	0.51 (n.s)
		Year	0.8 (n.s)
		Area*Year	0.04
Cod survey	Adult cod	Area	0.02
		Year	0.0003
		Area*Year	0.0003
Cod survey	juvenile cod	Area	0.004
		Year	0.23 (n.s)
		Area*Year	0.34 (n.s)

The sole survey

Data from 2008-2011 was statistically evaluated using a two way ANOVA with Year and Area as factors.

The response variable was Adult cod (age 2+) and juvenile cod (age 0 and 1).

Adult cod in the sole survey

Table 7. Anova Table (Type II tests) for Adult cod in the Sole survey

		Rank ANOVA		**Log+1 ANOVA**		**Permanova**	
	DF	F	p	F	p	F	p
Year	3	9.2	<0.05	12.2	<0.05	8.1	<0.05
Area	3	7.7	<0.05	9.3	<0.05	3.7	<0.05
Year*Area	9	3.4	<0.05	3.8	<0.05	1.7	0.064
Residuals	295						

Table 8. Anova Table (Type III tests) for Adult cod in the Sole survey

		Rank ANOVA		**Log+1 ANOVA**	
	Df	F	p	F	p
Intercept	1	9.3	<0.05	2.3	0.12
Year	3	3.8	<0.05	6.5	<0.05
Area	3	0.57	0.62	0.2	0.86
Year*Area	9	3.4	<0.05	3.8	<0.05
Residuals	295				

Table 9. The simple effect of area on the CPUE of adult cod by year, only significant years are evaluated using a pairwise t-test with Bonnferoni adjustments of p-values

a) 2009

	Black	Orange	Red
Orange	1		
Red	1	1	
Kattegat	0.7	<0.05	1

b) 2011

	Black	Orange	Red
Orange	1		
Red	0.13	0.07	
Kattegat	<0.05	<0.05	1

Table 10 The simple effect of year on the CPUE of adult cod by area, only significant areas are evaluated using a pair wise t-test with Bonnferoni adjustments of p-values

a. Kattegat

	2008	2009	2010
2009	<0.05		
2010	1	<0.05	
2011	1	<0.05	1

b. Black

	2008	2009	2010
2009	0.2		
2010	1	0.3	
2011	<0.05	1	0.07

c. Orange

	2008	2009	2010
2009	<0.05		
2010	<0.05	0.8	
2011	<0.05	1	0.5

Table 10.1 a.Pairwise test permanova AREA

	Black	Orange	Red
Orange	0.36		
Red	0.17	<0.05	
Kattegat	<0.05	<0.05	0.7

Table 10.1 b.Pairwise test permanova Year

	2008	2009	2010
2009	<0.05		
2010	<0.05	0.07	

2011	<0.05	<0.05	0.6

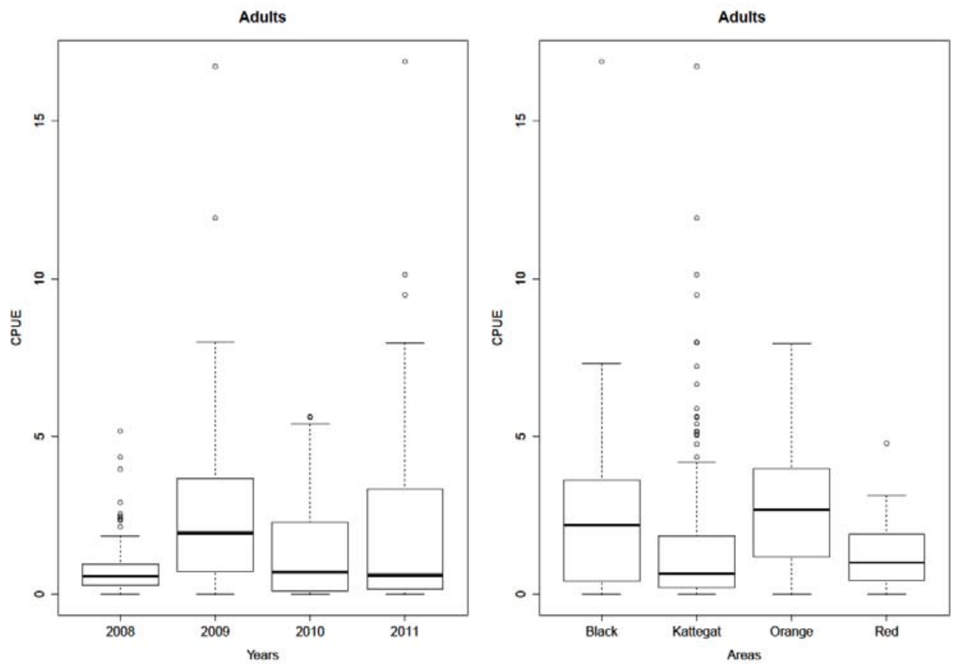

Fig 1. Boxplot of CPUE of Adult cod by area (left) and by Year (right) from Sole survey 2008-2011

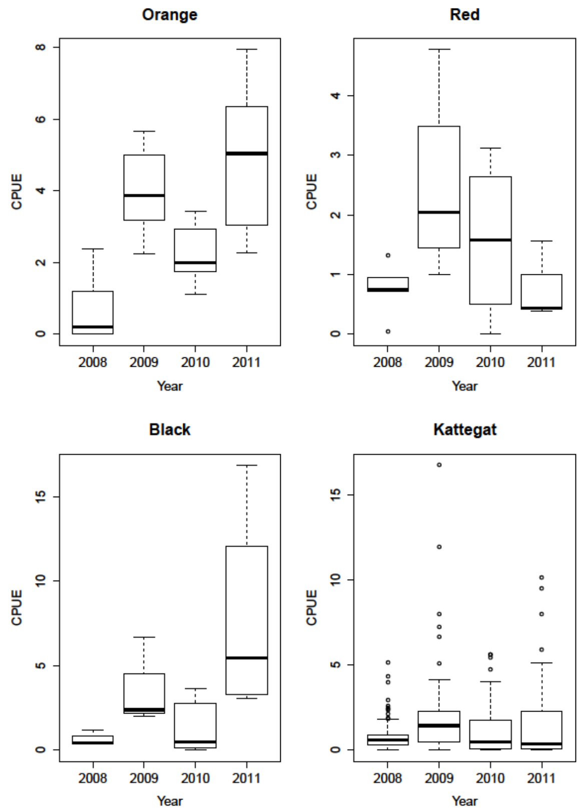

Fig 2. Boxplot of CPUE of Adult cod by Area and time. From Sole survey 2008-2011

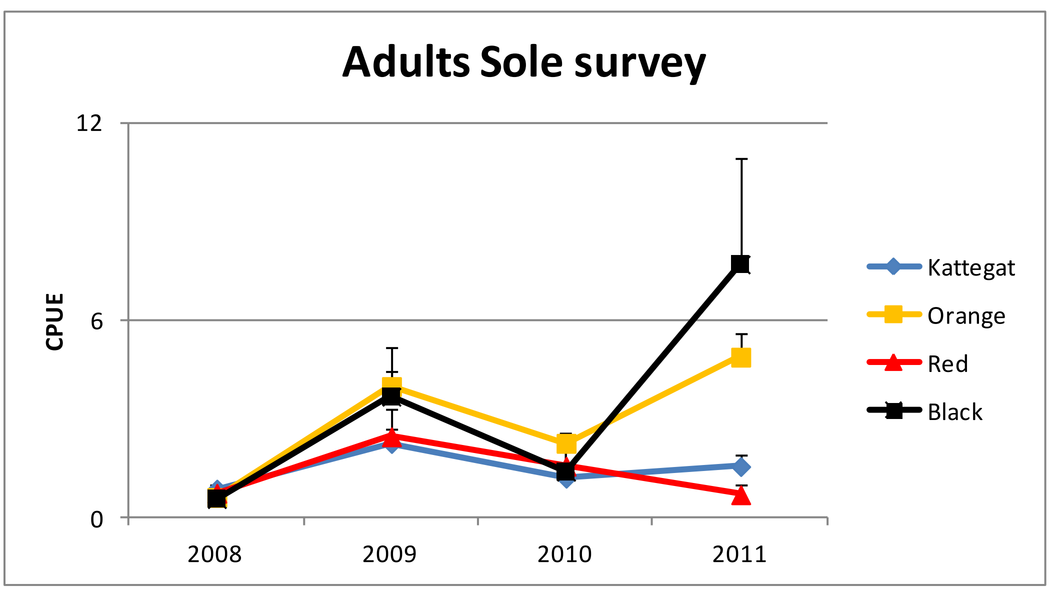

Fig 3. CPUE of Adult cod by Area and time. (mean, ±1SE) From Sole survey 2008-2011.

Juveniles sole survey

Table 11.Anova Table (Type II tests) for juvenile cod in the Sole survey

		Rank ANOVA		Log+1 ANOVA	
	Df	F	p	F	p
Year	3	17.2	<0.05	14.9	<0.05
Area	3	3.1	<0.05	2.9	<0.05
Year*Area	9	3.0	<0.05	2.5	<0.05
Residuals	295				

Table 12. Anova Table (Type III tests) for juvenile cod in the Sole survey

		Rank ANOVA		Log+1 ANOVA	
	Df	F	p	F	p
Intercept	1	3.5	0.06	16.6	<0.05
Year	3	2.6	<0.05	1.8	0.14
Area	3	8.3	<0.05	7.6	<0.05
Year*Area	9	3.0	<0.05	2.5	<0.05
Residuals	295				

Table 13.The simple effect of area on the CPUE of juvenile cod by year, only significant years are evaluated using a pair wise t-test with Bonnferoni adjustments of p-values

a.2008

	Black	Orange	Red
Orange	1		
Red	1	0.09	
Kattegat	0.23	<0.05	1

Table 14 The simple effect of year on the CPUE of juvenile cod by area, only significant areas are evaluated using a pairwise t-test with Bonnferoni adjustments of p-values

a.Kattegatt

	2008	2009	2010
2009	1		
2010	0.22	1	

2011	<0.05	<0.05	<0.05

b. Black

	2008	2009	2010
2009	1		
2010	1	0.4	
2011	<0.05	0.4	<0.05

c.Orange

	2008	2009	2010
2009	<0.05		
2010	0.4	<0.05	
2011	<0.05	0.5	<0.05

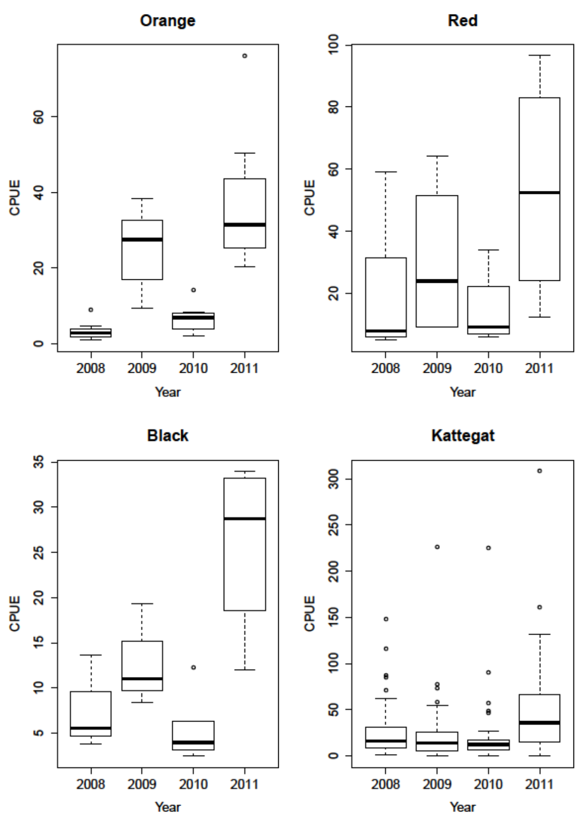

Fig 4. Boxplot of CPUE of juvenile cod by Area and time. From Sole survey 2008-2011

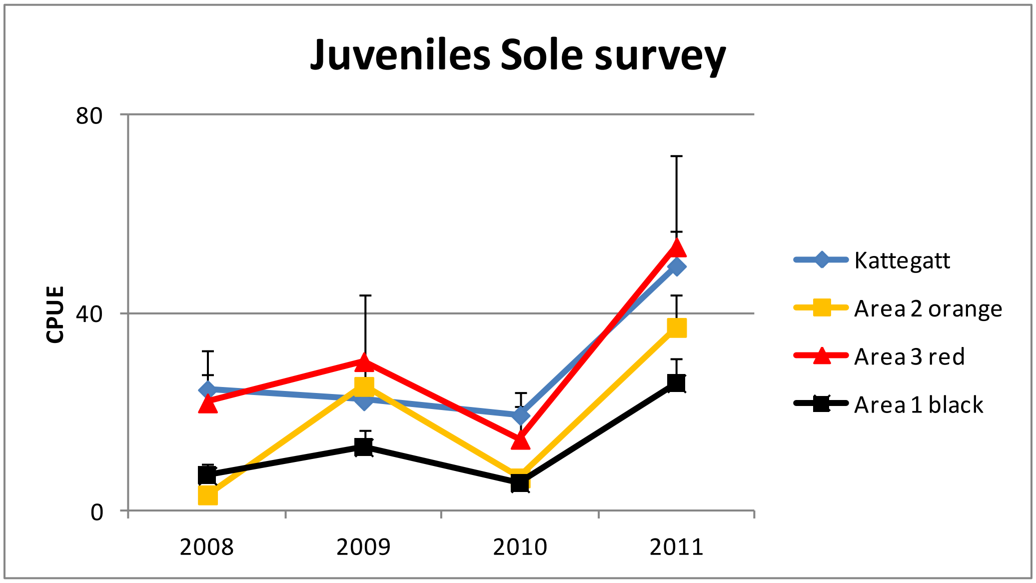

Fig 5. CPUE of juvenile cod by Area and time (mean, ±1SE). From Sole survey 2008-2011.

The Cod survey

Data from 2008-2011 was statistically evaluated using a two way ANOVA with time and area as factors.

The response variable was Adult cod (age 2+) and juvenile cod (age 0 and 1).

Table 15. Anova Table (Type II tests) for Adult cod in the Cod survey

		Rank ANOVA		**Log+1 ANOVA**		**Permanova**	
	DF	F	p	F	p	F	P
Year	3	8.0	<0.05	8.3	<0.05	6.2	<0.05
Area	3	18.1	<0.05	17.5	<0.05	10.2	<0.05
Year*Area	9	1.4	0.16	1.8	0.06	1.9	<0.05
Residuals	292						

Table 16. Anova Table (Type III tests) for Adult cod in the Cod survey

		Rank ANOVA		**Log+1 ANOVA**	
	Df	F	p	F	P

Intercept	1	108	<0.05	113	<0.05
Year	3	2.5	0.06	2.1	0.09
Area	3	7.7	<0.05	8.6	<0.05
Year*Area	9	1.4	0.17	1.8	0.06
Residuals	292				

Table 17. Pair wise t-test: Area. P value adjusted =Bonferroni

	Black	Orange	Red
Orange	0.3		
Red	0.06	<0.05	
Kattegat	<0.05	<0.05	1

Table 18. Pairwise t-test: Year. P value adjusted =Bonferroni

	2008	2009	2010
2009	0.05		
2010	0.41	1	
2011	0.55	<0.05	<0.05

Table 18.1 Permanova results pairwise tests Area by year

a. Kattegatt

	2008	2009	2010
2009	<0.05		
2010	0.06	<0.05	
2011	<0.05	<0.05	0.84

b. Orange

	2008	2009	2010
2009	0.11		
2010	<0.05	0.50	
2011	0.06	<0.05	<0.05

c. Red

	2008	2009	2010
2009	0.25		
2010	0.43	0.26	
2011	0.45	0.13	<0.05

d. Black

	2008	2009	2010
2009	0.06		
2010	<0.05	0.8	
2011	0.90	0.13	0.10

Table 18.2 Permanova results pairwise tests year by Area

a. 2008

	Black	Orange	Red
Orange	0.8		
Red	0.06	<0.05	
Kattegat	<0.05	<0.05	0.8

b. 2009

	Black	Orange	Red
Orange	0.15		
Red	0.14	<0.05	
Kattegat	0.07	<0.05	0.40

c.2010

	Black	Orange	Red
Orange	0.60		
Red	<0.05	<0.05	
Kattegat	0.06	0.4	<0.05

d.2011

	Black	Orange	Red
Orange	<0.05		
Red	0.6	0.12	
Kattegat	0.10	<0.05	0.4

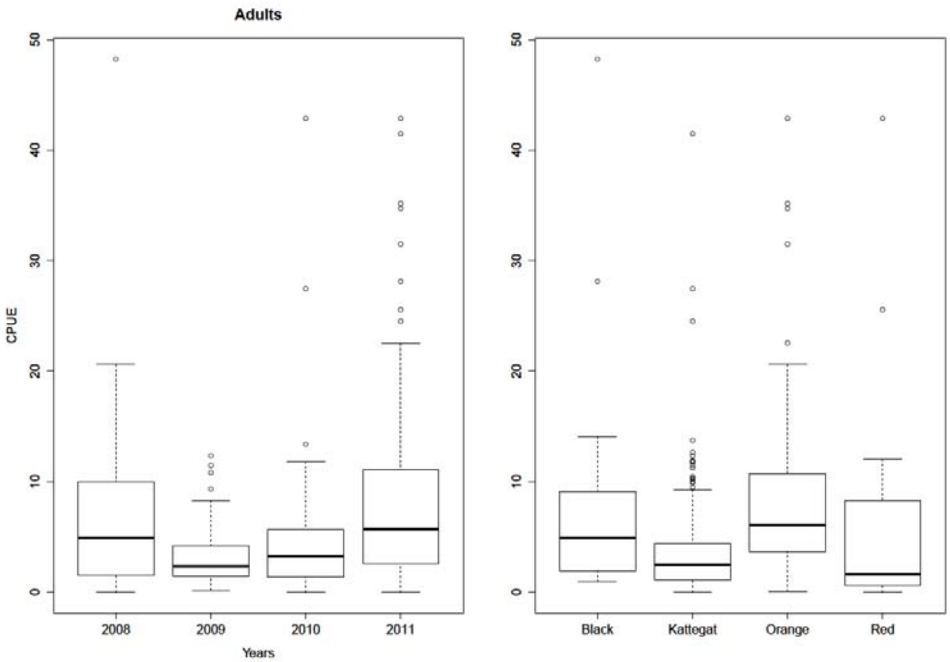

Fig 6. Boxplot of CPUE of Adult cod by area (left) and by Year (right) from Cod survey 2008-2011

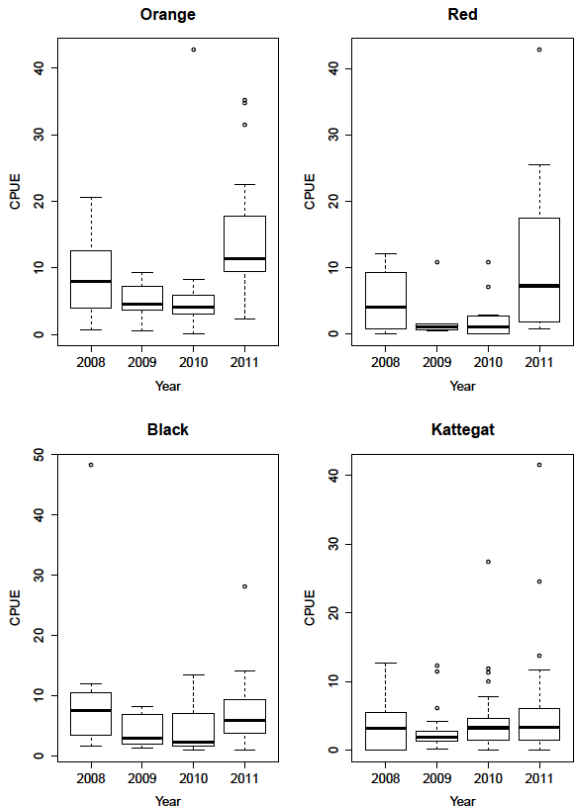

Fig 7. Boxplot of CPUE of Adult cod by Area and time. From Cod survey 2008-2011

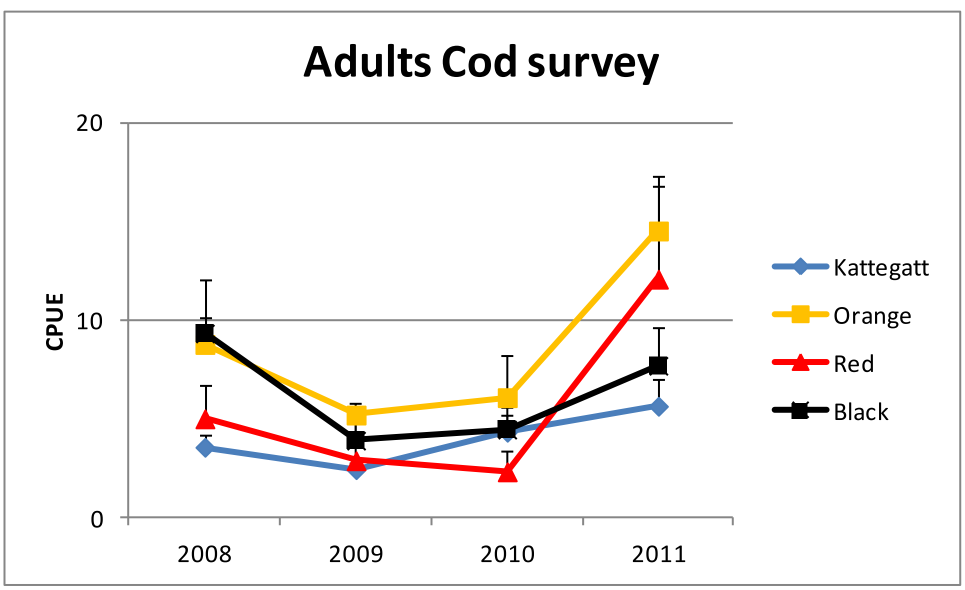

Fig 8. CPUE of Adult cod by Area and time (mean, ±1SE). From Cod survey 2008-2011.

Juveniles cod survey

Table 19.Anova Table (Type II tests) for juvenile cod in the Cod survey

		Rank ANOVA		Log+1 ANOVA	
	Df	F	p	F	P
Year	3	11.3	<0.05	11.5	<0.05
Area	3	0.6	0.64	0.5	0.72
Year*Area	9	4.5	<0.05	3.9	<0.05
Residuals	292				

Table 20. Anova Table (Type III tests) for juvenile cod in the Cod survey

		Rank ANOVA		Log+1 ANOVA	
	Df	F	p	F	P
Intercept	1	23.0	<0.05	152.7	<0.05
Year	3	2.2	0.09	1.7	0.16
Area	3	2.7	<0.05	1.3	0.26
Year*Area	9	4.5	<0.05	3.9	<0.05
Residuals	292				

Table 21.The simple effect of area on the CPUE of juvenile cod by year, only significant years are evaluated using a pair wise t-test with Bonnferoni adjustments of p-values

a. 2008

	Black	Orange	Red
Orange	1		
Red	0.07	<0.05	
Kattegat	1	1	0.25

b. 2009

	Black	Orange	Red
Orange	0.08		
Red	1	0.17	
Kattegat	1	0.08	1

c. 2010

	Black	Orange	Red

Orange	0.7		
Red	0.18	1	
Kattegat	1	0.11	<0.05

d. 2011

	Black	Orange	Red
Orange	0.9		
Red	0.08	0.9	
Kattegat	1	0.4	<0.05

Table 22. The simple effect of year on the CPUE of juvenile cod by area, only significant areas are evaluated using a pair wise t-test with Bonnferoni adjustments of p-values

a. Kattegatt

	2008	2009	2010
2009	0.13		
2010	0.07	1	
2011	0.19	1	1

b. Black

	2008	2009	2010
2009	0.8		
2010	0.08	1	
2011t	0.06	1	1

c. Orange

	2008	2009	2010
2009	<0.05		
2010	1	<0.05	
2011t	<0.05	1	<0.05

d. Red

	2008	2009	2010
2009	1		
2010	0.07	1	
2011t	0.5	0.06	<0.05

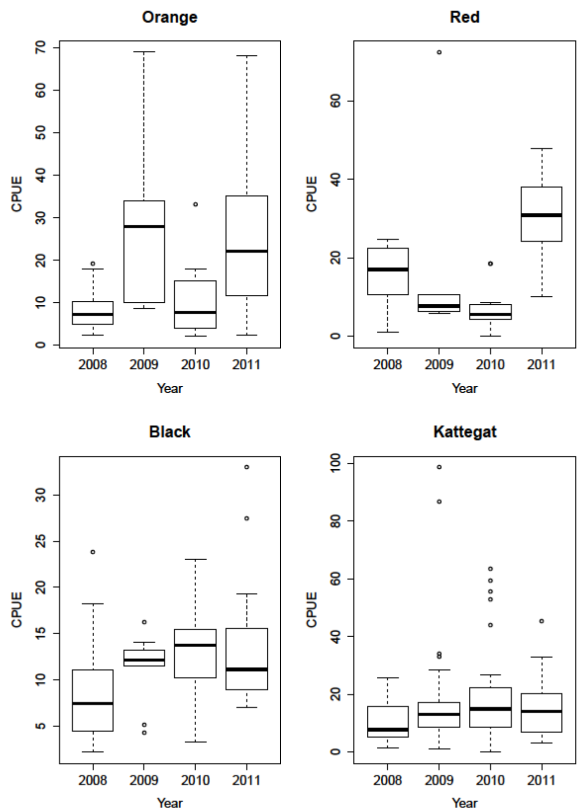

Fig 9. Boxplot of CPUE of juvenile cod by Area and time. From Cod survey 2008-2011

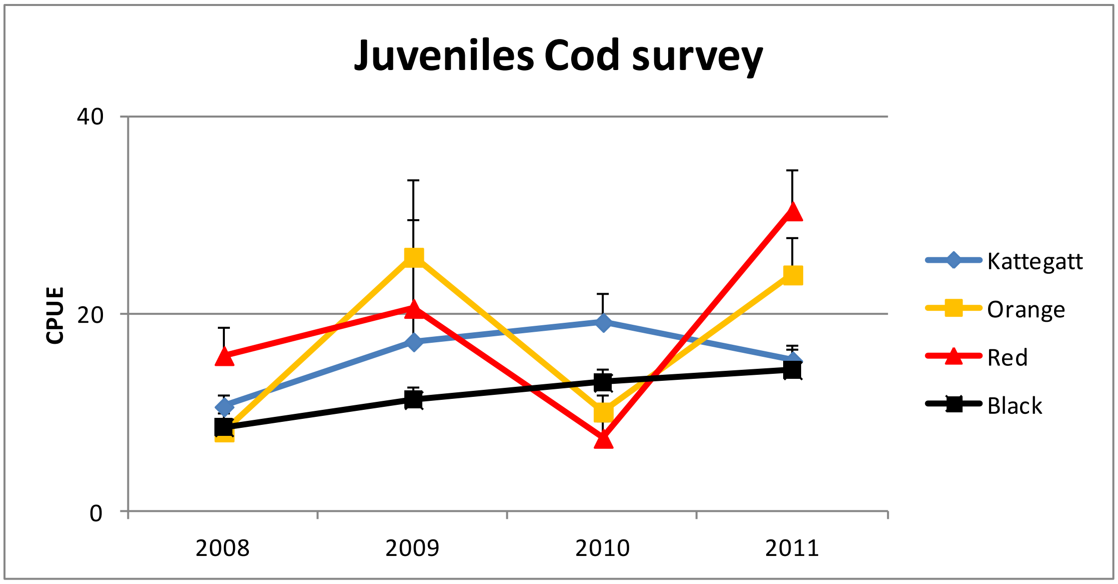

Fig 10. CPUE of juvenile cod by Area and time (means, ±1SE). From Cod survey 2008-2011

Cod survey large cod (larger than 30 cm)

Table 23.Anova Table (Type II tests) for large cod in the Cod survey

		Rank ANOVA		**Log+1 ANOVA**	
	Df	F	p	F	P
Year	3	0.8	0.5	0.7	0.57
Area	3	13.3	<0.05	12.8	<0.05
Year*Area	9	1.7	0.09	1.6	0.10
Residuals	304				

Table 24.Anova Table (Type III tests) for large cod in the Cod survey

		Rank ANOVA		**Log+1 ANOVA**	
	Df	F	p	F	P
Intercept	1	89.6	<0.05	105	<0.05
Year	3	1.7	0.17	1.3	0.27
Area	3	4.7	<0.05	5.8	<0.05
Year*Area	9	1.7	0.10	1.6	0.10
Residuals	304				

Table 25. Pairwise t-test: AREA. P value adjusted =Bonferroni

	Black	Orange	Red
Orange	0.12		
Red	0.65	<0.05	
Kattegat	<0.05	<0.05	1

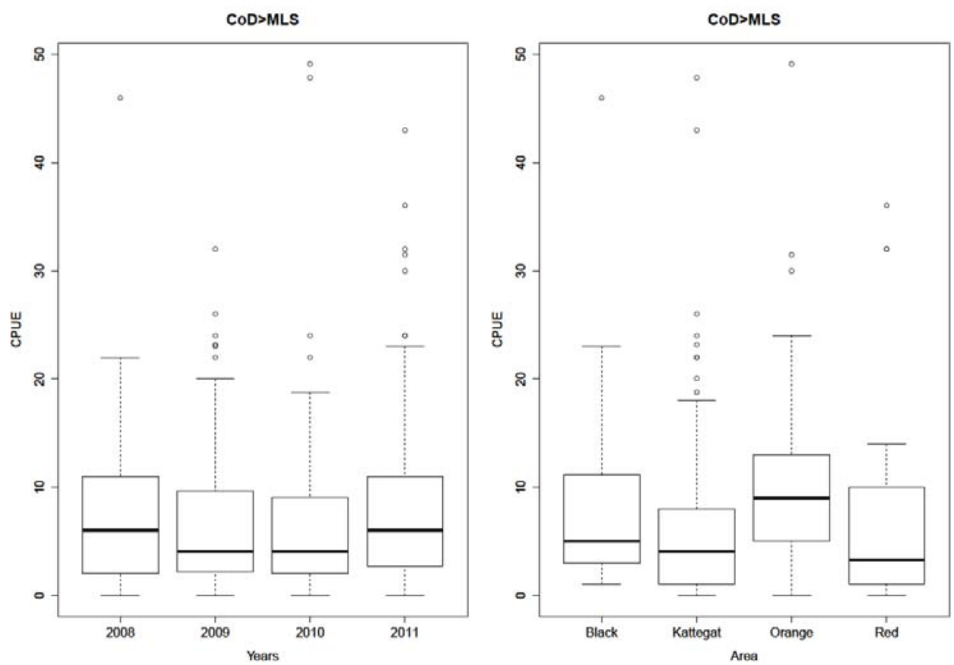

Fig 11. Boxplot of CPUE of large cod by area (right) and by Year (left) from Cod survey 2008-2011

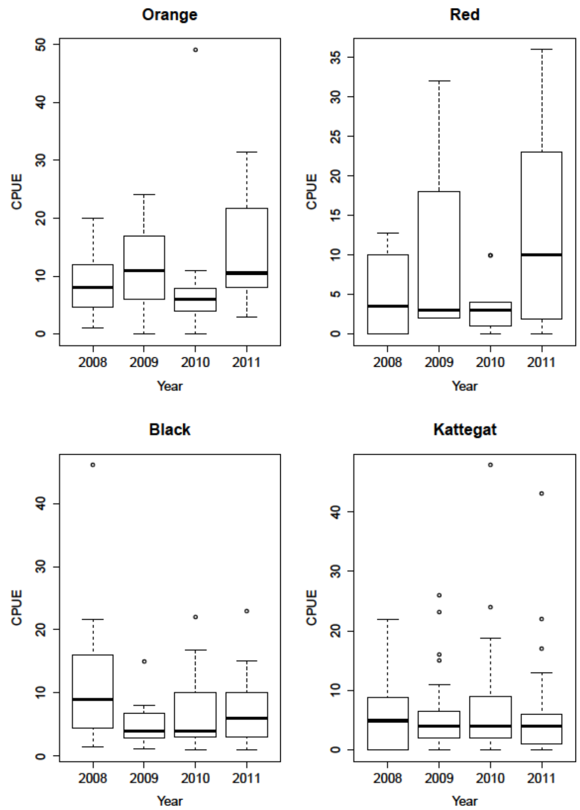

Fig 12. Boxplot of CPUE of large cod by Area and time. From Cod survey 2008-2011

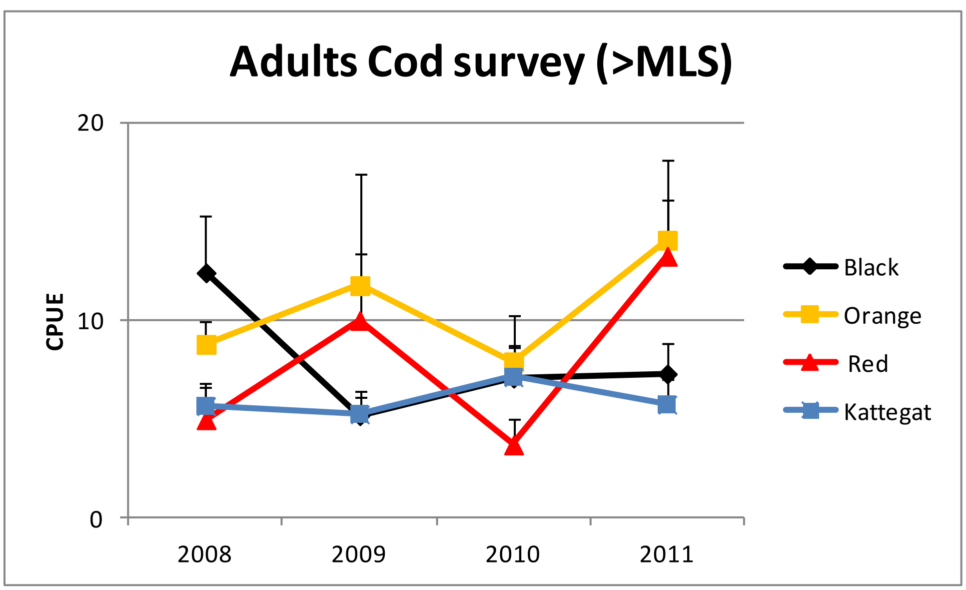

Fig 13. CPUE of adult cod by Area and time (means, ±1SE). From Cod survey 2008-2011

