

Stock Annex: Cod (*Gadus morhua*) in ICES Subarea 14 and NAFO Division 1.F (East Greenland, South Greenland)

Stock specific documentation of standard assessment procedures used by ICES.

Stock: Cod

Working Group: North-Western Working Group (NWWG)

Created:

Authors:

Last updated: January 2015

Last updated by: Benchmark Workshop on Icelandic Stocks (WKICE)

A. General

A.1. Stock definition

ICES advice is given for three separate cod stocks in Greenland waters:

- 1) West Greenland offshore (NAFO 1A–1E)
- 2) East Greenland offshore (NAFO1F+ICES 14.b)
- 3) West Greenland inshore (NAFO 1A–1F) inside the 3 nm limit.

Tagging data from Greenland shows, that when fish are maturing (>40 cm) they will primarily stay in West Greenland waters when tagged north of NAFO 1F, while fish tagged in NAFO 1F or East Greenland only move east or stay (Stor-Paulsen *et al.*, 2003). Hence, the distinct spawning stocks are maintained and seem to be spatially separated at roughly the NAFO 1F northern limit which corresponds to 60°45N. This may not be historically stable, but in the current situation with a very low West Greenland offshore stock size, it seems the most appropriate division of the stocks. A similar conclusion can be made based on the distribution of year classes. Currently, the West Greenland stock biomass is so low, that the majority of the fish found in West Greenland are of East Greenland/Icelandic origin, and consequently, when these fish approach maturity, they migrate out of West Greenland waters. Consequently, fish age four and older are predominantly in either NAFO 1F or ICES 14.b, whereas juveniles are found in NAFO Areas 1A–1E, which is currently considered a nursing area for the East Greenland/Icelandic stock (Figure A.1.1).

Tagging information show that cod in the fjords in West Greenland are resident and do occasionally migrates to the adjacent coastal areas (Hansen, 1949; Hovgård and Christensen, 1990; Storr-Paulsen *et al.*, 2004). Likewise, bank cod in West Greenland are predominantly resident and migrate to a lesser extent into the coastal areas. In contrast cod tagged in the coastal areas are found distributed over all the three habitats. Hence, tagging indicate that the West Greenland offshore and inshore cod are generally separated but that the coastal area is a mixing zone.

