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

Stock specific documentation of standard assessment procedures used by ICES.

Stock: Cod (*Gadus morhua*) in Subdivision 21 (Kattegat), cod.27.21

Working Group: Baltic Fisheries Assessment Working Group (WGBFAS)

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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 (Nielsen *et al.* 2003; Berg *et al.* 2015; André *et al.* 2016). André *et al.* (2016) suggested that 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 reference fish samples 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. Recently, an extensive genetic survey used the regional baseline groups "North Sea" (composed of individuals collected at spawning time in the North Sea) and "Kattegat" (composed of individuals collected at spawning time in the Kattegat (SD21), western Baltic (SD22) and Öresund (SD23), and a high-powered genetic tool to deterine the population of origin of 1800 cod collected in Kattegat between 1996 and 2016, with the majority of samples from the most recent years (ICES WKBALT 2017; Annex 3.1). This work confirmed temporal stability of baseline groups and the presence of North Sea cod in the Kattegat. Very limited data from outside the Kattegat suggested that Kattegat fish may also be present in the Skagerrak Moreover, there were clear north-south gradients in mixing proportions with higher proportions on North Sea fish in the northern parts of the Kattegat (Figure A.1.1; ICES WKBALT 2017; Annex 3.1).

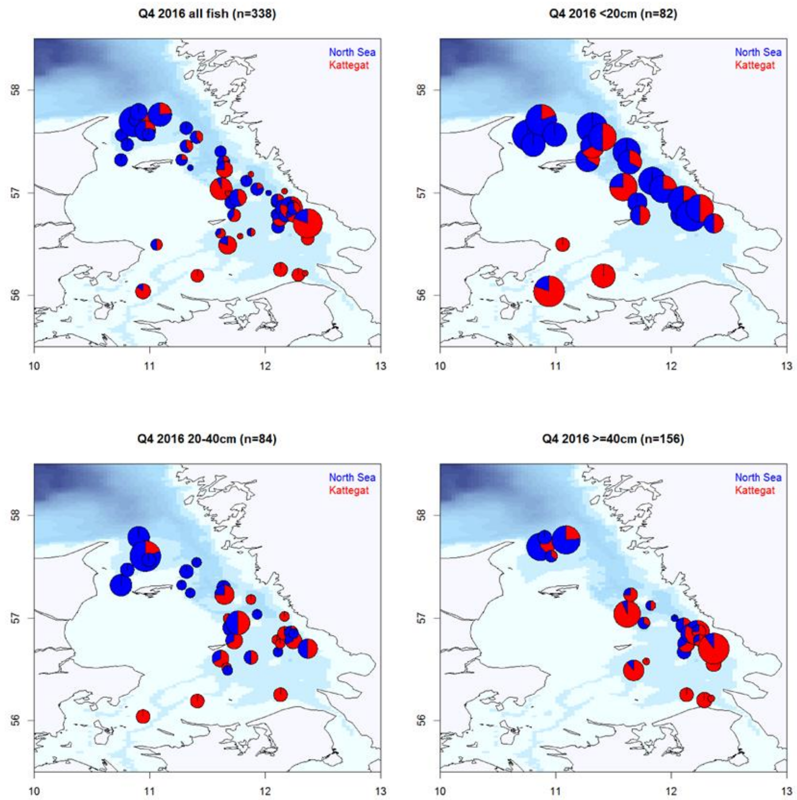

Figure A1.1. Proportions of cod of North Sea (blue) and Kattegat (red) origin in the fourth quarter 2016. See ICES WKBALT 2017; Annex 3.1for coverage of full data series. Size of pie is proportional to samples size.

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 migrations to the North Sea are commonplace (Svedäng and Svenson, 2006; Svedäng *et al.*, 2007). The principal age when most return migration from the Kattegat towards the North Sea seems to take place is hypotheized to be at age 2 to 3 (Svedäng *et al.*, 2007). The hypothesis of return migration to the North Sea is supported by recent genetic data showing that North Sea fish were much more frequent among younger/smaller fish in the Kattegat (Figures A.1.1 and A.1.2; ICES WKBALT 2017; Annex 3.1). As the recent study covered several consecutive years it was possible to examine the mixing proportion at the level of year classes within the Kattegat (ICES WKBALT 2017; Annex 3.1). These data also supported immigration of early life stages followed by return migration at later stages (ICES WKBALT 2017; Annex 3.1), and was particularly evident for a very dominant North Sea cohort in the 2011 year class (Figure A.1.2).

