Stock Annex: Cod (*Gadus morhua*) in Subdivision 21 (Kattegat)

Stock specific documentation of standard assessment procedures used by ICES.

Stock Cod

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A. General

A.1. Stock definition

Genetic surveys

The existence of separate subpopulations in the Kattegat in relation to putative subpopulations in the Skagerrak and the North Sea has been corroborated by genetic surveys (André et al., in prep.) based on nine reference samples gathered from the Kattegat, Skagerrak and North Sea. Analyses suggested that the nine reference samples could be pooled into two regional groups: "North Sea" and "Kattegat". The temporal stability of the genetic differentiation between the two regional groups was assessed by dividing all fish into year classes based on otolith ageing, and testing for genetic heterogeneity. This test did not indicate any temporal instability in either the North Sea or the Kattegat reference, and verified the genetic differentiation between the two regions. All samples within the two regions were thus pooled in subsequent statistical analyses; the overall FST between the pooled North Sea reference sample (n=201) and the pooled Kattegat sample (n=435) was 0.0041 (P < 0.0001).

Migration and natal homing, mixing of stocks between assessment units

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 Kattegat may function as a nursery area for North Sea cod, and that return migration to the North Sea are commonplace (Svedäng and Sven-son, 2006; Svedäng et al., 2007). The principal age when most return migration from the Kattegat towards the North Sea seems to take place is observed to be at age 2 to 3 (Svedäng et al., 2007).

The migrations of cod (>37 cm) in the Skagerrak and Kattegat were investigated in an archival tagging programme conducted between 2003 and 2006 (Svedäng et al., 2007). Cod tagged at different localities showed non-random, directional movements in agreement with the hypothesis that the cod population in this region comprises a mixture of resident and migratory stocks. Cod tagged off the eastern Skagerrak coast migrated towards the North Sea, predominantly during the spawning period from January to April, and most of these fish returned to the eastern Skagerrak later in spring. In contrast, concurrently tagged cod in the Kattegat and the Gullmar Fjord (Skagerrak) showed a higher degree of resident behaviour. However, some fish also left these two areas for migration towards the North Sea, predominantly during the spawning period, in accordance with the theory that recruits from the North Sea will eventually leave the Kattegat and the eastern Skagerrak coast for their natal spawning sites. Taken together, these findings implied natal homing behaviour to be the intrinsic mechanism that underlies population separation in marine fishes such as Atlantic cod.

Genetic surveys along the Skagerrak coast have shown that the composition of young-of-the-year cod change from year to year consistently with year class strength variation in the entire Skagerrak (Knutsen et al., 2004). Thus, in years with a general low level of recruitment, juveniles were assigned to neighbouring coastal cod populations (i.e. reference material attained from adult, spawning fish), whereas in years with high levels of recruitment, the juveniles were, in contrast, assigned to reference populations sampled at spawning in the western part of the Skagerrak or in the eastern North Sea. This implies that immature cod also in the Kattegat are an assortment of North Sea and Kattegat cod stock components where the proportion of the two stocks in the area varies between years.

The spatial distribution of observed cod recruits (0-group in the IBTS third quarter) gives an illustration of the impact of various recruitment sources. Since the beginning of 2000s abundance of 0-group cod has declined sharply south off 57º N. To the opposite, north off 57º N, the level of recruitment shows interannual variation but no trend during the same period of time. The differences in recruitment patterns are probably due to an inflow of recruits from the Skagerrak/ North Sea into the northern Kattegat, whereas south off 57º N the decline in local recruitment has had a much higher impact on juvenile abundance.

At the present, the question whether subpopulation structures may occur on an even finer scale than those observed between the Kattegat and Skagerrak/ North Sea has been tentatively addressed (Svedäng et al., 2010a). Such a differentiation is very likely considering following observations: a) The occurrence of several separate spawning sites within the Kattegat (e.g. Vitale et al., 2008), b) the fact that some previously important spawning sites such as Laholmsbukten and Skälderviken were abandoned during 1990s but have not been recolonised in spite of the presence of juvenile cod, c) a demographically separate cod subpopulation in the adjacent sea area Öresund (ICES Subdivision 23).

Spawning activities (first quarter of the year) in the Kattegat show that the southernmost spawning area stretches into the northern Öresund 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 Öresund/ southernmost part of the Kattegat both from other parts of the Kattegat and from the Öresund south of Helsingborg/ Helsingør (Svedäng et al., 2010b). This behaviour is confined to the spawning period, indicating a homing behaviour to this particular area for some cod in the Öresund and Kattegat.

Spawning areas

Before the stock decline in the 1990s, spawning cod could be found throughout the Kattegat, but the southern part was generally recognized as the main spawning area, especially the bay of Skälderviken and Laholmsbukten (Pihl and Ulmestrand, 1988; Hagström et al., 1990; Svedäng and Bardon, 2003). Historically, large spawning aggregations were also observed in the bay of Kungsbackafjorden and north of Läsö (Hagberg, 2005). The stock decline coincided with the disappearance of large spawning aggregations and the abundance of adult fish in the area has dropped to very low levels (Cardinale and Svedäng, 2004).

