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

Stock	Offshore cod in South (NAFO Subdivision 1F) and East Greenland
Working Group	Northwestern Working Group
Date	May 2016
Updated by	Anja Retzel
Revised by	WKICE (2015)

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 (NAFO 1F and ICES 14.b)
3) West Greenland inshore (NAFO 1A–1F) inside the 3 nm limit.

Tagging data from Greenland show, 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/Iceland stock (Figure A.1.1).

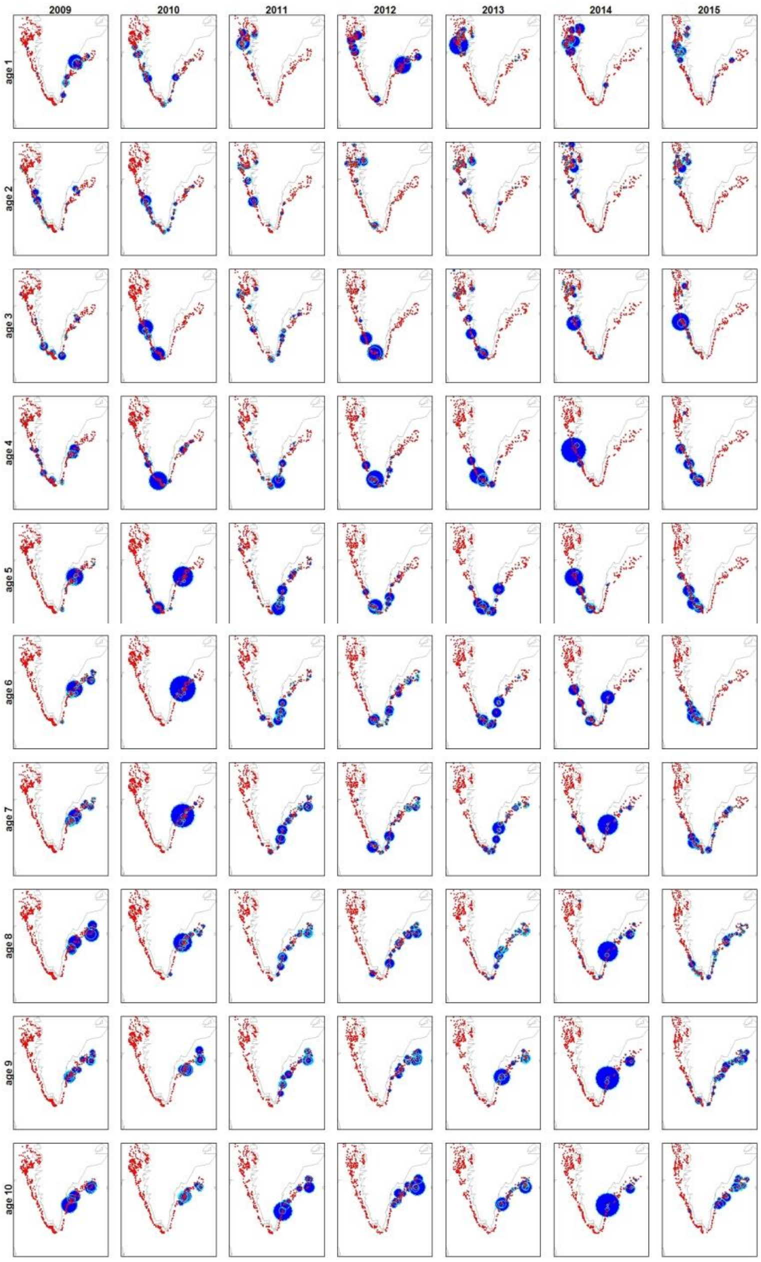

Figure A.1.1. Abundance (%) of ages 1–10 in the years 2009–2015 from the Greenland survey. The size of blue circles denotes the percentage of the cohort in the given year, where each square equals 100%. Red circles are trawl stations.

