English name: **Cod**	Scientific name: ***Gadus morhua***
Taxonomical group: Class: Actinopterygii Order: Gadiformes Family: Gadidae	Species authority: (Linnaeus, 1758)
Subspecies, Variations, Synonyms: –	Generation length: 13,5 (10-19)
Past and current threats (Habitats Directive article 17 codes): Fishery (FO2), Eutrophication (H02.01), Unknown (U)	Future threats (Habitats Directive article 17 codes): Eutrophication (H02.01), Unknown (U), Climate change (M01)
IUCN Criteria: **A2b,c + A4b,c**	**HELCOM Red List Category:** **VU Vulnerable**
Global / European IUCN Red List Category: VU/-	Habitats Directive: –
Previous HELCOM Red List Category (2007): EN	
Protection and Red List status in HELCOM countries: Denmark –/-, Estonia –/NE, Finland –/NA, Germany –/* Not Threatened, Latvia - / -, Lithuania –/–, Poland -/-, Russia –/–, Sweden Protected from fishing during spawning 1st of January to 31st of March in coastal areas in Kattegat. An MPA, with a central no-take zone, was established in southern Kattegat in 2010 with the goal to restore Kattegat cod / EN	

Distribution and status in the Baltic Sea region

Cod occurs in the whole HELCOM area (the Baltic Sea, including the Kattegat) but reproduction is limited to the more saline parts. The cod is managed in three management units: the Eastern stock in ICES subdivisions 25-32, the Western stock (ICES SD 22-24) and the Kattegat stock (ICES SD 21).

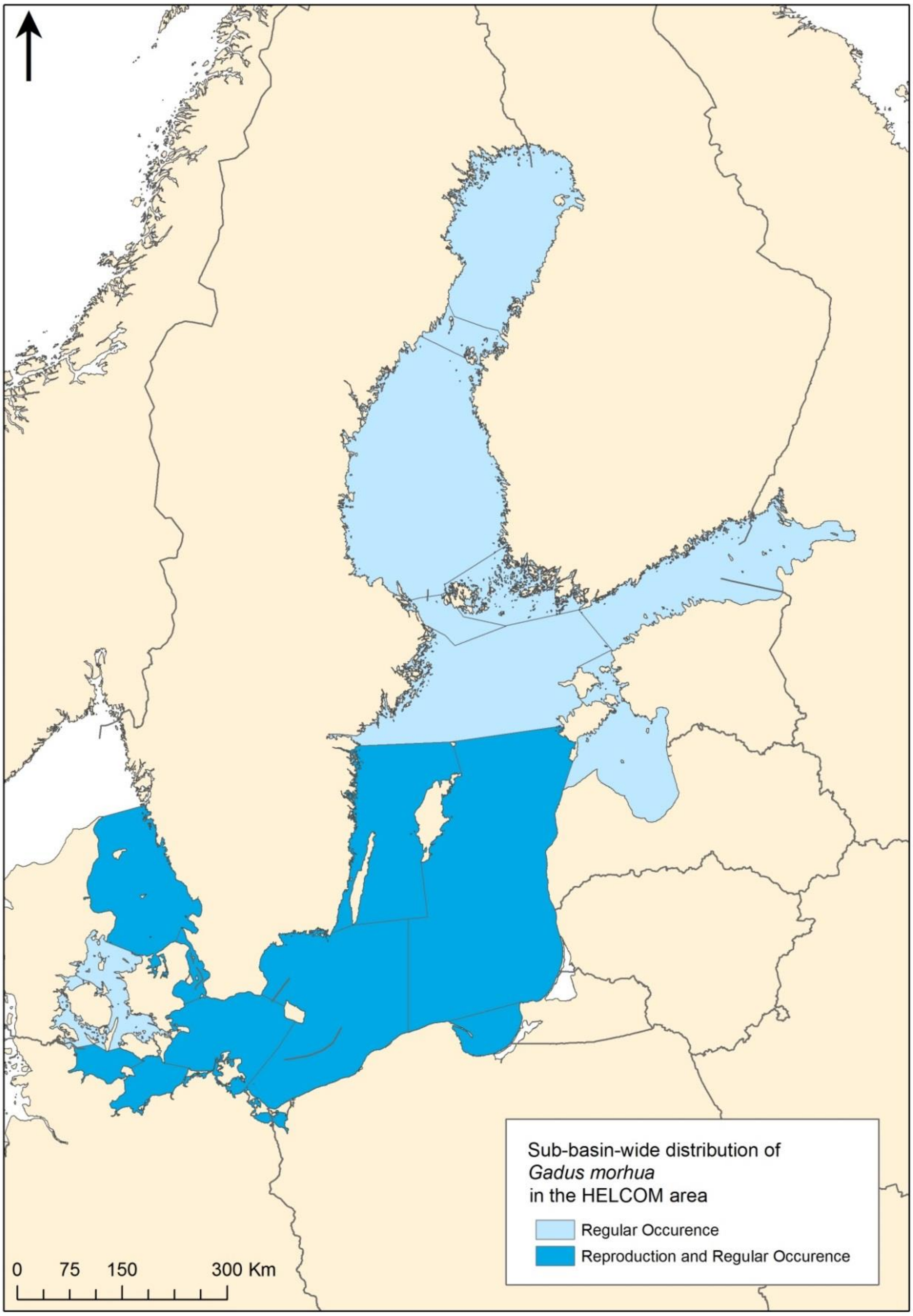
The Eastern Baltic cod makes up the majority of cod in the HELCOM area and the stock has drastically declined since the 1980s. This has been in part due to overfishing but it has also been negatively affected by degradation of spawning areas due to oxygen depletion in the deeper water in the eastern part of the Baltic Sea (ICES 2012b). Recently also a problem with extremely bad physical condition among the cod has been discovered that might jeopardize the recovery of the population (Eero et al 2012a). Fishing is now being managed in the EU management plan adopted in September 2007 (ICES 2012b). Since 2005, there has been an increase in the Eastern cod stock.

The Western Baltic cod stock has been decreasing over the last three generations but the decrease has levelled off since the cod management plan was put into action in September 2007.

The situation for the cod in the Kattegat is critical with a drastic decline in spawning stock biomass (SSB) and also a reduction in number of spawning areas. The main threat is overfishing that has continued over a long time. An EU Management plan was adopted for the Kattegat cod stock in December 2008 (ICES 2012a).

Distribution map

The map shows the sub-basins in the HELCOM area where the species is known to occur regularly and to reproduce (HELCOM 2012a).



Habitat and Ecology

Cod is a demersal, marine coastal fish species occurring in the whole HELCOM area. Reproduction in this marine species is however limited to areas with salinities of >11 PSU. Within the HELCOM area it takes place in coastal areas of the western Baltic Sea and the Kattegat and in the deeper areas in Eastern Gotland Basin, Gdansk basin and Bornholm basin. Due to the special hydrographic conditions of the Baltic Sea, recruitment is impaired in most years. It is dependent on inflows of oxygenated ocean water, i.e. the recruitment success is strongly dependent on salinity and oxygen conditions in the spawning area.

Cod undertake migrations between spawning and feeding areas and have strong homing behaviour resulting in fine-scaled population structure. In the Kattegat, for example, there are resident coastal spawning cod mixing with juveniles originating from the North Sea and the Sound. The latter will however return to their native areas to spawn and will not contribute to the Kattegat stock.

Cod is a predatory fish foraging mainly on small pelagic fishes such as sprat and herring but also juvenile cod.

It spawns during spring in the western Baltic Sea, during summer in the eastern Baltic Sea, and during late winter or early spring in the Kattegat. Eggs and larvae are pelagic.

Maturity is reached at 2-6 years of age and at a size of 31-74 cm. Maximum size recorded is 2m total length and 96 kg and maximum age has been estimated to 40 years.

Photo by Martin Karlsson, Swedish University of Agricultural sciences.

Description of Major threats

Cod has been a commercial and highly appreciated fish species for centuries and fishery has been the major identified threat (ICES 2012a, b). An EU management plan was adopted in September 2007 for the Eastern and Western Baltic cod stocks and in December 2008 for the Kattegat cod. The aim of these management plans is to decrease fisheries pressure and signs of recovery can already be seen in the Eastern Baltic cod.