Spawning activity of cod in the Kattegat during the last decades has been investigated (Vitale et al., 2008) based on combined fishery data and survey information for the first quarter of the year that corresponds to the main spawning period of cod in the Kattegat (Vitale et al., 2005). Data from 1996–2004 indicated that cod catches during the Swedish bottom trawl fishery were made to a large extent in spatially rather restricted areas in the south eastern part of the Kattegat, i.e. either close to the entrance to the Öresund, or off the coast at Falkenberg. In some years, large landings of cod were also reported from Fladen and from the northern part of the Kattegat, i.e. north off Läsö. The CPUE of spawning cod in the IBTS data 1996–2004 was not evenly distributed throughout the area, but coincided to a large extent with the areas identified as hot spots for the commercial landings. Put together, these data sources indicate several possible spawning grounds for cod in the Kattegat.

For the time being, two areas in the southeastern part appear to be most important, one close to the entrance to the Öresund and one off the coast at Falkenberg. This observation is in general agreement with previous information on location of spawning aggregations in the Kattegat for the periods 1981–1990 (Pihl and Ulmestrand, 1988; Hagström et al., 1990), and 1975–1999 (Svedäng and Bardon, 2003) and with the ongoing study on egg distribution (Svedäng et al., 2004). However, the present number of spawning localities in the Kattegat is indicated to be reduced in comparison to what can be elucidated about the past distribution of spawning activities, i.e. before 1990. Besides the two areas presently indicated as the main spawning grounds, only weak signals of spawning activities were obtained in the central and northern parts of Kattegat. These areas might no longer be recognized as spawning grounds, although large spawning aggregations were frequently encountered by research surveys in the early part of 20th century (Hagberg, 2005). Moreover, it was also noted that possibly separate spawning locations may have been abandoned in the bights of Skälderviken and Laholmsbukten. Svedäng and Bardon (2003) depicted rather big spawning aggregations in these areas, which eventually disappeared in the 1990s.

Summary

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

- There is a small but significant genetic differentiation between spawning aggregations of cod in the Kattegat versus the North Sea /Skagerrak area (André et al. in prep.), i.e. the resident Kattegat cod stock is unlikely to be replenished from elsewhere at least in a mid-term perspective.
- The historical spawning grounds in Kattegat are well documented (Pihl and Ulmestrand, 1988; Hagström et al., 1990; Svedäng and Bardon, 2003). Spawning still occurs in these particular grounds albeit some of them might have become abandon (Vitale et al., 2008)
- There are indications of a significant transportation of cod larvae from the North Sea stocks into the Kattegat. Immature cod in the Kattegat are an assortment of North Sea and Kattegat stock components, where the proportion of the two stocks in the area varies between years. The principal age when most return migration from the Kattegat towards the North Sea seems to take place is observed to be at age 2 to 3.

- One spawning ground is more or less shared between SD 21 and 23, as one spawning area stretches from the Kattegat into the northernmost part of the Öresund. On the whole, the Kattegat cod is however well separated from the cod stock in the Öresund (SD 23), as there is a limited migration going on between the two areas. The population dynamics in the two areas are also showing considerable deviating patterns.

A.2. Fishery

The fishery is almost exclusively Danish and Swedish, with these countries taking about 60-70% and 30-40% of the landings, respectively. Kattegat cod are mainly taken by trawls, Danish seines and gill-nets, the former being the most important. Within the trawling group, three fleets have historically been important for the cod catches, the *Nephrops* fisheries, the flatfish fisheries and the cod directed fisheries usually taking place during the first months of the year.

Besides TAC regulation, fishing in Kattegat are restricted by effort limitations. The system was first introduced in the first cod recovery plan (EC No. 423/2004). Effort was limited by allowed number of fishing days for individual fishing vessels. Details were given each year in an annex of the TAC regulation. The system was quite complicated since different types of fishing gear, mesh-size ranges and types of selection devices gave different number of allowed fishing days. The sorting grid used in Swedish *Nephrops* fisheries was given unlimited days since it was shown that by-catches of cod were very small. In 2007 fishermen were allocated additional fishing days when using trawls with an exit-window with square-meshes at a minimum 120 mm. Usage of exit-window may have had an influence on discarding of small cod, the effect can however not be evaluated with available data. Since 1st February 2008, the usage of the exit-window in trawls has been made mandatory in Denmark. In 2008, in order to restrict the targeted Kattegat cod fisheries, each fishing day during the period between 1 February and 30 April was further counted as 2.5 days. In 2009, following the introduction of the new management plan (EC No. 1342/2008) for North Sea (incl. Kattegat) cod a new effort system was introduced. In this system each Member State is given amounts of kWdays for different gear groups. It is then the MS responsibility to distribute the kWdays among the fishing vessels. The amount of kWdays for gear groups catching cod will be subject to yearly cuts as long as the cod stock is below reference points in the management plan. MS can apply for derogation from the kWdays system if the catches in a certain part of the fleet can be shown (after evaluation by STECF) to consist of less than 1.5% cod (article 11(2)(b)). Sweden did so in 2009 and got derogation from the kWdays system for *Nephrops* trawlers using the Swedish grid. MS can further avoid cuts (or part of cuts) if they introduce highly selective gear and cod avoidance plans (article 13). Denmark introduced such a cod avoidance plan in 2010. As a part of this plan, since 2011 it is mandatory in Danish fisheries to use a SELTRA trawl with 180 mm panel during the first three quarters of a year.