Cod survey small cod (smaller than 30 cm)

Table 26. Anova Table (Type II tests) for small cod in the Cod survey

		Rank ANOVA		Log+1 ANOVA	
	Df	F	p	F	p
Year	3	13.6	<0.05	13.1	<0.05
Area	3	1.9	0.13	2.1	0.08
Year*Area	9	2.8	<0.05	2.5	<0.05
Residuals	304				

Table 27. Anova Table (Type III tests) for small cod in the Cod survey

		Rank ANOVA		Log+1 ANOVA	
	Df	F	p	F	p
Intercept	1	25.2	<0.05	86	<0.05
Year	3	1.9	0.12	1.8	0.15
Area	3	1.6	0.18	1.2	0.32
Year*Area	9	2.8	<0.05	2.5	<0.05
Residuals	304				

Table 28. The simple effect of area on the CPUE of juvenile cod by year, only significant years are evaluated using a pairwise t-test with Bonnferoni adjustments of p-values

a.2011

	Black	Orange	Red
Orange	0.8		
Red	0.06	0.9	
Kattegat	1	0.17	<0.05

Table 29. The simple effect of year on the CPUE of juvenile cod by area, only significant areas are evaluated using a pairwise t-test with Bonnferoni adjustments of p-values

a. Kattegat

	2008	2009	2010
2009	0.1		
2010	0.15	1	
2011	<0.05	1	1

b.Orange

	2008	2009	2010
2009	<0.05		
2010	1	<0.05	
2011	<0.05	1	<0.05

c. Red

	2008	2009	2010
2009	1		
2010	0.4	0.78	
2011	<0.05	0.18	<0.05

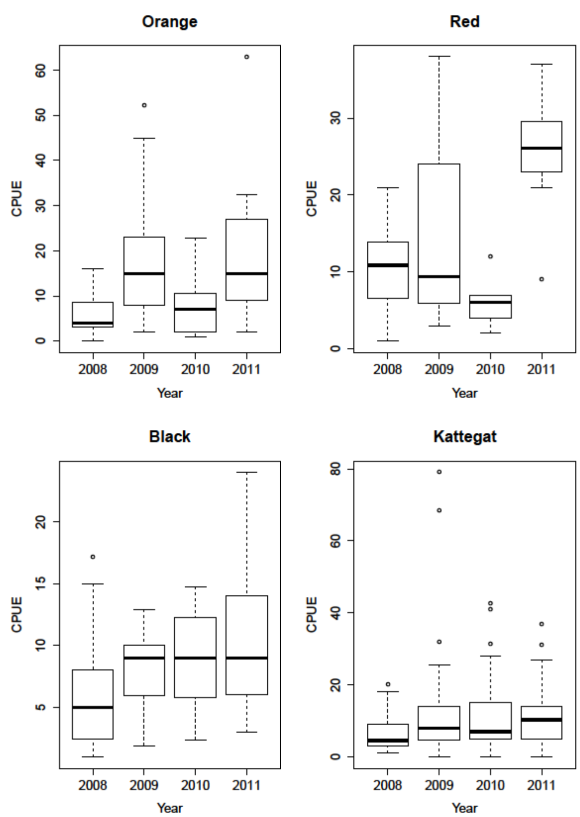

Fig 14. Boxplot of CPUE of small cod by Area and time. From Cod survey 2008-2011

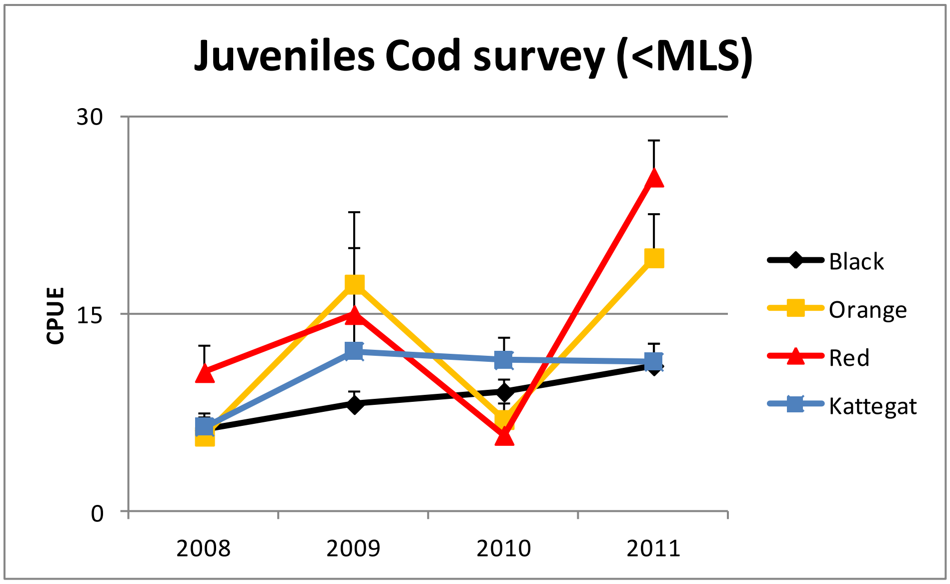

Fig 15. CPUE of juvenile cod by Area and time (means, ±1SE). From Cod survey 2008-2011

Adult cod.

Sole survey:

There was a significant interaction between time and area in the Sole survey indicating that the development of CPUE of adult cod differed between areas over time. The CPUE of adult cod increased over time in the black and in the orange area compared to the Kattegat and the red area. (Fig 2, 3, Tab7-10).

The Permanova which represents a different statistical approach compared to the two way ANOVA did not find the interaction term to be significant but significant main effects of Area and Year on the CPUE of adult cod (Tab 7). The pairwise t-test of main factor area shows that the CPUE of adult cod is higher in the black and orange area compared to the Kattegat area, furthermore is the CPUE of adult cod higher in the orange area than in the red area (Tab 10.1 a, Fig 1) The pair wise t-test of main factor Time shows that the lowest CPUE of adult cod was found in the year 2008 and the highest CPUE of adult cod was found in 2009 (Tab 10.1 b fig 1).

Cod survey

There was no significant interaction between Area and time using two-way ANOVA. There was a significant effect of Area and Year on the CPUE of adult cod (Tab 15, 16). The pairwise t-test of the different areas showed that CPUE of adult cod was significantly higher in the Black and Orange area compared to the Kattegat area (Table 17, Fig 7 right). There was also a significantly higher CPUE of adult cod in the Orange area compared to the Red area (Table 17, Fig 7). There was a significant year effect in that the CPUE of adult cod was higher in 2011 than in 2009 and 2010. (Tab.17, Fig 7,left). The same results was found in the ANOVA using CPUE of cod above minimal landing size (MLS=30cm) from the cod survey as a proxy for adults (Tab 23,24, 25 fig 11).

Contrary to the above analyses of adult cod in t he cod survey , the permanova analyses found the interaction term of Area and Time to be significant (Tab 15). The CPUE of adult cod by area over time were in many ways similar, with a decrease in CPUE in 2009 and 2010 compared to 2008. However, in the Red and orange area the highest CPUE of adult cod was found in 2011 (Tab 18.1 -18.2, Fig. 8)

Juvenile cod.

Sole survey.

There was a significant interaction effect of time and area for the CPUE of juvenile cod in the Sole survey(Tab. 11 ,12 Fig 5). The analysis of the simple main effect of year on the different areas shows that there was a significantly higher CPUE of juvenile cod in the Orange area than in the Kattegat are in 2008 (tab 13 a). The analyses of how the different areas developed over time shows that the CPUE of juvenile cod was significantly higher 2011 and 2009 than in 2008 and 2010 in the Black and orange area (Tab 14b and c, Fig 5). In the Kattegat area there was a significantly higher CPUE of juvenile cod 2011 than the other years (Tab 14 a, Fig 5) There was no significant difference in the CPUE of juvenile cod between years in the red area.

Cod survey

The interaction term between time and area was found to be significant for the CPUE of cod juveniles also in the Cod survey (Tab 19, Tab 20). The evaluation of the simple main effect of year on the different areas show that there is a significant higher CPUE 2009 of juvenile cod in the orange area compared to the red area in 2008 (Tab 21a, Fig 12).

In 2010 there was a significant lower CPUE of juvenile cod in the red area compared to the Kattegatt area (Tab 21c, Fig 12). The next year 2011, the pattern changed, now the CPUE of juvenile cod was significantly higher in the red area than in the Kattegat area (Tab 21d, Fig 12).

In the Orange area, there was a significantly higher CPUE of juvenile cod in 2011 and 2009 compared to 2010 and 2008 (Tab 22c, fig 12). There was a significantly higher CPUE of juvenile cod in 2011 than in 2010 in the Area 3 red area (Tab 22d, fig 12). There was no significant effect of Year on the CPUE of juvenile cod in the black and Kattegat area. The same results was found in the ANOVA using CPUE of cod below minimal landing size (MLS=30cm) from the cod survey as a proxy for adults (Tab 26,27,28 fig 15).

Discussion

The main differences between the Two-way anova and the Permanova is that Permanova can cope with non normality's and unbalanced designs per se. To cope with these assumptions necessary in parametric statistics, ranking and transformation of data is necessary when using ANOVA.

There are two major differences between the cod survey and the sole survey that could related to the catchabillity of large and juvenile cod. The sole survey, targeting sole, are performed during night with a mesh size of 55 mm. The Cod survey, targeting Cod, are performed during daytime with a mesh size of 70 mm. There are several studies in the North sea and Barents sea that shows that catches of cod in bottom trawls are lower during dark hours than during light hours (Wieland et al 1998, Aglen et at 1999, Adlerstein and Ehrich 2003).

In conclusion for adult cod, the most accurate results would be those from the cod survey as this survey more accurately samples adult cod fishing during the day with a commercial gear targeting adult cod (Jørgensen et al. 2012). Whether, a lower catch rate for juvenile cod in the sole survey during night is compensated by a lower mesh size is an open question.

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Appendix 5. Assessment from hydroacoustic surveys

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To follow up effects of the closed areas in Kattegat a hydroacoustic survey was carried out by SLU-Aqua in late November – early December 2009, 2010 and 2011. In contrast to traditional bottom trawl surveys, the hydroacoustic method provide means to obtain information on fish abundance in all habitats, i.e. not only in habitats where trawling is possible. It is also possible to sample the whole water column, while bottom trawling only samples the height of the trawl gear used. Species composition still need to be verified by fishing however, since acoustics cannot discriminate between species. The acoustic survey where therefore carried out during the same time of year as the joint Swedish and Danish survey for cod in the Kattegat. The survey covered the closed and the partially closed area, as well as a reference area located west of the closed areas. The survey used a systematic zig-zag design with random starting point. Three transects were allocated to each area providing a degree of coverage above six. Each transect traversed its respective area generating three independent abundance measures per area and year (figure 1).

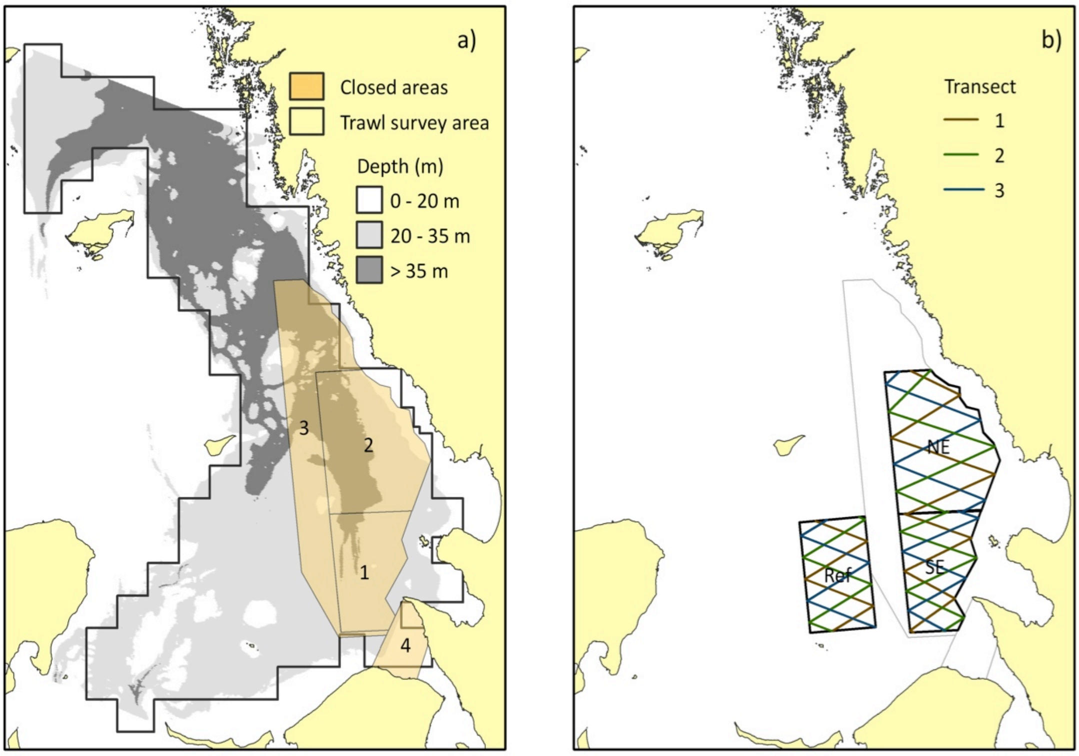

Figure 1. a) Map showing the closed area and the area for the joint Swedish and Danish survey for cod in the Kattegat. b) Surveyed areas during the hydroacoustic survey 2009 – 2011, and survey design (transects from 2010).

The hydroacoustic equipment used was a 120 kHz Simrad EK60 with a hull mounted 7°split-beam transducer. Pulse duration was set to 0.128 ms and the pulse rate to 5 pings s^{-1}. The effect was 100

W. Abundance estimates were generated from echo integration and *in situ* distribution of single echoes using Sonar5 Pro post-processing software. The number of single echo detections (SED's) was higher at night time since several species of fish moved up into the water. All data collection was therefore carried out at night. Catch data for estimation of species composition were available from the joint Swedish and Danish survey for cod in the Kattegat carried out in November – December each year. Proportion by species was calculated according to method 1 in Simmonds and MacLennan (2005) using the target strength values presented in table 1. Based on the observed and estimated (from catch data) distribution of single echoes, thresholds used in the processing was set to -39 dB for single echoes and -45 dB in the amplitude echogram. Data was aggregated in two size classes for analysis; small cod 20 – 40 cm (-39 to -33 dB), and large cod 40 – 100 cm (-33 to -25 dB).

Table 1. Target strength (*TS*) values used in the calculations.

Species/group	*TS*	Reference
Cod/species with closed swim bladder	-65.0 dB	Rose and Porter (1996)
Herring/species with open swim bladder	-71.1 dB[1]	ICES 2011
Spiny dogfish	-78.0 dB[2]	Goddard and Welsby (1986)

[1]Based on 38 kHz. [2]13 dB lower than similar sized cod.

The estimated fish abundance (not compensated for species composition) decreased from 2009 to 2011. Small fish (20 – 40 cm) was observed throughout the surveyed area, whereas large fish (40 – 100 cm) likely to be cod were confined to a few hot-spots; along the 20 m depth contour to the north-east of the partially closed area, and in the north-eastern part of the reference area. During 2010 and 2011 the abundance of large fish was also relatively high on the border between the closed areas (Figure 2 and 3).

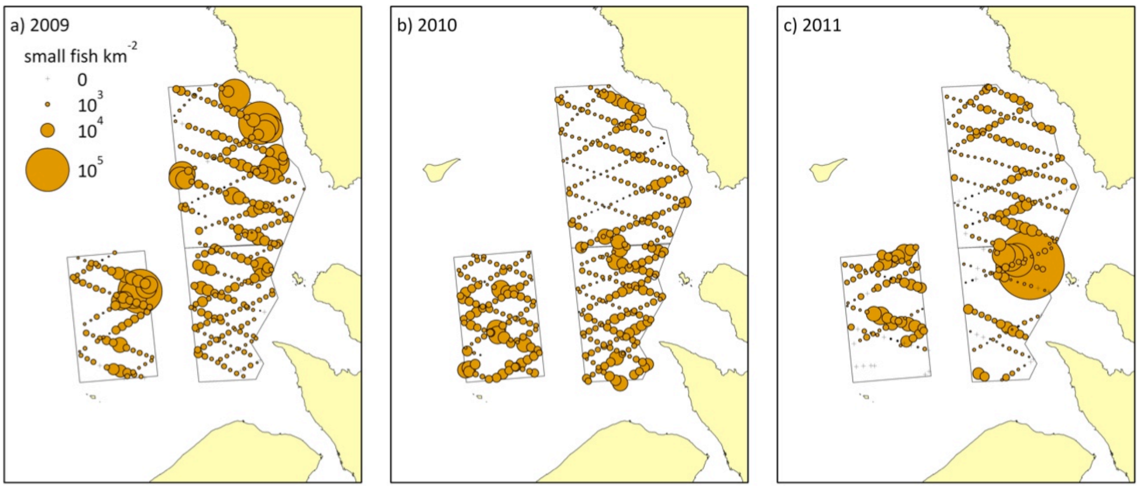

Figure 2. Spatial distribution of small fish (20 – 40 cm) based on acoustic survey data. a) 5 – 16 November 2009; b) 22 November – 8 December 2010; c) 21 November – 7 December 2011.

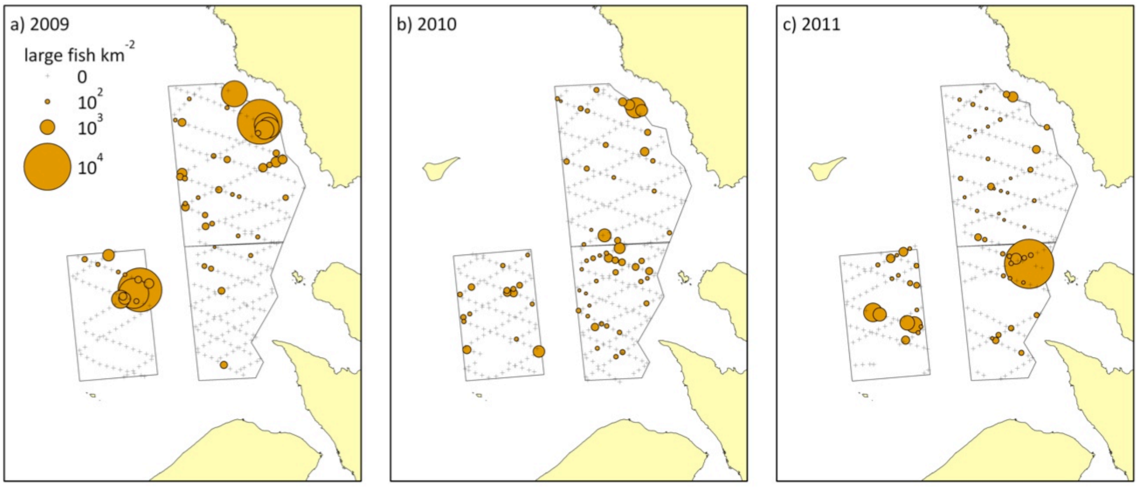

Figure 3. Spatial distribution of large fish (40 – 100 cm) based on acoustic survey data. a) 5 – 16 November 2009; b) 22 November – 8 December 2010; c) 21 November – 7 December 2011.

The estimated abundance of cod decreased from 924 to 317 individuals km^{-2} in 2009 – 2010, followed by an increase to 496 individuals km^{-2}in 2011 (table 2).

Table 2. Area-weighted estimate of abundance (number km^{-2}) based on log_{10}-transformed data.

	Small cod (20 – 40 cm)		Large cod (40 – 100 cm)	
Year	Number km^{-2}	95% confidence interval	Number km^{-2}	95% confidence interval
2009	890	756 - 1048	33.6	8.4 - 134.8
2010	302	160 - 573	14.6	11.2 - 19.0
2011	474	249 - 900	22.0	10.2 - 47.7

For small cod there was a weak effect of year (ANOVA, $F = 3.60$, $df = 2, 17$, $p< 0.05$) reflecting the general decrease in abundance from 2009 to 2010. For large cod there was significant interaction between area and year ($F = 3.82$, $df = 4, 17$, $p = 0.02$), the analysis was therefore performed separately for each area. In the partially closed area, the abundance of large cod decreased from 2009 to 2011 (2009 vs. 2010: $t = -2.97$, $p = 0.02$; 2009 vs. 2011: $t = -3.47$, $p = 0.01$) whereas there was an increasing trend in the closed area (2009 vs. 2010: $t = 1.26$ $p = 0.25$; 2009 vs. 2011: $t = 2.50$ $p<$ 0.05, figure 4b). No effect was detected on abundance of cod in the reference area.

Abundance of small cod estimated from acoustic data was significantly higher than abundance based on catch data, but the overall trend was similar, showing the general decrease from 2009 to 2010 followed by a slight increase in 2011 (figure 5a). The difference in absolute numbers probably reflects a bias in the estimated proportion of small cod used in the calculation. Whether this bias is caused by variable catchability, restricted gear height (approximately 1.5 m) or presence of pelagic species, such as herring, which are not representatively caught in the bottom trawl, is not known.

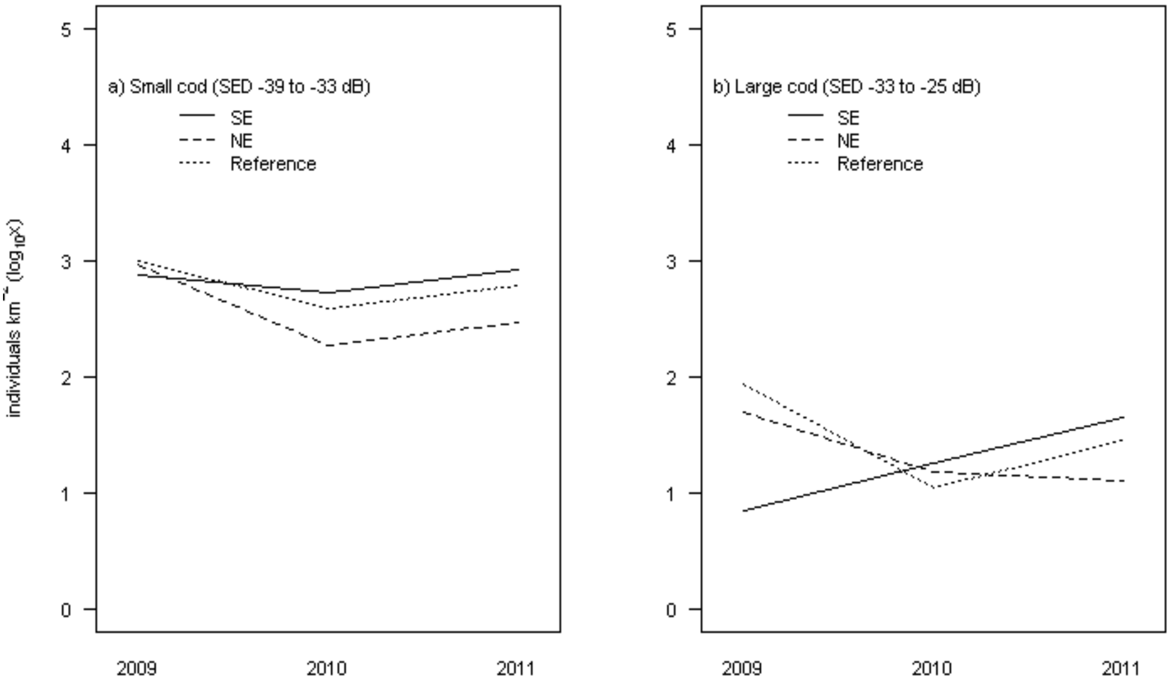

Figure 4. Estimated cod abundance ($\log_{10}$individuals km-[2]) per area and year; a) small cod (20 – 40 cm) and b) large cod (40 – 100 cm).

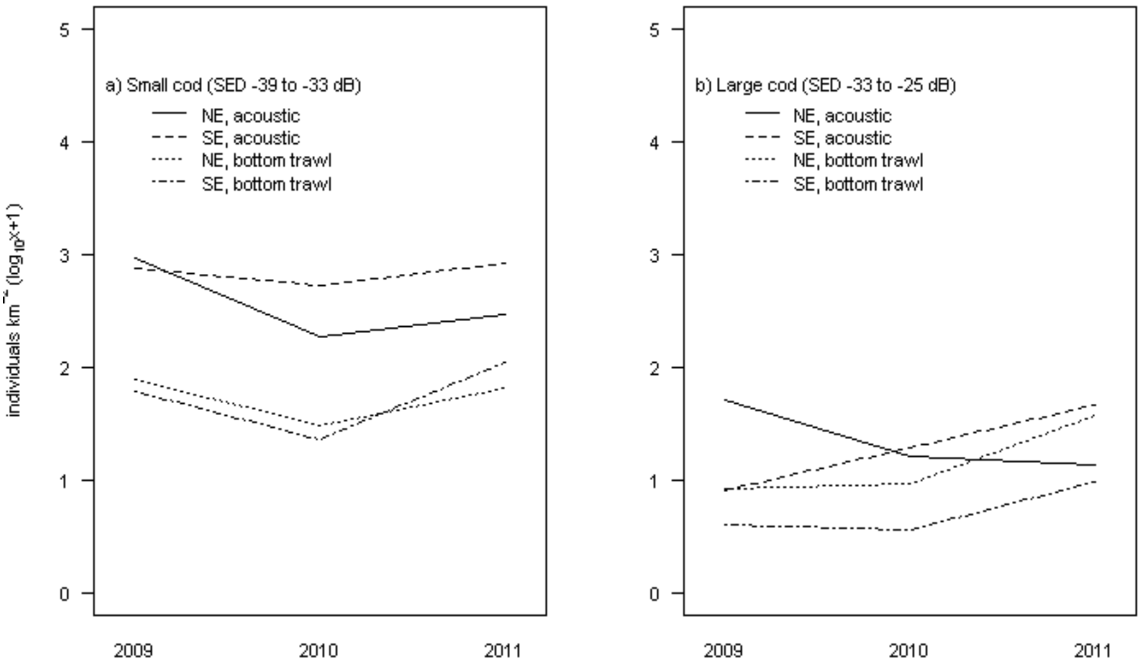

Figure 5. Estimated cod abundance ($\log_{10}$individuals km^{-2}) per area and year; a) small cod (20 – 40 cm) and b) large cod (40 – 100 cm). Comparison of acoustic and trawl data.

Estimation of large cod does not suffer from the problems associated with species composition of small fish and should provide a reliable estimate. The acoustic and the catch generated abundance estimates of large cod were also within the same order of magnitude although the acoustic estimate was slightly higher. However, whereas the catch based abundance estimates increased from 2009 to

2011 and consistently was higher in the partially closed area than in the closed area, the acoustic abundance of large cod in the partially closed area decreased over time and (figure 5b).

In conclusion, based on acoustic data, the estimated abundance of cod, especially large cod, in the closed areas and in the reference area was very low in 2009, 2010 and 2011. In the closed area, the trend was increasing which agrees with data from the joint Swedish and Danish survey for cod in the Kattegat. In the partially closed area however, the abundance of large cod decreased from 2009 to 2011.

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Appendix 6. Documentation on trawls used in the Swedish Kattegat demersal fisheries

Daniel Valentinsson, Institute of Marine Research, Department of Marine Resources, Swedish University of Agriculture

As a response to the critical state for the cod stocks in the Skagerrak and Kattegat, the Swedish grid concept (Fig. 1) was developed in the early 2000s in a collaborative work between scientist and industry in order to find a technical solution that allowed for the continuation of Nephrops trawling but with a minimal by-catch of cod. The grid concept (35 mm sorting grid and 70 mm square mesh codend) was first introduced in national waters (inside 3/4 nautical miles) in 2004 (Valentinsson and Ulmestrand 2008).

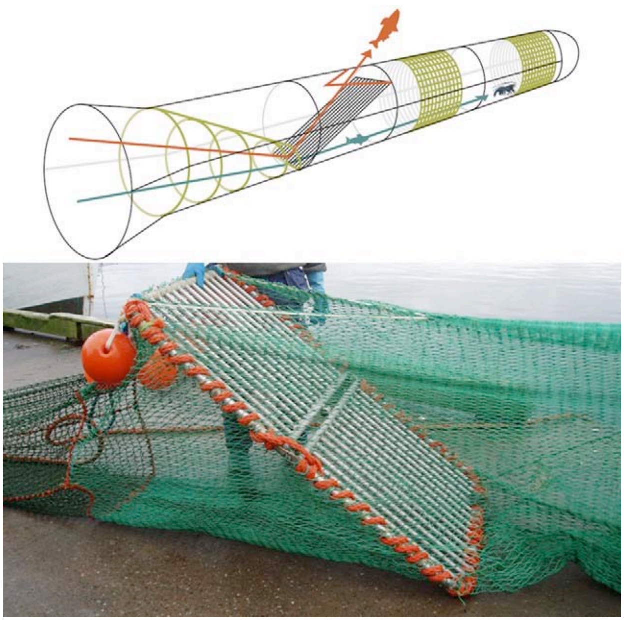

Fig. 1. (Top) A conceptual drawing of a standard grid with a square-mesh cod- end. Large fish are deflected out by the grid. Smaller fish and *Nephrops* pass through the grid and enter the cod-end. Escapement of juvenile fish and under- sized *Nephrops* is facilitated by the square-mesh cod-end. (Bottom) A standard 35 mm Nordmøre grid with a 70 mm square-mesh cod-end.

The use of the sorting grid by Swedish fishers has gradually increased since its introduction in 2004. For the years 2009-2011, *Nephrops* landings in the Skagerrak and Kattegat by vessels using the grid reached 52-68% of total *Nephrops* landings. The grid is now being used by most demersal trawlers at some time of the year. Its use has been promoted by incentives such as an increased quota share (50% of Swedish IIIa quota allocated to grid trawls), access to commercially important *Nephrops* areas that are closed to other trawls, and unlimited kW-days due to documented cod catches of less than 1.5% of total catch (in accordance with art 11.2 of EC Council Reg. 1142/2008).

Technical legislation in Kattegat today

As opposed to 7 legal gear alternatives in Danish legislation (gears no. 1-7 below), Swedish fishermen can only use 3 gear alternatives in the Kattegat (gears no. 4,5 and 8 underlined in the list below):

1. 4-panel codend with a 180 mm square mesh panel installed 4-7 meter from the codline.
2. 4-panel codend with a diamond mesh panel with a minimum mesh size of 270 mm installed 4-7 meter from the codline.
3. 2-panel codend with a 180 mm square mesh panel installed 4-7 meters from the codline.
4. Trawl gear with a Swedish *Nephrops*-grid and 8 m long 70 mm square mesh cod-end installed.
5. Codend with a 300 mm square mesh panel installed 3–6 meters from the codline.
6. Topless trawl in combination with a codend with a minimum 175 mm square mesh panel installed 3-6 meters from the codline.
7. 90 mm codend with a 120 mm square mesh panel installed 6-9 meters from the codline (only legal in the last quarter of the year for the trawl fleet in Kattegat)
8. 90 mm codend

Of these three alternatives only design 4 and 8 are used by Swedish fishermen in the Kattegat. Designs 4 and 5 are the two legal alternatives for the demersal trawls inside the seasonally and partially closed areas, but to SLU Aquas knowledge, design 5 has only been used a few days by one vessel in 2011. Designs 4 and 8 are both used outside the closed areas, of which design 4 dominates effort and value.

Scientific background to the Swedish grid

This section only focusses on design 4 above, as the other alternatives are described in the Danish gear annex. The scientific background presenting gear trials for the sorting grid and square mesh cod-end are described in Valentinsson and Ulmestrand 2008, Catchpole et al 2006, Frandsen et al 2009 and Madsen and Valentinsson 2010.

The selectivity of the Swedish grid and square mesh cod-end is a result of two counteracting selectivity processes that results in a atypical bell-shaped selectivity curve (Madsen and Valentinsson 2010, Fig. 2): The two selectivity processes involves that larger cod are deflected out of the trawl by the grid, while smaller cod may pass through the grid and either be retained or escape the square mesh cod-end. Thus cod smaller than 19 cm and larger than 32 cm have a low retention probability (i.e. <5%). Highest retention probability is at around 26 cm (Fig. 2).

