Stock Annex for Northeast Arctic Greenland Halibut

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Northeast Arctic Greenland Halibut; ghl-arct_SA
Working Group	Arctic Fisheries Working Group
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A. General

A.1 Stock definition

Greenland halibut (*Reinhardtius hippoglossoides,* Walbaum) is distributed in the Arctic and boreal waters in the North Atlantic and in the North Pacific (Shuntov, 1965; Fedorov 1971; Godø and Haug 1989; Bowering and Brodie 1995; Bowering and Nedreaas 2000). In the northeastern Atlantic the distribution is more or less continuous along the continental slope from the Faroe Islands and Shetland to north of Spitsbergen (Whitehead *et al.,* 1986; Godø and Haug 1989), with the highest concentrations from 500 to 800 m depth between Norway and Bear Island, which is also regarded as the main spawning area (Nizovtsev, 1968; Godø and Haug 1987; Albert *et al.,* 2001b). Peak spawning occurs in December in the main spawning area, but also in nearby localities during summer (Albert *et al.,* 2001b). Atlantic currents transport eggs and larvae northwards and the juveniles are distributed around Svalbard and in the northeastern Barents Sea, to the waters around Franz Josef Land and Novaja Zemlya area and into the Kara Sea (Borkin, 1983; Nizovtsev, 1983; Godø and Haug, 1987; Godø and Haug, 1989; Albert *et al.,* 2001a, Ådlandsvik *et al*., 2009, Smirnov, 2009; Hallfredsson and Vollen, 2015a,b). As they grow older they gradually move southwards and eventually may alternate between the spawning area and feeding areas in the central-western Barents Sea (Nizovtsev, 1989).

The Northeast Arctic Greenland halibut stock is a pragmatically defined management unit. The degree of exchange with other stocks is not fully resolved but later and still ongoing studies indicate that it may be more pronounced than previously thought (Knudsen *et al.*, 2007; Albert and Vollen, 2015; Westgaard *et al*. (submitted)). Potential routes of exchange may be drift of larvae towards Greenland and migration of adults between the Barents Sea and the Iceland-Faroe Islands area. Revision of stock structure is regarded as a relevant issue for a future Benchmark.

A.2 Fishery

Before the mid-1960s the fishery for Greenland halibut was mainly a coastal longline fishery off the coasts of eastern Finnmark and Vesterålen in Norway. The annual catch of the coastal fishery was about 3000 t. In recent years this fishery has landed 3000—6000 t although now gillnets are also used in the fishery. In 1964 dense Greenland halibut concentrations were found by Soviet trawlers in the slope area to the west of the Bear Island (Nizovtsev, 1989). Following the introduction of international trawlers in the fishery in the mid-1960s, the total landings increased to about 80 000 t in the early 1970s. The total Greenland halibut landings decreased steadily to about 20 000 t during the early 1980s. This level was maintained until 1991, when the catch increased sharply to 33 000 t. From 1992—2009 total landings varied between 9000—19 000 t with a peak in 1999. Since then landings have increased steadily from 13 000 t in 2009 to 22 000 t in 2014. From 1980 to 1989 around 90% of the total landings of Greenland halibut were by trawlers. Regulations enforced in 1992 reduced landings by trawlers from 20 000 to about 6 000 t. Since 1992 the total landings have been approximately equally divided between longline/gillnet and trawl fisheries.

From 1992—2009 the fishery was regulated by allowing only the longline and gillnet fisheries by vessels smaller than 28 m to be directed for Greenland halibut. This fishery was also regulated by seasonal closure. Target trawl fishery was prohibited and trawl catches limited to bycatch only. From 1992 to autumn 1994 bycatch in each haul was not to exceed 10% by weight. In autumn 1994 this was changed to 5% bycatch of Greenland halibut on board at any time. In autumn 1996 it was changed to 5% bycatch in each haul, and in January 1999 this percentage was increased to 10%. In August 1999 it was adjusted further to 10% in each haul but only 5% of the landed catch. In 2001 the bycatch regulations changed again to 12% in each haul and 7% of the landed catch.

The 38th JRNFC's Session in 2009 decided to cancel the ban against targeted Greenland halibut fishery and established the TAC at 15 000 t for next three years (2010—2012). The TAC was allocated between Norway, Russia and other countries with shares of 51, 45 and 4% respectively. The 40th JRNFC's Session in 2011 decided to increase TAC for 2012 up to 18 000 t, and the TAC for 2013—2015 has been 19 000 t each year.

