Greenland halibut

K. Nedreaas[1] and O. Smirnov[2]: Stock characteristics, fisheries and management of Greenland halibut (*Reinhardtius hippoglossoides* Walbaum) in the northeast Arctic

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Abstract

Greenland halibut (*Reinhardtius hippoglossoides* (Walbaum)) are widely distributed over wide geographic areas of the Northeast Atlantic Ocean, with no break in the continuity of the distribution from the arctic Frans Josef Land and Novaya Zemlya archipelagos in the north and east to beyond the boreal Shetland Islands in the south. Although the entire Greenland halibut resource in the North Atlantic is genetically homogeneous, they comprise a single interbreeding stock in the Barents Sea and Norwegian Sea areas, which is known as the Northeast Arctic stock. In general, and for most of the year, larger fish become more abundant and smaller fish less abundant in progressively deeper water with peak abundance occurring over a depth range of 400-1 000 m. But during the spring and summer, the mature and bigger fish may be shallower. Greenland halibut in the Northeast Atlantic were observed to be most abundant in bottom temperatures mainly between 0º C and 4º C.

The fishery for Greenland halibut in the Northeast Arctic was unregulated until 1992, although since 1995 catches have substantially exceeded those advised. The spawning stock size reached historically low levels during the 1990s and recruitment to the spawning stock remained uncertain. The stock is now showing clear signs of improvement, and is at present rebuilt to above the long-term average of the past 20 years.

KEYWORDS: *Greenland halibut, Northeast Atlantic, distribution, biology, fisheries, management*

Introduction

The Greenland halibut (*Reinhardtius hippoglossoides* (Walbaum)) is a deepwater flatfish distributed throughout the entire rim of the North Atlantic (Nizovtsev 1989a; Bowering and Brodie 1995; Godø et Haug 1987; Vis et al. 1997). Recent studies of the structure of Greenland halibut stocks using mitochondrial DNA have also indicated that they are genetically homogeneous throughout the North Atlantic (Vis et al. 1997). This is not surprising given it’s the highly migratory nature of the species over extreme distances, as deduced from tagging experiments (Nizovtsev 1974; Sigurdsson 1981; Boje 1994; Bowering 1984). Although it is now recognized that there is an extensive gene flow among populations of Greenland halibut in the North Atlantic, it has been concluded that studies of the distribution of local spawning components are still essential for effective management (Vis et al. 1997).

Greenland halibut in the Northeast Arctic from 1960s have been the subject of considerable study regarding their distribution, biological characteristics and fisheries (Table 1). In 1964-1967 the area of the main spawning grounds was outlined, the period of mass spawning was specified and the first representative data on age-length structure of commercial and spawning stocks were acquired (Sorokin 1967; Nizovtsev 1968; 1969; 1970). Using materials collected and processed in 1964-1970, the feeding of Greenland halibut was analyzed, and the data from tagging experiments conducted in 1965-1973 revealed its seasonal migrations between spawning and feeding grounds (Nizovtsev 1972; 1989). In 1968-1972, issues relative to gametogenesis and the sexual cycle were studied. (Sorokin and Grigoryev 1968; Fedorov 1968; 1969; 1971). As result of expeditions to the northern Barents Sea in 1978-1980, Greenland halibut nursery grounds were found to the northeast of Svalbard and in the area of Franz Josef Land (Borkin 1983). In the 1980s, on the basis of long-term observations the peculiarities of growth and maturation taking into account dimorphism inherent in Greenland halibut were revealed, and the dynamics of length-age structure of stock were retraced (Kovtsova and Nizovtsev 1985; Nizovtsev 1987). The level of knowledge achieved by that time allowed relationships between different stock components and between stock and environment (Kovtsova et al. 1987; Nizovtsev 1985 1989a 1989b) to be sought.

Table 1. Publications regarding, distribution, biological characteristics and fisheries of Northeast Arctic Greenland halibut.

Time period	Objects	References
1964-1967	Area of spawning grounds, period of mass spawning, first representative data on age-length structure of stock	Lahn-Johannessen 1965 1972, Sorokin 1967, Nizovtsev 1968 1969 1970, Hognestad 1969
1964-1970	Feeding	Nizovtsev 1972 1989
1965-1973	Seasonal migrations between spawning and feeding grounds	Lahn-Johannessen 1965 1972, Nizovtsev 1989
1968-1971	Gametogenesis and the sexual cycle	Sorokin et Grigoryev 1968, Fedorov 1968 1969 1971
1978-1980	Nursery grounds to the northeast of Spitsbergen and near Fr. Josef Land	Borkin 1983
1980s	Peculiarities of growth and maturation, dynamics of length-age structure of the stock	Kovtsova et Nizovtsev 1985, Nizovtsev 1987
	Migration and recruitment patterns in the Spitzbergen area	Godø et Haug 1987
	Distribution and feeding of larval Greenland halibut	Haug et al. 1989
1990s	Biological implications of a multi-gear fishery, gear selection	Nedreaas et al. 1996, Huse et al. 1997
	Fecundity	Smirnov 1998, Gundersen et al. 1999
	Spawning, recruitment	Hylen et Nedreaas 1995, Smirnov 1995, Albert et al. 1997, Albert et al. 1998, Stene et al. 1999
	Feeding	Michalsen et Nedreaas 1998, Dolgov et Smirnov 2001

Godø and Haug (1987) reported on migration and recruitment patterns of Greenland halibut in the Spitzbergen area using data available during the early 1980s. Godø and Haug (1989) also reviewed the available literature on the natural history, fisheries and management of the species in the eastern Norwegian and Barents Seas until that time. More recently, Nedreaas et al. (1996) evaluated the biological implications of a multi-gear fishery for Greenland halibut in the Northeast Arctic while Michalsen and Nedreaas (1998) reported on a food and feeding study of Greenland halibut in the Barents Sea and East Greenland waters. A number of other studies on Greenland halibut in the Northeast Atlantic have been presented at recent NAFO or ICES symposia and are currently being reviewed for publication or are in press;. e.g. gear selection (Huse et al. 1997), fecundity (Gundersen et al. 1999), spawning (Albert et al. 1998; Stene et al. 1999) and recruitment studies (Albert et al. 1997).

For Greenland halibut in the Northeast Atlantic, stock status is determined and scientific advice on management is provided annually. This is the responsibility of the Arctic Fisheries Working Group and the Advisory Committee on Fisheries Management of the International Council for the Exploration of the Sea (ICES) (see Anon. 2002).

Bowering and Nedreaas (2001) made a useful comparison of Greenland halibut fisheries and distribution in the Northwest and Northeast Atlantic, which revealed both differences and features in common, and discussed the implications for fisheries management within the individual areas. A Nordic report (Boje et al. 2002) has reviewed the current status of Greenland halibut research and knowledge and made suggestions for future research that would be useful for management.

The aim of the present paper is to review current knowledge about the characteristics of the Northeast Arctic Greenland halibut stock (e.g., its size, distribution, position in the food web, management unit), the history of the stock, its fishery and management system. Current management strategy, including scientific advice (e.g., stock monitoring, stock assessment and prognoses, precautionary reference points, form of advice), TAC decisions and international/national sharing of the TAC, the fishery (fishing methods, fleets), fisheries regulations (legal size, mesh size, selectivity measures, area closures), enforcement, control and collection of fisheries statistics are also described.

Materials and methods

The geographical distribution presented here (see Figure 1) is taken from Nizovtsev (1989a) and Bowering and Nedreaas (2001).

Figure 2 illustrates the **size** of Greenland halibut at depths shallower than 500 metres on the nursery grounds north and east of Spitsbergen and on the shelves and slopes of the Barents and Norwegian Seas, and at depths greater than 500 metres along the continental slope and on the main spawning grounds. The individual **mean size** of Greenland halibut as this varies **with depth** along the continental slope area, as well as north and east of Spitzbergen, and on the Svalbard and Barents Sea shelf, is shown in Figure 3 (based on Norwegian survey data.

Distribution and relative **abundance with depth** are expressed as mean number and weight (kg) per standard set by 100-m depth intervals for depths to 500 m and 250-m intervals for depths greater than 500 m. A cursory examination of the data indicated that for the geographic areas investigated any trends with respect to time were similar. Therefore, data for all years were combined in the analyses. The areas and survey time series that were evaluated are identified in Table 2. Results are shown in Figure 4.