A.2. Fishery

A short historical review

The fishery in East Greenland started in 1954 as a trawl fishery (Horsted, 2000). However, until 1971 a substantial part of the landings from West Greenland were reported as ‘unknown NAFO area’. Parts of the “unknown catches” were likely caught in NAFO Division 1F and were allocated to this NAFO region according to the proportion of the landings in this NAFO division (Retzel 2015). The historical catches in East Greenland are shown in Figure A.2.1. Landings of about 30–60 kt dominated until the early 1970s, followed by a decrease to 10–30 kt until the early 1990s supported by the large year classes 1973 and 1984. For more than a decade catches were close to null, and cod was only caught as bycatch in the redfish fishery until the mid-2000s. Since then a fishery has developed with catches of approximately 5000 t annually.

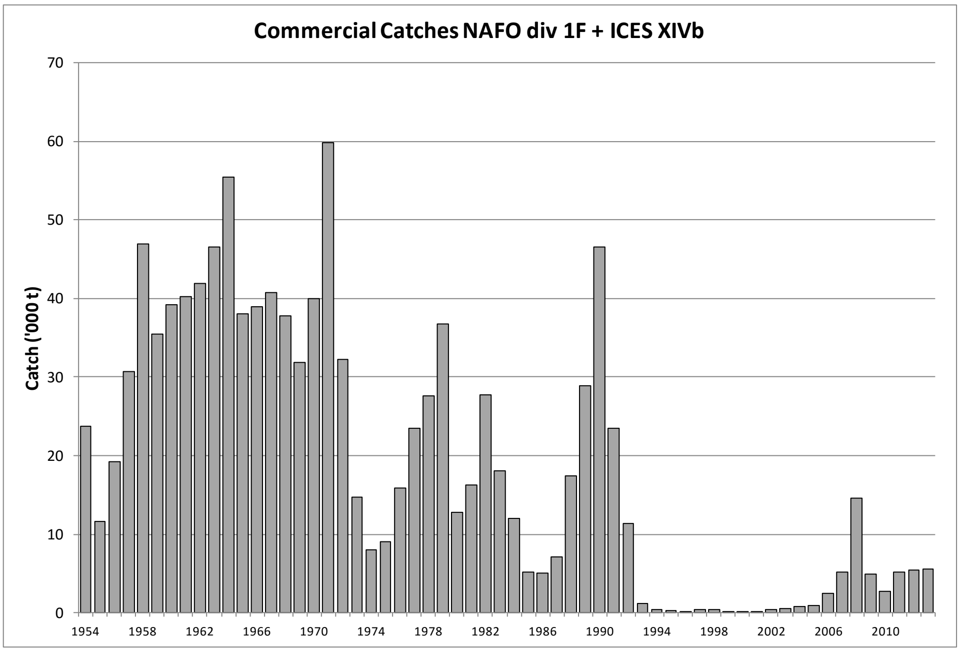

Figure A.2.1. Landings in the management area East Greenland (NAFO Division 1F and ICES 14.b).

The present fishery

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

The East Greenland area has been subject to several area closures in recent years. In 2008 fishing north of N63°00′ was not allowed in order to protect the potential spawning segments, especially on Kleine Banke. In 2009–2010 the delimitation was at N62°00′ and additionally NAFO 1F was closed in 2010 primarily to protect the relatively strong incoming year classes.

In 2011 a management plan was implemented that allowed a small 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.

Historically several countries took part in the fishery but recently catches are taken primarily by Greenland followed by Germany/UK (EU) and Norway.

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).

B. Data

B.1. Commercial catch

The information on landings in weight are compiled and processed by the Greenland Fisheries Licence 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.

Offshore sampling is laborious to acquire as most vessels produce frozen fillets that are commonly landed outside Greenland. However when it is done, it is by GFLK observers or in some cases skippers that organize the length measuring of random samples and/or to freeze individual cod for later analysis at the laboratory.

Since 2011 the offshore TAC was set as an experimental fishery which meant that the industry themselves take length measurement and biological samples of the catches and coverage of the fishery has therefore been very well.

