

Evaluation of the effect of effort redistribution and gear changes in relation to the closed areas in Kattegat

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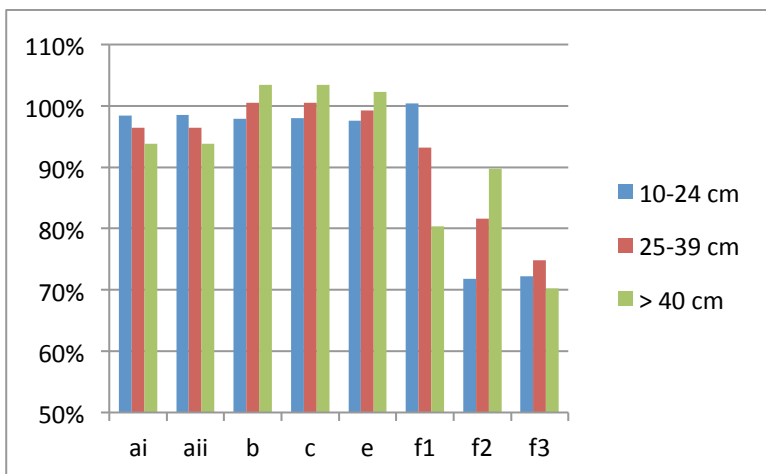
Kattegat cod meeting 2013

This analysis was requested by the Swedish Ministry for Rural Affairs and the Danish Ministry of Food, Agriculture and Fisheries to estimate the selectivity of different gear and to evaluate scenarios for effort redistribution and gear changes in relation to the closed areas in Kattegat to protect cod. The work has been organized through a Working Group consisting of Danish and Swedish scientists. The group held one meeting in Göteborg 22nd of August with the focus on gear selectivity and one meeting in Copenhagen the 17-18 September where focus was on the effort reallocation and fishing impact under different management scenarios.

Summary

The main conclusions from the analysis:

- Opening of Box 3 for fisheries with SELTRA gears or grid from 1st of May to 31st of December has little influence on the overall fishing impact on cod in Kattegat.
- Extending the closure in Box 2 to include April has also little influence on the fishing impact.
- Exclusion of SELTRA in Box 2 has a large fishing impact on larger cod.
- Replacement of the 90mm gear outside the closed areas by SELTRA gears or grid has a large fishing impact on all size groups.



Scenarios: Fishing impact relative to baseline (100 %) by size group of cod

ai	Opening Box 3 for grid 1/5-31/12
aii	Opening Box 3 for grid + close Box 2 in April
b	Opening Box 3 for grid and SELTRA 1/5-31/12
c	Opening Box 3 for grid and SELTRA 1/5-31/12 + close Box 2 in April
e	Opening Box 3 for grid and SELTRA 1/5-31/12 + close Box 1,2 and 4 in April
f1	Maintain present regulation but substitute SELTRA 300 by Grid in Box 2
f2	Maintain present regulation but allow only SELTRA or Grid in open areas
f3	Closure of Box 2 and 3 in Quarter 1, Grid only in Box 1 in Q1, Grid Only in Box 2 in Q2-Q4 . Grid or SELTRA are mandatory in all other areas and time periods.

These conclusions are dependent on several assumptions made: 1) the total effort (e.g. Kw-Days) will be as observed for 2012; 2) all SELTRA gears are having the same selection curve; 3) the baseline effort distribution outside the closed areas is as observed for 2012; 4) the proportion of the effort entering a closed areas follows the relative effort distribution as observed for 2007-2008.

Background

Present management areas in Kattegat

The present management of the closed areas in the Kattegat is the following:

- Box 1: seasonally closed area, closed from January 1–March 31, except for fisheries with selective gears;
- Box 2: partially closed area, closed for all fisheries in the period from January 1–March 31. Fisheries with selective gears are allowed from April 1–December 31;
- Box 3: permanently closed area, closed for all fisheries, including recreational fisheries.
- Box 4: seasonally closed area in the Northern Sound, closed from February 1–March 31, except for fisheries with selective gears.

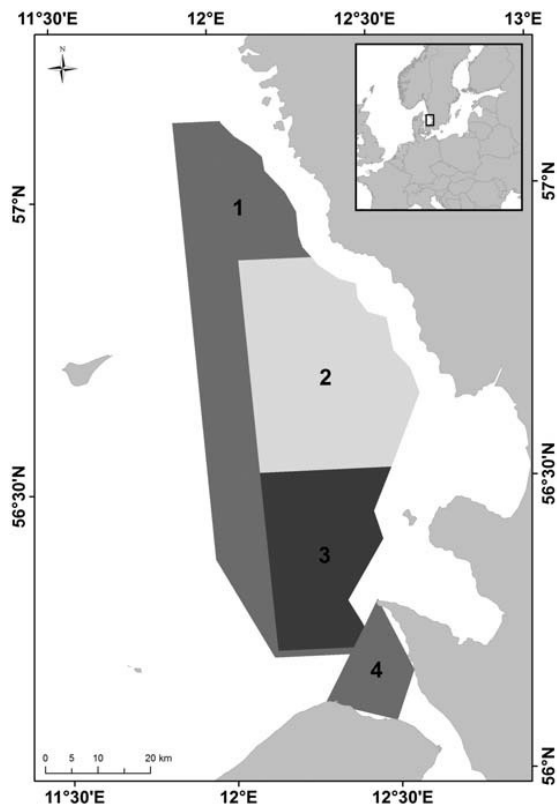


Figure 1. Present management in Kattegat

Terms of Reference for the gear meeting

1. Selection curves by cm for the gears used presently in Kattegat (SELTRA 270/ 180 / 300 and the grid) and provision of the data behind the estimation.
2. To assess the robustness of these estimates in relation to how the gears are being used in commercial practice, as well as a description if the gear has been tested in experiments or the values has been extrapolated.