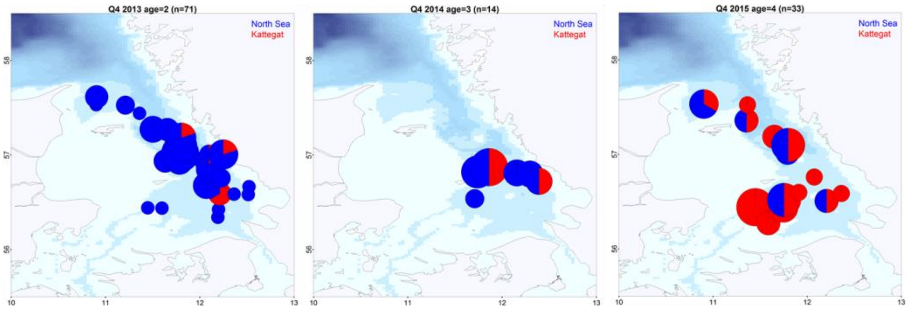

Figure A.1.2. Proportions of cod of North Sea (blue) and Kattegat (red) origin in the 2011 year class sampled as age 2 in 2013 (left), age 3 in 2014 (center) and age 4 in 2015 (right). Size of pie is proportional to sample size.

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. These tagging data are supported by the recent genetic study where fish in spawning condition in the main spawning areas in the southern Kattegat were found to be primarily of local Kattegat origin (ICES WKBALT 2017; Annex 3.1). Thus, tagging and genetic data are in accordance with the hypothesis that recruits from the North Sea will eventually leave the Kattegat and the eastern Skagerrak coast for their natal spawning sites.

Genetic surveys along the Skagerrak coast have shown that the composition of young-of-the-year cod changes 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 assigned to reference populations sampled at spawning in the western part of the Skagerrak or in the eastern North Sea. The genetic data from the recent extensive study (ICES WKBALT 2017; Annex 3.1) confirms 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. In contrast, north of 57º N, the level of recruitment showed interannual variation but no trend during the same time period. The differences in recruitment patterns are probably due to an inflow of recruits from the Skagerrak/ North Sea into the northern Kattegat, whereas south of 57º N the decline in local recruitment has had a much higher impact on juvenile abundance. These patterns are consistent with genetic data showing a north-south gradient in the proportion of North Sea fish. The recent genetic study also found a marked difference between cohorts, for example a very dominant 2011 year class of

North Sea origin (Figure A.1.3). Thus, the mixing may be driven at least partly by independent dynamics in the different populations (ICES WKBALT 2017; Annex 3.1).

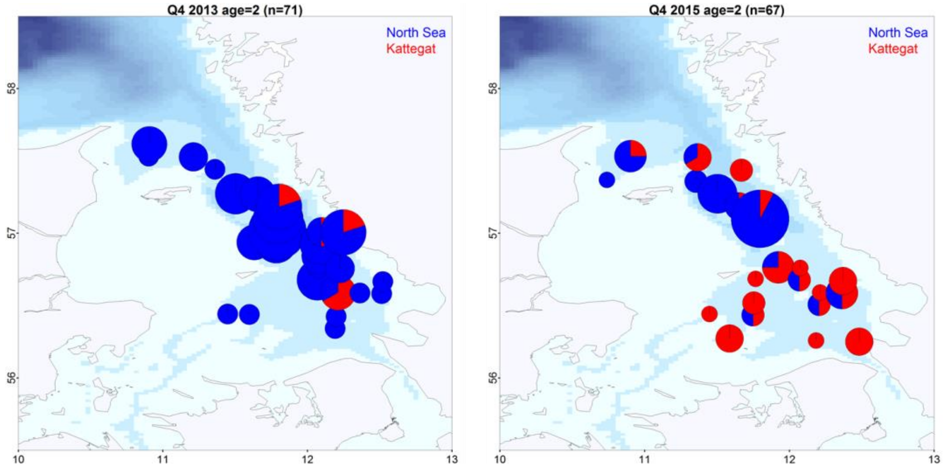

Figure A.1.3. Proportions of cod of North Sea (blue) and Kattegat (red) origin in the 2011 (left) and 2013 (right) year classes. Size of pie is proportional to sample size.