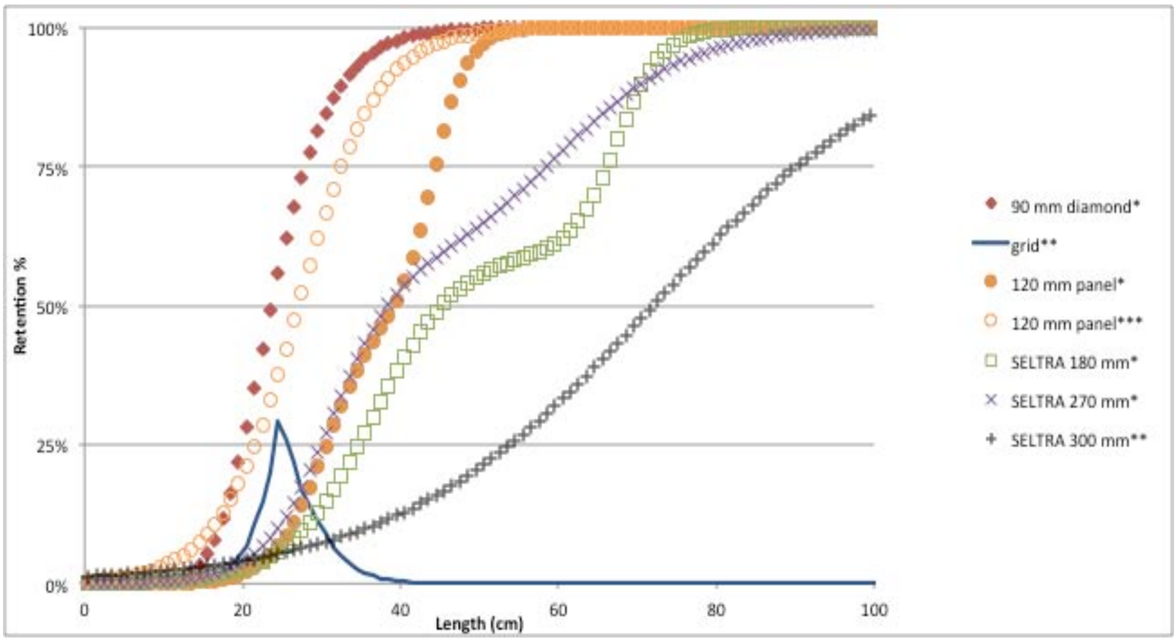

Fig. 1. Selectivity for different Nephrops trawl options in the Kattegat fishery. Asterisks denotes references to reported results: (*) Danish gear annex to this report (**) Madsen and Valentinsson 2010 (***) Frandsen et al 2009.

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APPENDIX 7. NOTAT

Til Jacob Munkhøj Nielsen

Vedr. Documentation of selective effect of gear designs used in Kattegat.

Dato:12.02.2012

Fra DTU Aqua /LAK, BHE

Background

The critical state of the cod stock in Kattegat has led to a mandatory use of more cod-selective fishing gear. The standard trawl in Kattegat used to be a 90 mm codend with a 120 mm square mesh panel installed 6-9 meters from the codline. In July 2011 SELTRA codends with either a 180 mm square mesh panel or a 270 mm diamond mesh panel installed 4-7 meters from the codline, were made mandatory in Kattegat during the first 3 quarters of the year (Fig.1). The standard 90 mm codend with a 120 mm square mesh panel is legal in the last quarter of the year, to reduce losses of sole in the economically important sole fishery occurring at the end of the year.

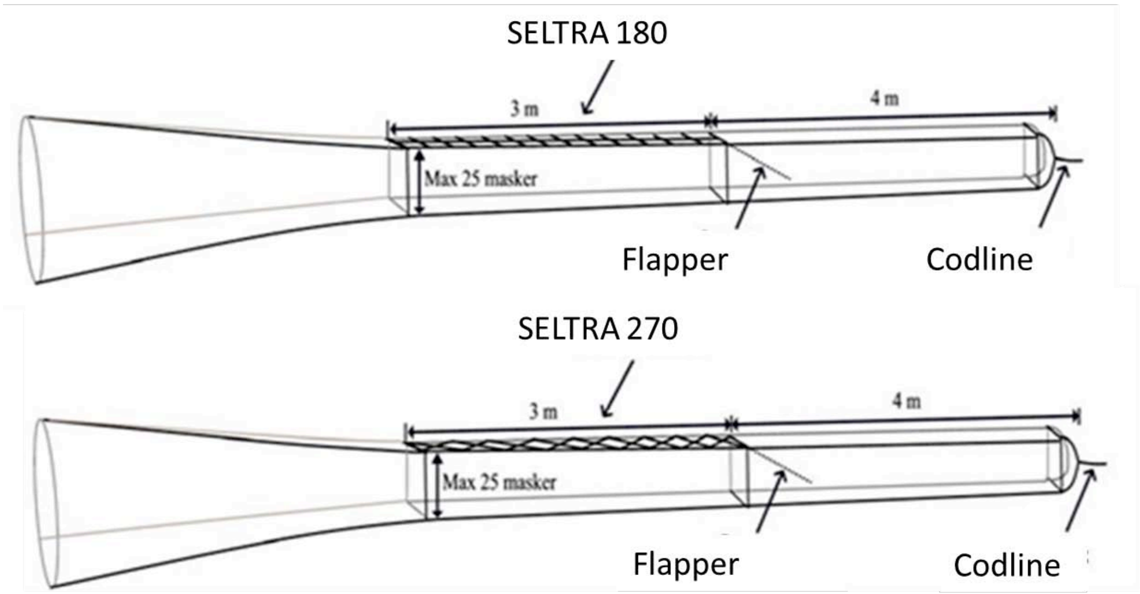

Figure 1. A 90 mm codend in 4- panels with a SELTRA 180 mm square mesh (top) and a 90 mm codend in 4 – panels with the SELTRA 270 nm diamond mesh panel.

The implementation of the SELTRA 180 was initially based on results from experimental fishing conducted in the 120 mm fishery in the northern North Sea. These results demonstrated that a 180 mm SELTRA panel reduced the cod catches substantially. The results were however not directly transferable to 90 mm *Nephrops* fishery in Kattegat primarily due to differences in codend mesh size and population structure.

Technical legislation in Kattegat today

There are today 7 legal gears alternatives for the Danish trawl fleet operating in Kattegat:

1. 4-panel codend with a 180 mm square mesh panel installed 4-7 meter from the codline.
2. 4-panel codend with a diamond mesh panel with a minimum mesh size of 270 mm installed 4-7 meter from the codline.
3. 2-panel codend with a 180 mm square mesh panel installed 4-7 meters from the codline.
4. Trawl gear with a Swedish *Nephrops*-grid installed.
5. Codend with a 300 mm square mesh panel installed 3–6 meters from the codline.
6. Topless trawl in combination with a codend with a minimum 175 mm square mesh panel installed 3-6 meters from the codline.
7. 90 mm codend with a 120 mm square mesh panel installed 6-9 meters from the codline (only legal in the last quarter of the year for the trawl fleet in Kattegat)

These 7 legal alternatives are not all used by the Danish fleet in Kattegat. To DTU Aquas knowledge, designs 4 and 6 never have been used. Designs 1, 2, 3 and 5 are in use today and design 7 is used in the last quarter of the year. Design 5 is mandatory for the fishery inside the closed areas south east in Kattegat. Most of the fleet outside the closed areas use designs 1 and 2. The following section will present the selectivity for designs 1, 2 and 7 in addition to a standard 90 mm without any selective devices installed.

In October 2011 DTU Aqua conducted experimental fishing onboard a commercial vessel in Skagerrak. The experiment was conducted in Skagerrak as cod catches in Kattegat were so low that a robust statistical analysis of the different gears selective effect would be impossible. These new experiments were conducted as covered codend experiments for each of the following four codends:

1. 90 mm 2 - panel codend with 100 open meshes in the circumference.
2. 90 mm 2 - panel codend with a 120 mm square mesh panel inserted 6-9 meters from the codline. 100 open meshes the in circumference.
3. 90 mm 4 - panel codend with at SELTRA 180 mm square mesh panel inserted 4-7 meters from the codline. 100 open meshes in the circumference.
4. 90 mm 4 - panel codend with at SELTRA 270 mm diamond mesh panel inserted 4-7 meters from the codline. One 270 mm diamond mesh was joined to four 90 mm meshes. 100 open meshes in the circumference.

Thirteen tows were conducted with codends 1 and 2 and 19 tows with codends 3 and 4. Fishing was conducted around the clock with an average towing time about four hours.

Traditional the size selection in trawl codends are described in terms of a simple logistic curve or a Richard curve (see Wileman et al. 1996). This approached have successfully been applied for traditional diamond mesh codends where there is only one selection device. For composite designs like SELTRA with more than one selection device (panel and codend) the traditional approach cannot be expected to be able to describe the size selection process sufficient well. In the SELTRA design it cannot be expected that all the cod entering the gear are able to come into contact with the escapement panel. Thus only a limited fraction of the fish entering the gear will have their size selection defined by the panel. The rest of the fish will have their size selection defined by the less selective codend. Averaging the panel contact over fish size the panel contact likelihood can be described by a single number between 0.0 (no fish contact the panel) and 1.0 (every fish contact the panel) leads to a double logistic selection model on the form:

$$r(l) = contact_{panel} \times \frac{\exp((l - L50_{panel}) \times \ln(9) / SR_{panel})}{1.0 + \exp((l - L50_{panel}) \times \ln(9) / SR_{panel})} + (1.0 - contact_{panel}) \times \frac{\exp((l - L50_{codend}) \times \ln(9) / SR_{codend})}{1.0 + \exp((l - L50_{codend}) \times \ln(9) / SR_{codend})} \quad (1)$$

r(l) expresses the retention likelihood at length *l* for fish entering the dual selection system consisting of panel and codend. $L50_{panel}$ and SR_{panel} describe the size selection in the panel for the fraction of fish contacting the panel. $contact_{panel}$ quantify the likelihood for contacting the panel. $L50_{codend}$ and SR_{codend} describe the size selection in the codend part.
The data belonging to each design tested in the cruise was pooled over hauls to provide an average selection set each design. Using a maximum likelihood estimation methods the traditional selection curves (logistic and Richard) were fitted to the pooled data. For the panel based systems the double logistic model described by equation (1) was applied as well.
Models to describe data for each codend design were then selected based on their AIC-value where the model with the lowest AIC value was used in the analysis. All data analyses were made with the SELNET software developed by Bent Herrmann, DTU Aqua. To avoid underestimation of the confidence limits for the parameters in the selection models when estimating based on pooling data over hauls a double bootstrapping method implemented in SELNET was applied which take both within and between haul variation into account (Sistiaga et al 2010). The same bootstrapping method was applied to estimate the confidence limits for the entire selection curve following the procedure described in Herrmann et al. 2012. For each design 1000 bootstrap repetitions were applied in the analysis.

Results

Inspections of the more traditional models used to describe selectivity data, e. g. a logistic model, have as expected, demonstrated that they cannot describe the data obtained with the three panel designs based on obtained fit statistic (AIC, p-value, deviance, DOF). The models used to describe the data obtained for each gear type is given in table 1 along with fit statistics for the selected models.

Table. 1. Models used to describe data and their fit statistics.

Design	Model	p-value	Deviance	DOF
90 mm	Richard	0.2417	82.14	74
90mm + 120 mm panel	Double logistic	0.5706	60.37	63
SELTRA 180 mm (square mesh)	Double logistic	0.081	88.23	71
SELTRA 270 mm (diamond mesh)	Double logistic	0.0431	97.24	75

Selectivity curves

In the following section, figures with retention curves for each of tested gear designs are presented. In addition to the mean estimate, the 95 % confidence limits are given. The confidence limits are based on the 1000 bootstrap repetitions. The populations of cod caught during the experiments are given as a green line in fig. 2-5 with a green line.

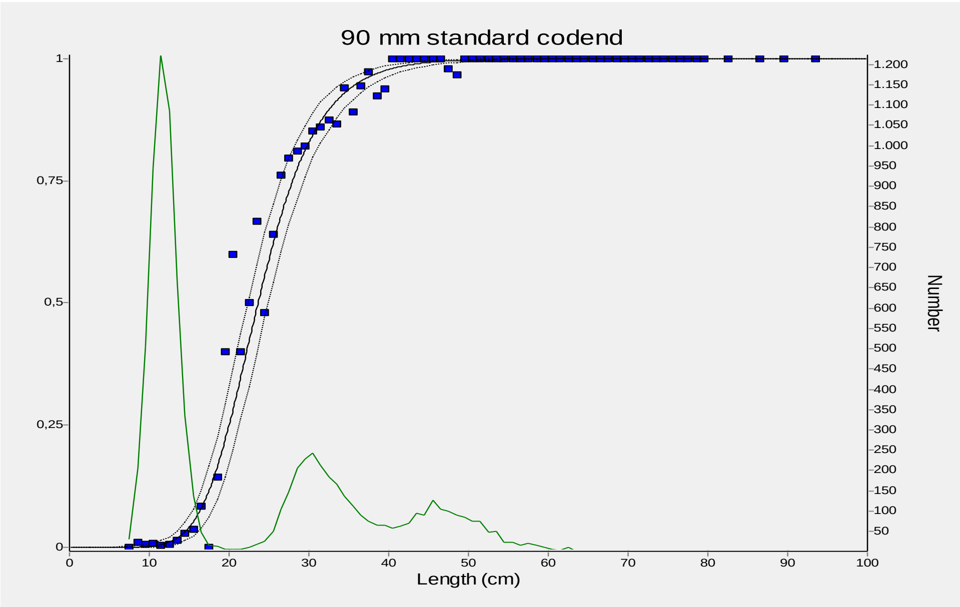

Figure 2. Retention curve with 95% confidence limits for a 90mm standard codend. The population of cod is indicated with a green line.

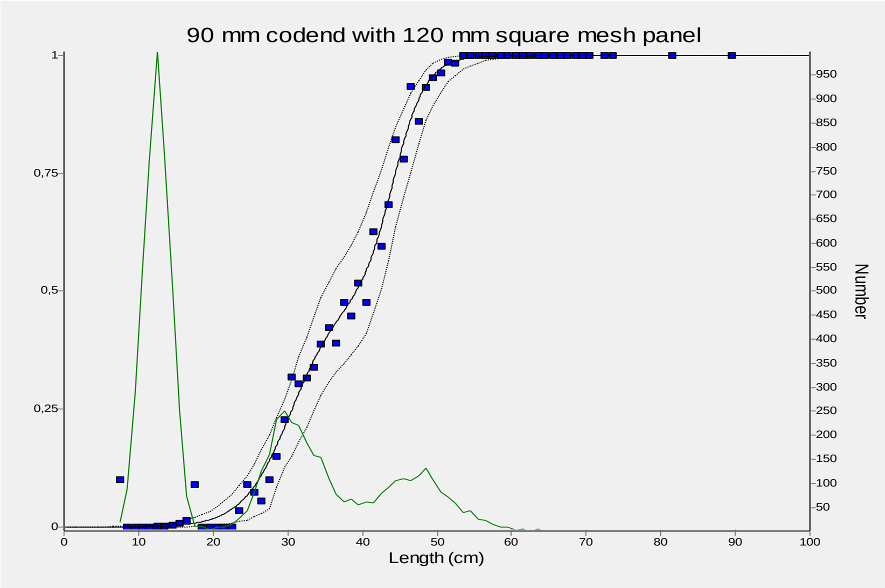

Figure 3. Retention curve with 95% confidence limits for a 90 mm codend with a 120 mm square mesh panel inserted 6-9 meters from the codline. The population of cod is indicated with a green line.

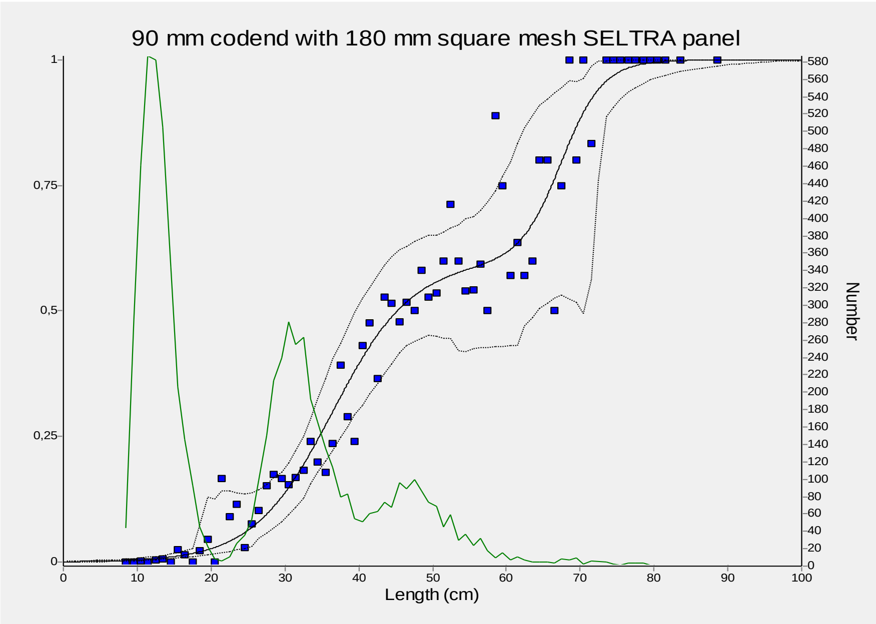

Figure 4. Retention curve with 95% confidence limits for 90 mm codend with a SELTRA 180 mm square mesh panel. The population of cod is indicated with a green line.

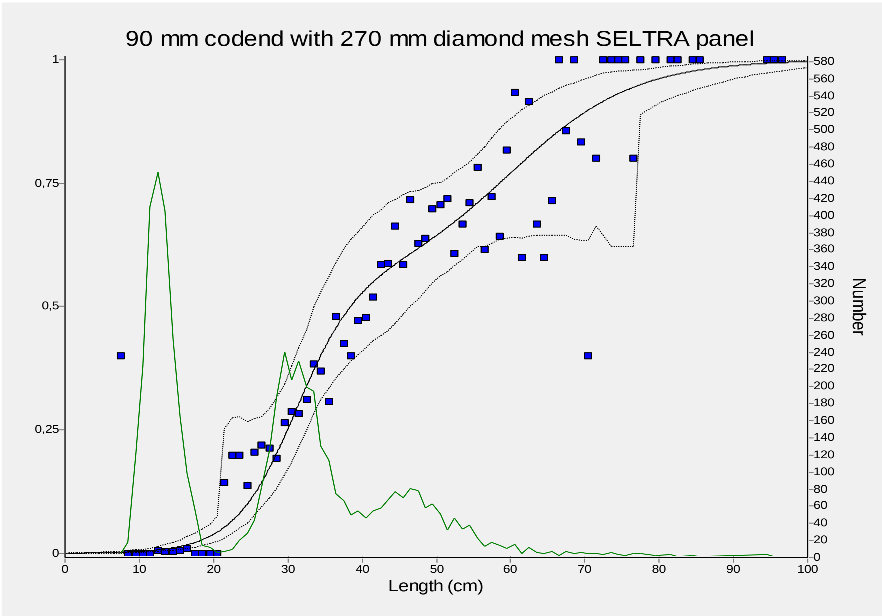

Figure 5. Retention curve with 95% confidence limits for 90 mm codend with a SELTRA 270 mm diamond mesh panel. The population of cod is indicated with a green line.

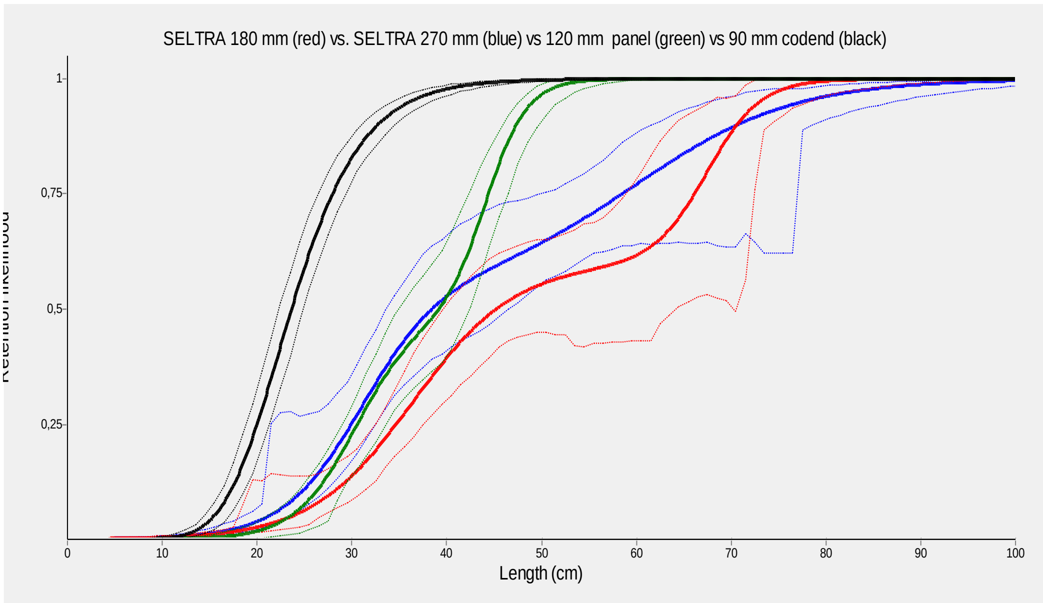

Figure 6. Selectivity curves with 95% confidence limits for the four different gears plotted together.

Selectivity

The selectivity curve of the 90 mm codend obtained the traditional s-shape in contrast to the three designs with sorting panels. If we insert a selective panel into a codend, the single fish can escape through the panel, through the codend meshes, or be retained. There are two selection processes occurring in the gear. If the mesh size in the panel and the codend are very different these two selection processes are also very different. Figure 3 shows a signature of a dual selection process where the mean curve is more curved than the traditional s-shape in Figure 2. In figure 4, the difference between the codend (90 mm) and panel mesh size (180 mm) is increased further and so the double s-shaped curve is more pronounced as expected. The selectivity in codends is traditionally given as the selection parameters L50 and SR. With the more composite designs, like the three panel designs presented here, L50 and SR parameters alone can be inadequate in describing the selection in terms of e. g. potential discard or loss of target species. The over-all L50 and SR are given for the four gears in Table 2. In addition the L50 and SR for the panels and codends are given to describe the contribution of each part to the overall selectivity.

The 270 mm diamond mesh SELTRA panel was included due to a strong industry interest in a cheaper and a simpler alternative repair wise, to the 180 mm square mesh (Ultra Cross). There was not detected any significant differences in the selectivity between these two panels as there is overlap along the full length-span between confidence limits (Figure 6). Figure 6 demonstrates that the selectivity can be substantially improved in a 90 mm codend by inserting selective panels.

The contact probability given in Table 2 indicates the proportion of fish that comes in contact with the panel of those that enters the codend. The contact probability reveals that not all fish come in contact with the selective panel and that a large proportion of the fish entering the codend therefore will have their faith determined by the smaller meshes in the codend.

The retention likelihood for each length class is given in Table 3 for the four gear designs.

DTU Aqua has earlier conducted experiments with the 120 mm square mesh panel inserted 6-9 meters from the codline in the Danish *Nephrops* directed fisheries in Kattegat and Skagerrak (Krag et al., 2008; Frandsen et al., 2009). These earlier experiments indicated that the panel had a limited (non-significant) effect on cod and are very different from the significant effect found in the above presented experiment. The old experiments were conducted as catch comparison experiments where the 9 meter codend section, in which the square mesh panel was inserted, was attached directly to the end of the last tapered section in the body of the trawl. In the 2011 covered codend experiment, the 9 meter codend section was attached to a 4 meters extension piece. It can be speculated that a longer un-tapered extension makes the panel section more flat and thereby increase the contact probability between fish and panel. A relative large loss of *Nephrops* through the panel supports such a speculation. Further did the analysis carried out on the old data not consider the dual selection aspect of the selection process in such designs as only traditional selection models were considered then.

Tabel 2. Selectivity parameters for all four tested designs with 95% confidence limits. See text for further explanation the single parameters. The contact probability for the three different panels is given in percent (%).

	Gear design			
	90 mm	90 with 120 mm panel	SELTRA 180 mm	SELTRA 270 mm
Overall L50	23.63	39.16	45.2	38.42
low	22.3	35.41	39.18	32.55
high	24.86	42.42	50.13	44.35
Overall SR	7.96	13.84	31.45	28.55
low	7.32	11.96	19.59	20.73
high	9.06	15.94	39.6	45.82
Panel L50	no panel	44.16	67.46	60.1
low	no panel	39.19	49.48	47.25
high	no panel	45.99	72.55	77.01
Panel SR	no panel	4.8	6.18	18.29
low	no panel	0.96	1	15.85
high	no panel	9.23	16.83	25.34
Codend L50	23.63	30.35	36.45	30.98
low	22.3	28.46	26.69	21.31
high	24.86	34.13	39.87	34.74
Codend SR	7.96	7.03	11.79	9.02
low	7.32	1.64	6.179	1
high	9.06	9.56	13.69	11.8
Panel contact	no panel	51.88%	40.23%	45.47%
low	no panel	19.04%	25.78%	21.75%
high	no panel	73.16%	74.45%	78.53%

Table 3. Retention likelihood per length for the four tested gear ± 95% confidence limits

	90 mm codend			120 mm panel			SELTRA 180 mm square			SELTRA 270 mm diamand		
Length (cm)	Value	Low	High	Value	Low	High	Value	Low	High	Value	Low	High
0.5	0.0000	0.0000	0.0001	0.0000	0.0000	0.0003	0.0007	0.0003	0.0018	0.0007	0.0002	0.0017
1.5	0.0000	0.0000	0.0001	0.0001	0.0000	0.0003	0.0009	0.0004	0.0020	0.0008	0.0002	0.0019
2.5	0.0000	0.0000	0.0001	0.0001	0.0000	0.0004	0.0011	0.0005	0.0023	0.0010	0.0003	0.0022
3.5	0.0000	0.0000	0.0002	0.0001	0.0000	0.0005	0.0013	0.0006	0.0027	0.0012	0.0004	0.0025
4.5	0.0000	0.0000	0.0004	0.0001	0.0000	0.0007	0.0015	0.0008	0.0031	0.0014	0.0005	0.0029
5.5	0.0001	0.0000	0.0008	0.0002	0.0000	0.0009	0.0019	0.0010	0.0036	0.0017	0.0006	0.0035
6.5	0.0002	0.0000	0.0013	0.0003	0.0000	0.0011	0.0022	0.0012	0.0043	0.0021	0.0008	0.0041
7.5	0.0004	0.0000	0.0022	0.0004	0.0000	0.0014	0.0027	0.0015	0.0050	0.0026	0.0010	0.0049
8.5	0.0008	0.0000	0.0034	0.0005	0.0000	0.0017	0.0033	0.0019	0.0059	0.0032	0.0013	0.0059
9.5	0.0016	0.0002	0.0054	0.0007	0.0000	0.0024	0.0039	0.0024	0.0069	0.0039	0.0018	0.0072
10.5	0.0031	0.0005	0.0083	0.0010	0.0000	0.0030	0.0047	0.0030	0.0081	0.0049	0.0023	0.0090
11.5	0.0059	0.0015	0.0134	0.0013	0.0000	0.0040	0.0057	0.0036	0.0095	0.0060	0.0031	0.0112
12.5	0.0109	0.0034	0.0211	0.0018	0.0001	0.0051	0.0068	0.0045	0.0111	0.0075	0.0041	0.0140
13.5	0.0192	0.0071	0.0330	0.0025	0.0001	0.0068	0.0082	0.0055	0.0133	0.0093	0.0053	0.0176
14.5	0.0323	0.0136	0.0521	0.0034	0.0002	0.0086	0.0098	0.0066	0.0157	0.0116	0.0068	0.0216
15.5	0.0519	0.0224	0.0790	0.0046	0.0004	0.0120	0.0118	0.0079	0.0186	0.0144	0.0086	0.0271
16.5	0.0797	0.0383	0.1176	0.0063	0.0007	0.0172	0.0142	0.0094	0.0221	0.0180	0.0107	0.0340
17.5	0.1168	0.0626	0.1672	0.0085	0.0011	0.0213	0.0170	0.0112	0.0263	0.0224	0.0133	0.0409
18.5	0.1636	0.0990	0.2268	0.0116	0.0017	0.0263	0.0204	0.0129	0.0741	0.0280	0.0163	0.0494
19.5	0.2193	0.1431	0.2940	0.0157	0.0025	0.0327	0.0244	0.0149	0.1301	0.0348	0.0200	0.0605
20.5	0.2824	0.1999	0.3654	0.0212	0.0038	0.0440	0.0291	0.0168	0.1260	0.0433	0.0249	0.0764
21.5	0.3505	0.2622	0.4377	0.0285	0.0057	0.0548	0.0347	0.0193	0.1424	0.0537	0.0312	0.2527
22.5	0.4209	0.3282	0.5122	0.0381	0.0080	0.0699	0.0413	0.0215	0.1412	0.0663	0.0402	0.2748
23.5	0.4909	0.3972	0.5789	0.0507	0.0118	0.0880	0.0491	0.0240	0.1377	0.0815	0.0508	0.2776
24.5	0.5582	0.4726	0.6444	0.0667	0.0147	0.1085	0.0582	0.0268	0.1365	0.0995	0.0613	0.2677
25.5	0.6210	0.5426	0.7024	0.0868	0.0218	0.1341	0.0687	0.0315	0.1379	0.1207	0.0773	0.2722
26.5	0.6781	0.6063	0.7537	0.1113	0.0286	0.1644	0.0809	0.0482	0.1432	0.1450	0.0936	0.2774
27.5	0.7290	0.6618	0.7971	0.1403	0.0398	0.1959	0.0949	0.0582	0.1544	0.1724	0.1120	0.2939
28.5	0.7736	0.7124	0.8329	0.1734	0.0848	0.2313	0.1107	0.0686	0.1675	0.2027	0.1324	0.3164
29.5	0.8120	0.7568	0.8628	0.2095	0.1264	0.2702	0.1285	0.0805	0.1789	0.2353	0.1592	0.3424
30.5	0.8447	0.7978	0.8899	0.2473	0.1508	0.3122	0.1483	0.0938	0.1961	0.2693	0.1857	0.3795
31.5	0.8723	0.8281	0.9108	0.2850	0.1809	0.3607	0.1700	0.1087	0.2224	0.3041	0.2159	0.4178
32.5	0.8954	0.8548	0.9272	0.3211	0.2121	0.4016	0.1936	0.1279	0.2506	0.3385	0.2509	0.4541
33.5	0.9145	0.8791	0.9415	0.3543	0.2461	0.4459	0.2187	0.1556	0.2850	0.3716	0.2835	0.4984
34.5	0.9304	0.8994	0.9531	0.3841	0.2795	0.4864	0.2451	0.1791	0.3240	0.4029	0.3120	0.5290
35.5	0.9434	0.9166	0.9622	0.4107	0.3076	0.5193	0.2724	0.2009	0.3652	0.4317	0.3353	0.5599
36.5	0.9540	0.9306	0.9699	0.4349	0.3294	0.5485	0.3002	0.2225	0.4039	0.4577	0.3546	0.5898
37.5	0.9627	0.9420	0.9761	0.4582	0.3476	0.5722	0.3280	0.2476	0.4363	0.4810	0.3739	0.6179
38.5	0.9698	0.9520	0.9809	0.4824	0.3649	0.5976	0.3552	0.2686	0.4667	0.5016	0.3911	0.6368
39.5	0.9756	0.9600	0.9848	0.5101	0.3833	0.6262	0.3815	0.2933	0.4970	0.5197	0.4029	0.6518
40.5	0.9802	0.9666	0.9879	0.5437	0.4115	0.6669	0.4065	0.3129	0.5248	0.5358	0.4176	0.6692
41.5	0.9840	0.9723	0.9904	0.5854	0.4537	0.7104	0.4299	0.3349	0.5457	0.5502	0.4302	0.6854
42.5	0.9871	0.9770	0.9924	0.6361	0.5043	0.7580	0.4515	0.3549	0.5716	0.5632	0.4410	0.6959
43.5	0.9896	0.9810	0.9940	0.6941	0.5654	0.8057	0.4711	0.3755	0.5911	0.5751	0.4522	0.7101
44.5	0.9916	0.9842	0.9953	0.7552	0.6358	0.8473	0.4888	0.3934	0.6078	0.5862	0.4659	0.7170
45.5	0.9932	0.9870	0.9963	0.8138	0.7010	0.8861	0.5044	0.4169	0.6221	0.5969	0.4840	0.7263
46.5	0.9945	0.9892	0.9971	0.8648	0.7513	0.9193	0.5183	0.4307	0.6290	0.6074	0.5000	0.7328
47.5	0.9956	0.9911	0.9977	0.9055	0.8138	0.9474	0.5304	0.4399	0.6382	0.6177	0.5145	0.7357
48.5	0.9964	0.9926	0.9982	0.9360	0.8617	0.9689	0.5409	0.4450	0.6450	0.6282	0.5309	0.7417
49.5	0.9971	0.9939	0.9986	0.9575	0.8933	0.9832	0.5501	0.4511	0.6513	0.6388	0.5476	0.7495
50.5	0.9977	0.9949	0.9989	0.9722	0.9212	0.9918	0.5580	0.4497	0.6500	0.6497	0.5623	0.7525
51.5	0.9981	0.9958	0.9991	0.9820	0.9437	0.9963	0.5649	0.4449	0.6566	0.6610	0.5702	0.7599
52.5	0.9985	0.9966	0.9993	0.9884	0.9569	0.9982	0.5711	0.4449	0.6647	0.6726	0.5823	0.7714
53.5	0.9988	0.9972	0.9995	0.9926	0.9702	0.9992	0.5766	0.4208	0.6715	0.6847	0.5964	0.7824
54.5	0.9990	0.9977	0.9996	0.9952	0.9779	0.9995	0.5817	0.4183	0.6847	0.6972	0.6079	0.7929
55.5	0.9992	0.9981	0.9997	0.9970	0.9837	0.9998	0.5866	0.4250	0.6881	0.7100	0.6224	0.8081
56.5	0.9994	0.9984	0.9997	0.9981	0.9887	0.9999	0.5918	0.4266	0.6994	0.7232	0.6231	0.8231
57.5	0.9995	0.9987	0.9998	0.9988	0.9921	0.9999	0.5974	0.4280	0.7158	0.7366	0.6289	0.8422
58.5	0.9996	0.9989	0.9998	0.9992	0.9944	1.0000	0.6040	0.4290	0.7394	0.7502	0.6370	0.8612
59.5	0.9997	0.9991	0.9999	0.9995	0.9966	1.0000	0.6121	0.4300	0.7679	0.7639	0.6379	0.8745
60.5	0.9997	0.9993	0.9999	0.9997	0.9979	1.0000	0.6223	0.4307	0.7968	0.7777	0.6416	0.8881
61.5	0.9998	0.9994	0.9999	0.9998	0.9986	1.0000	0.6353	0.4313	0.8344	0.7914	0.6393	0.8994
62.5	0.9998	0.9995	0.9999	0.9999	0.9990	1.0000	0.6520	0.4695	0.8641	0.8050	0.6428	0.9081
63.5	0.9999	0.9996	1.0000	0.9999	0.9993	1.0000	0.6730	0.4859	0.8888	0.8183	0.6440	0.9183
64.5	0.9999	0.9997	1.0000	0.9999	0.9995	1.0000	0.6986	0.5053	0.9088	0.8312	0.6442	0.9277
65.5	0.9999	0.9997	1.0000	1.0000	0.9997	1.0000	0.7289	0.5161	0.9228	0.8438	0.6438	0.9352
66.5	0.9999	0.9998	1.0000	1.0000	0.9998	1.0000	0.7627	0.5260	0.9339	0.8559	0.6441	0.9424
67.5	0.9999	0.9998	1.0000	1.0000	0.9999	1.0000	0.7985	0.5313	0.9446	0.8675	0.6443	0.9485
68.5	1.0000	0.9998	1.0000	1.0000	0.9999	1.0000	0.8342	0.5231	0.9589	0.8785	0.6371	0.9538
69.5	1.0000	0.9999	1.0000	1.0000	0.9999	1.0000	0.8676	0.5179	0.9571	0.8889	0.6340	0.9588
70.5	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000	0.8971	0.4947	0.9639	0.8987	0.6341	0.9634
71.5	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000	0.9219	0.5628	0.9873	0.9078	0.6642	0.9695
72.5	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000	0.9419	0.7588	0.9983	0.9164	0.6448	0.9733
73.5	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000	0.9574	0.8877	0.9990	0.9243	0.6224	0.9763
74.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9691	0.9060	0.9995	0.9315	0.6225	0.9778
75.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9778	0.9214	0.9998	0.9382	0.6226	0.9779
76.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9841	0.9355	0.9999	0.9444	0.6226	0.9790
77.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9887	0.9446	0.9999	0.9500	0.8893	0.9794
78.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9920	0.9529	0.9999	0.9551	0.8988	0.9817
79.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9943	0.9602	1.0000	0.9597	0.9078	0.9838
80.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9960	0.9649	1.0000	0.9639	0.9151	0.9857
81.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9972	0.9694	1.0000	0.9677	0.9214	0.9872
82.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9980	0.9735	1.0000	0.9711	0.9273	0.9887
83.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9986	0.9766	1.0000	0.9742	0.9328	0.9899
84.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9990	0.9796	1.0000	0.9770	0.9379	0.9910
85.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9993	0.9820	1.0000	0.9795	0.9428	0.9920
86.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9995	0.9842	1.0000	0.9817	0.9473	0.9930
87.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9996	0.9861	1.0000	0.9837	0.9515	0.9938
88.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9997	0.9880	1.0000	0.9855	0.9554	0.9946
89.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9998	0.9895	1.0000	0.9871	0.9590	0.9952
90.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	0.9910	1.0000	0.9885	0.9624	0.9958
91.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	0.9923	1.0000	0.9898	0.9655	0.9963
92.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	0.9936	1.0000	0.9909	0.9684	0.9968
93.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	0.9948	1.0000	0.9919	0.9710	0.9972
94.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9956	1.0000	0.9928	0.9734	0.9976
95.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9963	1.0000	0.9936	0.9757	0.9979
96.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9970	1.0000	0.9943	0.9776	0.9981
97.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9974	1.0000	0.9950	0.9794	0.9984
98.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9980	1.0000	0.9955	0.9811	0.9986
99.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9983	1.0000	0.9960	0.9826	0.9987
100.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9986	1.0000	0.9965	0.9840	0.9989
101.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9989	1.0000	0.9969	0.9853	0.9990
102.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9991	1.0000	0.9972	0.9865	0.9991
103.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9992	1.0000	0.9975	0.9876	0.9993
104.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9993	1.0000	0.9978	0.9886	0.9994
105.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9994	1.0000	0.9981	0.9895	0.9994
106.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9995	1.0000	0.9983	0.9904	0.9995
107.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9996	1.0000	0.9985	0.9912	0.9996
108.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9997	1.0000	0.9986	0.9919	0.9996
109.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9997	1.0000	0.9988	0.9925	0.9997
110.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9998	1.0000	0.9989	0.9932	0.9997
111.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9998	1.0000	0.9991	0.9937	0.9997
112.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9998	1.0000	0.9992	0.9942	0.9997
113.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9993	0.9947	0.9998
114.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9993	0.9951	0.9998
115.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9994	0.9955	0.9998
116.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9995	0.9959	0.9998
117.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9995	0.9962	0.9999
118.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9996	0.9966	0.9999
119.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9996	0.9968	0.9999
120.5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9997	0.9971	0.9999