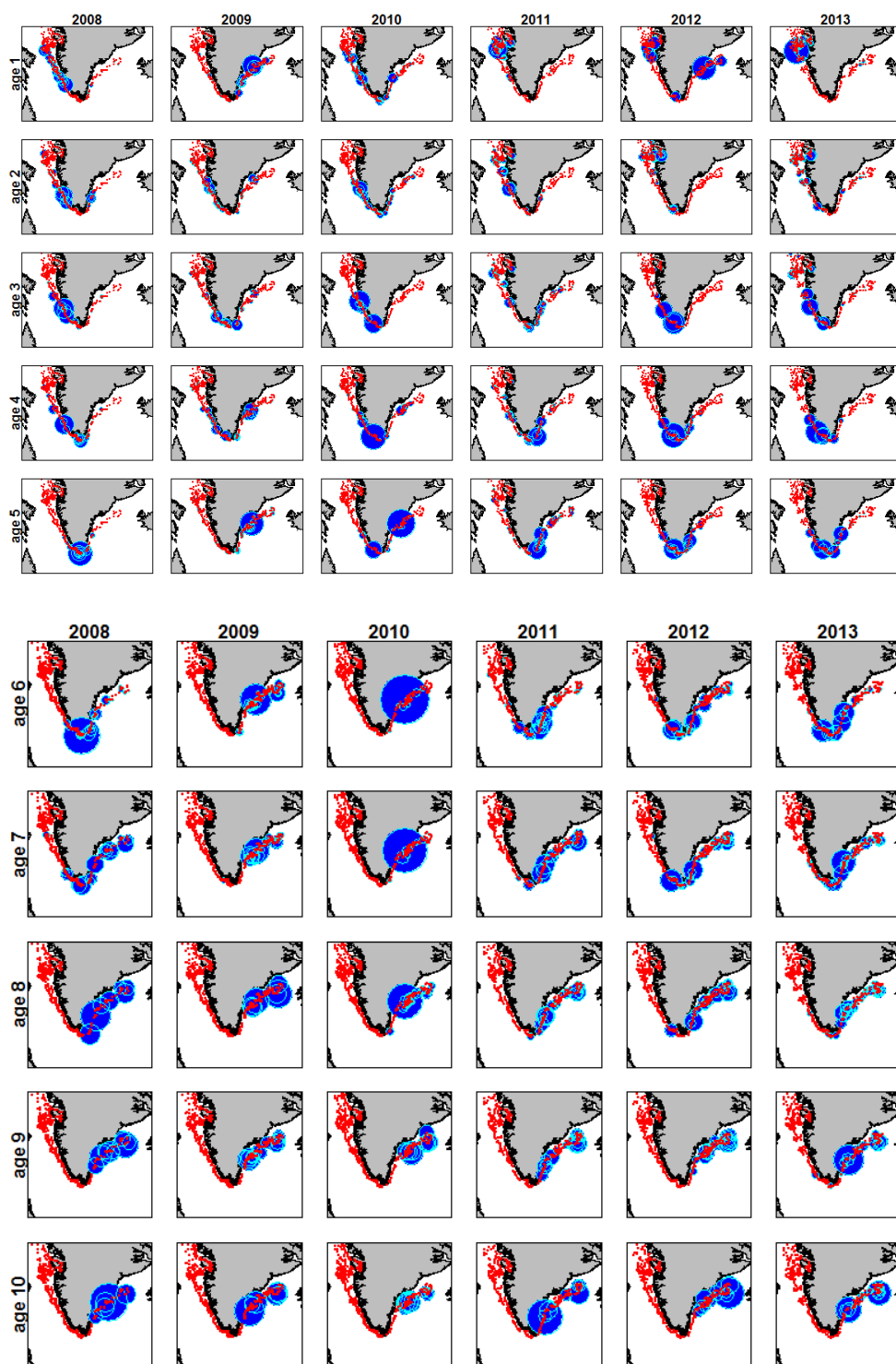


Figure A.1.1. Abundance (%) of ages 1–10 in the years 2008–2013 from the Greenland survey. The size of blue circles denotes the percentage of the cohort in the given year, where each square equals 100%. Red circles are trawl stations.

A.2. Fishery

A short historical review

The offshore fishery in the last century took off in 1924 when Norwegian fishers discovered dense concentrations of cod on Fylla Bank in NAFO Division 1D. The West

Greenland offshore fishery rapidly expanded to reach 120 000 t in 1931; a level that remained for a decade (Horsted, 2000). During World War II landings decreased by $\frac{1}{3}$ as only Greenland and Portugal participated in the fishery. Until 1951 landings are total West Greenland, including NAFO 1F, but from 1952 landings have been split per NAFO divisions. However, until 1971 a substantial part of the landings from West Greenland were reported as 'unknown NAFO area'. Parts of the "unknown catches" were allocated to each NAFO region according to the proportion of the landings in each NAFO division (ICES 2015).

During a period from the mid-1950s to 1960 the total annual landings taken offshore averaged about 270 000t. In 1962 the offshore landings culminated with landings of 400 000 t. After this historic high, landings decreased sharply by 90% to 25 000 t in 1976 and even further down to 15 000 t in 1980. Annual catch level of 40 000 t was only exceeded in the periods 1977–1979 (where unreported catches of up to 50 000 t where believe to take place, Horsted, 2000) and 1988–1990 due to the occurrence of a few strong year classes. During 1989–1992 the fishery, which almost exclusively depended on one YC (1984 YC) shifted from West to East Greenland. The entire offshore fishery completely collapsed in 1993 (Figure A.2.1).

No directed offshore fishery was allowed for the period 1993–2005, except for some minor allocations to Norway and the Faroe Islands.