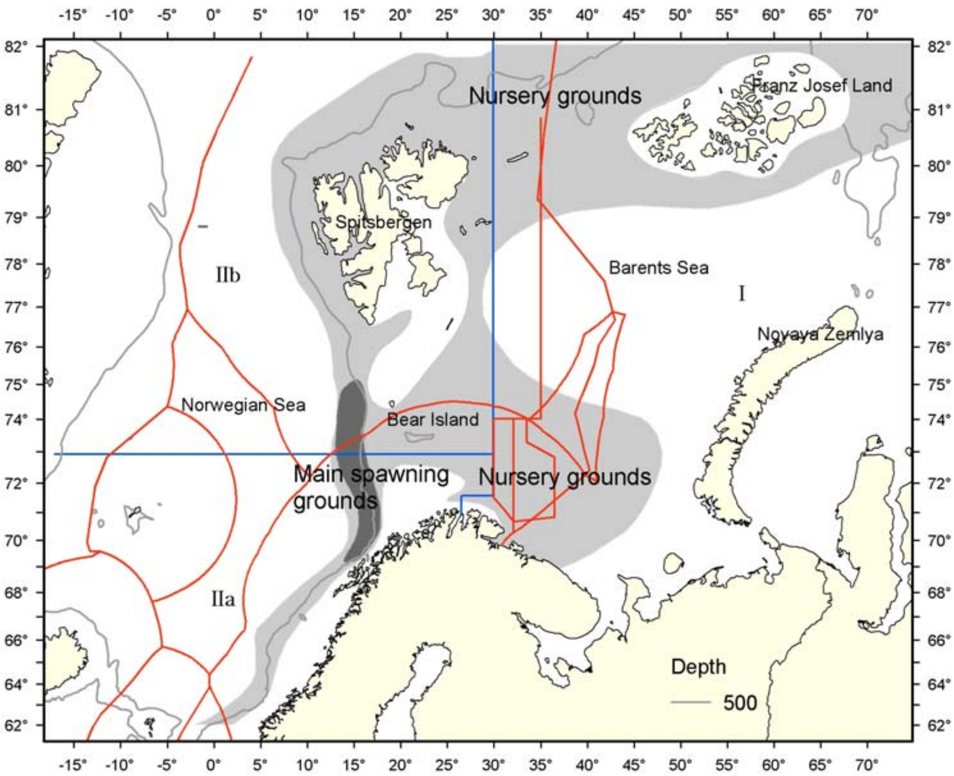

Figure 1. Schematic presentation of the geographic horizontal distribution of Greenland halibut. Nursery- and main spawning grounds are marked. National economic zones, the disputed border areas between Norway and Russian (i.e., the Grey Zone), the international Loophole, and the ICES areas are shown.

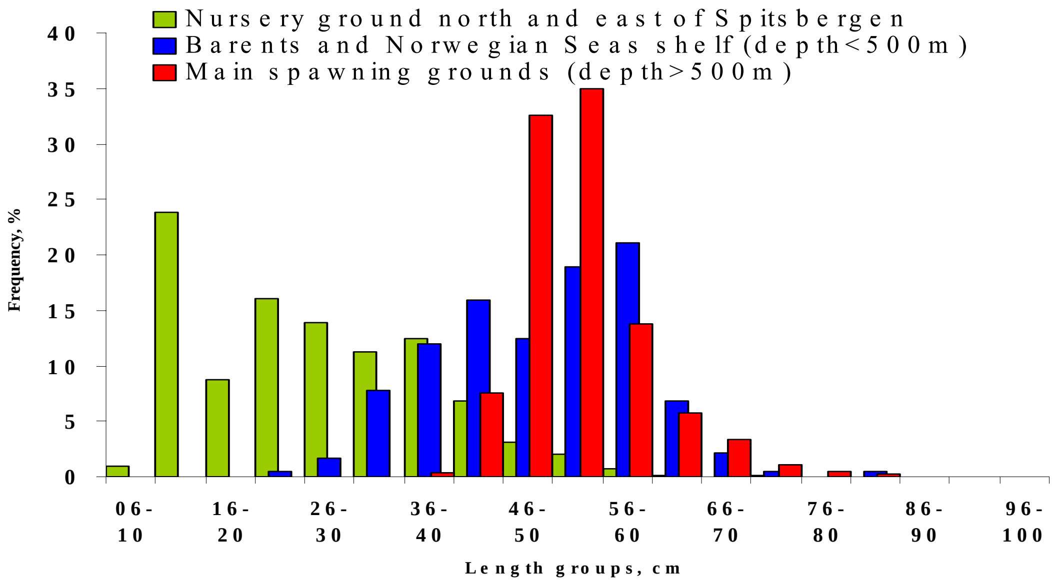

Figure 2. Length distributions of Greenland halibut typical of 1) the nursery grounds north and east of Spitsbergen (depth < 500 m), 2) the Barents and Norwegian Seas shelf areas (depth < 500 m), and 3) along the continental slope and the main spawning grounds (depth > 500 m). Data from Russian surveys in September-December 1999-2000. Small meshed trawls used everywhere.

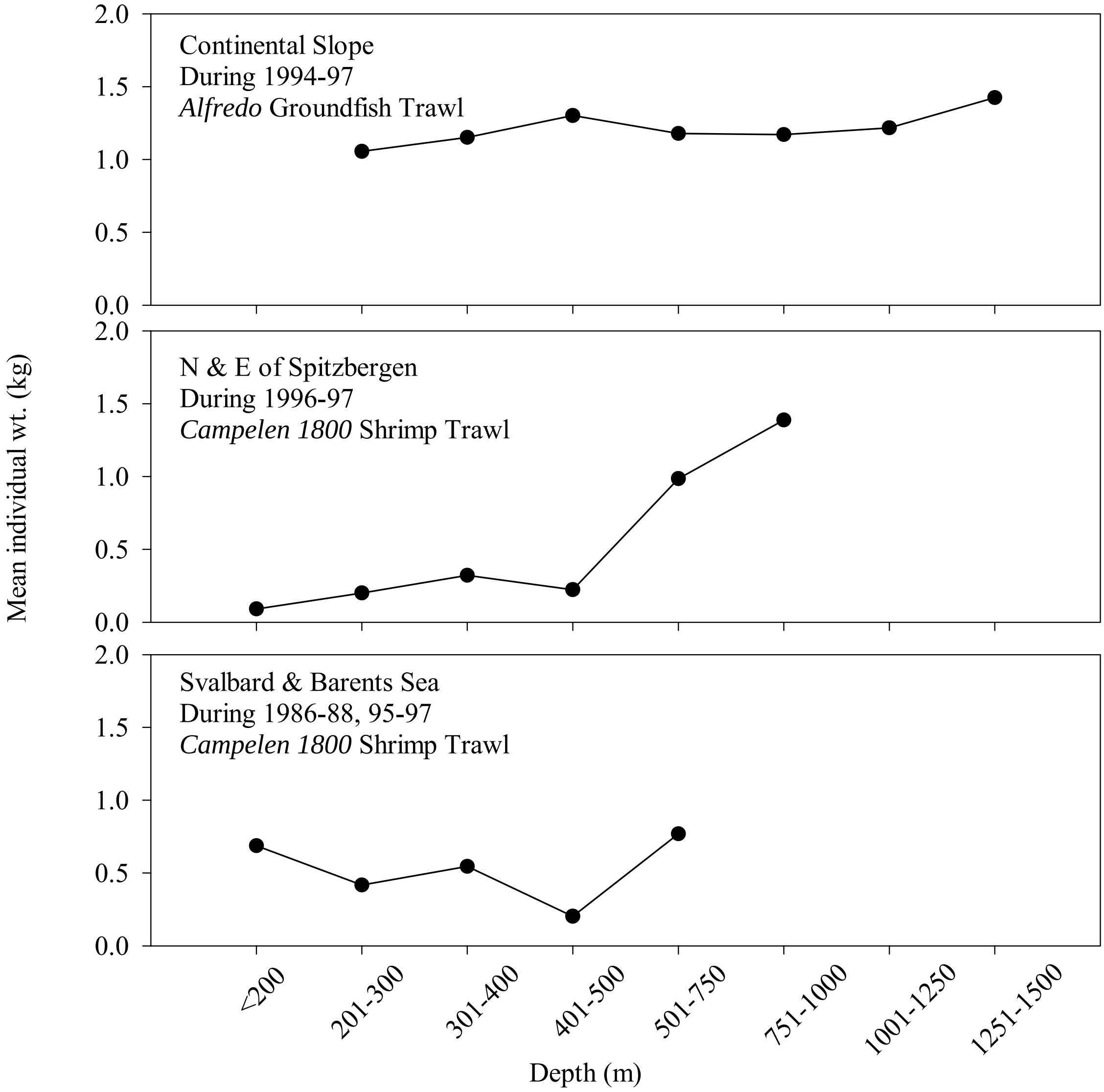

Figure 3. Individual mean size of Greenland halibut at various depths. Data from different years combined and presented for three different survey areas. All data are collected in August-September (source: BOWERING AND NEDREAAS 2001).

Table 2. Research vessel surveys by area, years and depth intervals used to study distribution and relative abundance of Greenland halibut in the Northeast Arctic.

