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Assessment of Greenland halibut abundance and biomass in Statistical Area 0 and Subarea 1 with application of the virtual population method

by

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Introduction

Stocks of some commercial fish species, especially of the relatively recent fishery for Greenland halibut and roundnose grenadier, have been insufficiently studied up to the present time. These resources inhabit the deep water areas of the continental slope and were started to be exploited by the modern fishery.

The densest concentrations of Greenland halibut were found in the northern part of the ICNAF Area, i.e. on the continental slope of central and northern Labrador (Div. 2H and 2G) and in Davis Strait (Subarea 1 and Stat. Area 0). Immature individuals prevailed in the trawl catches taken in the deepwater depressions of the continental shelf and on the slopes (Div. 2J, 3K and 3L). The catches per unit effort are less in the latter divisions than farther northward.

In 1959-60, the Canadian fishery for Greenland halibut with longlines occurred in the bays of eastern Newfoundland and Labrador (Div. 3K, 3L and 2J). In more recent years, the Canadian fishery was conducted with monofilament gillnets (mesh size 165-203 mm) and shifted to the open sea areas (Bowering 1977).

Initially, the fishing vessels of the USSR and other countries took small amounts of Greenland halibut as by-catch in their cod and redfish fisheries. In 1967, dense concentrations of roundnose grenadier and Greenland halibut were found in deepwater off Baffin Island (SA 0) through Soviet surveys in the area and experimental fishing. During summer and autumn, USSR vessels exploited Greenland halibut and roundnose grenadier in a mixed fishery. The bulk of the catches taken were, as a rule, roundnose grenadier, and only in extremely cold years (hydrologically) did Greenland halibut prevail in the catches.

From 1973, the area of fishing as well as the fishing period increased, as in October-November concentrations of pre-spawning Greenland halibut were found to the north of the Greenland-Canadian Ridge (Div. 1B) and spawning aggregations to the south of the Ridge (Div. 1C and 1D). In the following years, commercial concentrations of Greenland halibut were found on the continental slope off Labrador in Div. 2G and 2H.

The biology of Greenland halibut has been studied very little, in spite of its great significance for the fishery in the Northwest Atlantic. In particular, the length and age composition and population dynamics of the Greenland halibut stock in the Davis Strait area have been poorly investigated. The biological data currently available is used to analyze the effect of the directed fishery for Greenland halibut in recent years in the Davis Strait area, on the basis of which concrete advice for the rational exploitation of the stock can be made.

Materials and Methods

The Greenland halibut fishery in Davis Strait has been conducted exclusively with bottom trawls. The biological data were collected from the catches (by conventional gears) of research and scouting vessels from PINRO and the Northern Fishery Scouting Service.

Ages were generally determined from scales using a microprojection and binocular microscope, but otoliths were used when scales were unsuitable, the ageing being done with a binocular microscope using reflected light. Large otoliths were first ground to a smooth surface and moistened with a mixture of glycerine and alcohol. Age reading from otoliths is difficult because of the presence of secondary zones and deeply cut edges.

Age determinations in quantity from otoliths are possible only for young fish. Readability decreases with increase in size of fish. From the total number of otoliths examined, age reading was possible in only 30% of the fish greater than 60 cm in length.

Scales from the posterior part of the body (near the tail) are best for age reading. Scales from frozen or fresh specimens are easy to prepare for age reading. The scales of large fish, which were difficult to age, were photographed and then examined in detail.

It should be noted that about 20% of the fish in each age sample could not be aged by otoliths or scales, especially the older age-groups. In order to obtain the most representative age compositions, age-length keys were applied to length compositions of the catches.

In order to estimate the total fishing effort of all countries for Greenland halibut off Baffin Island (SA 0) and off West Greenland (SA 1), the catch rates of Soviet BMRT-type vessels exploiting Greenland halibut in the area was used as the standard. VNIRO statistical data on their activities off Baffin Island (SA 0) were applied ("Statistical data of the USSR catches in Northwest Atlantic for 1969-76"). As for the West Greenland area, due to the fact that the above statistical data on BMRT activities in the Greenland halibut fishery on the continental shelf incorporated data on directed fishing for cod, redfish and American plaice, a special selection of the data relevant to Greenland halibut fishing in the area had to be made for SA 1. A summary of the fishing effort data for Soviet BMRT vessels exploiting Greenland halibut in Davis Strait is given in Table 1.