At 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 possible considering the 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 the 1990s and 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). Genetic data has shown that spawning Kattegat fish are concentrated in the southern parts of the Kattegat (ICES WKBALT 2017; Annex 3.1). Several mark-recapture experiments showed 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 declined in the 1990s, spawning cod could be found throughout the Kattegat, though 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), and through egg surveys (Börjesson *et al.* 2013). Data from 1996–2004 indicated that cod catches during the Swedish bottom trawl fishery were came to a large extent from 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 for 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. The geographical distribution of cod eggs was found to be largely consistent with adult cod abundances in the first quarter of the year, although eggs showed a slight shift towards a more southern distribution in some years (Börjesson *et al.* 2013). 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; Börjesson *et al.* 2013). However, the present number of spawning localities in the Kattegat seems 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 have been 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 the 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 those the North Sea/Skagerrak area (Nielsen *et al.* 2003; Berg *et al.* 2015; André *et al.* 2016; ICES WKBALT 2017; Annex 3.1) 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 on these particular grounds albeit some of them might have been abandoned (Vitale *et al.*, 2008; Börjesson *et al.* 2013)
- There are indications of a significant transportation and/or migration of cod early life stages from the North Sea into the Kattegat. 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 geographically along a north-south gradient as well as between years and fish size/age, possibly at least partly as a result of different year class sizes in the different populations

(ICES WKBALT 2017; Annex 3.1). The principal age when most return migration from the Kattegat towards the North Sea seems to take place is hypothesized to be at age 2 to 3, and spawning fish in the Kattegat are primarily of local Kattegat origin.

- 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 however seems separated from the cod stock in the Öresund (SD 23), as there is limited migration between the two areas. The population dynamics in the two areas are also showing considerably deviating patterns.

A.2. Fishery

A.2.1 General description

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 the Kattegat is restricted by effort limitations. The TAC 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 had 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-windows may have had an influence on discarding of small cod, the effect can however not be evaluated with the available data. Since 1st February 2008, the usage of an 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 1 February to 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 (MS) 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 set 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 the cod stock in the Kattegat, Denmark and Sweden, introduced protected areas on historically important spawning grounds. The protected zone consists of three different areas in the 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 A.2.1).

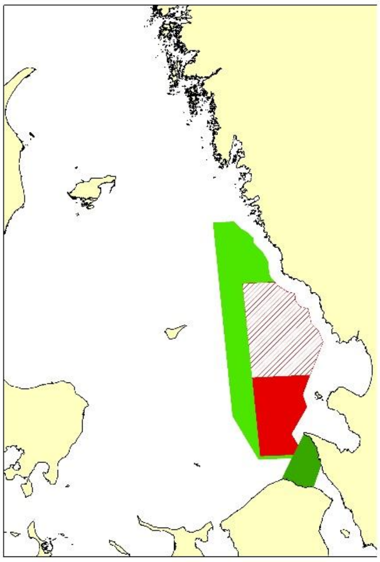

Figure A.2.1. Protection zones for Cod in the Kattegat. The red zone is closed for all fisheries the whole year. The red striped area, all fisheries are forbidden between 1 January to 31 March, from 1 April to 31 December only selective gears are allowed. In the light green area, only selective gears are allowed from 1 January to 31 March, while from April to the end of December the area is open for all gears. In the dark green Area only selective gears are allowed from 1 February to 31 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. 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 at 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 at 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; 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 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).

A.2.2 Fishery management regulations

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 regulate recruitment. Especially in the northern part of the Kattegat, most of the youngof-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 years between 1987 and 2003. Growth was clearly found 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 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 fish 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 due to fish predation is considered to have possibly decreased since 1980s.