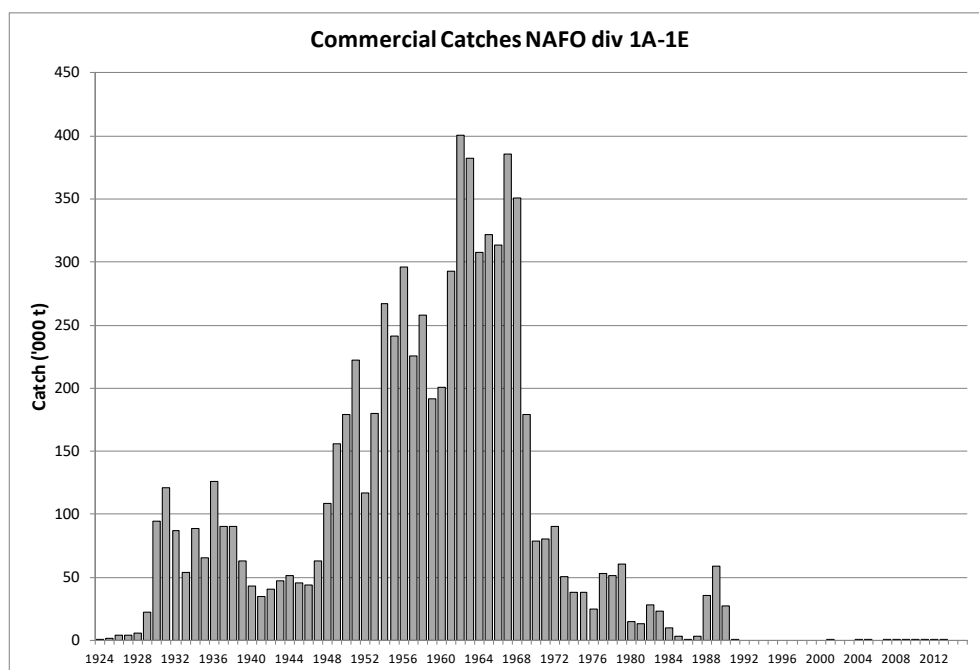


Figure A.2.1. Landings in the management area West Greenland (NAFO Division 1A–1E). Until 1951 1F is included.

The present fishery

Vessels in the offshore fisheries are vessels above 75BT/120BT and restricted to the area more than 3 nm off the baseline. The vessels require a licence that stipulates a unique vessel quota. Trawl and longline are the dominating gear.

Since 2005 directed cod fishery was introduced but catches were insignificant with only 550 t in 2008. In 2009 and 2010 fishery was closed in West Greenland. The measures introduced since 2009 had the objective to rebuild the stock in West Greenland by minimizing exploitation of the young fish and potential spawning fish.

In 2011 a management plan was implemented that allowed an experimental fishery of 5000 tons per year in the period 2011–2013 in all offshore areas in Greenland (both West and East). This management plan was replaced for the period 2014–2016 where annual quota was set at 10 000 tons as experimental fishery in South and East Greenland, whereas West Greenland north of N60°45' (corresponding to NAFO Divisions 1A–1E) was closed for fishery.

A.3. Ecosystem aspects

Some studies indicate that cod recruitment in Greenland waters is significantly influenced by environmental factors like air and sea surface temperatures in the Dohrn Bank region during spawning, in addition with the zonal wind component in the region between Iceland and Greenland during the first summer (Stein and Borokov, 2004). In addition emergence and especially decline of the cod stock in Greenland waters can be linked to sea temperature leaving the stock vulnerable to overfishing in cold periods (Hovgård and Wieland, 2008).

When and if the fishery is reopened, it may be necessary to allow for the fact that productivity could have declined. The consequence of a decline in productivity would be that a rebuild to previous levels may not be possible.

B. Data

B.1. Commercial catch

The information on landings in weight are compiled and processed by the Greenland Fisheries License Control (GFLK). The offshore information is available on the haul-by-haul scale provided by logbooks. Sampling of length frequencies and information on age, weights and maturities are collected and compiled by the Greenland Institute of Natural Resources.

Due to recent very low catches, samples from the commercial fleet have been limited.

B.2. Biological data

Spawning

No spawning of significance has been documented on the banks in West Greenland. In 2013 a random stratified bottom-trawl survey was conducted during the main spawn event and on the traditionally main offshore west spawning areas in order to detect spawning on the banks. On Dana Banke, Fiskenæs Banke, Fyllas Banke, Lille Hellefiske Banke and Store Hellefiske Banke covering N62°66'–N68°07' and depth between 80–130 m. Out of 34 stations, very little amount of cod was registered (maximum 2.7 kg at one station, Figure B.2.1). Hence no greater amount of spawning in western offshore areas is currently considered present.

