Stock annex: Cod (*Gadus morhua*) in subareas 1 and 2 (Norwegian coastal waters cod)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Cod
Working Group:	Arctic Fisheries Working Group (AFWG)
Created:	
Authors:	Asgeir Aglen
Last updated:	30 January 2015
Last updated by:	WKARCT, Asgeir Aglen (stock coordinator)

A. General

A.1. Stock definition

Cod in the Barents Sea, the Norwegian Sea and in the coastal areas living under variable environmental conditions form groups with some peculiarities in geographical distribution, migration pattern, growth, maturation rates, genetics features, etc. The degree of intermingling of different groups is uncertain (Borisov *et al.*, 1999).

Both types of cod (the Norwegian Coastal cod and the North-East Arctic cod) can be found together on spawning grounds during spawning period as well as in catches all the year-round both inshore and offshore in variable proportions.

The assessment area for Norwegian Coastal cod (NCC) is the Norwegian statistical rectangles 0, 3, 4, 5, 6 and 7. The catch reporting separates catches inside and outside the 12 nautical mile limit. In the map in Figure A2.1 each statistical rectangle is split along the 12-mile limit so that area 300+301 is area 3, 400+401 is 4 etc.

Spawning areas are located in fjords as well as offshore along the coast. The spawning season extends from March to late June, with peak spawning early April. The 0 and 1-group of NCC inhabit shallow water both in fjords and in coastal areas and are hardly found in deeper trawling areas until reaching about 25 cm. Afterwards they gradually move towards deeper water. NCC starts on average to mature at age 4–6 and migrates towards spawning grounds in early winter. The majority of the biomass (about 75%) is located in the northern part of the area (North of 67°N).

Tagging experiments of cod inhabiting fjords indicate only short migrations (Jakobsen 1987, Nøstvik and Pedersen 1999, Skreslet, *et al.*, 1999). From these experiments very few tagged cod migrated into the Barents Sea (<1%). Some investigations based on genetics found large differences between NCC and North-East Arctic cod (NEAC) (Fevolden and Pogson 1995, Fevolden and Pogson, 1997; Jørstad and Nævdal, 1989, Møller 1969), while others did not find clear differences (Árnason and Pálsson, 1996, Mork, *et al.*, 1984, Artemjeva and Novikov, 1990). Investigations also indicate that NCC probably consists of several separate populations.

Ongoing studies on the genetic structure of cod along the entire Norwegian coast have revealed considerable genetic differences (WD 25 to WKARCT 2015). Two main clusters have been indicated, with a separation line somewhere between 63 and 66 degrees north. Within these clusters there are further genetic variations indicating a rather complex stock structure, and several regions may possibly be defined.