Terms of Reference for the fishing impact meeting

ToR for a meeting between Danish and Swedish fisheries scientists in order to evaluate the effort allocation in relation to where the close areas are placed

1. The effects on the Kattegat cod population should be estimated relative to maintaining the current closures and on the basis of the following scenarios:
 - a) Box 3 is reopened for fisheries using creels and Swedish grid during the period from 1 May until 31 December
 - i) In combination with unchanged provisions for Area 2)
 - ii) In combination with extended closure with one month (April) of area 2.
 - b) Box 3 is reopened in the period from 1 May until 31 December for fisheries using very selective gears (SELTRA 300 or Swedish grid).
 - c) Box 3 is reopened for fisheries using very selective gears (SELTRA 300 or Swedish grid) in the period from 1 May until 31 December in combination with extended closure with one month (April) of area 2.
 - d) Box 3 is reopened for fisheries using very selective gears (SELTRA 300 or Swedish grid) in the period from 1 May until 31 December in combination with extended closure with one month (April) of area 2 and area 4.
 - e) Box 3 is reopened for fisheries using very selective gears (SELTRA 300 or Swedish grid) in the period from 1 May until 31 December in combination with extended closure with one month (April) of area 1,2 and 4.
 - f) The effect of introducing more selective gear in the part of Kattegat not currently affected by closed area all year.

The effect should be presented in terms of:

- i. total cod fishing mortality
- ii. discard rates
- iii. effort reallocation
- iv. fishing mortalities on other species
- v. impact on fisheries (both Swedish and Danish)

2. What is the relationship between fishing effort and mortality on cod in the Kattegat (i.e to meet the goals of the cod avoidance plan)?

Participants

Gear selection meeting in Göteborg the 22nd of August:

Johan Lövgren (Sweden)

Rikke Frandsen (Denmark)

Fishing impact meeting in Copenhagen the 17-18th of September

Joakim Hjelm (Sweden)

Johan Lövgren (Sweden)

Marie Storr-Paulsen (Denmark)

Mattias Sköld (Sweden)

Morten Vinther (Denmark)

Background for the request

The 2nd of July 2013 a meeting was held with participants from the Swedish Ministry for Rural Affairs and the Danish Ministry of Food, Agriculture and Fisheries as well as scientists from both countries. As a conclusion from this meeting it was agreed that:

- The Swedish and Danish scientist should hold a meeting on selective gears in week 34. At this meeting special effort should be allocated to the grid and the SELTRA 300. Furthermore, alternative gears presently used in Kattegat should be included.
- A Back-to-back meeting where the conclusion from the first meeting is used to estimate the effort allocating –and consequence of the area closure. The Swedish and Danish managers should in cooperation agree on the agenda and ToRs for this meeting.

The meeting on gear selection was held in Göteborg where Swedish and Danish scientist in advance had collated all new information on the gear used. The scientists agreed to create a joint document in where information of the general uptake of the gears in Kattegat by country and quarter was presented. It was also decided that the selection curves of the allowed gears in Kattegat for both cod and Nephrops were to be included. In addition the scientists decided to add comments about the quality of the data from which the selection curves was produced. A joint document was produced (Frandsen et al. 2013; Appendix 1) and presented to the members in the fishing impact meeting 17-18th September.

The next meeting was hosted by ICES in Copenhagen and here the results from the first meeting was used to analyse the effect of changing the closed areas in different time periods and the effect of different gears. Eight different scenarios were tested during the meeting including the scenarios in the ToR:s and additional scenarios included by the scientist at the meeting. Not all of the ToR:s were answered fully as it was not possible to include box 4 (the Sound) in the analyses. There was not sufficient time to include other species than cod in the analysis.

Fishing impact analysis

The relative fishing impact (proxy for fishing mortality) has been quantified for the Danish and Swedish TR2 segment, which are the most economical important fishery in Kattegat and the fishery with the largest catches of cod. Fishing impact is calculated from the static long-term temporal and spatial distribution of the cod stock estimated from scientific survey observations, the fishery effort estimated from positioning of fishing vessels (VMS) and the selection of the applied gears. It is thus assumed that fishing impact is proportional to the sum of the product of the local cod density, local fishing effort and the size selection of the applied gears. In other words, the method gives a prediction of the fishing impact on the cod stock, given that we know the seasonal distribution of the cod and the fishery (see Vinther and Eero 2013 for further details). The analysis does not take into account how harvest rates differ between stock units i.e. the influence of cod from the North Sea population, nor does it take into account any potential between-year variations in distribution, e.g. due to the establishment of the closed areas.

Data used for Cod Stock distribution

The data on seasonal cod stock distribution is based on 5 surveys, including the most recent observations:

- IBTS Q1, 1996-2013
- IBTS Q3, 2001-2012
- BITS 2001-2013
- Cod Survey 2008-2011
- Sole Survey 2008-2012

There is no survey data available for quarter 2. The data on cod abundance is divided into three size groups; 10-24 cm, 25-39 cm and 40+ cm to reflect the differences in stock distribution of recruit, juveniles and the mature stock. The survey data for quarter 1 and 4 include a large number of hauls, but survey data from quarter 3 include only around 20 hauls per year, which is not sufficient for an adequate estimate of stock distribution. However, the estimated stock distribution for the oldest cod is quite similar in quarter 3 as estimated for quarter 4. Hence, in this analysis it is assumed that data from quarter 1 represents stock distribution in month 1-6. This is considered a very conservative estimate. Data from quarter 3 represent stock distribution in months 7-9 and data from quarter 4 represents stock distribution in months 10-12. The rationale of extrapolating stock distribution from 1st quarter to 2nd quarter was based on ToR:s to explore the effect of adding April to the closed areas. The distribution in April (quarter 2) should be more similar to March (quarter 1) than to quarter 3.

Distribution of fishing effort

The baseline distribution of effort for the Danish and Swedish TR2 segment was estimated from 2012 VMS data (figure 2) and assessed by gear and "special condition" i.e. the derogation from the kW-days system by the Swedish grid according to the cod management plan. A speed correction during fishing ($DK * 1.2$) was used to compensate the difference in trawling speed between Danish and Swedish fishing vessels.

