Stock Annex: Cod (Gadus morhua) in NAFO Subarea 1A-C, Northern West Greenland Inshore Spawning Cod

Stock: Northern West Greenland Inshore spawning cod (*Gadus morhua*, NAFO subarea 1A-C) (Cod.21.1a-c.isc)

Working Group: North Western Working Group (NWWG)

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A. General

A.1. Stock definition

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

1) West Greenland Offshore Spawning Cod (hereafter called WOSC)
2) East Greenland and Iceland Offshore Spawning Cod (hereafter called EGIOSC)
3) West Greenland Inshore Spawning Cod (hereafter called WISC)

Extensive mixing occurs in West Greenland especially in the inshore area (Buch et al. 2023). Genetic and tagging data (Stor-Paulsen *et al*. 2003, Hedeholm 2018) combined with survey data show that the EGIOSC stock typically migrate eastwards out of West Greenland waters at onset of spawning at age 5-6 yrs. The WOSC stock has its spawning sites on the offshore banks in West Greenland but do migrate inshore both as juveniles and adults. The WISC stock will to a large extent stay inshore. The inshore area is therefore a mixing area of all three stocks whereas the offshore area is primarily a mixing site for the WOSC and the EGIOSC stocks (figure A.1.1).

The assessment for the WISC stock does not distinct between the offshore and inshore area but covers both areas in West Greenland. The assessment of the WISC stock is split into two, one for the northern area, NAFO subareas 1A-C (hereafter called N-WISC) and one for the southern area, NAFO subarea 1D-F (hereafter called S-WISC). This stock annex is for the N-WISC stock based on data for NAFO subareas 1A-C.

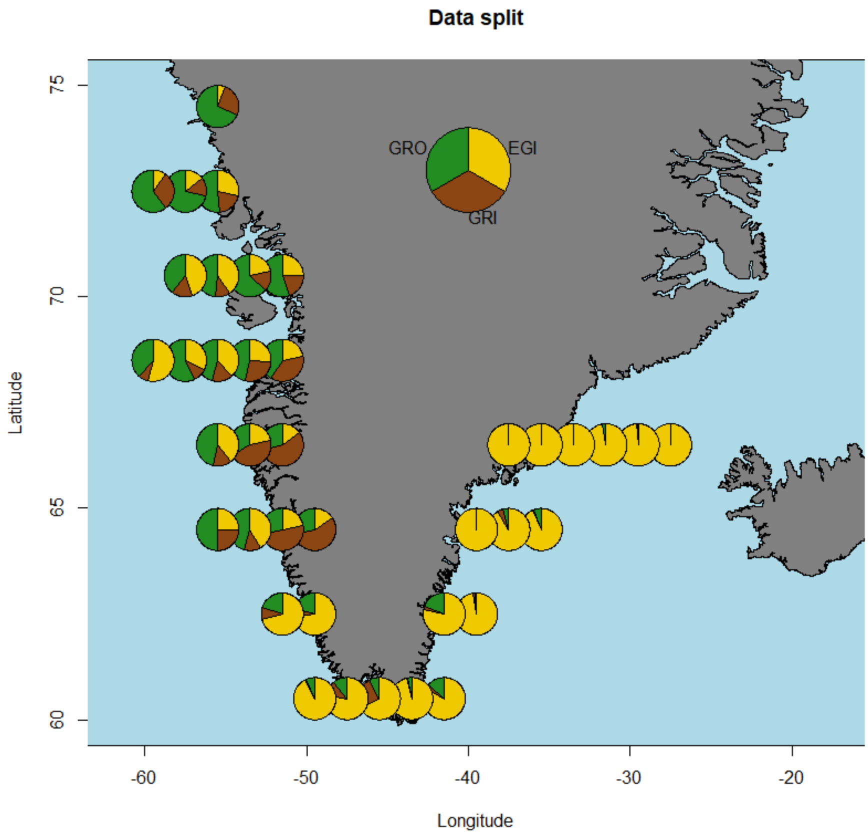

Figure A.1.1. Map of Greenland with piecharts showing the proportion of each of the three cod stocks based on the individual cod sample for genetics from both commercial fisheries and scientific surveys in the period 2000-2021.

A.2. Fishery

A short historical review

The inshore fisheries in West Greenland started in 1911 (figure A.2.1). The fishery has fluctuated through time, with four peaks that reached a maximum of 35,000 – 40,000 tons in the 60ies, the beginning of the 80ies, beginning of the 90ies and lastly in 2016. The peaks were followed by a sharp decline in catches, especially in the 80ies and 90ies, where the catches were below 1,000 tons. This lasted until the beginning of the 00ies where the fishery increased.

The West Greenland offshore fishery in the last century started in 1924 (Figure A.2.1). The 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 1/3 as only Greenland and Portugal participated in the fishery. From the mid-1950s to 1960, the total annual landings taken offshore averaged about 270,000 tons. In 1962 the offshore landings culminated with landings of 400,000 tons. After this historic high, landings decreased sharply by 90% to 28,000 tons in 1976 and even further down to 15,000 tons in 1980. An annual catch of 50,000 tons have only later been exceeded in 1977–1979 and 1988–1990 due to 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 fishery in East Greenland (ICES subarea 14b) started in 1954 (Figure A.2.1) and has never reached the same heights as in West Greenland. Landings of 20,000–35,000 tons dominated until the early 1970s, followed by a decrease to 10,000–30,000 tons until the early 1990s, supported by the large year classes in 1973 and 1984. The entire fishery in East Greenland completely collapsed in 1991, and cod was only caught as bycatch in the redfish and Greenland halibut fishery in East Greenland until the mid-2000s.