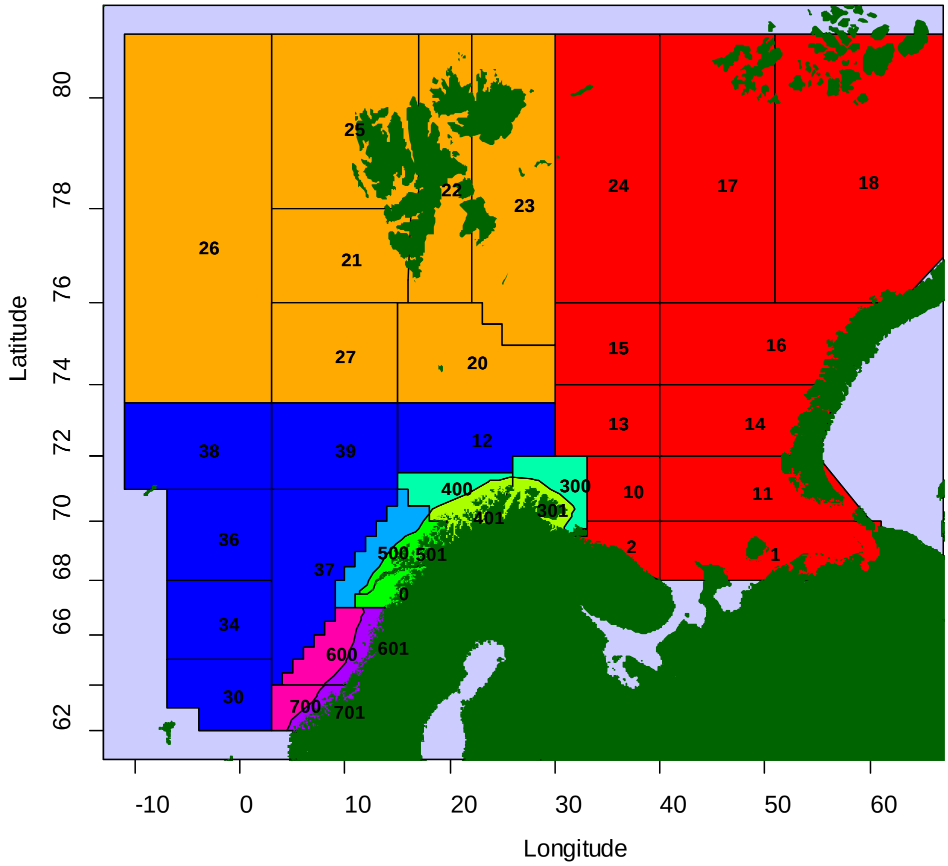

Figure A2.1. Norwegian statistical rectangles areas 3-7 are here split along the 12 nmile limit (300 and 301, 400 and 401, etc.).

A.2. Commercial Fishery

Coastal cod is mainly fished by coastal vessels using traditional fishing gears like gillnet, longline, handline and Danish seine, but some is also fished by trawlers and larger longliners fishing at the coastal banks. The fishery is dominated by gillnet (50%), while longline/handline account for about 20%, Danish seine 20% and Trawl 10% of the total catch. There was a shift around 1995 in the portion caught by the different gears. Before 1995 the portion taken by longline and handline was higher, while the portion taken by Danish seine was lower. Norwegian vessels take all the reported catch. However, trawlers from other countries probably take a small amount of NCC when fishing near the Norwegian coast fishing for North-East Arctic cod and North-East Arctic haddock.

When setting the annual cod quota an expected catch of coastal cod is added to the Norwegian TAC for North-east Arctic cod, giving a total combined TAC to distribute on fishing vessels. In 2010 and later years 7000 tonnes of the Norwegian cod quota has been set aside to cover the catches taken in the recreational and tourist fisheries and to cover catches taken by young fishers (to motivate young people to become fishers).

Cod catches are not identified to stock at landing, and therefore no landings are counted against a separate coastal cod quota. When the fishing year is finished the catches of coastal cod are estimated from otolith sampling. All regulations for North-east Arctic cod also apply to coastal cod. These include minimum catch size, minimum mesh size, maximum bycatch of undersized fish, and closure of areas having high densities of juveniles. In addition, trawl fishing for cod is not allowed inside the 6-n.mile, and since the mid-1990s the fjords in Finnmark and northern Troms (areas 03 and 04) have been closed for fishing with Danish seine. Since 2000 the large longliners have been given restrictions and are now only allowed to fish outside the 4 nautical mile. Since 2004 additional restrictions on coastal fisheries have been introduced to reduce catches of coastal cod. In these new regulations "fjord-lines" are drawn along the coast to close the fjords for direct cod fishing with vessels larger than 15 meters. A box closed for all fishing gears except handline and fishing rod is defined in the Henningsvær-Svolvær area. This is an area where spawning concentrations of coastal cod are usually observed and where the catches of coastal cod have been high. Since the coastal cod is fished under a combined coastal cod/North-east arctic cod quota, these regulations are supposed to turn parts of the traditional coastal fishery over from catching coastal cod in the fjords to catch more cod outside the fjords where the proportion of Northeast Arctic cod is higher. Further restrictions were introduced in 2007 by not allowing pelagic gillnet fishing for cod and by reducing the allowed bycatch of cod when fishing for other species inside fjord lines from 25% to 5%, and outside fjord-lines from 25% to 20%. Since 2009 a fjord area near Ålesund has been closed in the spawning season for fishing with all gears except handline and fishing rod.

Recreational and tourist fishing

Recreational and tourist fishing occurs all along the coast. The total amount of coastal cod taken in these fisheries is considered to be rather large. In 2010 and later years 7000 t of the Norwegian cod quota has been set aside to cover the catches taken in the recreational and tourist fisheries and to cover catches taken by young fishers (to motivate young people to become fishers).

The time-series for this fishery is considered highly uncertain (Hallenstvedt and Wulf, 2004, WD 17 AFWG 2010). It shows a rather constant catch over the time-series. WKARCT propose to assume a constant fishing mortality as an alternative approach to illustrating the effect of these fisheries.