In 2009, as a part of the attempts to rebuild of the cod stock in Kattegat, Denmark and Sweden, introduced protected areas on historically important spawning grounds. The protected zone consists of three different areas in Kattegat in which the fisheries are either completely forbidden or limited to certain selective gears (Swedish grid and Danish SELTRA trawl) during all or different periods of the year (Figure 1) The effect of the protected area is going to be evaluated in 2012.

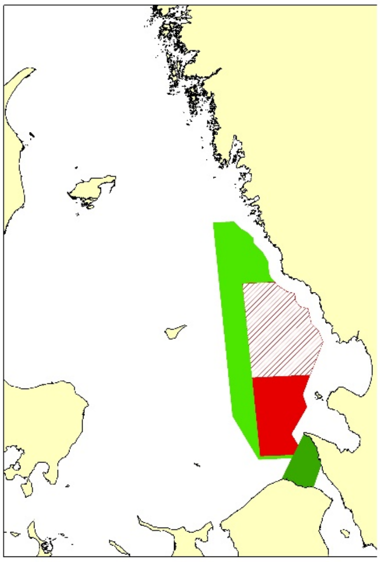


Figure 1. Protection zones for Cod in the Kattegat. The red zone is closed for all fisheries the whole year. The red striped area, all fisheries are forbidden between 1 of January to the 31 March, from April to 31 December only selective gears are allowed. The light green area, only selective gears are allowed from 1 of January to the 31 of March, from April to the end of December the area is open for all gears. The dark green Area only selective gears are allowed from the 1 of February to the 31 of March.

During recent years, in Danish Kattegat fisheries, cod is mainly caught as a bycatch species and landings are distributed throughout a year. It should however be noted that a considerable targeted cod fishery has historically been taking place in the border area between Kattegat and Öresund (northern part of SD 23) that belongs to the management area of western Baltic cod. The total nominal effort (kWdays) of Danish fleet in the Kattegat has decreased by half between the years 2000–2008 (STECF Sub-group EWG 11-11).This is mainly due to a decrease in trawls of 70–89 mm mesh size (87%) and trawls with mesh >100mm mesh size (69%). The ban of the 70–89 mm trawl caused an increase in effort by trawls in 90–99 mm mesh size category during 2004. Effort within this category remained stable in the period 2006–2009, but increased slightly in 2010 (Figure 2). Before 2007, the quotas in Denmark were split into 14-days rations which were continuously adjusted to the amount of quota left. In 2007, this system was changed to a right-based system (FKA - Vessel Quota Share). The year 2007 is considered as a transition year to the new system, which implies that Danish quotas of several stocks were not fully utilized in 2007, including the cod in Kattegat. The Danish minimum landing size was set down to 30 cm from Feb. 25 in 2008, in order to match the international minimum landing size and potentially reduce cod discards.

In Swedish fisheries, cod has traditionally been caught as target species during the spawning season in the beginning of the year and as by-catch in fisheries primarily targeting *Nephrops*. The status of the stock and the corresponding large cuts in quota has reduced and finally eliminated the targeted cod fisheries. In 2007 the cod landings were more evenly distributed between the quarters, indicating that most cod is caught as by-catch. The total nominal effort (kWdays) of Swedish fleet was stable during 2004–2008 (Fig 1); whereas the effort of *Nephrops* trawls equipped with sorting grid has increased. During 2009, due to several regulations, the Swedish effort in the 90–99 mm trawl segment decreased by 63% compared to 2008 whereas the effort deployed by vessels using the sorting grid increased by 36%. This trend has continued in 2010. The effort deployed by Swedish vessels using the sorting grid was in 2010 larger than the effort deployed by vessels using the traditional 90–99 mm trawl. In Sweden, the landings of cod were regulated by weekly rations, administered by the Swedish Fishermen Federation until 2008. The rations were continuously adjusted to the amount of quota left. The Swedish fisheries were also during the period 2003–2007 characterised by long periods (usually in the 2nd and 3rd quarter) of prohibition to land cod. These "cod stops" had a serious impact on discard rates and the size composition of the cod discards but also on the behaviour of the fishing fleets. In 2009, the Swedish Board of Fisheries took over the administration of the cod landings in Kattegat. New national rules which severely limit the possibilities to target/catch cod were put in place. These rules include limiting the number and amount of landings of cod and *Nephrops* for each vessel each week. Vessels equipped with sorting grids were allowed to land more times each week than a vessel using a conventional trawl. Cod is further only allowed to be fished as by-catch species and landings are only allowed to contain 30% of cod. However cod accidentally caught in access of the by-catch rule should be landed as well but the fisherman will not keep the full revenue. Also in order to promote selective gears; the *Nephrops* quota were divided in a way that 50% were allocated to vessels using sorting grids, 20% to the *Nephrops* creel fishery for and 30% to the conventional trawl fishery. The cod quota was also divided, 80% were allocated to the trawl fishery and 20% to fisheries using static gears (gill and trammel nets).

