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Spawning Stock, Population Fecundity and Year-class Strength of Greenland Halibut From the Northwest Atlantic in 1969-1988

by

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ABSTRACT

An attempt is made to analyse spawning stock abundance and biomass and population fecundity of Reinhardtius hippoglossoides against the background of fluctuations in year-class strength. Individual absolute fecundity was calculated, the 1969-1988 year class abundance derived and population fecundity obtained. The survival rate coefficients were used to establish different levels of population fecundity at which the emergence of strong year classes can be provided under various ambient conditions during early life. The fish reproduction capacity was found to be at the equilibrium state in 1969-1988. A close reverse relationship was revealed between survival rate and water temperature at 50-200 m.

SPECIAL SESSION ON CHANGES IN FISH POPULATIONS

INTRODUCTION

Greenland halibut is distributed above the shelf and slope off Canada from 42°N to 78°N in the Baffin Sea (Andriyashev, 1954; Boyar, 1964; Hubbs & Willimovsky, 1964; Leim & Scott, 1966; Smidt, 1969; Templeman, 1973). The fish is an important commercial species off the Eastern Newfoundland, along the Baffin Land slope, off Labrador and in the West Greenland fjords (Bowering, 1977, 1978, 1979, 1980, 1987; Chumakov & Savvatimsky, 1983, 1984, 1987; Bowering & Brodie, 1981, 1986). A single population is recognized to inhabit these areas (Templeman, 1973; Chumakov, 1975; Bowering, 1977, 1982; Chumakov & Serebryakov, 1982; Ernst, 1987).

The fishery for Greenland halibut was initiated by Canada in shore areas of the Eastern Newfoundland in the 50-ties to extend later in high seas (3KL). The trawl fishery for halibut was not actually developed until 1968. The species was incidentally taken as by-catch in cod and redfish fishery, conducted by USSR and other European countries in Subareas 2 and 3.

The fishery was not regulated until the 200-mile zones were established and the catches varied from 29 to $53.6 \cdot 10^3$ t.

The annual catch was determined mainly by the fishing effort applied.

The introduction of 200-mile zones in 1976 and the subsequent termination of fishery for halibut by the USSR, Poland and GDR (Subarea 1) as well as a reduction in fishing effort by the above-mentioned countries in the Canadian zone (Subareas 0, 2 and 3) resulted in a downward trend in their catches.

At the same time the Canada and Greenland catches of halibut in inshore areas showed an increase, which gave the total catch of $30 \cdot 10^3$ t in the NAFO Subareas 0, 2 and 3 in 1988* (Table 1).

The present paper attempts at estimating the dynamics of Greenland halibut reproduction capacity in 1969-1988.

MATERIAL AND METHODS

The 1969-1988 biostatistical date were used as a basic material. A total of 13 898 age determinations were performed to obtain maturity ogive which was averaged for the entire period of investigations. VPA data on the fish abundance and biomass at age were applied to calculate spawning stock abundance and biomass.

Individual absolute fecundity was determined in 245 females caught in the Davis Strait, off Baffin Island, Western Greenland (Subareas 0 and 1) and Northern and Central Labrador (Divis. 2GH) in 1975-80 and 1987-1988.

The ovaries of newly-caught fish were weighed, labelled and preserved in 5 per cent formaldehyde to be dried later in laboratory, weighed and subsamples (3 g each) were taken from different parts of the ovaries. Eggs were separated from the ovary tissue, weighed of 0.0001 g.

The following regression equations were derived to describe individual fecundity (E_{ind}) as the function of age (A), length (L) and weight of fish:

$$E_{ind} = 10^{2.156 \cdot \lg A + 2.303} \qquad (r = 0.987);$$

$$E_{ind} = 10^{3.632 \cdot \lg L - 2.223} \qquad (r = 0.964);$$

$$E_{ind} = 10^{1.052 \cdot \lg W + 0.754} \qquad (r = 0.981).$$

* Preliminary estimates.

The individual fecundity of the halibut caught in the Davis Strait and off Labrador was found to be similar to that of individuals of the same age and size from the southern Labrador area as reported by Lear (1970) and Bowering (1980).

Population fecundity (E_p) can be defined as the total contribution of each age group:

$$E_p = \sum_{i=5}^{n} C_\varepsilon, \qquad (1)$$

where i=5 - is age at recruitment to the spawning population;
n - is number of age groups;
C_ε - is contribution to the population fecundity of each age group:

$$C_\varepsilon = E_{ind} \cdot N \cdot m \cdot R, \qquad (2)$$

where E_{ind} - is mean individual absolute fecundity of the given age group;
N - is VPA derived abundance of a given age group;
m - is mature fish proportion in a given age group;
R - is sex ratio.

