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Institute of Marine Research
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DTU Aqua

This Memorandum is a joint statement developed by DTU Aqua, Denmark and Institute of Marine Research, Swedish Board of Fisheries based on the original Swedish proposal (PM-2008-06-17).

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Proposal for Marine Protected Areas in the Kattegat to promote the rebuilding of the cod stock

Summary
The recovery plan for the Kattegat cod has been proven unsuccessful. Spawning stock biomass is historically low and the fishing mortality remains high. Even though TAC has decreased tenfold since 2001, there is no sign of reduced fishing mortality. Hence, the present management has not been successful and complementary measures are needed in order to achieve cod recovery.

This document present management measures to complement the TAC and fishing effort measures in the cod recovery plan. The aim is to protect the local cod population in the Kattegat using Marine Protected Areas (MPAs) and to reduce the overall fishing mortality on the Kattegat cod management unit, and hence to allow the resident and historically productive Kattegat cod stock to rebuild. The limited migration behaviour of the Kattegat cod stock and the well-known spawning grounds imply that MPAs are likely to contribute to the protection and rebuilding the cod stock resident in the Kattegat. The proposal includes a year-round no-take zone encompassing the main spawning grounds and in addition, a seasonally closed area surrounding the no-take zone. The northern Sound is included in the seasonally closed area because of its vicinity to the cod spawning grounds in southern Kattegat and because cod migration is known to take place between the two areas.

The desired effects of the area closures are to allow the cod stock to rebuild by:

1) Reduce fishing mortality on the Kattegat cod stock by limiting fisheries in areas and spawning seasons when catchability and catches are high.
2) Reduce discards by limit the fishery targeting cod as key species. This could be enforced by implementing a max. 30% cod in landings rule and using the available cod TACs as a by-catch quota in the demersal fisheries mainly targeting other species (this will reduce cod discards when following closures when quotas are full).

We foresee that the suggested MPAs will have a limited effect on the national cod quota uptake in the Kattegat. Fishing mortality is, however, predicted to be reduced since the suggested MPAs are likely to obstruct targeted fisheries on the cod stock resident in the south eastern Kattegat. The effect on other economically important species such as *Nephrops*, sole and plaice, will be limited as these fisheries can operate outside the no-take zone and after the seasonal closure. The cod catch reduction following from the closure in the northern Sound is unlikely to be fully compensated by effort reallocation.

The proposed management actions and the effect of the complementary measures to the cod recovery plan should be evaluated within 3-5 years.

State of the stock

The Kattegat cod is covered by the cod recovery plan for the North Sea (Council Reg. 423/2004). However, no signs of recovery of the stock have hitherto been observed (Anon, 2007). The SSB trend indicates a fivefold decrease since 1970 and SSB has been at a historically low level since the early 2000s. The estimates of fishing mortality do not indicate a major decline in F in the past five years. The recruitment has steadily declined since 1970 and has in recent years been the lowest in the time-series.

The exact level of fishing mortality is highly uncertain. Fishery-independent information indicates that removals from the stock are substantially higher than reported landings and that the mismatch between TAC/official landings and the total removals has increased in the most recent years (ICES 2008). In addition removals from the stock may in part be explained by the inherent return migration behaviour of North Sea cod.

The assessment does not indicate a major decline in fishing mortality in the latest five years, although the TAC has been reduced to a third during 2003–2007. This suggests that the management measures have likely not been effective in terms of achieving a major reduction in fishing mortality.The recovery of the stock as well as a future viable cod fishery in the area is ultimately depending on a significant reduction of fishing mortality.

Fisheries

The description of the Swedish and Danish fisheries is based on official catch statistics and VMS data. ICES assessment estimates a significantly higher mortality than derived from official landings only, which indicates that the official landing statistics for cod may underestimate real catches.

The Swedish fishery in the Kattegat

Swedish demersal fisheries in the Kattegat are dominated by trawling (approximately 94% of effort in 2006). Effort deployed by passive gear (gill- trammel nets and longline) is relatively small (app. 5 % of total annual effort). Approximately 80% of the landed cod originate from trawl fisheries using 90-99 mm mesh size (Anon.2007).

Swedish trawl fisheries in the Kattegat can be divided into three categories. The majority of trawling effort is deployed in a mixed fishery that catches *Nephrops*, cod and flatfishes. There is also a distinct fishery that targets cod and a clean *Nephrops* fishery in trawls with and without sorting grids.

Presently, cod is primarily caught in the mixed fishery (Fig. 1 and 2). To a smaller extent there is a fishery on spawning aggregations in the south eastern Kattegat. For several years, the main part (up to 70%) of Swedish cod quota has been taken early in the year by the cod targeting fishery. This has since 2003 led to depletion of quota and repeated landing prohibitions of cod during parts of the year, with considerably discards rates as a consequence.

The majority of the Swedish fisheries in the Sound take place in the southern part of the area. In the northern part, proposed for a seasonal closure, Sweden in 2007 caught 80 tonnes. The catches were however almost exclusively caught in the first quarter, indicating that the fisheries are targeting spawning aggregations

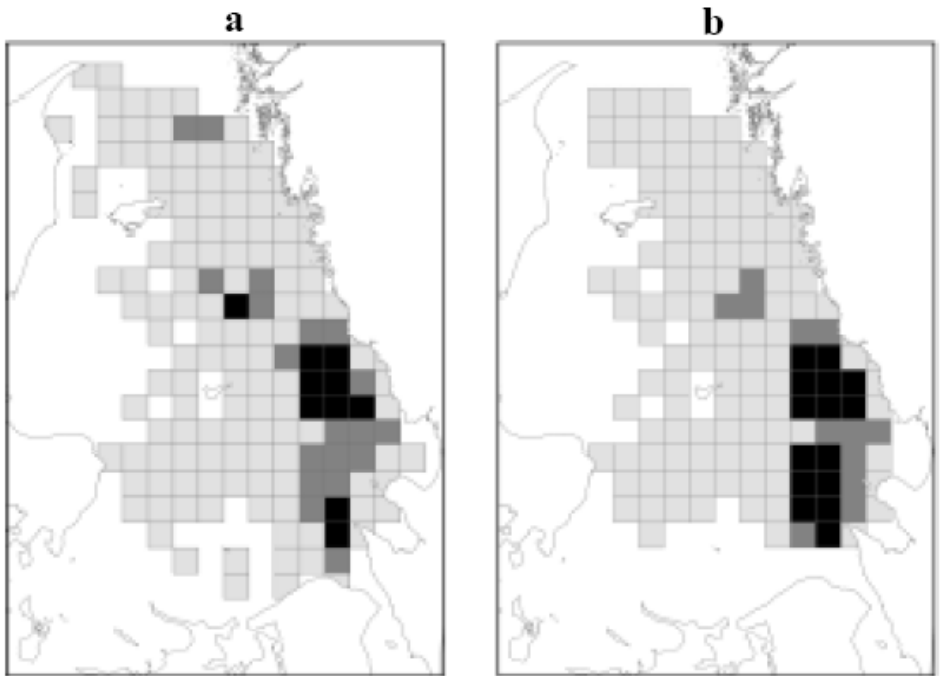

Figure 1. Average distribution of a) commercial landings of cod (>=30 cm) in kg in the first quarter of the year based on logbook set positions and b) average distribution of fishery independent catches in the Kattegat 1996 - 2004. Light low; dark grey = medium; black high biomasses. Grid size approximately 10 x 10 km (i.e., 5 x 5 nautical miles) (Vitale et al. 2008).