Instantaneous fishing mortality (F) and absolute abundance (N) of Greenland halibut are determined separately for males and females of different ages and for all year-classes analyzed. It is assumed that the fishing mortality coefficient is constant throughout each year and the natural mortality coefficient (M) is constant over the period from t_p to t_λ. The age at recruitment (t_p) for males and females is considered to be 5 years and the maximum age in the commercial stock (t_λ) to be 14 years for males and 19 years for females. M is assumed to be 0.2 for both males and females.

$$N_t = \frac{C_t Z_t}{F_t(1 - \exp(-Z_t))} \qquad \text{(1)}$$

where Z_t = instantaneous total mortality at age t

C_t = number of males (or females) caught at age t, of a single generation,

and $Z_t = F_t + M$.

Analogously,

$$N_{t+1} = \frac{C_{t+1} Z_{t+1}}{F_{t+1} (1 - \exp(-Z_{t+1}))} \qquad \text{(2)}$$

It is known also that

$$N_{t+1} = N_t \exp(-Z_t)$$

Therefore,

$$N_{t+1} = \frac{C_t Z_t \exp(-Z_t)}{F_t (1 - \exp(-Z_t))}$$

or

$$\frac{N_{t+1}}{C_t} = \frac{Z_t \exp(-Z_t)}{(Z_t - M)(1 - \exp(-Z_t))}$$

Taking N_{t+1}/C_t as b_t, where $b_t > 0$, results in the transendental equation

$$Z_t - b_t(Z_t - M)(\exp(Z_t) - 1) = 0 \qquad \text{(3)}$$

Equation (2) allows us to take "b_t" as a known value, if F at age (t+1) is known. It can be shown that equation (3) has a single solution within the interval (M, ∞).

The parameter Z_t for males and females was determined by the Baranov method (Zasosov, 1970) as follows:

Z_t (males) = 0.70

Z_t (females) = 0.82

Taking into account equations (2) and (1) and solving equation (3) for all age-groups of the year-classes analyzed, values for F and N are calculated (Tables 2 and 3).

The instantaneous fishing mortality factors (F*) for males (or females) in the exploited stock by different years are derived from the formula

$$F^* = \ell n \left[\frac{\sum_{t^1_\rho}^{t_\lambda} (N_t - C_{Mt})}{\sum_{t^1_\rho}^{t_\lambda} (N_t - C_{Mt} - C_t)} \right]$$

where C_{Mt} is the number of fish dying due to natural mortality at age t, that is,

$$C_{Mt} = N_t \frac{M}{Z_t} (1 - \exp(Z_t))$$

and t^1_ρ is the age when fish enter the commercial fishery and is taken to be 7 years for both males and females. The results of the calculations are given in Table 2.

A linear stockastic relationship between F* and fishing effort (f) exists for males and females, the zero hypotheses "Ho : R = 0" being rejected at the level of P = 0.05. The regression equations obtained permits the determination F* values for males and females at different fishing effort levels. The equations are:

$$F^* \text{ (male)} = 0.00002f - 0.02 \quad (r = 0.96)$$
$$F^* \text{ (female)} = 0.000003f - 0.01 \quad (r = 0.82)$$

Taking into account some variation in the numbers of male and females recruited, and applying the Beverton and Holt method, the maximum allowable catch may be calculated. The parameters necessary for the calculations are given in Table 3.

Results

The length and age compositions of Greenland halibut (males and females separately) from USSR catches in SA 0+1 (along the slopes of the Davis Strait Ridge) are shown in Fig. 1 and 2 respectively. The samples from Statistical Area 0 and Subarea 1 were combined under the assumption that the fishery exploits a single population. Up to 1971, the commercial removals of Greenland halibut were unsignificant (Fig. 3), and up to 1972 large males and females were encountered in the catches (Fig. 2). Due to the very low level of fishing in the earlier years, it is very unlikely that the changes in the length and age compositions were due to the effects of the fishery. In particular, the length composition data for 1970 show many peaks which may be due to an insufficient number of length measurements.