Area	Combined Survey Years	Depth Range (m)
Continental Slope (62º N to 68º N)	1995	400-1500
Continental Slope (68º N to 80º N)	1994-97	200-1500
N. et E. of Spitzbergen	1996-97	<200-800
Franz Josefs Land (BORKIN 1983)	1978-80	200-1150
Russian Svalbard and Barents Sea surveys	1984-2002	<200-800
Norwegian Svalbard and Barents Sea surveys	1986-88, 1995-97	<200-500

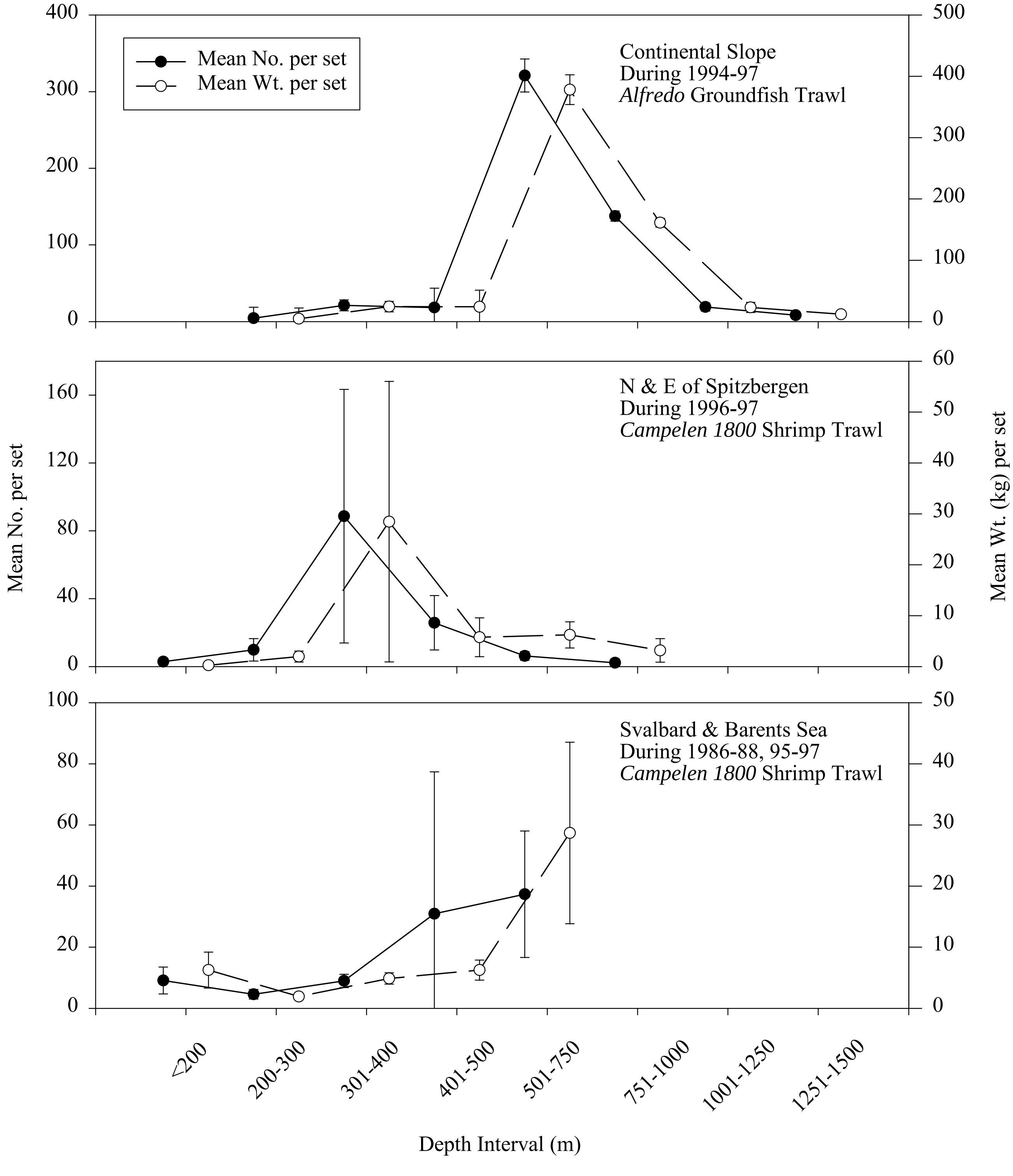

Figure 4. Distribution and relative abundance with depth expressed as mean number and weight (kg) per standard set by depth intervals. Data from different years combined and presented for three different survey areas. All data are collected in August-September (source: Bowering and Nedreaas 2001).

The distribution and relative abundance of Greenland halibut as these vary **with bottom temperature** for the Northeast Arctic data are expressed as mean number and weight (kg) per standard set by 1.0º C intervals for bottom temperatures in the range of –1.9º C to 5.0º C. All catches made at temperatures <1.9º C are grouped as well as those at temperatures >5.0º C. For catch and temperature data analyzed, the areas and survey time series combinations examined were identical to those used in the analyses of distribution with depth (see Table 2). The results are shown in Figure 5.

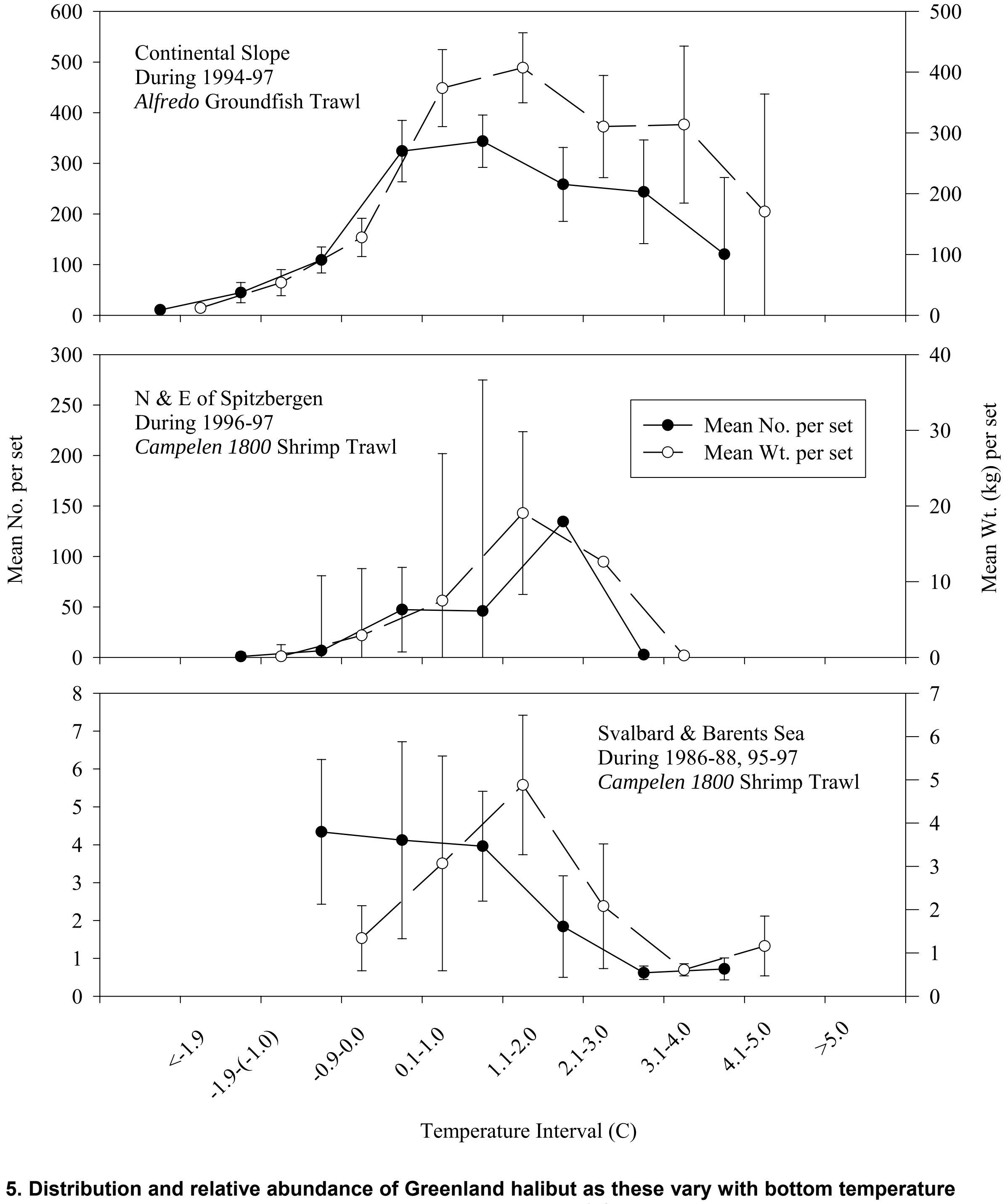

Figure 5. Distribution and relative abundance of Greenland halibut as these vary with bottom temperature expressed as mean number and weight (kg) per standard set by 1.0º C intervals. All data were collected in August-September (source: Bowering and Nedreaas 2001).

Concerning the material and methods used to describe the stock's position in the food web, the authors refer to work done by several authors (e.g., NIZOVTSEV 1989a, MICHALSEN and Nedreaas 1998, Dolgov and Smirnov 2001, Hovde et al. 2002, and Vollen et al. 2003).

The material used for describing and discussing stock assessment, fishery and management are taken from the ICES Arctic Fisheries Working Group reports (e.g., Anon 2002), related reports of the ICES Advisory Committee for Fisheries Management, protocols from the Joint Norwegian-Russian Fisheries Commission, and laws and regulations of the Norwegian and Russian authorities.