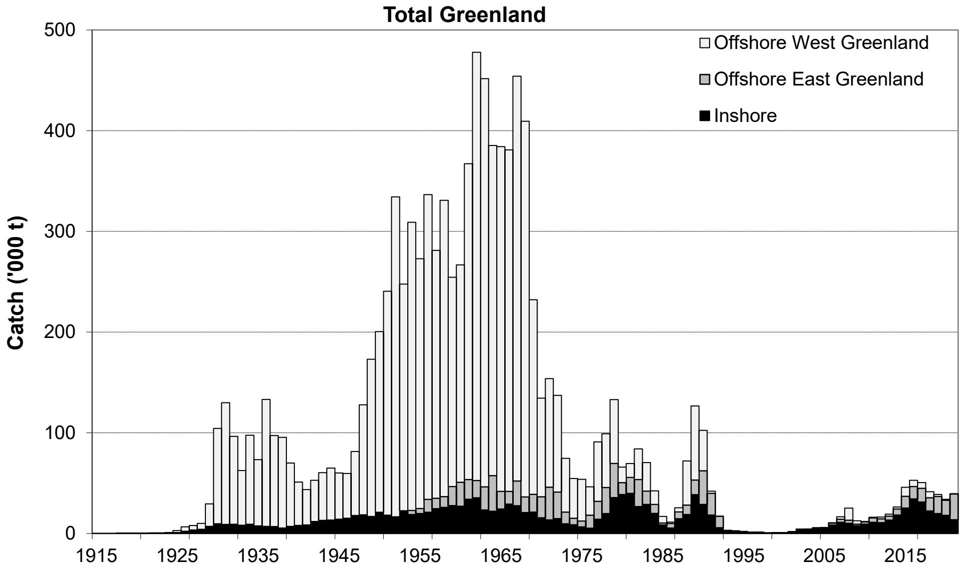

Figure A.2.1. Landings in Greenland divided into 3 areas; Offshore West Greenland, Offshore East Greenland and Inshore West Greenland.

The present fishery

The catches in West Greenland (both offshore and inshore) have been split into the three stocks, WOSC, WISC and EGIOSC from 2000. The split is based on genetic samples and a GAM model (see section B4). Further the WISC stock is split into N-WISC comprising the area of NAFO divisions 1A-1C and S-WISC comprising the area of NAFO divisions 1D-1E. Here is described the catch of the WISC stock in the northern area (N-WISC).

The catch of N-WISC started from almost zero in 2000. In 2001 there were no samples from the fishery and hence no split by stock can be made for this year. The catch steadily increased from 2,000 tons pr year to a maximum of 14,000 tons in 2016 and 2017 (figure A.2.2). Hereafter the catches have declined.

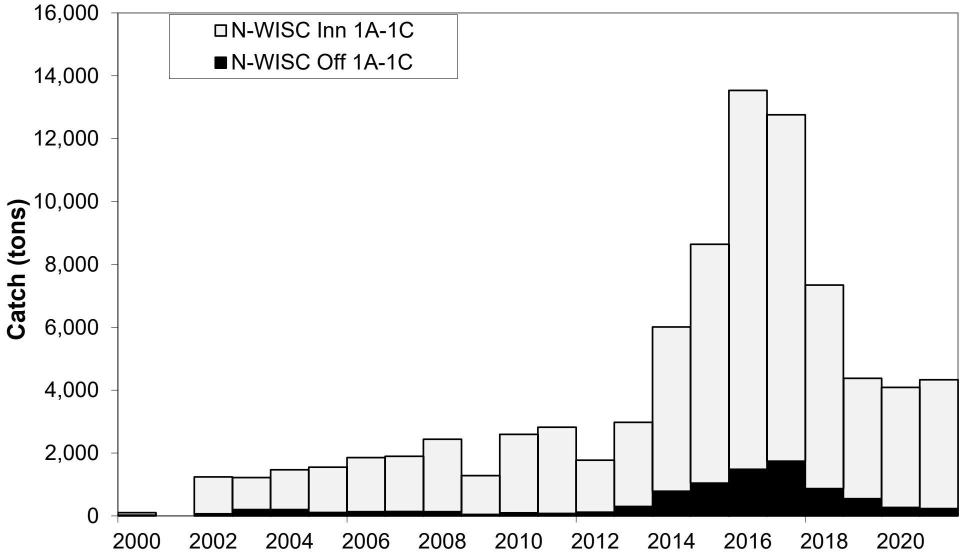

Figure A.2.2. Catch of the Inshore West Greenland cod stock (WISC) in the inshore and offshore area in NAFO divisions 1A-1C in West Greenland. No samples from the fishery in 2001.

The N-WISC is mainly caught in the inshore fishery (average 95%, figure A.2.2). The most important gear in the inshore fishery is pound nets (taking app. 60-80% of the annual catches) anchored at the shore and fishing the upper 20 m. Due to the ice conditions and vertical migration of cod, pound nets are not used during November-April. The inshore fishery uses long-lines, jigs and gillnets in autumn and winter. The catches usually peak in summer and are lowest during late winter or early spring, when the lumpfish fishery dominates. About half of the catches are taken by small dinghies. The other half of the catches are taken by larger vessels (cutters). Catches in NAFO division 1A are mainly from the Disco Bay area and cod are here mainly caught as bycatch in the Greenland halibut fishery which uses longlines and gillnets.