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Appendix 8. Analysis of the Danish and Swedish fishery in the restricted areas in Kattegat and the Sound initiated 1st January 2009

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Background

The Danish and Swedish authorities initiated the 1st January 2009 various restrictions for the fishing activities in three specific areas in Kattegat plus an adjacent area in the Sound in order to help increasing the size of the cod stock in Kattegat. The background for these initiatives was that the reductions in the cod quota over the last years did not result in an increase in the cod stock, and further initiatives were therefore considered necessary in order to accomplish this.

Therefore, the following restrictions were initiated in the following areas and periods:

a) Area 1 consisting of a subarea in Kattegat, where it is not allowed to fish in the period from 1st January to 31rd March plus another subarea in the Sound ("Kilen"), where fishing in not allowed in the period from 1st February to 31rd March. However, some selective fisheries are allowed the whole year in these two subareas,
b) Area 2 where fishing is not allowed the entire year, except for some selective fisheries,
c) Area 3 where no fishing is allowed.

Maps of the three areas are shown in Fig. 1.

In the following the Danish Fisheries Analysis Database (DFAD) are used as source for the statistical analysis of the Danish fishery undertaken. For the statistical analysis of the Swedish fishery log book data and sales notes stored at the Swedish Agency for marine and water management are used. For the data on value of landings for the Swedish vessels average prices for the west coast, south coast and east coast is used.

The first objective of this note is to describe the Danish and Swedish fishery in Kattegat and the development in dependency of the restricted areas before and after the closure. By comparing the situation in the years before the closure (2005-2008) with the year just after the closure (2009) and the latest available year (2011) some overall trends can be shown.

The second objective is to analyse the dependency of fishing activities in the restricted areas for the harbour of Gilleleje in Denmark and Träslövsläge and Glommen in Sweden.

The third objective is to analyse the development in the Danish and Swedish fishery in "Kilen".

In the first section, the analysis of the Danish fishery is undertaken, and in the second section the analysis of the Swedish fishery is made. After that there is a discussion about costs associated with the area closure.

1. *The Danish fishery in Kattegat ~an overall perspective*

At the overall level, Table 1 below shows the number of Danish fishing vessels that catch fish in Kattegat during a year on economic size classes and length groups. There has been a steady decrease in the number of vessels being active in Kattegat since 2005, primarily for the commercial vessels.

Table 1. Number of fishing vessels active in Kattegat.

		2005	2006	2007	2008	2009	2011
Commercial vessels	<12m	56	53	45	34	28	30
	12-15m	105	88	70	69	65	53
	15-18m	74	72	57	51	50	57
	18-24m	60	61	39	31	30	28
	24-40m	9	14	9	8	4	2
	>40m	2	2	2	2	2	
	Total	306	290	222	195	179	170
Non-commercial vessels	<12m	43	30	41	46	40	27
	12-15m	7	7	6	3	5	6
	15-18m	2	2	1		2	2
	18-24m		1		2		
	Total	52	40	48	51	47	35
Total		358	330	270	246	226	205

Note: A commercial vessel has a total yearly landing value above the following thresholds: 2005= 216,731 DKK, 2006=229,050 DKK, 2007 = 252,720 DKK, 2008 = 261,791 DKK, 2009 = 245,875 DKK and 2011= 271,306 DKK.

The total landings value for the vessels having activity in Kattegat during the year is shown in Table 2. However, most of these vessels also have activity in other fishing areas besides Kattegat.

Table 2. Total landings value for vessels with activity in Kattegat (1,000 DKK).

		2005	2006	2007	2008	2009	2011
Commercial vessels	<12m	32,598	33,962	30,182	21,105	14,311	22,482
	12-15m	124,977	128,064	104,632	94,211	72,880	80,904
	15-18m	161,252	172,345	150,967	120,045	111,114	158,375
	18-24m	173,674	209,308	161,351	119,193	94,340	132,461
	24-40m	41,512	74,200	46,034	38,800	17,454	7,779
	>40m	24,058	30,575	24,995	33,471	34,863	0
	Total	558,071	648,453	518,160	426,826	344,962	402,001
Non-commercial vessels	<12m	3,790	2,542	3,685	3,705	4,468	2,740
	12-15m	1,028	810	934	303	772	684
	15-18m	263	148	181	0	51	256
	18-24m	0	65	0	352	0	0
	Total	5,081	3,566	4,800	4,360	5,290	3,680
Total		563,152	652,019	522,960	431,186	350,252	405,680

Note: A commercial vessel has a total yearly landings value above the following thresholds: 2005= 216,731 DKK, 2006=229,050 DKK, 2007 = 252,720 DKK, 2008 = 261,791 DKK, 2009 = 245,875 DKK and 2011= 271,306 DKK.

The importance of the Kattegat fishery for the various fleets is shown in Table 3. Especially for the commercial vessels below 15m, Kattegat is an important fishing area despite that they also fish in other areas. For these vessels, Kattegat accounts for around 50% of their total landings value. Also the economically less important non-commercial vessels below 15m have a high share of the landings value originating from their fishery in Kattegat.

Table 3. Kattegat dependency (Kattegat landings value as a share of total landings value in %).

		2005	2006	2007	2008	2009	2011
Commercial vessels	< 12m	41	39	39	49	52	48
	12-15m	31	38	46	44	48	49
	15-18m	33	31	35	35	32	32
	18-24m	22	19	26	28	24	20
	24-40m	23	14	19	20	28	45

	>40m	9	9	14	13	11	
	Total	28	26	32	33	32	33
Non-commercial vessels	< 12m	49	63	44	48	44	55
	12-15m	59	78	50	43	68	67
	15-18m	43	100	100		100	12
	18-24m		100		100		
	Total	50	68	48	52	48	54
Total		28	26	33	33	32	33

Note: A commercial vessel has a total yearly landings value above the following thresholds: 2005= 216,731 DKK, 2006=229,050 DKK, 2007 = 252,720 DKK, 2008 = 261,791 DKK, 2009 = 245,875 DKK and 2011= 271,306 DKK.

Table 4 shows the composition of landings from the Kattegat fishery. In live weight, industrial species (sprat) is most important followed by herring. In landings value, Norway lobster and various flatfish are the most important ones.

Table 4. Composition of landed species in Kattegat.

	Live weight % of total live weight						**Landings value % of total landings value**					
	2005	**2006**	**2007**	**2008**	**2009**	**2011**	**2005**	**2005**	**2007**	**2008**	**2009**	**2011**
Cod	1.4	1.5	1.1	1.2	0.6	0.6	4.0	4.0	3.1	2.7	1.1	0.7
Other codfish	0.6	0.7	0.9	1.3	0.8	0.5	1.1	1.2	1.7	1.6	1.0	0.5
Flatfish	5.8	6.9	7.5	8.9	6.8	5.7	30.1	32.2	24.3	24.4	23.6	17.0
Norway lobster	3.6	3.5	5.3	8.6	9.3	9.1	43.7	40.7	51.1	53.5	55.0	63.4
Herring	28.5	29.2	28.5	31.2	23.9	13.9	9.8	10.1	9.0	9.1	9.4	4.7
Other species	0.9	6.0	2.2	1.1	0.9	4.5	1.2	2.6	1.7	1.9	2.1	3.0
Industrial species	59.1	52.2	54.4	47.7	57.7	65.7	10.0	9.2	9.0	6.8	7.9	10.6
Total weight (tons)/ value (1,000 DKK)	32,492	27,352	23,254	16,387	15,371	12,338	157,726	170,480	169,965	141,491	111,920	134,051

In order to have a closer analysis of the development in sub-areas in Kattegat, the fishing activity can further be analysed at the ICES-square level[1]. The two restricted subareas 2 and 3 are placed in the ICES-squares 41G2 and 42G2, but does not cover them perfectly. Thus it is possible to fish in these squares without necessarily breaking the law.

[1] In the following only data from landings related to ICES-squares in Kattegat (3AS) are included.

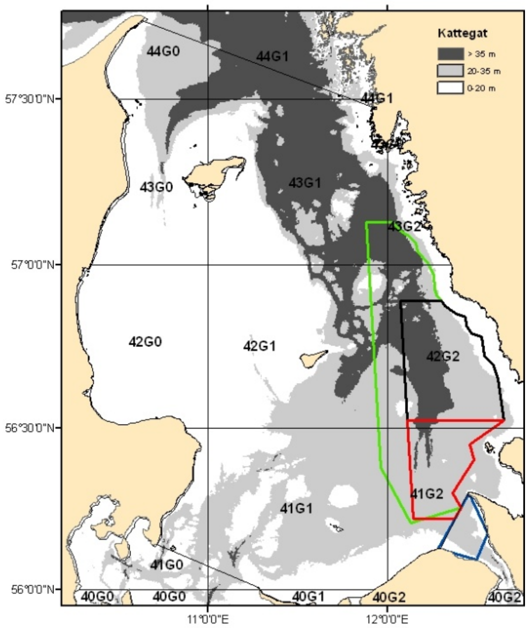

Fig. 1 Kattegat with ICES squares and closed areas.

In total, there are 12 ICES-squares in Kattegat. As shown in Table 5, ICES-square 41G2 was before restricting access accounting for 22% of the live weight and 13% of the yearly landings value, but have since implementing the restrictions been reduced to 10% and 9-10% respectively.

Table 5. Distribution of landings value in Kattegat on ICES-squares.

	Yearly live weight (tons)			Yearly landings value (1,000 DKK)			Yearly live weight (%)			Yearly landings value (%)		
	2005-08	**2009**	**2011**	**2005-08**	**2009**	**2011**	**2005-08**	**2009**	**2011**	**2005-08**	**2009**	**2011**
40G0	0	0	7	11	5	68	0	0	0	0	0	0
40G1	7	22	3	249	350	132	0	0	0	0	0	0
41G0	576	197	454	3,308	1,217	1,215	3	2	4	2	1	1
41G1	4,798	2,630	4,005	30,113	24,865	27,315	22	21	38	20	25	22
41G2	*4,807*	*1,191*	*1,064*	*19,812*	*8,818*	*12,613*	*22*	*10*	*10*	*13*	*9*	*10*
42G0	669	141	101	4,795	2,434	922	3	1	1	3	2	1
42G1	1,821	1,270	872	27,955	20,736	23,842	8	10	8	19	21	19
42G2	*302*	*61*	*468*	*3,914*	*1,733*	*8,463*	*1*	*0*	*4*	*3*	*2*	*7*
43G0	5,066	5,378	2,335	10,311	10,529	9,729	23	44	22	7	11	8
43G1	2,860	1,238	1,118	43,294	26,155	33,341	13	10	10	29	26	27
43G2	85	0	152	189	0	658	0	0	1	0	0	1
44G1	607	160	107	3,441	2,754	4,211	3	1	1	2	3	3
I alt	21,599	12,287	10,686	147,392	99,595	122,503	100	100	100	100	100	100

Finally, Table 6 gives an overall impression of, where the vessels fishing in Kattegat have their home port. The most important one was in the entire period Gilleleje accounting for 16-18% of the landings value in Kattegat.

Table 6. Distribution of landings value on home port for vessels fishing in Kattegat (%).

	2005-2008	**2009**	**2011**
Gilleleje	16	18	16
Strandby	10	13	12
Østerby	15	10	11

Vesterø	9	9	7
Bønnerup	6	5	6
Other homeports	44	45	48

More detailed information about the landings composition in ICES-square 41G2 and 42G2 is shown in Table 7 and Table 8. Cod has not been an important species in this area, and the importance was naturally reduced even further after restricting access.

Table 7. Landings composition in 41G2 and 42G2 (1,000 DKK).

	2005-08			2009			2011		
	41	**42**	**41+42**	**41**	**42**	**41+42**	**41**	**42**	**41+42**
Cod	736	152	888	65	35	100	71	65	136
Other codfish	167	74	241	96	22	118	15	6	22
Flatfish	2,133	523	2,656	974	231	1,206	1,369	926	2,295
Norway lobster	8,267	2,809	11,075	5,161	1,440	6,601	8,115	6,256	14,371
Herring	8,206	284	8,490	2,204	0	2,204	2,256	1,099	3,354
Other species	74	10	84	111	3	114	320	18	338
Industrial species	230	61	291	207	1	208	467	94	561
Total	19,812	3,914	23,726	8,818	1,733	10,551	12,613	8,463	21,076

Table 8. Landings composition in 41G2 and 42G2 (%).

	2005-08			2009			2011		
	41	**42**	**41+42**	**41**	**42**	**41+42**	**41**	**42**	**41+42**
Cod	4	4	4	1	2	1	1	1	1
Other codfish	1	2	1	1	1	1	0	0	0
Flatfish	11	13	11	11	13	11	11	11	11
Norway lobster	42	72	47	59	83	63	64	74	68
Herring	41	7	36	25	0	21	18	13	16
Other species	0	0	0	1	0	1	3	0	2
Industrial species	1	2	1	2	0	2	4	1	3

It is observed in the tables above that the fishery in ICES-squares 41G2 and 42G2 have at the overall level not being the main source of income for the vessels operating in Kattegat and that landings of cod have been low. However, the picture might be different at the individual vessel level.

Table 9 shows the importance of ICES-squares 41G2 and 42G2 at the individual vessels level using three intervals, below 10% of total landings value, between 10% and 25% and above 25%. For vessels in the last two intervals, the fishery in 41G2 and 42G2 is of some importance and important, respectively.

Before the closure, 26 commercial vessels had more than 10% of their landings value from the two squares. This was reduced to 15 commercial vessels in 2009, but increased to 30 in 2011, thus indicating that the squares were still interesting to fish in despite the restrictions.

Table 9. Importance of ICES-square 41G2 and 42G2 for individual vessels based on landings value.

		2005-08 No. of vessels			2009 No. of vessels			2011 No. of vessels		
		41	**42**	**41+42**	**41**	**42**	**41+42**	**41**	**42**	**41+42**
Commercial vessels	> 25 %	11	1	13	8		9	10	2	13
	10-25 %	8	4	13	5	3	6	9	8	17
	< 10 %	34	24	42	17	11	23	29	31	34
Non-commercial	> 25 %	3		3	2		2	5		5
	10-25 %	3		3	3		3	0		0

vessels	< 10 %	3		3	3		3	4		4
Total		62	29	76	38	14	46	57	41	73

Note: A commercial vessel has a total yearly landing value above the following thresholds: 2005= 216,731 DKK, 2006=229,050 DKK, 2007 = 252,720 DKK, 2008 = 261,791 DKK, 2009 = 245,875 DKK and 2011= 271,306 DKK.

Looking at the length size of these commercial vessels, cf. Table 10, it is observed that it is primarily vessels below 18m, which have had important fishing activity in ICES-square 41G2 and 42G2 before and after 2009.

Tabel 10. Distribution of commercial vessels with more than 10% of their landings value in 41G2 and 42G2.

		Average 2005-08 No. of vessels			2009 No. of vessels			2011 No. of vessels		
		41	**42**	**41+42**	**41**	**42**	**41+42**	**41**	**42**	**41+42**
Landings value above 25 % in 41G2/ 42G2	< 12 m	1		1	2		2	2		2
	12-15 m	2	1	2	3		3	5	1	6
	15-18 m	5		5	3		3	3	1	5
	18-24m	3		3	0		1	0		0
	24-40 m	1		1	0		0	0		0
	Total	**11**	**1**	**13**	**8**		**9**	**10**	**2**	**13**
Landings value between 10-25 % in 41G2/ 42G2	< 12 m	2		2	1		1	1		1
	12-15 m	3	2	5			0	2	2	3
	15-18 m	2	2	4	1		2	4	6	9
	18-24m	1	1	1	3	2	3	2		3
	24-40 m			0		1	0			1
	Total	**8**	**5**	**13**	**5**	**3**	**6**	**9**	**8**	**17**

As it is shown in Table 11, vessels with home port in Gilleleje has been the most important ones in relation to the fishery in ICES-square 41G2 and 42G2, accounting for more 70% of the total landings value from these two squares. However, in 2011 this level is reduced to 56% and especially vessels from Strandby increased their share. This development is primarily driven by the increased catches of Norway lobster, cf. Table 7.

Table 11. Distribution of landings value on home port for vessels fishing 41G2 and 42G2 (%).

	2005-2008	**2009**	**2011**
Gilleleje	72	88	56
Strandby	2	1	11
Østerby	2	0	6
Vesterø	3	1	5
Bønnerup	0	0	3
Other homeports	20	10	19

Based on the above, it is observed that the fishery in Kattegat has been reduced over the years, even before the restrictions were implemented. The number of vessels fishing in Kattegat as well as the total weight and value has been reduced. The importance of cod, flatfish and herring has been reduced, while especially Norway lobster has increased its importance.

Looking specifically at the restricted areas is difficult due to the fact that the necessary detailed data is not available. The restricted areas are placed in ICES-square 41G2 and 42G2, but it is still possible to fish in the squares without being in the restricted areas. The two squares accounted for around 16% of total landings value in Kattegat before and after. Despite of this, it is observed that the landings of cod from the two squares have been reduced since implementing the restrictions 1st January 2009. The number of commercial vessels having more than 10% of their landings value in 41G2 and 42G2 was 26 in the period 2005-2008 but increased to 30 in 2011, and these consisted primarily of vessels below 18m.

2. *Development in fishing communities ~ Gilleleje*

As seen from Table 6 and Table 11, the harbour of Gilleleje is the most dependent one on fishery in Kattegat as well as in 41G2 and 42G2. Table 12 shows the development in number of Gilleleje vessels with activity in Kattegat. The total number of vessels has been stable around 35, but a decrease is observed for the number of commercial vessels, while the number of non-commercial vessels has increased.

Table 12. Number of Gilleleje vessels with activity in Kattegat.

		2005	2006	2007	2008	2009	2011
Commercial vessels	< 12m	8	7	9	6	4	4
	12-15m	5	6	4	6	5	6
	15-18m	6	4	5	5	5	5
	18-24m	6	6	6	4	4	3
	24-40m	2	2	3	3	2	2
	Total	27	25	27	24	20	20
Non-commercial vessels	< 12m	9	10	14	15	13	14
	12-15m			1			1
	Total	9	10	15	15	13	15
Total		36	35	42	39	33	35

Note: A commercial vessel has a total yearly landing value above the following thresholds: 2005= 216,731 DKK, 2006=229,050 DKK, 2007 = 252,720 DKK, 2008 = 261,791 DKK, 2009 = 245,875 DKK and 2011= 271,306 DKK.

The restricted areas had a share of around 32% of total landings value for the commercial Gilleleje vessels before the closure. This share was then reduced to 21% in 2009, but then increased to 26% in 2011, cf. Table 13.

Table 13. Total landings value and share in 41G2 and 42G2.

		Total landings value (1,000 DKK)			Share in 41G2 and 42G2 (%)		
		2005-2008	2009	2011	2005-2008	2009	2011
Commercial vessels	<12m	4,302	2,840	2,930	9	36	41
	12-15m	6,079	6,564	6,530	14	29	41
	15-18m	12,555	11,257	14,596	64	35	31
	18-24m	19,629	13,192	12,955	28	16	19
	24-40m	10,380	9,443	7,779	20	3	9
	Total	52,945	43,295	44,790	32	21	26
Non-commercial vessels	<12m	1,182	794	1,055	16	10	26
	12-15m	44	0	20	0		0
	Total	1,226	794	1,075	15	10	26
Total		54,171	44,089	45,864	31	21	26

Note: A commercial vessel has a total yearly landing value above the following thresholds: 2005= 216,731 DKK, 2006=229,050 DKK, 2007 = 252,720 DKK, 2008 = 261,791 DKK, 2009 = 245,875 DKK and 2011= 271,306 DKK.

Looking at the average landings value per commercial Gilleleje vessel, this has increased after 2009, cf. Table 14. In Table 14, it is also shown that the average landings value per Gilleleje vessel in 41G2 and 42G2 decreased just after the closure, but then increased to around 578,000 DKK per vessel in 2011.

Table 14. Average landings value per Gilleleje vessel and in 41G2 and 42 G2 (1,000 DKK).

	Average landings value per vessel			Average landings value per vessel in 41G2 and 42G2		
	2005-2008	2009	2011	2005-2008	2009	2011

Commercial vessels	<12m	574	710	732	50	258	301
	12-15m	1,158	1,313	1,088	161	385	445
	15-18m	2,511	2,251	2,919	1,607	778	905
	18-24m	3,569	3,298	4,318	1,010	530	821
	24-40m	4,152	4,722	3,889	823	121	350
	Total	2,056	2,165	2,239	655	460	578
Non-commercial vessels	<12m	98	61	75	16	6	20
	12-15m	177		20			
	Total	100	61	72	15	6	19
Total		1,426	1,336	1,310	449	281	338

Note: A commercial vessel has a total yearly landing value above the following thresholds: 2005= 216,731 DKK, 2006=229,050 DKK, 2007 = 252,720 DKK, 2008 = 261,791 DKK, 2009 = 245,875 DKK and 2011= 271,306 DKK.

Finally, Table 15 and Table 16 show the development in landings composition for the Gilleleje vessels in Kattegat in general and 41G2/42G2 specifically. The landings composition for 41G2/42G2 and Kattegat is rather similar. The importance cod for the Gilleleje vessels has been reduced both in Kattegat as well as in 41G2 and 42G2 together with Other codfish, flatfish herring, while especially Norway lobster have increased its importance.

Table 16. Landings composition for Gilleleje vessels in 41G2 and 42G2.

	1,000 DKK			%		
	2005-08	**2009**	**2011**	**2005-08**	**2009**	**2011**
Cod	522	95	68	3.1	1.0	0.6
Other codfish	144	108	12	0.8	1.2	0.1
Flatfish	1,650	1,034	1,124	9.7	11.1	9.5
Norway lobster	6,255	5,566	6,653	36.7	59.9	56.2
Herring	8,204	2,186	3,349	48.1	23.5	28.3
Other species	46	89	180	0.3	1.0	1.5
Industrial species	235	208	456	1.4	2.2	3.8
Total	17,055	9,286	11,841	100	100	100

In conclusion, the number of Gilleleje vessels has been reasonably stable since 2005. The importance of IC-ES-squares 41G2 and 42G2 has been reduced for the vessels. The average landings value per Gilleleje vessel has been reduced and so has the average landings value in 41G2 and 42G2.The latter reduction has primarily been due to reduced landings of cod and herring, while the landings of Norway lobster have increased. Whether the reduction in average landings value in 41G2 and 42G2 has been due to the implemented re-strictions or are just following the trends observed in the rest of Kattegat is impossible with the available in-formation to analyse. However, the two squares still seem to be attractive for the Gilleleje vessels, given the increased number of vessels fishing there.

3. The fishery in "Kilen"

"Kilen" is placed at the entrance to the Sound starting at the straight line drawn from Gilleleje in Denmark to Kullen in Sweden. Undertaking an analysis of possible economic consequences of implementing the re-strictions from the 1st January 2009, where some fishing is forbidden from 1st February to 31rd March is even more problematic than doing it for the fishery in 41G2 and 42G2. The reason is that "Kilen" is only covering a small part of the part of 41G2 placed in the Sound (3B).

However, Table 17 shows the number of vessels fishing in 41G2 in the Sound, and this is observed to have decreased to almost half the number before and after 2009. Furthermore, the average landings value obtained by a vessel fishing in 41G2 in the Sound has also been reduced after 2009, but was approximately at the same level in 2011 as in 2005. Before 2009, the Gilleleje vessels accounted for around 60% of the landings value obtained from fishing in 41G2 in the Sound, but this level was increased to around 90% after 2009. Thus vessels from other harbours were not fishing so intensively in 41G2 in the Sound after 2009.

Table 17. Number of vessels fishing in 41G2 in the Sound.

		2005	2006	2007	2008	2009	2011
Commercial Vessels	< 12m	15	16	20	19	7	7
	12-15m	15	13	11	9	5	5
	15-18m	15	10	14	11	4	4
	18-24m	17	11	14	7	4	2
	24-40m	4	2	4	2	2	2
	>40m	1		2	2		
	Total	67	52	65	50	22	20
Non-commercial Vessels	< 12m	13	12	21	21	17	15
	12-15m		1	1	1	1	1
	18-24m			1			
	Total	13	13	23	22	18	16
Total		80	65	88	72	40	36

Note: A commercial vessel has a total yearly landing value above the following thresholds: 2005= 216,731 DKK, 2006=229,050 DKK, 2007 = 252,720 DKK, 2008 = 261,791 DKK, 2009 = 245,875 DKK and 2011= 271,306 DKK.

Table 18. Average landings value per vessel fishing in 41G2 in the Sound (1,000 DKK).

		2005	2006	2007	2008	2009	2011
Commercial vessels	< 12m	215	315	284	253	313	250
	12-15m	304	260	420	719	70	56
	15-18m	186	289	419	428	805	548
	18-24m	369	490	795	992	840	1177
	24-40m	316	1273	470	2642	549	341
	>40m	31		223	995		
	Total	271	370	456	604	464	363
Non-commercial vessels	< 12m	49	72	59	71	50	46
	12-15m		1	163	4	222	1
	18-24m			137			
	Total	49	67	66	68	60	43
Total		235	309	354	440	282	221

Note: A commercial vessel has a total yearly landing value above the following thresholds: 2005= 216,731 DKK, 2006=229,050 DKK, 2007 = 252,720 DKK, 2008 = 261,791 DKK, 2009 = 245,875 DKK and 2011= 271,306 DKK.

Finally, Table 19 shows that the importance of cod in 41G2 in the Sound was reduced significantly from 2009 and forwards compared to the years before. Herring is now the most important species in 41G2 in the Sound.

Table 19. Landings value composition vessels fishing in 41G2 in the Sound.

	2005	2006	2007	2008	2009	2011
Cod	51.4	43.9	63.1	46.5	16.0	18.4
Other codfish	0.3	0.7	0.6	0.6	0.1	0.1
Flatfish	15.8	15.9	9.9	6.9	9.6	8.8
Norway lobster	13.5	12.1	5.5	5.4	2.5	2.6
Herring	13.1	20.4	19.2	38.3	63.4	61.8
Other species	5.4	4.7	1.0	1.5	4.0	4.6
Industrial species	0.5	2.2	0.6	0.8	4.3	3.7
Total landings value (1,000 DKK)	18,782	20,117	31,144	31,686	11,291	7,954

4. The Swedish fishery in Kattegat ~an overall perspective

In Table 20 the number of Swedish vessels operating in Kattegat is shown. In Sweden vessels are not categorized into commercial and non-commercial vessels, so only the total number of vessels for each length class is shown. The table shows that the number of vessels increased 2005-2008 and then there has been a decrease. The decrease has taken place for all length classes.

Table 20. Number of fishing vessels active in Kattegat

Length class	2005	2006	2007	2008	2009	2010	2011
<12	100	113	124	127	130	111	108
12-15	22	24	28	34	28	24	21
15-18	24	23	23	22	21	19	12
18-24	25	26	26	27	22	18	11
24-40	32	25	25	18	15	14	14
>40	4	5	5	7	4	4	4
Total	207	216	231	235	220	190	170

Total value of landings increased 2005-2007, but has then decreased. Especially for the length classes 18-24 meters and 24-40 meters there has been a strong decrease. For the smallest vessels the value of landings has been stable since 2007. As can be seen in the Table 20 above, the decrease in revenue follows a decrease in number of vessels active in Kattegat.

Table 21. Total landings value for vessels with activity in Kattegat (1,000 SEK).