Results and discussion

Stock characteristics

Distribution and management units

Greenland halibut in the Northeast Arctic are distributed extensively from south of 62º N along the continental slope near the European Union (EU)-Norway border, continuously to the northeast of Spitzbergen beyond 82º N (Figure 1). They have also been observed as far east as the eastern coast of Franz Josefs Land at 73º E (Figure 1). Catches are highest along the edge of continental slope, although differences in fishing gear in the Northeast Atlantic surveys make it difficult to compare catches accurately. They are abundant in the deep channels running between the shallow fishing banks but are absent from the tops of the banks in the Barents Sea (Figure 1). Relatively large catches have been made northeast of Spitzbergen and are widely distributed east of Svalbard towards Franz Josef Land In the central part of the Barents Sea small quantities occur in catches as far to the east as the Goose Banks (47º E). (Figure 1).

Nizovtsev (1989a), Bowering and Nedreaas (2001) conclude that Greenland halibut appear to be distributed with little or no break in the continuity of the distribution throughout both the Northwest and Northeast Atlantic Ocean. According to the results of earlier investigations, Greenland halibut in the Northeast Arctic spawn along the continental slope primarily between 71º N and 75º N (Nizovtsev 1989a) or between 72º N and 74º N (Godø and Haug 1989), i.e. about the mid-latitude of the distribution range (see Figure 1). Albert et al. (1998) also observed spawning Greenland halibut along the slope between 70º N and 75º N with peak spawning occurring in December. These authors, like Fedorov (1969), however, noted that some spawning occurred in adjacent areas more than six months later, although this was much less extensive.

The main nursery area in the Northeast Atlantic is reported also to be more to the northern end of the distribution surrounding the Spitzbergen archipelago (Godø and Haug 1989). Recent studies have shown that the areas north and east of Spitsbergen and eastwards to Franz Josef Land are important nursery areas. Since the northernmost areas are covered by ice during most of the year the northeastern border of the distribution could not be delineated (IMR/PINRO-report series no. 7, 2002).Young Greenland halibut may occasionally also occur in the eastern part of the Barents Sea towards Novaya Zemlya (Nizovtsev 1983; 1989a).

In the Northeast Atlantic there is no apparent change in individual mean size of Greenland halibut with depth along the continental slope area. However, to both the north and east of Spitzbergen surveys and the Svalbard and Barents Sea surveys indicate an increase in mean individual size in the catches in depths greater than 500 m (Figure 3). Greenland halibut catches exhibited a tendency to increase in size with depth, peak and then decline (Figure 4). However, no latitudinal depth trends in peak abundance could be established.

The affinity for young juvenile Greenland halibut to nursery areas in the north and larger fish to be in deep water along the continental slopes of the Northeast Atlantic might explain some of the variability apparent in the preferred depth range. For example, the distribution data from surveys along the slope of the Norwegian Sea did not demonstrate any change in mean individual fish size over the range of depths fished. Since this survey series includes the spawning area (Albert et al. 1998), young fish would have a tendency to be less abundant here; therefore a change in mean individual size with depth would probably be less apparent. Age compositions from these surveys reported in Anon. (2002), in fact, indicated that very few Greenland halibut less than five years old were caught. On the other hand, unpublished survey and commercial catch rate data from the Institute of Marine Research show that from September onwards there seems to be a clear trend in mean individual size with depth. Larger mature fish appear to migrate to shallower depths and to some extent into regions of the Barents Sea as shallow as 200-metrese. Data from Russian longliners (Popov et al. 2003) demonstrate that some large post-spawning specimens in March - April may migrate to the central part of the Barents Sea (Grey Zone) and stay there at depths of 300-360 metres at least until the middle of summer, then leave this area gradually. This suggests a degree of seasonality in the distribution pattern, which might be associated with feeding or spawning behaviour.

Trends in distribution and relative abundance of Greenland halibut with respect to bottom temperature in the Northeast Atlantic surveys are more evident than in the Northwest Atlantic (Figure 5) (Bowering and Nedreaas 2002). In all the survey series presented, the average weight (kg) per set increases to peak within a bottom temperature range of 1.1º C to 2.0º C, beyond which the average weight (kg) per set declines. The trend is similar for average number per set from the continental slope surveys. However, the peak occurs within a bottom temperature range of 2.1º C to 3.0º C for the north and east of Spitzbergen data and below 0.0º C for the Barents Sea and Svalbard data (Figure 5).

This also agrees with Nizovtsev (1989a), who showed that the distribution of various length groups of Greenland halibut in the continental slope area versus sea temperature confirms a certain regularity, i.e., smaller fish meet at the extreme limits of a temperature range, whereas larger specimens live near the middle of a temperature range (2-3° C).

Nonetheless, Bowering and Nedreaas (2002) found that Greenland halibut in the Northeast Atlantic tend to be more widely distributed at lower bottom temperatures than those of the Northwest Atlantic, rather surprisingly, given the apparent slower growth rate of the latter (Anon. 1997, Bowering and Nedreaas 2002). Peak spawning in the Northeast Atlantic is reported to occur at bottom temperatures of 2.0-3.0º C (Nizovtsev 1989a) or 2.0º C (Albert et al. 1998) compared to 3.0º C to 3.5º C for Davis Strait (Jørgensen 1997a).

Size, age, growth and maturity

A joint Northwest Atlantic Fisheries Organization (NAFO) – International Council for the Exploration of the Sea (ICES) "Workshop on Greenland halibut Age Determination" was held in Reykjavik, Iceland in 1996 to deal with the age determination of Greenland halibut and standardization of methodology (Anon. 1997). Bowering and Nedreaas (2001B) based their review of age validation and growth upon the results and recommendations from this workshop. In most instances female growth rates are slightly higher than those of males after about six or seven years of age (Figure 6a). The joint NAFO/ICES workshop only discussed otoliths, as these are the most widely used measure and are regarded as the most appropriate structures for age determination. PINRO and Russia, on the other hand, have routinely used scales for age determination. Also on the basis of scale interpretation, females grow faster than males from an age of six to seven years.

Irrespective of geographical areas and method of age determination, it has been confirmed and agreed that females have a longer life-span than males.

Bowering and Nedreaas (2001B) showed that Greenland halibut in the northeast Atlantic are generally larger at age, i.e., display higher growth rates, up to about eight year of age than those of the northwest Atlantic. However, the results suggest that the growth patterns between the two regions may have been converging on a more similar pattern in recent years.

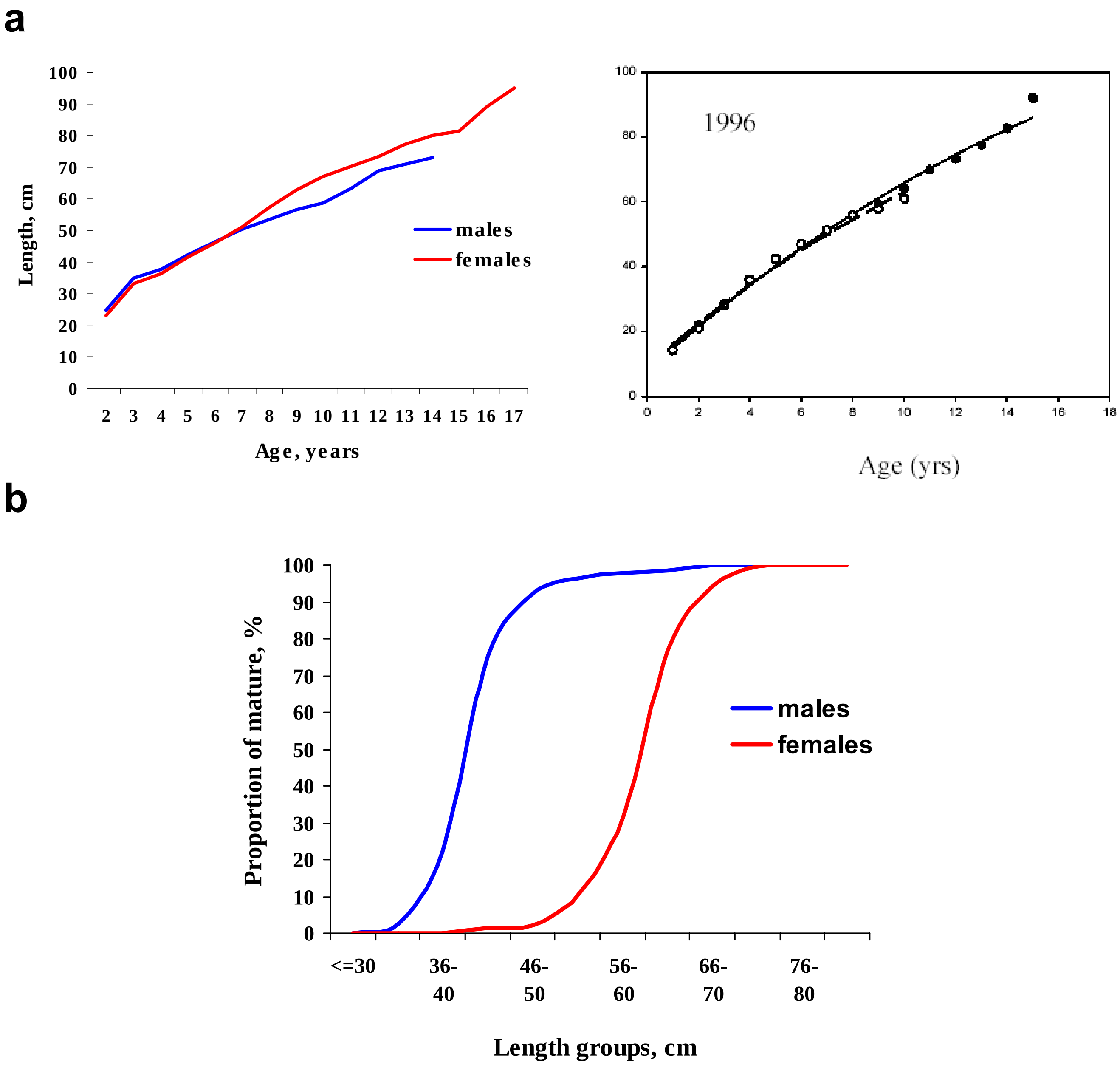

Figure 6. a)-left: Greenland halibut length at age determined by otolith growth rings (example from Bowering and Nedreaas (2001b). a)-right: Mean length at age for the years 1981-1997 as age determined by scales. b) Proportion mature at length (mean for 1984-1998) (Russian scale readings)