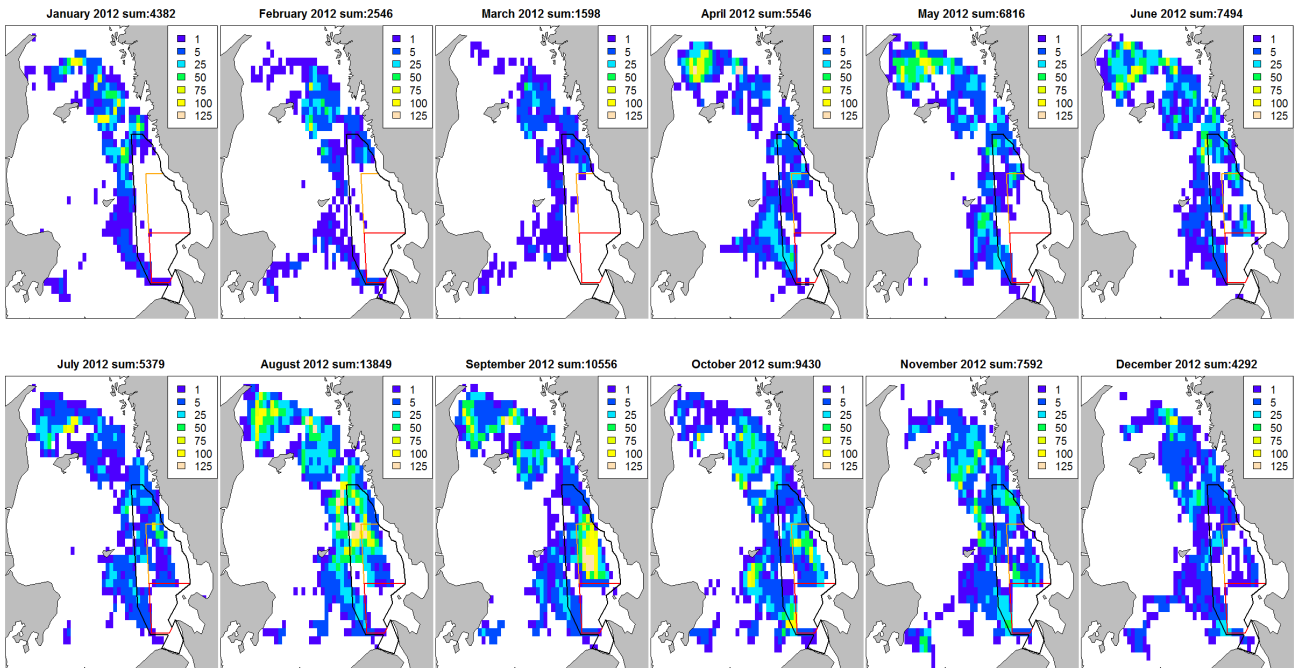


Figure 2. Effort distribution of both Danish and Swedish fishing vessels (TR2) per month in 2012.

For scenarios including reopening an area, the reallocation is determined by the historical effort within the boxes as presented in table 1.

Table 1. Effort distribution by Box and country in the period 2007-2008, before the closure.

a) Percentage of effort by box

Box 0	Box 1	Box 2	Box 3	Total
64.0	14.4	15.6	6.1	100

b) Percentage of effort by box and country

	Box 0	Box 1	Box 2	Box 3	Total
DNK	70.9	7.7	12.1	9.2	100
SWE	51.3	26.5	21.9	0.3	100

c) Percentage of effort within box by country

	Box 0	Box 1	Box 2	Box 3
DNK	71.6	34.8	50.1	98.1
SWE	28.4	65.2	49.9	1.9
All	100	100	100	100

The highest effort by country was deployed in the area outside the closed areas (Box 0) and that this is the case for both countries (Table 1 a, b). Denmark had the highest percentage of the effort in all areas except in Box 1 (Table 1, c). Notice the low Swedish effort in Box 3 (b, c).

Table 2. Effort distribution by Box and country in 2012, and used as baseline.

a) Percentage of effort by box

Box 0	Box 1	Box 2	Box 3	Total
71.4	15.8	12.8	(0.2)	100

b) Percentage of effort by box and country

	Box 0	Box 1	Box 2	Box 3	Total
DNK	81.3	9.0	9.3	(0.4)	100
SWE	53.5	28.0	18.5	NA	100

d) Percentage of effort within box by country

	Box 0	Box 1	Box 2	Box 3
DNK	73.2	36.7	47.4	(100)
SWE	26.8	63.0	52.6	NA
All	100	100	100	100

The distribution of effort in 2012 (baseline) presented in Table 2 is surprisingly similar to the distribution in 2007-2008, when the effect of the closure of Box 3 is taken into account. For both countries the proportion of effort in 2012 is however slightly lower in Box 2 compared to the distribution before the closures. The observed effort (VMS signals) in box 3 seems to be a misclassification of commercial fishing activity.

Gears used and their Selectivity

It was decided that the analysis of fishing impact should be based on gears within the TR2 group as the main effort, for both Danish and Swedish fisheries, is within this group. Both countries do also have small fisheries in TR1 but that is less than 5 % compared to the total demersal effort deployed in the area.

Danish and Swedish scientist have compiled available data on the selective properties regarding cod for the following gears commonly used by Danish and Swedish demersal fisheries in Kattegat (Frandsen et al. 2013; Appendix 2):

- SELTRA 270/SELTRA 180,
- SELTRA 300,
- 90 mm diamond mesh cod-end (90DMC),
- 90 mm diamond mesh cod-end with a 120 mm square mesh panel (120SMP),
- 70 mm square mesh cod-end with a 35 mm grid (Swedish grid; SG)

Based on the gear groups data compilation, it was concluded that there was only adequate selective information for SELTRA 270, 90 mm diamond mesh cod-end, 90 mm diamond mesh cod-end with a 120 mm square mesh panel, 70 mm square mesh cod-end with a 35 mm grid. There have been no trials testing the selective properties of the SELTRA 300 as it is rigged commercially today. However, for cod below 40 cm we expect no significant difference in selectivity between SELTRA 270 and SELTRA 300 and accordingly the selective properties of SELTRA 270 was used in the analysis of fishing impact in the Kattegat.

Table 3. Average retention (numbers per 1000 cod) per size class and gear. It is assumed that the size distribution in the sea is as observed during IBTS 1991-2011. Based on this assumption it is possible to calculate the retention by cm group of cod and then convert this to size categories.