Another major threat, loss of spawning areas due to oxygen depletion that has been caused by climatologically induced physical changes and eutrophication, has not ceased (Casini 2011, ICES 2012, HELCOM 2013a, b, Hinrichson et al 2011, Figure 1). Instead, it is predicted to increase in the future (HELCOM 2013a, Meier et al 2012). Today oxygen depletion has led to two out of three spawning areas (the Gotland and the Gdansk basins) having ceased to significantly contribute to the reproduction of the Eastern Baltic cod due to oxygen deficiency (ICES 2012b).

The reasons for the poor physical condition of the Eastern Baltic cod stock are unknown and so far unidentified threat factor(s) contribute to the poor physical condition and may do so also in the future (Eero et al 2012a).

Since the reproduction of cod is dependent on high salinity and cod is a cold-water species the predicted changes of the Baltic Sea towards a warmer and less saline status are also a threat towards cod (Gårdmark et al 2013, HELCOM 2013).

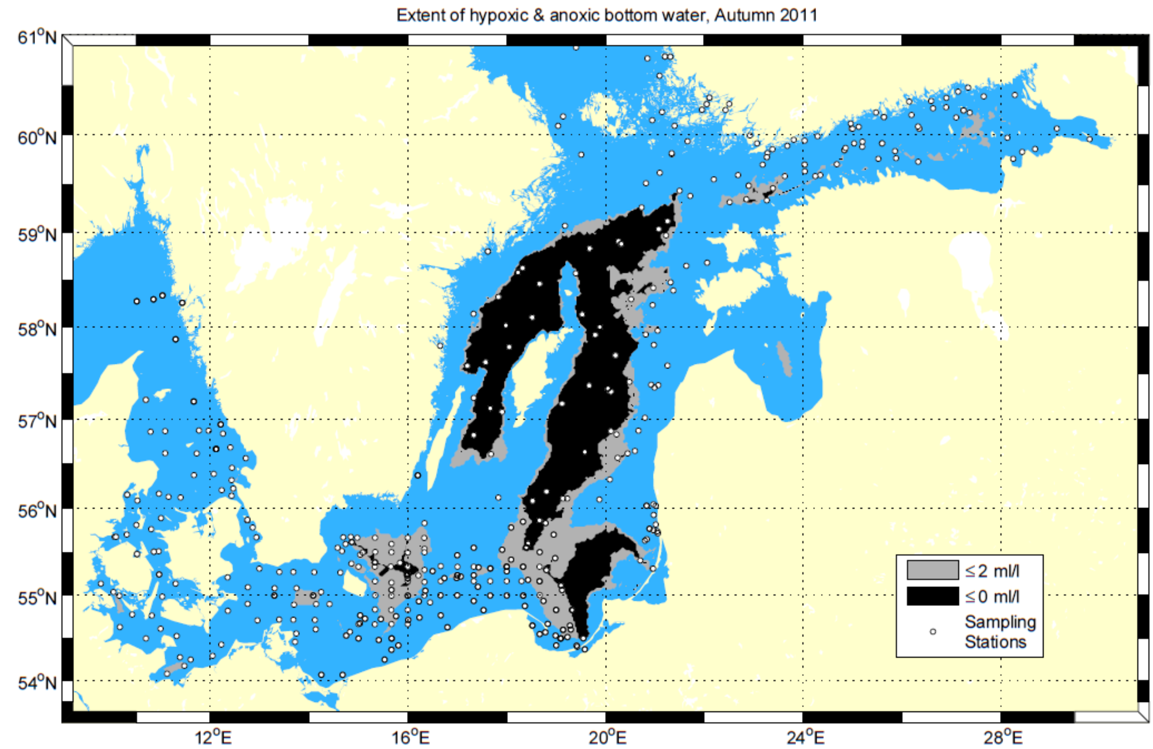


Figure 1. Extent of hypoxic and anoxic bottom water, autumn 2011. From Hansson et al (2012)

Assessment justification

Assessment period

For cod the assumption of higher relative fecundity of older individuals, warranting z=1/3 in the calculation of generation time, is certainly fulfilled. Laboratory experiments on cod have demonstrated that first-time spawners have a lower reproductive success, breeding for a shorter time and producing fewer and smaller eggs with lower fertilization and hatchings rates (Solemdal *et al.*, 1995; Trippel, 1998; Tomkiewicz *et al.*, 2003b). It has also been shown that older/larger cod in the Baltic Sea produce eggs with better quality (Vallin & Nissling 2000) and that big female cod produce larger eggs which have a higher buoyancy, which in turn result in a better survival rate (Cardinale and Arrhenius 2000, Figure 2). Furthermore, in multiple spawning fishes like cod, older individuals are likely to produce more batches, within the spawning season, over a longer period than younger ones (Parrish *et al.*, 1986; Lambert, 1990). In addition, the fertilization rate is higher when bigger males are involved in the spawning act

(Hutchings *et al*., 1999).

Figure 2. In 1987, during the cod boom years, it was possible to hit a school of fish where most of the fish were 15 years old. Photo: Eero Aro.

There are several estimations of age at maturity for cod from different sources. For Atlantic cod age at maturity seem to vary between 2-10 years (Curry- Lindahl 1985, Jonsson & Semb-Johansson 1992) or 3-15 years (Froese & Pauly 2012). According to Muus et al (1999) the migrating cod in the North-East Atlantic mature at 8-12 years while coastal cod at western Norway reach maturity at 4-6 years. Data from older literature probably presenting a more pristine situation gave values of 8-10 years (cited in Pethon 1998). In the Baltic Sea, the range of age at maturity in the 2000s seem to be the same as in the 1960s, i.e. 2-4 years although there has been a shift towards maturing at smaller size and younger ages between the late 1980s and today (Cardinale & Modin 1999, Vainikka et al 2003). From Ojaveer et al (2003) the majority of contemporary cod mature at an age of 3 years although some already at 2 and in the Gulf of Finland maturity is not reached until 4 or 5 years old. Combining these sources gave an estimated average age of maturity for cod in the HELCOM area of 4 years.

In the same way there are different estimates of maximum lifespan of Atlantic cod ranging from 25 years given in Fishbase (Froese & Pauly 2012) to 40 years in several other sources (Curry- Lindahl 1985, Jonsson & Semb-Johansson 1992, Pethon 1998). In the Baltic Sea cod has been shown to be at least 22 years old[1]. Given the same weight for the two different published figures resulted in an estimated maximum life span for cod in the HELCOM area of 32.5. This resulted in a reproductive period of 32.5-4=28.5 years and a generation time of 4 + (28.5/3)=13.5 years, - and hence an assessment period of 3*13.5 = 40.5 years. Initially, the assessment period was therefore decided to be 1971-2011. In this recent update, figures from 2012 have been added due to a request by HELCOM Contracting Parties but the start of the reference period was left the same, i.e. the assessment period used here was 1971-

[1] Investigations of the Institute of Food Safety, Animal Health and Environment "BIOR" Fishery Department, Latvia between 1949 and 2012.

2012. Using the lower estimates of average age of maturity (3 years) and maximum life span (25 years) would result in a generation time of 10.33 and an assessment period of 31 years while using the higher estimates for age at maturity (9 years) and longevity (40 years) would result in a generation time of 19.33 and an assessment period of 58 years.

This uncertainty increases the possibility for the assessment period to start anywhere between 1954 and 1981 but with a higher probability for 1971 according to the rationale presented above. In appliance with the IUCN Guidelines 2011 section 3.2.5 this uncertainty has been included in the documentation of the assessment.

Assessment units

It was decided that assessments will be done for all fish and lamprey species at species level. As a result of the request by HELCOM HABITAT 14/2012, assessments have been made both for the species as a whole and divided in the three assessment units defined by ICES, i.e. Kattegat cod (ICES Subdivision 21), Western Baltic cod (ICES Subdivisions 22-24) and Eastern Baltic cod (ICES Subdivisions 25-32).