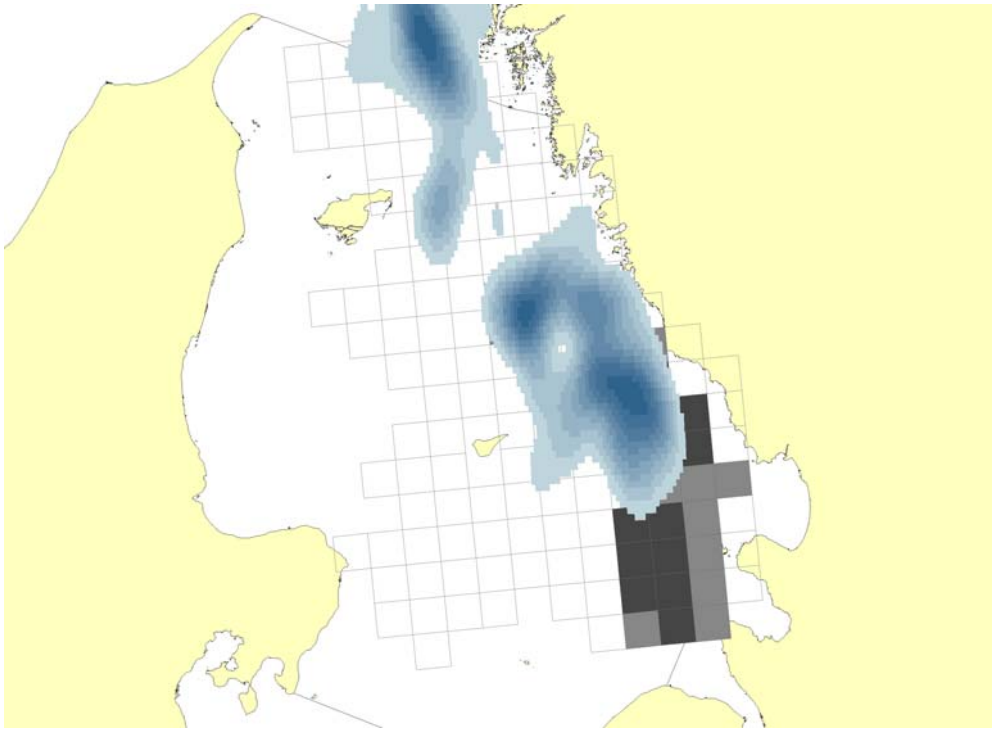

Figure 2. Kernel density estimates of activities of Swedish VMS-equipped trawlers fishing a mixture of *Nephrops norvegicus*, cod and other demersal fish (cod weight >20% of landings) in 2007. Light colours refer to low effort, dense colours high effort. Trawlers are assumed to be fishing at speed between 0,25-3,5 knots. Fishery independent catches as in Fig. 1.

The Danish fishery in Kattegat

The Danish Kattegat fleet based on numbers of vessels are at present composed of mainly bottom trawlers (52%) with a mesh size >90mm, gillnetters (25%), Pair trawler with a mesh size < 32mm (7%), and some Danish Seine (6 %). There are at present no known Danish fishermen using sorting grid. The main part of the fleet (60%) is smaller than 15 meters and is therefore not equipped with VMS.

At present there is a limited directed Danish cod fishery in Kattegat and the main part of landed cod is caught as by-catch in other fisheries, mainly for *Nephrops*.. A directed cod fishery is here defined as more than 30% cod of the total landed weight by fishing trip. In the Northern part of the Sound, we see a rather different picture (appendix 1) 80% of the total Danish landings in the area (Kattegat and the northern part of the Sound) were reported from the ICES square in the Northern part of the Sound. The main part of these catches is taken in the winter months, December to March; which indicates a fishery targeting spawning cod.

The two ICES squares in the proposed closed areas accounted based on logbook information in 2007 for 12% of the total value fished by bottom trawlers in Kattegat. Estimating the catch value for bottom trawlers larger than 15 meters the importance increases to 18% of the total catch value in Kattegat.

Danish VMS data (vessel>15 meter) from bottom trawlers in 2007 in Kattegat and the Sound confirm the importance of the northern part of the Sound. However, VMS data indicates that the proposed no-take zone area is more important than indicated by logbook data (appendix 1).

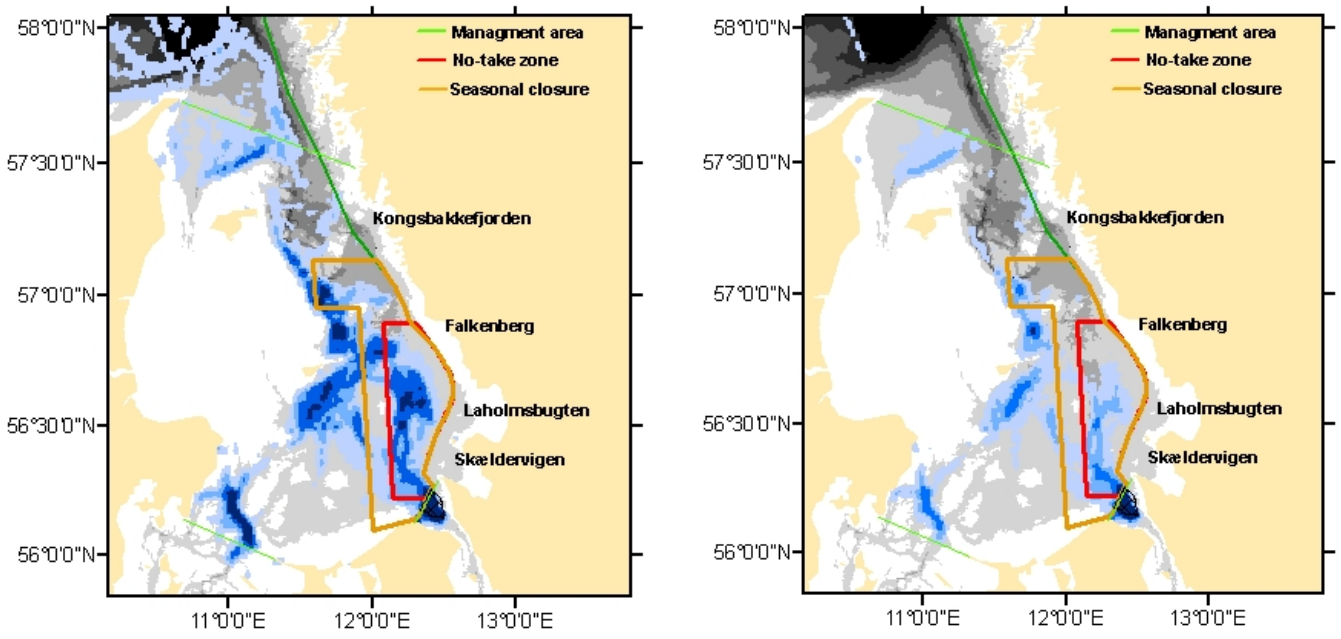

Figure 3. Danish VMS data from 2007 from the bottom trawl fishery with mesh size >50mm. Only logbook data were landings have been appointed to Kattegat or the Sound has been included. Map to the left shows VMS data for all year, and the right maps only in the timeframe January-April.