Length class	2005	2006	2007	2008	2009	2010	2011
<12	11 619	12 692	15 746	14 067	14 252	14 668	15 272
12-15	8 492	10 699	15 363	15 919	11 217	10 282	11 941
15-18	13 126	16 816	22 787	21 474	17 070	19 091	20 143
18-24	13 864	17 950	21 565	17 929	14 348	9 531	7 362
24-40	22 592	29 402	23 508	14 700	17 600	7 539	8 519
>40	2 576	3 070	8 779	3 164	3 235	4 029	2 713
Total	72 269	90 628	107 747	87 254	77 723	65 141	65 952

Many of the vessels also fish in other areas than Kattegat. In Table 22, total landing value for the vessels active in Kattegat is shown. What can be seen is that also regarding total value of landings for the vessels fishing in Kattegat there has been a decrease, except for the smallest vessels.

Table 22. Total value of landings, all areas, for vessels active in Kattegat (1,000 SEK).

Length class	2005	2006	2007	2008	2009	2010	2011
<12	20 509	24 898	29 560	31 776	32 732	33 331	35 940
12-15	22 766	26 833	32 308	33 489	27 071	24 667	26 017
15-18	30 504	39 621	37 658	39 850	28 953	29 090	29 486
18-24	59 616	71 136	65 444	69 609	64 541	67 743	37 655
24-40	161 794	119 533	134 876	120 217	112 680	95 739	109 734
>40	44 886	85 747	89 112	117 017	87 037	61 685	91 415
Total	340 074	367 769	388 958	411 958	353 015	312 255	330 248

The average share of value of landings from Kattegat for all vessels is around 25%. The area is more important for smaller vessels. For vessels shorter than 18 meters the value of landings in Kattegat is about half of the total value of landings. (Table 23)

Table 23. Kattegat dependency (Kattegat landings value as a share of total landings value).

Length class	2005	2006	2007	2008	2009	2010	2011
<12	0,57	0,51	0,53	0,44	0,44	0,44	0,42
12-15	0,37	0,40	0,48	0,48	0,41	0,42	0,46
15-18	0,43	0,42	0,61	0,54	0,59	0,66	0,68
18-24	0,23	0,25	0,33	0,26	0,22	0,14	0,20
24-40	0,14	0,25	0,17	0,12	0,16	0,08	0,08
>40	0,06	0,04	0,10	0,03	0,04	0,07	0,03
All	0,21	0,25	0,28	0,21	0,22	0,21	0,20

Over the years 2005-2011 the quantity of landed cod has decreased from a low level. The landings of Norway lobster has increased a lot, whereas the landings of herring, sprat and mackerel has decreased (mackerel is a very small part of the landings all years). In the category “other” in Table 24 greater weever explains much of the increase in 2009 and 2011.

Table 24. Share of quantity of landed species in Kattegat, live weight.

	2005	2006	2007	2008	2009	2010	2011
Herring, sprat, mackerel	91%	90%	89%	77%	65%	77%	59%
Flat fish	1%	2%	2%	3%	4%	4%	3%
Norway lobster	2%	3%	4%	7%	8%	11%	9%
Shrimp	0%	1%	0%	1%	3%	1%	0%
Cod	3%	2%	2%	2%	1%	1%	1%
Other cod fish	2%	1%	1%	1%	1%	1%	0%
Other	6%	2%	3%	9%	19%	6%	27%

The most economically important species in Kattegat for the Swedish vessels is Norway lobster. Its importance has increased over time. The importance of cod and of herring and sprat has decreased a lot 2005-2011.

Table 25. Share of value of landings, species in Kattegat

	2005	2006	2007	2008	2009	2010	2011
Norway lobster	36%	40%	45%	53%	49%	60%	60%
Lobster	3%	2%	2%	2%	3%	2%	3%
Prawn	1%	5%	1%	4%	14%	2%	0%
Cod	7%	6%	4%	3%	1%	1%	1%
Flat Fish	8%	10%	10%	9%	11%	12%	10%
Herring, sprat, mackerel	34%	32%	31%	18%	13%	14%	13%
other cod fish	4%	1%	2%	1%	1%	1%	0%
Other	7%	6%	7%	10%	8%	8%	13%
Total landing value	72 269	90 628	107 747	87 254	77 723	65 141	65 952

(1,000 SEK)	

Landed quantities in Kattegat have decreased substantially in 2009-2011 compared to 2005-2008. The restricted subarea 3 is placed in the ICES-squares 41G2, but does not cover it perfectly. Thus it is possible to fish in these squares without necessarily breaking the law. In both 41G2 and 42G2 (as in most of the ICES-squares) there is a large decrease in tonnes of landed fish.

Table 26. Distribution of landed quantities in Kattegat on ICES-squares, tonnes live weight

	Average 2005-2008	2009	2010	2011
41G0	-	1	-	20
41G1	359	522	169	329
41G2	774	102	53	107
42G0	0	1	0	-
42G1	951	618	262	557
42G2	1 314	210	269	235
43G0	814	180	1 365	11
43G1	4 736	3 235	1 176	1 595
43G2	707	189	177	406
44G0	1 144	582	229	1
44G1	1 281	230	209	248
Total	12 081	5 870	3 910	3 509

As can be seen in Table 27, the share of landed quantity taken in the ICES-squares 41G2 and 42G2 has decreased since the closure of the areas.

Table 27. Distribution of landed quantities in Kattegat on ICES-squares, share of live weight.

	Average 2005-2008	2009	2010	2011
41G0	0%	0%	0%	1%
41G1	3%	9%	4%	9%
41G2	6%	2%	1%	3%
42G0	0%	0%	0%	0%
42G1	8%	11%	7%	16%
42G2	11%	4%	7%	7%
43G0	7%	3%	35%	0%
43G1	39%	55%	30%	45%
43G2	6%	3%	5%	12%
44G0	9%	10%	6%	0%
44G1	11%	4%	5%	7%
Total	100%	100%	100%	100%

It is hard to see any trends for the value of landings in 41G2 and 42G2 as there is large variation between the years in value of landings (Table 28).

Table 28. Distribution of landings value in Kattegat on ICES-squares (1,000 SEK).

	Average 2005-08	2009	2010	2011
41G0	-	10	-	64
41G1	1 041	1 164	483	915
41G2	3 479	4 178	2 707	2 946
42G0	11	26	7	-
42G1	5 433	5 277	3 545	3 241
42G2	19 925	12 876	19 962	17 482
43G0	2 065	636	4 128	165
43G1	35 771	38 115	21 041	25 877
43G2	10 310	8 499	8 949	10 375
44G0	3 618	1 926	825	67
44G1	7 821	5 016	3 495	4 822
Total	89 474	77 723	65 141	65 953

In 42G2, a large share of the value of landings in Kattegat is taken. Neither in 42G2 or 41G2 there is a trend that share of value of landings decrease after the implementation of the closed areas. (Table 29)

Table 29. Distribution of landings value in Kattegat on ICES-squares, share of total value in Kattegat.

	Average 2005-08	2009	2010	2011
41G0	0%	0%	0%	0%
41G1	1%	1%	1%	1%
41G2	4%	5%	4%	4%
42G0	0%	0%	0%	0%
42G1	6%	7%	5%	5%
42G2	22%	17%	31%	27%
43G0	2%	1%	6%	0%
43G1	40%	49%	32%	39%
43G2	12%	11%	14%	16%
44G0	4%	2%	1%	0%
44G1	9%	6%	5%	7%
Total	100%	100%	100%	100%

In ICES-square 41G2, the economic importance of herring, sprat and mackerel has decreased (the value of mackerel is very small all years). The importance of flatfish has increased (Table 30 and 31). In 2010 and 2011, a large part of the increase in the share of the category “other” is explained by a large share of lump-fish and for 2011 also salmon.

Table 30. Landings composition in 41G2 value of landings (1,000 SEK).

	2005-08 41G2	2009 41G2	2010 41G2	2011 41G2
Norway lobster	88	81	61	76
Lobster	92	76	14	30
Cod	27	56	16	29

Flat fish	657	3028	1624	1415
Herring, sprat and mackerel	1760	30	10	207
Other cod fish	21	3	1	1
Other	833	904	981	1187
Total value of landings (1000 SEK)	3 479	4 178	2 707	2 946

Table 31. Landings composition in 41G2 (Share of value of landings).

	2005-08 41G2	2009 41G2	2010 41G2	2011 41G2
Norway lobster	3%	2%	2%	3%
Lobster	3%	2%	1%	1%
Cod	1%	1%	1%	1%
Flat fish	19%	72%	60%	48%
Herring, sprat and mackerel	51%	1%	0%	7%
Other cod fish	1%	0%	0%	0%
Other	24%	22%	36%	40%
Total value of landings	100%	100%	100%	100%

In ICES-square 42G2 the value of landings for different species in Table 32 and 33 show that the value of landings of cod and other cod fish has decreased sharply. Also for herring, sprat and mackerel there has been a large decrease (the value of landings of mackerel is small for all eight years).

Table 32. Value of landings for different species in 42G2

	2005-08 42G2	2009 42G2	2010 42G2	2011 42G2
Norway lobster	9487	9163	14287	9249
Lobster	314	273	168	223
Prawn	0	4	15	0
Cod	1785	79	107	109
Flat fish	4243	2637	4338	4277
Herring, sprat and mackerel	1985	31	17	407
Other cod fish	1019	82	14	5
Other	1093	606	1017	3212
Total value of landings (1000 SEK)	19 925	12 876	19 962	17 482

Table 33. Share of value of landings for different species in 42G2.

	2005-08 42G2	2009 42G2	2010 42G2	2011 42G2
Norway lobster	48%	71%	72%	53%
Lobster	2%	2%	1%	1%
Prawn	0%	0%	0%	0%
Cod	9%	1%	1%	1%

Flat fish	21%	20%	22%	24%
Herring, sprat and mackerel	10%	0%	0%	2%
Other cod fish	5%	1%	0%	0%
Other	5%	5%	5%	18%
Total value of landings	100%	100%	100%	100%

The number of vessels active in 41G2 decreased 2009 and 2010 but then increased in 2011 to the same number as in 2005.

Table 34. Number of fishing vessels active in 41G1

Length class	2005	2006	2007	2008	2009	2010	2011
<12	16	14	15	20	15	13	15
12-15	2	2	5	2	1	1	1
15-18	2	3	2	6	3	5	5
18-24	1	2	4	3	3	2	2
24-40	4	8		2	1		2
>40		1	1				
Total	25	30	27	33	23	21	25

The number of vessels active in 42G2 has decreased since the closure of the areas. Especially for vessels larger than 18 metres the number has decreased.

Table 35. Number of fishing vessels active in 42G2

Length class	2005	2006	2007	2008	2009	2010	2011
<12	20	24	24	22	20	18	16
12-15	9	8	9	11	11	7	5
15-18	10	9	9	13	8	10	9
18-24	10	8	10	11	6	4	3
24-40	10	9	4	4	1	3	2
>40		1	1				
Total	59	59	57	61	46	42	35

Regarding value of landings in ICES-square 41G2, only vessels shorter than 12 meters have more than 25% of their landings value there (Table 36). The number of vessels with more than 25% of their landings value in 42G2 varies between the years. In 2009-2011 there has been less vessels fishing in the area per year than in 2005-2008. Most of the larger vessels have a smaller share of their landings value in the two ICES-squares (Tables 36-38).

Table 36. Importance of 41G2 and 42G2 for individual vessels based on landings value. Number of vessels with more than 25% of their landed value in 41G2 or 42G2

	2005-08		2009		2010		2011	
>25%	41G2	42G2	41G2	42G2	41G2	42G2	41G2	42G2

<12	11	19	8	14	8	15	10	11
12-15		6		4		5		2
15-18		5		7		7		4
18-24		3				2		1
24-40		2						
>40								
Total	11	34	8	25	8	29	10	18

Table 37. Importance of 41G2 and 42G2 for individual vessels based on landings value. Number of vessels with 10-25% of their landed value in 41G2 or 42G2

	2005-08		2009		2010		2011	
10-25%	41G2	42G2	41G2	42G2	41G2	42G2	41G2	42G2
<12	1	2	1	1	1		1	2
12-15		2		5				1
15-18		2		4		1		3
18-24		2				1		1
24-40	1	3		1		2		
>40								
Total	2	10	1	11	1	4	1	7

Table 38. Importance of ICES-square 41G2 and 42G2 for individual vessels based on landings value. Number of vessels with less than 10% of their landed value in 41G2 or 42G2

	2005-08		2009		2010		2011	
<10%	41G2	42G2	41G2	42G2	41G2	42G2	41G2	42G2
<12	5	2	6	5	3	2	4	3
12-15	3	2	1	2	1	2	1	2
15-18	3	4	3	3	5	2	5	2
18-24	2	5	3		2	1	2	1
24-40	3	2	1			1	2	2
>40	1	1						
Total	16	16	14	10	11	8	14	10

A conclusion that can be drawn from the Swedish analysis above is that the share of the Kattegat value of landings in the ICES-squares that covers a large part of the closed areas has been at the same level before and after the closure of the areas. The main target species in the fishery in Kattegat is Norway lobster, which can be caught during a large part of the year in the northern part of the closed area. Data on vessels active and landings in the ICES-square 41G2 covering a large share of the permanently closed area before the closure show that almost the same number of vessels had more than 25 percent of their value of landings in that ICES-square both before and after the closure. The same holds for the number of vessels with 10-25 percent of the landings in 41G2. There has been a decrease in number of vessels with more than 25 percent of their landings in 42G2.

5. *Development in fishing communities ~ Träslövsläge and Glommen*

Träslövsläge and Glommen are the two Swedish ports with the largest share of value of landings in the ICES-squares 41G2 and 42G2 on average from 2005-2011. Also, Galtabäck has had a large share of the value of landings the years after the closure, especially in 2011, when the share was 27%.

Table 39. Distribution of landings value on home port for vessels fishing in 41G2 and 42G2

	2005-2008	2009	2010	2011
Träslövsläge	35%	34%	41%	24%
Glommen	38%	27%	30%	29%
Galtabäck	3%	7%	11%	27%
Hönö	3%	0%	0%	0%
Vejbystrand	0%	19%	7%	7%
Other	20%	13%	11%	13%

As is seen from Table 39, vessels from Träslövsläge and Glommen are the most dependent on catches from the ICES-squares 41G2 and 42G2. Also in Galtabäck, there has been an increase in dependency after the closure. As the dependency of Galtabäck was low before the closure, and there are only two vessels with home port Galtabäck fishing in the two ICES-squares, Galtabäck is not included in the analysis of effects on selected fishing communities. There has been a decrease in vessels from Glommen fishing in Kattegat from an average of 13 in 2005-2008 to 7 in 2011. Four of the vessels with home port Glommen have in 2009-2010 received subsidies for scrapping their vessels as a part of the cod recovery plan. For Träslövsläge, there was a decrease in number of vessels active in Kattegat in 2011 (Table 40).

Table 40. Number of Träslövsläge and Glommen vessels with activity in Kattegat.

	2005-2008		2009		2010		2011	
	Glommen	Träslövsläge	Glommen	Träslövsläge	Glommen	Träslövsläge	Glommen	Träslövsläge
<12	4	10	2	9	2	10	3	8
12-15	4	3	3	6	1	5		3
15-18	2	4	2	6	2	6	2	6
18-24	4	2	3	2	3	1	2	1
24-40	0	6		3		4		2
Total	13	26	10	26	8	26	7	20

The total value of landings has decreased for vessels 12-15 meters in Glommen. In 2011, there was one vessel 12-15 meters with home port Glommen, but it did not fish in 41G2 or 42G2. The total value of landings increased for vessels 18-24 meters with home port Glommen. Also for the vessels 15-18 meters with home port Träslövsläge, the value of landings has increased after the closure (Table 41).

Table 41. Total landings value for the Träslövsläge and Glommen vessels (1,000 SEK)

Glommen	2005-2008	2009	2010	2011
<12	651	*	*	640
12-15	4209	902	*	*
15-18	4148	3183	4243	4338
18-24	15070	19074	20478	22766
Träslövsläge	2005-2008	2009	2010	2011

<12	2442	2726	3270	2556
12-15	2686	3270	3343	2410
15-18	8448	10738	14788	15852
18-24	6130	5129	*	*
24-40	19129	13236	14810	17105

* if there in a length class is less than three vessels landings value is not presented

Share of total landings value in the ICES-squares 41G2 and 42G2 has been stable for the vessels from Glommen, except for the vessels 12-15 meters. In 2011 no vessel 12-15 meters fished in the two ICES-squares. For the Träslövsläge vessels, the share of value of landings seems stable for the vessels shorter than 12 meters. For the vessels 12-15 meters there has been an increase. For larger vessels, the share from the two ICES-squares has decreased. In 2011, vessels larger than 18 meters had almost no revenue from the two IC-ES-squares (Table 42).

Table 42. Share of total landings value in 41G2 and 42G2 (%).

Glommen	2005-2008	2009	2010	2011
<12	89%	92%	100%	93%
12-15	72%	29%	15%	0%
15-18	67%	48%	82%	75%
18-24	17%	13%	12%	9%
Träslövsläge	2005-2008	2009	2010	2011
<12	29%	21%	29%	20%
12-15	24%	27%	36%	34%
15-18	32%	32%	42%	19%
18-24	16%	13%	12%	2%
24-40	16%	2%	2%	2%

The average value of landings per vessel has increased for the vessels after the closure of the areas. This is the case for both Glommen and Träslövsläge vessels and all length classes.

Table 43. Average landings value per Träslövsläge and Glommen vessel (1,000 SEK).

Glommen	Average 2005-2008	2009	2010	2011
<12	175	-*	-*	213
12-18	1 393	817	1 499	1 975
18-24	2 732	3 179	3 413	4 553
Träslövsläge	Average 2005-2008	2009	2010	2011
<12	229	273	297	284
12-18	1 542	1 167	1 648	2 029
18-24	2 290	1 710	-*	-*
>24	3 263	4 412	3 702	4 276

* if there in a length class is less than three vessels average landings value is not presented

In Table 44 and 45, the landings composition expressed in value of landings is shown for the vessels from Träslövsläge and Glommen. There is a large decrease in value of landings from cod for vessels from both ports.

Table 44. Landings composition for Träslövsläge vessels in 41G2 and 42G2 (1,000 SEK).

	2005	2006	2007	2008	2009	2010	2011
Norway lobster	2100	2281	3542	6170	5183	8791	4353
Cod	816	1113	633	559	37	18	22
Flat fish	485	1039	905	882	300	169	178
Herring, sprat, mackerel	2960	3959	2187	2	0	0	49
Other cod fish	1236	159	196	212	17	5	4
Other	178	281	463	319	300	395	268
Total	7775	8833	7926	8143	5837	9378	4873

Table 45. Landings composition for Glommen vessels in 41G2 and 42G2 (1,000 SEK).

	2005	2006	2007	2008	2009	2010	2011
Norway lobster	3741	5627	6320	6800	3851	5496	4969
Cod	745	1185	760	484	37	53	87
Flat fish	1183	1997	2397	1261	548	934	586
Herring, sprat, mackerel	5	0	0	0	0	0	0
Other cod fish	975	259	548	315	63	8	1
Other	180	399	264	164	155	244	221
Total	6829	9468	10290	9024	4654	6735	5865

The share of value of landings from Norway lobster has increased. Apart from a decrease in share of value of landings from cod, other codfish and herring, sprat and mackerel, the relative share of flat fish has also decreased (Table 46 and 47).

Table 46. Landings composition for Träslövsläge and Glommen vessels in 41G2 and 42G2, share of different species.

Träslövsläge	2005	2006	2007	2008	2009	2010	2011
Norway lobster	27%	26%	45%	76%	89%	94%	89%
Cod	10%	13%	8%	7%	1%	0%	0%
Flat fish	6%	12%	11%	11%	5%	2%	4%
Herring, sprat, mackerel	38%	45%	28%	0%	0%	0%	1%
other cod fish	16%	2%	2%	3%	0%	0%	0%
Other	2%	3%	6%	4%	5%	4%	5%
Total	100%	100%	100%	100%	100%	100%	100%

Table 47. Landings composition for Träslövsläge and Glommen vessels in 41G2 and 42G2, share of different species.

Glommen	2005	2006	2007	2008	2009	2010	2011
Norway lobster	55%	59%	61%	75%	83%	82%	85%
Cod	11%	13%	7%	5%	1%	1%	1%
Flat fish	17%	21%	23%	14%	12%	14%	10%
Herring, sprat, mackerel	0%	0%	0%	0%	0%	0%	0%
Other cod fish	14%	3%	5%	3%	1%	0%	0%
Other	3%	4%	3%	2%	3%	4%	4%
Total	100%	100%	100%	100%	100%	100%	100%

There is no trend to be seen that the implementation of the closed areas in Kattegat have affected total or average value of landings of the vessels in Glommen and Träslövsläge. In Glommen total value of landings has increased after the closure. There is a trend that larger vessels have decerased their share of value of landings in the ICES-squares 41G2 and 42G2. The number of Glommen vessels active in the two ICES-squares has decreased, from 13 to 7 vessels. For Träslövsläge, the number has been stable except for a decrease in 2011. Also in Kattegat as a whole there has been a decrease in number of vessels active, so it is uncertain to what extent the closed areas has contributed to the development. The most important effect of the closure is probably on costs, as the closures gives the fishermen incentive to move further away from their home port to new fishing grounds. It has not been possible to calculate the increase in costs due to the closed areas, but in the section below “Discussion about costs” there is a discussion about possible effects on the costs for the fishermen.

6 *The Swedish fishery in “Kilen”*

There are mostly vessels shorter than 12 meters that have fished in Kilen 2005-2011.The number of vessels active in Kilen has been relatively stable over the years. In 2011, there was a decrease. Since the implementation of the closure of areas no vessels larger than 24 meters has been active in the area.

Table 48. Number of vessels fishing in 41G2 in the Sound.

	2005	2006	2007	2008	2009	2010	2011
<12	17	18	19	20	20	22	18
12-15	1	3	3	3	3	1	
15-18		1	1	1		1	
18-24	1		2	1			
24-40	2	3	3				
Total	21	25	28	25	23	24	18

For the vessels shorter than 12 meters, the average landings value in Kilen increased in 2005-2008 and then decreased in 2009-2011 (Table 49). The share of value of landings for the vessels shorter than 12 meters has varied from 54 to 78% in 2005-2011, but there is no clear trend after 2008 (Table 50).

Table 49. Average landings value per vessel fishing in 41G2 in the Sound (1,000 DKK).

	2005	2006	2007	2008	2009	2010	2011
<12	183	234	294	313	246	214	196
12-15	*	263	172	26	159	*	-
15-18	-	*	*	*	-	*	-
18-24	-	-	*	*	-	-	-
24-40	*	376	403	-	-	-	-
All	194	383	266	255	235	196	196

*For length classes with less than three vessels no data is shown.

Table 50. Share of total landings value in 41G2 in the Sound per vessel.

	2005	2006	2007	2008	2009	2010	2011
<12	71%	78%	72%	54%	72%	62%	64%
12-15	22%	16%	9%	4%	18%	0%	

15-18		0%	1%	0%		0%
18-24			2%	1%		
24-40	3%	11%	7%			

There has been a large reduction in the share of value from cod for the Swedish vessels in Kilen. Also the share of value of herring landings has decreased. Lumpfish has increased in relative importance for the vessels.

Table 51. Landings value composition of vessels fishing in 41G2 in the Sound.

	2005	2006	2007	2 008	2009	2010	2011
Eel	39,2%	26,9%	47,6%	38,8%	15,9%	39,7%	34,7%
Lumpfish	9,4%	30,4%	15,3%	37,9%	69,4%	50,6%	51,8%
Cod	30,9%	19,3%	17,7%	16,8%	11,6%	6,5%	5,6%
Herring	10,4%	17,7%	16,0%	0,2%	0,1%	0,1%	0,4%
Flat fish	9,2%	5,4%	2,9%	5,8%	2,8%	2,9%	7,3%
Other cod fish	0,4%	0,1%	0,2%	0,2%	0,1%	0,1%	0,0%
Other	0,6%	0,2%	0,3%	0,4%	0,1%	0,1%	0,2%
Total landings value (1,000 SEK)	4,070	6,133	7,459	6,367	5,396	4,698	3,524

In summary, for the vessels operating in Kilen there has been a decrease in the total value of landings, but there is no clear trend regarding average value of landings per vessel. The value of landings from cod has decreased significantly, while the relative importance of lumpfish has increased.

7. Discussion about costs

It is not possible to investigate any potential cost changes arising from the implemented restrictions in Kattegat. The collected cost data are not detailed enough in order to undertake such specific analysis.. Instead it will be discussed, which cost changes could take place following such closures for the fishermen influenced by this.

The costs for the fisheries can be divided into variable costs and fixed costs. Variable costs are expenses that vary with the length and number of trips and includes quantities and prices of inputs used to catch fish such as labour, fuel, ice, fishing supplies, and food and water for the crew. Fixed costs are expenses that do not vary directly with the number of trips a vessel take during a year and includes the cost for the vessel, insurance, repair and maintenance, and the cost of adding or replacing equipment and gear.

The applied restrictions have most likely primarily affected the variable costs. When an area is closed, the fishermen are forced to change behavior, and start fishing somewhere else, if possible. This implies three things.

First, that they potentially have to move further away from their home port to new fishing grounds, thus implying changes in use of fuel, labour and other variable costs. Based on the available data, it has not been possible to identify such changes at a detailed level, which could have made it possible to calculate the changes in costs arising from such behavioral changes.

However, especially fishermen who got a large part of their revenue from fishing in the southern part of the area may be affected, as this area is permanently closed. Though data on vessels active and landings in the EU-square covering a large share of the permanently closed area before the closure show that almost the same number of vessels had more than 25 percent of their value of landings in that EU-square both before and after the closure. The same holds for the number of vessels with 10-25 percent of the landings in 41G2.

In the northern part of the closed area, it is permitted to fish with selective gears that do not catch cod during parts of the year. In the western part of the closed area selective gears are demanded in the first quarter of the year. In these periods the fishermen thus are able to fish there with a sorting grid. Therefore no extra costs are incurred for vessels who previously fished in these areas, during these periods, all other things equal. There may be an extra cost in the first quarter in the northern part of the area, as the northern area is completely closed then.

Secondly, there could also be an increase in fixed costs if the fishermen have to invest in selective gears to be able to fish in the areas where it is demanded that the fishermen use a sorting grid when they use bottom trawls. Using a sorting grid also implies that less are caught, thus reducing the value of landings. In February 2009, a system with KW-days (meaning fishing capacity measured in engine power in kilowatts, multiplied with number of fishing days at sea.) was introduced that limits the effort of bottom-trawling vessels longer than 10 meters in the Kattegat and the Skagerrak. The system gives incentive to use a sorting grid in the trawl as this gear is exempted from restrictions in effort. So both the closed areas and the KW-days system gives incentives to use trawls with a sorting grid, and it is hard to say to what extent the closure has meant an increase in cost for gears.

Finally, fishermen may have been forced to change behavior towards less attractive fishing grounds with lower Catch Per Unit of Effort, less valuable species and/or species of less quality, i.e. lower price per landed kilo. This implies lower landings value in total for the affected vessels.

8. ***Costs and benefits of keeping the closure***

Important ecosystem services that the cod stock potentially may provide, if it is rebuilt, is food, recreation (recreational fishing) and the cultural values that active fishing vessels contribute with. It may also contribute to the ecosystem services biodiversity and resilience.[2] All these ecosystem services have an economic value. For many people there is also a value in knowing that the cod stock exists now and for future generations. The economic value of the catches of fish in commercial fisheries is the resource rent. The resource rent is the extra revenue above normal profit that is possible to gain in fishery (and other industries with production based on renewable resources) due to the fact that the fishermen does not have to buy the raw material for the production. Recreation, cultural values and existence values are to a little extent priced at the market, but can be estimated by different valuation techniques, even though this is complex to do.

It is hard to evaluate the specific effects of the closed areas on the fishery as there are many factors that affect the development of the fishery. For example the quotas have changed during the analyzed period (2005-2011) and fuel costs have increased substantially. There is also a general trend of rationalization that result in a decrease in number of vessels.

An active fishery is needed for an active management of harbours, vessels and of the characteristic buildings and equipment used in fisheries. When the smaller vessels decrease in number, there is a large probability that the older, smaller harbours are shut down or loose in significance and that landings are concentrated to fewer and larger harbours[3].This has a negative effect on the cultural values that the active vessels contribute with. In the short term, there can be a negative effect of the closure if fishermen are forced to shut down due to increased costs for the fishing trips.

[2] Naturvårdsverket (2008) Ecosystem services provided by the Baltic sea and Skagerrak, Rapport 5873
[3] http://www.miljomal.se/Miljomalen/Alla-indikatorer/Indikatorsida/Fordjupning/?iid=142&pl=1&t=Land&l=SE

A study made by Eggert and Olsson[4] show that the residents of Halland and Västra Götaland (about one million people living in the west coast of Sweden) would be willing to pay 400-700 million SEK for getting the cod back to the Swedish west coast again. The probability that the closed areas will contribute to a rebuilding of the cod stock is hard to measure, but there is a possibility that it will contribute to a rebuilding.

The potentially large, but uncertain, benefit of keeping the areas should be compared to the costs of keeping them. The economic cost of the closed area is the loss in resource rent, ev. cultural values and costs for control. Unfortunately we do not have enough data to make any calculations of these costs, but it is probable that at least the resource rent has been affected by the closure. The resource rent in the Swedish fisheries was in general low before the closure (2005-2008). For the Norway lobster trawl fishery the resource rent was negative.[5] In the long term, the closed areas may contribute to an increase in resource rent and strengthened cultural values, although there is also uncertainty about this.

The coast guard estimates that their control costs for the fisheries in Kattegat are about the same before and after the closure. They do extra checks when they are out in other business anyway[6].

9. Costs and benefits and distributional effects

The costs of the closed areas are primarily taken by affected fishermen. For some of the vessels fishing in Kattegat, the closure can have changed their variable costs and/or changes in revenue. These changes can have been substantial for the individual fisherman. Especially, if the changes on the margin forces the fisherman to shut down, there can be a high private cost, as many of the fishermen have sole proprietorship, and thus may be left with substantial loans if the business is closed down.

The persons that potentially will benefit from a rebuilt cod stock is both people who get satisfaction from knowing that there is a safe cod stock by the coast, people who like to go fishing or to have the option to go fishing for cod in the future and also future fishermen and maybe also people who enjoy harbours with active fishermen[7] (to know it exists/to experience it/to know that other people can experience it/ to have the option to experience it in the future).

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[4] Eggert H and Olsson B, Valuing multi-attribute marine water quality, Marine policy, Volume 33, Issue 2, March 2009, Pages 201–20

[5] Agrifood Policy Brief Nr 2010:3

[6] See the text in appendix about control issues

[7] This to a large extent depends on other factors such as the general trend of rationalisation in the fisheries.

Potential effects for obtaining good environmental status

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ToR. d) Describe potential effect of the closure for obtaining good environmental status (GES)

Background

ToR d is premature in the sense that indicators and quantitative limits for GES have not yet been decided, but nevertheless highly important for future management decisions. The Marine Strategy Framework Directive (MSFD) is the environmental corner stone of the Integrated Maritime Policy and it can therefore be anticipated that the new CFP will be developed with GES as the overall target to be achieved through an ecosystem approach to fisheries management. Indicators and limits for GES proposed by the member states are presently under public consultation and will subsequently need to be approved and ratified by the Commission. Functional indicators and monitoring programs should be operational by 2014 and the first full assessment of the environmental status is scheduled for 2018. EU requires that member states (MS) report on the environmental status at the scale of sub-regions (i.e. The Greater North Sea in this case), but MS may also choose to report at smaller spatial scales such as the Kattegat. Indicators and limits for GES should be harmonized among MS sharing a marine area.

Teleost fishes generally have generation times ranging from two years to over ten years, and elasmobranchs are found in the higher end of that spectrum. Closed areas may allow local fish populations to recover, given that the MPAs are large enough, positioned so that critical life history stages are protected and lead to substantial reductions in fishing mortality. Given the generation times of fish it is however unlikely that a recovery would be detected as early as after the three years of closure in the present study. Earlier studies suggest that that there may be considerable delays (≥ 6 yrs) between changes in pressure (exploitation rate) and fish community metrics (Daan et al. 2005, Greenstreet et al. 2011).

ToR d is therefore primarily addressed theoretically, describing the potential effects of the closure for obtaining GES. Exploratory analyses other fish species and benthic macrofauna have also been carried out to indicate if any trends related to presence of the closed area could be detected despite the short time span of the closure.

The theoretical approach to ToR d)

The MSFD provides 11 qualitative descriptors of good environmental status (GES) with more specific criteria defining what aspects of the environmental status that should be protected and evaluated. Descriptors 1, 3, 4 and 6 representing biodiversity, commercial species, food webs and seafloor processes are proposed to be the ones potentially most affected by fishing and fishing activities (Le Quesne et al. 2011).

Descriptor 1.Biodiversity

Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.

Biodiversity includes everything from genetic diversity to the diversity of communities and also the status and areal extension of habitats. It was considered beyond the scope of this exercise to evaluate all aspects of descriptor 1.

Preliminary exploration of fish assemblages using survey data

Multivariate statistics indicated that the fish assemblages differed among areas and among the four years investigated, but there was no significant interaction between area and year to indicate that any differences related to the closure had developed over the 3 years. Fish species differ in how they are harvested by fisheries, and life-history data can be used to rank species according to their predicted vulnerability to fishing (Quesne and Jennings 2012). The Elasmobranchs that are found at the top of that list are generally absent or close to zero in the contemporary surveys from the Kattegat. In the appended exploratory analyses the trends in abundance of the most common fish species in the four areas are shown. The species are listed in a falling order of their potential vulnerability to fishing as defined by Quesne and Jennings (2012). For a few species, a higher abundance is indicated in the closed area (Fisherman's survey). This was not supported by "the sole survey". As expected, only a few differences were indicated over the short time span (3 years) of the closure.