The increasing harbour seal population since 2000s has likely increased natural mortality of cod, though the available data on seal diet composition is still too limited to quantify the resulting predation mortality (WKBALT 2017).

Adult cod feed on herring and tagging studies using data storage tags clearly indicated 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

B.1.1 Landings data

The landings statistics are considered unreliable between 1991 and 1994. During this period, a considerable amount of the catches was possibly not reported or mis-reported by area or species. The control and enforcement measures have been tightened considerably since 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 mis-reporting 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 could 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.

Landings in numbers and weight-at-age in the landings

Information about quarterly landings composition and mean weight-at-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 at this stage nationally aggregated to quarter, sub-division and gear type (active, passive) even though the sampling in each country often is stratified by 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 appropriate. If additional biological information from other countries are not appropriate, only total landings in tons are given. The national data are submitted to Intercatch and to the Stock coordinator. 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 base to the countries which have performed sampling in the strata. All data extrapolations are logged for documentation.

B.1.1.1 Country XX landings

B.1.1.1.1 Data coverage and quality

B.1.1.2 Country ZZ landings

B.1.1.2.1 Data coverage and quality

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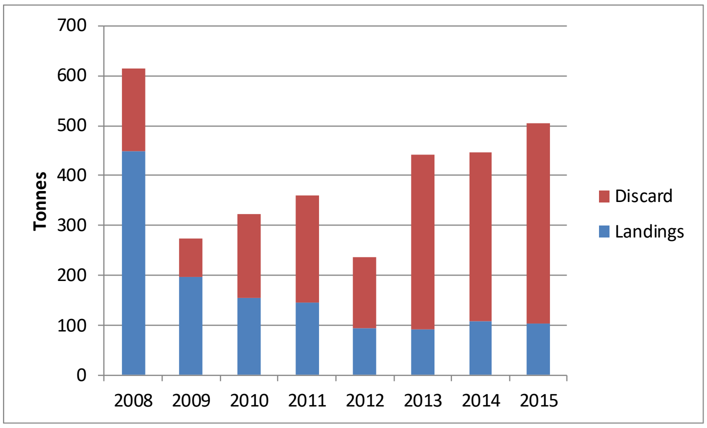
B.1.2 Discards estimates

Discard estimates are available from Sweden since 1997 and from Denmark since 2000. Estimated discard weights and numbers indicate that, in recent years, the amount cod discarded exceeds the amount landed (Figure B.1.1). Numbers-at-age in the discards are calculated using an age-length key. The age-length key is constructed from fish aggregated quarterly from both strata and the numbers and mean weight-at-age by fishery are derived by applying length distributions from each fishery to the ALK. The total discard weight by quarter is derived from the numbers-at-age and the mean weights-by-age (the sum of products from numbers and mean weights).



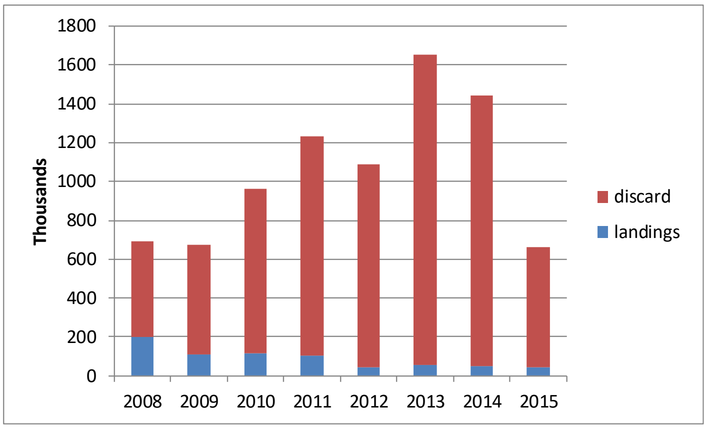


Figure 3 showing composition of cod catches in weight (top) and numbers (bottom).

The discard data indicate that discarding mostly affects cod at ages 1-2. If discarding of larger fish also occurs due to high-grading, it is questionable whether this is to be revealed by incidentally having observers on board. However, analyses of species and size distribution of Danish catches by vessels with observers oboard compared to other vessels did not reveal substantial bias in the discard estimates in most recent years (analyses done on 2015 data) (WKBALT 2017).