Year-class survival rate can be found as percentage of 5-year olds which have survived from the total number of eggs laid:

$$S_i = N_i \cdot 10^2 / E_{pi}, \qquad (3)$$

where S_i - is survival of a given generation up to the age of 5 years;
N_i - is number of 5 year olds in a given generation i;
E_{pi} - is population fecundity in a given year i.

Year-class survival rate can be regarded as index of ambient conditions during early life.

To describe relationship between population fecundity, year-class strength and ambient conditions the following definitions are introduced:

1. Safe population fecundity which provides strong year-classes under moderate ambient conditions during early life.

2. Minimal population fecundity which can provide strong, medium and poor year-classes under favourable, moderate and unfavourable ambient conditions during early life.

3. Critical population fecundity which provides strong year-class only under favourable ambient conditions during early life.

To estimate the above-given levels of population fecundity the following equations were used:

$$E_{spf} = N_{ab} / S_{med}, \qquad (4)$$

$$E_{mpf} = N_{av}/S_{med}, \qquad (5)$$

$$E_{cpf} = N_{ab}/S_{max}, \qquad (6)$$

where E_{spf} - is *safe* population fecundity;
E_{mpf} - is minimal population fecundity;
E_{cpf} - is critical population fecundity;
N_{ab} - is the strong year-class abundance at age 5;
N_{av} - is the medium year-class abundance at age 5;
S_{med} - is the medium survival index;
S_{max} - is the maximal survival index.

Water temperature was taken along the standard hydrological section 8A across the Southern Labrador shelf and slope (Fig. 1). The hydrological observations realized there by PINRO regularly in November. The temperature observations were collated with the strength of the year-classes and the survival rates.

Simple and multiple regression analyses were made to reveal correlation between spawning stock biomass, population fecundity, strength of the year-classes, survival rate and water temperature.

RESULTS

Males of Greenland halibut become first mature at the age of 5-7 years and the length of 46-47 cm, whereas the respective figures in females are 6-7 and 52-53. Age at 100 per cent maturity can vary in males depending on the area of observations. A 100 per cent maturity was recorded at the age of 12-13 years and 70-73 cm and 16-17 years and 92-95 cm in males and females, respectively (Table 2). In Division 2J and 3K immature females were occasionally found. Mature individuals were not abundant along the shelf and continental slope of the Southern Labrador.

Scarcity of mature fish along the shelf continental and slope off the Baffin Island and the Western Greenland can probably be the result of the northward migration (Chumakov, 1975; Chumakov & Serebryakov, 1982).

Significant variations were found in the total spawning stock biomass, fecundity and abundance of 5-year olds in the Greenland-Canadian population throughout the entire period of observations (Table 3).

The highest and lowest abundance of spawning stock was recorded in 1974-1979 and in 1969-1970 respectively. The population fecundity varied from 844.2×10^9 eggs in 1969 to 2446.6×10^9 in 1976.

However the survival rate in the poor year-classes of 1969 and 1970 was found to be higher than that in the rich year-class of 1976.

Survival rate coefficients as estimated in the year-classes of 1969-1983 showed more significant fluctuations than the population fecundity. There was a 5-fold difference between the maximum (1982) and minimum (1977) survival rates.

Survival rate can serve as integrated indicator of ambient conditions during early life of fish which implies both biotic and abiotic factors.

The water temperature of various horizons is often used as an abiotic environment indicator.

The comparison of the survival coefficient to the water temperature 4 different horizons of section 8A revealed the inverse correlation. The higher temperature at the horizon of 50-200 in the year of a generation development corresponds the lower survival rate.

Regression analysis obtained correlation coefficient of a good significance ($r = -0{,}754$; $N = 15$; $P = 0{,}05$) between survival rate and water temperature at 50-200 in horizon of part "A" section 8A in November. That correlation coefficient has made it possible to elaborate a simple model to forecast a survival index (S) and then the strength of the year-class (R) if the population fecundity (PF) and temperature are estimated:

$$S = (-0.02107 \cdot PF - 12.98633 \cdot T + 115.48901) \cdot 10^{-4};$$

$$R = S \cdot PF \cdot 10^{-2}.$$

This regression equation could be used to predict recruitment abundance in advance of 5 years. Thus the 1984 year class can be estimated as a strong one, the 1985-87 year-classes as medium ones, and the 1988 year class as a poor one (Table 3).