Minimum size regulation for Greenland halibut is 45 cm, and starting in 2012 it became mandatory to use sorting grids during target Greenland halibut trawl fishery.

During fishing for other species, it is permitted to have an intermixture of Greenland halibut of up to 7% by weight on board at the end of fishing operations and in the catch landed.

Norwegian regulations (quota figures are for 2015)

The annual catch (including bycatch) for each trawler and conventional vessel above 28 m is limited to 57 t pr. vessel.

The Norwegian conventional fleet, vessels smaller than 28 m, are allowed to conduct a targeted fishery with longlines and gillnets in a limited area in approximately one month each year. For these vessels the TAC is set to 22.5, 26.3 and 30 t, dependent of size of the vessel.

A.3 Ecosystem aspects

Greenland halibut is a large fish predator that occurs over a wide range of depths (from 20 to 2200 m) and temperatures (from -1.5 to 10°C) (Shuntov, 1965; Nizovtsev, 1989; Boje and Hareide, 1993) with the continental slope between the Barents Sea and the Norwegian Sea as its most important area, but it is also found in wider range of the northern Kara Sea, Barents Sea and Norwegian Sea at different life stages.

Food composition of the Greenland halibut in the Barents Sea includes more than 40 prey species (Nizovtsev 1989; Dolgov and Smirnov 2001, Hovde *et al.*, 2002; Vollen *et al.*, 2004). Investigations over a wide area of the continental slope up to Novaya Zemlya show that the main food source of Greenland halibut consists of fish, mostly capelin (*Mallotus villosus villosus*), polar cod (*Boreogadus saida*) and herring (*Clupea harengus*), and cephalopods and shrimp (*Pandalus borealis*). During the 1990s an important component of the diet was waste products from fisheries for other species (heads, guts, etc.). Ontogenetic shift in prey preference was clear with decreasing proportion of small prey (shrimps and small capelin) and increasing proportion of larger fish with increasing predator length. The largest Greenland halibut (length more than 65—70 cm) had a rather big portion of cod and haddock in the diet.

Given a Greenland halibut stock of nearly 100 000 tonnes, the total food consumption of the NEA stock was estimated to be about 280 000 tonnes (Dolgov and Smirnov, 2001). The biomass of commercial species consumed (shrimp, capelin, herring, polar cod, cod, haddock, redfish (*Sebastes* sp.), long rough dab (*Hippoglossoides platessoides*) did not exceed 5000—10 000 tonnes per species. The effect of Greenland halibut as predator on other commercial species in the Barents Sea may thus be minor.

According to Russian data (Dolgov and Smirnov, 2001), among the variety of fish, seabirds and marine mammals investigated, Greenland halibut were found in the diet of three species; Greenland shark (*Somniosus microcephalus*), cod (*Gadus morhua morhua*) and Greenland halibut itself. Additionally, killer whale (*Orcinus orca*), grey seal (*Halichoerus grypus*) and narwhal (*Monodon monoceros*) are potential predators. However, the presence of Greenland halibut in the diet of the above species was minor. Predators fed mainly on juvenile Greenland halibut up to 30—40 cm long.

The mean annual percentage of Greenland halibut in cod diet in 1984—1999 constituted 0.01—0.35% by weight (0.05% in average) (Dolgov and Smirnov, 2001). Cannibalism was highest in 1960s (up to 1.2% in frequency of occurrence) according to Russian stomach content data. During the 1980s frequency of occurrence of juveniles in the stomachs did not exceed 0.1%. During the 1990s, the portion of juveniles (by weight) was at the level of 0.6—1.3%. Low levels of consumption of juveniles are related to the distribution pattern of juvenile Greenland halibut. Young Greenland halibut occur mostly in the northeastern Barents Sea (Spitsbergen archipelago and further east to Franz Josef Land and Northern Kara Sea) where the presence of adult Greenland halibut and other main predators appear minimal in most years. Therefore, the observed variability of recruitment may be driven mainly by environmental factors. However in some years predation might affect recruitment, and the resent northward extension in distribution of potential predators such as cod, and high abundance of cod, is a concern in that respect. Predation on eggs and larvae is unknown, and a future research topic.