B.2. Biological

Spawning

The recent offshore fishery has shown dense concentrations of large spawning cod off East Greenland from at least 2004. In 2007 the Greenland Institute of Natural Resources (GINR) carried out an observer programme on board two Greenland trawlers in April and May to document spawning in East Greenland. 14 000 cod were measured and 1000 examined for maturity. The average length was 70 cm. Cod maturity was determined according to Tomkiewicz *et al*. (2002). All maturity stages were recorded (non-mature 27%; maturing 23%; active spawning 36% and spent 14% spent). Length at 50% maturity was 58 cm.

In April–May 2009 an Icelandic survey in East Greenland found dense concentrations of spawning cod north of 62° at the banks between “Skjoldungen” (62°30′) and “Kleine Bank” (64°30′). The major contribution to the spawning biomass was made by the 2003 YC. Length at 50% maturity was approximately 60 cm which was consistent with the results in the 2007 observer programme.

B.3. Surveys

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

<u>NAFO Division 1F:</u> 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.

ICES Subdivision 14.b: The East Greenland area was for the first time properly covered in 2008. The area was intended covered in 2007, but due to a vessel breakdown only eight days were available, allowing only for a short pilot investigation.

The survey is carried out with the same gear and survey protocols as used in West Greenland. Stratification is based on the "Q-areas" used for the East Greenland survey for Greenland halibut. The areas are further depth stratified into 0–200 m, 200–400 m and 400–600 m zones, the areas are shown in Figure B.3.1 and the sizes are given in Table B.3.1.

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 (km^2) in the Greenland shrimp and fish survey in NAFO subdivision 1F and ICES Subarea 14.b.

NAFO 1F (SouthWest Greenland)							
	Depthstrata						
Area	0–100	100–150	150–200	200–300	300–400	400–600	Total
W7 part of 1F	-	-	466	184	73	106	829
W8 (1F)	-	-	357	516	476	636	1985
W9 (1F)	-	-	2003	991	740	477	4211
1F	1497	5248	-	-	-	-	6745

ICES 14.b (East Greenland)				
	Depthstrata			
Area	0–200	200–400	400–600	Total
Q1 (14.b)	217	35445	6975	42637
Q2 (14.b)	93	7657	1246	8996
Q3 (14.b)	3363	22547	9830	35740
Q4 (14.b)	1337	7770	2054	11161
Q5 (14.b)	469	2785	1819	5073
Q6 (14.b)	6307	6130	2063	14500
All strata				131390