In a note from ICES to HELCOM dated 12 September 2013, ICES explains the differences to assessment units between the IUCN and ICES approaches are the following: "*ICES investigates the dynamics of stocks of fish. A stock is a tool for assessment and management. Defining a stock involves both ecological and social aspects (see Reiss et al., 2009). A fish stock does not "exist" unless it is exploited e.g. we have sandeel stocks in the North Sea but not in the Irish Sea, however there are certainly sandeel populations in both seas. So there exists a fundamentally different approach between assessed populations and assessed stocks. IUCN assesses species and also permits regional and national assessments of threats to species (IUCN, 2012). When using fish stock assessment information the differing units of observation, and units for implementation of action, must be reconciled.*"

Data used

As an index for reduction in population size (criterion A1b-A4b) the data for spawning stock biomass (SSB) were taken from the most recent publication of ICES Advice (ICES 2012a,b) as well as the draft report from 2013 (ICES in press).

Another index of reduction in population size is the decline of extent or quality of habitat (A1-4c). For this we have used information on available spawning areas from different publications, and the references are given in the text. The latter is also used in combination with SSB for evaluation of criteria B, C and D.

For both the SSB and reduction of habitat we used five year averages at the beginning of the assessment period (i.e. 1971-1975, 1954-1958 or 1981-1985) in combination with an average of the last five years of available data.

Criterion used

According to the IUCN guidelines all taxa should be tested against all criteria where there is information available. In this assessment, Criterion A – D was used. Due to limited resources, the HELCOM RED LIST team was not able to carry out the Criterion E assessment.

Criterion E is a quantitative analysis of the probability of extinction over the next three generations or 10 years whichever is the longer time. There are some long term predictions available for the future development of the Baltic cod (Meier et al 2012, MacKenzie et al 2011, Gårdmark et al 2013). They show that depending on climate, salinity, seals, eutrophication and fishery, the scenarios are very different - from a positive development to a continued decline. From a multimodel simulation of future development of the Baltic Sea Meier et al (2012) draw the conclusion: “Although cod biomass is mainly controlled by fishing mortality, climate change together with eutrophication may result in a biomass decline during the latter part of this century, even when combined with lower fishing pressure”.

Based on the ICES note to HELCOM dated 12 September 2013, ICES informs that current ICES advice on the three cod stock in the Baltic includes short-time projections of population development through to 2015. “*For cod in Western Baltic Sea (ICES Subdivisions 22–24), if the management plan is adhered to, the SSB will increase by 17% by 2015 and remain above* B_{lim} *and the precautionary buffer. It is estimated that only a sizable increase in TAC2 (>25%) will reduce the projected SSB in 2015. For cod in Eastern Baltic Sea (ICES Subdivisions 25–32), if the management plan is adhered to, the SSB will increase by 15% by 2015 and remain well above* B_{lim} *and the precautionary buffer. Again, it is estimated that only a sizable increase in TAC (>50%) will reduce the projected SSB in 2015.. For cod in Division IIIa East (Kattegat), ICES advises that no directed fishery takes place and bycatch and discards should be minimised. The stock has been below* B_{lim} *since 2000. The lack of any estimates of fishing mortality prevents ICES from making any projections about future stock dynamics of cod in the Kattegat.*”

Choice of criteria A2 instead of A1

Although one of the major threats, fishery, is managed according to EU management plan adopted in September 2007 for the Western and Eastern Baltic cod and in December 2008 for the Kattegat cod, the other major threat identified for cod, i.e. loss of spawning areas due to oxygen depletion, has not ceased (Casini 2011, ICES 2012, HELCOM, 2013b, Hinrichson et al 2011). In fact, oxygen depletion is predicted to continue and get worse in the future (HELCOM 2013a and Meier et al 2012). Hence, Criterion A2 is appropriate for cod. In addition, the factors causing the poor physical condition of the cod in Eastern Baltic stock are still unknown and may well be considered a future threat to the population as well (Eero et al 2012a). SSB is also not the sole predictor for future stock size. For instance, recruitment of Eastern Baltic cod has been shown to be significantly related also to the winter North Atlantic Oscillation index, and the reproductive volume in the Gotland Basin in May (Margonski et al 2011). Hence, the recovery of the Eastern Baltic cod cannot be attributed solely to good fisheries management since also favourable biological conditions are needed (Cardinale & Svedäng 2011 and Eero et al 2012b). In summary, it may be concluded that recovery cannot be guaranteed even when fishery has ceased. The Canadian Atlantic cod has not yet recovered since it collapsed in the early 1990s despite a complete cod fishing ban in offshore waters since 1992 (Hutchings & Rangely, 2011).

The IUCN guidelines for managed stocks state that commercially harvested species should not be downgraded into a lower category due to the existence of management schemes. Successful management in itself will in time guarantee a better status for the species. "*Such listing should not be problematic in the medium to long term because, if the fishery is managed effectively, although it currently exhibits symptoms consistent with endangerment, the population will eventually stabilize at a target level and the decline will end, such that the taxon no longer qualifies for listing. If the declines would continue there would be reasons for concern and the listing would still apply.*" IUCN Guidelines 2011 section 5.5.

Differences between IUCN and ICES assessment approaches for commercial species

The HELCOM RED LIST team, IUCN and ICES worked together during the red listing process to clarify some differing views from conservation and fisheries-linked communities towards assessment of commercial fish species. Upon a request by HELCOM HOD 42/2013, ICES provided a note to HELCOM (dated 12 September 2013) to further explain differences in the approaches. This note states that:

“*ICES and IUCN use different language. Further consideration about the differences between the approaches employed by IUCN and ICES explain that a divergence of approaches has been highlighted by*

Rice and Legace (2007) when they showed that across 89 exploited fish species, the IUCN decline criterion suggested a serious risk-of-extinction in 87% of cases; whereas most of the stocks were within a zone that according to criteria in relevant international commitments allowed exploitation to continue. Rice and Legace (2007) suggested that the disparities were rooted in different approaches to tolerance to risk between fisheries advice and IUCN listing criteria.

Wherever possible ICES sets a minimum biomass limit for a stock (called Blim). When a stock falls below this level, the ICES advice for immediate management action becomes extremely vocal. Blim is defined in a pragmatic manner but generally either reflects the biomass at which scientists think recruitment will begin to be impaired (reduced as a result of the low biomass of adults) or the lowest observed biomass in the time series (this is used when data or knowledge is lacking). Usually a precautionary buffer is added to this Blim threshold to account for uncertainty or noise in the stock assessments. As shown by Rice and Legace (2007) the numbers of individual fish that make up a Blim sized stock are larger by at least a factor of 100 than the trigger for conservation action using the IUCN Absolute Numbers criterion. So in terms of number, the Blim approach of ICES is more precautionary than the IUCN criteria. Especially as Blim is derived for stocks and not for species or amalgamated regional populations of species.

Regarding the approach to precaution and the underlying knowledge base, ICES advice is provided using all available knowledge and scientific understanding at the time. The analysis method to assess the dynamics of the stock does not have precautionarity built in. The precautionary approach is built into the framework for advice accounting for the risks and uncertainties. ICES advice requires the use of the most scientifically robust assessment method."

Overall assessment of cod in the HELCOM area

Decline in spawning stock biomass

For the assessment period between 1971 and 2012, the cod stock in the HELCOM area, covering the whole Baltic Sea and the Kattegat, has decreased by 46% (based on a comparison between the mean value of 1971-1975 and 2008-2012, Figure 3), which merits a VU assessment (more than 30% decrease) under the A2b criterion (decrease in population size indicated by an index).

Using a longer generation time, data is only available for the Eastern Baltic cod stock giving an estimated loss of 41%,.Using a shorter generation time estimate or applying the A4 criteria, using the years after the cod boom (1986-1990) as reference point, and assuming a status quo for the future stock size, results in a decrease of 48%. Both estimates are well above the threshold for VU status. Applying A3 will not lead to any threat categorisation as the decline in the stock gives the impression of having levelled off.