B. Data

B.1 Commercial catch

Norwegian commercial landings in tonnes by quarter, area and gear are derived from the sales notes statistics of the Directorate of Fisheries. Data from 21 subareas are aggregated by quarter on four main areas for the gears, gillnet, longline, bottom trawl and shrimp trawl. For bottom trawl the quarterly area distribution of the landings is adjusted by logbook data from The Directorate of Fisheries and the total bottom trawl landings by quarter and area is adjusted so that the total annual landings for all gears is the same as the official total landings reported to ICES. No discards are reported or accounted for in the catch statistics.

The sampling strategy is to have length samples from all major gears in each area and quarter. There are at present no defined criteria on how to allocate samples to unsampled landings, but the following general process has been applied: First look for samples from a similar area in the same quarter. If there are no samples available in similar areas, search for samples from other gears with the most similar selectivity in the same area or similar areas. The last option is to search in neighbouring quarters, first from the same gear in the same area, and then from similar areas and similar gears.

ALKs from research surveys (commercial bottom trawl or shrimp trawl) are also used to fill gaps in age sampling data.

Russian catch based on daily reports from the vessels are combined in the statistics of the All-Russian Research Institute of Fisheries and Oceanography (VNIRO, Moscow). Data are provided separately by ICES areas, quarter and gear (trawl and longline).

Norway and Russia, on average, have accounted for about 90—95% of the Greenland halibut landings during more recent years. Data on landings in tonnes from other countries are either reported directly to the Working group, taken from ICES official statistics (by ICES area) or from reports to Norwegian authorities.

The analytical GADGET assessment, which was run for 1992—present, uses landings from ICES Area I, IIa and IIb. For the assessment, the Norwegian landings are split on year, quarter, gear (fleet.trawl=bottom trawl, shrimp trawl, purse-seine and Danish seine; fleet.gil=gillnet, longline, handline and other gears) and sex. Russian landings data by year, fleet and quarter are split on sex according to same-year proportions in Norwegian landings. Finally, landings from other nations were added to the Norwegian fleet.trawl and split on quarter and sex accordingly.

Length distributions from Norwegian landings are split on year, gear (fleet.trawl and fleet.gil) and sex. 1 cm length categories are used from 1—113 cm, with a plus group for larger fish. Length categories smaller than 20 cm are set to zero.

B.2 Biological

Parameters of the length–weight relationship in the fisheries (W=a*L^b) was calculated yearly from all available samples. Not split on sex.

A fixed natural mortality of 0.1 is used both in the assessment and the forecast.

At present in the analytical assessment ogives are calculated based on data from all EggaNor surveys since 2000. The L50 for males of 42 cm is similar to what has been found in previous studies (Smirnov 2011, Hallfredsson *et al.*, 2011), while L50 of 62 cm is slightly higher than previously calculated due to adjustment as suggested in Núñez *et al.* (2015).

B.3 Surveys

The results from the following research vessel survey series have been evaluated by the Working Group and/or in the benchmark process (2013—2015).

1) Norwegian Greenland halibut slope survey *(NO-GH-Btr-Q3)* in August, from 1994, split on sex since 1996. Biennial since 2009. The survey covers the continental slope from 68 to 80°N, in depths of 400—1500 m north of 70.30°N, and 400—1000 m south of this latitude. The survey covers the main spawning areas and a commercially sized bottom trawl is used.
2) Joint Russian-Norwegian ecosystem bottom-trawl survey in the Barents Sea in autumn (*Eco-NoRu-Q3 (Btr)*), from 2004. Survey covers depths of less than 100 m and mainly down to 500 m. Its precursor was the Norwegian bottom-trawl survey in August in the Barents Sea and Svalbard, from 1984.
3) The Norwegian juvenile Greenland halibut survey north and east of Svalbard in autumn, from 1996. From 2000 this survey was conducted as a joint survey between Norway and Russia. From 2004 it was part of the Joint Russian-Norwegian ecosystem bottom-trawl survey in the Barents Sea in

autumn (*Eco-NoRu-Q3 (Btr)*). During later years, parts of the Kara Sea have occasionally been included in the survey.

4) Russian bottom-trawl survey in the Barents Sea from 1984 in fishing depths of 100–900 m (*RU-Btr-Q4*). This series has been revised substantially since the 1998 assessment in order to make the years more comparable with respect to area coverage and gear type.

5) Norwegian (from 2000 Joint) Barents Sea bottom-trawl survey in winter (*BS-NoRu-Q1 (Btr)*) from 1989. Survey covers depths of less than 100 m and down to 500 m.