Descriptor 3. Commercial fish

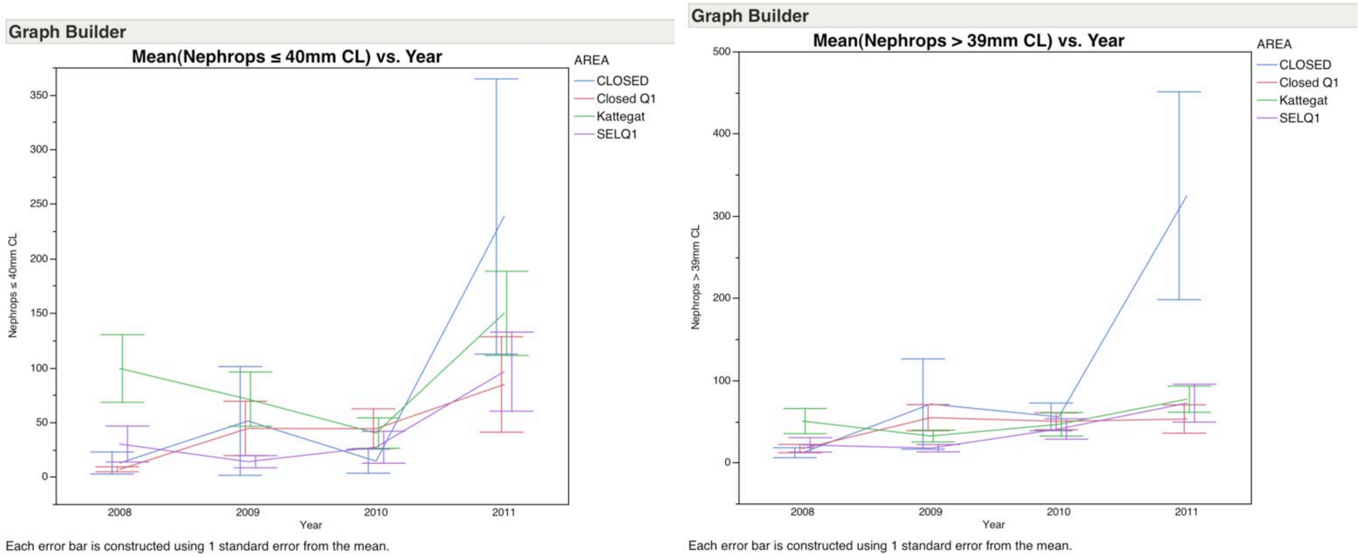
Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

This is the most detailed descriptor stating that all commercial stocks should have a fishing mortality (F) below FMSY and a SSB larger than BMSY-trigger. In the case of cod, it can therefore be concluded that the closure contributes to improve the status, as indicated by the decrease in F and increase in SSB over the last years partly attributed to the closure. The cod stock is however still found to be sub-GES. Several other commercial stocks in the area are similarly not being managed at the level of MSY (ICES, latest advise) at present. The main measure to achieve GES for these species should, however, be to reduce fishing mortality explicitly. Closed areas could be a complementary measure to achieve GES for these species, given that the habitat use of critical life history stages are protected spatially as in the case of cod. Closed areas could also be a tool to counteract unwanted evolutionary effects of size-selective fishing on size and age at maturity, addressing Criteria 3.3 of the MSFD. Other management tools such as reduced harvest rate and a maximum landing size may be more effective to reduce selection on size, but may be harder to enforce than a closed area (Baskett et al. 2005).

Preliminary exploration of commercial species using survey data

Norway lobster was chosen as an example because it is stationary once larvae have settled and occurs in relatively high densities in all areas. The catches were separated into two size classes; > and < than 40 mm carapace length. The graphs indicate that the abundance of large Norway lobsters have increased in the closed area whereas the abundance small lobsters is independent of area (Fig 1) The analyses of the Kattegat cod stock clearly falls under descriptor 3 but is not reported here

Fig 1. Trends in the abundance of small (< 40 mm CL) and large (≥ 40 mm CL) Norway lobsters in the four areas differing in regulations. Data from the Fisherman's survey covering the year before the closure and the three years that the clousre has been in effect.



5.2.3 Descriptor 4. Food webs

All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.

The fish community contains species that are top-predators within the systems, but also important forage species. Top-predators often have the capacity to structure food webs (e.g. Casini et al) and pelagic forage species feeding on zooplankton may be important for several groups in the food web. These two groups of fishes are the main targets for the consumption fishery and for the industrial fishery, respectively and fishery may thus have a considerable impact on food webs. Cod is a species that can act as a top-predator in the ecosystem. Closed areas (no-take zones) are less likely to protect entire food webs simply because the component species all have their own population structures and sensitivity to pressures. To obtain GES from a food web perspective it will be important to consider how all relevant pressures on the food web are managed within an MPA.

Descriptor 6. Sea-floor integrity

Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

The rationale of this descriptor is that by protecting structures and species, critical functions of the ecosystem will be maintained sustainably. There are however huge gaps in the understanding of how these ecosystem function and a lack of basic knowledge on a majority of the taxa. The establishment of closed areas is clearly a starting point for obtaining benthic ecosystems that are not affected by trawling. The downside is that effort reallocation is likely to follow making other parts of the seabed more exposed to trawling. Until science has developed our understanding of how trawling effects ecosystem function it is nevertheless suggested that sea-floor integrity is managed with closed areas.

Exploratory analyses of benthic macrofauna

Introduction

Seafloor integrity is one of the 11 descriptors for determining Good environmental Status (GES) according to the Marine strategy framework directive. The directive also states that Marine protected areas are an important contribution to the achievement of GES. In that perspective is the permanent closure, i.e. the SE area (crossed in Fig. 2) in the Kattegat an area that since 2009 fully protects bottom habitats and the associated organism from abrasion by bottom trawling which is one of the pressures that affects the status of the seafloor. Ecological impact of bottom fishing is well described (e.g., Jennings and Kaiser, 1998; Thrush and Dayton, 2002) and the intention of this study was primarily to evaluate the performance of satellite positioning of fishing vessels (VMS) as an indicator of seabed status in the Kattegat. Secondarily, the aim was to evaluate potential recovery of benthic community on the permanently closed area.

Benthic habitats are patchy on different scales and so are the use of the ecosystem e.g. fishery by bottom trawling. The topography and substrates of Kattegat overlaid by positions of active bottom trawlers is a good example of that as shown in Fig. 3.

Fig. 2. Depth contours and Swedish and Danish bottom trawlers positions as indicated by hourly VMS (black dots).

To evaluate the potential recovery of benthic organism from bottom trawling and trawling impact ion the areas, a grid 1 X 1 km was constructed and the sum of trawling positions from fishing vessels satellite positioning (VMS) within each cell during the years 2004-2007 (Swedish vessels) and 2006-2007 (Danish vessels). A stratified sampling design was then applied to the trawled areas to allocate 16 benthic grab sample stations to be taken in each part of the closure. Eight samples within each area were allocated to either high trawling frequency (>30 positions) or low trawling frequency (0-10 positions). If possible, stations sampled by Swedish national and regional monitoring programmes were included (Fig. 2). The samples of benthic infauna were taken in May 2009-2011 with a Smith-McIntyre grab (0,1 m2), sieved through a 1mm sieve whereafter organisms were preserved in 4% borax buffered formalin. Organisms were identified to species under microscope and weighed after blotting.

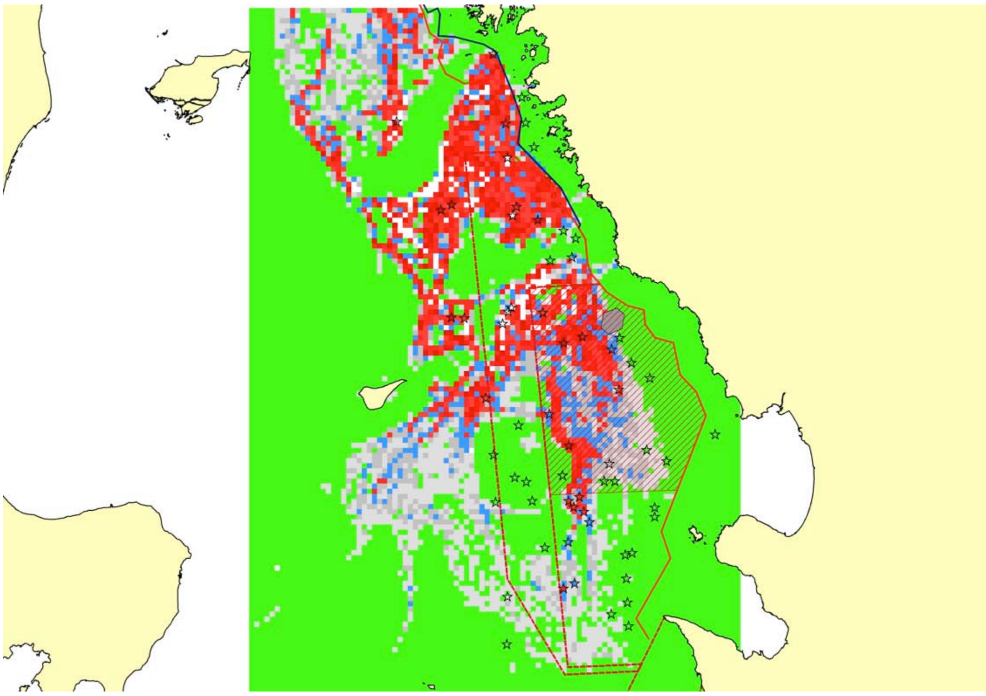


Fig. 3. 1X1 km grid of VMS positions. Red quadrats are defined as high trawling intensity (>30 positions) and green quadrats low (0-10 positions)

Statistical analysis

The putative effects on species were tested against the factors area and year and age, using the multivariate statistical program PRIMER 6 together with PERMANOVA (Anderson 2001; McArdle and Anderson 2001; Anderson 2005). Permutation of residuals was under a reduced model and with 999 permutations. Each data set to be tested was adjusted for missing values and transformed by fourth root (x). Euclidean distance measure was used to construct the similarity matrices. Data distribution graphs (Canonical correspondence analysis, CAP) were used to visualize potential associations and proportional significance of each variable (species) to explain the association pattern.

Results and discussion

The multivariate analysis shows difference between all 3 factors year, area (zone) and trawling intensity both for abundance of species and biomass (table 1, abundance statistics shown only). No interaction between area and year indicating recovery in the permanently closed area were found. An interaction was found significant for the factors area and intensity, probably indicating that intensity may differ within the categorisation of high and low trawling intensity in the different areas that may affect the community pattern.

Canonical correspondence analysis for the factor trawling intensity showed a correlation of 0.68. The correlation between the explanatory score (z) for each species and its abundance revealed a pattern illustrating positive (higher) or negative (lower) abundance by the different species. In summary 76 species showed significantly lower, 12 species higher, and 166 no difference between stations with high trawling intensity in comparison to low.

In summary this study show that there was both temporal differences and differences among the four areas in the benthic fauna assemblage, but no interaction between year and area to indicating a recovery in the area where trawling has ceased.

There are several reasons why a recovery of the seafloor ecosystem are not detected yet:

• Three years is a short period for the recovery of benthic macrofauna, especially for large long-lived species believed to be most vulnerable to trawling.

• Interannual variability in benthic macrofauna community structure is large, making it difficult to detect changes

• Trawling activity may have occurred within the closed area despite the regulation hindering recovery

There was however differences in the community structure between sampling stations categorised as having high or low trawling intensity indicating that VMS positioning of bottom trawlers are a promising indicator for the pressure trawling exhibits on benthic infauna species composition.

Table 1. Permutational MANOVA of Abundance of species

Resemblance worksheet

Name: Resem1

Data type: Similarity

Selection: All

Transform: Fourth root

Resemblance: S17 Bray Curtis similarity

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 1000

Factors

Name	Abbrev.	Type	Levels
Year	Ye	Fixed	3
Zone	Zo	Fixed	4
Intensity	In	Fixed	2

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Ye	2	14124	7061,8	4,0627	0,001	999
Zo	3	19592	6530,7	3,7571	0,001	999
In	1	23854	23854	13,723	0,001	1000
YexZo	6	9739,9	1623,3	0,93389	0,6813	995
YexIn	2	3653,2	1826,6	1,0509	0,3656	998
ZoxIn	3	22214	7404,8	4,26	0,001	1000
YexZoxIn	6	8827,5	1471,2	0,84641	0,9081	999
Res	168	2,92E+05	1738,2			
Total	191	3,94E+05				

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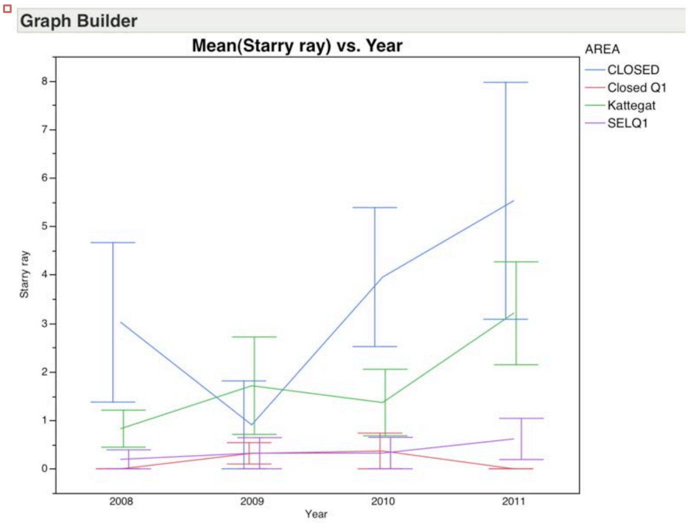
Exploratory analyses. Trends in other fish species (numbers per area) present in the four different areas as captured by the Fisherman survey. Sampling started in 2008 and the new fishing regulation came into effect during 2009. For details on sampling see the description of the fisherman survey. Selection of species were made based on overall abundance and the assumption that they were sampled properly by a benthic trawl and therefore also vulnerable to a benthic trawl fishery. The species are presented in order of their ranked vulnerability to fishery based on life history characteristics (Le Quesne & Jennings 2011). Where available, comparable data is shown from the Danish "Sole survey" covering the years 2004-2011.

Fisherman Survey

Sole Survey



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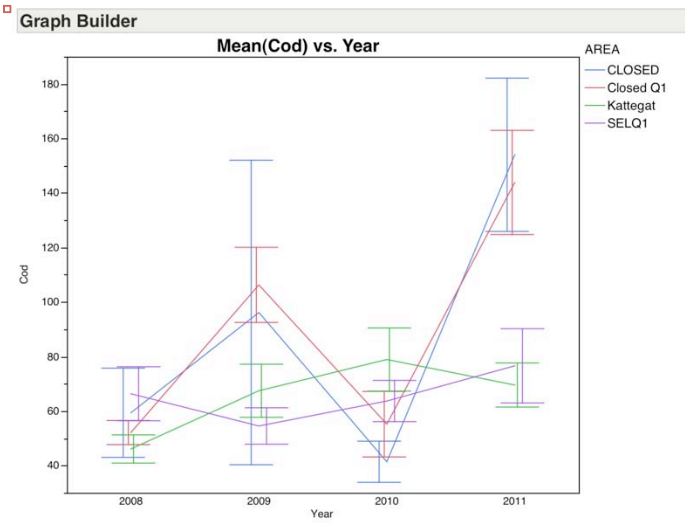

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Fisherman Survey

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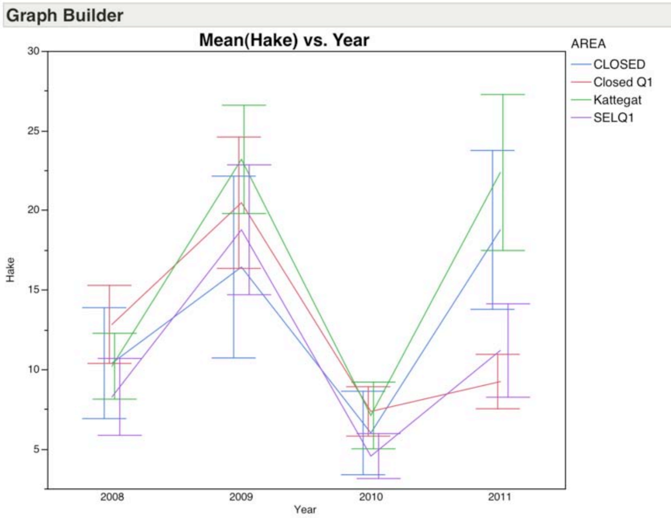

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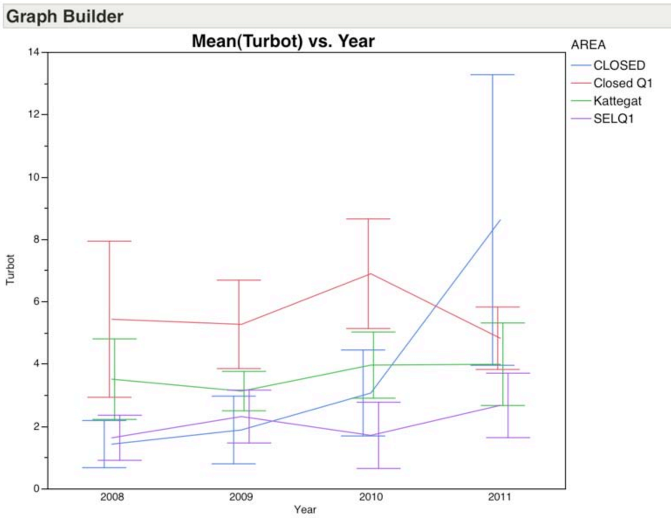

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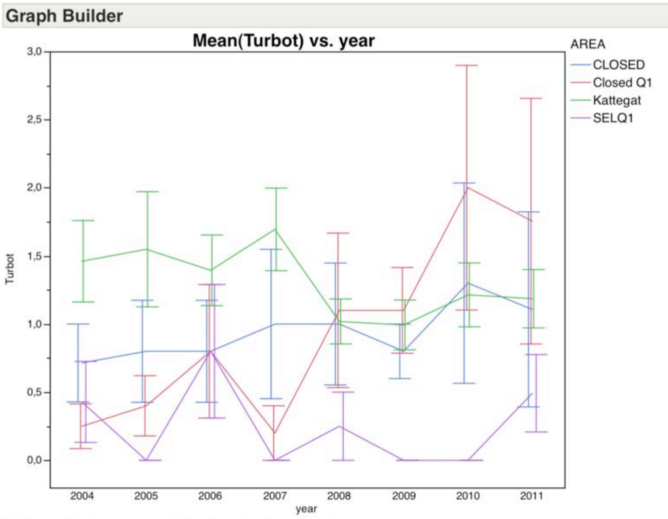

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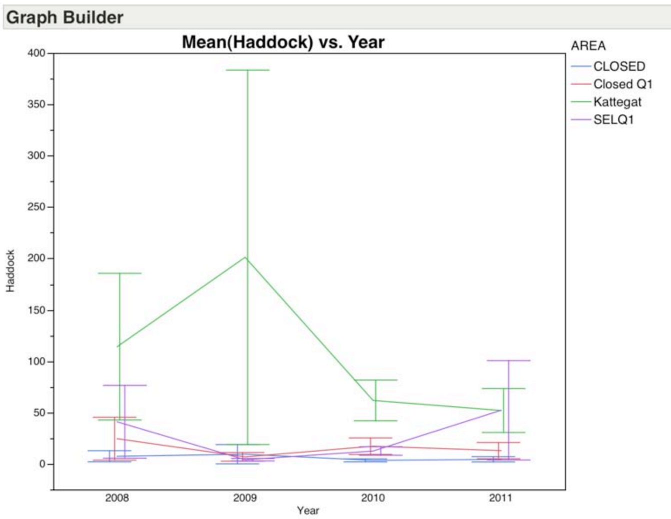

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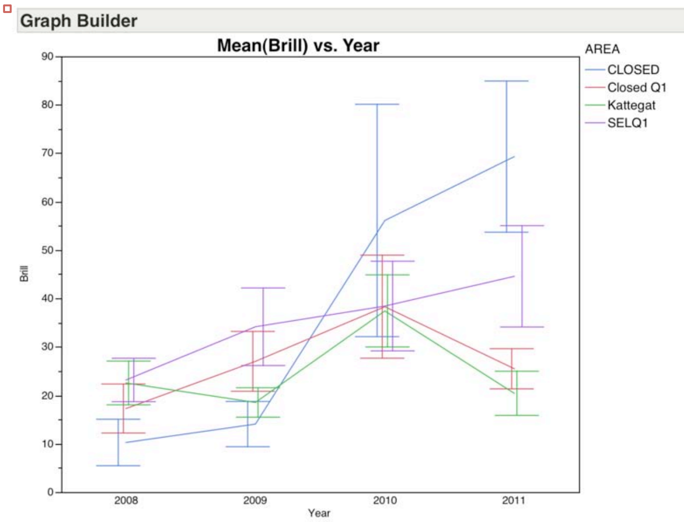

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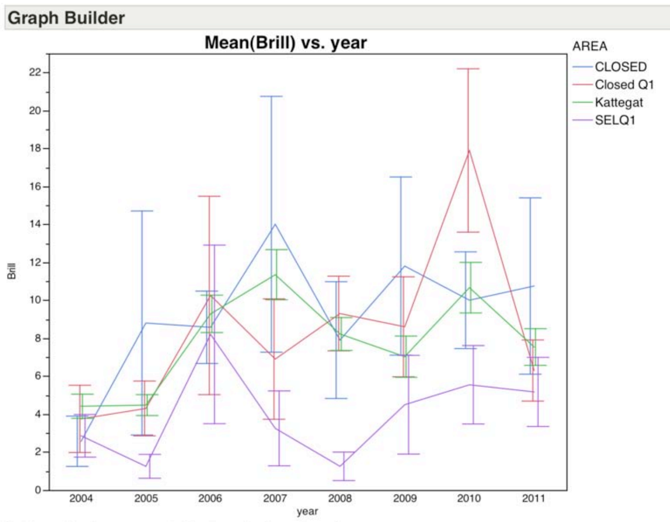

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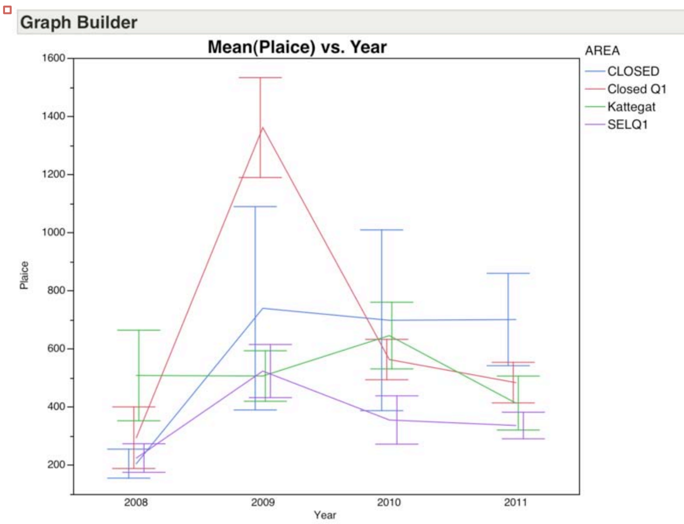
Fisherman Survey

Sole Survey



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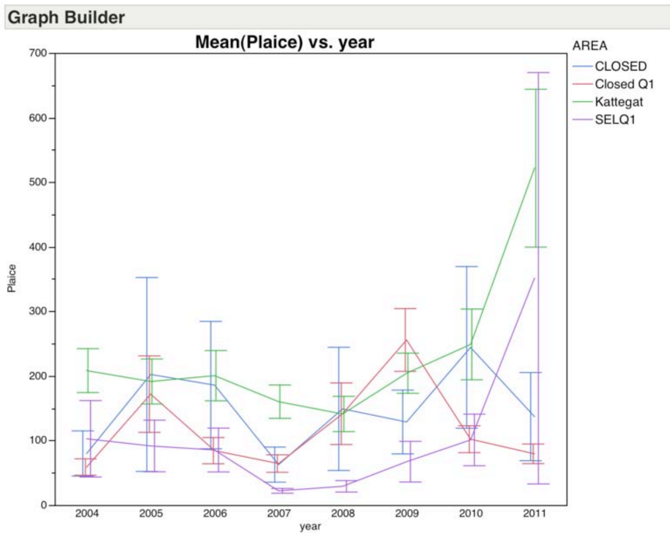

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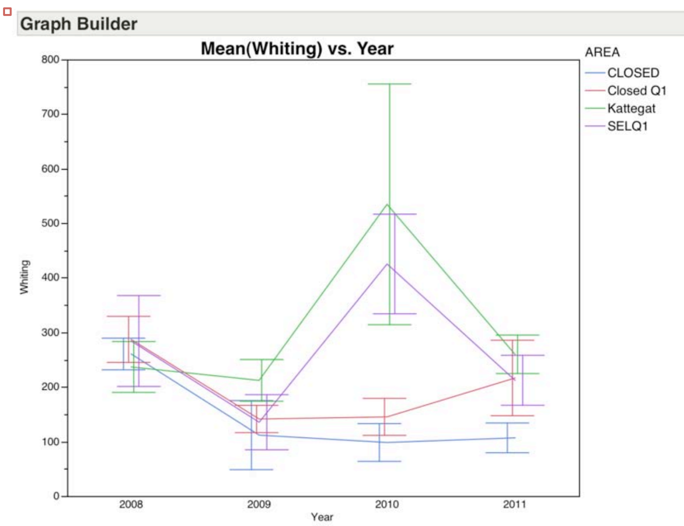

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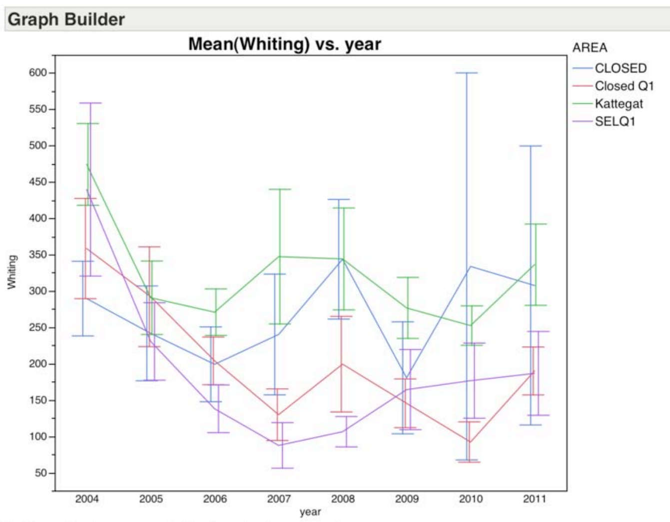

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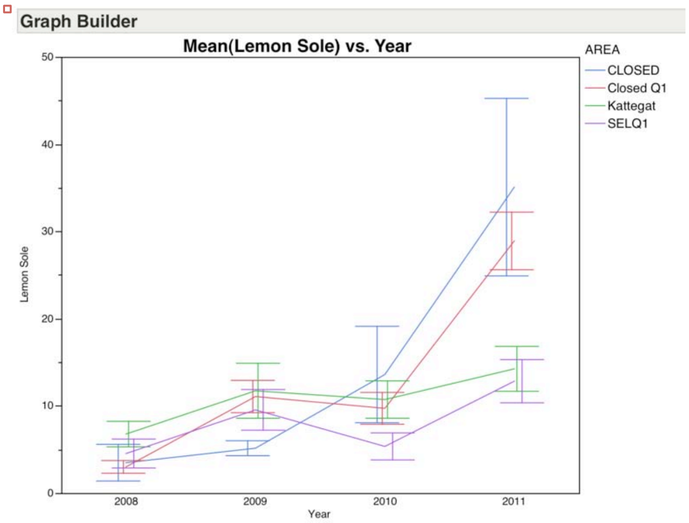
Fisherman Survey | Sole Survey



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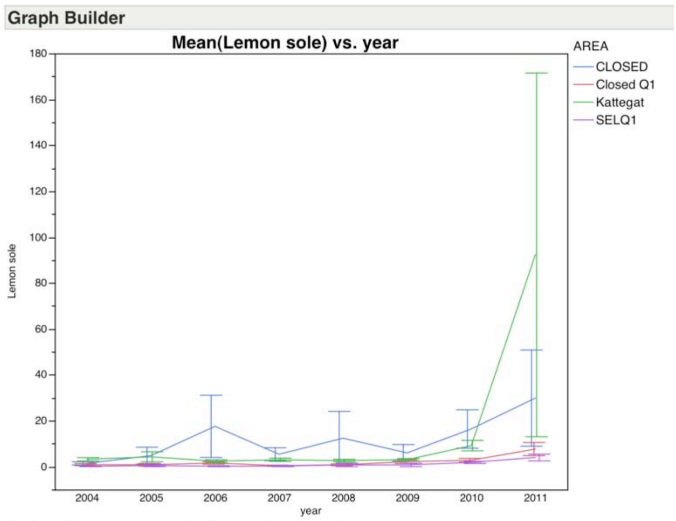

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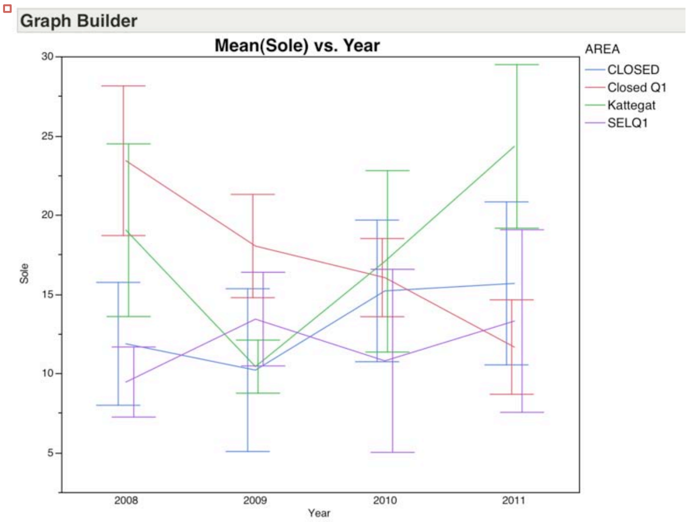

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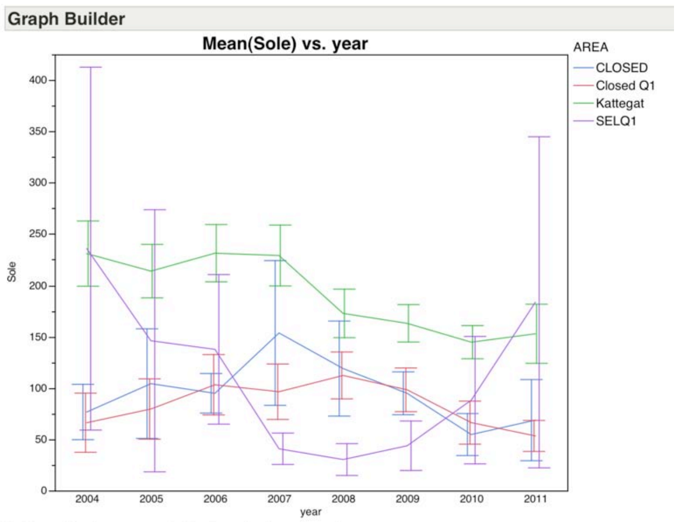

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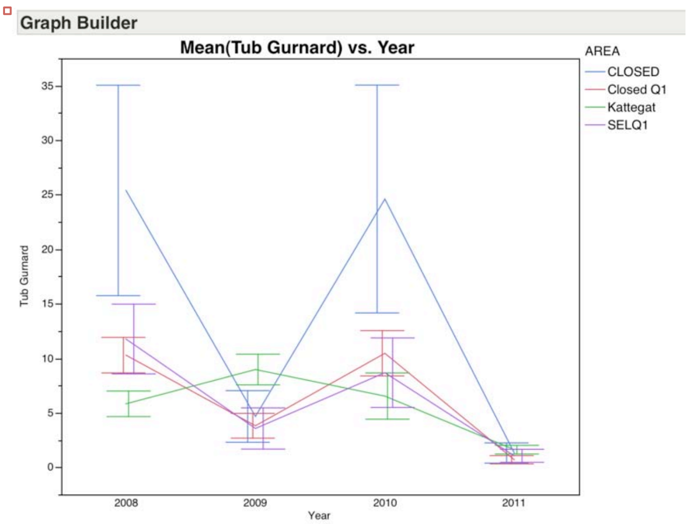

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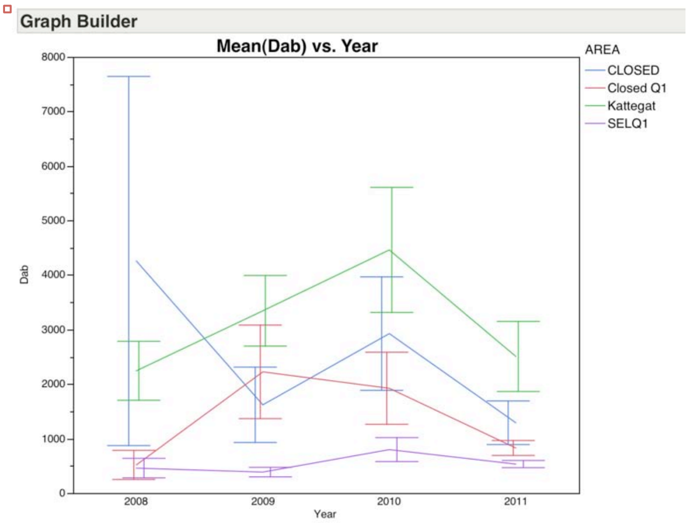
Fisherman Survey