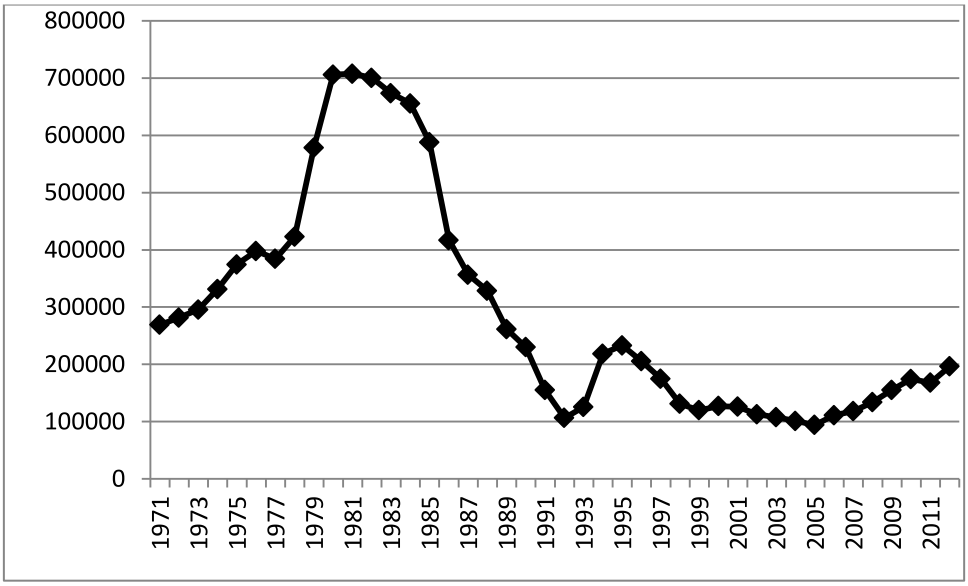


Figure 3. Cod in the Helcom area, total SSB (tonnes) in 1971-2012 for all three stocks assessed.

Decline in habitat quality

Two out of three spawning areas (the Gotland and the Gdansk basins) have ceased to significantly contribute to the reproduction of the Eastern Baltic cod due to oxygen deficiency (ICES 2012b, Figure 4). In addition, important areas which previously served as spawning grounds have been lost in the Kattegat. This implies a considerable reduction in resilience of the whole cod stock in the Helcom area and fulfils the criteria A2c, decrease in habitat quality.

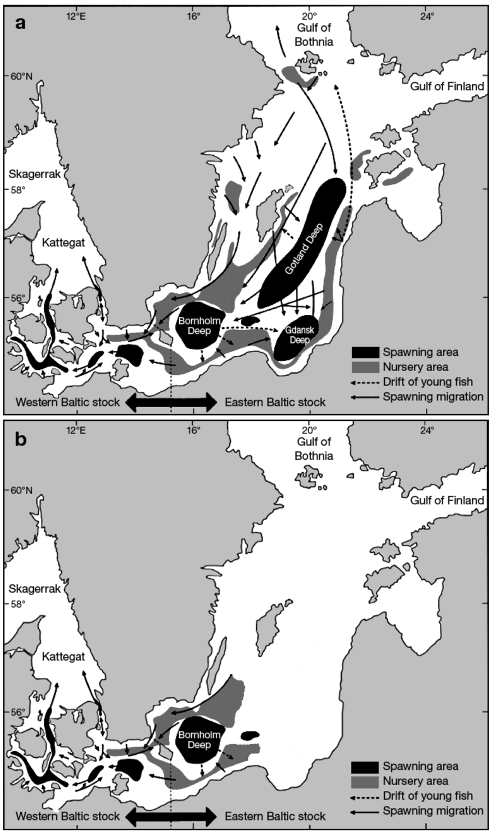


Figure 4. Changes in the historical main spawning areas of cod *Gadus morhua* in the western Baltic, eastern Baltic and Danish Belt Sea (redrawn from Bagge et al. 1994). (a) Cod spawning in the Gotland Deep and Gdansk Deep as it was depicted in the 1980s; (b) cod reproduction still occurs in the Bornholm Deep, but it is nowadays negligible in the Gotland and Gdansk Deeps (from Cadinale & Svedäng 2011).

Using the decrease of spawning areas in the whole HELCOM area based on the HELCOM sub-division into sub-basins (Figure 5), assuming a total loss of spawning area in the Gdansk Basin and the Eastern Gotland Basin, results in a reduction in spawning area of 49% This is probably an overestimation since cod do not use all areas for reproduction.

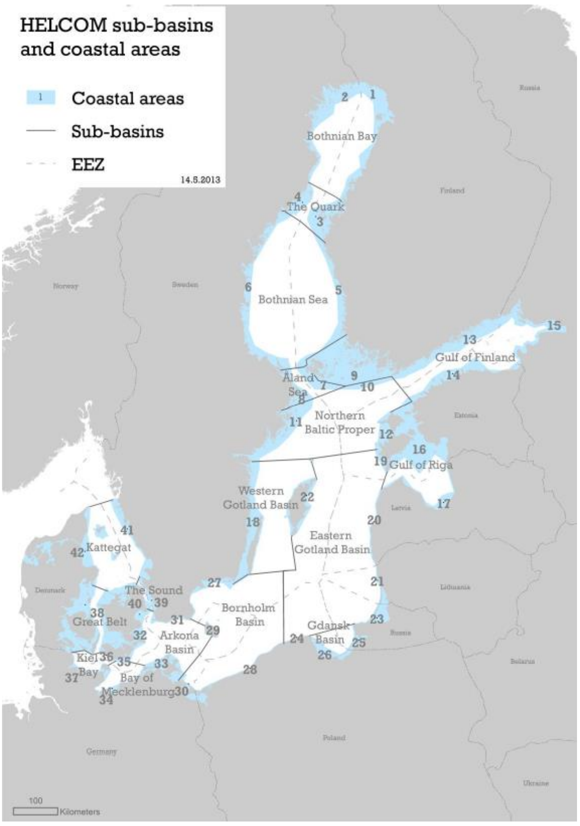


Figure 5. Map of the Baltic Sea presenting the HELCOM sub-division into 17 off-shore sub-basins (white) and 42 coastal areas (blue) as presented in the [HELCOM Monitoring and Assessment Strategy (2013)](). EEZs of the countries are shown with a grey dashed line.

Table 1. HELCOM off-shore sub-basins with potential cod reproduction

HELCOM sub-basins	Area
Eastern Gotland Basin Offshore waters	70749
Gulf of Gdansk Basin Offshore waters	3650
Bornholm Basin Offshore waters	38836
Arkona Basin Offshore waters	13458
Bay of Mecklenburg Offshore waters	3477
Kiel Bight Bay Offshore waters	2716
Great Belt Offshore waters	1944
The Sound Offshore waters	254
Kattegat Offshore waters	15672
Total area:	150756
Total area minus Eastern Gotland Basin and Gdansk Basin:	76357
Decrease in total area:	49%
Area for Eastern Baltic cod (Eastern Gotland Basin + Gdansk Basin+ Bornholm Basin)	113235
Area for Eastern Baltic cod minus Eastern Gotland and Gdansk Basins	38836
Decrease in area for Eastern Baltic cod:	68%

A more conservative estimate of loss of spawning area for the Eastern Baltic cod which is based on loss in reproductive volume (Figure 6) gives a value of 38% for the reduction. As there are additional losses of spawning areas in the Kattegat, the total loss in is between the threshold levels for Vulnerable (30% decrease) and Endangered (50% decrease) resulting in the status VU A2c. Application of A3, projection into the future, will lead to LC status while A4, just as A2, ranges between EN and VU.

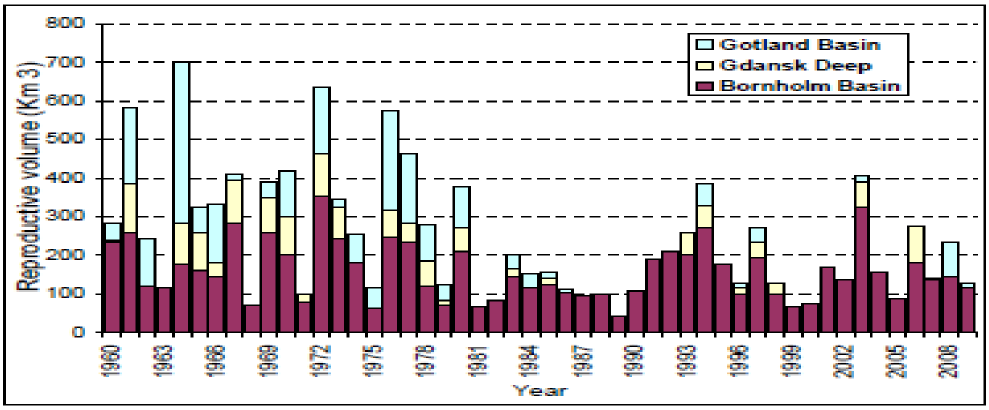


Figure 6: Reproductive volume of the Baltic cod in the main spawning areas. From Casini, 2011.