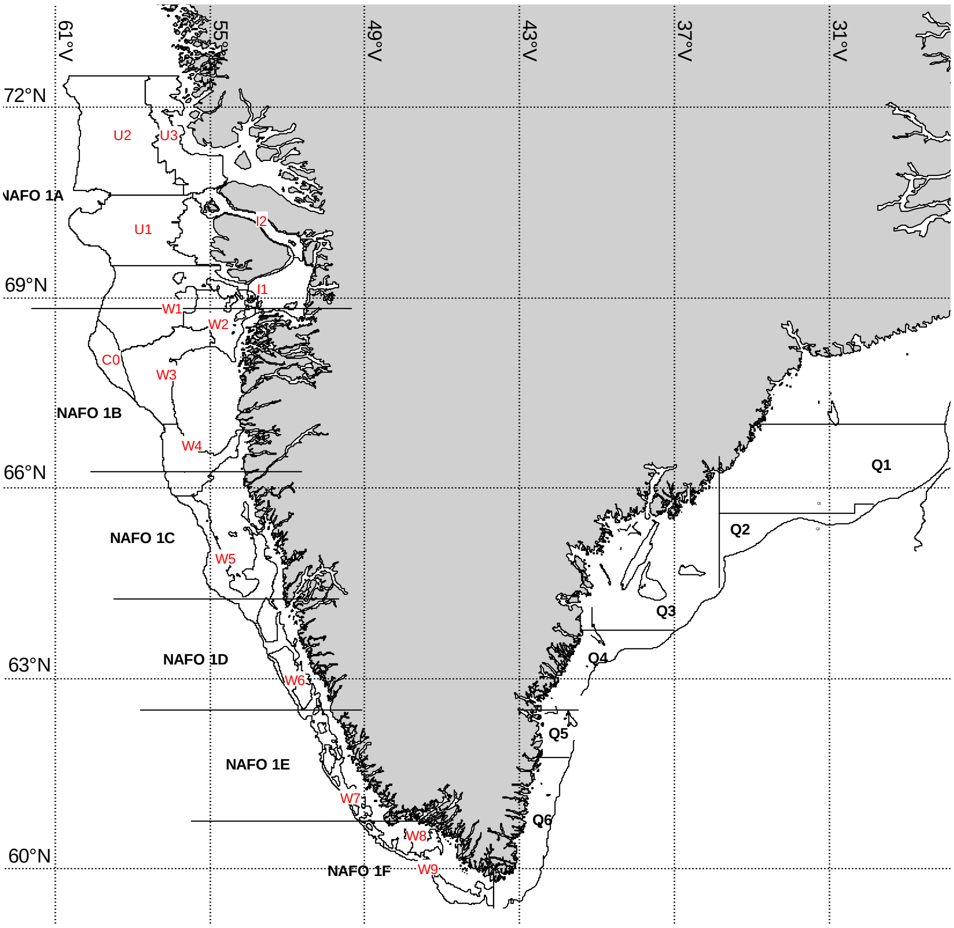

Figure B.3.1. The stratification areas used in the Greenland shrimp and fish survey. In West Greenland each strata is divided in depth strata of 150–200 m, 200–300 m, 300–400 m and 400–600 m. "Shallow" water strata of 0–100 m and 100–150 m are delimited by the 3 nm line (not shown) and the NAFO Divisions. 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 B.3.2; Figure B.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 where 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 m^2, 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 (nm^2). In West GLD stratification equals NAFO stratification, in East GLD based on assignment to ICES rectangles, therefore geographic boundaries given as ca-values.

	BOUNDARIES				DEPTH	AREA
Stratum	south	north	east	west	(m)	(nm2)
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
Sum						31 607

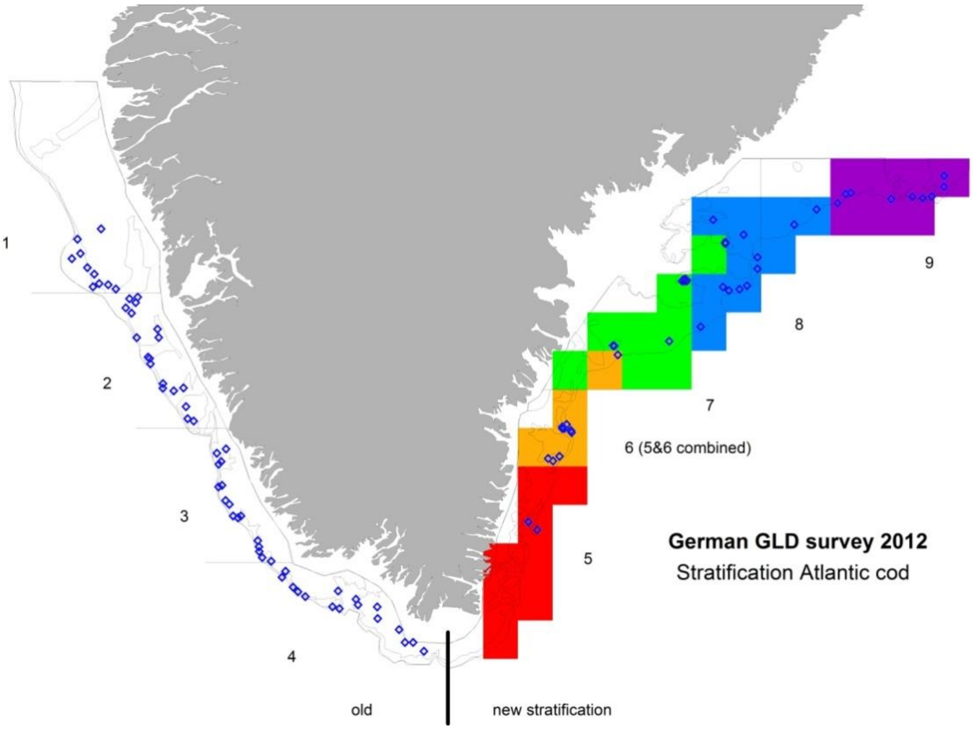

Figure B.3.2. The Stratification areas used in the German Greenland groundfish survey. Each stratum is divided into two depth zones, 0–200 m and 201–400 m.