	10-24 cm cod	25-39 cm cod	40+ cod
Q 1			
D90DMC	178	847	995
120SMP	155	700	984
SELTRA 270	44	446	710
Swedish Grid	58	89	0
Q 4			
D90DMC	96	835	994
120SMP	106	680	979
SELTRA 270	25	432	684
Swedish Grid	30	97	1

Model assumptions

In order to explore the different scenarios outlined by the ToR's, there were some assumptions that had to be made. These assumptions are

Effects of opening a closed area (Box opening): When a closed area is opened it is assumed that the effort going into the box can be estimated from proportion of the historical (2007-2008) effort within the box. The spatial distribution within the box is likewise assumed to follow the historical distribution of VMS observations. At the same time we remove this proportion of effort from outside such as the total effort is maintained in Kattegat. All calculations are done at lowest possible aggregation level (by country, month, box, longitude and latitude).

Effects of closing an area (Box closure): Data for 2012 were used as a baseline for analysis. It is assumed that effort from a closed box is redistributed outside proportionally to 2012 effort distribution.

Based on the gear report all effort with the Danish SELTRA was assumed to have the selective properties of the SELTRA 270 and all scenarios assume that the effort level in 2012 is maintained. This assumption may be valid as not all Kw-days are utilized today. Furthermore, in Sweden, there is national system regulating numbers of Swedish grid days available. However, if area 3 would be opened for fishery there is a high probability that there will be a high effort initially deployed in that area due to expectancy of profitable catches due to increased biomass and size of Norway lobster following the closure. This has been ignored in the analysis.

The fishing impact analysis uses the average cod distribution pattern over all the years considered. Previous analysis (Vinther et al, 2010) showed that the centre of gravity of survey CPUE may change between years, but this seems more due to the variance in CPUE and not related to consistent changes in distribution. However, if a change in cod distribution has happened within the last three years, the fishing impact results will be biased. Given an anticipated relative higher increase of cod within the closed areas, the effect of the closures might be even higher than estimated, as a larger proportion of the cod stock would then have gained protection from the closures.

General results

Statistical analysis of trawl survey catches of cod shows that the distribution of young and older cod is different and that the distribution changes over time.

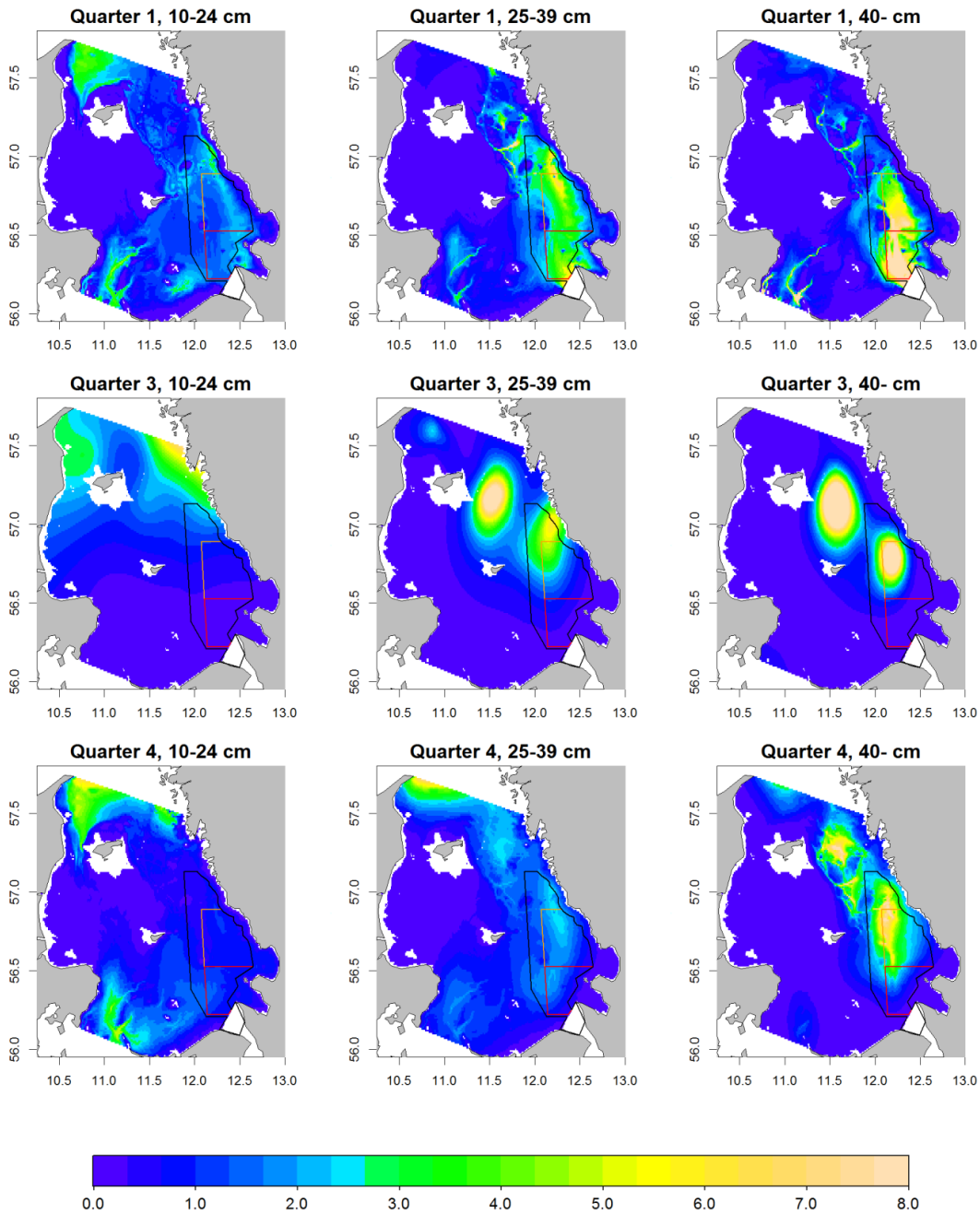


Figure 3. Estimated stock distribution of cod by age and quarter averaged over years. The blue colour shows a low density, green medium and orange the highest density of cod. White areas inside the Kattegat are areas with depth less than 5 m.

All the closed areas in quarter 1 (at spawning time) contain a large proportion of the population of older cod (>40 cm). In quarter 4 cod age 2 (25-39 cm) and older is mainly found in box 1 and 2 and outside the MPA.