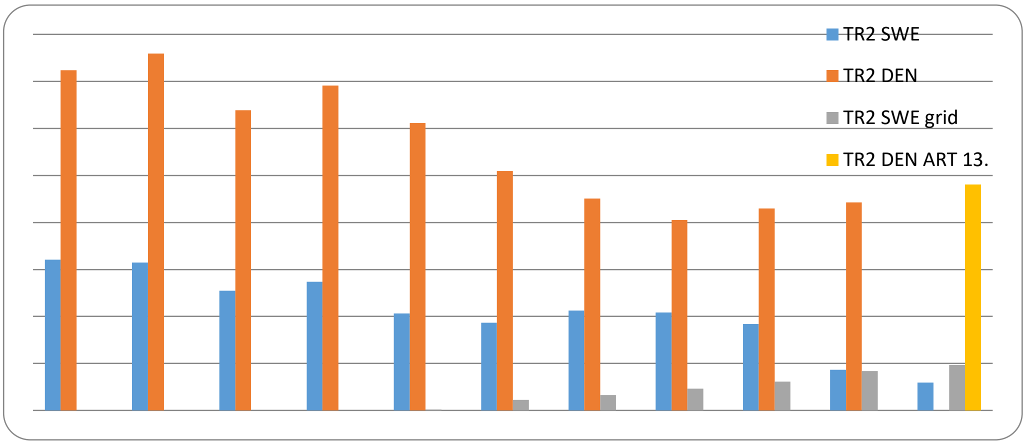


Figure 2.Effort (kilowatt-days) deployed in the Kattegat in major fisheries affecting Kattegat cod (TR2, i.e. trawlers within the mesh sizes interval 70–99 mm), including the effort in fisheries using sorting grid and effort in fisheries utilising article 13 in the cod recovery plan.

A.3. Ecosystem aspects

Recruitment is possibly partially dependent on inflow of eggs and larvae from the Skagerrak-North Sea cod stock (Munk *et al*., 1999; Cardinale and Svedäng, 2004). No relationship has been found between recruitment success and sea surface temperature for Kattegat cod stock (Cardinale *et al*., 2008). Also, the decline of adult cod abundance and recruitment could not be attributed to any of the environmental factors tested and thus no evidence was obtained which could link the observed decline in cod abundance to environmental factors (Cardinale and Svedäng, 2004). It has been hypothesised that the abundance of young-of-year in both the Kattegat–eastern Skagerrak is dependent on an inflow of offspring from the same spawning stock, i.e. cod larvae transported from spawning areas in the eastern North Sea (Munk *et al*., 1999). However, appearance of large year classes of cod in the Kattegat are associated with those in the Skagerrak and therefore it is likely that similar processes in both areas probably regulate the recruitment. Especially in the northern part of the Kattegat, most of the young of year might be of North Sea origin but they do not contribute to the Kattegat stock as they migrate back to the North Sea prior to maturation (Svedäng *et al*., 2007).

The growth pattern in the Kattegat and Öresund was compared for age groups 1-4 between 1987 and 2003. Growth was clearly indicated to be cohort dependent whereas no sex or area differences could be evidenced. The growth performance in the first year of life, measured as mean length at age 1, propagated into higher age groups within the same cohort. Size at age 1, in its turn, was found to be correlated to the water temperature regime in the year of birth. Such correlations between growth performance and temperature are however commonplace; it has been shown for most major cod stocks in the North Atlantic that changes in size at age are temperature related (Brander, 2007).

The most important predator on cod in the Kattegat in the last decades has presumably been adult cod foraging on juvenile cod. As other predator species such as whiting, pollack and haddock have declined as much as cod or even more, there are no other likely piscivore candidates. Due to the decline of the cod stock, natural mortality is considered to have possibly decreased since 1980s. Increasing harbour seal populations during the last decades, partly coinciding in time with decline of the cod stock, could to some extent have led to increased natural mortality of juvenile cod. Adult cod feed on herring and tagging studies using data storage tags clearly indicate an active, almost semi-pelagic feeding behaviour at least for cod bigger than 40 cm (Svedäng unpubl. data). There are no indications that cod in the Kattegat is experiencing food limitation as the growth patterns in both the Kattegat and in the adjacent Öresund are very similar, although the cod density is much higher in the Öresund than in the Kattegat.

B. Data

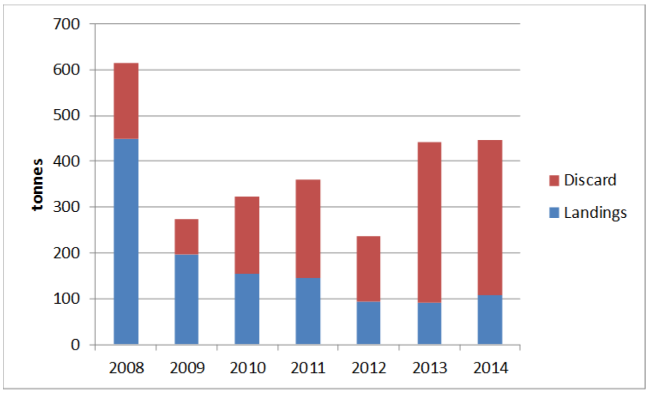
B.1. Commercial catch

Landings

The landings statistics are considered unreliable from the period 1991 and up to 1994. During this period, a considerable amount of the catches were possibly not reported or mis-reported by area or species. The control and enforcement measures have been tightened considerably since the late 1994. Since 2000–2001, the ration sizes in the Kattegat were reduced substantially and the rations in the Kattegat were lower compared to adjacent areas, giving incentives for misreporting of catches by area (Hovgård, 2006). Kattegat cod stock is currently subject to stringent management measures and one obvious consequence can be a serious decline in the quality of catch data due to misreporting and discarding. In 2006–2007, a substantial change was observed in size composition of Danish cod landings. The proportion of small cod (sorting category 5) in landings has historically varied between 30 and 50 percent, but fell below 10 percent in 2007. As a consequence the proportion of larger cod in landings increased. This can possibly be an indication of high-grading. In 2011, in the Danish data the proportion of small cod in the landings was higher in the trips with observers onboard compared to the trips without observes onboard.