Sole Survey



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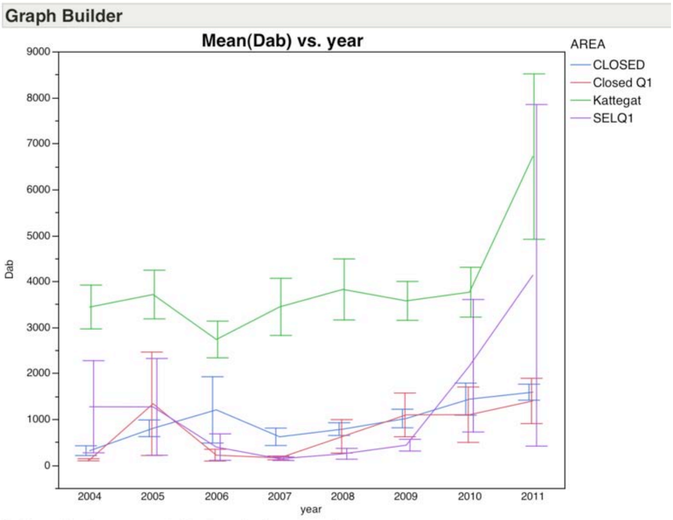

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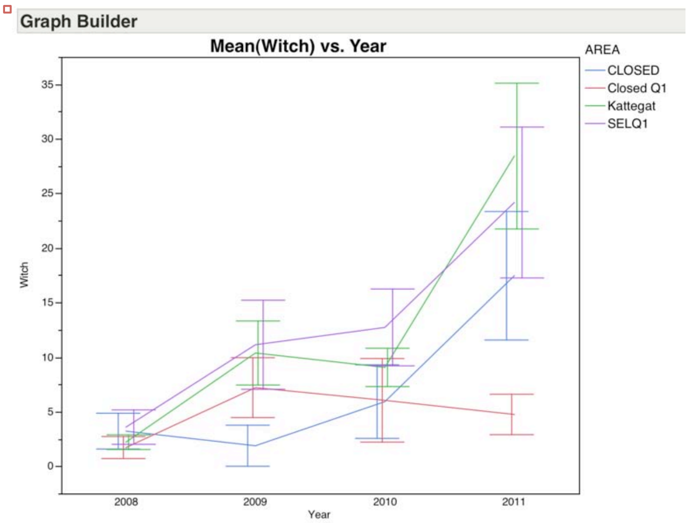

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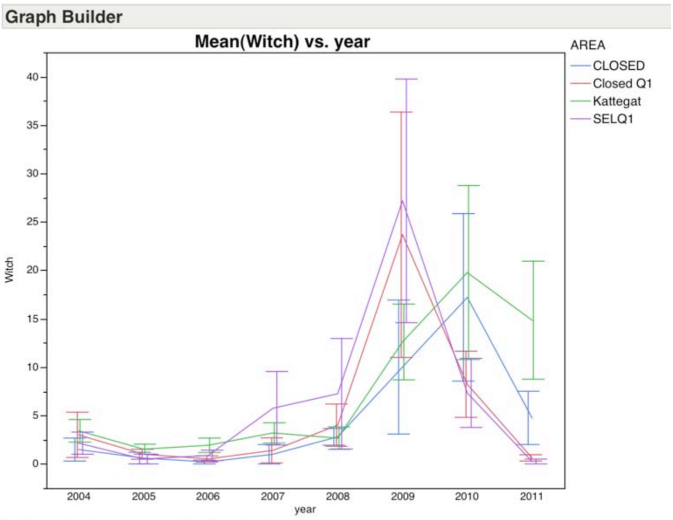

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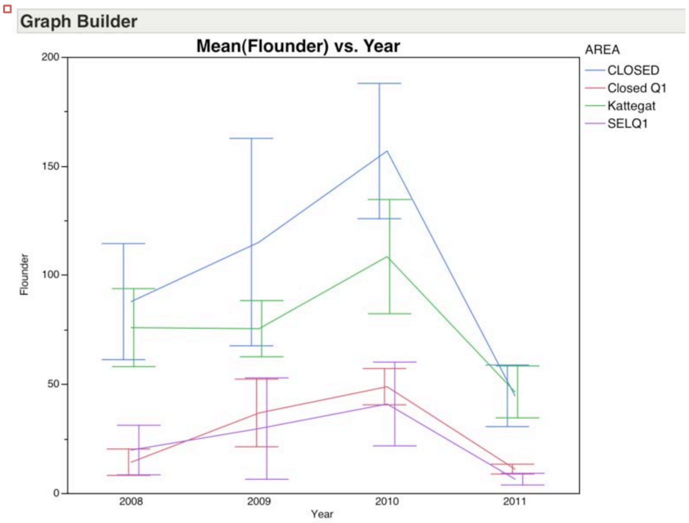

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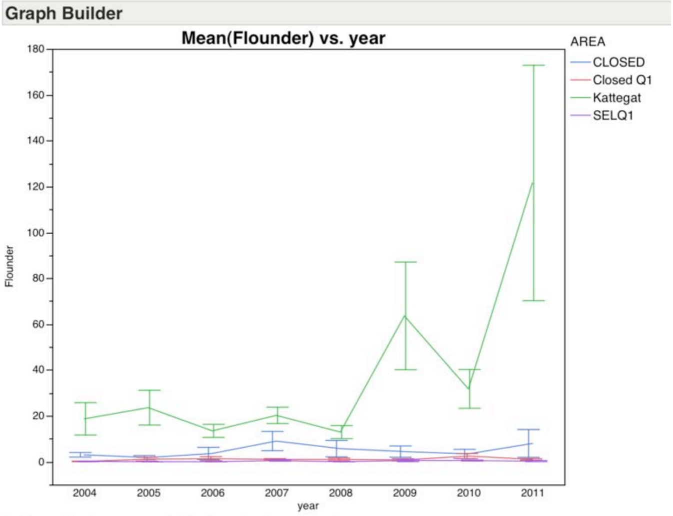

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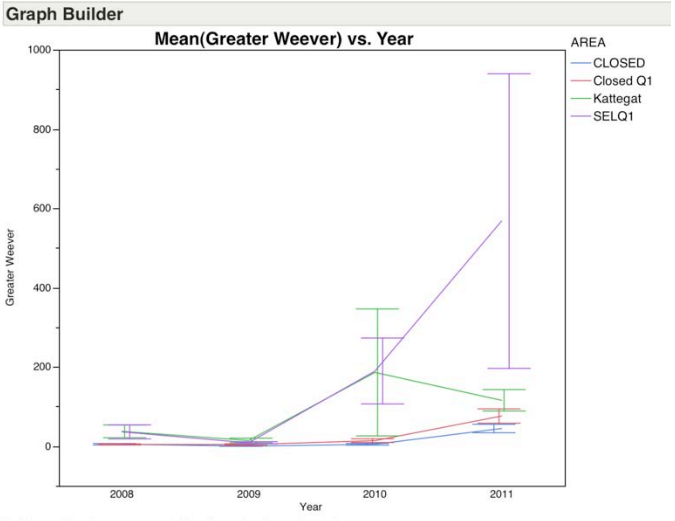
Fisherman Survey



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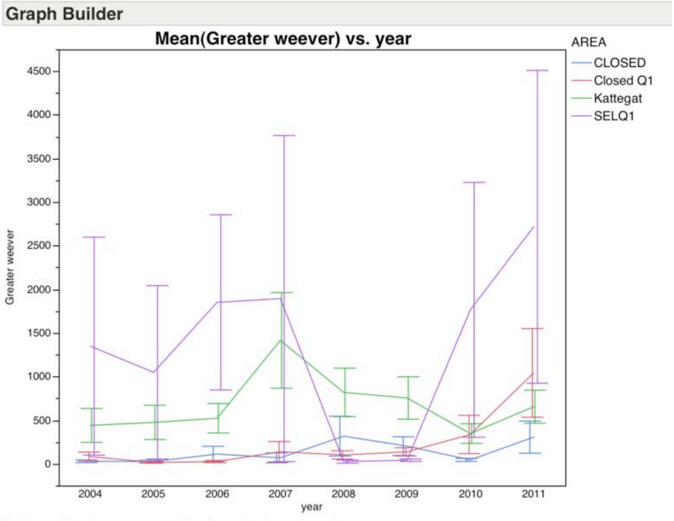
Sole Survey



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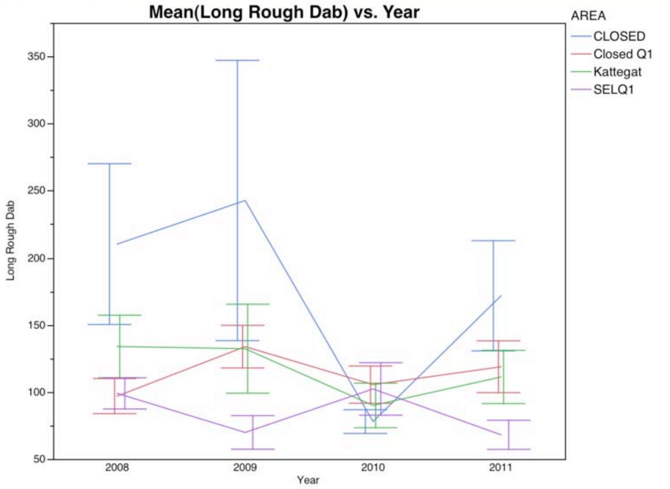
Fisherman Survey

Sole Survey

Graph Builder



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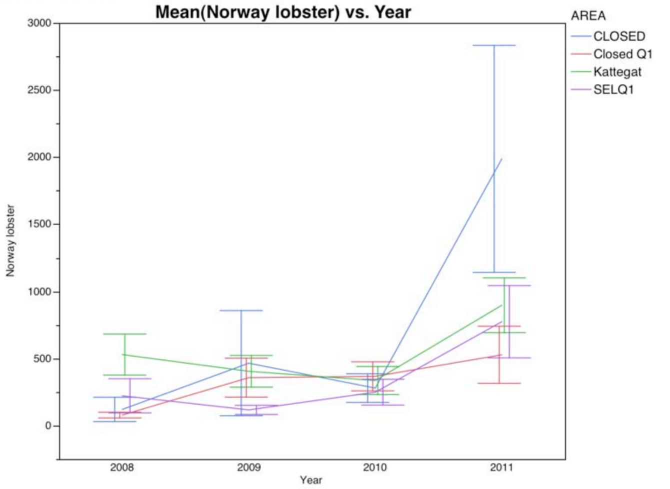
Graph Builder



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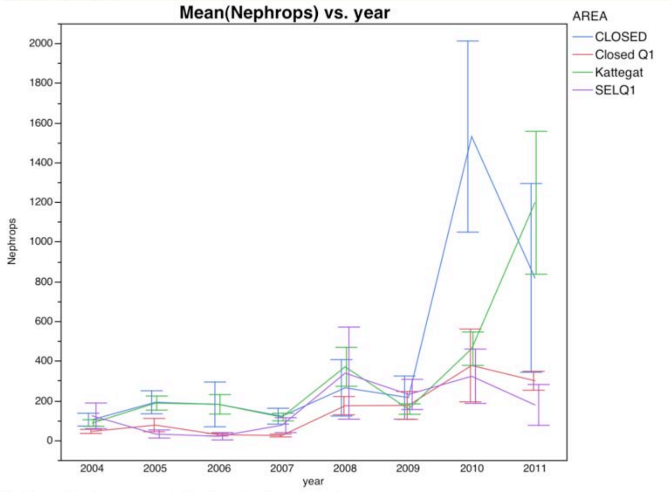

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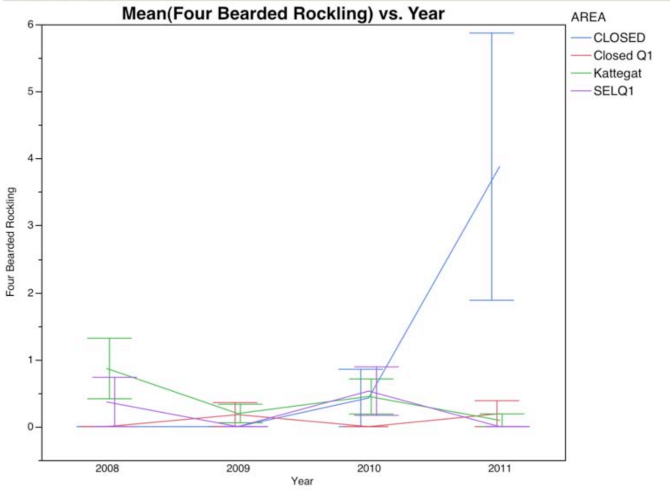

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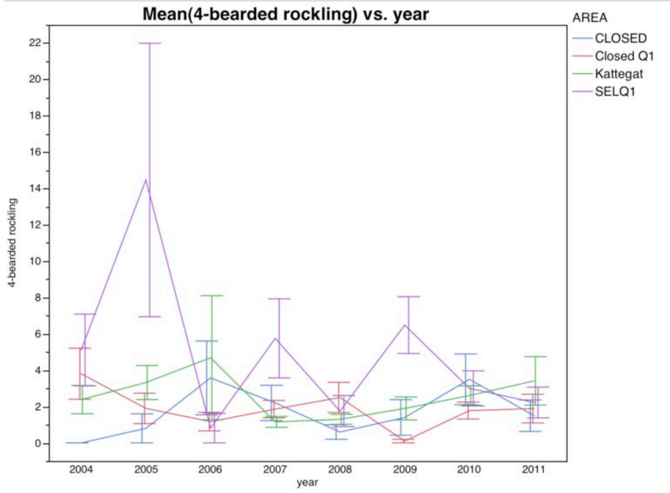


Each error bar is constructed using 1 standard error from the mean.

Appendix 10. Description of the Swedish control

Jonas Ericson, The Swedish Agency for Marine and Water Management

Ola Vesterlund, Swedish Coastguard, Region West

The Swedish fisheries control at sea is carried out by vessels and airplanes from the Coast Guard. The Coast Guard has always had surveillance of the area that, after the regulation was introduced in 2009, has intensified.

The Coast Guard has a number of ships from different stations that patrol the area to achieve a high presence. Continuous inspections at sea are carried out to ensure that the rules are followed. In early 2009, the Coast Guard informed both commercial and recreational fishermen on the new rules. This was done both at sea and in ports around the area.

Aerial surveillance is an effective way to ensure that no illegal fishing is carried out in closed areas.
The Coast Guard air surveillance has a high presence in the area. On average almost one flight per day over the area is carried out. Since 2009 they have a special focus on the closed areas.

The Coast Guard cooperation with the Navy´s marine surveillance has contributed with radar monitoring to the fisheries control. Real time monitoring is also carried out via SJÖBASIS where VMS (vessel monitoring system) are included.

Number of inspections at sea and observed infringements

A total of 27 inspections carried out at sea in the closed areas 2009-2011. These break down as follows:

- 2009 - 8
- 2010 - 10
- 2011 - 9

The gear registered in the logbook is always verified during inspections at sea.
In total over the three years that the rules have been in force, Sweden has been observed and reported 24 infringements in the fully closed area as follows:

- 2009 - 9
- 2010 - 15
- 2011 - 0

All reports except two have been reported by the Coast Guard air surveillance. The reports are submitted in accordance with normal procedures to the Police for further investigation.

VMS

With VMS, combined with logbook data, an estimation of possible fishing is conducted. Swedish fishing in closed areas in the Kattegat can be estimated by counting the number of received VMS positions that fall within each area. These are divided in bottom trawls with and without sorting grid.

It is also possible to estimate fishing by VMS signals without logbook data. By filtering results with a speed range corresponding to the rate used for trawling (0.5 to 3.5 knots) it´s possible to illustrate probable fishing patterns (Appendix 8). Swedish positions in the fully closed area have been evaluated and were found to be fishing for research purposes and a single position of a pelagic trawler likely not under fishing.

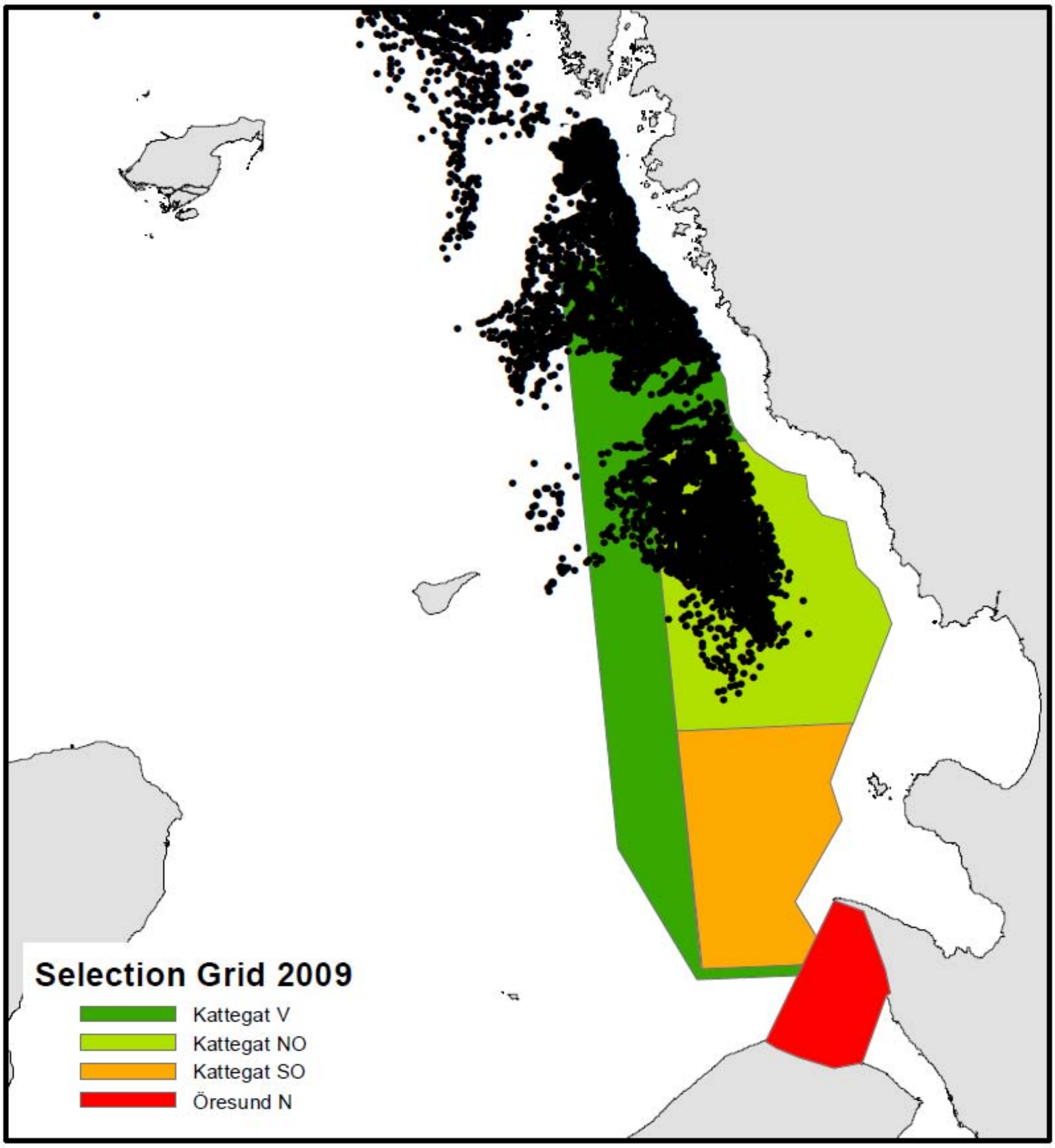
6.1.3 Discussion

We can conclude that it was not until 2011 that infringements ceased to be observed or reported. There can be several explanations for this, for example:

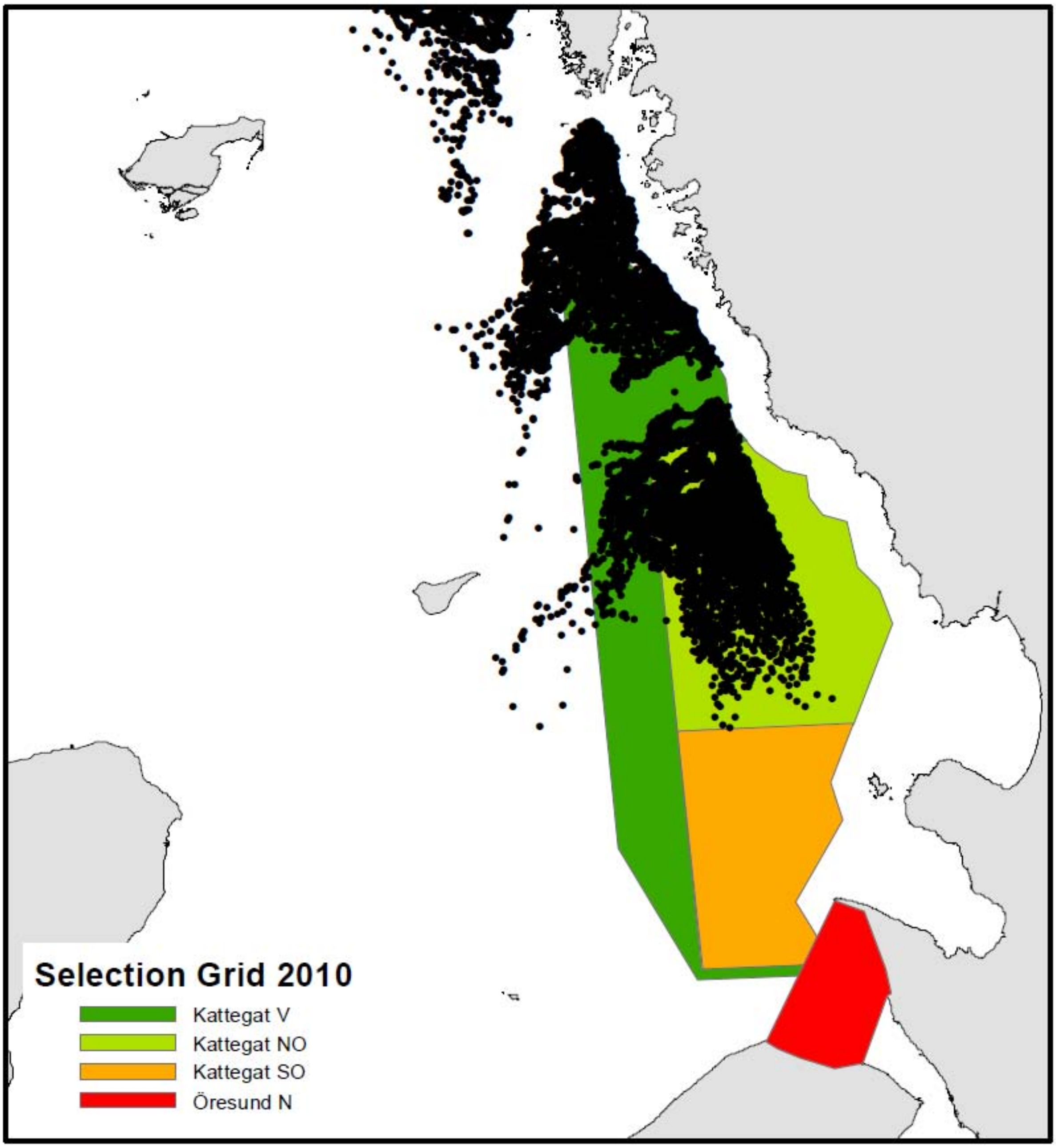
- Acceptance of the new rules will take time.
- Modification of established fishing patterns.
- Social influences.

For the Swedish fisheries control at sea, the closed areas have not caused any changes in surveillance approach. From a monitoring point of view, it's easier to verify compliance when areas are fully closed for all types of fishing.

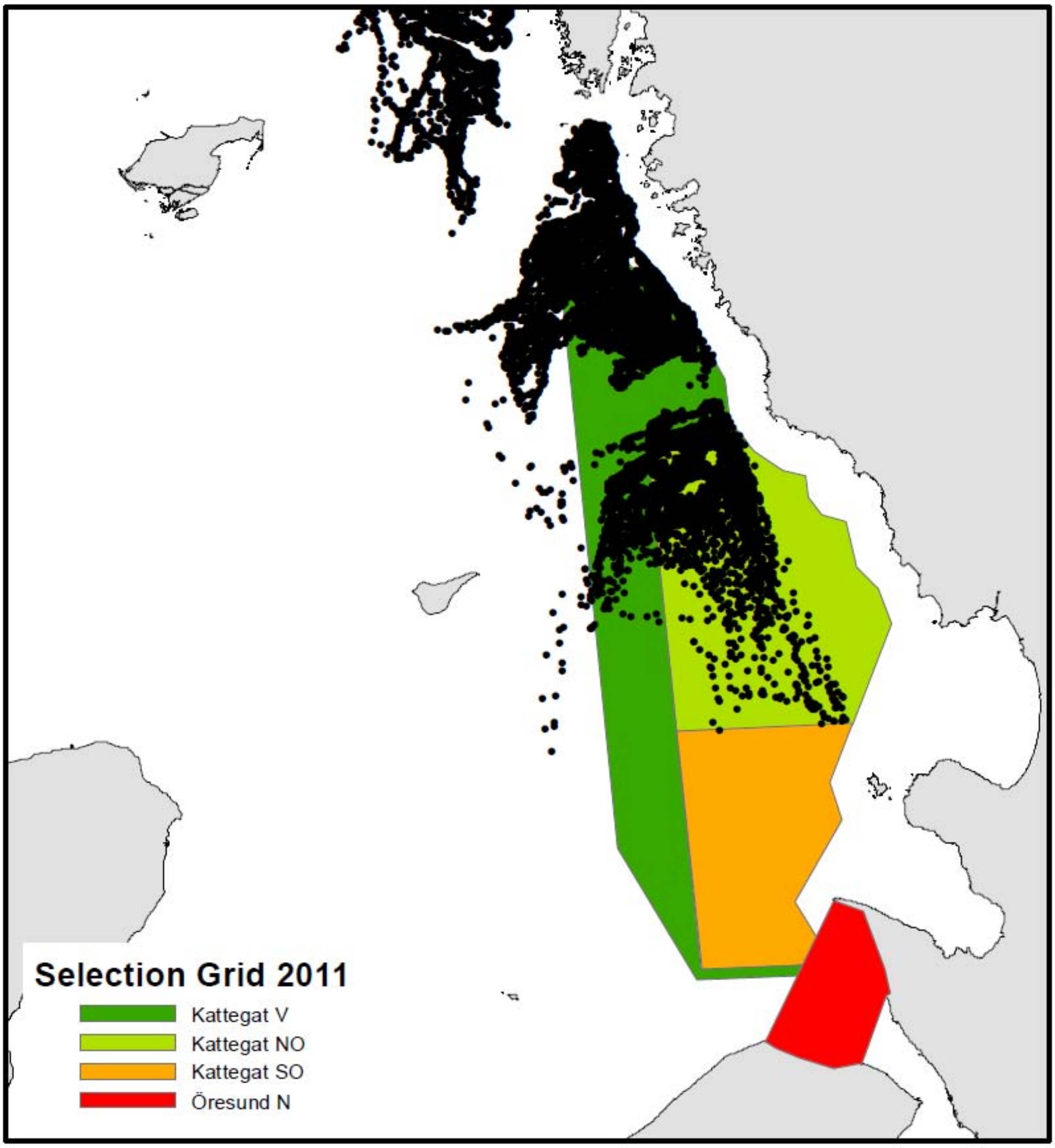
Rules applicable to protected areas should apply to all nations who have the right to fish within a given sea area. The resulting effect of allowing fishing for certain countries may be considered provocative and lead to disrespect for the current rules of the fishermen affected by the ban.



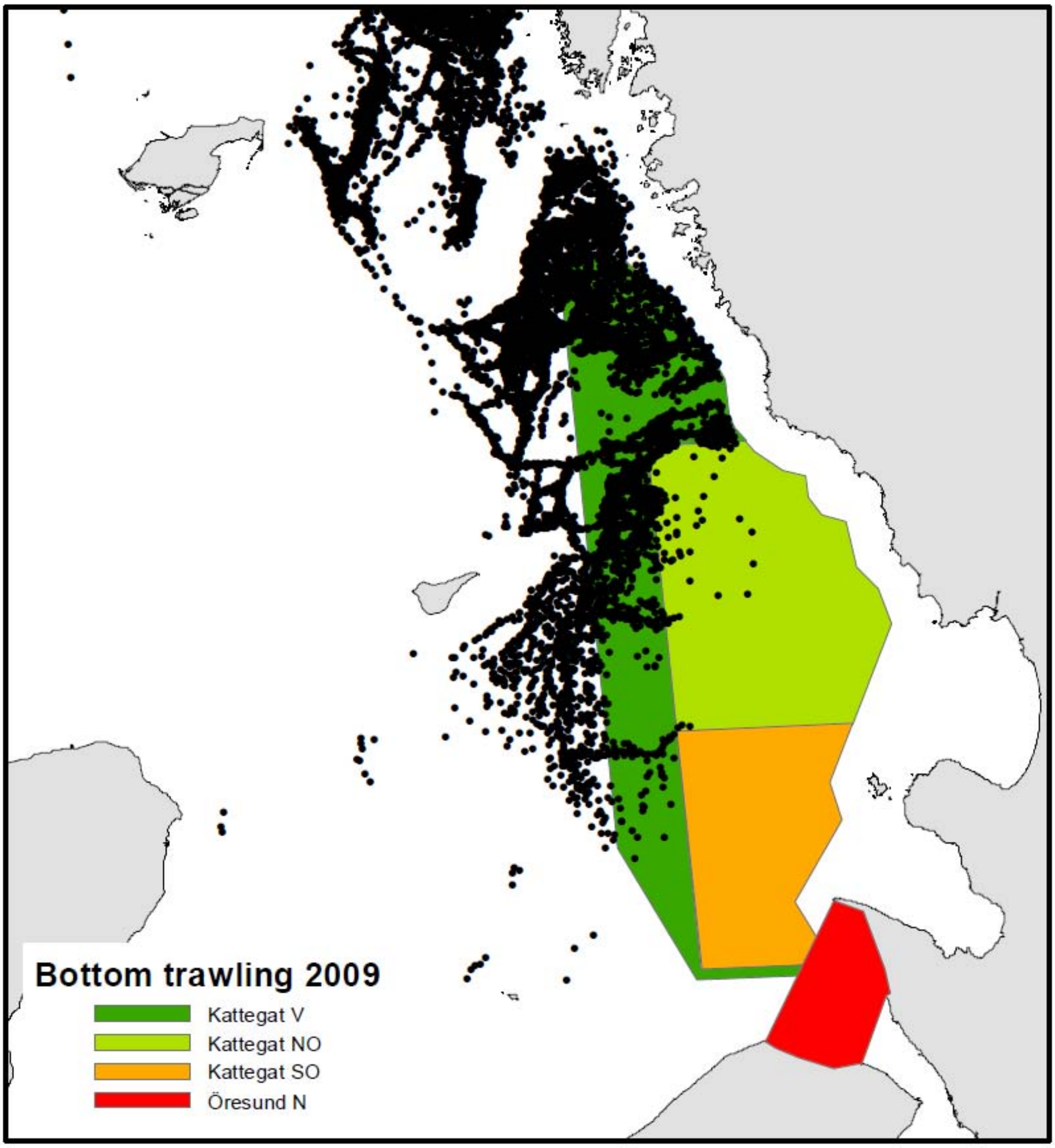
a) Swedish VMS-signals combined with logbook data (Selection grid 2009)