Fishing impact results

The effects on the Kattegat cod population is estimated relative to maintaining the current closures and on the basis of the following scenarios:

Scenario ai): Box 3 is reopened for fisheries using creels and Swedish grid during the period from 1 May until 31 December; In combination with unchanged provisions for Area 2

Box 3 is opened for fishery with Swedish grid in 9 months (April – December). The effort in box 3 with Swedish grid is assumed to be in the same proportion of the total effort deployed in box 3 in 2007-2008 (see table 1). The results show that the fishing impact on a relative basis is lower (table 4) for all cod size classes and especially for the larger size group. The decrease in fishing impact is due to effort reallocation from the area outside box 3 with less selective gears to the mandatory use of grid within the reopened Box 3. For cod size group 10- 24 cm the fishing impact in this scenario is 98.4 % relative to the baseline, for the size group 25-39 cm the fishing impact is reduced a bit further to 96.4 % relative to baseline and the largest reduction is found for the largest size group with a fishing impact at 93.8 % relative to the baseline.

Table 4. Fishing impact on cod per country, area, and size class.

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
Total	98.4	96.4	93.8

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
DNK	96.9	94	91.5
SWE	99.9	99.8	99.6

Scenario relative to Baseline in %		Box 0	Box 1	Box 2	Box 3
	10-24cm	92.4	91.1	88.3	NA
DNK	25-39cm	92.2	91.7	89.1	NA
	>40cm	92.1	92	89.6	NA
	10-24cm	99.8	99.8	99.8	NA
SWE	25-39cm	99.7	99.8	99.8	NA
	>40cm	99.6	99.6	99.6	NA

Table 5. Fishing impact on cod per country, size class and month

Scenario relative to Baseline in %		Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec
	10-24cm	100	100	100	100	98.1	97.9	90.6	95.9	91.5	97.3	98	97.2
DNK	25-39cm	100	100	100	100	98.9	93.4	90.1	95.6	90.4	89.3	92	93.6
	>40cm	100	100	100	100	90.9	84.8	88.4	95	89.1	86.4	90	92.2
	10-24cm	100	100	100	100	100	100	99.4	99.9	99.9	99.7	100	99.2
SWE	25-39cm	100	100	100	100	100	100	99.4	99.9	99.9	99.5	100	98.7
	>40cm	100	100	100	100	99.9	100	99.4	99.9	99.9	99.4	100	98.3

When comparing the impact between Sweden and Denmark the reduction in impact is larger in the Danish fishery. The reason for this is due to the very low fishing effort by Sweden in box 3 in the reference years (2007-2008) (see Table 1). Table 4 shows that the main part of the reduction in impact is irrespective of size classes and is a result of a reduced Danish effort in box 2. Table 5. shows the impact reduction by month, cod size class and country.

The result is based on the assumption that effort is maintained at the 2012 level and that the relative proportion of effort within the opened box 3 is as observed in 2007-2008. Both assumptions are probably not fully meet, however the purpose of the scenarios is to illustrate the consequences of effort reallocation and related gear changes, not for management purposes. Presently, neither Sweden nor Denmark is effectively limited by effort days. However, if this would not be the case an introduction of the grid could allow an effort increase according to EC Council Reg.1342/2008, Article 11, which would reduce the positive effect of this scenario.

Discard of cod (cod below MLS) will in this scenario decrease slightly. The fishing mortality for other species will likely be reduced as an effect of increased use of the grid. However, data on other species than cod have not been included in our analysis.

The real effect of opening a box on the fishery on a national level is hard to predict as Swedish fishermen historically have practically not utilized box 3 since 2004 and are presently using the grid. The Danish fishermen have used the area for fishing up to the closure in 2009 (9 % of total effort), but are presently not using the Swedish grid.

Pots and creels are presently only utilized in the coastal area in Sweden and precise information on the effort distribution is lacking. Hence, creels are not evaluated in this scenario. However, creels and pot are considered to have a lower impact on cod mortality as well as having a lower environmental impact on the seafloor, lower bycatches and less discards than the bottom trawl gears considered in this report. The amount of discarded fish by kilogram caught Nephrops in the creel fishery is seven times lower compared to a kilogram Nephrops caught in the trawl fishery with sorting grid (Jansson 2008).

Scenario aii): Box 3 is reopened for fisheries using creels and Swedish grid during the period from 1 May until 31 December; In combination with extended closure with one month (April) of area 2.

This scenario is similar to the former scenario ai) in that box 3 is reopened for fishery with grid in 9 months (April – December), however box 2 has the extended closure including April. The effort in box 3 with Swedish grid is assumed to be in the same proportion of the total effort deployed in box 3 2007-2008. The analysis shows that the extended closure with one month (in box 2) has a limited additional effect on the fishing impact on cod compared to scenario ai) and only on the smallest size group (table 6). The fishing impact is similar during all month (table 6 and 7). The reason for the low effect of an increased closure period is that a rather low effort in box 2 in April (see figure 2.).

Table 6. Fishing impact on cod per country, area, and size class.

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
Total	98.5	96.4	93.8
Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
DNK	96.9	94	91.5
SWE	100	99.7	99.5

Scenario relative to Baseline in %		Box 0	Box 1	Box 2	Box 3
	10-24cm	92.4	91.1	88.3	NA
DNK	25-39cm	92.2	91.7	89.1	NA
	>40cm	92.1	92	89.6	NA
	10-24cm	100.3	101.1	91.6	NA
SWE	25-39cm	100	100.5	95.1	NA
	>40cm	99.8	100.1	94.3	NA

Table 7. Fishing impact on cod per country, size class and month.

Scenario relative to Baseline in %		Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec
	10-24cm	100	100	100	100	98.1	97.9	90.6	95.9	91.5	97.3	98	97.2
DNK	25-39cm	100	100	100	100	98.9	93.4	90.1	95.6	90.4	89.3	92	93.6
	>40cm	100	100	100	99.9	90.9	84.8	88.4	95	89.1	86.4	90	92.2

	10-24cm	100	100	100	101.4	100	100	99.4	99.9	99.9	99.7	100	99.2
SWE	25-39cm	100	100	100	98.8	100	100	99.4	99.9	99.9	99.5	100	98.7
	>40cm	100	100	100	97.6	99.9	100	99.4	99.9	99.9	99.4	100	98.3

Scenario b): Box 3 is reopened in the period from 1 May until 31 December for fisheries using very selective gears (SELTRA 300 or Swedish grid).