6) International pelagic 0-group surveys in the Barents Sea since 1970. Year-class strengths are currently available for the period 1980—2014. It should be noted that the survey, which now is executed within the frame of the Ecosystem survey, has not been considered optimal for Greenland halibut. Further work is needed to evaluate the value of the series regarding recruitment.

7) Spanish bottom-trawl survey in the slope of Svalbard area, from 73.5°—81°N and depths 500—1500 (*SP-Svalbard-Q4)*. The survey was run in autumn in 1997—2005, 2008, 2010 and 2012—2014, and in spring in 2008, 2009 and 2011. In Basterretxea *et al.* 2013 (ICES AFWG WD13 2013, ANNEX III: Spanish Survey standardization) an attempt was made to standardize survey indices for Greenland halibut in earlier Spanish surveys (1997—2005) with resent surveys (2008—2012). The conclusion was that it is considered not possible to obtain a reliable standardization of the surveys. As the survey in autumn is run biennially, the Spanish index is available for years 2008, 2010, 2012 and 2014.

8) Polish Greenland halibut bottom-trawl survey in the Svalbard-Bears Island area (73.5°—76.5°N) at depths 500—1200 m in October 2006, April 2007, April 2008, June 2009 and March 2011.

Four indices go into the current assessment:

- EggaNor – based on the Norwegian Greenland halibut slope survey *(NO-GH-Btr-Q3)* (1996—present).
- EcoJuv – a juvenile index based on data from the northern/eastern areas of the Joint Ecosystem survey (*Eco-NoRu-Q3 (Btr)*) (2004—present) and the precursory Norwegian juvenile Greenland halibut survey north and east of Svalbard (1996—2002).
- EcoSouth – an index for the Barents Sea south of 76.5°N, based on data from the Joint Ecosystem survey (*Eco-NoRu-Q3 (Btr)*)(2004—present).
- Russian – Russian bottom-trawl survey in the Barents Sea from (*RU-Btr-Q4*) (1992—present).

Future work should consider including other survey indices in the analytical assessment. At present, trends in these surveys will be evaluated qualitatively by the working group.

The GADGET assessment is currently run back to 1992, and no data prior to that are used. This can preferably be extended further back in time in future work. The EggaNor index split by sex is only available since 1996.

The split of the Joint Ecosystem survey into two indices was described by Hallfredsson and Vollen, 2015a and 2015b). In the northern and eastern survey area mainly juveniles and immature fish <40 cm are found, whereas larger immature and mature fish (> 40 cm) are found south of 76.5°N and west of Svalbard. Thus the juvenile index (Eco Juv) was based on areas north of 76.5°N, excluding areas west of Svalbard. The EcoSouth index is based on the remaining area of the Joint Ecosystem Survey.

Length distributions were split on year and sex. One cm length categories were used from 1—113 cm, with a plus group for larger fish, and length categories smaller than 10 cm were set to zero.

The coverage of the northern, and particularly eastern, part of the juvenile area has been very variable, partly due to ice conditions. Thus, areas south of Frantz Josef Land and in the northern Kara Sea are not included in the juvenile index (EcoJuv) although considerable amounts of juveniles have been observed in this area (Smirnov, 2011; Hallfredsson and Vollen, 2015b). It therefore needs to be assumed that trends in the EcoJuv index, which is based on the western part of the juvenile area only, are representative for the whole area.

B.4 Commercial cpue

Several cpue series are available from Russian and Norwegian fisheries (ICES, 2014). Nedreaas (2014) reviewed the cpue series which previously have been used in stock assessment. His main conclusion was that many of the cpue indices conflicted in the signals and could thus not all reflect the underlying stock trends. Because of limitations due to effort, area, time, regulations and technological differences one should be very careful when using the trawl cpue. If used in assessment tuning, any long-term commercial trawl cpue series must be well described how it has been derived with regards to all the mentioned limitations and pitfalls. The Norwegian standardized cpue survey with rented trawlers during (1992) 1994—2005, is probably the only series sufficiently standardized for an abundance estimation purpose, but even this has many shortcomings compared with the scientific swept-area surveys along the slope since 1994. The experimental cpue series, or commercial cpue series when limited in area and time, should hence be avoided used as tuning series in stock assessments as long as better scientific research surveys are available. This applies both to Russian and Norwegian cpue series in the time period after 1992 when regulations were implemented. The scientific swept-area surveys are better stratified and cover a much larger area (by latitude and depth) than the experimental cpue series.