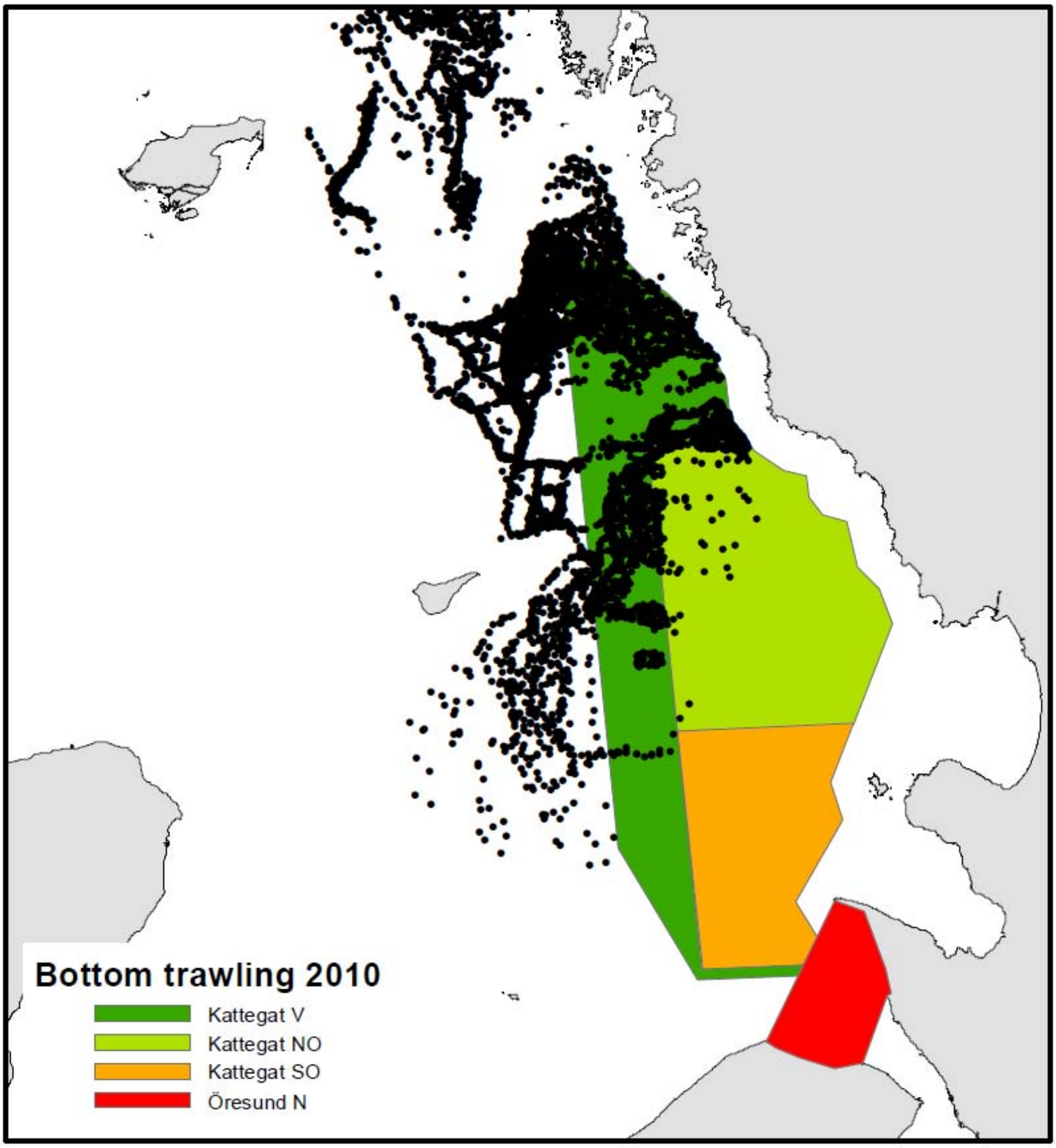
b) Swedish VMS-signals combined with logbook data (Selection grid 2010)



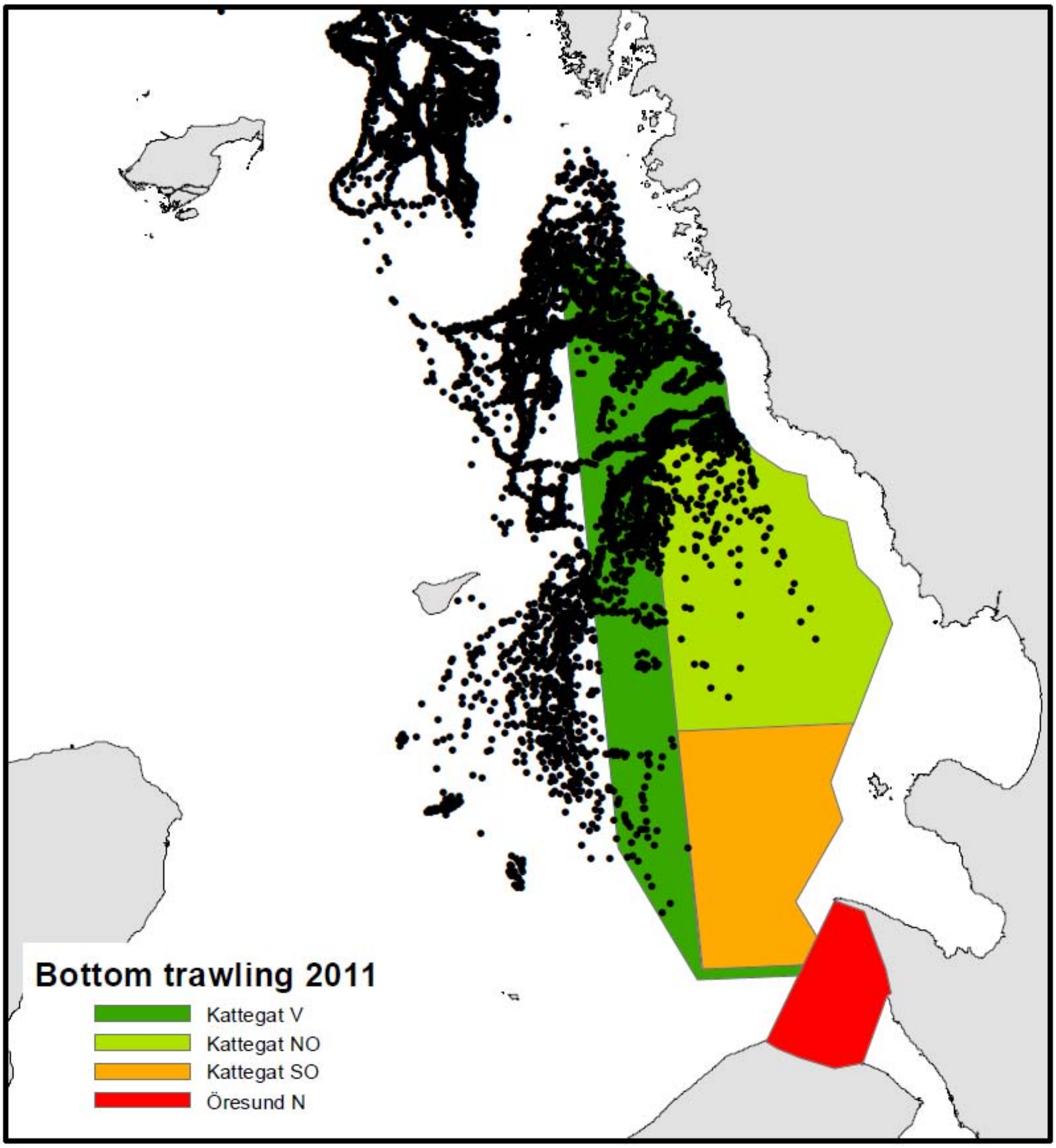
c) Swedish VMS-signals combined with logbook data (Selection grid 2011)



d) Swedish VMS-signals combined with logbook data (bottom trawl without grid 2009)

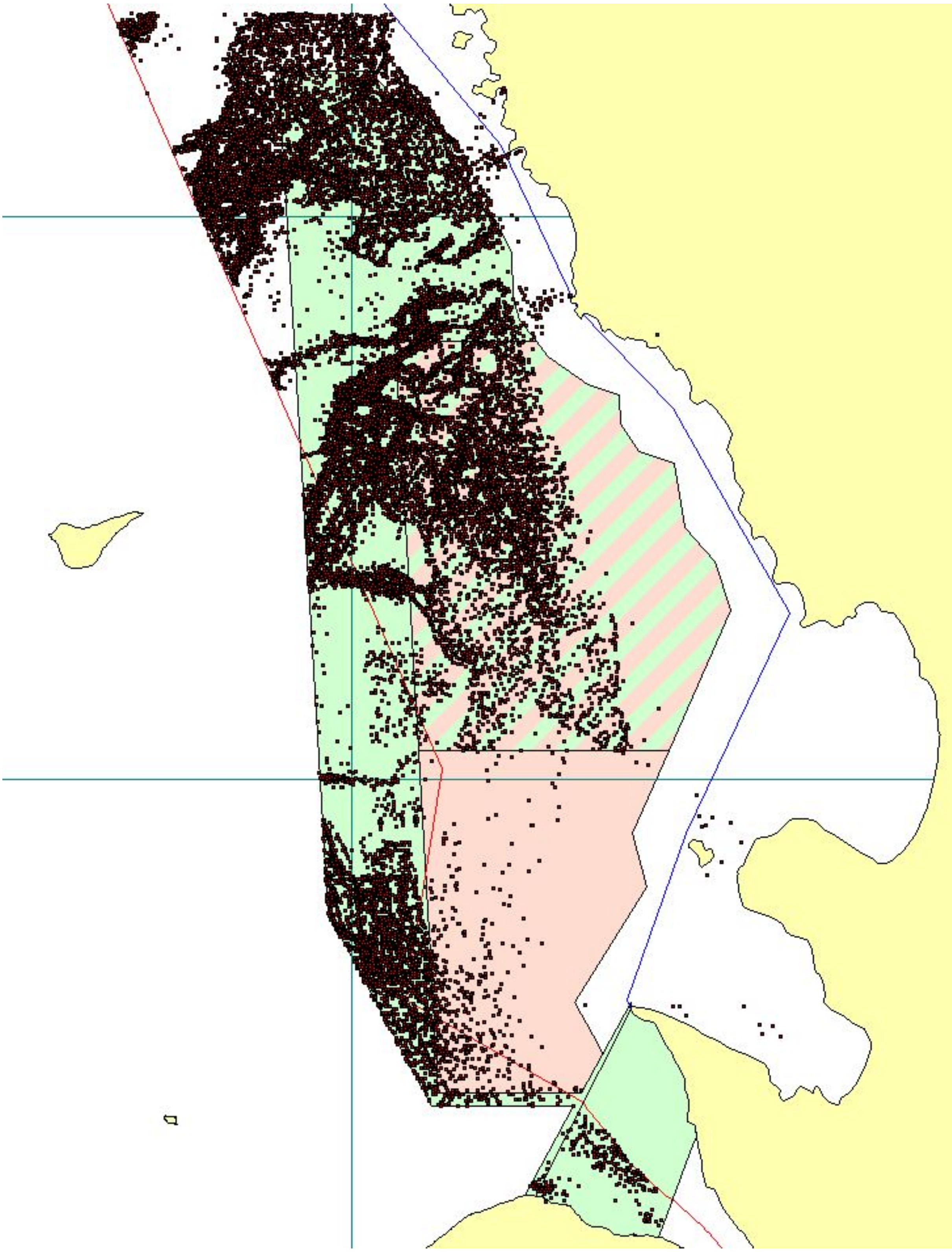


e) Swedish VMS-signals combined with logbook data (bottom trawl without grid 2010)

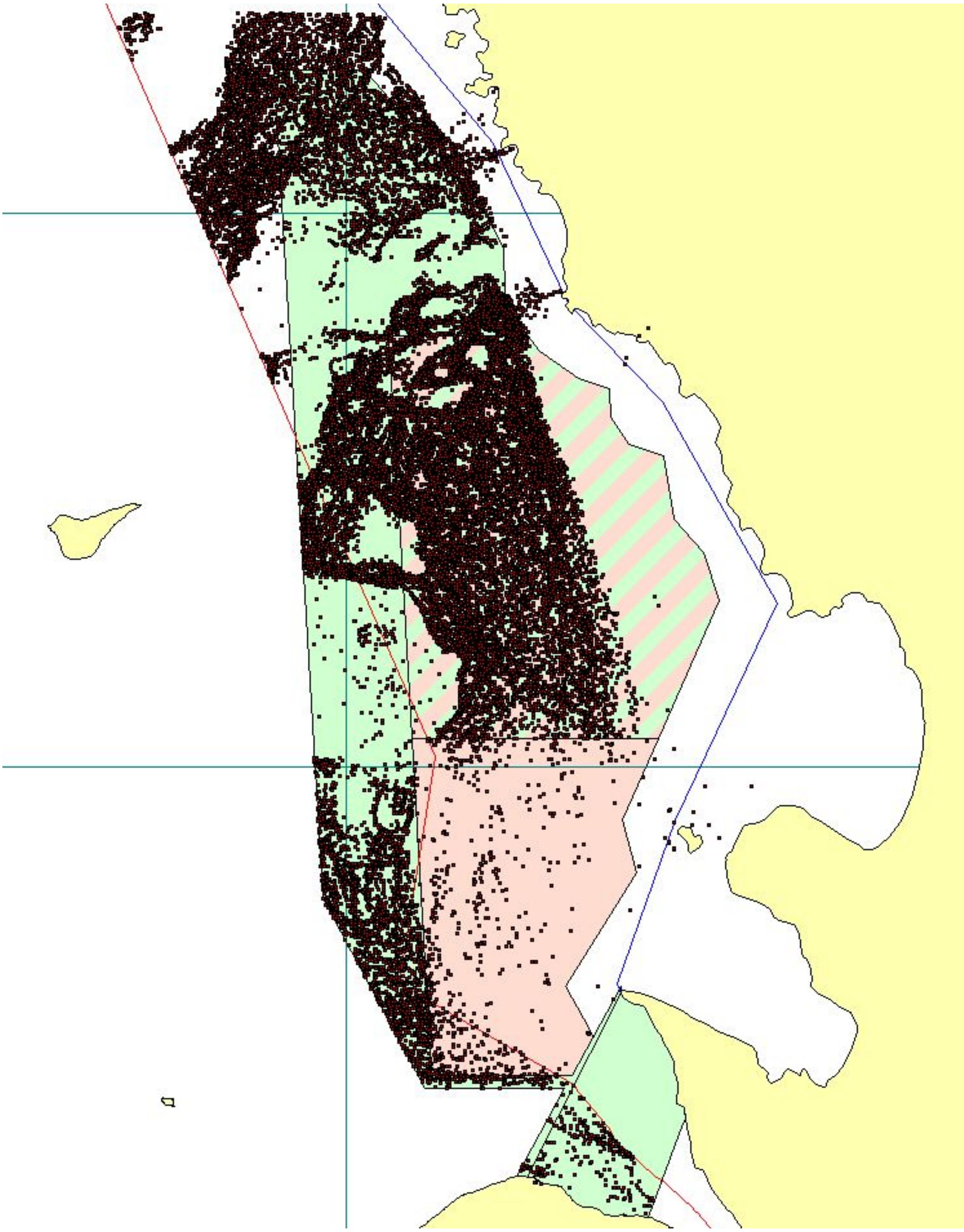


f) Swedish VMS-signals combined with logbook data (bottom trawl without grid 2011)

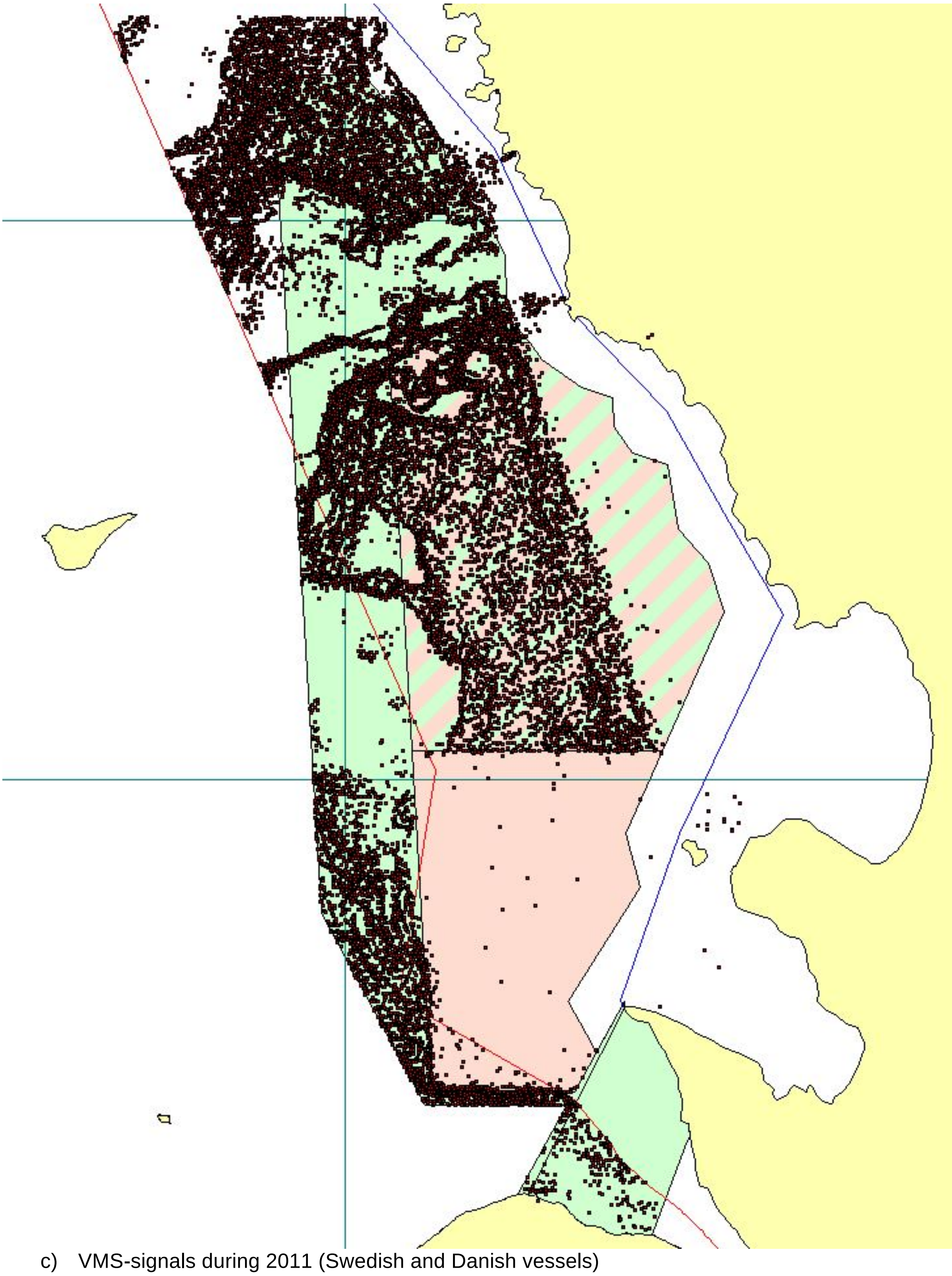
Appendix 2



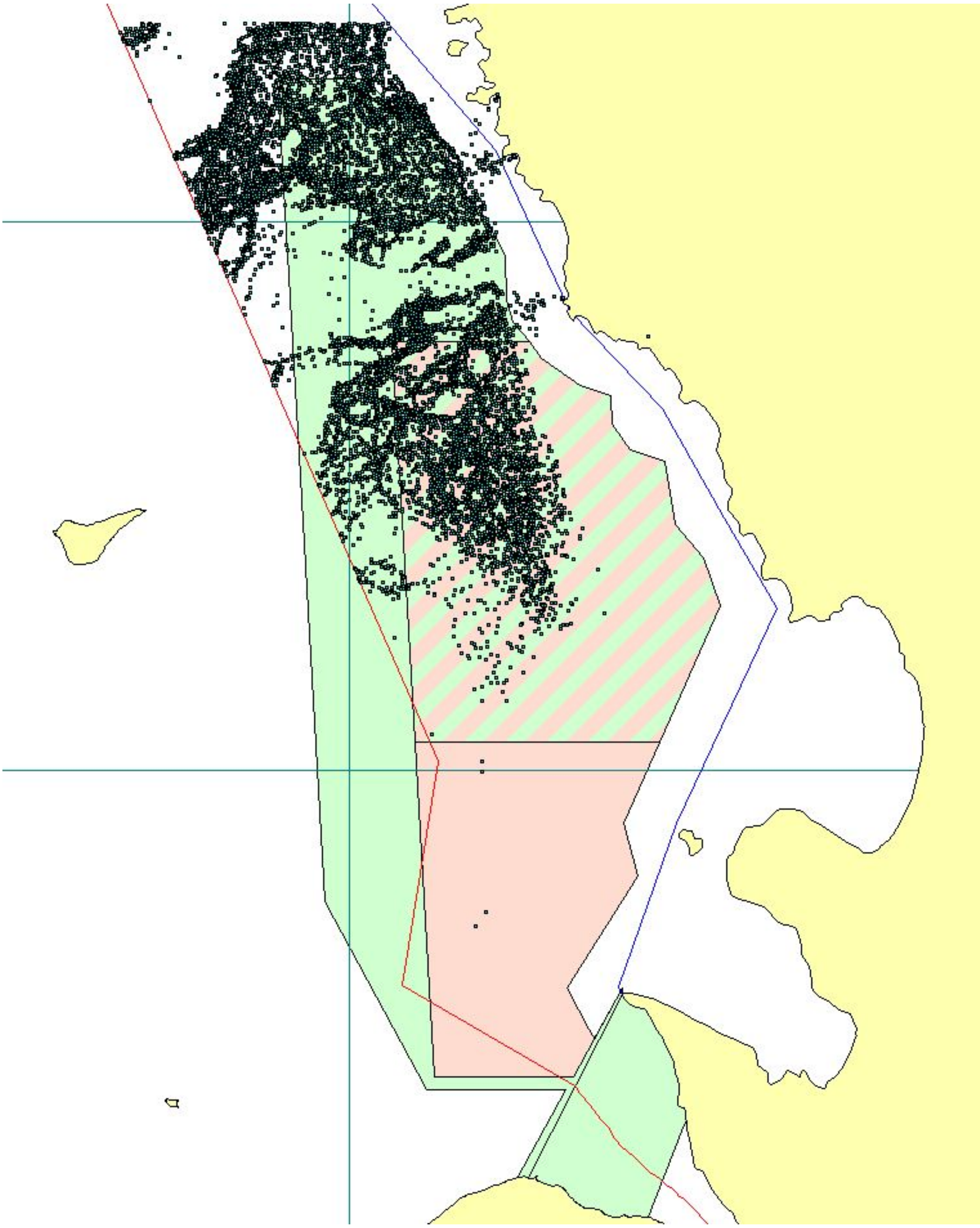
a) VMS-signals during 2009 (Swedish and Danish vessels)



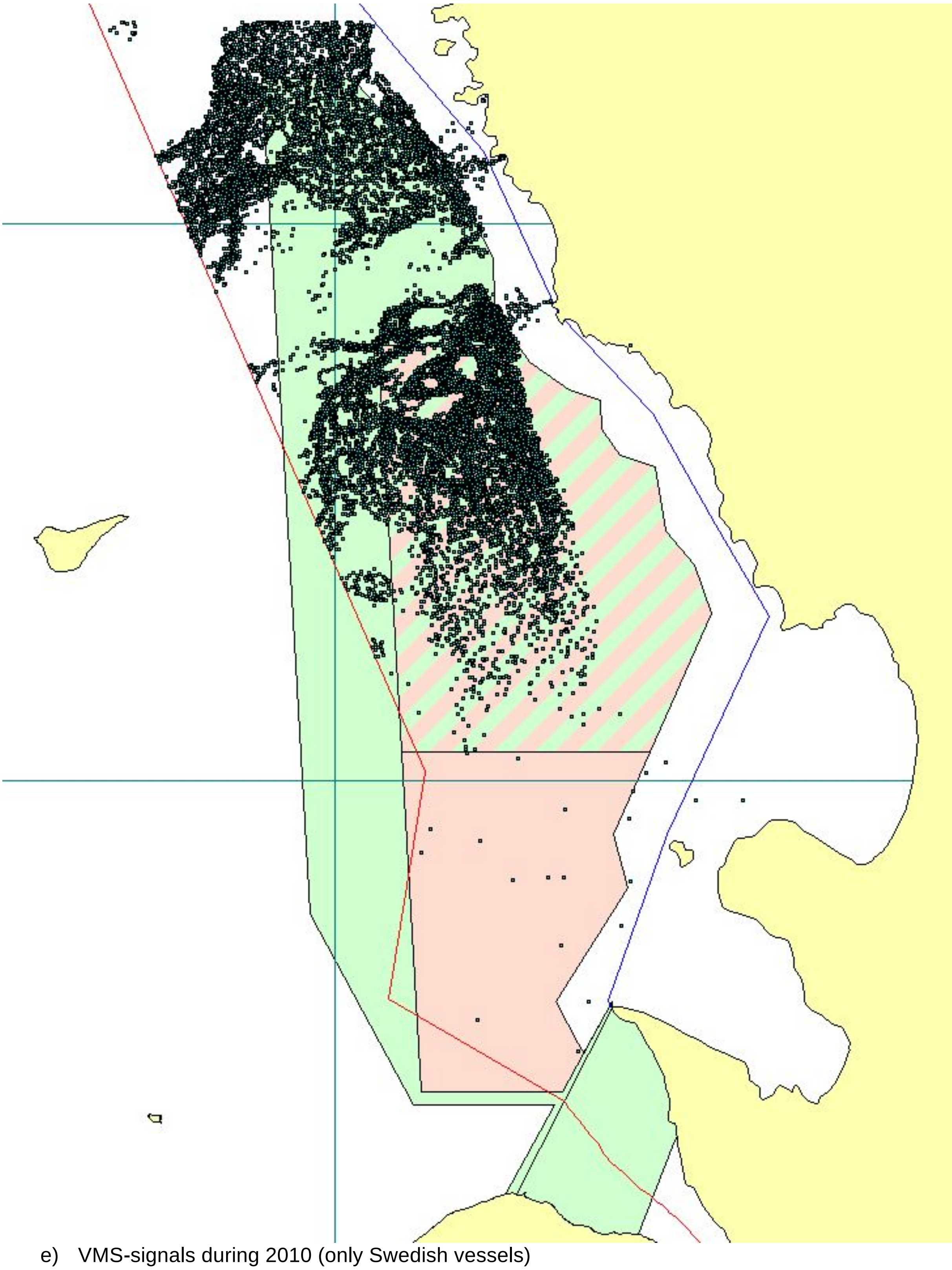
b) VMS-signals during 2010 (Swedish and Danish vessels)



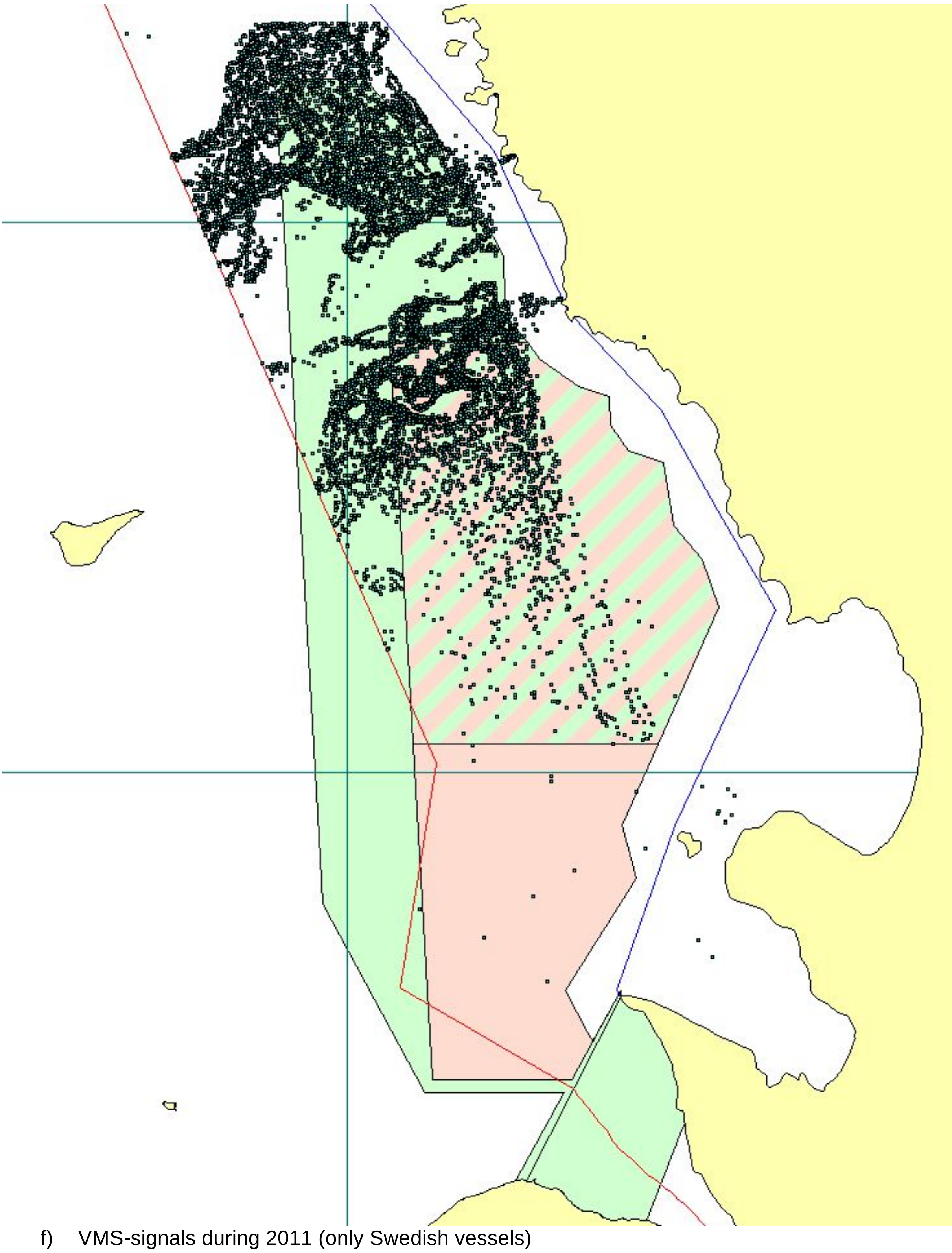
c) VMS-signals during 2011 (Swedish and Danish vessels)



d) VMS-signals during 2009 (only Swedish vessels)



e) VMS-signals during 2010 (only Swedish vessels)



f) VMS-signals during 2011 (only Swedish vessels)

Jacob Handrup

Appendix 11. Presentation of the Danish control measures in place in relation to the Cod Avoidance Plan in 2011.

Control measures in place in Kattegat during 2011:

- Control measures in relation to the closed area in Kattegat (and the Northern part the Sound)
    - VMS Surveillance.
    - Sea-going inspection/FPV surveillance.
    - Use of the approved selective gears in the closed areas.
- Control of use of the new SELTRA cod-ends in Kattegat
    - Obligation to report the type of SELTRA-panel actual used.
    - Description of the co-operation with DTU Aqua, net-makers and fishing industry concerning the approval of the correct insertion of the SELTRA escape windows
    - Control at sea
    - Control at landing

Overview:

During the period from 2009 to 2011 the inspection of fishing vessels and the surveillance of the closed areas in Kattegat, has been given high priority by the Danish AgriFish Agency. It has also been prioritized to inspect fishing vessels in port after fishing in Kattegat. The main focus for the inspections has been to assure compliance with the rules governing the closed areas, and the compliance with the rules governing the use of more selective fishing gears which was introduced in the second half of 2011. In order to document the selective gear type fishing vessel is using, national regulation was issued on the 14th of July, demanding fishermen to report the exact type of gear used in the logbook. Inspections at sea and on landing in 2011 has shown that all the inspected vessels actually used or carried on board the new selective gears as prescribed -although this was not always correctly registered in the vessels logbook.

Control measures in relation to the closed area in Kattegat (and the Northern part of the Sound)

VMS surveillance:

The Fisheries Monitoring Center (FMC) has the closed areas under surveillance by means of the VMS system. The system works by alarming the FMC if a vessels VMS system transmits a position in the closed area with a speed less than 4 knots. If an alarm is raised, the FMC makes contact with the local inspectors ashore, or a FPV if present. Once a week all VMS positions within the closed areas with a speed less than 4 knots, and all vessels in the vicinity of the closed areas with missing VMS positions, is subject for investigations. During this administrative investigation, it is decided if further investigation is needed. In case of further investigation this is performed by the local department. During 2011 the FMC has made investigations of 274 cases, of which 2 were sent for further investigation in the local department. Furthermore 17 cases of missing VMS positions have been investigated. None of these had indications which needed further investigation.

FPV surveillance:

During 2011 there has been an inspection vessel present in or in the vicinity of the closed area in Kattegat in total 113 days. By these 27 days has solely been in the closed area. Primarily the areas have been under surveillance by FPV Vestkysten and FPV Havternen, and only a few days from FPV Nordsøen.
In total 7 vessels has been inspected in the closed areas by the FPV's. All vessels complied with the gear rules for the area. During the inspection inside or in the vicinity of the closed areas, the FPV's has not detected any illegal fishing activity referred to the cod avoidance plan.

Issues related to use of fishing gear in Kattegat.

During inspections at sea, it is part of the general procedure to inspect the fishing gear. During inspections ashore, the gear has been inspected during the Joint Deployment Plan (JDP) campaigns, and it was given high priority in particular during the introductory phase for the new SELTRA 140 mm square mesh /270 mm diamond mesh escape windows in July and August 2011.

Danish vessels mainly use 3 types of gear in Kattegat when targeting Nephrops:

- A 4-panel gear, with 90 mm cod-end and 270mm diamond meshed escape window.
- A 4-panel SELTRA gear, with 90 mm cod-end and 300 mm square meshed escape window.
- 90 mm codend with a 120 mm square meshed escape window.

It is the general opinion by the Danish fishermen that the 4 panel gear is sorting well. After implementation it is very common to have no by-catch of cod at all, or if any only large cod as by-catch. It should be noted that there has been close co-operation between DTU Aqua gear experts, net-makers, the fishing industry and the Danish authorities concerning both the development of the new selective gears and the approval of the correct insertion of the escape windows.

Furthermore it has been observed that a number of vessels now voluntary are using the 4 panel SELTRA gear in Skagerrak.

Co-operation with Swedish authorities in relation to the closed area in Kattegat:

The Danish AgriFish Agency has a close co-operation with the Swedish authorities. In general the co-operation applies in form of the FPV's informing of inspection activities in or in the vicinity of the closed areas. During activities the Swedish Navel Control often informs FPV's of radar contacts in the area which may need investigation. The FPV's may also be allowed by the Swedish authorities to make inspections within Swedish territorial waters, in order to make sure that trans-boundary fishing can be inspected.
The Swedish authorities have in 2011 made 2 inquiries to the Danish FMC concerning observations of Danish fishing vessels in the closed areas. None of these inquiries have initiated further investigations in the FMC.