A.3. Ecosystem aspects

B. Data

B.1. Commercial catch

In 1996, a time-series of coastal cod numbers-at-age in catches inside the 12 nautical mile zone was presented to AFWG. Reported catches of cod were separated into Norwegian coastal cod and North-east Arctic cod based on biological sampling (Berg, *et al.*, 1998) The method is based on otolith-typing (Rollefsen, 1933). The catches of Norwegian coastal cod (NCC) were calculated back to 1984 using available data on otolith typing. This has been updated annually and reported to AFWG. During this period (1984–2013) the catches have been between 22 000 and 75 000 t. Further details are described in the stock Annex of the AFWG report in 2014 and earlier years.

At the meeting of WKARCT 2015 a new time-series of catch-at-age and weight at age was presented. The main reasons for recalculating the series were:

- The Norwegian catches used in the historical NEAC-assessment and the CC-assessment for the years 1984-2012 do not add up to the total Norwegian annual catch;
- Improving NEAC/CC split by using the ECA-model (Hirst *et al.*, 2012), utilizing both otolith typing and length/age-differences, and providing uncertainty estimates;
- Including coastal cod at coastal banks outside 12 nautical mile.

At WKARCT 2015 the data were accepted as relevant information for describing the stock dynamics. The reasons for the differences between the old and new series are not clear and need to be further explored.

Norway accounts for all NCC landings. The text table below shows which kind of data are collected:

			Kind of data		
Country	Caton (catch in weight)	Canum (catch-at-age in numbers)	Weca (weight at age in the catch)	Matprop (proportion mature by age)	Length composition in catch
Norway	X	X	X	X	X

B.2. Biological

Weight at age in the stock is obtained from the Norwegian coastal survey in from 1995 onwards. From 1984 to 1994 weight at age in stock is taken from weight at age in the catch because no survey data from this period are available. The mean values are weighted by biomass in the respective areas. A fixed natural mortality of 0.2 is used in the assessment. Some fjord studies (Pedersen and Pope, 2003a and b, Mortensen 2007, Pedersen *et al.,* 2007) indicate that the main predators on young cod are larger cod, cormorants and saithe. There are no estimates of annual predation mortality for the stock complex.

Both the proportion of natural mortality before spawning (M_{prop}) and the proportion of fishing mortality before spawning (F_{prop}) are set to 0.

B.3. Survey

Since 1995 a Norwegian trawl-acoustic survey (Norwegian coastal survey) specially designed for coastal cod has been conducted annually in September (prior to 2003) and in October-November (28 days). The survey covers the fjords and coastal areas from the Varangerfjord close to the Russian border and southwards to 62°N. The aim of conducting an acoustic survey targeting Norwegian coastal cod has been to support the stock assessment with fishery-independent data of the abundance of both the commercial size cod as well as the youngest prerecruit coastal cod. The survey therefore covers the main areas where the commercial fishery takes place, normally dominated by 4–7 year old fish.

The 0- and 1 year-old coastal cod, mainly inhabiting shallow water (0–50 m) near the coast and in the fjords, are also represented in the survey, although highly variable from year to year. However, the 0-group cod caught in the survey is impossible to classify to NCC or NEAC by the otoliths since the first winter zone is used in this separation. A total number of about 150 trawl hauls are conducted during the survey.

The survey abundance indices at age are total numbers (in thousands) computed from the acoustics.

Ages 2–8 are used in the XSA-tuning.

B.4. Commercial cpue

No commercial cpue are available for this stock.

B.5. Other relevant data

A number of bottom-trawl tows are made during the coastal survey, and since 2003 the survey has aimed for towing at the same fixed positions each year. This might be used to calculate a bottom-trawl index.

C. Historical stock development

Using the new coastal cod catch in number series in an XSA tuned by the coastal survey gave poorer diagnostics than when using the old series. It is recommended not to use XSA tuned by the acoustic survey as a basis for a full analytic assessment. The converged period is relevant to the historic trends and stock dynamics. The converged part can also be used for "calibrating" survey mortalities for the purpose of estimating recent Fs from survey mortality, as described in the Stock Annex since 2010 (see below). Using the XSA for estimating the historic series of SSB should take account of the time-lag between spawning time and the time of the survey, where maturity and stock weights are observed. The maturity based on commercial sampling presented at the 2012 AFWG should be updated and considered for use.