Discard

Discard estimates are available from Sweden for 1997–2011 and from Denmark for 2000–2011. Estimated discard weights and numbers indicate that, in recent years, the amount cod discarded exceeds the amount landed (Figure 3).



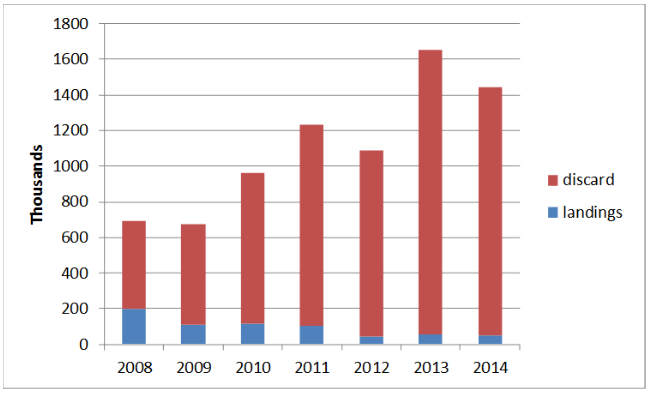


Figure 3 showing composition of cod catches in weight and numbers.

The discard data indicates that discarding mostly affects cod at ages 1-2. If discarding of larger fish also occurs due to high-grading, it is unlikely to be revealed by incidentally having observers on board. Swedish fisheries were during the period of 2003–2007 characterized by long periods with prohibition to land cod in order to not overshoot the quota. This resulted in substantial discarding of cod of older age classes.

Discard data, has historically not been included in the assessment due to large uncertainties in the provided estimates. Discard estimates were only used in exploratory runs during benchmark workshop in 2009. This is mainly due to uncertainty in the estimation of Danish discards, which is related to a low sampling level, high variability in discard rates and the calculation procedures that until 2009 were averaging discard rates over four years. Effort in Danish discard sampling have however increased in recent year. In 2011 discards were included in one of the assessment runs.

Discard samplings by Denmark and Sweden have been conducted since 1995. Considering the fact that many different fisheries are taking place in the Kattegat, it has been difficult to allocate sufficient sampling effort in order to estimate reliable discard rates. In addition, bias in selection of fishing vessels may have occurred as large parts of the Swedish fishing fleet in the Kattegat from time to time have refused to admit sampling officers onboard. The sampling strategy during the first years of the sampling period was to get an overview of the discard rates in all fisheries and then in the later years the sampling effort was concentrated on the fisheries where the highest discard rates were demonstrated. The fishery, which in the later years has been sampled most intensively, is the *Nephrops* fishery, which generally has demonstrated high discards rates.

The sampling procedure differs somewhat between Denmark and Sweden which could not be handled in a common estimation process. The discard estimation is therefore conducted independently by the two countries.

Danish discard numbers were calculated separately for Danish seines and demersal trawls with mesh size >90 mm for 2004–2006. For 2000–2003 discards were calculated additionally for trawls with mesh size 70–89 mm, however fishery with this mesh size has basically disappeared after 2003. No discard estimation was conducted for gill-net fishery, however discarding in this part of the fishery is considered to be of relatively little importance. Due to low sampling level and high variability in discard rates, samples from four years for a given quarter were pooled in order to stabilize the estimates of discard rates. Average discard rates based on samples from 2000–2003 were applied for these years. From 2004 onwards, running mean over four years was applied. The discards during the sampling trips were raised to the level of a fishery based on landings of all species in this particular fishery in a given year. From 2008 onwards the annual discard numbers are calculated based on data for a particular year only.

Swedish discard numbers were until 2007 calculated separately for cod bottom trawl fishery and *Nephrops* fishery. The hauls in log-books with more than 10% *Nephrops* were included as *Nephrops* fishery and the rest was included as fishery with cod bottom trawls. The 10% limit was defined based on the landing structure observed during discard sampling tours, when fishermen defined it as a fishery after *Nephrops* or cod. The discards from samplings of *Nephrops* and cod bottom trawl fisheries were raised to the level of total fisheries with the landings of *Nephrops* and cod, respectively:

During 2006 and 2007, after serious reductions in the cod directed fishery, all bottom trawls were sampled within one stratum. The discards from the sampling were raised to the level of total fisheries using the landings of a group of target species (*Nephrops*, cod, plaice and sole).

$$\frac{Nephrops, cod, plaice, sole\_landed(fishery)}{Nephrops, cod, plaice, sole\_landed(samples)} = \frac{cod\_discarded(fishery)}{cod\_discarded(samples)}$$

Swedish fisheries were during the period of 2003–2007 characterized by long periods with prohibition to land cod and considerable amount of discarded cod above MLS. During these years samples from discard trips taking place within periods of "cod stops" were raised independently from samples taken when it was allowed to land cod.

In 2008 the Swedish *Nephrops* fisheries with sorting grids started to increase in Kattegat. From 2008 and onwards, this fishery has been sampled within a separate stratum. Data from this fishery has been raised using landings of *Nephrops*.