According to PINRO data, Greenland halibut in the Barents Sea reach a maximum length of 120 cm and an age of 20 years (Nizovtsev 1989a). Earlier investigations (Kovtsova and Nizovtsev 1985) showed higher growth and maturation rates in the 1970-80s than in the 1940-60s. The reduction of stock abundance is considered to be the main reason for this trend.

This increase in growth and maturation rates continued until the end of the 80s. In the 90s, the average annual length increments began to decrease.

As with other fish species, the length and age at which Greenland halibut reach sexual maturity vary widely (Kovtsova and Nizovtsev 1985), but males become mature when they are younger and smaller than females. In the 80s and 90s, 50% of males had reached maturity at an average length of about 41 cm and at an age of five years, which is close to parameters observed in the 1970ies, and 50 % of the females – likewise at a length of about 59 cm and an age of eight years, which is a little bit earlier than in the 70s (Figure 6b).

The fecundity of Greenland halibut is rather low compared to other flatfish. Estimates ranged from 6.4 to 94.4 thousand eggs per female, depending on body size. Mean fecundity has been evaluated by various authors at 18.1-28.1 thousand eggs per female (Figure 7).

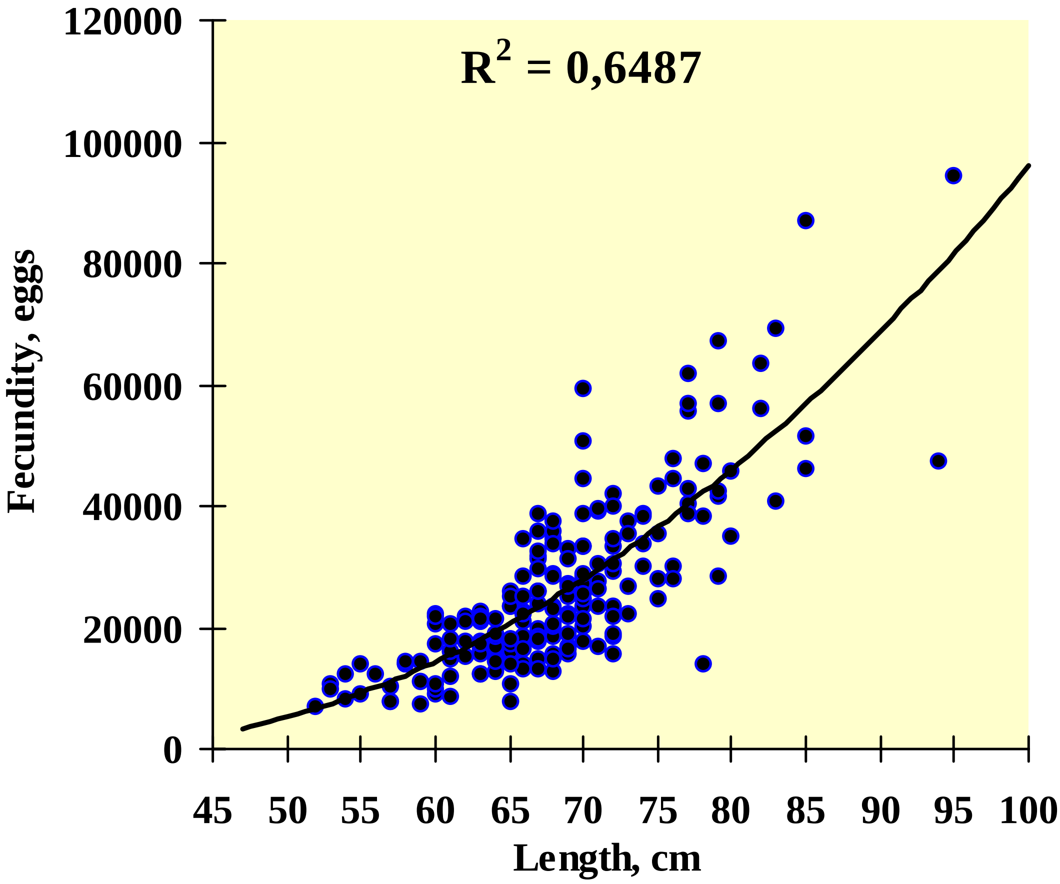

Figure 7. Fecundity of Greenland halibut as function of on body size.

Total egg production (TEP) by the northeast Arctic Greenland halibut stock by age in 1996-1998 is shown in Figure 8 (Gundersen et al. 2000).

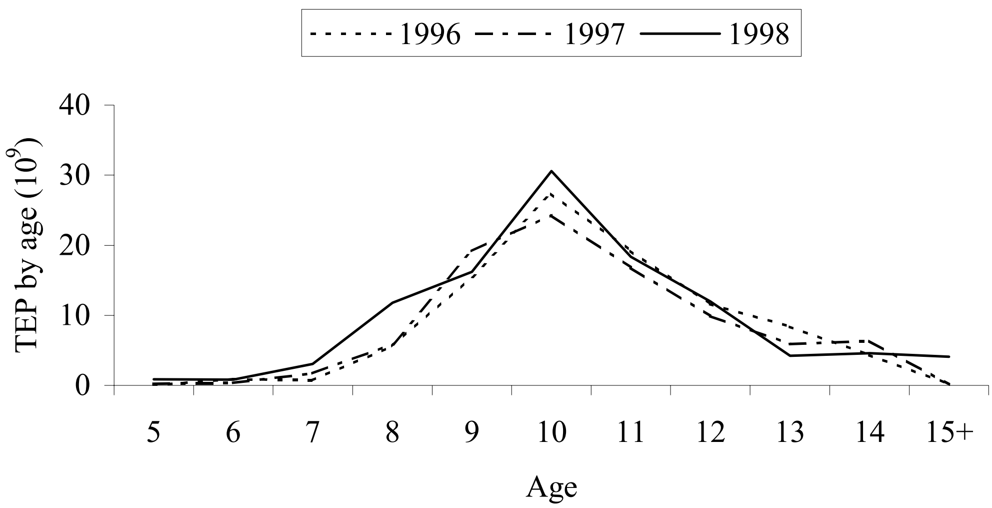

Figure 8. Total egg production (TEP) by the northeast Arctic Greenland halibut stock by age in 1996-1998 (ref. Gundersen et al. 2000).

Position in the food web

As Russian investigations show (Dolgov and Smirnov 2001), among the variety of fish, seabirds and marine mammals, Greenland halibut were found in the diet of just three species - Greenland shark (*Somniosus microcephalus*), cod (*Gadus morhua morhua*) and Greenland halibut itself. The killer whale (*Orcinus orca*), grey seal (*Halichoerus grypus*) and narwhal (*Monodon monoceros*) are other potential predators. However, the role of Greenland halibut in the diets 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 diets in 1984-1999 accounted for 0.01-0.35% by weight (0.05% in average). Low levels of consumption are related to the distribution pattern of juvenile Greenland halibut as they spend the first years of their life mainly in the outlying areas of their distribution, in the northern Barents Sea, where both adult Greenland halibut and other abundant predator species are virtually absent.

The level of cannibalism was highest in the 1960s (up to 1.2% by frequency of occurrence). In 80s, in Greenland halibut stomachs the frequency of occurrence of their own juveniles did not exceed 0.1 %. In the 90s, the portion of their own juveniles (by weight) was around 0.6-1.3%.

The composition of the food of the Greenland halibut in the Barents Sea includes more than 40 prey species (Nizovtsev 1989a; Dolgov and Smirnov 2001). The results of monitoring by PINRO of a wide area from the continental slope up to Novaya Zemlya show that the main food of the Greenland halibut consists of fish, mostly of capelin (*Mallotus villosus villosus*) and polar cod (*Boreogadus saida*) as well as cephalopods and shrimp (*Pandalus borealis*). In 1990's an important place in the diet was occupied by waste products from the fisheries for other species (heads, guts etc.). With growth, a decrease in the importance of small food items (shrimp, capelin) in the diet and an increase in the proportion of large fish such as cod and haddock (*Melanogrammus aeglefinus*) were observed.