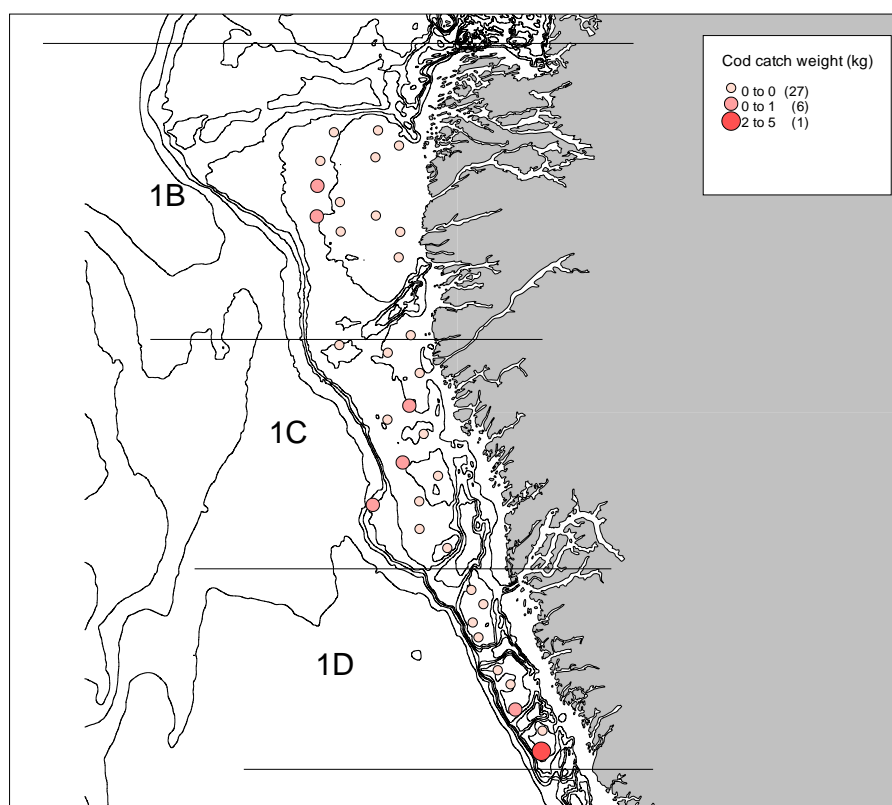


Figure B.2.1. Cod catches during cod spring survey in 2013 (May 20 to June 3) with RV Sana, covering N62°66'–N68°07'.

B.3. Surveys

At present, two offshore trawl surveys provide the core information relevant to stock assessment purposes.

Trawl survey by Greenland (Greenland Shrimp and Fish survey (GRL-GFS))

Since 1992, GINR has conducted an annual stratified random bottom-trawl survey at West Greenland. The Greenland survey covers depth from 0–600 m and covers the area south of N72°00' in West Greenland. From 2008 East Greenland was included in the survey and covers the area south of N67°00' in East Greenland. Approximately 125 hauls are taken each year in NAFO Division 1F and East Greenland. The survey provides catch and weight-at-age.

Survey area and stratification

NAFO Division 1A–1E: The stratification is based on designated 'Shrimp Areas' that is divided into depth zones of: 151–200, 201–300, 301–400 and 401–600 m, as based on depth contour lines. The depth zones 0–100 m and 100–150 m are delimited by the NAFO Subdivision boundaries. The "shrimp areas" are shown in Figure B.3.1 and their sizes are provided in Table B.3.1. After the split of the two offshore cod stock, the "Shrimp Area W7" that covers both NAFO Division 1E and 1F was re-measured in order to find out the area that constitutes this "shrimp area" in each NAFO division.

The survey trawl and its operation: The initially used trawl was a 3000/20-mesh "Skjervøy" trouser trawl, but was from 2005 replaced by a "Cosmos" trouser trawl.

Calibration experiments with the two trawls were conducted in the main shrimp areas in 2004 and 2005 and a formal analysis of conversion factors were established for shrimp (Rosing and Wieland, 2005). The catch of cod in the calibration experiments was low. However a comparison of the catch efficiency towards cod indicates that the Cosmos trawl is ca. 1.5 times as efficient as the Skjervøy (Rosing and Wieland, 2005; ICES 2008). Tow duration has over the years been gradually reduced from 60 minutes to 30 and is from 2005 fixed at 15 minutes. Survey abundance and biomass is expressed per swept-area: Wingspread*towed distance, where wingspread is inferred from SCANMAR recordings and the towed distance is measured by GPS.