B.4. Commercial cpue

Commercial cpue data are available from the period 1973 to present. However, due to time restrains the cpue series have not been thoroughly scrutinized as several issues need to be addressed such as; different fleets before and after the 1990s, primarily bycatch in the 1990s and recent periodic area closures.

B.5. Other relevant data

NA.

C. Assessment: data and method

C.1 Smoothed surveys

The East Greenland area is highly dynamic due to migrations to and from adjacent areas. Inflow of eggs and larvae from Iceland is a common and sometimes large event and some year classes found in East Greenland are primarily from this area (e.g. 2003 YC). West Greenland functions to a very large extent as nursing grounds for East Greenland juveniles and the return migration often produce very sudden and large biomass increases. Jointly, this dynamic can cause large between year variations in survey indices that may appear unrealistic. Furthermore, survey indices are associated with large uncertainties in this area, particularly because of single very large hauls. As the surveys form the basis for the advice, such uncertainty is unwanted and a random effects survey smoother was applied to the estimates of biomass. The underlying survey biomass is modelled with a random walk with process errors, and the observations of survey biomass estimates are estimated with observation errors:

$z_t = z_{t-1} + a_t$

$y_t = z_{t-1} + e_t$

where z_t is the natural log of true survey biomass at time t, y_t is the natural log of estimated survey biomass, and a_t and e_t are process and observation errors, respectively, modelled with normal distributions. For a more throughout description see ICES (2015).

C.2 DLS approach (method 3.2, ICES 2012)

The stock was benchmarked in 2015 (WKICE, ICES 2015). None of the analytical assessments presented at the benchmark were agreed to be capable of being used as single basis for making catch advice. It was generally considered that the big uncertainty in the two surveys was not properly accounted for in the different model runs. However, the two surveys were to a high degree thought to reflect the stock trends, especially when considering how alike the two indices are. Therefore it was decided to use survey indices in future advice approach. One way of doing that is using the indices in a DLS framework (ICES 2012, method 3.2.) where trends are multiplied with the commercial catches. For producing catch advice, it was decided to use the method 3.2 with the following catch equation:

$$C_{y+1} = C_y \left(\frac{\sum_{i=y-x}^{y-1} I_i / x}{\sum_{i=y-z}^{y-x-1} I_i / (z - z)} \right)$$

where C_{y+1} is the catch advice for the next year, C_{y-1} is the advice from last year, I = Survey biomass index value for the Greenland survey, x equals 2 and z is 5.

Uncertainty cap or "change limit" of +- 20% change in C_{y+1} if C_{y+1} from the equation is 20% greater or less than C_{y-1} is applied to C_{y-1} to address uncertainty or noise in the data and its potential influence on the catch advice.

C. 3 DLS F_{proxy} reference point approach (method 3.3, ICES 2012)

As a period of relatively stable catches with low fishing mortality (figure C.3.1) is co-occurring with rising survey indices (2011—2014, figure C.3.2), a derived F_{proxy} would be a better basis for advice and more precautionary than the method 3.2. Hence, the catch advice should be based on an F_{proxy} multiplier on the Greenland survey (smoothed) which has the best coverage of the stock. The F_{proxy} was the catch divided by the Greenland survey biomass indices (observed) from 2011—2014 and the average of this (0.049) was multiplied with the smoothed Greenland survey biomass index to give catch advice.