In a diet study carried out on the continental slope of the Norwegian Sea Michalsen and Nedreaas (1998) found a generally high proportion of empty stomachs, but with decreasing percentage of empty stomachs with increasing predator length. The cephalopod *Gonatus fabricii* was a very important prey item. Of the fish prey, herring and blue whiting were the most important. Much of the prey was pelagic, and few strictly bottom living organisms were found.

Recent studies of diet composition and feeding behaviour of Greenland halibut have also been presented by Hovde et al. (2002) and Vollen et al. (2003). Hovde et al. (2002) found spatial and temporal components to have more influence on the variation in diet composition than biotic variables, although in smaller Greenland halibut (< 50 cm) crustaceans and the cephalopod *Gonatus fabricii* were the prevailing prey, whereas for larger specimens (> 50 cm) teleosts and fish offal were the dominant components.

With a Greenland halibut stock of nearly 100 000 tonnes, the total food consumption by their population comes to about 280 000 tonnes. The biomass of commercial species consumed (shrimp, capelin, herring, polar cod, cod, haddock, redfish (*Sebastes sp*.), long rough dab (*Hippoglossoides platessoides*) does not exceed 5 000-10 000 tonnes per species.

The Greenland halibut as a species thus has a negligible effect on the other commercial species of the Barents Sea, while at the same time it is not subject to their predatory influence.

History of the fishery, the stock and its management

Fishery

Historically, in the Northeast Atlantic there was little demand and poor prices for Greenland halibut compared to other groundfish such as cod, therefore it received little attention from enterprising fishermen. It was not until a trading relationship (known as the Pomor trade) developed between Russia and Norway during the 1760s that Norway began to fish this species commercially using longlines. Greenland halibut were more common in the Russian marketplace and the demand was sufficiently high to warrant the development of the fishery (Ytreberg 1942). The trading relationship eventually collapsed with the arrival of the Russian Revolution in 1917, and the fishery declined. After 1935 the longline fishery once again developed. Catches increased from about 1 000 tonnes at the beginning to 10 000 tonnes by the 1960s (Figure 9). In 1964, dense spawning concentrations of Greenland halibut were found to the west of Bear Island by Soviet fishermen testing new deep-water trawl equipment (Pechenik and Troyanovsky 1970; Nizovtsev 1989a). This provided an incitement for the prompt development of an international trawl fishery. With the introduction of international trawling fleets to the fishery during mid 1960s, catches increased rapidly to peak at 90 000 tonnes in 1970 before declining (Anon. 1998b). The fishery has been regulated since 1992, and from 1992 until 1997 catches averaged around 11 000 tonnes annually, the lowest since the early 1960s. The average annual official catches for 1998-2002 have been 15 000 tonnes (Figure 9). The fishery for Greenland halibut in the Northeast Atlantic has been conducted mainly along the continental slope of the Norwegian Sea between 68º N and 74º N in ICES Division IIa and along the continental slope of southern ICES Division IIb. High variability in catches is generally associated with those proportions taken in ICES Division IIb and it was here that the peak catches were made in 1970-71 (GODØ and HAUG 1989). The Greenland halibut fishery in the Norwegian and Barents Seas in 1970-1980s has primarily been carried out by fishing fleets from the former Soviet Union (about 50% on average), Norway (about 25%), the German Democratic Republic and the Federal Republic of Germany as well as Poland and the United Kingdom (Figure 9) (Anon. 2002). During 1992-1999, however, more than 80% of the catches have been taken by Norway, with Russia accounting for most of the remainder. In 2000-2002, the Norwegian share of the total official catches fell to about 60%.

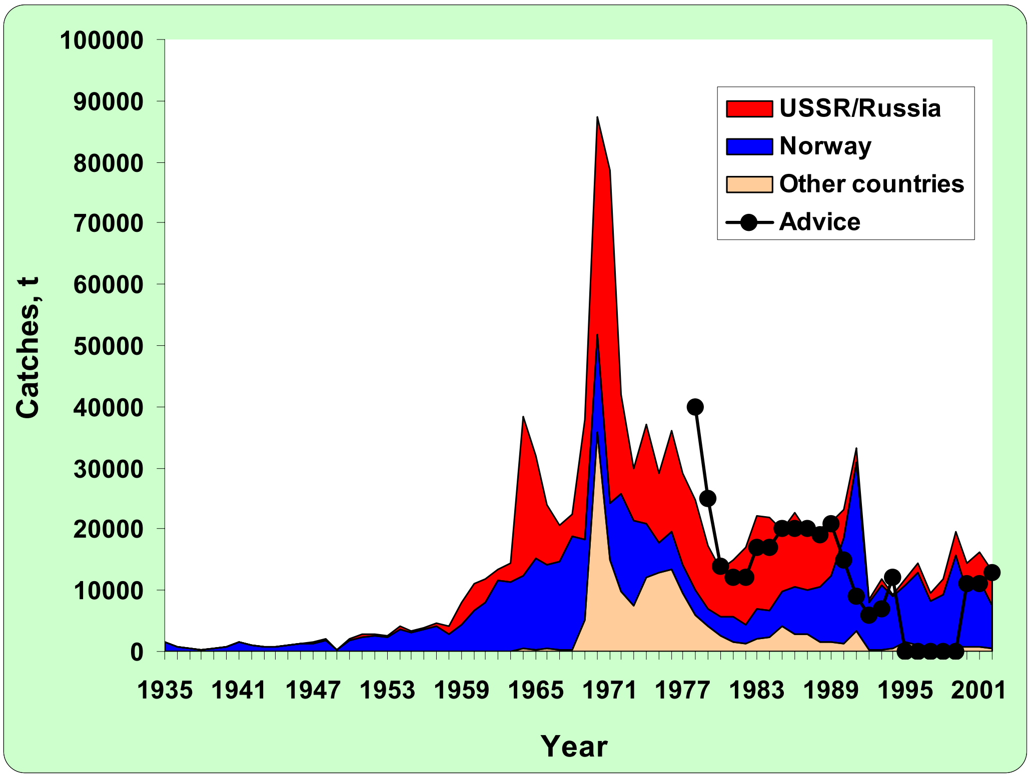

Figure 9. International landings of Greenland halibut from the Barents and Norwegian Seas, 1935-2002.

ICES has provided annual scientific advice on catch levels for this stock since 1978; however, the fishery remained unregulated until 1992. Since most of the Greenland halibut stock is located within the Norwegian Exclusive Economic zone (NEEZ) and Svalbard area, all regulations have been imposed and implemented by Norway. In view of the poor state of the stock, since 1992 the fishery has been regulated by permitting only vessels less than 28 m in length using longlines and gillnets to target Greenland halibut, with a small assigned quota that can only be fished during the month of June. In addition, catches by all other vessels and gears are restricted to by-catch only. The by-catch regulations have also become rather strict. This included a by-catch weight limit on Greenland halibut for other fisheries carried out in the area, which has varied between 5% and 12% since 1992 (Anon. 2002). ICES advised a zero catch for this stock during 1995-2002, on the basis of the low spawning stock and the apparent failure of several pre-recruit year-classes. However, because Greenland halibut is an allowable by-catch in other major groundfish fisheries such as cod and haddock, while a small targeted fishery is permitted, the actual catch substantially exceeded the advised TACs (Figure 9).

Stock

Stock evaluations of the Greenland halibut resource in the Northeast Atlantic indicate that the stock has been declining steadily since the 1970s, and by the early 1990s the spawning stock here had reached the lowest level observed (Anon. 1998b). This was mainly a result of excessive exploitation over the period, given that the fishery was unregulated until 1992. Recruitment failures were deduced from extremely low survey abundance indices of Greenland halibut at ages 0-4 from 1989 onwards. Later estimates of the abundance of these same year-classes aged five or more, on the other hand, suggest that these year-classes may not be nearly as weak as the earlier ages would suggest (Anon. 1998b). It seems clear from recent studies and the data presented here that important areas for young Greenland halibut might be found further north and east of Svalbard than previously considered. These areas would have been outside the former surveyed areas from which the pre-recruit abundance indices were derived (Joint IMR/PINRO report 2002). Albert et al. (1997) also showed that the southwestern end of the distribution area of age one fish was gradually displaced northwards along west and north Spitzbergen in the period 1989-92 (partly outside the former surveyed areas) and southwards in 1994-96. These displacements seem to have corresponded to changes in hydrography, i.e., a more northerly distribution when the temperature in the Barents Sea is high and a more southerly distribution when the temperature is low. It has been hypothesized that this may have caused the main concentrations of at least the 1989-1992 year-classes at early ages to move outside the areas formerly covered by the surveys. If this is correct, the implications for evaluating stock status are particularly worrisome for this resource, bearing in mind the fishery-independent database used in the assessments and advised TACs of recent years. Nevertheless, these year-classes as yet would have little effect on current estimates of the low spawning stock size, which alone would warrant the very strict scientific advice. On the other hand, if the estimates of the 1989-94 year-classes at older ages are confirmed as being more representative of year-class size, then improvements to the spawning stock could occur earlier than previously anticipated, provided that catches are kept low.