The length and age compositions for the 1973-76 period are not very different and are essentially the same as that for 1971 when the directed fishery of Greenland halibut began.

The largest catch of Greenland halibut in the area occurred in 1975, and most of this was taken in the autumn-winter period in the area of the Greenland-Canadian Ridge (23,380 tons) rather than in the Baffin Island area (1,568 tons).

It is known that the fishery in the area of the Greenland-Canadian Ridge is based on Greenland halibut concentrations during the pre-spawning period in autumn and winter, when males predominate in the catches (Zilanov *et al.*, MS 1975). It would be expected therefore that intensive fishing may have a considerable effect on the numbers of males. Table 2 shows that, in 1975, the fishing mortality for males is 0.41, which is higher than for all previous years. This is characteristic of almost the entire catch there. The highest fishing mortality for females was 0.08 for 1972, which is considerably lower than F_{max} indicated on the yield-per-recruit curve of Fig. 4. The maximum sustainable yield of males is 10,437 tons and that of females is 23,101 tons. The statistics of the fishery show that these yields were not attained in any year since the fishery began. Besides, the estimated values for F* are considerably lower than those which correspond to the maximum sustainable yield. In fact, the catch of males could be increased to 1.5 times the 1976 level and the catch of females by 2.6 times. The allowable Greenland halibut catch could be increased to 30,000 tons, considering that half of the catch could be taken in the Baffin Island area where the sex ratio is close to 1:1 in the summer-autumn period.

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Table 1. Fishing catch and effort in the USSR fishery (BMRT vessels) for Greenland halibut in SA 0+1 and the estimated effort for all countries, 1969-76.

Year	USSR BMRT (0+1)[1] Fishing effort (hrs)	G. halibut catch (tons)	Catch per hr (tons)	SA 0 catch by all countries (tons)	SA 1 catch by all countries (tons)	SA 0+1[2] estimated effort all countries (hrs)
1969	1434	813	0.57	813	1639	4403
1970	436	215	0.49	215	1669	3845
1971	4105	1298	0.32	1298	3038	13550
1972	10373	9392	0.90	9960	3937	15441
1973	5502	4087	0.74	2130	7428	12916
1974	10061	9511	0.94	889	13369	15168
1975	16373	17061	1.04	1568	23380	23988
1976	8163	10126	1.24	4906	10882	12732

[1] The calculations include exclusively data relating the USSR vessels type BMRT.

[2] The estimated effort for the halibut fishery by all countries based on the efficiency of Soviet vessels BMRT type, Subareas 0+1.

Table 2. Stock size estimates and fishing mortality for Greenland halibut in SA 0+1, 1969-76.

Year	Males Stock Size Weight (tons)	Males Stock Size Numbers (000)	Males Number of age 5 halibut (000)	Males Fishing mortality (F)	Females Stock Size Weight (tons)	Females Stock Size Numbers (000)	Females Number of age 5 halibut (000)	Females Fishing mortality (F)
1969	56265	18692	7210	0.10	18894	31447	14590	0.02
1970	67848	14808	8911	0.02	26756	38549	13144	0.01
1971	96539	31302	11733	0.17	33041	62172	21910	0.04
1972	131131	36583	12508	0.28	39015	94785	44655	0.08
;973	138212	45897	18793	0.17	45736	90072	14541	0.04
1974	182334	52261	17200	0.22	54918	94968	30101	0.05
1975	181916	49515	10029	0.41	58034	102888	16576	0.07
1976	183228	33220	12911	0.19	52718	97228	14500	0.05

Table 3. Parameters of the Bertalanffy growth equation and those of allometric growth for Greenland halibut.