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 sampling 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 handle the data in a common estimation process. The discard estimation is therefore conducted independently by the two countries.

In Denmark, the sampling design of the discard sampling program in the Kattegat has changed over time. Before 2000, the design is unknown and a very large part of the sampled discard trips were conducted on gillnetters although the main part of the landings came from the trawlers. From 2000 to 2009 the sampling design was a ”quota sampling”, where a fixed numbers of trips were conducted every year in the fisheries considered having most discard problems with the sampling effort distributed by quarters and fleet. In 2010 the design changed to a probability based sampling with a random draw list including a selected part of the active fleet.

At the benchmark meeting in 2017 (WKBALT), Danish discard estimates for the entire time series were revised. The estimation method used for the old and the new time series is fundamentally the same. The main differences in the estimation and results are mainly due to the stratification of the samples in the estimation. The discarded amount is estimated with a ratio estimator – using landings of all species as raising factor. Total number and number per length class of discarded cod are calculated by pooling the sampled hauls and thereby weighting the samples by the amount of discarded cod in the hauls. The age distribution is calculated with the use of an age-length key (ALK) and mean weight-at-length/ age is also calculated with the use of a weight-(length/ age) key (WLK, WAK). The estimation strata for calculating discarded amounts, numbers and numbers-at-length depend on the number of sampled trips in a particular stratum (year, quarter and fishery). If more than 3 samples were available then a stratification by year, quarter and fishery (métier) was used, if less than 3 samples were available then all samples from a year and fishery were used for that stratum. The stratification of the keys (ALK, WLK and WAK) follows the same rule.

The fisheries (métier (national)) used in the estimation were Danish seines (SDN) and demersal trawls (OTB) with the following mesh size ranges – 70-89, 90-119 and >=120 mm. Gillnets are grouped into the following mesh size ranges – 100-119, 120-219 and >=220 mm. The sampling program in general covers the most important fisheries. The sampling of gillnetters is in general low and often missing, but discarding in this part of the fishery is considered to be of relatively little importance.

Swedish discard numbers were until 2007 calculated separately for the cod bottom trawl fishery and the *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 trips, when fishermen defined it as a fishery targeting *Nephrops* or cod. The discards from sampled trips 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 2003–2007 characterized by long periods with prohibition to land cod and considerable amount of discarded cod above MLS. During these years samples from observed 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 the 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 for 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.

Overall, discards estimates are associated with uncertainties, however the estimated level of dicards is considered to be of reasonable quality from 2011 onwards, and discards are not considered to explain the large fraction of unaccounted removals in the assessment from 2011 onwards (WKBALT 2017).

B.1.2.1 Country XX landings

B.1.2.1.1 Data coverage and quality

B.1.2.2 Country ZZ landings

B.1.2.2.1 Data coverage and quality

…

B 2.3 Recreational catches

B 2.3.1 Country XX data

B 2.3.2 Country ZZ data

….

B.2. Biological sampling

B.2.1Maturity

The time series of maturity ogives is based on the macroscopic analysis of the gonads collected on board of the Danish RV “Dana”, during the 1st quarter of the IBTS in the Kattegat. The maturity index is 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 skip spawning in the given year (Rideout *et al*., 2005 and references therein). A large interannual variability in food abundance has an obvious effect on fish condition and will lead to a large interannual variation in the number of skip spawners (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, since Sweden is the only country doing maturity in Kategatt) level during the IBTS survey in the 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 was implemented from 2009.

The advantages deriving from the use of this new scale are to be found not only in the identification of individuals skipping 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.

B.2.2 Natural mortality

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

B 2.3 Length and age composition of landed and discarded fish in commercial fisheries

B 2.4 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 Q1 data is calculated by Swedish Institute of Marine research.

B.3. Surveys (use the ICES surveys acronym)

Survey data were available from the IBTS 1st and 3rd quarter surveys (Swedish R/V Argos until 2009 , afterwards using the Danish research vessel DANA) and from the Danish Kattegat Bottom trawl 1st quarter surveys (Danish R/V Havfisken), which is part of BITS. BITS 4th quarter survey had been used in the assessment until 2016, but was omitted at WKBALT 2017, due to poor consistency of the data with other data sources.