Management of the stock

Stock assessment and current management strategy

The stock is annually estimated by the ICES Arctic Fishery Working Group (AFWG) in spring using the XSA-model. The assessment is finally quality checked and recommendations are subsequently provided by the ICES Advisory Committee on Fishery Management (ACFM) at its June meeting.

The basic data for the estimations are the data on annual catches of various age groups (in numbers) and average individual (round) weights of specimens of various age groups. Maturity ogives are necessary for calculations of spawning stock. Table 3 indicates the type of data provided by different countries.

Table 3. Data for stock assessment provided by different countries participating in the fishery.

Country	Kind of data				
	Catch in weight	Catch at age in numbers	Weight at age in the catch	Proportion mature by age	Length composition in catch
Norway	+	+	+		+
Russia	+	+	+	+	+
Germany	+				
United Kingdom	+				
France	+				
Spain	+				
Portugal	+				
Ireland	+				
Greenland	+				
Faroe Islands	+				
Iceland	+				
Poland					

The analytical assessment method XSA (eXtended Survivor Analysis) is used for tuning the model, i.e., matching the catch-at-age data with the scientific survey indices and/or catches per unit of effort. The model produces a diagnostic output to be evaluated and discussed before making any adjustments needed and performing a final run. This enables the quality of the assessment to be estimated.

At present, the AFWG possesses data on catches for the period back to and including 1964, and abundance indices from the following surveys (see also Figure 10):

- Norwegian bottom trawl survey in August in the Barents Sea and Svalbard areas at fishing depths from less than 100 m down to 500 m (since 1984).
- Norwegian Greenland halibut survey in August. The survey covers the continental slope from 68 to 80ºN, at depths of 400–1500 m north of 70º30'N, and 400–1000 m south of this latitude (since 1994).
- Norwegian bottom trawl survey north and east of Svalbard in autumn (since 1996, and conducted since 2000 as a joint Norwegian-Russian survey).
- Russian autumn bottom trawl survey in the Barents Sea and Svalbard in October-December at fishing depths of 100–900 m (since 1984).
- Spanish bottom trawl survey on the slope of Svalbard area in October (since 1997)
- Norwegian Barents Sea bottom trawl survey in February at fishing depths from less than 100 m and down to 500 m (back to 1981, but present design since 1993, and conducted since 2000 as a joint Norwegian-Russian survey).
- International pelagic 0-group survey (back to 1965, but present design since 1980).
- Norwegian experimental commercial fishery (CPUE), two weeks every May since 1992.

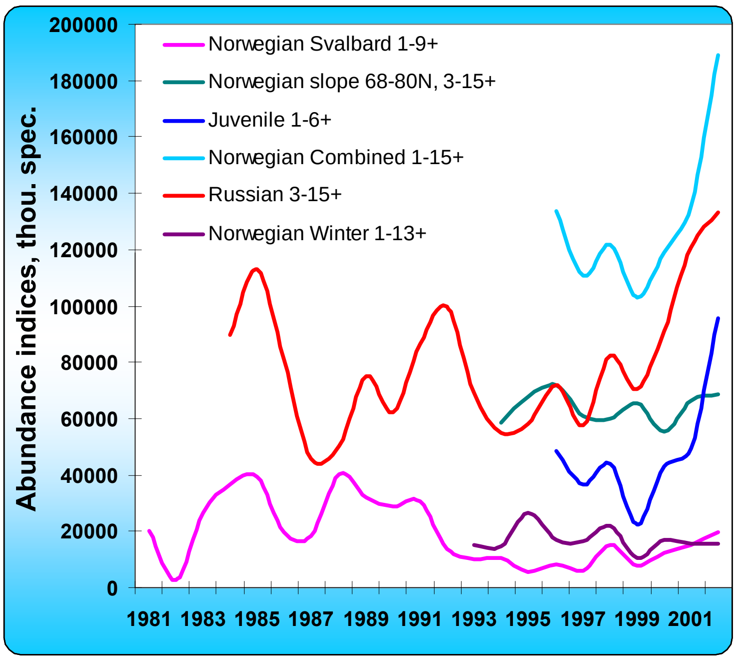

Figure 10. Abundance indices of Northeast Arctic Greenland halibut from different surveys.

During the past two years (2002-2003) three datasets have been used for the tuning: a combined index series of the three first surveys from the list above, indices of the Russian autumn trawl survey, and catch-rates from the experimental Norwegian fishery in spring.

The last stock assessment (2003) estimates the total fishable stock (5 years and older) in 2002 to have been 82 000 tonnes and the spawning stock (biomass of mature females) to 28 000 tonnes (Figure 11). Although commercial and spawning stocks of Northeast Arctic Greenland halibut in 2002 have remained below the long-term mean level for the whole monitoring period since 1964 (121 and 48 000tonnes respectively), both of them already exceed the mean level for the past 20 years (77 and 26 000 tonnes). The level of fishing mortality in 2002 (F=0.20) was the lowest since 1981.

Short-term projection has shown that the fishable and spawning stocks in the beginning of 2003 were predicted to be about 87 and 32 000 tonnes respectively. With an expected catch of 15 000 tonnes (F=0.21) in 2003, the fishable and female spawning stocks will increase up to 90 and 35 000 tonnes respectively, at the beginning of 2004. These assessment results thus confirm the growth of the Greenland halibut stock, which is expected to continue further under condition of catch in 2004 will not exceed 16 000 tonnes.

At the same time, despite the emergence of a slight optimism, the reliability of the received estimates continues to provoke doubts. The reason for this is that there are many assumptions in the basic data used in the assessment. Some doubts regarding the veracity of the given fishery statistics and the data quality of the surveys exist. Other sources of uncertainty are mentioned below. Estimates have been made only for age groups five years and older due to the fact that survey results on fish younger than five years of age inadequately reflect their real numbers. Individual weights at age are accepted as identical "in catch" and "in stock". The natural mortality (M) is set to 0.15 for all ages in all years. Differences between the sexes other than the maturity ogive have not been taken into account.

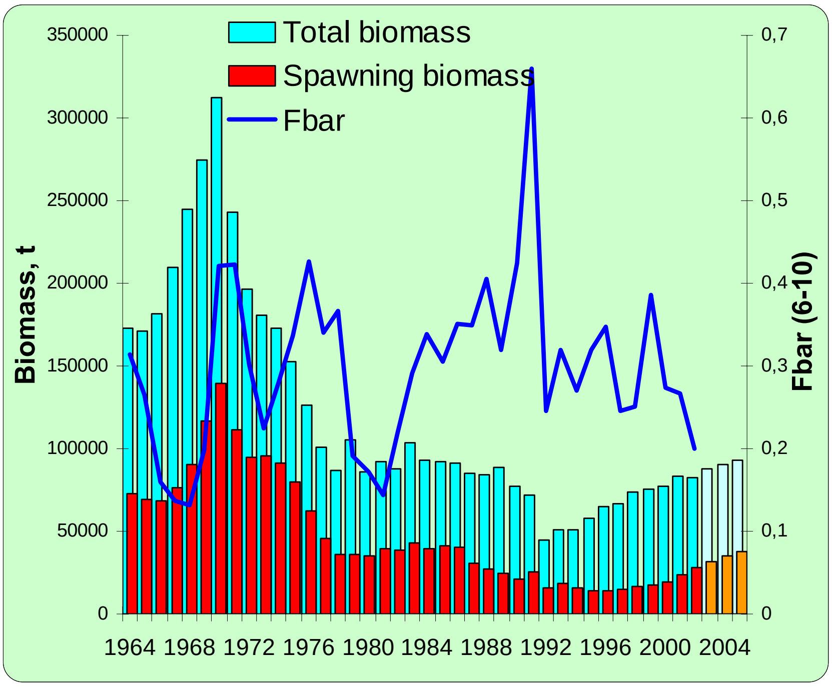

Figure 11. Assessment results of the Northeast Arctic Greenland halibut stock showing the estimated total biomass of five-year-old and older fish, female spawning biomass and the average fishing mortality of ages 6-10. A prediction for 2003-2005 is also shown.

Working Group in 2003 summarized: "Although many aspects of the assessment remain uncertain, nearly all fishery independent indices of stock size indicate positive trends in recent years. However, given the uncertainties in the assessment it is desirable to maintain a relatively low fishing mortality to ensure continued stock improvement. Additional management measures to control catches, e.g. TACs, area closures and reduced by-catch limits, need to be introduced and enforced effectively" (Anon 2003).

Thus, under the existing conditions of uncertainty and, in consequence, the difficulty of defining proper biological reference points, the current strategy of Greenland halibut stock management will be to focus on its rebuilding.

Stock monitoring and form of advice

The Norwegian and Russian authorities have agreed to monitor this stock as a joint stock. The stock is currently being monitored by the scientific surveys listed above, and biological sampling from the international bycatch fisheries and the Norwegian coastal fishery in June.