Current approach

Since about 2006 the XSA assessment (tuned by 1 survey series) has been considered relevant to historic trends only. The 2010 AFWG was asked to evaluate a rebuilding plan for coastal cod, which then created a need for a more robust analytical assessment. In addition, a new time-series on catch-at-age in the recreational fishery was presented and added to the canum for commercial catches. It is recommended to continue that procedure.

An estimate of F in the latest survey year (F_{term}) is obtained from surveys by calibrating survey Zs to the Fs in the converged part of a trial XSA. These estimates are used for deciding on a best estimate of (F_{term}) that is further used as terminal F in a traditional VPA. Selection at age in the terminal year and Fold for earlier years is taken from the trial XSA. The traditional VPA is then taken as the final assessment.

Further details on the procedure:

1) Run a trial XSA (IFAP / Lowestoft VPA suite) with updated catch-at-age and survey data with the following model options chosen:
    a) Tapered time weighting applied, power = 3 over 20 years
    b) Catchability independent of stock size for all ages
    c) Catchability independent of age for ages ≥8
    d) Survivor estimates shrunk towards the mean F of the final 2 years or the 4 oldest ages
    e) S.E. of the mean to which the estimate are shrunk = 1.0

f) Minimum standard error for population estimates derived from each fleet =0.300

g) Prior weighting not applied

h) Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1984–last data year	2–10+	Yes
Canum	Catch-at-age in numbers	1984–last data year	2–10+	Yes
Weca	Weight at age in the commercial catch	1984–last data year	2–10+	Yes
West	Weight at age of the spawning stock at spawning time. (shifted to January the following year)	1984–last data year	2–10+	Yes, but for the period 1984-1994 set equal to the average of 1995-2000
Mprop	Proportion of natural mortality before spawning	1984–last data year	2–10+	No, set to 0 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1984–last data year	2–10+	No, set to 0 for all ages in all years
Matprop	Proportion mature at age	1984–last data year	2–10+	Yes, observed from catch sampling March-April
Natmor	Natural mortality	1984–last data year	2–10+	No, set to 0.2 for all ages in all years
Tuning fleet	Norwegian coastal survey	1995–last data year	2–8	

1) Estimate annual F(4–7) from survey Z at age

a) Survey Z at age a in year y is calculated as Za,y = -Log(Ua+1,y+1 / Ua,y) where U is the survey index (observed late in the year). If both catchability and natural mortality is stable between years, those factors will only influence the scaling of the “survey mortality” while the trends observed would be driven by F. Within years the Z-values have been averaged over various age groups, and the 4–9 average have shown the highest correlation with the F(4–7) in the converged years of the trial XSA (1995–2005 in the 2010 assessment. 1995–2006 in the 2011 and 2012 assessment). The annual values of Z(4–9) is then fitted by a linear regression to the F(4–7) in the converged part of the VPA, and the regression parameters are used to convert Z(4–9) to F(4–7) for the terminal year.

b) Average F at age for the 3 latest years in the trial XSA is then scaled to this survey based F(4-7) and further used as terminal F at age in a standard VPA (“user-defined VPA” in the Lowestoft version of the program). The historical Fs for the oldest true age group are also taken from the trial XSA.

2) The procedure is repeated for total catch including recreational fisheries

The current time-series of recreational and tourist catches has a rather weak basis and shows nearly constant catches over time. As long as no further information is available, a fixed recreational F (fixed effort assumption) or a recreational F scaled to indicators of effort could be used as alternative scenarios to illustrate the effect of these rather unknown catches.

I. References

Árnason, E. and Pálsson, S. 1996. Mitochondrial cytochrome b DNA sequence variation of Atlantic cod Gadus morhua, from Norway. Molecular Ecology 5: 715-724.

Artemjeva, K.F. and G.G. Novikov. 1990. Peculiarities of population structure of the Northeast Atlantic cod. In: Ecology, reproduction and conservation of biological resources in seas of the Northern Europe. Murmansk, p.162-164 (in Russian)

Berg, E., Eriksen, I. A. and Eliassen, J.-E. 1998. Catch-statistics for Norwegian Coastal cod 1984-1997, -data and methods. Fiskeriforskning, 10/1998.

Borisov, V. M., Ponomarenko, V. P. and Yaragina, N. A. 1999. A Critical Review of the Population Status in Coastal cod (Gadus morhua) from Barents Sea Region of Norway. Journal of Ichthyology 39: 18-28.