From 2015 onwards a dedicated cod survey was included in the assessment. The survey takes place in the 4th quarter, with large spatial coverage, using fishing vessels with a standardized trawl. The distribution area of the surveys is shown on Figure B.3.1.

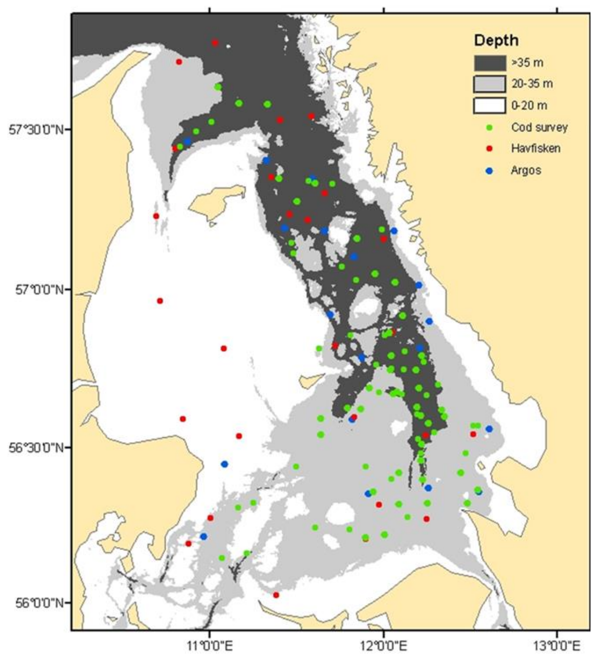


Figure B.3.1. Spatial coverage of the IBTS;,the Havfisken and the Cod survey (based on example of the 1st quarter for IBTS and Havfisken, and 4th Quarter for Cod survey).

The annual number of stations in these surveys in the time period included in the assessment is the following:

IBTS	IBTS	HAVFISKEN	COD SURVEY
Q1	Q3	Q1	Q4
16-19	16-19	21-27	80

The quality of survey indices are evaluated by internal consistency (numbers-at-age a plotted against numbers-at-age a+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 inconsistency with younger age-groups were excluded from the assessment. The final selection of age-groups is presented in the following section.

IBTS 1st and 3rd quarter surveys:

The IBTS tuning indices are produced by ICES from DATRAS database. The indices are derived from arithmetic mean values per ICES rectangles, unweighed by the area of the rectangle.

IBTS 1st quarter data for assessment year is included in the assessment.

"Havfisken" 1st quarter survey

The indices from "Havfisken" Q1 survey are produced by ICES from DATRAS database, and the data from assessment year are included in the assessment, similar to IBTS.

"Cod survey 4th quarter:

Survey design:

The Kattegat cod survey has been carried out since 2008 with the exception of 2012. The survey is a joint effort by Sweden and Denmark with the aim to provide fishery independent data with improved spatial coverage for estimating abundance, biomass, recruitment index and distribution of Kattegat cod. The survey is conducted in November-December.

The bottom-trawl survey follows a stratified random sampling design. From the start the survey area was stratified into three geographic strata based on information from the fishery: (1) a stratum with expected high density of cod, (2) a stratum with medium density and (3) a stratum with low density of cod. In 2010 and 2011 minor re-stratification was done to adapt strata to the catch information collected during the previous years. In 2014 the survey area was partly re-stratified to include a fourth stratum in its south-eastern range to ensure that a sufficient number of samples would be collected from an area closed for fisheries.

The survey is planned with 20 hauls in 6 days for each of the 4 vessels, in total 80 hauls. The sampling frame is a list of 120 5×5 NM squares divided into the four strata. The high density, the medium density and the closed area strata have been allocated relatively more stations than the low density strata. Each vessel fish in 20 different squares allocated to the four strata according to the design. All vessels have the same number of hauls in each stratum. In the high density, the medium density and the closed area strata vessels can get hauls in the same square, i.e, squares are selected with replacement. In the low density areas squares are sampled without replacement, i.e., only one haul can take place in each square. To reduce steaming time, the low density stratum is divided into a northern and a southern part.