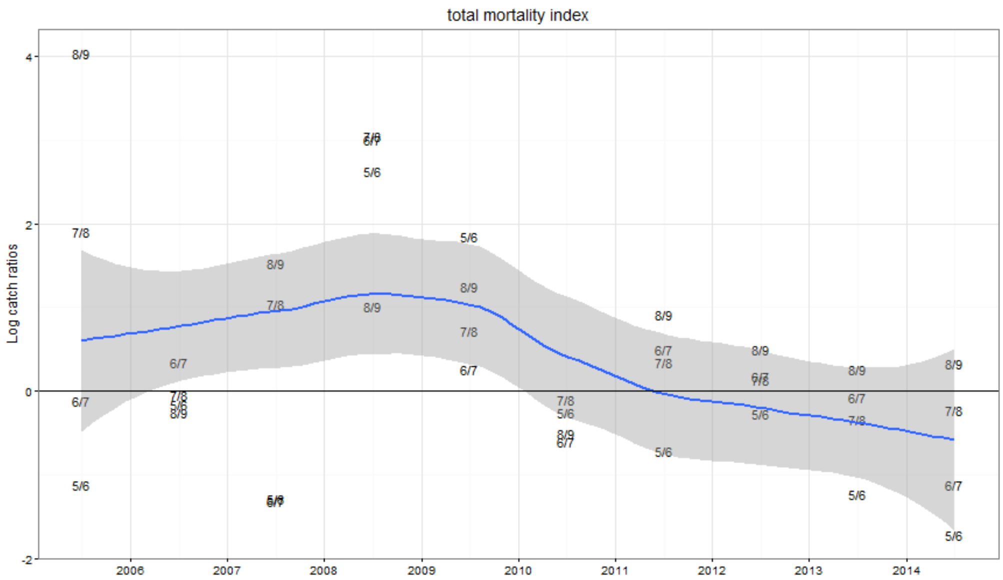

Figure C.3.1: Log catch ratios from the commercial catches fitted with a Loess smoother. The Fproxy used in generating catch advice is calculated from the 2011-2014 period. Labels are age specific log catch ratios in a given year.

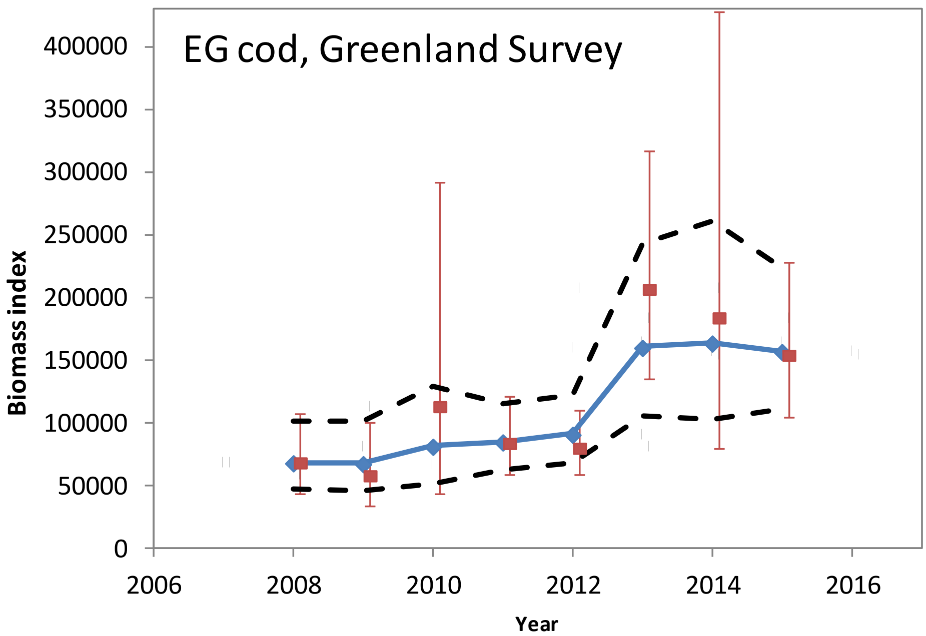

Figure C.3.2: Biomass index for NAFO 1F and ICES Subarea 14.b. Red squares are the estimated mean value from the survey and the vertical connected lines are upper and lower 95% confidence intervals. The smoothed estimates are displayed as the blue line and the 95% confidence intervals of the smoothed values are shown as dashed lines.

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