Discard and high-grading of cod is by ICES considered a major problem in Kattegat. Analysis of the change in size-composition of landings indicates that high-grading is increasing in later years. The change in size compositions of landed cod seems larger in Denmark than in Sweden.

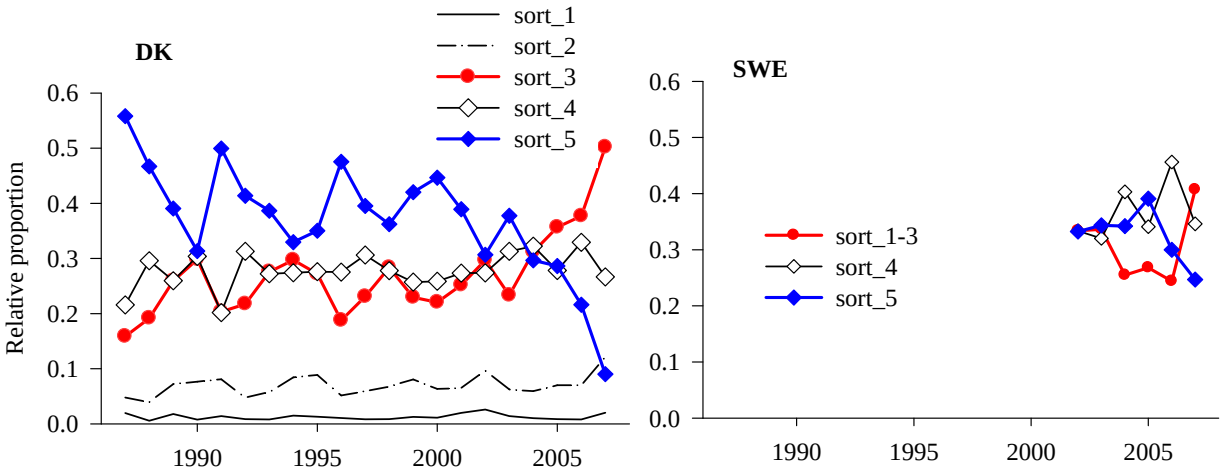

Figure 4. Relative (in percentage) Danish and Swedish cod landings in the Kattegat by sorting categories (sort 1: >7 kg, sort 2: 4-7 kg, sort 3: 2-4 kg, sort 4: 1-2 kg, sort 5: 0.3-1 kg).(ICES 2008).

Stock identity

Stock identity and management units may not always be the same. We define the biological Kattegat stock as cod spawning in the Kattegat area. Cod spawning aggregations are well known in the central and southern part of the Kattegat (Hagström et al., 1990, Svedäng & Bardon 2003, Vitale et al., 2008). However, the Kattegat management unit is composed of cod caught in the Kattegat and may comprise a mixture of cod originating from different areas (Kattegat, North Sea and Western Baltic including the Belts and the Sound).

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

- The biological Kattegat cod have limited migration (Svedäng et al. 2007)
- There is a small but significant genetic differentiation between spawning aggregations of cod in the Kattegat versus the North Sea /Skagerrak area (Carl André et al. in prep.), i.e. the biological Kattegat stock is unlikely to be replenished from elsewhere in mid-term perspective.
- The historical spawning grounds in Kattegat are well documented (Pihl & Ulmestrand 1988; Hagström et al. 1990; Svedäng & Bardon 2003)
- Spawning still occurs in these particular grounds (Fig. 1, Vitale et al. 2008)
- The distribution of codeggs is concentrated to the putative spawning grounds, confirming local spawning and indicating retention of eggs and larvae (unpublished, IMR).

Spawning activities (first quarter of the year) in the Kattegat shows that the southernmost spawning area (Fig. 1) stretches into the northern Sound from an area northwest of the Swedish peninsula Kullen (Vitale et al. 2008). Several mark-recapture experiments have shown that cod in the spawning period migrate towards the northern Sound/ Kullen both from the Kattegat and from the Sound south of Helsingborg/ Helsingör (Svedäng in prep.).

There are indications of a significant transportation of cod larvae from the North Sea stocks into the Kattegat (Munk et al., 1999; Cardinale and Svedäng, 2004). Recent tagging studies also suggest that the northern Kattegat may function as a nursery area for North Sea cod, and that return migration to the North Sea is common (Svedäng and 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).

Closed area

Objectives

The objective of the proposed management measures is a significant reduction of fishing mortality to allow rebuilding of the biological Kattegat stock.

The limited migration behaviour of the Kattegat cod stock and the well-known spawning grounds imply that MPAs are likely to be effective management measures to protect and rebuild the Kattegat stock. The proposal includes a permanent no-take zone encompassing the main spawning grounds and in addition, a seasonally closed area surrounding these grounds. These measures are proposed in order to avoid fishery targeting cod during the spawning season.

The goals are to:

1. Reduce fishing mortality on the Kattegat cod stock by limiting fisheries in areas and spawning seasons when catchability and landings are high.
2. Reduce discards by limit the fishery targeting cod as key species. This could be enforced by implementing a max. 30% cod in landings rule and using the available cod TACs as a by-catch quota in the demersal fisheries mainly targeting other species (this will reduce mandatory cod discards following closures when quotas are full).

The proposal

1. A no-take zone

The major spawning grounds for Kattegat cod are situated in the south-eastern part of the Kattegat (Fig 1). In the central zone of the Kattegat cod spawning ground a no-take zone is suggested. A year round no-take zone encompasses a complete prohibition for all kinds of fishing, including recreational fisheries. The area is suggested to be enclosed by straight lines sequentially joining the following geographical coordinates (Fig 5) meeting the Swedish trawl boundary to the east:

- 56,89^{o}N, 12,30 ^{o}E at the Swedish trawl boundary
- 56,89^{o}N, 12 ,07 ^{o}E
- 56,22^{o}N, 12,14 ^{o}E
- 56,22^{o}N, 12,38^{o}E where the Swedish trawl boundary meets the border to the Sound i.e. the western Baltic management unit.

2. A seasonal closure zone

It is suggested that an area (as shown in Fig. 5) is seasonally closed from the 1st of January until the 31th of March. During this period, it will be prohibited to conduct fishing activities using demersal trawls, large mesh midwater trawls, gillnets, long- and handlines. It will however be allowed to use gears that have been scientifically acknowledged not to catch cod. The area (Fig. 5) is enclosed by straight lines sequentially joining the following geographical coordinates:

- a point on the west coast Sweden at 57,13^{o}N, 12,03^{o} E at the Swedish trawl boundary
- 57,13^{o}N, 11,58^{o} E
- 56,95^{o}N, 11,60^{o} E
- 56,95^{o}N, 11,90^{o} E
- 56,09^{o}N, 12,00^{o} E at the Danish trawl boundary
- The whole northern part of the Sound (the area between the border to Kattegat and a line between Ellekilde hage and Lerberget).