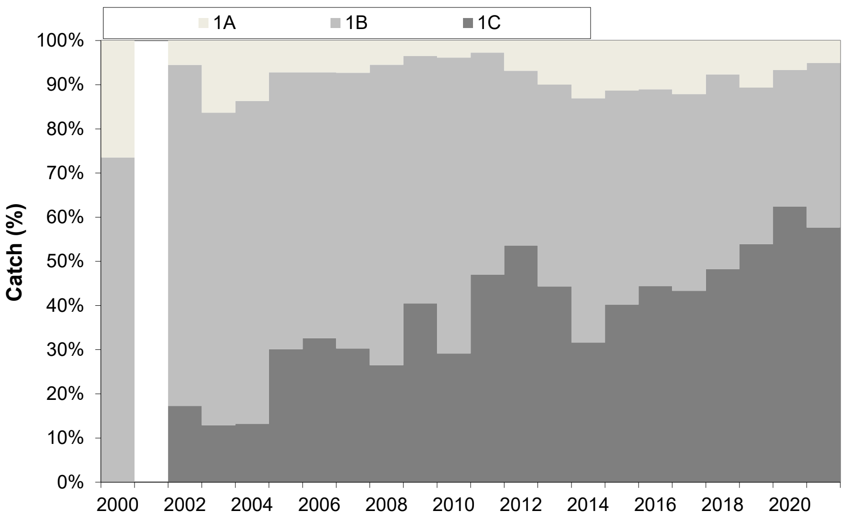

Figure A.2.3. Proportion (%) of catch of the Inshore West Greenland cod stock (WISC) by NAFO divisions (1A-1C) in West Greenland. NAFO division 1A furthest to the north. No samples from the fishery in 2001.

The N-WISC is mainly caught in NAFO divisions 1B and 1C where in average 90% of the total catch of N-WISC is caught (figure A.2.3). Especially in later years the proportions of the catch in 1C have increased to almost 60%.

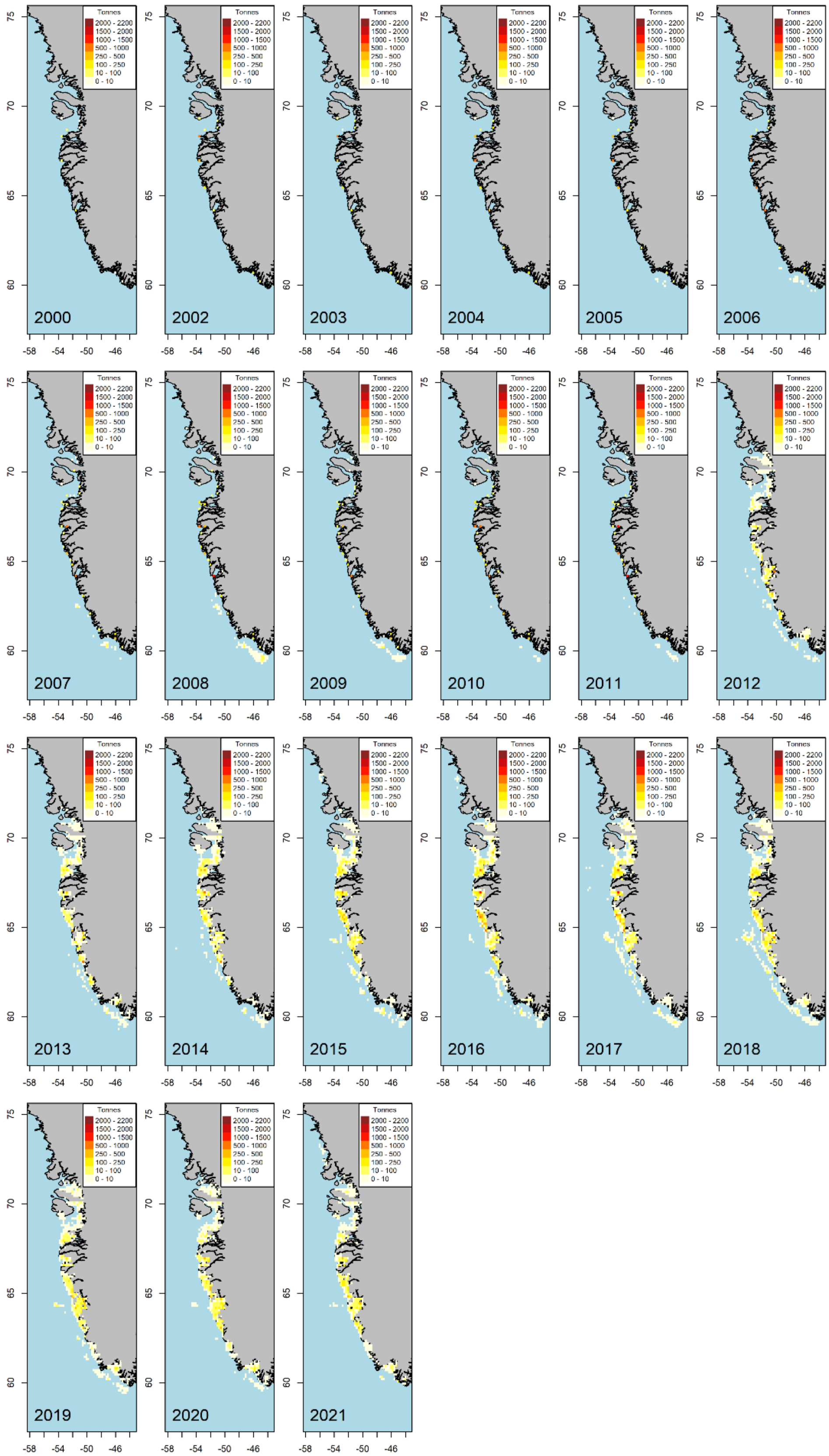

Figure A.2.4: Catch (tons) by field code in West Greenland 2000-2021 for the West Greenland Inshore stock (WISC).

Fishery management regulations

The coastal fisheries did not require a license until 2009 and have historically not been constrained from catch ceilings. In 2009 a TAC of 10,000 tons was introduced, and since, yearly TAC has been used. In general, however, when the TAC is fished, additional tons are added, increasing the TAC over the year. This situation happened in 2010-2011 and 2014-2016. From 2016 to 2019 it was allowed to fish offshore both in West and East Greenland on the inshore quota, but limited amount (less than 500 tons) was fished. Trawling is not allowed within 3 nm off the baseline (figure A.2.5), and vessels above 75BRT/120BT are not allowed to fish within the 3 nm-line off the baseline.