Criteria B, C and-D

In criterion B, both the extent of occurrence (EOO) and area of occupancy (AOO) of cod are above the threshold for being Near Threatened (<40 000km^2 and < 4000km^2). For criterion C, the number of mature individuals is above 20 000 and the AOO above 40 km^2. Hence cod does not fulfil the criterion C or D.

Regional assessment adjustment

In a regional assessment, the threat category should be downgraded if conspecific populations outside the region are judged to affect the regional extinction risk. For example, immigration from outside the region will tend to decrease extinction risk within the region (IUCN 2011). For cod this is not the case since there is clear evidence for cod in the HELCOM area being separated from North East Atlantic and Skagerrak cod (Nielsen et al 2002, Svedäng et al 2007, 2010b, Neuenfeldt et al 2013). This is also reflected in the separate management units for cod used by ICES (2012a,b).

Conclusion

It is possible that the current positive trend in the Eastern Baltic cod stock will continue as also projected by ICES up to 2015, despite the severe loss of spawning habitat, and in the next evaluation of the RED LIST cod will not fulfill the criteria for being threatened. However, at the moment, following the IUCN guidelines and looking back over the last three generations, cod in the HELCOM area fulfills the VU criteria both for the loss of spawning area and loss of SSB. A summary of the assessment, including separate assessment for the different management units is given in table 2.

Table 2. Summary of the assessment of cod in the HELCOM area.

Assessment unit	Category	Criteria
Cod in total Helcom area	VU	A2b,c + A4b,c,
Cod in Kattegat	CR	A2b,c
Cod in Western Baltic	NT	A2b+A4b
Cod in Eastern Baltic	VU	A2b,c +A4b,c

Separate assessment by stocks

Kattegat cod

Spawning stock biomass

Spawning stock biomass (SSB) of cod in the Kattegat has been at its historically lowest level and below biomass reference points since 2000, with the lowest values of SSB estimated for 2010 (ICES 2012a). Since 1971, SSB has decreased more than 90% and since 1981 the decrease is 84% (Figure 7). No historic estimates of SSB are available for comparison of decrease using the longer estimated generation time, however using the catch per unit effort in the Danish fishery in Kattegat 1953-1992 (Nielsen & Richardson 1996) indicate that the stock in the late 1950s where of the same size as in late 1980s – if this is true the estimated decrease in SSB over the longer time frame is 74%. The Kattegat stock is already considered depleted (ICES 2012a) and a projection into the future using A3 would probably not lead to a future decrease of the same amount as has already happened in the past. For the same reason any combination of past and future time using A4 would result in a worst case scenario of more than 90% decrease and a best case of no decrease, or even an increase and hence using criteria A3 or A4 does not give any additional information compared to using A2.

The estimated decrease in the past for Kattegat stock leads to a range in threat category between Endangered and Critically Endangered depending on generation time used. Using the most probable estimate for generation time it fulfils the criteria A2b for the level of Critically Endangered. This is also in line with the precautionary principle. Criterion A1 is not applicable since there is no recovery in the Kattegat stock despite a management plan (ICES 2012a).

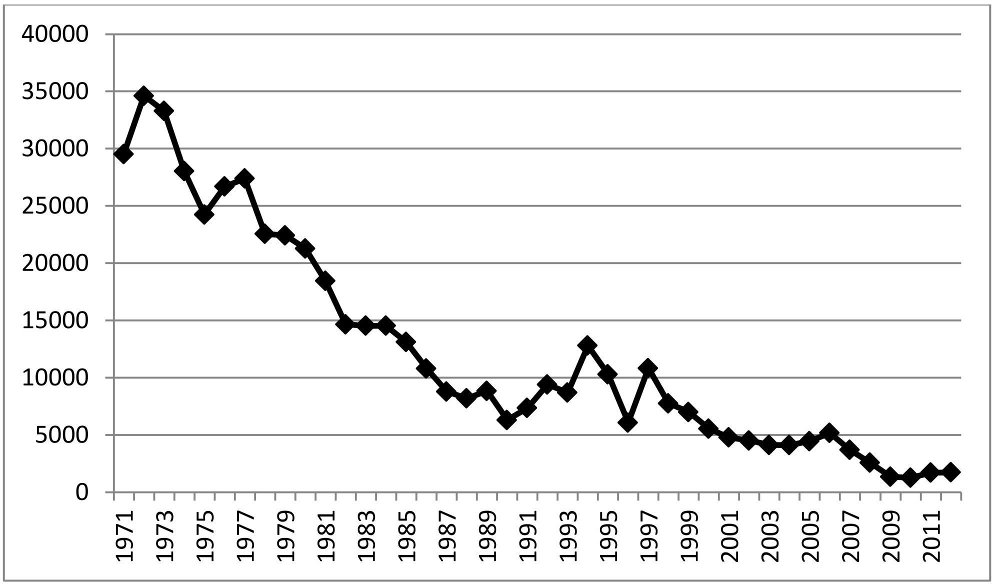


Figure 7. Kattegat Stock, SSB (tones) 1971-2012.

Spawning areas

Cod spawning aggregations have been observed in the central and southern part of the Kattegat (Hagström et al. 1990, Bagge et al. 1994, Svedäng & Bardon 2003, Vitale et al. 2008, Svedäng et al. 2010a, b). There are clear indications that several subpopulation units and spawning areas have been lost over the last 40 years, as spawning for instance has ceased in the Skälderviken and Laholmsbukten (Svedäng et al. 2010a). This means that the loss of numbers of spawning areas in Kattegat probably is between 70 and 85% (only 1 or 2 spawning areas left out of at least 6 previously known) meaning that the population probably has decreased with the same amount due to decline in area of occupancy. Even though there is no perceived threats to the spawning areas the strong natal homing behaviour (Svedäng et al 2010 a, b) might prevent it from being re-colonised even if the stock would increase. This fulfils the criteria A2c for the level of Critically Endangered. Since the loss has already happened and there are no indications of future loss of spawning areas using A3 projecting into the future will not result in any different assessment, for the same reason using any combination of past and future time using A4 will result in estimations ranging from CR to LC. Criterion A1 is not applicable since there is no recovery in the Kattegat stock despite a management plan (ICES 2012a)

Criteria B, C and D

In criterion B both extent of occurrence (Kattegat, table 2) and area of occupancy (spawning areas, Vitale et al 2008) of cod is below the threshold for being Vulnerable (<20 000 km^2 and < 2000 km^2 respectively) and fulfilling the sub-criteria of being severely fragmented (2-6 locations) and declining, and hence fulfils the criteria B1a, c and B2a, c for the level of Vulnerable.

The Kattegat cod does not fulfil the criteria C , small and continuously declining population, since the number of mature individuals is above 20 000 the threshold for being Near Threatened (in HELCOM RED LIST 2/ 2010). The Kattegat cod neither fulfils the criterion D, very small and restricted population, since the number of mature individuals is estimated above 2000 individuals, and area of occupancy is above 40km^2 which is the thresholds for Near Threatened in the regional guidelines (HELCOM RED LIST 2/ 2010).

Regional consideration

Cod is generally known to display natal homing and evidence of a fine scaled population structure exist (Nielsen et al 2002, Svedäng et al 2003, 2007, 2010a, b and Neuenfeldt et al 2013). Cod from outside Kattegat are highly unlikely to contribute to the spawning population since the migration from Skagerrak and North sea cod have been shown to be only feeding migration (Svedäng et al 2007, 2010a, b) Furthermore the adjacent Western Baltic Sea stock have been decreasing the last three generations hence there is little probability of a spill-over effect from areas outside the Kattegat and the suggested threat level is not downgraded

Western Baltic cod

Spawning stock biomass

According to ICES (2012b) the SSB in the Western Baltic cod stock has been fluctuating just above the precautionary level since 2000 with an increase in recent years. Looking at the assessment period 1971-2012, SSB decreased with 20 % over the last 40 years (Appendix 1, Figure 8). Unfortunately, no older data are available, making a comparison with the longer assessment period impossible. Usage of the shorter generation time results in a decrease of 27 % which is almost equivalent to the estimated decrease of 29% using criteria A4. The latter assuming a future with no decrease in biomass since although the decrease has stopped there is no indication of a full recovery (ICES 2012b). This also prevents the use of A1 since there is no evidence of recovery despite the management plan, which also calls into question if the reasons of the decline are fully understood and solved. The decrease in SSB leads to estimates of decline within the range of NT for A2b and A4b.