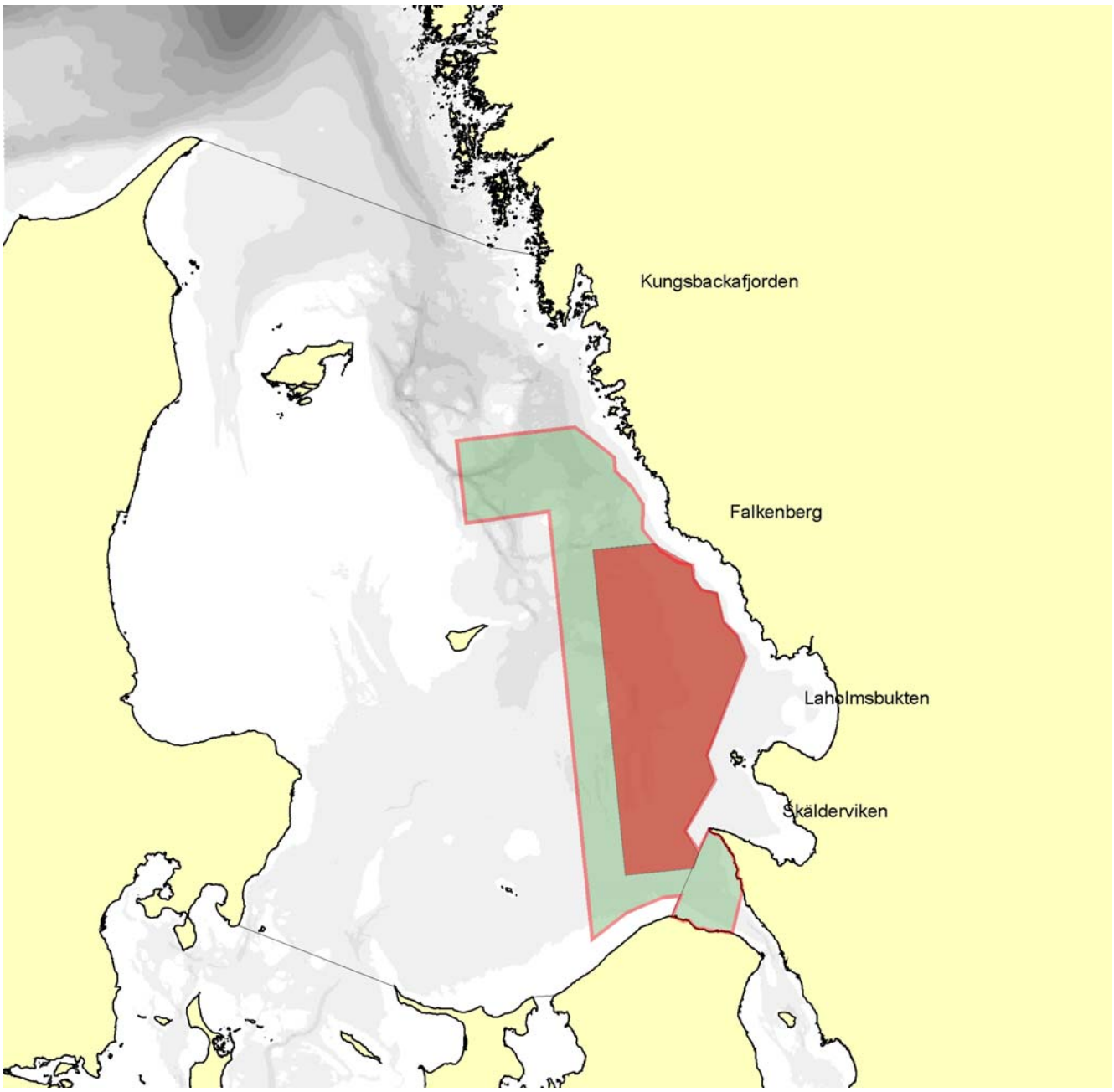

Fig. 5. Map of the proposed seasonally closed area (green area enclosed by a red line) and the permanent no-take zone (red area).

Rationale and justification

No-take zone

The area proposed includes the main spawning areas for cod and tagging experiments indicate that cod in this area is relatively stationary (Svedäng et al. 2007). To avoid effort reallocation to other times of the year and to protect the core area of the biological Kattegat stock, an all-year no-take zone is proposed.

Seasonal closure zone

A seasonal closure of fisheries in the south eastern part of Kattegat and the northernmost part of the Sound is suggested in order to avoid cod fishery in the season with high catchability and historically large landings. The seasonal closure area surrounds the no-take zone to limit the possibilities for cod fisheries to increase effort in areas adjacent to the no-take zone.

The spatial and temporal exploitation patterns of the fisheries show that significant amounts of cod are caught in the proposed areas. Implementing the closed areas should thus entail cod to be landed as by-catch thereby economizing the use of the quotas. The mandatory discards of by-catches of cod when quotas are full would then be reduced since a larger part of the available quota is allocated to demersal fisheries not targeting cod. The proposed by-catch rule, restricting the proportion of landed cod in relation to other species to 30 %, is however essential to encourage fishermen to avoid areas where cod is more abundant.

Control
The proposed areas are large enough to be controlled efficiently using VMS. A closure for all fisheries in northernmost part of the Sound (SD 23) during spawning season obstruct area misreporting in the south east Kattegat and the Sound (Western Baltic).

Monitoring the effects of closure
Evaluation of the effect
The objective of the proposed management measures is a significant reduction of fishing mortality to allow rebuilding of the stock. A more precise objective, e.g. a target fishing mortality, is not specified due to the very uncertain stock assessment. It is unlikely that the uncertainties in stock assessment will decrease significantly in short term. Hence, ICES assessments are insufficient to define exact objectives and to be used as basis for an evaluation of the performance of the proposed management measures.

In December 2008 a new combined Swedish and Danish cod survey is planned to be conducted in Kattegat and adjacent area. The aim of the survey is to estimate the total abundance, biomass and distribution of cod in Kattegat in a co-operation between fishermen and scientist. Furthermore, a recruitment index should be established and a time series of fisheries independent catch and effort data. The results should be used, together with commercial catch and effort data to strengthen the scientific advice on the cod stock in Kattegat.

The survey is conducted on 4 commercial vessels (2 Danish and 2 Swedish), with scientific participants on board. Duo to the large coverage in Kattegat and the Sound, this survey can be used to monitor the cod abundance in the proposed closed area in December 2008 – to set a baseline for the cod abundance before the closure and if the survey also in the future will be founded it can on an annual basis estimate the stock abundance to monitor the effect of an closure. Besides two Swedish surveys conducted with Argos and Ancylus have some stations in the proposed closed area and data from these surveys can compliment the estimates from the new cod survey.

The planned bilateral cod survey using commercial fishing vessels, will if continued for several years, provide valuable input to assess the stock development in the entire Kattegat area, but the survey is not sufficient for a thorough monitoring of the effect of the closure. Right now, it is not possible to specify in details the necessary scientific and sampling activities needed. The specific sampling schemes needed must be determined and agreed at an international meeting before the closure will be in force. Sufficient information should be available to make an evaluation of the performance of the proposed management measures within 3-5 years.