Currently, a major research and monitoring effort is being devoted to this stock through the three-year (2002-2005) Russian-Norwegian research programme for improvement of future management and advice. This programme is focusing on:

- Distribution and migrations
- Life history, reproductive biology, trophic relations
- Accuracy in determination of age and its influence on the stock assessment
- Improvement of time series by surveys and fishery
- Catchability of research trawls and comparative selectivity of research and fishing trawls and longlines
- Searching the ways of improvement of stock assessment on the basis of fulfilment of all projects
- Development of biological reference points.

Since neither precautionary reference points nor explicit management objectives have been established for this stock, and until the joint Norwegian-Russian research programme is completed, the current form of advice from ICES is to let the stock size further increase. In order to achieve this, landings should be kept at the 2002 level. ICES further advises that additional management measures to control catches, e.g. TACs, area closures and reduced bycatch limits, need to be introduced and enforced effectively.

TAC decision and international/national sharing of the TAC

The Greenland halibut fishery was fully free until 1977 when exclusive economic zones were established in the Barents Sea and the Joint Russian-Norwegian Fishery Commission (RNFC) began to resolve questions concerning exploitation of the Greenland halibut stock. In 1978-1991 Norway allocated annual quotas for the Soviet Union (Russia) in the NEEZ with volumes from 2.0 up to 12.5 thousand tonnes. From 1992, Norwegian and Russian authorities stopped all targeted fishery, except for Norway allowing a limited traditional non-trawl coastal fishery south of 71º30’ N by vessels less than 28 m. The coastal fishery was to be kept at the historic annual level of ca. 2 500 tonnes, but with hindsight, the regulations have not fully succeeded in maintaining the coastal fishery at this low level. The allowable bycatch for other fisheries comes in additional this.

Both countries also catch certain amounts of Greenland halibut during the joint investigations confirmed by the RNFC. Catches taken for scientific purposes are limited by vessel numbers and by the length of time they are present on the fishing grounds. During the past two years restrictions on the catch volume for scientific purposes have been set. In 2002 each of the parties had the right to take 1.5 thousand tonnes, and in 2003 and 2004 - 3 000 tonnes each.

Based on data regarding Greenland halibut distribution and fishery and reference to the historical contribution to research on the stock, the Joint Russian-Norwegian Fishery Commission (RNFC) will make a decision on the future management, utilization and international/national sharing of the TAC of this stock. This will probably take place at the earliest during the 34th Session in 2005, i.e., after the final report from the joint Norwegian-Russian research programme has been submitted. Until then, the present fishery regime will continue in effect. Table 4 shows the recommended, agreed and official catches during the period 1987-2004, while Table 5 and 6 show the decisions made by the Joint Norwegian-russian Fishery Commision in the periods 1978-1991 and 1992-2003, respectively.

Table 4.Recommended, agreed and official catches of Northeast Arctic Greenland halibut in 1987-2004.

Year	ICES advice	Predicted catch corresp. to advice	Agreed TAC	Official catches
1987	Precautionary TAC	-	-	19
1988	No decrease in SSB	19	-	20
1989	F = F(87); TAC	21	-	20
1990	F = F (89); TAC	15	-	23
1991	F at $\mathbf{F}_{med}$; TAC; improved expl.	9	-	33
1992	Rebuild SSB (1991)	6	2.5[1]	9
1993	TAC	7	2.5[1]	12
1994	F < 0.1	<12	2.5[1]	9
1995	No fishing	0	2.5[1]	11
1996	No fishing	0	2.5[1]	14
1997	No fishing	0	2.5[1]	10
1998	No fishing	0	2.5[1]	13
1999	No fishing	0	2.5[1]	19
2000	No fishing	0	2.5[1]	14
2001	Reduce catch to rebuild stock	<11	2.5[1]	16
2002	Reduce F substantially	<11	2.5[1]	13
2003	Reduce catch to increase stock	<13	2.5[1]	
2004	Do not exceed recent low catches	<13	2.5[1]	

For footnote explanation, see Table 6.

Table 5. Decisions made by the Joint Norwegian-Russian Fishery Commission 1978-1991.

Year of regulation, Session #	Main decisions			Details	
	TAC advised by ICES	Total catch in NEEZ	USSR/Russia quota in NEEZ	Other measures	By-catch during shrimp fishery
1978 (4th)	40 000	30 000	12 500	-	-
1979 (7th)	25 000	20 000	7 600	-	-
1980 (8th)	14 000	10 500	2 000	-	-
1981 (9th)	12 000	9 000	2 000	-	-
1982 (10th)	12 000	9 000	2 400	-	-
1983 (11th)	17 000	13 000	5 500	-	-
1984 (12th)	17 000	13 000	5 500	-	-
1985 (13th)	20 000	15 000	7 000	-	-
1986 (14th)	20 000	15 000	7 000	-	-
1987 (15th)	20 000	15 000	7 000	-	-
1988 (16th)	19 000	14 750	6 600	-	-
1989 (17th)	21 000	16 300	8 100 + 3 000	-	-
1990 (18th)	15 000	12 000	4 100	-	-
1991 (19th)	9 000	7 000	2 100	Norway introduced 45 cm as minimum legal catch size for foreign vessels fishing in NEEZ and at Jan Mayen and for Norwegian vessels	300 individuals per tonne of shrimp

Table 6. Decisions made by the Joint Norwegian-Russian Fishery Commission 1992-2003.

Year of regulation, Session #	Main decisions			Details		
	TAC advised by ICES	Total catch in NEEZ[1]	Russian quota in NEEZ	Comments	By-catch during groundfish fishery	By-catch during shrimp fishery
1992 (20th)	6	2 500	-	*Ban placed on the targeted Greenland halibut trawl fishery*	10% in haul	300 spec. per 1 ton of shrimp
1993 (21st)	7	2 500	-	The same	10% in haul	The same
1994 (22nd)	<12	2 500	-	The same	10% in haul	The same
1995 (23rd)	0	2 500	-	The same	5% in haul	The same
1996 (24th)	0	2 500	-	The same	5% in haul	The same
1997 (25th)	0	2 500	-	The same	5% in haul	The same
1998 (26th)	0	2 500	-	The same	5% in haul	The same
1999 (27th)	0	2 500	-	The same	10% in haul	The same
2000 (28th)	0	2 500	-	The same	10% in haul but 5% on board	The same
2001 (29th)	<11	2 500	-	The same	12% in haul but 7% on board	The same
2002 (30th)	<11	2 500	-	The same	12% in haul but 7% on board	The same
2003 (31th)	<13	2 500	-	The same	12% in haul but 7% on board	The same

[1] Set by Norwegian authorities. This TAC relates to the traditional non-trawl coastal fishery south of 71°30' N by vessels less than 28 m. Allowable bycatch for others in addition to this. This corresponds also to the regulations set by Norwegian authorities in 1992-1994 although ICES (ACFM) probably included the anticipated bycatch when interpreting the set TAC as being 6, 7 and <12 thousand tonnes, respectively for these years.

Fisheries regulations, enforcement, control and collection of fisheries statistics

Since 1992 the Greenland halibut fishery has been regulated by allowing only a longline and gillnet fishery by vessels smaller than 28 m to be aimed at Greenland halibut. This fishery is also regulated by seasonal closure to keep the total landings comparable to the historic catch level for this group of fishermen. A targeted trawl fishery has been prohibited, and trawl catches are limited to by-catches only. From 1992 to autumn 1994 the by-catch in each haul was not to exceed 10% by weight. In autumn 1994 it was changed to 5% by-catch in each haul, and from January 1999 this percentage was again raised to 10%. In August 1999 it was adjusted further to 10% in any one haul but only 5% of the landed catch. In 2001 the by-catch regulations were again changed to 12% in any one haul and 7% of the landed catch.

The control of by-catches at sea is carried out by the Norwegian and Russian Coast-guards and observers (both military (Russia) and civilian (both countries)) on board fishing vessels, while inspectors audit vessels as they unload their catches in harbour.

A minimum legal catch size for Greenland halibut has not yet been stipulated and implemented in the Russian fishery regulations. In 1992, Norway introduced a minimum legal catch size of 45 cm for foreign vessels fishing in NEEZ and at Jan Mayen and for Norwegian vessels irrespective of fishing area on this stock, with permission to fish and keep up to 15% undersized specimens in each haul. When operating in NEEZ, Russian fishermen are required to follow Norwegian rules.

An additional measure aimed at the protection of young Greenland halibut in the Barents Sea is closing of areas for shrimp fishery in cases of excessive by-catches of

Greenland halibut. Russia and Norway have agreed to close and protect geographical areas from shrimp fishing if the number of Greenland halibut per 10 kg shrimp exceeds three.

Russian fisheries statistics are based on daily reports from the vessels to the All-Russian Research Institute of Fisheries and Oceanography (VNIRO, Moscow). Data are then reported to ICES by ICES areas and gears.

Norwegian fisheries statistics are based on sales notes of landed Greenland halibut at fishing ports reported to the Directorate of Fisheries. For trawlers, the sales note statistics are compared and quality checked with the log-books. Data are then reported to ICES by ICES areas and gears.

Other countries report to Norway when fishing in the NEEZ and at Svalbard, and to Russia when fishing in the REEZ. In cases where third countries have not reported to ICES, scientists use these countries' reports to Norway and Russia to obtain the total international catch to be used as input in the assessment.

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