This scenario is also similar to ai), however with the inclusion of SELTRA, in box 3. The effort in box 3 is assumed to be in the same proportion of the total effort deployed in box 3 2007-2008. The overall effect is a reduction in fishing impact on small cod (97.9 %) but there is a higher impact on larger cod (103.4 %, table 8). The total effect of reopening box 3 for fisheries with both SELTRA and Swedish grid from 1 May to 31 December is very close to status quo. The reason for the low effect on impact is that effort is moved from areas with a higher cod density to an area with lower cod density (in the months July to December). One of the model assumptions is that the cod distribution in quarter 2 is similar to quarter 1. This is probably not fully correct and can lead to an overestimation of the fishing impact on the larger cod (Figure 3).

Table 8. Fishing impact on cod per country, area, and size class.

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
Total	97.9	100.5	103.4
Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
DNK	95.8	101	105
SWE	99.9	99.8	99.6

Scenario relative to Baseline in %		Box 0	Box 1	Box 2	Box 3
	10-24cm	92.4	91.1	88.3	NA
DNK	25-39cm	92.2	91.7	89.1	NA
	>40cm	92.1	92	89.6	NA
	10-24cm	99.8	99.8	99.8	NA
SWE	25-39cm	99.7	99.8	99.8	NA
	>40cm	99.6	99.6	99.6	NA

Table 9. Fishing impact on cod per country, size class and month

Scenario relative to Baseline in %	Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec
10-24cm	100	100	100	100	96.5	94.9	90	95.6	90.8	95.4	96.6	96.3
DNK												
25-39cm	100	100	100	100	125.2	121.6	93.9	97	93.4	99.4	99.1	98.8
>40cm	100	100	100	100	151.5	161.4	92	96.4	90.9	99.2	96.3	98.6
10-24cm	100	100	100	100	100	100	99.4	99.9	99.9	99.7	100	99.2
SWE												
25-39cm	100	100	100	100	100	100	99.4	99.9	99.9	99.5	100	98.7
>40cm	100	100	100	100	99.9	100	99.4	99.9	99.9	99.4	100	98.3

The result is based on the assumption that effort is maintained as in 2012 and that the relative distribution of effort is reallocated between areas. The effect is due to effort reallocation of the Danish fishery from all adjacent areas to box 3, the largest effect is from box 2 (table 8). The fishing impact markedly increases in May and June but is similar during the rest of the year (table 9).

Scenario c) Box 3 is reopened for fisheries using very selective gears (SELTRA 300 or Swedish grid) in the period from 1 May until 31 December in combination with extended closure with one month (April) of area 2.

This scenario is similar to scenario b), however with an extended closure of box 2 with one month. The overall effect is a reduction in fishing impact on small cod (98 %) but a higher impact on larger cod (103.4%) (table 10).

Table 10. Fishing impact on cod per country, area, and size class.

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
Total	98.0	100.5	103.4

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
DNK	95.8	101	105
SWE	100	99.7	99.5

Scenario relative to Baseline in %	Box 0	Box 1	Box 2	Box 3
10-24cm	92.4	91.1	88.3	NA
DNK				
25-39cm	92.2	91.7	89.1	NA
>40cm	92.1	92	89.6	NA
10-24cm	100.3	101.1	91.6	NA

SWE	25-39cm	100	100.5	95.1	NA
	>40cm	99.8	100.1	94.3	NA

Table 11. Fishing impact on cod per country, size class and month.

Scenario relative to Baseline in %		Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec
	10-24cm	100	100	100	100	96.5	94.9	90	95.6	90.8	95.4	96.6	96.3
DNK	25-39cm	100	100	100	100	125.2	121.6	93.9	97	93.4	99.4	99.1	98.8
	>40cm	100	100	100	99.9	151.5	161.4	92	96.4	90.9	99.2	96.3	98.6
	10-24cm	100	100	100	101.4	100	100	99.4	99.9	99.9	99.7	100	99.2
SWE	25-39cm	100	100	100	98.8	100	100	99.4	99.9	99.9	99.5	100	98.7
	>40cm	100	100	100	97.6	99.9	100	99.4	99.9	99.9	99.4	100	98.3

The result is also based on the assumption that effort is maintained as in 2012 and that the relative distribution of effort between areas is reallocated. The effect is due to the effort reallocation of the Danish fishery from box 2 to box 3 (table 10). The reason for the low effect of an increased closure period (compared to scenario b) is that a rather low effort in box 2 in April (see figure 2.) The fishing impact markedly increases in May and June but is similar during the rest of the year (table 11).

Scenario d): Box 3 is reopened for fisheries using very selective gears (SELTRA 300 or Swedish grid) in the period from 1 May until 31 December in combination with extended closure with one month (April) of box 2 and box 4.

This scenario is not relevant because box 4 is closed in April due to the spawning closure in western Baltic and has therefore not been included in the analysis.

Scenario e): Box 3 is reopened for fisheries using very selective gears (SELTRA 300 or Swedish grid) in the period from 1 May until 31 December in combination with extended closure with one month (April) of box 1, 2 and 4.

This scenario is similar to scenario c), however with an extended closure with one month in box 1 and 2. The effect of box 4 is not evaluated (see scenario d) above). The overall effect is a reduction in fishing impact on small cod (97.6 %) but a higher impact on larger cod (102.3%, table 12) explained by the expected effort reallocation from box 1 and 2 to box 0 and 3 (table 12) and the low effort in April in Box 2.

Table 12. Fishing impact on cod per country, area, and size class.

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
Total	97.6	99.3	102.3

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
DNK	96.1	100.4	104
SWE	98.9	97.8	98

Scenario relative to Baseline in %	Box 0	Box 1	Box 2	Box 3	
10-24cm	93.5	82.3	88.3	NA	
DNK	25-39cm	92.7	85	89.1	NA
	>40cm	92.6	81	89.6	NA
	10-24cm	104.5	86.9	91.6	NA
SWE	25-39cm	102.9	92.6	95.1	NA
	>40cm	101.4	94.8	94.3	NA

Table 13. Fishing impact on cod per country, size class and month.