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 license that stipulates a unique vessel quota. No directed offshore fishery was allowed for the period 1993–2005. Since 2005 the offshore area in West Greenland has been subjected to partial closures leaving the southern part (corresponding to NAFO division 1F) open to fishery.

Figure A.2.5: Map of Greenland with NAFO divisions in West and Q division in East. 3 NM line of the baseline, the EEZ and depth curves are indicated.

A.3. Ecosystem aspects

There is little bycatch in the poundnet or jig fishery. Additionally, fish below the minimum size are easily released from the poundnets and are believed to survive. Poundnet selectivity means that fish ages six and older are not caught in proportion to the stock composition.

Cod in the inshore region feed on a several prey items, but the summer spawning of capelin in shallow water seems to be linked to intense feeding from cod (GINR unpublished data). There is no quantification of the predatory impact of cod, but as capelin in the inshore area are not commercially exploited there are no possible regulations.

B. Data

The information on landings in weight are compiled and processed by the Greenland Fisheries Licence Control (GFLK). Sales slips document inshore catches, but logbooks have been mandatory since 2008 for vessels larger than 30 ft. The main fishing gear of these vessels is pound nets that catch live fish until the nets are saturated. Information on CPUE from this type of fishing gear is therefore questionable. Information from vessels smaller than 30 ft is only from sale slips. Until 2011, these were of poor quality, meaning that catches were compiled using landing data from the factories with no information on the effort, gear type or field code of the actual catch. Since 2012, the quality of sale slips has improved and includes information on the effort, gear type and field code (7.5 min and 15 min per Lat Lon, respectively, figure A.2.4) of each catch that is landed at a factory.

Sampling of length frequencies and information on age from the inshore catches, weights and maturities are collected and compiled by the Greenland Institute of Natural Resources. A well-balanced sampling of the Greenland inshore catches has always been impeded by the geographical conditions, i.e., the existence of many small landing sites separated along the over 1,000 km coast. Except for the Nuuk area in NAFO division 1D (Figure A.2.5), which is easily covered, sampling relies on dedicated sampling trips supplemented with ad hoc samplings when ports are called through other institute activities.

The offshore information is available on the haul-by-haul scale provided by logbooks. The ship crew collect individual measurements (length, weight, and gutted weight) and biological samples, such as otoliths, from randomly selected cod in the catches. This has been a part of the license requirements since 2011. From these collections, length and age frequencies are constructed.

Catch and weight at age are compiled on NAFO division (Figure A.2.5) in West Greenland for the inshore and offshore areas separately. When there are no samples from a NAFO division, samples from the neighboring area is used. Length samples are weighted by gear and quarter of the year to catch when sampling allows it.

Collection of otoliths is often more complicated to archive than length measurements of the commercial catch, especially for the inshore area, as cod is often landed at the factory without a head. In years with poor sampling from the commercial fishery, information from otoliths collected from surveys in the area is used.

An overview of sampling from the fishery in the period used in the assessment (from 2000) is seen in tables B.1.1 and B.1.2.

Table B.1.1: Sampling of the Inshore fishery.

Year	Length Samples	N fish measured	Otolith samples from surveys	Otolith samples from fishery
2000	1	375	145	-
2001	No samples			
2002	21	10157	220	209
2003	22	4402	303	322
2004	4	1585	633	222
2005	9	1820	480	197
2006	34	9496	368	-

2007	69	19297	199	767
2008	41	8366	297	1226
2009	47	11541	425	1429
2010	50	11590	378	2332
2011	63	9572	1202	914
2012	79	13503	710	317
2013	68	11406	729	470
2014	49	6446	730	407
2015	115	21854	740	218
2016	110	21816	893	179
2017	110	15402	1407	-
2018	44	7168	1274	246
2019	98	17711	1212	297
2020	50	10192	891	84
2021	57	10082	1112	298

Table B.1.2: Sampling of the Offshore fishery in West Greenland.

YEAR	LENGTH SAMPLES	N FISH MEASURED	OTOLITH SAMPLES FROM SURVEYS	OTOLITH SAMPLES FROM FISHERY
2004	No samples			
2005	8	1800	445	47
2006	No samples		988	35
2007	22	3081	793	83
2008	8	1277	1117	106
2009	40	7329	641	247
2010	25	4523	922	575
2011	46	5985	831	1199
2012	41	5601	750	671
2013	70	9045	980	437

2014	64	4727	898	748
2015	132	10312	1082	531
2016	67	3652	785	83
2017	234	32176	1071	1712
2018	157	21379	878	971
2019	65	9167	1317	642
2020	6	900	908	-
2021	No samples		-	-

The genetic composition of the three cod stocks in West Greenland (Buch et al. 2023) changes from south to north and inshore to offshore. Therefore, to calculate the catch of each stock, catch- and weight at age are compiled on field code level instead of the larger NAFO areas (Retzel et al. 2023). Field codes are squares of 7.5 minutes (0.125 degrees) latitude (North) and 15 minutes (0.25 degrees) longitude (West) (Figure B.1.1).