Three levels of the population fecundity required to produce an abundant year class under favourable and moderate survival conditions during early life as well as a critical level of the population fecundity where calculated for the Canadian-Greenland population. These three levels of the population fecundity are as follows:

safe population fecundity estimated as high as 2323×10^9 eggs;

minimal safe - 1512×10^9 eggs;

critical population fecundity was calculated equal to 1226×10^9 eggs.

DISCUSSION

Population fecundity of the critical level was observed in 1969 and 1970, when the poor year-classes emerged under moderate survival index. In all the other cases the Greenland halibut population fecundity was either close or well above the critical level That equilibrium state of a reproduction capacity induced the natural fluctuations of the year-classes abundance.

There is a slight inverse correlation between the population fecundity and the strength of the year class ($r = -0.425$). Much nigher correlation was obtained between the population fecundity and the survival index ($r = -0.889$), that reflected probably the density dependant component of the survival during early life. The other component of survival affected by the abiotic ambient conditions could be obtained from correlation between survival index and such an indicator of environmental conditions as water temperature.

The Greenland halibut spawns in the ares of southern part of Greenland-Canadian threshold at the depth of 1000-1500 meters with temperature 3,2-3,4 °C in January-April. Eggs development takes place mainly in deep water layer of the continental slope (Jensen, 1935; Smidt, 1969; Templeman, 1970). The Greenland halibut larvae ascend to the upper surface layers in June-July where from are dispersed with currents to the north along the West Greenland coast and to the West to Baffin Island and Labrador.

The maximal number of Greenland halibut larvae is observed in the upper 50 meter layer (Smidt, 1969). The young halibut at age 3-4 years distributed mainly at the depths of 200-350 m over the continental shelf water practically everywhere along West Greenland, Baffin Island, Labrador and on the Grand Bank of Newfoundland (Bowering & Chumakov, 1987: Chumakov et al., 1988).

The temperature at the depth of 50-200 meters on the hydrological section across the Hamilton bank correlated significantly with the survival index and therefore could be used as one of the predictor of the strength of the year-class development.

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Table 1

Halibut catches taken by all countries
in the Northwest Atlantic (0+1 and 2+3KL), t
(according to NAFO Statistical Bulletin)

Year	USSR	Canada	FRG	Greenland	GDR	Poland	Faeroes	Portugal	Others	Total
I965	48I	8082	-	3045	-	942	I8	-	2	I2570
I966	242	I6209	423	2573	I355	III4	2	-	2	2I920
I967	4287	I6604	300	I834	I650	3296	-	-	-	2797I
I968	I02I7	I3322	I37	I568	4259	5806	-	-	-	35309
I969	I0204	II553	270	I477	I0022	5407	I	-	96	39030
I970	8043	I0706	26	I2I2	9I58	8266	-	-	875	38286
I97I	I0937	9408	I6	II59	I02I	5234	38	-	II77	28990
I972	I9825	8952	2I4	2950	965	7I2I	I4I2	-	2280	437I9
I973	I2783	6840	772	4632	2435	9060	950	207	823	38502
I974	I9I6I	5745	5I7	4060	3302	7I05	4	I93	I293	4I380
I975	29669	7807	646	3724	208I	8447	825	272	I58	53629
I976	I7733	9306	I020	3546	I672	5942	95I	I68	49	40387
I977	8664	I7967	I345	6II0	2528	5998	I357	II9	502	44590
I978	5632	24692	5987	5985	I636	52I5	820	-	2I8	50I85
I979	2948	29940	I2893	5273	I78	I8I3	50	38	I24	53257
I980	I784	3I9I0	I229	5356	3I6	203	60	2I	35	409I4
I98I	695I	24I25	I0	5755	I350	I806	I70	I6	60	40243
I982	5009	I9248	66	5397	2487	IIII	337	I8I8	22	35495
I983	4709	I7II3	I6	4I36	2587	5258	774	I9I8	I5	36526
I984	549	I7283	24	6509	2498	943	370	26I2	IIII	32I8I
I985	328	II979	482	8956	2I85	460	7I8	2938	434	2878I
I986	802	8076	I6	8705	I867	I77	69I	3I07	744	24I85
I987	4092	I4448	-	8634	3266	I00I	2I58	I390	3I4I	38I30

Table 2

Relative number of mature Greenland halibut by age on the continental slope in SA 0+1 and Divs. 2GH and 2J (by age samples for 1970-1988), %