Different cpue series exist from the time period before regulations were introduced in 1992, and the ICES DCWKNGHD concluded that these potentially give useful information on stock development until 1991 (ICES, 2014). The Russian cpue series has been standardized (Kovalev and Tretyakov, 2015).

B.5 Other relevant data

None.

C. Historical stock development

Model used: Gadget (see ICES, 2015 and Howell *et al.*, 2015).

Time period: 1992—2014, monthly time-steps

Model structure:

- 1 cm length classes (1—114+ cm) and 1 year age classes (1—30+)
- Two sexes, split into mature and immature
- Logistic maturity estimated for each sex
- Von Bertanlanffy growth estimated separately for males and females
- L–W relationship fixed based on data from the Norwegian slope (Females: a=1.4E-6 and b=3.47. Males: a=5.7E-6 and b=3.12)
- Natural mortality set to 0.1 for all fish
- Initial size of recruits fixed at 8.5 cm (necessary to fix this in the absence of age data)
- Recruitment modelled as annual numbers, no relationship with SSB
- Four aggregated fleets, each with sex-specific selectivity (logistic for gill fleets, asymmetric dome shaped for trawl)
    - Norwegian Trawl (bottom trawl, purse-seine, Danish seine)
    - Russian Trawl (bottom trawl, purse-seine, Danish seine)
    - Norwegian Gillfleet (gillnet and longline)
    - Russian Gillfleet (gillnet and longline)
- Four surveys (as described above), all with asymmetric dome shaped selectivity
    - EggaNor (split by sex)
    - EcoJuv (split by sex)
    - EcoSouth (split by sex)
    - Russian (sex aggregated) (can be split by sex in future work)

Note that in order to avoid the problem of modelled fish not covered by any fleet (and therefore not tuned to any data) the gillfleets have been assumed to have logistic (flat-topped) selectivity.

Estimated parameters:

> l50 and slope for the maturation (male and female separately), two growth parameters per sex, two maturation parameters per sex, one annual recruitment parameter per year, two parameters for s.d. of length of recruits, parameters governing commercial selectivity (two per sex per gillfleet and three per sex per trawlfleet), one effort parameter per year for each fleet, three parameters per survey per sex governing selectivity, initial population numbers for male and female fish by age, initial population s.d. of lengths by sex and age

Data used for tuning are:

- Quarterly length distribution of the landings from commercial fishing fleets (by sex)
- Quarterly catch in tonnes for each fleet (by sex)
- Length disaggregated survey indices from the four surveys (by sex except for the Russian survey)

- Overall survey index (by biomass) for the four surveys (by sex except for the Russian survey)
- Estimated maturity ogives (maturity at length in the population) for 1992—2014 (by sex)

Note that no age data are used in tuning the model. Although age readings are available for some years there is no agreement on which age-reading methodology should be used, and these data are thus not suitable for inclusion in an assessment model.

Concerning the recruitment it should be noted that age 1 is the age for recruitment to the stock, NOT the age for recruitment to the fishery, which is the quantity normally used to describe recruitment. But since age 1 recruitment is the quantity estimated by the model and the age of recruitment to the fishery can't be defined due to disagreement on age reading, we use age 1 as the recruitment age for this stock. Even if there had been agreement on age-reading methodology, the strong sexual dimorphism in growth would make it very difficult to define an appropriate recruitment age.

D. Short-term projection

Not done/incorporated into medium term projections.

E. Medium-term projections

Five year projections conducted using the Gadget assessment model under the following assumptions:

- split between fleets and between quarters assumed to remain unchanged from the average of the previous two years;
- fishing intensity in the current year assumed to be the average of the intensity in previous two years;
- fishing intensity in the following four years assumed to be a multiplier of the two most recent years average levels;
- Results are presented for 1 January the following year.

F. Long-term projections

Not done.

G. Biological reference points

The last observed year with good recruitment occurred in 1995 at 487 000 tonnes fishable (45+ cm) biomass. There is evidence that an earlier good recruitment event occurred in the 1980s from a lower biomass, but the exact biomass level is unknown as this is before the model period. The precautionary reference point is therefore taken at 487 000 tonnes. Using 45+ cm biomass (rather than total or female SSB) avoids uncertainty around maturation sizes and the different distributions of males and females, and relates directly to the fishable stock.

H. Other issues

Lack of agreement on age reading methodology precludes using age-based data for the assessment.

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