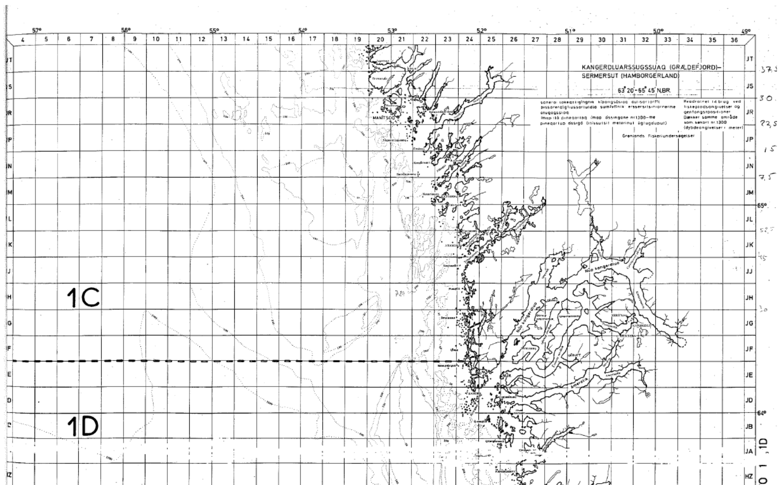

Figure B.1.1: Example of Field codes in the Nuuk area (NAFO division 1C and 1D).

For the inshore area, since 2012 and onwards, catch positions have been available by field code levels. From 2000-2011, catch areas are only known from factory locations. Nevertheless, as fishermen only sail short distances, we find it reasonable to assume that the catch landed at a factory is caught in a nearby area. Therefore, the field code of where the factory is situated is used as the catch field code for the period 2000-2011 (figure A.2.4).

For the offshore area, information on catches is on a haul-by-haul basis in logbooks with precise gps positions. These are compiled as catch by field code.

B.1.2. Discards estimates

There is a discard ban in Greenland waters and there is no reason to suspect that discarding takes place.

B.1.3 Recreational catches

There are some recreational catches, but these are considered negligible.

B.2. Biological sampling

B.2.1 Maturity

Maturity stage of Atlantic cod in Greenland is classified after Tomkiewicz et al. (2002) from stage 1-9; 1-2 are juveniles, 3-4 is ripening, 5-7 is spawning and 8-9 is spent. For maturity ogive calculation stages 1-2 are juveniles and stages 3-9 are adult. Ogives are calculated on cod that has been genetically assigned (Buch et al. 2023) and from spawning month (March, April, May and June) as there can be errors in classification between stage 2 and 9 outside spawning season. Due to low sampling size and no yearly genetic analysis in spawning season (table B.2.1.1), the proportion of mature fish by age is left unchanged from year to year (table B.2.1.2). The maturity ogive for WISC was estimated by a general linear model (GLM) with binomial errors (using the glm function from 'The R Stats Package' version 4.0.5). Estimated A_{50} is 4.56 for WISC.

Table B.2.1.1: Number of samples with information on maturity, age and genetic composition in March, April, May and June by year used in maturity ogive for the West Greenland Inshore stock (WISC).

Year	WISC
2008	58
2010	16
2011	162
2012	34
2013	38
2016	214
2017	515
2018	88
2019	299
2021	164
Total	**1588**

Table B.2.1.2: Maturity ogive by age for the West Greenland Inshore stock (WISC).

Age group	WISC
1	0.004
2	0.020
3	0.085
4	0.299
5	0.661
6	0.899
7	0.976

8	0.995
9	0.999
10	1.000

B 2.2 Natural mortality

Natural mortality is differentiated by age but fixed at 0.2 for all ages. Tagging data shows, that there is migration from the coastal area to offshore regions and further to East Greenland and Iceland (Storr-Paulsen et al. 2004, Hedeholm, 2018). Genetic investigations have shown that the migration is limited to the East Greenland-Iceland offshore stock EGIOSC (Bonanomi *et al.* 2016) and has therefore no effect on the WISC stock and natural mortality is by default set to value of 0.2.

B.3. Surveys

B 3.1 Inshore gillnet survey (N6619)

A Gillnet survey covers the inshore area in two NAFO divisions 1B and 1D (Figure B.3.1.1). The survey in division 1B is used in the assessment of N-WISC.

The survey is a multi-meshed gillnet survey designed to target juvenile cod age 2 and 3 yrs old in the inshore area in West Greenland. The objective of the survey is to assess the abundance and distribution of recruiting cod. However, given the different ways of being caught in a gillnet other than being gilled, the selectivity is not entirely dome shaped but elongated towards larger fish (Figure B.3.1.2). Therefore, gillnet catches of older fish ages 2–8 were included in the data set.

The survey uses gangs of gillnets with different mesh sizes (16.5, 18, 24, 28 and 33 mm, ½ mesh). The nets are set annually during late spring/early summer. They are set parallel to the coast in order to keep the depth constant. The survey effort is allocated evenly between the depth zones of 0–5 m, 5–10 m, 10–15 m and 15–20 m. The abundance index used in the survey is defined as 100*(# caught/net*hour). An average of 61 stations have been taken in the assessment period (2000-2021, table B.3.1.1).

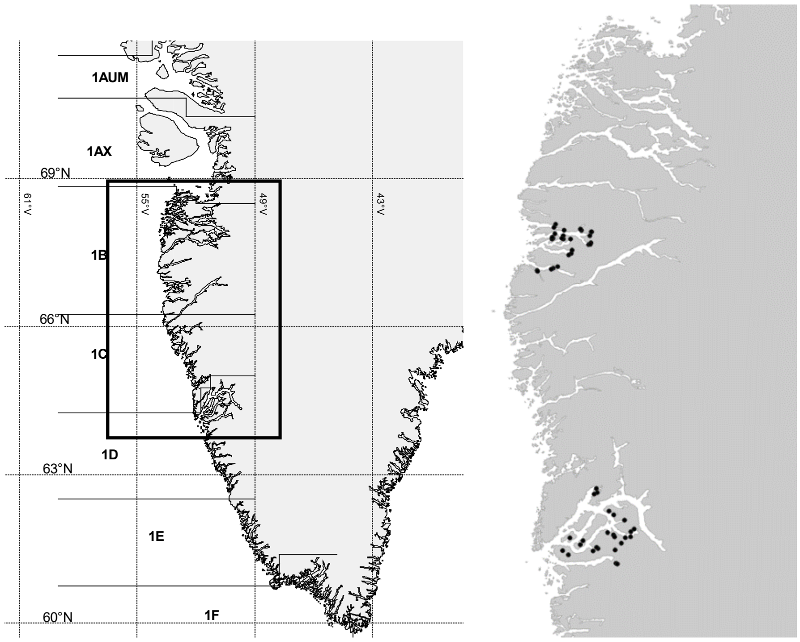

Figure B.3.1.1: Stations in the Gillnet survey. Only stations in the northern NAFO division 1B is used in the assessment.