Samples from 1997–1999 and 2000–2002 were pooled while estimating discard rates in these time periods, respectively. In calculation of annual discards for the years 2003–2005, data for some quarters were borrowed from other years inside of this period. In the last years it has been prohibited to land cod at certain periods of a year. Since this has an effect on the discard pattern, the discard rising for these periods was conducted separately.

No discards samples from Swedish fisheries are available for passive gears.

Landings in numbers and weight at age in the landings

Information about quarterly landings composition and mean weight by age was made available from Danish and Swedish sampling on board commercial vessels and in ports. For each country, the annual mean weights by age were derived by weighing the quarterly mean weight by the respective landings in numbers.

Landings in tons and in numbers at age and weight at age in the landings are up to the national level compiled by the national institutes. Data are in this stage nationally aggregated to quarter, sub-division and gear type (active, passive) even though the sampling in each country often is stratified on several fisheries (metiers). Not all landings strata have matching biological information and biological information must therefore be extrapolated from other Subdivisions, quarters or fisheries. On the national level, data extrapolations of biological data are only done for strata for which additional biological information from other countries are not relevant. If additional biological information from other countries are relevant, only total landings in tons are given. The national data are submitted to the data coordinator in a fixed EXCEL sheet format. The national data sheets are aggregated to stock level by quarter and Subdivision. The remaining extrapolations of age distributions and mean weight at age are made by applying the compiled data based on the countries which have performed sampling in the strata. All data extrapolations are logged for later documentation.

B.2. Biological data

Weight at age

The data on the stock weights for age-groups 1–3 were based on the Swedish IBTS 1st quarter survey, whereas the weights at age 4-6+ were set equal to the catch mean weights at age. Mean weight at age in the stock based on IBTS data is currently calculated by Swedish Institute of Marine research.

Maturity ogives

The time series of maturity ogives is based on the macroscopic analysis of the gonads collected on board of the Swedish RV "Argos", during the 1st quarter of the IBTS in the Kattegat. The maturity index is currently calculated by the Swedish Institute of Marine Research.

From 1991 until 2006, the IBTS maturity data for gadoids have been recorded using the ICES 4-stages scale. According to this scale, only individuals assigned to the first stage are considered immature (juveniles) and therefore have to be excluded from the calculation of the spawning biomass. The second stage should include all the maturing individuals that are going to finalize their maturation by the forthcoming spawning season. The third stage, i.e. spawning, includes only individuals which are expelling eggs when captured. The last stage, i.e. spent, comprises the individuals that have recently released all the eggs, but also specimens that have already entered a post-spawning condition (resting stage). All the stages from the second and upwards are therefore considered to contribute to the annual reproductive potential of the stock and consequently included as mature in the estimations of the maturity ogives. However, variation in the spawners' condition can impact fecundity and viability of eggs and larvae, or even cause spawning omission the given year (Rideout *et al.*, 2005 and references therein). A large interannual variability in food abundance has an obvious effect on the fish condition and will give a high annual variation in the skip of spawning (Marshall *et al.,* 2003). The 4–stages scale maturity key does not allow classifying and giving an appropriate code to those individuals.

From 2007, an 8-stages maturity scale has been introduced on a national (Swedish) level during the IBTS survey in Kattegat and successively converted into the international conventionally approved staging system before being reported to ICES. This maturity scale facilitates more detailed classification of maturity stages and allows distinguishing specimens that are sexually mature but are skipping spawning in a given year, and thus must be excluded from the SSB. This implies that maturity data refers to spawning probability rather than a maturity ogive taking into account that all mature fish are not part of the spawning stock. Using only the proportion of fish that will spawn as a basis for the assessment improves the accuracy of the SSB estimate as an index of the egg production for determinate spawners (ICES, 2007).

During the Workshop on Sexual Maturity Staging of Cod, Whiting, Haddock and Saithe in 2007 a new improved international maturity scale has been proposed. The newly introduced common scale includes 6 stages (1 Juvenile/Immature, 2 Maturing, 3 Spawning, 4 Spent, 5 Resting/Skip of spawning and 6 Abnormal) and will be implemented from 2009.

The advantages deriving from the use of this new scale are to be found not only in the identification of individuals omitting spawning but also in the recognition and consequent exclusion from the SSB of individuals suffering from gonadal malformations.

This improvement in maturity scale for macroscopic analyses is expected to improve the accuracy of estimation of spawning proportion of the stock. However, a three years histological study of Kattegat cod gonads (Vitale *et al*., 2005, 2006) has shown that the macroscopic analysis overestimates the proportion of mature females for all age classes, but especially for first spawners. Histological analyses are generally considered to provide more accurate information on maturity ogives compared to visual inspection. Histological analyses are however laborious and costly and therefore difficult to conduct on a routine basis. Gonadosomatic and hepatosomatic indices may serve as robust proxies for distinguishing between mature and immature females and could greatly enhance the accuracy of macroscopic maturity evaluation of cod gonads when histological analyse are not available (Vitale *et al*., 2006). Furthermore the record of the hepatosomatic index on a routine base, also during the third quarter of the year, may be used as a bioindicator, allowing tracing the energetic condition of the stock. Therefore, recording gonad and liver weight of cod on a regular basis on research surveys is recommended.

Natural mortality

A constant natural mortality of 0.2 was assumed for all ages and years.