Table B.3.1. The survey area (km²) in the Greenland shrimp and fish survey.

West Greenland							
Area	Depthstrata						Total
	0-100	100-150	150-200	200-300	300-400	400-600	
W1	-	-	2873	6099	7520	816	17307
W2	-	-	1674	2612	1741	915	6941
W3	-	-	2122	4725	2085	2994	11926
W4	-	-	4119	1818	821	1961	8719
W5	-	-	3001	3648	1950	3021	11620
W6	-	-	1206	2006	1585	1234	6031
W7	-	-	2442	891	265	317	3915
W7 in 1E							
W7 in 1F							
W8	-	-	424	567	405	718	2114
W9	-	-	1711	938	516	430	3595
C0	-	-	-	903	2179	1154	4236
I1	-	-	407	1963	2441	1499	6310
I2	-	-	419	815	1085	1338	3658
U1	-	-	2486	4633	4785	5129	17033
U2	-	-	-	6710	8481	7994	23185
U3	-	-	2012	3017	1675	2710	9413
1A	3039	5220	-	-	-	-	8259
1B	11346	4966	-	-	-	-	16312
1C	4183	8169	-	-	-	-	12351
1D	4136	1538	-	-	-	-	5673
1E	494	2721	-	-	-	-	3215
1F	1497	5248	-	-	-	-	6745
All strata							188559

East Greenland				
Area	0001-0200	0201-0400	0401-0600	Total
Q1	217	35445	6975	42637
Q2	93	7657	1246	8996
Q3	3363	22547	9830	35740
Q4	1337	7770	2054	11161
Q5	469	2785	1819	5073
Q6	6307	6130	2063	14500
All strata				118107