	W_∞	L_∞	K	t_o	M	a	b
Male	244900	262	0.022	-2.511	0.2	0.004	3.22
Female	146708	230	0.024	-3.991	0.2	0.007	3.10

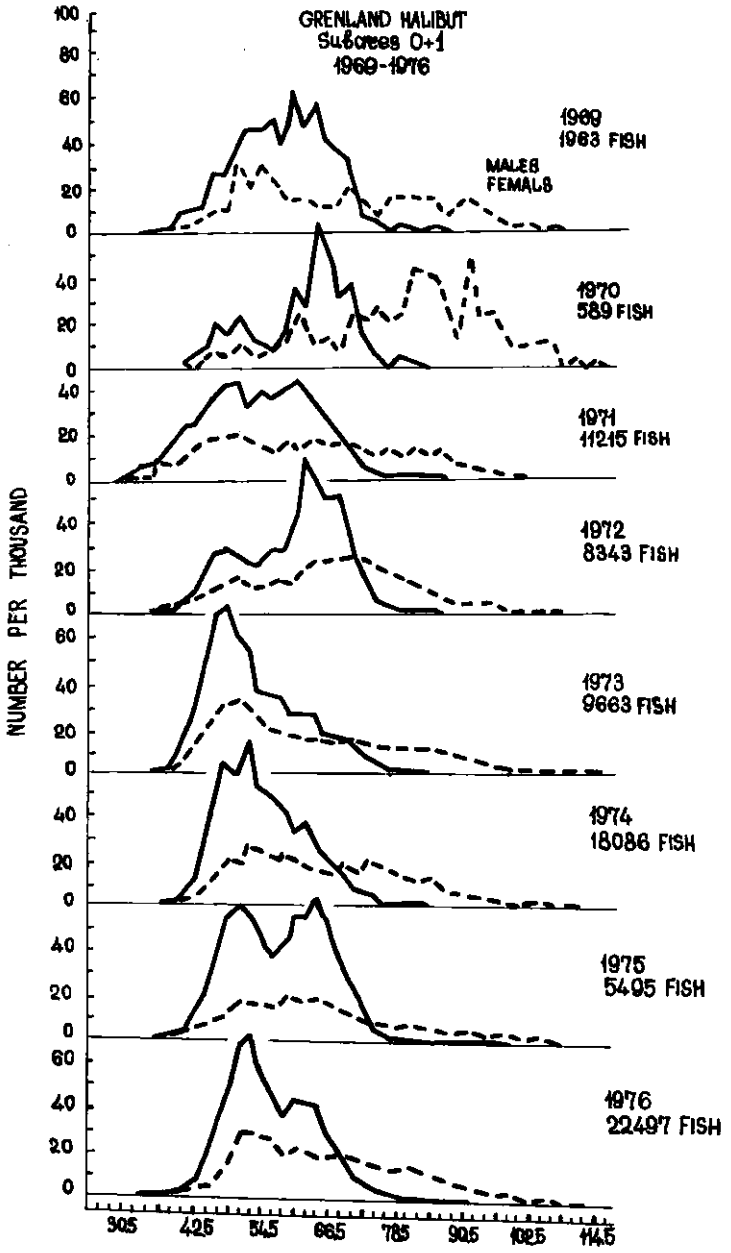

Fig. 1. Length composition (per mille) of Greenland halibut by sex in USSR catches from Davis Strait area, 1969-76.