Age	0+1		2GH		2J	
	Male	Female	Male	Female	Male	Female
4	0.0	0.0	0.0	0.0	0.0	0.0
5	I3.8	0.0	0.0	0.0	0.0	0.0
6	44.5	6.I	2.5	0.0	0.0	0.0
7	64.2	7.7	23.2	I.7	4.3	0.0
8	80.5	II.7	34.I	2.I	8.I	2.2
9	88.6	I8.2	72.8	7.6	I0.I	5.5
I0	94.6	35.I	82.I	I4.5	36.4	I2.5
II	99.I	52.0	90.2	25.0	40.0	I8.0
I2	I00.0	66.2	94.2	4I.8	50.0	30.0
I3	I00.0	78.4	98.4	59.8	80.2	40.I
I4	I00.0	88.3	I00.0	69.8	I00.0	55.0
I5	I00.0	95.0	I00.0	8I.5	I00.0	70.I
I6	I00.0	I00.0	I00.0	90.6	I00.0	83.2
I7	-	-	-	95.0	-	90.5
I8	-	-	-	I00.0	-	98.0
I9	-	-	-	I00.0	-	I00.0
Total	2448	II85	2948	2I35	2680	2502

Table 3

Spawning stock biomass (SSB), population fecundity (PF), yearclass strength (at age of 5 years) and survival (S) to 5 years (S) of Greenland halibut, 1969-1988

Year	SSB, thou.t	$PF \times 10^9$, eggs	Number of 5-year-olds $\times 10^6$	Yearclass strength^{x}	Survival rate to 5 years, %	Survival conditions^{xx}
1969	90.3	844.2	39.2	P	0.0046	A
1970	94.5	883.4	48.6	P	0.0055	A
1971	129.6	1211.6	55.3	m	0.0046	A
1972	170.1	1590.0	62.3	m	0.0039	A
1973	184.4	1724.0	63.7	m	0.0037	A
1974	230.2	2057.9	44.1	P	0.0021	U
1975	232.6	2147.7	48.5	P	0.0022	U
1976	221.3	2426.1	44.8	P	0.0018	U
1977	225.6	2446.6	36.0	P	0.0015	U
1978	221.4	2339.1	44.5	P	0.0019	U
1979	209.5	2178.1	50.4	m	0.0023	U
1980	153.6	1676.1	54.3	m	0.0032	U
1981	143.8	1480.3	65.6	St	0.0044	A
1982	124.7	1231.8	88.3	St	0.0072	F
1983	133.9	1157.9	68.1	St	0.0059	F
1984	134.6	1205.1	75.9^{xxx}	St	0.0063^{xxx}	F
1985	148.9	1302.2	54.7^{xxx}	m	0.0042^{xxx}	A
1986	142.1	1666.4	60.1^{xx}	m	0.0044^{xxx}	A
1987	167.0	1492.6	62.7^{xx}	m	0.0042^{xxx}	A
1988	185.1	1686.4	59.0^{xx}	m	0.0035^{xxx}	A

^{x} P - poor $< 50 \times 10^6$, number of fish;
m - medium - $(50\text{-}65) \times 10^6$ number of fish;
St - strong - $> 65 \times 10^6$ number of fish;

^{xx} F - Favourable > 0.0057;
A - Average - 0.0033-0.0057;
U - Unfavourable < 0.0033;

^{xxx} Forecast.

Table 4

Correlation factors (r) between the Greenland halibut yearclass strength at age of 5 years (R), survival rate (S) and water temperature in the layers of 0-50, 50-200 and 0-200 m in the parts A and C of the hydrographic section 8A in November 1969-1988

	Part A			Part C		
	0-50	50-200	0-200	0-50	50-200	0-200
Survival to 5 Years, %	-0.258	-0.522	-0.543	-0.464	-0.754	-0.676
Number of fish aged 5 years	-0.175	-0.533	-0.465	-0.457	-0.717	-0.655