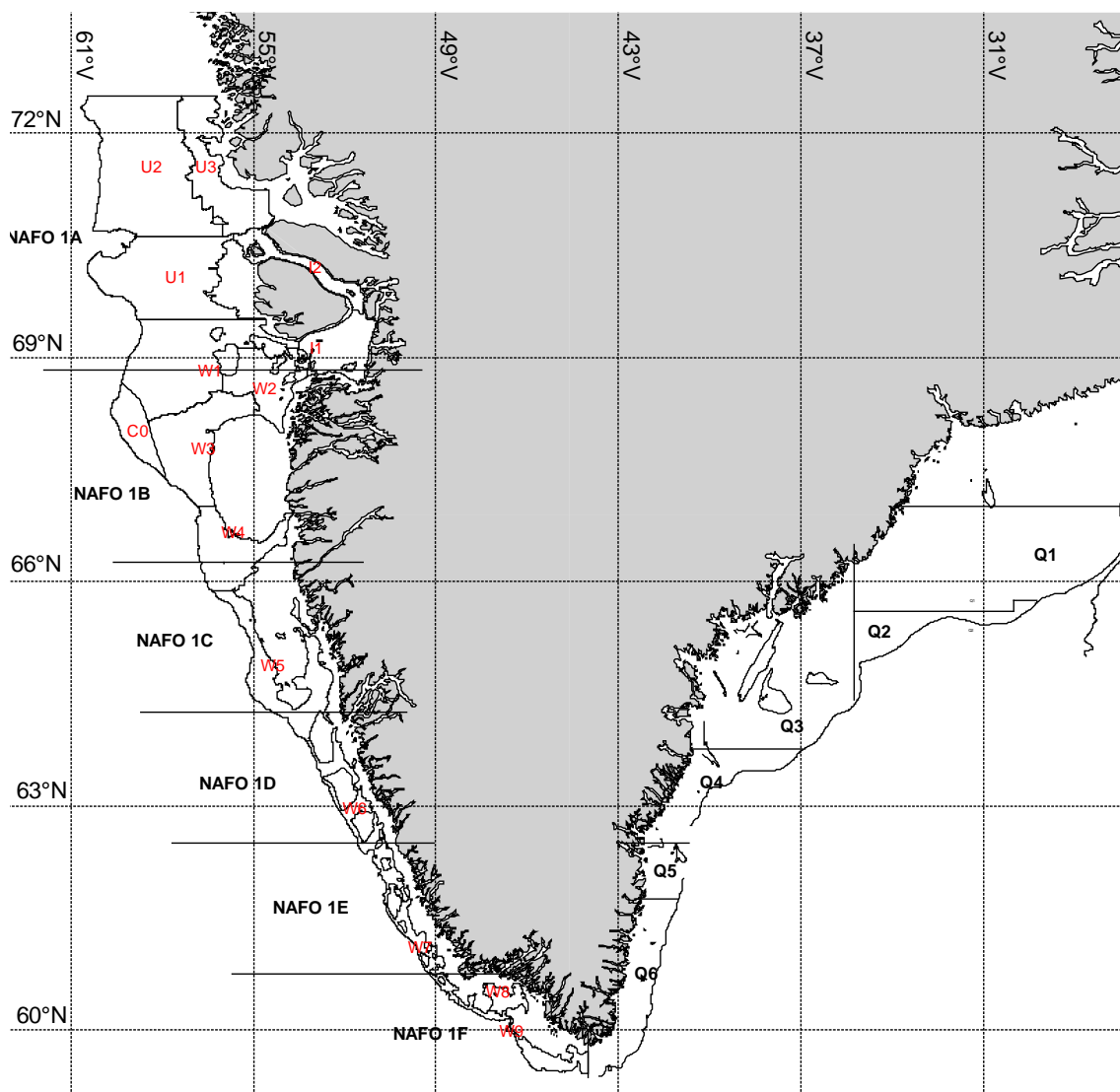


Figure B.3.1. The stratification areas used in the Greenland shrimp and fish survey. In West Greenland each strata is divided in depth strata of 150–200 m, 200–300 m, 300–400 m and 400–600 m. “Shallow” water strata of 0–100 m and 100–150 m are delimited by the 3 nm line (not shown) and the NAFO Divisions. In East Greenland each strata is divided in depth strata of 0–200 m, 200–400 m and 400–600 m. “Shallow” water strata of 0–200 m is delimited by the 3 nm line (not shown).

Trawl survey by Germany (German Greenland groundfish survey (Ger(GRL)–GFS–Q4))

The German survey has been conducted since 1982 and was designed for the assessment of cod. The survey covers both East (area south of N67°00') and West

Greenland (area south of N67°00'). Up to 2012, the surveyed area ranged from 0–400 m depth divided into seven geographical strata and two depth zones, 0–200 m and 200–400 m. Numbers of hauls were initially ca. 110 per year but were reduced from the early 1990s to 50–60 per year in South and East Greenland. In 2013, the survey was re-stratified, with four strata in West Greenland resembling NAFO division structure, and five strata in East Greenland for the depth intervals 0–200 m and 200–400 m (Table 3.2; Figure 3.2). For further information about the re-stratification see WD 25, ICES NWWG 2013.

The surveys were carried out by the research vessel (RV) WALTHER HERWIG II 1982–1993 (except in 1984 when RV ANTON DOHRN was used) and since 1994 by RV WALTHER HERWIG III. The fishing gear used was a standardized 140-foot wide bottom trawl, composed of a net frame rigged with heavy groundgear due to the rough nature of the fishing grounds. A small mesh liner (10 mm) was used inside the codend. The horizontal distance between wingends was 25 m and the vertical net opening being 4 m at 300 m depth. In 1994 smaller Polyvalent doors (4.5 m², 1500 kg) were used for the first time in order to reduce net damages due to overspread caused by bigger doors (6 m², 1700 kg), which have been used earlier.

Up to 2008 strata with less than five hauls were excluded in the annual stock calculations. From 2009 all valid hauls have been included and biomass indices for the entire time-series have been corrected. For strata with less than five haul samples, GLM and quasi-likelihood estimates have been recalculated based on year and stratum effects from the time-series. In some years (notable 1992 and 1994) several strata were uncovered, implying that the survey was incomplete.

Table B.3.2. Stratification in the German groundfish survey in the Greenland survey area (nm²). In West GLD stratification equals NAFO stratification, in East GLD based on assignment to ICES rectangles, therefore geographic boundaries given as ca-values.