Complementary measures

Current gear use
Vessels in the Kattegat predominantly use a 90mm codend in demersal trawl and seine fisheries for cod, flatfishes and *Nephrops* in the Kattegat. In addition, most effort is deployed with 90mm trawls with a 120mm square mesh window, the window is mandatory for Danish fishermen and is incentivized by extra days-at-sea for Swedish fishermen. Swedish trawl vessels also use a sorting grid

when targeting Nephrops (>50% of Swedish *Nephrops* trawl landings in the Skagerrak/Kattegat). No Danish vessels use the sorting grid.

An important difference between Danish and Swedish fisheries is that Danish fisheries in general targets a mixture of *Nephrops*, flatfishes (plaice and sole) and cod, while Swedish fishermen to a larger degree targets *Nephrops* and cod in a directed fishery. This pattern is to some extent a result of limited Swedish flatfish quota (mainly sole) in comparison to Danish quotas.

Gear-research and development needs

Cod discards of undersized fished can be reduced by traditional gear measures as mesh size increases, square mesh codends and escape windows. These measures will however to a varying degree result in loss of valuable species in the mixed fishery (*Nephrops*, sole and plaice), and will not reduce fishing mortality for adult cod. In order to have a significant effect as a complementary measure on adult cod mortality, a gear measure that decouples cod from other commercial species is needed.

The sorting grid in *Nephrops* trawls has a proven record and has been widely up taken by Swedish fishermen (Valentinsson and Ulmestrand 2008). The grid decouples *Nephrops* from cod (and most other fish species). Danish fishermen have no experience of grid usage and are more dependent of other fish species than Swedish fishermen as a result of their practise of a more non-specific mixed fishery for *Nephrops*, flatfishes and cod. Currently, no existent gear measure decouples cod from flatfishes and *Nephrops*. Further focussed research on this subject is hence needed.

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Annex 1

Danish fishery

In 2007, 21% of the Danish landed cod was caught in a directed cod fishery. An analysis of the fleet involved in this directed cod fishery showed that bottom trawler landed the main part 34%, gilnetters landed 24% and Danish Seines 12%.

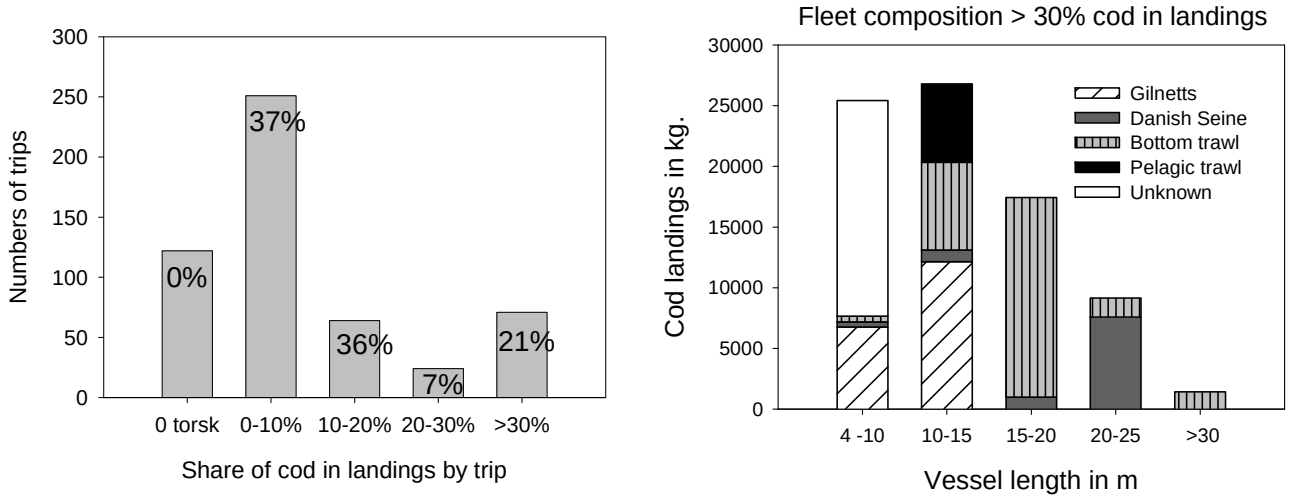
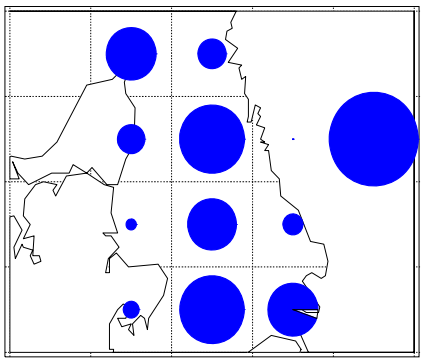


Figure 6 The figure to the left shows the share of cod by trip in 2007. The numbers within the column state the amount of cod landed in proportion to the total landed weight of cod. 71 of 532 trips (equalling to 13% of the trips) were fishing directed on cod and landed in 21% of all landed cod. The right figure show the fleet segments fishing directed on cod in Kattegat.

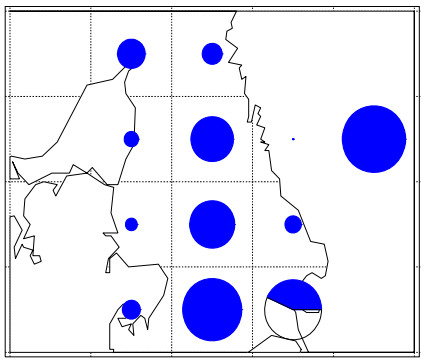
Danish VMS data indicate that the closed areas are more important than indicated by logbook information. 26% of all VMS data in Kattegat (Bottom trawlers larger than 15 meters, with mesh size > 50mm) are from within the no-take zone. An analysis on the fishery value based on logbooks (bottom trawlers >15 meters and without the pelagic species included), showed the importance of the two squares in the proposed closed area accounted for 18% of the total value in Kattegat (table 1). We are at present not able to explain the discrepancy between logbooks and VMS data.

The geographic distribution of Danish cod landings from the whole Kattegat and the Northern part of the Sound (41G2) is presented in figure 7 The landings are estimated from using logbook and sales note information. A drastic decline in landings is evident from 1987, however the geographic distribution of the landings in Kattegat is rather similar in the period. The proportion of cod reported landed in the northern part of the Sound (ICES square 41G2) has been increasing since the late 1980s and the cod fishery in the northern part of the Sound is at present the only significant cod fishery in the area and mainly conducted in the first quarter. Landings in the southern part of Kattegat (ICES square 41G2- with out “Kilen”) amounted in 2007 to 9 % of the total Danish landings in Kattegat. However, if the northern part of the Sound was included the landings account for nearly 80% of total landings in the area (Kattegat and the Sound). Fishing in the Sound has lately been restricted according to the closed period and days absent from port system in the Western Baltic Sea. This closed period covers April. This could explain the very sharp decline of landings from the first to second quarter, however analysing a longer timeframe indicates that landings have been rather low in April also before the restrictions in fishing days (Figure 8).