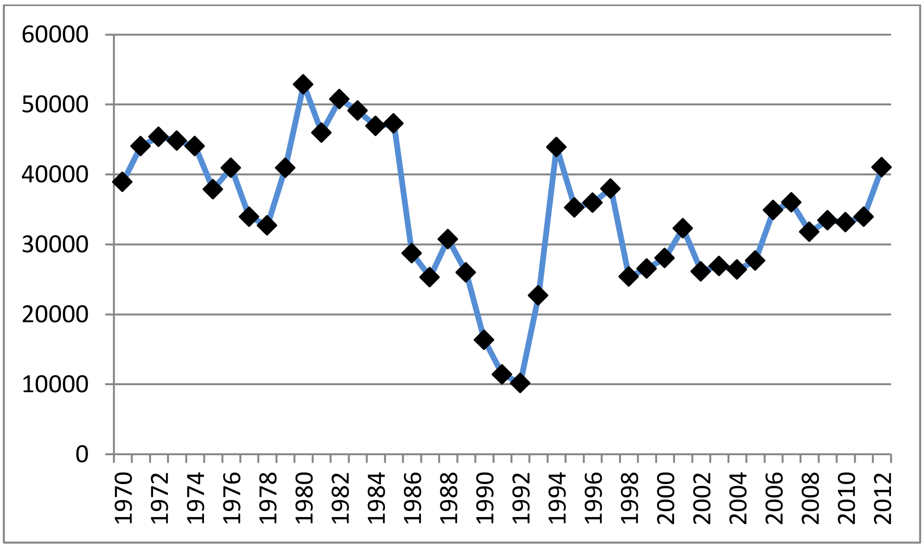


Figure 8. Western Baltic Stock, SSB (tones) 1971-2012.

Spawning areas

Spawning takes place in the Sound, in the Belt Sea and at various locations in the Arkona basin (Figure 4. Bagge et al. 1994). There is no information that any spawning areas have been lost during the extended assessment period, i.e. over the last 60 years, and there is no indication of future losses of spawning areas. Hence, the Western Baltic cod, based on A2c, A3c and A4c, is considered Least Concern. For reasons given above, the criterion A1 was not deemed appropriate.

Criterion B, C and D

In criterion B, both the extent of occurrence and area of occupancy of Western Baltic cod (Figure 4) are above the threshold for being threatened (>20 000 km^2 and > 2000 km^2, respectively) according to IUCN (2011), but below the threshold for being considered Near Threatened (<40 000km^2 and < 4000km^2, according to IUCN guidelines). However, the stock does not fulfil the required sub-criteria of being severely fragmented and declining, and hence the criterion B gives Least Concern.

The Western Baltic cod does not fulfil the criteria C or D since the number of mature individuals is above 20 000, and area of occupancy is above 40km^2, which are the thresholds for Near Threatened.

Regional consideration

Cod is generally known to display natal homing and evidence of a fine scaled population structure exist (Vallin & Nissling 2000, Nielsen et al 2002, Svedäng et al 2007, 2010a, b and Neuenfeldt et al 2013). Furthermore, both adjacent cod stocks i.e. the eastern Baltic Sea and the Kattegat have been decreasing the last three generations and hence there is little probability of a rescue effect from outside and the suggested threat level is not down-graded.

Eastern Baltic cod

Spawning stock biomass

For the assessment period between 1971 and 2012, the stock has decreased by 45 % (Figure 9). Use of the longer generation time of 58 years, and comparison of the values in the 1954-1958 with the current situation (average of years 2008-2012), results in a decrease of 41 %. The use of the shorter generation time of 31 years, using 1981-1985 as a reference period, results in a loss of 78%. However, the cod stock was exceptionally large in the early 80s and the cod-boom years 1979-1985 could be questioned as reference point since the decrease following these could be seen as part of a natural fluctuation. Choosing the years after the cod boom as a starting point, results in a decrease of 46%. As a conclusion, this means that the range of estimates for a decrease for criterion A2b all lie within the category Vulnerable.

There are indications of a major recovery over the last years with ICES projecting an increase of SSB by 15% by 2015, so a projection into the future using A3 based on SSB would result in LC status.

Using A4 and choosing the years after the cod boom 1986-1990 as a starting point and predicting that the current stock size remains the same (the positive trend has levelled off, Figure 9) results in an expected decrease of 46%, fulfilling the category Vulnerable.

A1 is not used since although the impacts of fishery on the population are being managed the other main threat, reduction of habitat extent and quality, has not ceased (HELCOM 2013a) but is rather projected to increase (HELCOM 2013a, Meier et al 2012). In addition, in connection with the recovery of the Eastern Baltic Sea cod there has been a considerable decrease in mean weight in the stock, i.e. reduced growth and decreased condition (ICES 2012b, Eero et al 2012a).

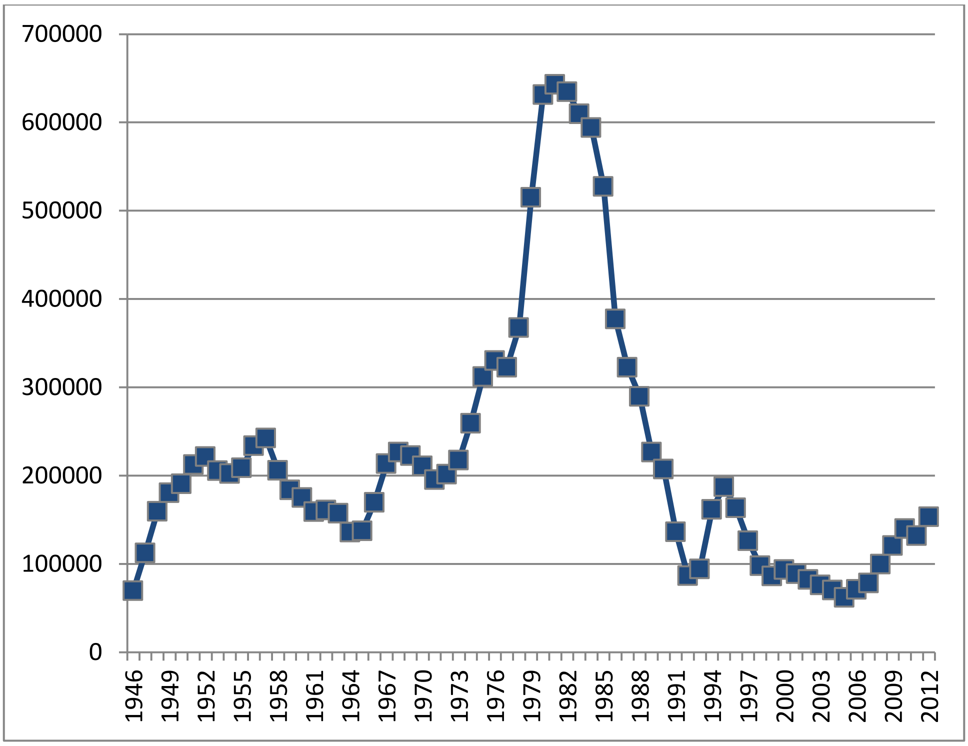


Figure 9. Eastern Baltic Stock, SSB (tones) 1967-2012.

Spawning areas

Eastern Baltic cod spawns according to Bagge et al. (1994) in the Bornholm basin, Gdansk deep and Gotland deep. Eero et al. (2007) evaluated the contribution from the three spawning areas over the last century and observed that the Gdansk and Gotland deeps ceased functioning as main contributors in the 1980s (i.e. before and up to the cod boom years in the mid-1980s, Figures 1 and 4).