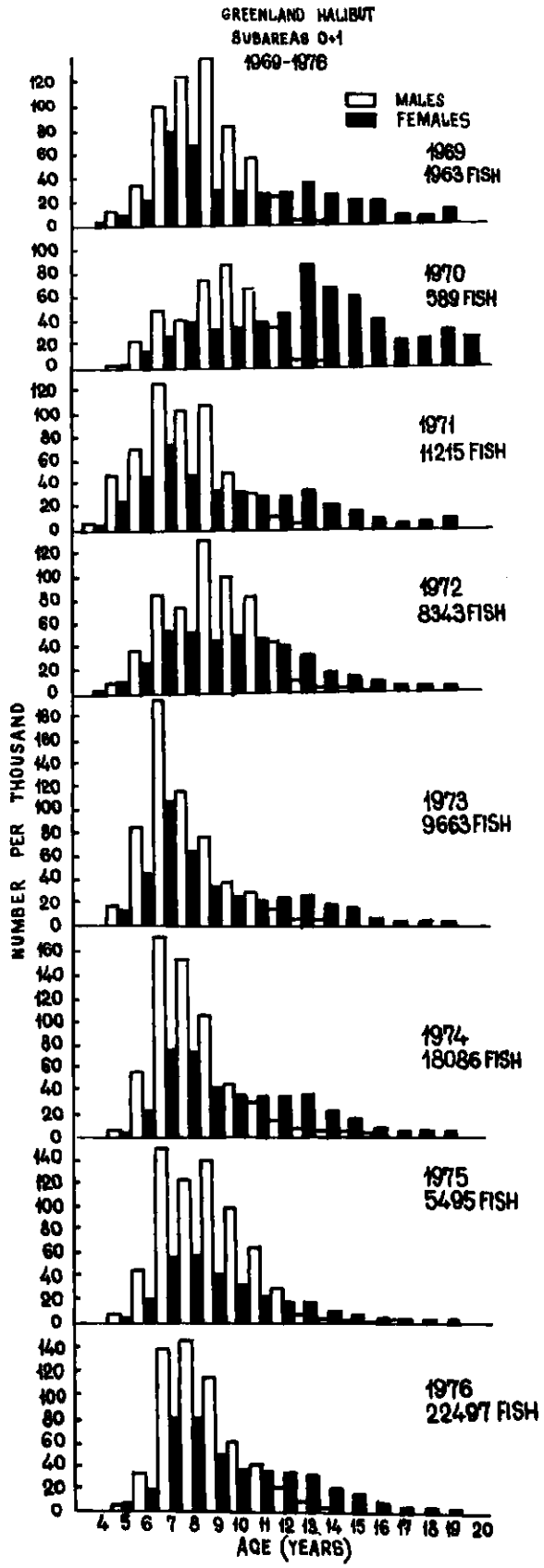

Fig. 2. Age composition (per mille) of Greenland halibut by sex in USSR catches from Davis Strait area, 1969-76.