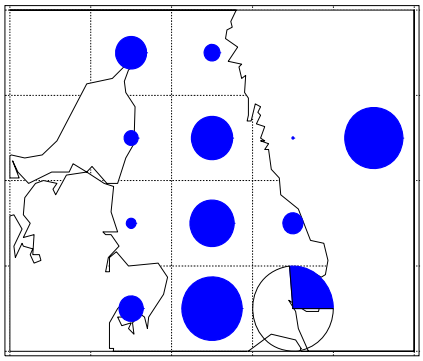
1987-1989
max landing 2298 t



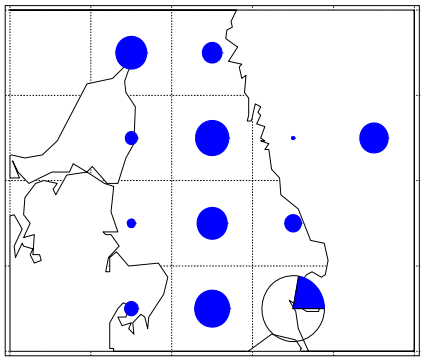
1990-1994
max landing 1160 t



1995-1999
max landing 1395 t



2000-2004
max landing 884 t



2005-2007
max landing 967 t

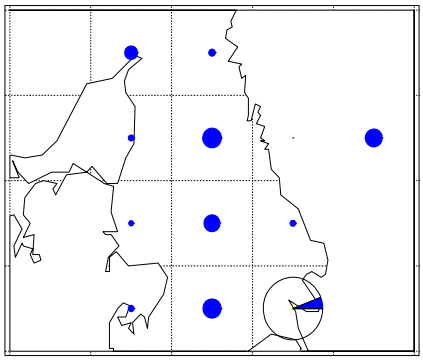


Figure 7. Annual average Danish cod landings per ICES square. The dark colour indicate landings rapported from Kattegat, the white colour indicate landings in ICES square 41G2, where the landings have been rapported caught in the Sound. Scaling is equal between all maps and maximum landings per square is shown for each period.

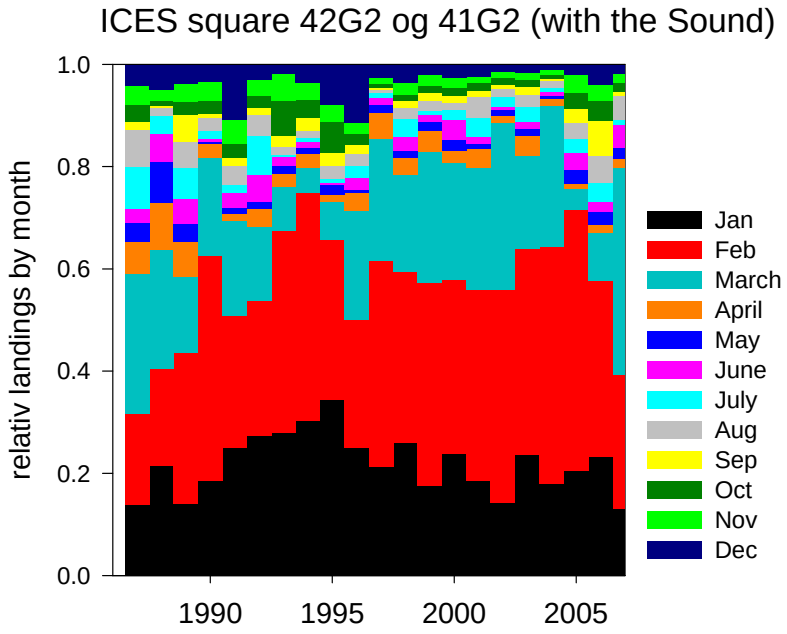


Figure 8. Relative landings by month of cod in the two ICES squares in the proposed closed area. The cod landings in the northern part of the Sound have been included.

In the northern part of the Sound (ICES square 41G2) 53% of the cod landings has been caught with bottom trawl the rest is target with Danish Seine (ca. 30%) and gillnetters (ca. 10%).

The Danish cod landings from Kattegat show a sharp decrease in the total landings since 2000 and it has affected all sorting classes. The relative share of the smallest cod (size grade 5) has historic been fluctuating between 30 and 50% of the total landing. However, since 2003 the share of the smallest size grade has been decreasing sharply and is at present below 10%. Concurrently the share of larger cod (size grade 2 and 3) has been increasing in the landings. This is an indication of high grading (fishermen keep the largest cod and discards the rest) or a large change in the age composition of the cod stock in Kattegat. Stock assessment does, however, not indicate a major change in age composition. Furthermore, analyses of research vessel survey data indicates that the largest discrepancy between calculated mortality and landings is at age 2 and 3 (size grade 5).

Table 1. The value of the Danish Kattegat landings (percent) grouped by ICES square and quarter in 2007. Only demersale fisheries by bottom trawlers > 15 meters have been included. The marked lines shows the two ICES squares (41G1 and 41G2) covered by the closed area.

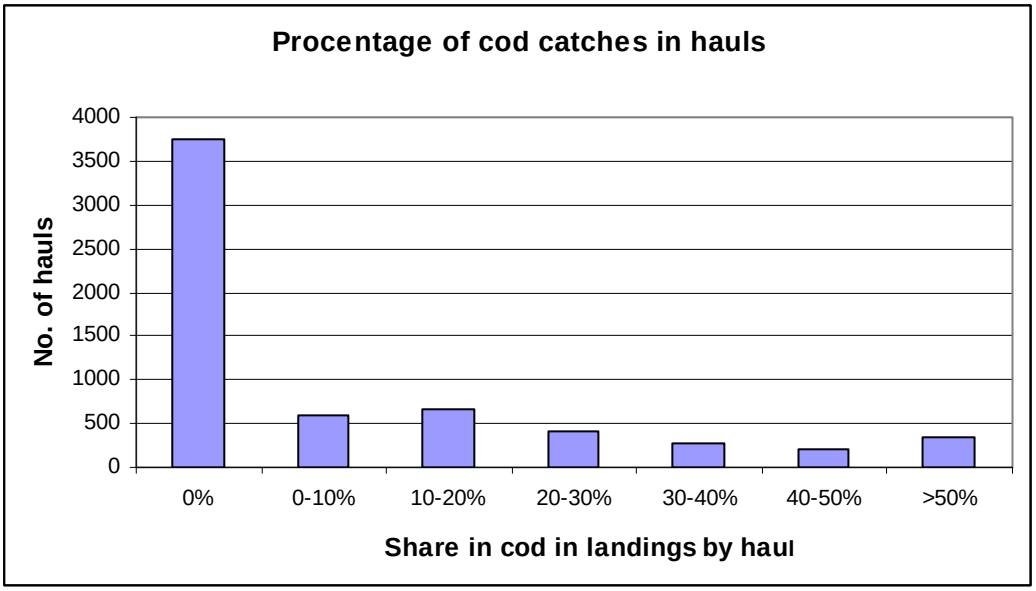
year 2007

	kvartal				
	1	2	3	4	All
Rektangel					
41G0	0.4			0.1	0.5
41G1	2.0	2.2	3.0	6.8	13.9
41G2	0.9	3.3	3.4	4.1	11.8
42G0				0.0	0.0
42G1	4.8	2.4	11.6	6.2	25.0
42G2	0.3	0.1	3.6	1.9	5.8
43G0	0.4	0.7	1.1	0.3	2.4
43G1	7.2	6.2	10.9	6.6	30.8
44G0	0.9	0.9	3.1	1.6	6.5
44G1	0.3	0.6	1.1	0.5	2.5
9999	0.0	0.2	0.3	0.3	0.8
All	17.1	16.6	38.0	28.3	100.0