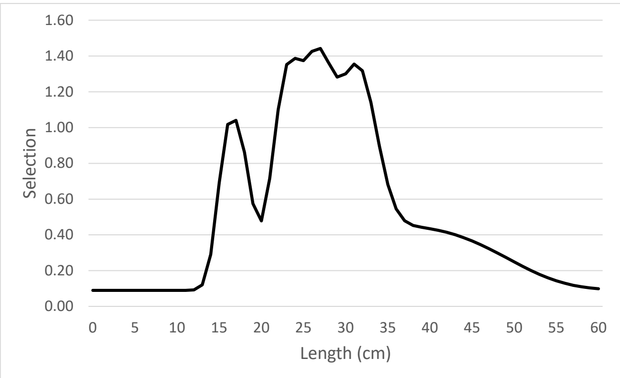

Figure B.3.1.2: Combined selection curve for all mesh sizes (16.5, 18, 24, 28 and 33 mm, ½ mesh).

The survey has been conducted since 1982 and historically three areas were covered: north-west (Sisimiut, NAFO Division 1B), mid-west (Nuuk, NAFO Division 1D) and south-west (Qaqortoq, NAFO Division 1F). South Greenland has only been covered in the period 1987–1995, 1998, 2000 and 2007–2009 and due to very scarce data from this survey this area is not included as a tuning fleet. In 2017 NAFO division 1C was added as a survey area, but due to short timeseries the survey in this area is not included as a tuning fleet.

The survey index of the area NAFO 1B is used as a tuning fleet for the years 2002-2021 except the period 2008-2009 where no survey was conducted.

Table B.3.1.1: Number of Stations by year and NAFO area in the inshore Gillnet survey.

YEAR	1B	1D	TOTAL 1B+1D
2000	-	-	
2001	-	-	

2002	63	63	126
2003	99	81	180
2004	80	90	170
2005	84	73	157
2006	43	51	94
2007	55	-	
2008	-	58	
2009	-	58	
2010	66	52	118
2011	57	44	101
2012	54	52	106
2013	58	52	110
2014	60	41	101
2015	59	44	103
2016	58	40	98
2017	57	46	103
2018	58	52	110
2019	48	54	102
2020	53	50	103
2021	54	53	107

B.4. Stock split model

Commercial and survey catch data are split into separate spawning stock units using a Generalized Additive Model (GAM). This is done for the three genetically distinct spawning stock units advised in Greenland waters. Below is a condensed description of the model, while Post *et al.* (2023) provides a more thorough description, including model selection and validation.

The model was a multinomial distribution model providing a ratio of the three individual stocks. In total, 8576 genetically assigned cod from the period 2000-2022 was used as data input. Explanatory parameters were:

PARAMETER	DESCRIPTION
Lat	Latitude in decimal degree
Lon	Longitude in decimal degree
InOff	In- or Offshore, coastal base line
Age	Age of fish
fCohortGr	Birth year as factor with multiple cohorts grouped
s(SampleID, bs='re')	A random effect of the sampling station to account for a possible grouping/schooling effect

In R terms, the model can be noted as:

gam(list(Stock~InOff+fCohortGr+s(Lat,Lon,Age,by=fCohortGr)+s(SampleID,bs="re"), ~InOff+fCohortGr+s(Lat,Lon,Age,by=fCohortGr)+s(SampleID,bs="re")),data,family=multinom(K=2))

This model was then used to split all catches by cohort, age, and area.

C. Assessment method and settings

C.1 Choice of stock assessment model

The analytical assessment presented here are based on genetic split of the data, opposed to previously where data were split based on geographical boundaries. The analytical assessment is for the northern part of the WISC stock (covering NAFO areas 1A, 1B, and 1C)

C.2 Model used as basis for advice

The stock is assessed using the state-space model SAM (Nielsen and Berg, 2014).

C.3 Assessment model configuration

Due to poor sampling no commercial data are available for 2001.

The available data are listed in the table below.

TYPE	NAME	YEAR RANGE	AGE RANGE	VARIABLE FROM YEAR TO YEAR
Canum	Catch-at-age in numbers	2000–present Except 2001	3–10+	Yes
Weca and West	Weight-at-age in the commercial catch and stock	2000–present	2–10+	Yes
Mprop	Proportion of natural mortality before spawning	2000–present	2–10+	No, set at 0.
Fprop	Proportion of fishing mortality before spawning	2000–present	2–10+	No, set at 0.
Matprop	Proportion mature at age	2000–present	2–10+	No

Natmor	Natural mortality	2000–present	2–10+	No, set to 0.2

Catch mean weight-at-age are calculated from commercial samples, and used as observations for the catch weight process within SAM. Stock mean weight-at-age are calculated from the offshore Greenlandic survey, and used as observations for the stock weight process within SAM. Both the catch and stock weight process are included as GMRF with cohort and within age correlations.

Fishing mortality is estimated individually for ages 3-8, age 9 and 10 are assumed to be the same, age 2 is set to -1 and therefore not used. It is assumed that there are no correlations across ages, this is supported by changes in the selectivity pattern during the assessment period. The Fbar range was set to 4-7 years old as these ages constitutes the main part of the catches.