B.3. Surveys

Survey data were available from the IBTS 1st and 3rd quarter surveys (Swedish R/V Argos) and from the Danish Kattegat Bottom trawl 1st and 4th quarter surveys (Danish R/V Havfisken)

From 2015 and onwards another survey was included in the assessment the Cod survey 4th quarter (2008-2014) a survey with large spatial coverage, using fishing vessels with a standardized trawl. Distribution area on the surveys is shown on Figure 2 a.

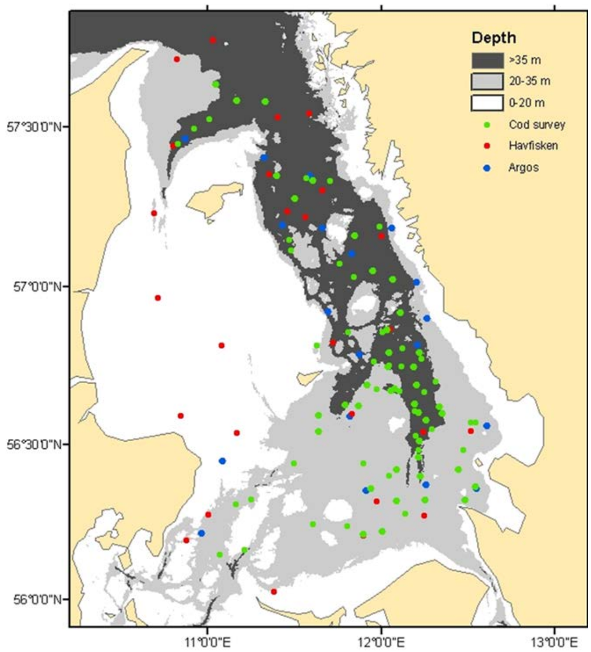


Figure 2. Spatial coverage of IBTS and Havfisken surveys and the Cod survey (based on example of the 1st quarter For IBTS and Havfisken and on 4th Quarter for Cod sut´rvey

IBTS 1st and 3rd quarter surveys:

The IBTS tuning indices are produced by ICES from DATRAS database. The indices are derived from arithmetic mean value over ICES rectangles, not weighed by the area of the rectangle. Age distribution of the IBTS 1st quarter survey indices for the years before 1996 are based on a combination of commercial age-length keys and modal separation for the fish below commercial sizes (Hovgård, 1995).

IBTS 1st quarter data for assessment year was available for the WG and the newest information from this survey was included in the assessment.

"Havfisken" 1st and 4th quarter surveys:

The indices from "Havfisken" surveys are calculated by DTU-Aqua using national database. The indices are calculated as a mean over all stations. The procedure for filling in missing age information is the following:

At first, length distribution data are merged with annual available ALKs, separately for the 1st and 4th quarter surveys. When no age information in ALK is found for a given length-group, then:

if the length of the fish <15 cm then

in the 1st quarter the age is set to 1

in the 4th quarter the age is set to 0

-if no match is found,

use the age information for 1cm smaller fish than itself

- if no match is found,

use the age information for 1cm larger fish than itself

-if no match is found,

use the age information for 2 cm smaller fish than itself

-if no match is found,

use the age information for 2 cm larger fish than itself

-if no match is found,

use the age information for 3 cm smaller fish than itself

-if no match is found,

use the age information for 3cm larger fish than itself

-if no match is found

use the age information for a given length using the average ALK for all year combined, separately by 1 st and 4th quarter surveys

-if no match is still found,

if the length of the fish >= 60 cm and < 70 cm the age is set to 4 and if the length > 70 cm the age is set to 5

As no age information is available for the 4th quarter survey in 1994 in the Kattegat, the average ALK for the years 1995–2000 is at first applied. For filling in the still missing age information, the general procedure is applied, as described above.

"Havfisken" survey in the 1st quarter takes place later in a year than IBTS 1st quarter survey, and indices for the assessment year were not available for the WG. Therefore, In contrast to IBTS 1st quarter survey where the data for assessment year was included, the latest year included for "Havfisken" surveys corresponds to the last data year.

The numbers of valid stations from all available surveys included in calculation of tuning indices are shown in the table below:

"Cod survey 4th quarter:

Calculation of biomass and abundance indices for the cod survey was based on the stratified random design, assuming sampling with replacement. Mean weights and age at length was estimated from Swedish samples only. From 2013 the survey area contained 120 5×5 Nm squares, but for consistency the total biomass was estimated for 119 squares throughout the period. All calculations were carried out in R, using the R-survey package.

YEAR	IBTS	IBTS	HAVFISKEN	HAVFISKEN	COD SURVEY
	Q1	Q3	Q1	Q4	Q4
1983	13				
1984	14				
1985	11				
1986	15				
1987	16				
1988	17				
1989	19				
1990	21				
1991	15	23			
1992	22	23			
1993	22	22			
1994	22	22		25	
1995	22	24		20	
1996	22	22	24	20	
1997	18	16	21	28	
1998	18	19		17	
1999	19	19	25	26	
2000	19		25	17	
2001	19	19	25	17	
2002	19	19	25	26	
2003	19	19	26	26	
2004	19	19	26	25	
2005	19	19	26	26	
2006	19	19	27	26	
2007	19	19	26	28	
2008	19	19	27	26	80
2009	19	19	25	22	80
2010	18	19	26 2	26	80
2011	16	19	26	27	80
2012	19	19	27	27	
2013	19	19	26	27	80
2014	19	19	26	27	80
2015	19		26		

The quality of survey indices was evaluated by internal consistency (numbers at age plotted against numbers at age+1 of the same cohort in the following year) and between surveys consistency analyses. Based on these analyses, older age-groups that have been caught in very few numbers (often 0-values) and show know consistency with younger age-groups were excluded from the assessment. The final selection of age-groups is presented in the subsequent section.