Annex 2

Swedish Fishery

In 2007, 90% of the Swedish landed cod was caught in trawl fisheries. An analysis of the trawl fisheries show that 75% of this cod were caught in hauls with a catch composition with >=30% of cod. The cod landings were limited in the majority of hauls (figure 9) while a relatively small amount of hauls contributed to the bulk landing (figure 9). Analysis could be performed at haul level since the minimum requirements in the Swedish logbook are extended compared to the EU logbook. The Swedish trawl fisheries in Kattegat have since 2003 been characterised by periods of prohibition to land cod. Such prohibitions could of cause have an impact on the analyses since they are based on composition in landings. In 2007 it was prohibited to land cod from the 15th of October.



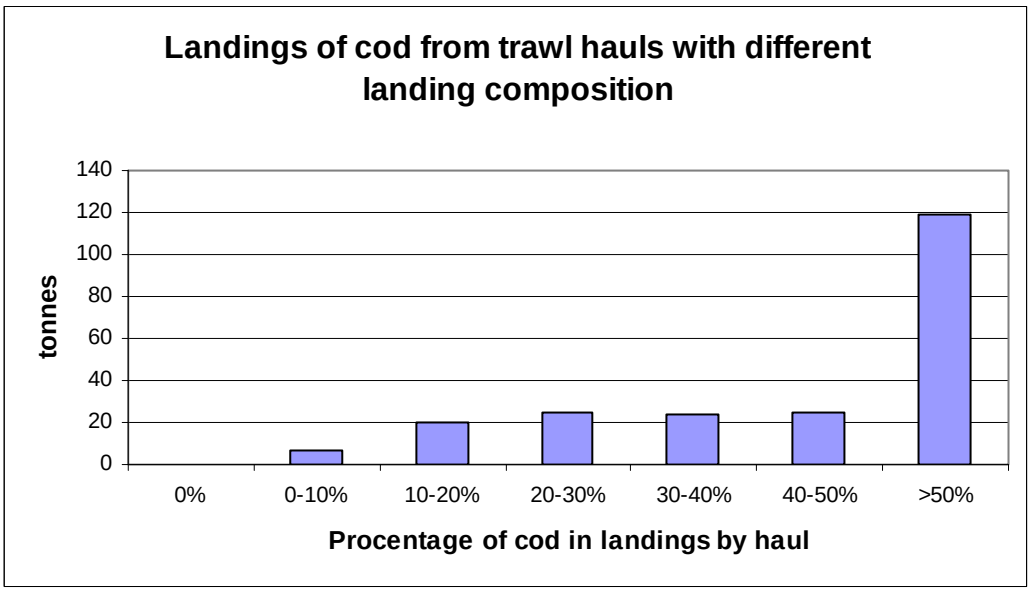


Figure 9 Showing (a) the number of hauls with different cod share in cod landings by haul and (b) the corresponding total landings of cod by “landing composition” group. Composition in landings from 805 out of 6221 trawl hauls exceeded 30% cod. The total landings of cod from these hauls were 176 tonnes, corresponding to 76% of the cod landings from trawl and 71% of the total Swedish cod landings from Kattegat in 2007.

Discard rates of cod in the Kattgat are routinely estimated within the Data Collection Programme. In 2007 it was estimated that approximately 50% (by weight) of the cod caught in the Swedish Kattegat trawl fisheries were discarded. The main reasons for discarding are capture of individuals below minimum landing size, catches exceeding the national rations or catches in periods with prohibition to land cod.

Swedish trawl fisheries in the Kattegat can be divided into three categories. The majority of trawling effort is deployed in a mixed fishery that catches *Nephrops*, cod and flatfishes. There is also a fishery targeting cod and a single species fishery targeting *Nephrops* in trawls with or without sorting grids. Presently, the same gear is used in all fisheries (except *Nephrops* fisheries with sorting grid). The targeted cod fishery have historically been important. The effort has however been reduced with 85% since the late 1990s. Efforts in fisheries targeting *Nephrops* or fisheries targeting a mixture of *Nephrops* and demersal fish have shown no such reduction (figure 10).

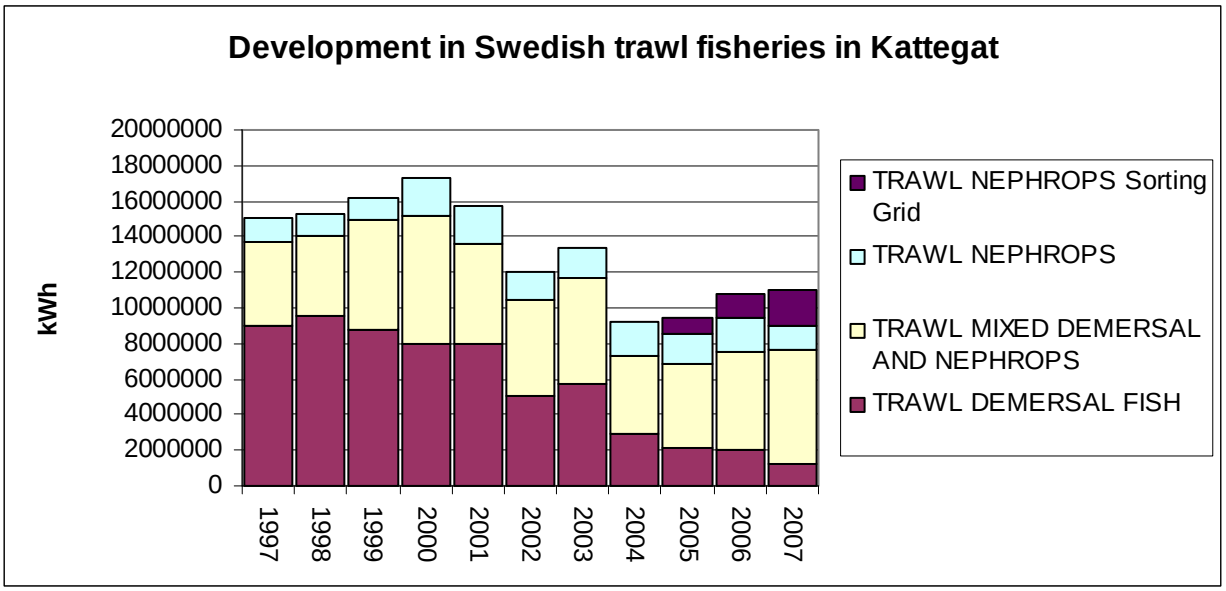


Figure 10 Showing development of fishing effort, expressed as kWhours, in the Swedish demersal trawl fisheries in the Kattegat.