The variance parameters for the catch are separate for age 3 and they are coupled for ages 4-10. Age to is set to -1 and not used.

The covariance structure for catch is assumed to be independent.

For the catches the variation around the mean were allowed to vary additionally, parameters were coupled for ages 2-3 and for ages 4-10.

No discarding is believed to take place.

The natural mortality is estimated at 0.2 for all ages.

For age 2 the coupling of the recruitment and survival process variance parameters for the log(N)-process are different from the other ages. In the model.R script the following was added: par$logSdLogN<-c(0,-5), which sets the process variance of N to a very low value. This was needed due to the short assessment time series.

Estimation of recruitment is an integrated part of the model. Recruitment parameters are estimated within the assessment model. The parameter structure is assumed as a plain random walk process.

Tuning data:

The model is tuned with one survey (see table below)

Type	Name	Year range	Age range
Tuning fleet 1	CPUE index (gillnet survey 1B)	2002–present	2–8
	Except	2008, 2009	

The survey catchability parameters are estimated individually for age 2, 3 and 4. Ages 5 and 6 and coupled and ages 7 and 8 are coupled.

The variance parameters for the survey are separate for age 2 and 3, ages 4-6 are coupled and ages 7 and 8 are coupled.

For the survey the covariance structure is assumed to follow an AR(1) structure. This was done because there was evidence of year effects in the observation residuals for the survey.

Assessment

The model output shows that the estimated catches are similar to observed catches. Retrospective analysis indicate that the model is stable when additional data are added.

C 3.1. Model Options chosen:

A configuration file is used to set up the model run once the data files, in the usual Lowestoft format, have been prepared. The file has the following form:

```
# Configuration saved: Mon Jan 16 14:23:05 2023
#
# Where a matrix is specified rows corresponds to fleets and columns to ages.
# Same number indicates same parameter used
# Numbers (integers) starts from zero and must be consecutive
# Negative numbers indicate that the parameter is not included in the model
#
$minAge
# The minimium age class in the assessment
 2

$maxAge
# The maximum age class in the assessment
 10

$maxAgePlusGroup
# Is last age group considered a plus group for each fleet (1 yes, or 0 no).
 1 0

$keyLogFsta
# Coupling of the fishing mortality states processes for each age (normally only
# the first row (= fleet) is used).
# Sequential numbers indicate that the fishing mortality is estimated individually
# for those ages; if the same number is used for two or more ages, F is bound for
# those ages (assumed to be the same). Binding fully selected ages will result in a
# flat selection pattern for those ages.
  -1 0   1   2   3   4   5   6   6
 -1  -1  -1  -1  -1  -1  -1  -1  -1

$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry,
# 2 AR(1), 3 separable AR(1).
# 0: independent means there is no correlation between F across age
# 1: compound symmetry means that all ages are equally correlated;
# 2: AR(1) first order autoregressive - similar ages are more highly correlated than
# ages that are further apart, so similar ages have similar F patterns over time.
# if the estimated correlation is high, then the F pattern over time for each age
# varies in a similar way. E.g if almost one, then they are parallel (like a
# separable model) and if almost zero then they are independent.
# 3: Separable AR - Included for historic reasons . . .  more later
 0

$keyLogFpar
# Coupling of the survey catchability parameters (nomally first row is
# not used, as that is covered by fishing mortality).
 -1  -1  -1  -1  -1  -1  -1  -1  -1
  0   1   2   3   3   4   4  -1  -1

$keyQpow
# Density dependent catchability power parameters (if any).
 -1  -1  -1  -1  -1  -1  -1  -1  -1
 -1  -1  -1  -1  -1  -1  -1  -1  -1

$keyVarF
# Coupling of process variance parameters for log(F)-process (Fishing mortality
# normally applies to the first (fishing) fleet; therefore only first row is used)
  -1   0   0   0   0   0   0   0   0
```

```
 -1  -1  -1  -1  -1  -1  -1  -1  -1

$keyVarLogN
# Coupling of the recruitment and survival process variance parameters for the
# log(N)-process at the different ages. It is advisable to have at least the first age
# class (recruitment) separate, because recruitment is a different process than
# survival.
 0 1 1 1 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations.
# First row refers to the coupling of the variance parameters for the catch data
# observations by age
# Second and further rows refers to coupling of the variance parameters for the
# index data observations by age
  -1   0   1   1   1   1   1   1   1
   1   2   3   3   3   4   4  -1  -1

$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US" for unstructured). | Possible
values are: "ID" "AR" "US"
 "ID" "AR"

$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) structure is chosen above.
# NA's indicate where correlation parameters can be specified (-1 where they cannot).
#2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10
  NA  NA  NA  NA  NA  NA  NA  NA
  0  0  0  0  0  0  -1  -1

$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, 2 for Beverton-Holt, 3 piece-wise constant,
61 for segmented regression/hockey stick, 62 for AR(1), 63 for bent hyperbola / smooth hockey stick, 64
for power function with degree < 1, 65 for power function with degree > 1, 66 for Shepher, 67 for Deriso,
68 for Saila-Lorda, 69 for sigmoidal Beverton-Holt, 90 for CMP spline, 91 for more flexible spline, and 92
for most flexible spline).
 0

$noScaledYears
# Number of years where catch scaling is applied.
 0

$keyScaledYears
# A vector of the years where catch scaling is applied.


$keyParScaledYA
# A matrix specifying the couplings of scale parameters (nrow = no scaled years, ncols = no ages).

$fbarRange
# lowest and higest age included in Fbar
 4 7

$keyBiomassTreat
# To be defined only if a biomass survey is used (0 SSB index, 1 catch index, 2 FSB index, 3 total catch, 4
total landings and 5 TSB index).
 -1 -1

$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 "LN" "LN"
```