Stratum	BOUNDARIES				DEPTH	AREA
	south	north	east	west	(m)	(nm ²)
1.1	64°15'N	67°00'N	50°00'W	57°00'W	1–200	6805
1.2	64°15'N	67°00'N	50°00'W	57°00'W	201–400	1881
2.1	62°30'N	64°15'N	50°00'W	55°00'W	1–200	2350
2.2	62°30'N	64°15'N	50°00'W	55°00'W	201–400	1018
3.1	60°45'N	62°30'N	48°00'W	53°00'W	1–200	1938
3.2	60°45'N	62°30'N	48°00'W	53°00'W	201–400	742
4.1	59°00'N	60°45'N	44°00'W	50°00'W	1–200	2568
4.2	59°00'N	60°45'N	44°00'W	50°00'W	201–400	971
5&6.1	59°00'N	ca 63°50'N	40°00'W	44°00'W	1–200	1562
5&6.2	59°00'N	ca 63°50'N	40°00'W	44°00'W	201–400	2691
7.1	ca 63°50'N	66°00'N	ca 33°00'W	41°00'W	1–200	298
7.2	ca 63°50'N	66°00'N	ca 33°00'W	41°00'W	201–400	2919
8.1	ca 63°50'N	66°00'N	ca 33°00'W	41°00'W	1–200	49
8.2	ca 63°50'N	66°00'N	ca 33°00'W	41°00'W	201–400	3895
9.1	64°45'N	67°00'N	29°00'W	33°00'W	1–200	0
9.2	64°45'N	67°00'N	29°00'W	33°00'W	201–400	1946

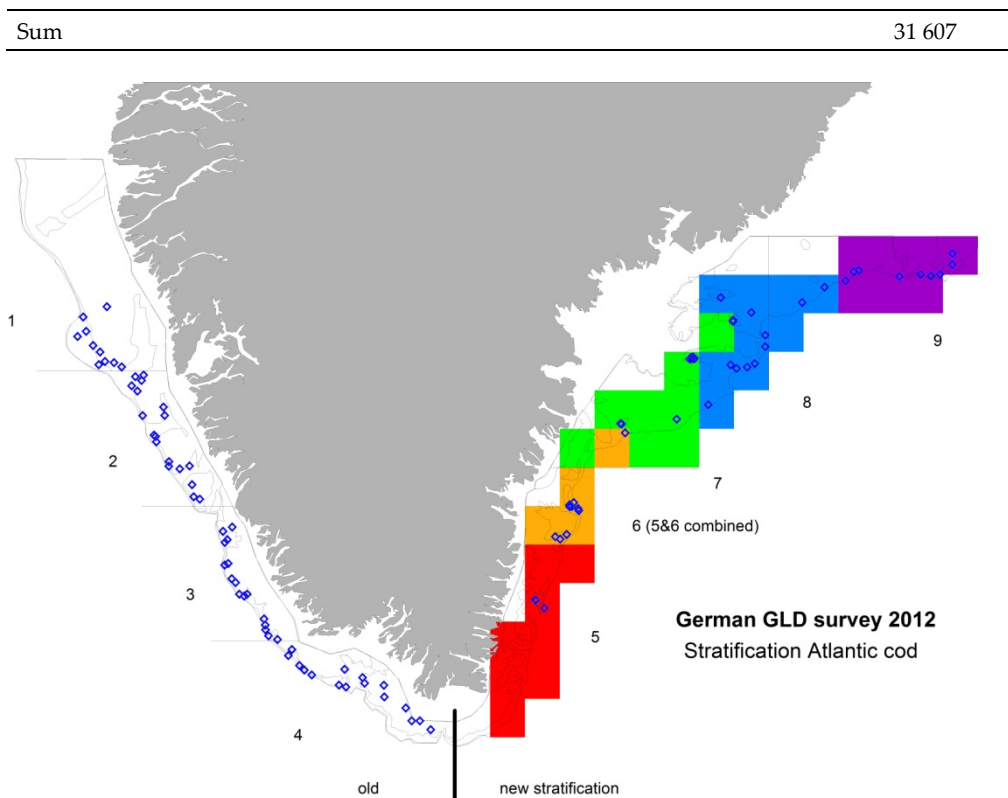


Figure B.3.2. The Stratification areas used in the German Greenland groundfish survey. Each stratum is divided into two depth zones, 0–200 m and 201–400 m.

B.4. Commercial cpue

Commercial cpue data are available. However, due to the limited fisheries in recent years they are of little use for stock assessment.

B.5. Other relevant data

C. Assessment: data and method

No stock assessment can be undertaken for this stock, due to the lack of significant rebuilding since the stock collapsed in the late 1960s. The advisory process should consider this rebuilding process when generating advice in the near future. WKICE agreed that there was little further work that this benchmark meeting could usefully undertake.

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