VMS-data from 2007 for vessels longer than 15 meters have been used to analyse the spatial distribution of the different fisheries. The south-eastern part of the Kattegat is shown to be of importance for the Swedish cod - and mixed fisheries (Fig. 11 and 12). However, it is not predicted that the suggested MPAs will affect the national quota uptake of cod or other economically important species such as *Nephrops*, since these fisheries can operate north of the MPAs and during the time of the year when the seasonal closed area is open. The targeted fishery for *Nephrops* (Fig 13) and pelagic species (i.e. sprat and herring, not shown) are not affected since these fisheries mainly take place north the suggested MPAs. Hence, the economic impact will be limited to mixed demersal and targeted cod fisheries.

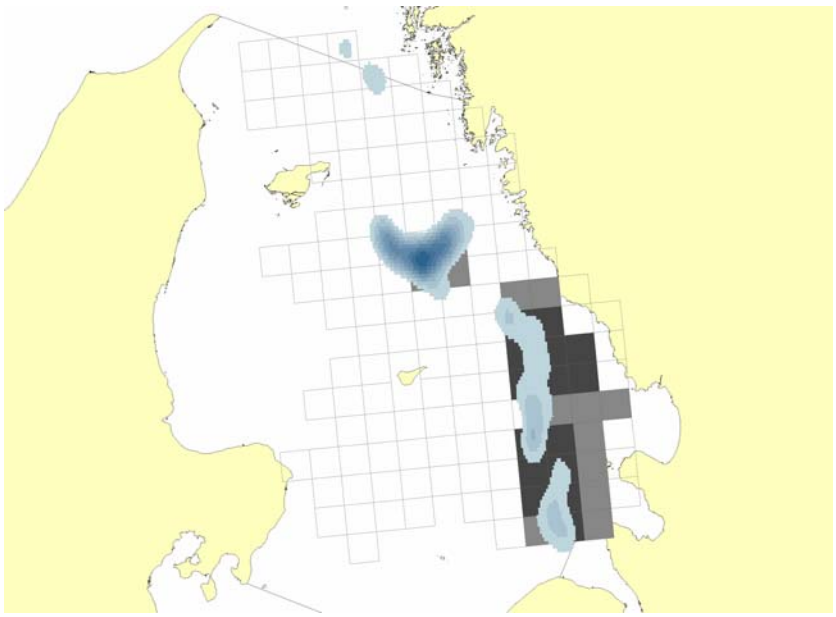


Figure 11. Kernel density estimates of activities of Swedish VMS-equipped trawlers targeting cod (cod weight >50% of landings) 2004. Light colours refers to low effort, dense colours high effort. Trawlers are assumed to be fishing at speed between 0,25-3,5 knots. Fishery independent catches as in Fig.1.

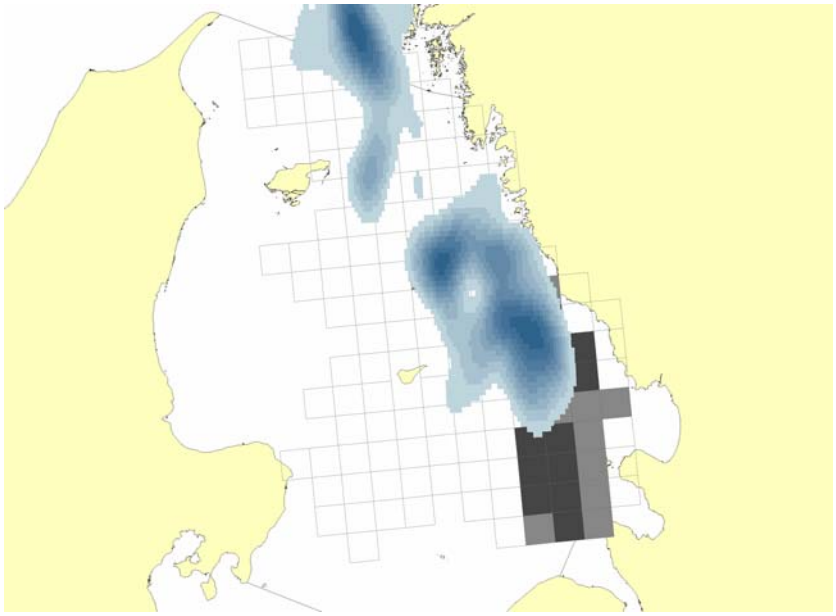


Figure 12. Kernel density estimates of activities of Swedish VMS-equipped trawlers fishing a mixture of *Nephrops* , cod and other demersal fish (cod weight >20% of landings) in 2007. Light colours refers to low effort, dense colours high effort. Trawlers are assumed to be fishing at speed between 0,25-3,5 knots. Fishery independent catches as in Fig. 1.

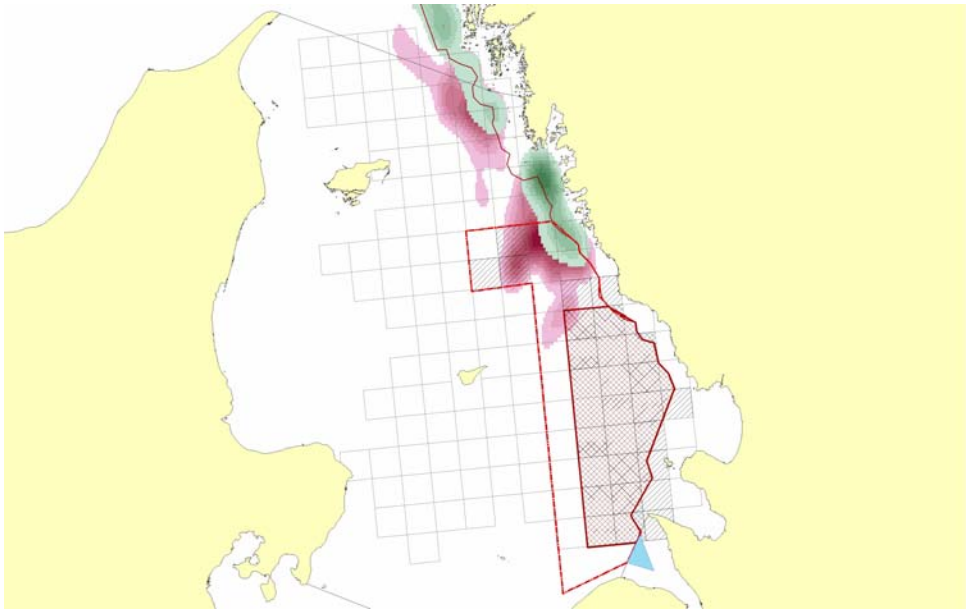


Fig. 13. The Swedish fishery targeting *Nephrops* in 2007. Fisheries visualized in green are using sorting grid. Fisheries visualized in red lands >=95% *Nephrops*

An assessment of the consequences for the Swedish fishery of a permanent no-take zone surrounded by a seasonally closed area in the central cod spawning areas shows that the mixed fishery on *Nephrops* and demersal fish is likely to become more intense in adjacent areas, especially during January to March. It is also predicted that future quotas of cod will be landed as by-catch. The discards of cod would be reduced since the available quota is allocated to demersal fisheries not targeting cod. A proposed by-catch rule, restricting the proportion of landed cod in relation to other species to 30 %, is however essential to encourage fishermen to avoid areas where cod is more abundant.