Scenario relative to Baseline in %	Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec
10-24cm	100	100	100	102.9	96.5	94.9	90	95.6	90.8	95.4	96.6	96.3
DNK	25-39cm	100	100	100	85.8	125.2	121.6	93.9	97	93.4	99.4	98.8
	>40cm	100	100	100	79.5	151.5	161.4	92	96.4	90.9	99.2	98.6
	10-24cm	100	100	100	86.3	100	100	99.4	99.9	99.9	99.7	99.2
SWE	25-39cm	100	100	100	58.7	100	100	99.4	99.9	99.9	99.5	98.7
	>40cm	100	100	100	52.2	99.9	100	99.4	99.9	99.9	99.4	98.3

The fishing impact markedly increases in May and June but is similar to the baseline during the rest of the year (table 13).

Scenario f): The effect of introducing more selective gear in the part of Kattegat not currently affected by closed area all year.

This scenario was interpreted more freely and hence we decided to explore the effect of selective gears (*f1* and *f2*, see below) and a scenario with “best practice” (*F3*) based on all scenarios explored above.

Scenario f1): Maintain the present regulation but redefine very selective gears to Swedish GRID only. Assume that the Danish effort is maintained in all areas, but a shift from SELTRA to GRID is assumed when it is necessary for maintaining present effort.

This scenario can in principle explore the differences in fishing impact between the grid and SELTRA (assessed as SELTRA 270) keeping all other factors constant. The analysis shows that the use of Swedish grid instead of a SELTRA would reduce the fishing impact on larger cod (to 80.4 % compared to baseline) and the reduced impact is mainly seen in the Danish fishery (table 14). There is slight increase the total impact on small cod, which can be explained by the better selectivity of SELTRA on smaller size classes of cod (table 14).

Table 14. Fishing impact on cod per country, area, and size class.

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
Total	100.4	93.2	80.4
DNK	101.2	89.7	75.3
SWE	99.6	97.9	92.9

Scenario relative to Baseline in %		Box 0	Box 1	Box 2	Box 3
DNK	10-24cm	100	101.7	132.5	NA
	25-39cm	100	95.2	27.7	NA
	>40cm	100	94.7	0.1	NA
SWE	10-24cm	100	99.9	95	NA
	25-39cm	100	99.9	80.8	NA
	>40cm	100	99.9	1	NA

Table 15. Fishing impact on cod per country, size class and month

Scenario relative to Baseline in %		Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec
	10-24cm	100.4	102.5	100.7	100	100	102.1	100.6	100.8	104.4	101.2	101.2	100.5
DNK	25-39cm	97.3	89.8	96.2	99.9	99.8	81.2	95.1	93.4	71.2	90.6	90.9	96.4
	>40cm	95	88.6	97.7	99.9	99.6	68.2	87.5	77.1	31.7	82.3	82.9	93.1
	10-24cm	99.6	100	99.9	98.3	100	99.6	99.9	99.5	100.1	99.6	99.8	98.9
SWE	25-39cm	99.4	100	99.6	95.1	100	98.4	99	97.4	97.2	95.8	99.6	97.8
	>40cm	99.3	100	99.6	88.7	100	98.8	96.4	94.3	75.5	89.1	98.8	94.2

In table 14 the impact on cod >40 cm for the Swedish fishery is 1 % compared to the baseline. The reason for this arbitrary value is probably due to (misclassification) of VMS signals as fishing activities for vessels using 90DMS in box 2. It will not change the perception of this model run in absolute terms, but in relative terms there is a huge effect from a change from 90DMS to a Swedish grid. The fishing impact is similar during the whole year (table 15).

Scenario f2): Maintain the present regulation. Use Grid (S using Grid), SELTRA (S previously using 90DMS) and SELTRA (DK all previously used gears) in not regulated areas/periods.

This scenario explores the effect of an overall shift towards more selective gears. Hence, substituting the fishery using 90 mm and 90 mm with 120 mm panel with more selective gears. The analysis shows marked decrease in fishing impact (71.8-89.8% compared to baseline) with the largest reduction for the small cod (Table 16). The main reason for the lower fishing impact is the reduction of impact in box 0 and 1 in the Swedish fishery (shift from 90DMS to SELTRA), but the Danish shift from 120SMP to SELTRA in 4th quarter does also contribute (Table 16).

Table 16. Fishing impact on cod per country, area, and size class.

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
Total	71.8	81.6	89.8
Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
DNK	85.2	95.4	97.0
SWE	59.3	62.8	72.0

Scenario relative to Baseline in %		Box 0	Box 1	Box 2	Box 3
	10-24cm	85.8	70.4	100.0	NA
DNK	25-39cm	95.0	92.7	100.0	NA
	>40cm	96.2	95.4	100.0	NA
	10-24cm	57.5	53.9	100.0	NA
SWE	25-39cm	58.3	58.4	100.0	NA
	>40cm	69.8	70.0	100.0	NA

Table 17. Fishing impact on cod per country, size class and month

Scenario relative to Baseline in %		Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec
	10-24cm	70.1	90.2	74.8	89.8	85.2	85.1	98.0	93.6	97.8	71.0	60.1	60.8
DNK	25-39cm	91.5	97.5	91.3	96.6	95.6	95.1	99.2	97.4	99.4	93.9	90.5	89.6
	>40cm	93.9	98.8	95.0	97.6	96.6	97.1	99.4	98.1	99.8	96.4	94.3	92.4
	10-24cm	31.7	55.4	46.9	61.3	53.6	65.6	64.6	56.7	79.6	50.5	41.8	43.1
SWE	25-39cm	53.9	61.0	58.2	66.0	60.4	69.1	68.3	60.5	75.4	62.4	57.4	56.7
	>40cm	71.5	71.3	71.4	74.7	71.0	71.4	71.5	72.1	78.1	72.7	69.2	70.6

Scenario f3): Seasonal closures of box 2 and box 3 in quarter 1. Swedish GRID is mandatory in quarter 1 for Box 1. GRID is mandatory Apr-Dec in box 2. GRID or SELTRA are mandatory Apr-Dec in box 3. Grid (S using Grid), SELTRA (S using 90DMS) and SELTRA (DK) are mandatory in not regulated areas/periods (Box 0)

This scenario explores the effect of shifting towards more selective gears but also increasing selectivity in all boxes. The effort in box 3 with SELTRA is assumed to be in the same proportion of the total effort deployed in box 3 in the timeframe 2007-2008. The analysis shows marked decrease in fishing impact irrespective of cod size (70.2-74.8% compared to baseline) (table 18). The main reason for the lower fishing impact is due to a reduction of impact by the Swedish fishery on all size classes of cod especially in box 0 and 1 and a reduction of impact for larger size groups in box 2 for the Danish fishery due to the mandatory use of Grid (table 18).