Strong environmental changes, including increased hypoxia, occurred in the Baltic deeper waters in the 1980s, negatively impacting the cod spawning areas (Casini, 2011, Figure 3). Reproductive volume (rv) for Eastern Baltic cod decreased by 38% over the last 40 years (based on comparison of mean value of reproductive volume 1971-1975 i.e. 285 km^3 - and 2005-2009 i.e. 175 km^3, Figure 6). Using the longer estimate for generation time results in a decrease of 53% (based on comparison with oldest available data 1960-1964 i.e. 380 km^3). Using the shorter generation time would result in no loss of reproductive value comparing the bottom years 1981-1984 (rv=150 km3) with most recent values. Using the criteria A4 for combining any time of past and future time and assuming that future situation is not improving results in a decrease of 51 % (using the years 1976-1980 as reference period). The uncertainty of the future is too great to allow a projection of three generations using A3.

It could be argued that the use of rv will lead to an overestimation of the population decrease since rv is not related to the number of recruits when the volume is smaller than 300 km^3. An alternative estimation of reduction in population size due to spawning habitat loss is to use the so called Area of Occupancy (AOO). Using the area of the offshore waters, according to “HELCOM sub-division” (Figure 5), and assuming a total loss of the Gotland basin and Gulf of Gdansk as spawning areas the reduction in AOO is 66%. Since this loss took place in the 1980s, the estimated decrease is the same regardless generation time used. Since there are no signs of improvement of the oxygen situation in the cod spawning areas (HELCOM 2013a, Hansson et al 2013) and there is also no foreseen continued loss of AOO (but see HELCOM 2013a), projecting into the future using A3 or A4 will not change the assessment. This calculation of loss in AOO is probably also an overestimation of loss, since cod does not utilise the whole basins for spawning and hence the more conservative value of more than 30% loss but less than 50% loss is used. This fulfils the criteria A2c, A4c for VU status.

A1 is not used since this threat, loss of spawning habitat due to oxygen deficiency caused by eutrophication, has not ceased (HELCOM 2013a) and it is unclear if recovery is possible since although the population size have increased the former spawning grounds in the Gotland deep and the Gulf of Gdansk have not been re-colonized (Casini 2011, Eero et al 2012a).

Criteria B, C and D

In criterion B both extent of occurrence and area of occupancy of Eastern Baltic cod are above the threshold for being Near Threatened (>40 000km^2 and <>4000km^2). The Eastern Baltic cod does not fulfil the criteria C or D, since the number of mature individuals is above 20 000 and area of occupancy is above 40km^2 .

Regional consideration

Cod is generally known to display natal homing and evidence of a fine scaled population structure exist (Vallin & Nissling 2000, Nielsen et al 2002, Svedäng et al 2007, 2010a, b and Neuenfeldt et al 2013). Furthermore the adjacent cod stock, i.e. the Western Baltic cod stock, has been decreasing the last three generations, hence there is little probability of a rescue effect from outside the eastern Baltic and the suggested threat level is not downgraded. Moreover, the genetic separation between Eastern and Western Baltic cod and the adaptations shown by the Eastern stock to low salinity conditions in the Baltic proper emphasize the rather unique character of the Eastern Baltic cod and the low likelihood that the stock is replenished from the western components.

Recommendations for actions to conserve the species

The EU management plan for cod should be followed. The species also needs eutrophication of the Baltic Sea proper to be reduced and through that, ultimately, an improvement oxygen conditions of the deep waters, as the species needs well-oxygenated deep water spawning habitats. The reasons of a reduced individual growth rate should be investigated. For cod in the Kattegat, fishing mortality must be kept at a very low level in order to give the stock a chance to recover.

Common names

D Kabeljau; GB – Cod; EST - Tursk; DK - Torsk; FIN - Turska; LV - Menca; LT - Menkė; PL -; RUS - Atlanticheskaya (baltiyskaya) treska; S - Torsk

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ANNEX

ICES Review of HELCOM draft (version 17 December 2012) Red List assessment of cod

The following ICES advice was produced in the course of preparing the assessment of the cod and most of the remarks made by ICES have been take into account in this final SIS for the cod.

8.3.3.1 **Special request, Advice February 2013**

ECOREGION **Baltic Sea**
SUBJECT **Review of HELCOM draft Red List assessment of cod (*Gadus morhua*)**

Advice summary

The advice below relates to each of the questions within the HELCOM request.

Has the HELCOM Red List assessment been carried out appropriately following the criteria of IUCN?

ICES advises that Criterion E should be used to assess reduction in population size, rather than screening assessments using Criterion A for the three cod stocks in the Baltic. In the current HELCOM assessment, ICES advises that Subcriterion A1 should have been used rather than Subcriterion A2 except for the Kattegat stock, and that habitat loss should have been assessed using Criterion B rather than Criterion A, because spawning-stock biomass (SSB) trends were available.

ICES advises that due to the separate past (and future) trajectories of the three stocks, it is not appropriate to assign one IUCN category collectively for all cod in the Baltic.

Has the assessment utilized correctly all appropriate data on the development of the cod stock(s) and its habitats?

ICES advises that further data should have been used in the assessment. With regards to habitats, the best information was generally used, but interpreted in an inconsistent manner, and should have been assessed using Criterion B.

Has the generation time of cod been estimated properly?

ICES advises that the calculation of generation time of cod was consistent with IUCN guidelines, but some of the parameters used were inappropriately specified..

Does any significant immigration exists between the Baltic Sea stock(s) and the North Sea population?

There is insufficient information to advise on the degree of mixing between the cod stocks in the Baltic and in the North Sea. From an assessment and management perspective, separation is assumed between the stocks.

Request

*"ICES is requested to evaluate whether the draft Red List assessment of Baltic Sea cod (*Gadus morhua*) by the Fish Experts Team of the HELCOM Red List project has been carried out appropriately following the assessment criteria of IUCN. More specifically, ICES is asked to check if the assessment utilizes correctly all appropriate data on the development of the cod stock(s) and its habitats. ICES is also*

requested to review whether the generation time of cod has been estimated properly, taking into account that it should represent pre-disturbance generation length and an age where 50% of the individual reproductive output has been reached. Additionally, ICES is requested to evaluate whether any significant immigration exists between the Baltic Sea stock(s) and the North Sea population."

ICES advice

Has the HELCOM Red List assessment been carried out appropriately following the criteria of IUCN?

ICES advises that the Criterion E (see IUCN (2012) for descriptions of the criteria) approach should be used, rather than assessment using Criterion A, for each of the three cod stocks in the Baltic (Kattegat, western Baltic, and eastern Baltic). In its application of Subcriterion A2 the HELCOM Red List assessment (the HELCOM assessment) generally follows the IUCN approach as provided in the 2012 guidelines (IUCN, 2012). However, the IUCN screening approaches that comprise Criteria A to D are suitable in relatively data-limited circumstances, but should be replaced if sufficient information is available to take quantitative approaches. ICES advises that quantitative stock assessments, with projections, are the most appropriate tools to determine extinction risk due to reductions in population size. Current fishery assessments, including information on the dynamics of recruitment and their demographic structure, are available for these cod stocks. It is thus possible to apply Criterion E. A further advantage to the fishery assessment process is that the extent to which the current status and trend of each stock is attributable to fishing pressure can be inferred, enabling a better specification of any conservation actions that may be needed.

In the current HELCOM assessment, Subcriterion A2 was used rather than Subcriterion A1. For at least two of the stocks (western Baltic and eastern Baltic) of cod in the HELCOM area, stock sizes are increasing. The causes of earlier decreases are understood and these changes are reversible, i.e. Subcriterion A1 should be used. In the Kattegat, Subcriterion A2 may be more appropriate. Habitat loss should have been assessed using Criterion B rather than Criterion A; as Criterion A uses a proxy for population size when assessing habitat loss and such proxies are not needed because population estimates (SSB trends) are available.

The projections provided in the ICES fishery assessments were not used in the analysis, neither was additional information offered by the stock assessments and the spatial survey data. The ICES projections to provide catch advice were short term, but the methodology could be extended to address the Criterion E probability of extinction.