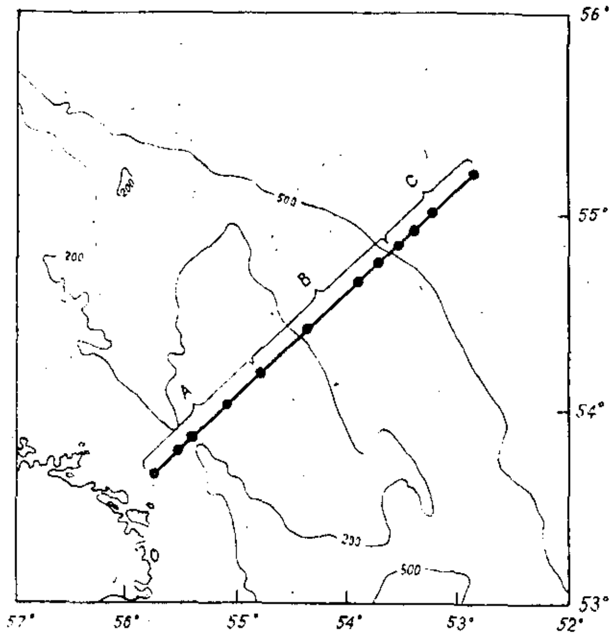

Fig.1. The 8A hydrographic section location

Site "A" positions
53°40'N 55°44'W - 54°11'N 54°47'W

Site "B" positions
54°26'N 54°19'W - 54°49'8"N 53°32'W

Site "C" positions
54°55'N 53°22'5"W - 55°13'N 52°52'W

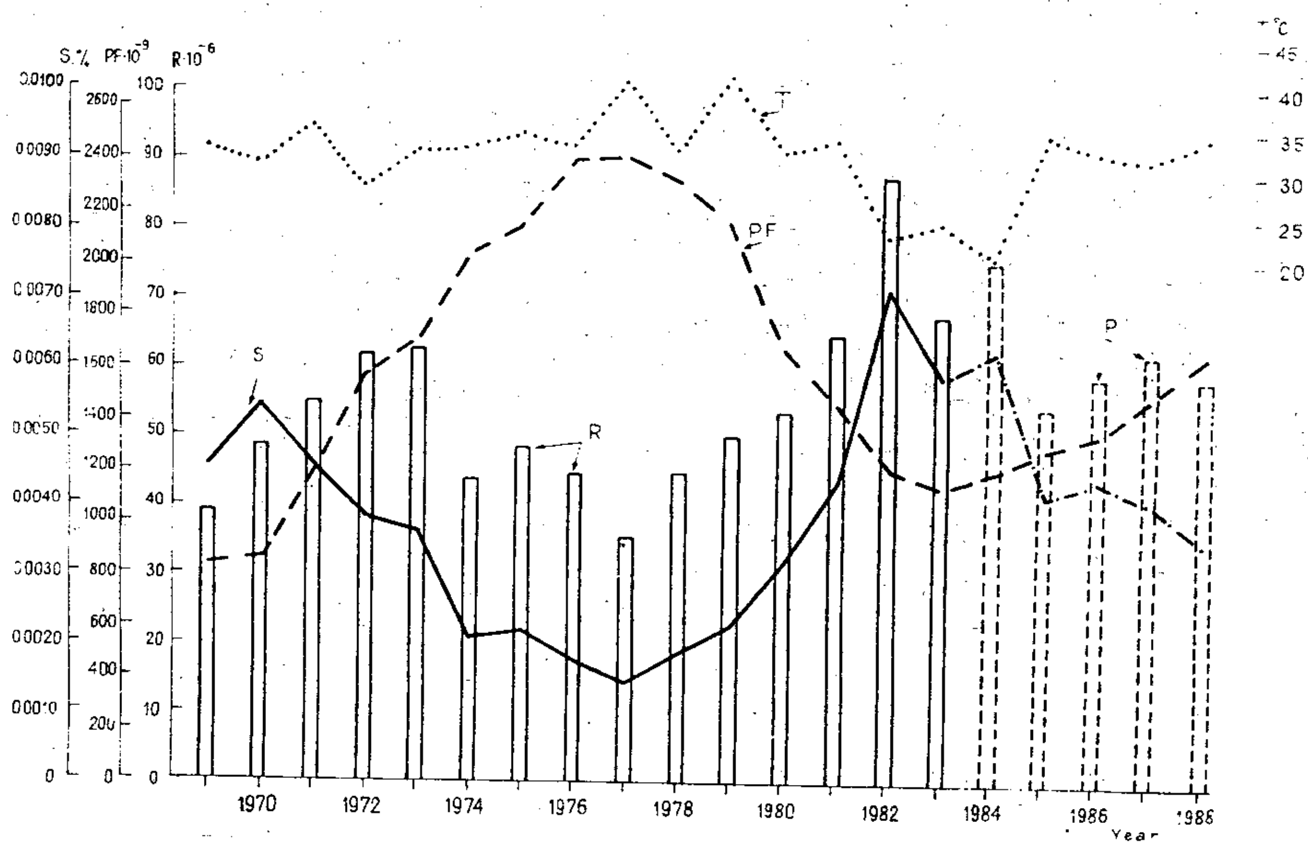

Fig. 2. Population fecundity (PF), abundance of year-classes at age 5 (R), ratios of survival of Greenland halibut at age less than 5 years (S) and water temperature (T) in the 50-200 m layer at site "C" of the 8A oceanographic section in November 1969-1988. (P - provisional figures)