Handling of the catch is done by personnel from DTU-AQUA and SLU-AQUA. In each haul, catch and length from all species is recorded but age sampling is only done for cod. The original instructions were to collect two otoliths per cm class and haul, up to five otoliths per cm class and area (North and South). Since then, the instructions for Swedish vessels have been changed to sample more otoliths, and from 2016 otoliths are sampled from all hauls. Samples for genetic analyses have also been collected in 2013, 2105 and 2016.

Estimation:

Data from the survey is stored in national data bases and exchanged between countries using the DATRAS format. The Kattegat cod survey indices are calculated by SLU-AQUA.

Biomass and abundance indices are estimated according to the survey design using the Horwitz-Thompson estimator (τ), where y_i are numbers-at-age in haul *i*, π_i, the inclusion probability of haul i, i.e., the probability that haul *i* is included in the sample

$$\hat{\tau} = \sum_{i=1}^{n} \frac{y_i}{\pi_i} \qquad \text{for the population total}$$

In the low density areas where squares are selected without replacement the inclusion probabilities for individual hauls are calculated as *nh*/*Nh*, where *nh* is the total number of sampled squares in stratum *h* and *Nh* is total number of squares in stratum *h*. In the high and medium density areas and in the closed area where squares are selected with replacement the inclusion probabilities are calculated as 1-(1-*nvh*/*Nh*)^*Nv* where *nvh* is the number of sampled squares per vessel in stratum *h*, *Nh* the total number of squares in stratum *h* and *Nv* is the number of vessels.

B.3.1. Survey design and analysis

B.3.2. Survey data used

B.4. Commercial CPUE

B.5. Other relevant data

C. Assessment: data and method

C.1. Choice of stock assess model

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

The model was run using the web interface that can be viewed at www.kcod.stock-assessment.org

Details concerning input data and model configuration can be found on this webpage.

Model configuration:

C.2. Model used of basis for advice

C.3. Assessment model configuration

Model used:

Software used:

Model Options chosen:

Fishing mortality-at-age is assumed constant for ages 4+ years

First age of catchability independent of stock size = 1 years

Variance parameters ares estimated separately for age 1 (in Catches and in all surveys) and for ages 2+

Common catchability (independent of age) for ages 4+, for younger ages catchability is estimated separately for each age.

Additionally, annual catch multipliers are estimated in SAM model for the years 2003 onwards, which are the same for all age-groups within a year. The multiplier represents unallocated removals that are considered to be related to fisheries, unaccounted natural mortality and migration. Thus the mortality estimates resulting from the assessment represent total mortality (which includes migration) minus the assumed natural mortality, i.e. Z-0.2.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to yearYes/No
Caton	Catch (landings +discards) in tonnes	1997 – last data year	1-6+	Yes
Canum	Catch (landings +discards) at age in numbers	1997 – last data year	1-6+	Yes
Weca	Weight at age in the commercial landings	1997 – last data year	1-6+	Yes
West	Weight at age of the spawning stock at spawning time.	1997 – last data year	1-6+	Yes
Mprop	Proportion of natural mortality before spawning	1997 – last data year	1-6+	No – set 0 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1997 – last data year	1-6+	No – set 0 for all ages in all years
Matprop	Proportion mature at age	1997 – last data year	1-6+	Yes
Natmor	Natural mortality	1997 – 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	1997-last data year	1-4
Tuning fleet 2	IBTS 1Q	1997-last data year	1-6+
Tuning fleet 3	Havfisken 1Q	1997- last data year	1-3
Tuning fleet 4	Cod survey	2008- last data year (excl 2012)	1-6+

D. Short-Term Projection

Short -term predictions are not conducted for this stock due to uncertainties in the estimates for recent years.