The three cod stocks in the HELCOM area have separate and distinct past (and likely future) trajectories. It is therefore not appropriate to assign one IUCN category collectively for all cod in the Baltic as this carries the risk of losing important signals from the individual stocks.

Has the assessment utilized correctly all appropriate data on the development of the cod stock(s) and its habitats?

ICES advises that the assessment has not fully used all appropriate data. The HELCOM assessment uses one metric provided by the stock assessments, the SSB time-series (time-series of the biomass of mature fish). However, the HELCOM assessment does not incorporate the additional information provided by the stock assessments, such as population assessments, nor does it consider recruitment dynamics.

The HELCOM assessment considered that habitat loss was a factor in the Kattegat cod stock. ICES advises that this conclusion is not appropriate as the reproductive capacity of this cod stock is reduced (ICES, 2012) and the reduction in habitat use is more likely due to a reduced stock size than to habitat loss (Svedäng *et al*., 2010).

That the 'cod boom years' were removed from the SSB time-series is understandable as the productivity of cod in the Baltic Sea in these years was higher than in the present times. However, much of the argument concerning the change in area of occurrence (spawning habitat) includes the estimates of the area of occurrence from this period of 'cod boom'. This is inconsistent.

Has the generation time of cod been estimated properly?

The IUCN guidelines (IUCN, 2011) provide several ways of calculating generation time. It is not clear in the HELCOM assessment text how the generation time of cod was estimated or whether it followed the IUCN guidelines. Questioned by ICES a member of the HELCOM Assessment group (M. Svensson, pers. comm.) explained how generation time was estimated and confirmed that the process had followed the IUCN guidelines. The IUCN guidance is generic, though, and perhaps not tuned to data-rich circumstances. In this case the life characteristics of Norwegian or global stocks has been used, which may not be appropriate (see Brander, 1995, 2007). ICES recommends that the calculation of generation time should, where possible, be based on the life characteristics of the stock under assessment. ICES does not use "pre-disturbance" generation times in its stock assessments as a harvested stock cannot be regarded as undisturbed (and would be unlikely to return rapidly to a "pre-disturbance state"). ICES calculates current generation times at 2–5 years.

Does any significant immigration exist between the Baltic Sea stock(s) and the North Sea population?

There is no conclusive study on the degree of mixing between cod in the Baltic Sea and the North Sea and this may well vary over time. ICES currently assesses and advises on the basis of three stocks in the HELCOM area, and they are managed as separate entities.

Additional advice

The three cod stocks show differing dynamics. Under these circumstances, the use of metrics of biomass to merge stock information when attempting a regional assessment of population status is unwise, as the signal from the most-at-risk stock is masked by the stronger signal from the healthier stocks. This has occurred in the assessment – see Figures 1, 6, and 7 in the HELCOM assessment. The assessment of the overall status of cod in the Baltic (Table 3 in the HELCOM assessment) is therefore not appropriate.

Background

Previous approach by ICES to the IUCN red listing of commercially exploited fish species.

In 2009, ACOM was asked by Norway to provide advice on the IUCN listing of marine fish species (ICES, 2009). ICES stated:

"*There are three general methods for evaluating extinction risk: (1) screening methods, such as the IUCN redlisting criteria; (2) simple population viability analysis based on time trends; and (3) age structured population viability analysis. The rate of false positives (prediction of extinction which does not occur) and false negatives (the occurrence of unpredicted extinction) is likely to be the highest for screening methods, lower for simple population viability analysis based on time trends, and lowest for age structure population viability analysis. None of the methods are considered reliable for accurately estimating the probability of extinction, but they may be useful to evaluate the relative probability of extinction between species or between management options."*

Later in the advice ICES stated:

"Screening methods may be useful to prompt a more comprehensive analysis, but should not be used as the basis for a listing decision when more detailed data are available, as is typically the case for exploited marine species. Screening methods also only provide an evaluation of stock status at a point in time. They do not include a projection into the future which is more useful for estimating the probability of extinction. As well, criteria based on the rate or magnitude of population decline may overlook the fact that even well managed exploited fish populations can experience large declines. Furthermore, in some cases even a small additional decline may induce a population to pass a tipping point and lead to an

increased chance of extinction.

Population Viability Analysis (PVA) is a method that projects a population forward in time using uncertainty to make statements about the probability of population abundance falling below some predetermined level in a given number of years. PVA is useful to indicate the relative risk of extinction (e.g., between stocks) rather than to estimate the absolute probability. The PVA is a forecast of what would be likely to happen to a stock if current conditions remain unchanged throughout the projection period. This assumption of stationarity implies that the conditions that generated the observed values will continue into the future.

Another approach is the Age Structured Population Viability Analysis. In the standard application of this approach the simple PVA is augmented to account for life stage/age structure allowing density dependence and other forms of non-stationarity to occur in the projections. This approach allows comparison of the relative probability of extinction for alternative management options.

Standard fishery models can also be used to examine the risk of extinction. Stock and recruitment estimates can be compared to the replacement line under the current mortality rate. When total mortality is too high, the replacement line will be to the left of recruitment values associated with low stock size, causing the stock to decline. If depensation is present in the stock-recruitment relationship (or if the stock-recruitment relationship changes over time causing a smaller slope at the origin), too high a mortality rate will cause the stock to eventually go extinct. There is no time period involved in this approach, but continued recruitment below the replacement line [at low stock size] *implies a high probability of extinction."*

ICES views a stock assessment with a projection as an appropriate analysis of the likely extinction risk of a commercially exploited marine organism due to reduction in population size. This is a more effective tool than the IUCN red listing Criterion A.

IUCN criteria and the HELCOM proposal

Most of the HELCOM assessment considers the three cod stocks (and the amalgamated HELCOM cod grouping) in relation to IUCN Criterion A – reduction of population size. The proposal suggests that the other IUCN criteria (B–E) are not appropriate and/or able to be applied to these cod populations. The HELCOM assessment document discusses the appropriateness of Subcriterion A1 or A2, and concludes that Subcriterion A2 is appropriate despite the existing management plans for Baltic cod. The assessment considers the decline criterion in relation to SSB (mature adults; IUCN, 2012) and spawning areas.

"Subcriterion A1 if causes of reduction are clearly reversible, understood and ceased.
Subcriterion A2 if the reduction or its causes may not have ceased, may not be understood or may not be reversible."
IUCN (2012)

ICES does not agree with the HELCOM assessment that "*there has been not enough data to apply criterion E*". The IUCN guidelines suggest the use of a PVA (population viability analysis; IUCN, 2011). The ICES stock assessment and management approaches incorporate the "precautionary approach", thus to some extent accounting for a large amount of the uncertainty associated with the stock assessments (see section 9.5 in IUCN, 2011), and also include clear documentation and evaluation of methods (ICES, 2013).

"Quantitative analysis (Criterion E).
A quantitative analysis is defined here as any form of analysis which estimates the extinction probability of a taxon based on known life history, habitat requirements, threats and any specified management options. … Quantitative analyses should make full use of all relevant available data. In a situation in which there is limited information, such data as are available can be used to provide an estimate of extinction risk (for instance, estimating the impact of stochastic events on habitat). In presenting the

results of quantitative analyses, the assumptions (which must be appropriate and defensible), the data used and the uncertainty in the data or quantitative model must be documented."
IUCN (2012)

ICES considers that the availability of quality assured stock assessments, which in turn provides a basis to perform projections into the future, allows for the quantitative calculation of extinction risk, taking the uncertainty of the data into account, which is the requirement under Criterion E. Once such a calculation becomes possible, the nature of a red list assessment changes. Criteria A–D applications typically involve screening methods, with the intent of "waving a flag" to indicate that a more intensive analysis is required. For that reason, the quantification of these criteria deliberately and defensibly errs on the risk-averse side. For example, a population decline estimate of 50% or 70% (depending on the circumstances) can see the subject of the assesment classified as endangered under Criterion A, when in terms of typical fisheries target levels, a population reduced by this extent below its pristine level would be seen to be close to an optimal level for harvesting and securing MSY. In contrast, an analysis meeting the Criterion E requirements subsumes the various considerations taken into account in a screening approach. The Criterion E approach should be integrative, risk-neutral, and a more soundly based process, leading to more reliable estimates of a population status as well as providing the basis to apply the quantitative criteria regarding extinction risk.

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