Table 18. Fishing impact on cod per country, area, and size class.

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
Total	72.2	74.8	70.2

Scenario relative to Baseline in %	10-24cm	25-39cm	>40cm
DNK	86.4	85.1	72.3
SWE	59.0	60.7	64.9

Scenario relative to Baseline in %		Box 0	Box 1	Box 2	Box 3
	10-24cm	85.8	72.1	132.5	NA
DNK	25-39cm	95.0	87.9	27.7	NA
	>40cm	96.2	90.1	0.1	NA
	10-24cm	57.5	53.8	95.0	NA
SWE	25-39cm	58.3	58.3	80.8	NA
	>40cm	69.8	69.9	1.0	NA

Table 19. Fishing impact on cod per country, size class and month

Scenario relative to Baseline in %		Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec
	10-24cm	70.5	92.7	75.6	89.8	85.2	87.3	98.7	94.5	102.2	72.1	61.3	61.3
DNK	25-39cm	88.8	87.4	87.6	96.5	95.5	76.3	94.3	90.8	70.7	84.4	81.5	86.0
	>40cm	89.0	87.4	92.6	97.5	96.2	65.2	86.9	75.1	31.5	78.7	77.3	85.5
	10-24cm	31.3	55.4	46.7	59.6	53.6	65.2	64.5	56.3	79.7	50.1	41.6	42.0
SWE	25-39cm	53.3	61.0	57.8	61.2	60.4	67.5	67.3	57.9	72.6	58.1	56.9	54.4
	>40cm	70.8	71.3	71	63.4	71	70.2	67.9	66.3	53.6	61.7	68	64.8

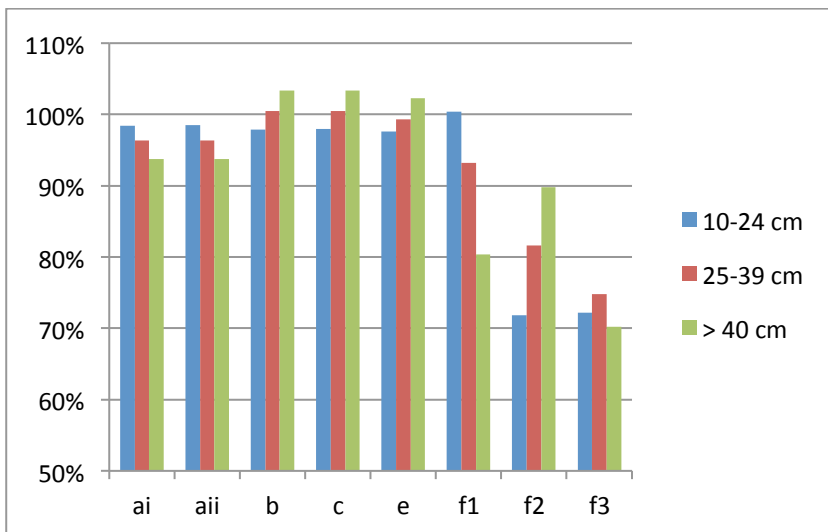
Conclusion

The main conclusions from the analysis:

- Opening of Box 3 for fisheries with SELTRA gears or grid from 1st of May to 31st of December has little influence on the overall fishing impact on cod in Kattegat.
- Extending the closure in Box 2 to include April has also little influence on the fishing impact.
- Exclusion of SELTRA in Box 2 has a large fishing impact on the larger cod.
- Replacement of the 90mm gear outside the closed area by SELTRA gears or grid has a large fishing impact on all size groups.

These conclusions are dependent on several assumptions made: 1) the total scenario effort (e.g. Kw-Days) will be as observed for 2012; 2) all SELTRA gears are having the same selection curve; 3) the baseline effort distribution outside the closed areas is as observed for 2012; 4) the proportion of the effort entering a closed areas follows the relative effort distribution as observed for 2007-2008.

The changes in fishing impact are due to the combination of effort reallocation and the use of more selective gears. The fact that opening box 3 would lead to a reduction in overall fishing impact for Swedish grid and a small overall increase for Swedish grid and SELTRA combined is mainly due to that effort is moved from an area with high density to a low density area, but also due to that effort is spread out in a larger total area. Although one of the assumptions is that the effort in box 3 would be at a similar level as in the time period 2007-2008 the incentive to fish in Box 3 initially would be large to catch the large Nephrops. Another model assumption is that the cod density by size groups are similar in 1st and 2nd quarter, this could led to a higher estimate of fishing impact in Box 3 for especially larger cod.



Scenarios: Fishing impact relative to baseline (100 %) by size group of cod

ai	Opening Box 3 for grid 1/5-31/12
aii	Opening Box 3 for grid + close Box 2 in April
b	Opening Box 3 for grid and SELTRA 1/5-31/12
c	Opening Box 3 for grid and SELTRA 1/5-31/12 + close Box 2 in April
e	Opening Box 3 for grid and SELTRA 1/5-31/12 + close Box 1,2 and 4 in April

f1	Maintain present regulation but substitute SELTRA 300 by Grid in Box 2
f2	Maintain present regulation but allow only SELTRA or Grid in open areas
F3	Closure of Box 2 and 3 in Quarter 1, Grid only in Box 1 in Q1, Grid Only in Box 2 in Q2-Q4 . Grid or SELTRA are Mandatory in all other areas and time periods

Overall, we conclude that scenarios a-e have little effect on the fishing impact on cod compared to the baseline (Fig. 4). However, scenarios *f1*, *f2* and *f3* can be considered to be more effective in reducing fishing impact on cod compared to scenario a-e and the baseline. Scenario *F1* where SELTRA trawl are not allowed in Box 2 would have a large effect on larger cod > 40 cm. Scenario *F2* have an large effect on small and middle size cod and a smaller effect on larger cod, and scenario *F3* have a large effect on both larger cod as well as on the smaller cod and thereby also reduce discard of cod. Given the assumed constant effort, these three latter scenarios thus provide the largest reduction of fishing impact and would increase the probability of the recovery of the cod stock.

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