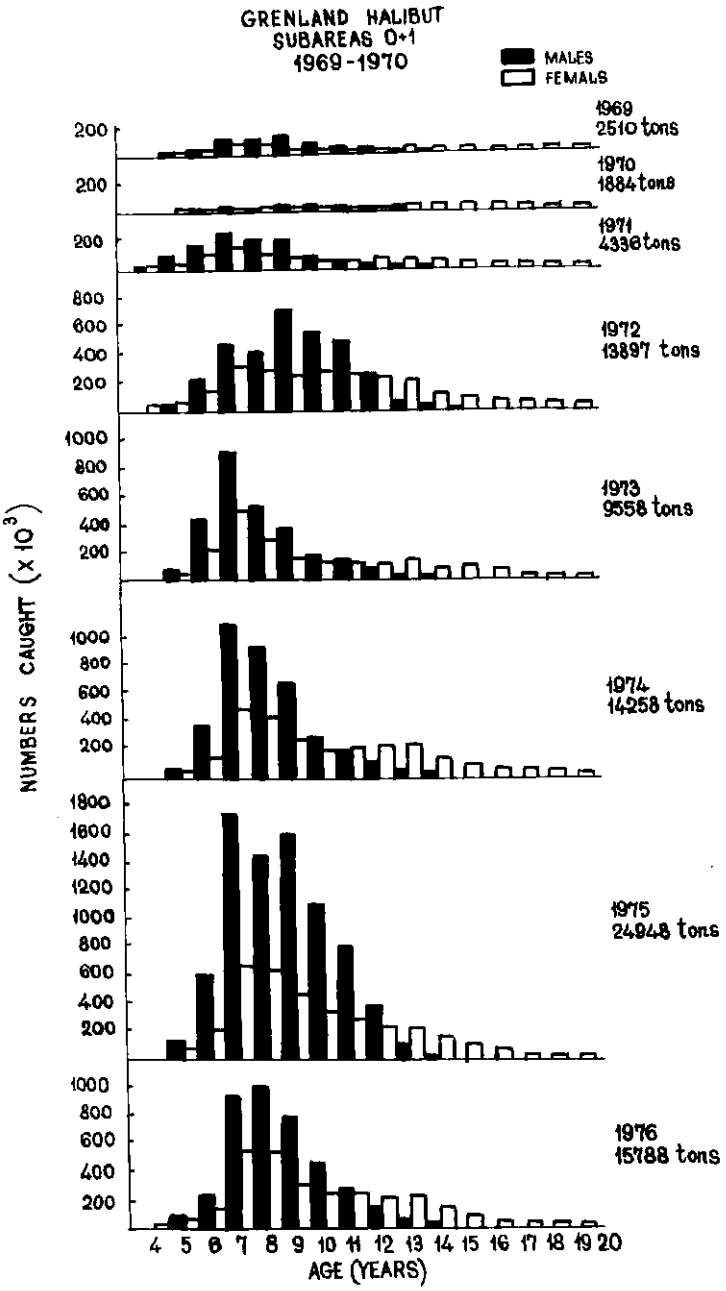

Fig. 3. Estimates numbers of Greenland halibut by sex and age caught in the commercial fishery in SA 0+1, 1969-76.

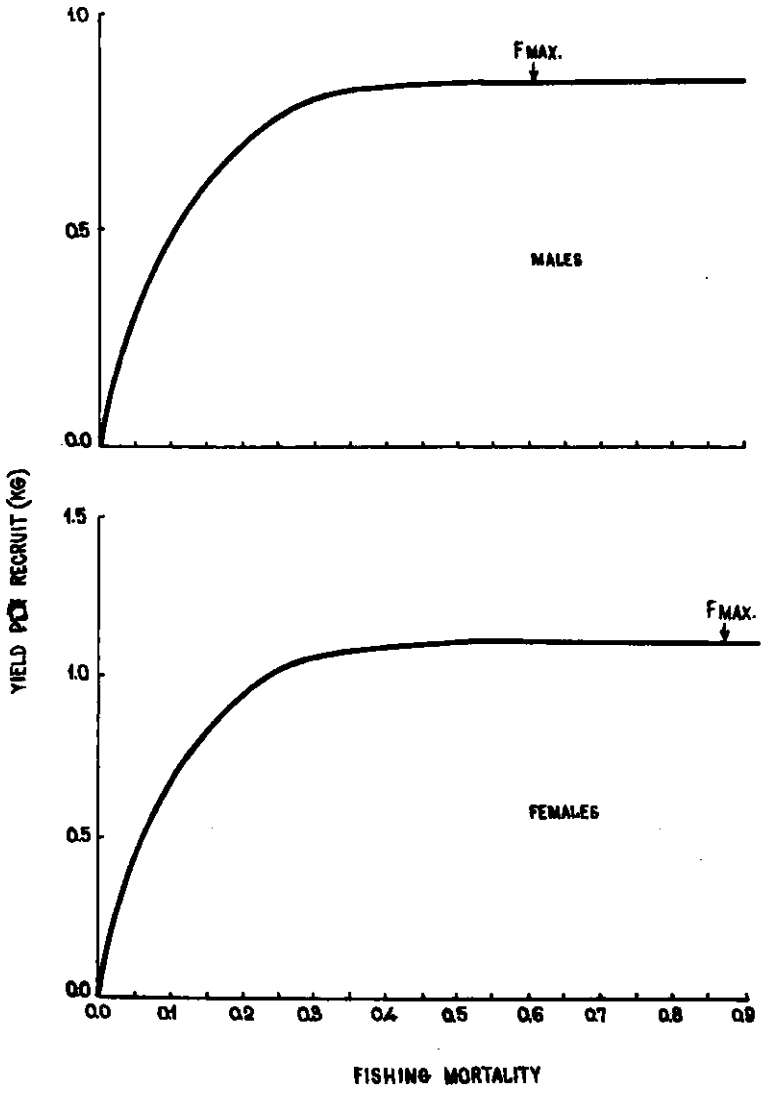

Fig. 4. Yield-per-recruit curves for male and female Greenland halibut in SA 0+1.