Model used:

Software used*:*

Initial stock size:

Maturity:

F and M before spawning:

Weight at age in the stock:

Weight at age in the catch:

Exploitation pattern:

Intermediate year assumptions:

Stock recruitment model used:

Procedures used for splitting projected catches:

E. Medium-Term Projections

Model used:

Software used:

Initial stock size:

Natural mortality:

Maturity:

F and M before spawning:

Weight at age in the stock:

Weight at age in the catch:

Exploitation pattern:

Intermediate year assumptions:

Stock recruitment model used:

Uncertainty models used:

F. Long-Term Projections

Model used:

Software used:

Maturity:

F and M before spawning:

Weight at age in the stock:

Weight at age in the catch:

Exploitation pattern:

Procedures used for splitting projected catches:

G. Biological Reference Points

MSY reference points have not been estimated for the stock due to lack of accepted analytical assessment. Precautionary reference points based on historically accepted analytical assessment were estimated last in 1999, which would need to be revised and updated when analytical assessment becomes available in future. Amongst others, the issue of mixing of North Sea and Kattegat cod within the Kattegat should be considered in defining reference points, which has not been the case in the historical estimates.

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 of the Kategatt stock alone.

The exploitation level has been considered high historically, at the time when reference points were estimated. 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 G.1.) 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.

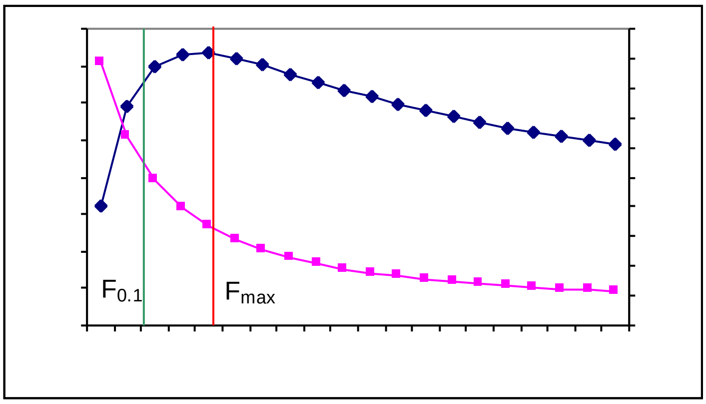


Figure 3. Yield per recruit curve indicating F_{max} and $F_{0.1}$

H. Other Issues

H.1. Biology of species

H.2. Stock dynamics, regulations – historic overview

YEAR (Y)	2007	2008	2009	2010	2011	2012
Assessment Model	ICA model	ICA model	ICA model	ICA model	ICA model	SAM Nielsen et al., 2012
Software						
Catch data range	19-?					1947-Y
CPUE Series 1 (years)	PT-TRF9a (1977-?)					
CPUE Series 2 (years)						
Index of Biomass (years)	PT-TRC9a (1989-2006)					
Error Type	Condition on yield					
Number of bootstrap	500					
Maximum F	8.0 (y-1)					
Statistical weight B1/K	1					
Statistical weight for fisheries	1,1					
B1-ratio (starting guess)	0.5					
MSY (starting guess)	3000 t					
K (starting guess)	20 000 t					
q1 (starting guess)	1d-5					
q2 (starting guess)	1d-4					
q3 (starting guess)						
Estimated parameter	All					
Min and Max allowable MSY	2000 (t) -10000 (t)					
Min and Max K	5000 (t) -500000 (t)					
Random Number Seed	1964185					

Summary of data ranges used in recent assessments:

Data	2006 assessment	2007 assessment	2008 assessment	2009 assessment
Catch data	Years: 1978–(AY-1) Ages: 1–8+	Years: 1978–(AY-1) Ages: 1–8+	Years: 1978–(AY-1) Ages: 1–8+	Years: 1978–(AY-1) Ages: 1–8+
Survey: A_Q1	Years: 1985–AY Ages: 1–7	Years: 1985–AY Ages 1–7	Years: 1985– AY Ages 1–7	Years: 1985– AY Ages 1–7
Survey: B_Q4	Years: 1996–(AY-1) Ages: 1–5	Years: 1996– AY-1) Ages 1–7	Years: 1996– AY-1) Ages 1–7	Years: 1996– AY-1) Ages 1–7
Survey: C	Not used	Not used	Not used	Not used

AY – Assessment year

H.3. Current fisheries

H.4 Management and advice

H.5 Others (e.g. age terminology)

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