$fixVarToWeight
If weight attribute is supplied for observations this option sets the treatment (0 relative weight, 1 fix variance to weight).
0

$fracMixF
The fraction of t(3) distribution used in logF increment distribution
0

$fracMixN
The fraction of t(3) distribution used in logN increment distribution (for each age group)
0 0 0 0 0 0 0 0 0

$fracMixObs
A vector with same length as number of fleets, where each element is the fraction of t(3) distribution used in the distribution of that fleet
0 0

$constRecBreaks
Vector of break years between which recruitment is at constant level. The break year is included in the left interval. (This option is only used in combination with stock-recruitment code 3)

$predVarObsLink
Coupling of parameters used in a prediction-variance link for observations.
0 0 1 1 1 1 1 1 1
-1 -1 -1 -1 -1 -1 -1 NA NA

$hockeyStickCurve
#
20

$stockWeightModel
Integer code describing the treatment of stock weights in the model (0 use as known, 1 use as observations to inform stock weight process (GMRF with cohort and within year correlations))
1

$keyStockWeightMean
Coupling of stock-weight process mean parameters (not used if stockWeightModel==0)
0 1 2 3 4 5 6 7 8

$keyStockWeightObsVar
Coupling of stock-weight observation variance parameters (not used if stockWeightModel==0)
0 0 0 0 0 0 0 0 0

$catchWeightModel
Integer code describing the treatment of catch weights in the model (0 use as known, 1 use as observations to inform catch weight process (GMRF with cohort and within year correlations))
1

$keyCatchWeightMean
Coupling of catch-weight process mean parameters (not used if catchWeightModel==0)
0 1 2 3 4 5 6 7 8

$keyCatchWeightObsVar
Coupling of catch-weight observation variance parameters (not used if catchWeightModel==0)
0 0 0 0 0 0 0 0 0

$matureModel
Integer code describing the treatment of proportion mature in the model (0 use as known, 1 use as observations to inform proportion mature process (GMRF with cohort and within year correlations on logit(proportion mature)))

```
 0

$keyMatureMean
# Coupling of mature process mean parameters (not used if matureModel==0)
 NA NA NA NA NA NA NA NA NA

$mortalityModel
# Integer code describing the treatment of natural mortality in the model (0 use as known, 1 use as
observations to inform natural mortality process (GMRF with cohort and within year correlations))
 0

$keyMortalityMean
#
 NA NA NA NA NA NA NA NA NA

$keyMortalityObsVar
# Coupling of natural mortality observation variance parameters (not used if mortalityModel==0)
 NA NA NA NA NA NA NA NA NA

$keyXtraSd
# An integer matrix with 4 columns (fleet year age coupling), which allows additional uncertainty to be
estimated for the specified observations
```

D. Short-Term Projection

Table D.1. Forecast assumptions. (Note that the values that appear in the catch options table of the advice sheet are medians from the distributions that result from the stochastic forecast.)

Initial stock size	**Starting populations are simulated from the estimated distribution at the start of the intermediate year (including co-variances).**
Maturity	Use average of last 5 years. Maturity is the same for all years.
Natural mortality	Use average of last 5 years. Natural mortality is fixed at 0.2 for all ages.
F and M before spawning	Both taken as zero.
Weight-at-age in the catch	Taken from the stock weight process
Weight-at-age in the stock	Taken from the catch weight process
Exploitation pattern	Several F options explored, including F_{MSY}. Selection pattern based on last five year average.
Intermediate year assumptions	Based on TAC and fishing patterns for intermediate year
Stock recruitment model used	Recruitment for the intermediate is taken from the last 10 years from the SAM assessment and asummes a random walk.

Short term forecast should be based on the range of Fmsy given in the reference point sections and not just the average.

E. Medium–Term Projections

Medium-term projections are not carried out for this stock.

F. Long-Term Projections

Long-term projections are not carried out for this stock.

G. Biological Reference Points

For estimating B_{lim} a categorization of the stock-recruitment relationship into type is required (ICES, 2021). The group agreed that the Type 2- S-R relationship corresponded best to the stock-recruitment relationship with a wide dynamic range of SSB and evidence that recruitment is or has been impaired. According to this SR type B_{lim} is based on the breakpoint in a segmented regression. This gave a B_{lim} of 2 147 t.

It was not possible to estimate reference points for this stock using EqSim. It was decided to look at the two stocks most similar to this, WOSC and S-WISC. The benchmark group therefore gives F_{msy} at the average of the two other stock and also suggest carrying out forecast covering the range of F_{msy}. Similarly, F_{pa} is given as a range based on the other two stocks and using the average as the actual F_{pa} value. B_{lim} and thus B_{pa} is based on B_{lim} from the segmented regression. Table below gives the final reference points.

Due to very high estimate of F_{lim}, it was decided to not report on this value.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	3 017 t	B_{pa}	WKGREENCOD 2023
	F_{MSY}	0.24 (0.18-0.29)	Based on the average of Fmsy from the WOSC (Fmsy=0.18) and S-WISC (Fmsy=0.29) stock	WKGREENCOD 2023
Precautionary approach	B_{lim}	2 147 t	From segmented regression breakpoint	WKGREENCOD 2023
	B_{pa}	3 015 t	B_{lim}*exp(sigmaSSB*1.645), sigmaSSB=0.207	WKGREENCOD 2023
	F_{lim}	NA	Equilibrium F, which will maintain the stock above Blim with a 50% probability.	
	F_{pa}	2.63 (1.34-3.92)	Based on the average of Fpa from the WOSC (Fpa=1.34) and S-WISC (Fpa=3.92) stock	WKGREENCOD 2023

H. Other Issues

There are no other issues.

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