Fevolden, S. E. and Pogson, G. H. 1995. Difference in nuclear DNA RFLPs between the Norwegian coastal and the Northeast Arctic population of Atlantic cod. pp. 403-415. In: Skjoldal, H. R., Hopkins, C., Erikstad, K. E. and Leinaas, H. P. (ed.) Ecology of Fjords and Coastal Waters, Elsevier Science B. V.

Fevolden, S. E. and Pogson, G. H. 1997. Genetic divergence at the synoptophysin (Syp I) locus among Norwegian coastal and north-east Arctic populations of Atlantic cod. Journal of Fish Biology 51: 895-908.

Hallenstvedt, A. and Wulf, I., 2004. Recreational fishery in the sea 2003. (In Norwegian). Norwegian College for Fisheries/University of Tromsø, 2004.

Hirst, D., Storvik, G., Rognebakke, H., Aldrin, M., Aanes, S., and Vølstad, J. H. 2012. A Bayesian modelling framework for the estimation of catch-at-age of commercially harvested fish species. Can. J. Fish. Aquat. Sci. 69: 2064–2076.

ICES 2010. Report of the Arctic Fisheries Working Group, Lisbon/Bergen, 22-28 April 2010. ICES C.M. 2010/ACOM:05, 664 pp.

ICES 2012c. Report of the Arctic Fisheries Working Group, Copenhagen, 20-26 April 2012. ICES C.M. 2012/ACOM:05, 633 pp.

ICES 2014. Report of the Arctic Fisheries Working Group (AFWG), 23–29 April 2014, Lisbon, Portugal. ICES CM 2013/ACOM:05.

Jakobsen, T. 1987. Coastal Cod in Northern Norway. Fisheries Research 5: 223-234.

Jørstad, K. E. and Nævdal, G. 1989. Genetic variation and population structure of cod, Gadus morhua L., in some fjords in northern Norway. Journal of Fish Biology 35: 245-252.

Mork, J., Giskeødegård, R. and Sundnes, G. 1984. Population genetics studies in cod (Gadus morhua L.) by means of the haemoglobin polymorphism; observations in a Norwegian coastal population. Fiskeridirektoratets Skrifter Serie Havundersøkelser 17, No. 12: 449-471.

Mortensen, E. 2007. Er det variasjon i diett og lengde ved alder hos torsk (Gadus morhua L.) nord for 64°N? [in Norwegian]. Master Thesis, University of Tromsø, June 2007.

Møller, D. 1969. The relationship between Arctic and coastal cod in their immature stages illustrated by frequencies of genetic charaters. Fiskeridirektoratets Skrifter Serie Havundersøkelser 15: 220-233.

Nøstvik, F. and Pedersen, T. 1999. Movement pattern and growth of wild cod (Gadus morhua L.) and hatchery-reared cod released as 1-group. pp. 315-333. In: Howell, E., Moksness, E. and Svåsand, T. (ed.) Stock Enhancement and Sea Ranching, Fishing News Books, Oxford.

Pedersen, T. and Pope, J.G. 2003a. Sampling and a mortality model of a Norwegian cod (Gadus morhua L.) fjord population. Fish. Res. 63, 1-20.

Pedersen, T. and Pope, J.G. 2003b. How may feeding data be integrated into a model for a Norwegian fjord population of cod (Gadus morhua L.). Sci. Mar. 67 (Suppl. 1), 155-169.

Pedersen, T., Nilsen, M., Berg, E., and Reigstad M. 2007. Trophic model of a lightly exploited cod-dominated ecosystem. In; Nilsen, M: "Trophic interactions and the importance of macrobenthic invertebrate production in two Arctic fjord systems". A dissertation for PhD, University of Tromsø, Autumn 2007.

Rollefsen, G. (1933). The otoliths of the cod. Fiskeridirektoratets Skrifter Serie Havundersøkelser IV, 15.

Skreslet, S., Albrigtsen, I., Andersen, A. P., Kolbeinshavn, A., Pedersen, T. and Unstad, K. 1999. Migration, growth and survival in stocked and wild cod (Gadus morhua L.) in the Vestfjord region, North Norway. pp. 306-314. In: Howell, E., Moksness, E. and Svåsand, T. (ed.) Stock Enhancement and Sea Ranching, Fishing News Books, Oxford.

Sunnanå, K. 2010. Dataseries on recreational and tourist fisheries for Norwegian Coastal Cod. WD17, ICES AFWG 2010.