C. Historical Stock Development

Assessment model: stochastic state-space model SAM (Nielsen, 2008; 2009).

The model was run using web interface that can be viewed at www.kcod.stockassess-ment.org

Details concerning input data and model configuration can be found on this webpage. Some model configurations chosen are specified below:

Model Options chosen:

Fishing mortality at age is assumed constant for ages 4+

First age of catchability independent of stock size = 1

Variance parameter is estimated separately for age 1 (in landings and in all surveys) and for ages 2+

Catchability independent of age for ages >= 4

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to yearYes/No
Caton	Landings in tonnes	1971 – last data year	1-6+	Yes
Canum	Landings at age in numbers	1971 – last data year	1-6+	Yes
Weca	Weight at age in the commercial landings	1971 – last data year	1-6+	Yes/No – constant from 1971-1977
West	Weight at age of the spawning stock at spawning time.	1971 – last data year	1-6+	Yes/No – constant from 1971-1977
Mprop	Proportion of natural mortality before spawning	1971 – last data year	1-6+	No – set 0 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1971 – last data year	1-6+	No – set 0 for all ages in all years
Matprop	Proportion mature at age	1971 – last data year	1-6+	Yes/No – constant from 1971-1990
Natmor	Natural mortality	1971 – last data year	1-6+	No – set 0.2 for all ages in all years

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	IBTS 3Q	1991-2011	1-4
Tuning fleet 2	IBTS 1Q	1983-2012, (excl. 1994)	1-6
Tuning fleet 3	Havfisken 1Q	1996-2012	1-3
Tuning fleet 4	Havfisken 4Q	1994-2011	1-3
Tuning fleet 5	Cod survey	2008-2014 (excl 2012)	1-6

D. Short-Term Projection

Short -term prediction was not conducted due to uncertainty in estimates for recent years.

E. Medium-Term Projections

F. Long-Term Projections

G. Biological Reference Points

The precautionary approach reference points defined in 1999 were: Blim=6400 tons, Bpa=10500 tons, Fpa=0.6, Flim=1.0. Technical basis for these values is given in the following table:

	Type	Value	Technical basis
Precautionary approach	Blim	6 400 t	lowest observed SSB before the late 1990s
	Bpa	10 500 t	Blim*exp(1.645*0.3)
	Flim	1.0	The spawning stock has declined steadily since the early 1970s at fishing mortality rates averaging F = 1.0. Flim is tentatively set equal to F = 1.0.
	Fpa	0.6	Flim*exp(-1.645*0.3)
Targets	Fmgt	0.4	

The S-R relationship has been previously analysed and the change point in recruitment estimated from segment regression has been found unrealistic, because it is close to the highest observed biomass. It has also been also pointed out that establishing meaningful stock-recruitment relationship for this stock is difficult due to inflow of recruits from adjacent areas (Cardinale and Svedäng, 2004). Therefore, current stock-recruitment data are considered uninformative of change level in recruitment.

The exploitation level has been considered high for most of the time series and around 1.0 or higher in the latest two decades. Such a high level of F has proved to be unsustainable. The F_{lim} at 1.0 is therefore considered invalid. As the estimation of F_{pa} is linked to F_{lim}, F_{pa} is invalidated as well.

During the benchmark in 2009, F_{01} and F_{max} from yield per recruit analysis (Figure 3) were estimated at 0.22 and 0.43, respectively. F 35% SPR was estimated at 0.26.

Suggested reference points by the Benchmark workshop in 2009:

	Type	Value	Technical basis
Precautionary approach	Blim	6 400 t	lowest observed SSB where recruitment was not impaired
	Bpa	10 500 t	Blim*exp(1.645*0.3)
	Flim	Not defined	
	Fpa	Not defined	
Potential targets	Fmax	0.43	Y/R analysis
	F0.1	0.22	Y/R analysis
	F35%SPR	0.26	Y/R analysis

Due to uncertainties in the current assessment, especially in the level of F, applicability of reference points is at present limited.

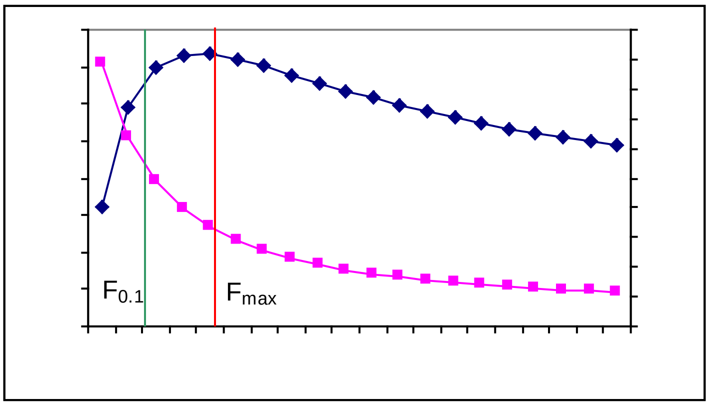


Figure 3. Yield per recruit curve indicating F_{max} and $F_{0.1}$

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