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The Relationship between Water Temperature and Distribution of Greenland Halibut on the Flemish Cap in 1988-2002

by

T.M. Igashov, S.E. Golovanov, and S.E. Lobodenko

Polar Research Institute of Marine Fisheries and Oceanography (PINRO)
6 Knipovich Street 183763 Murmansk Russia
e-mail: inter@pinro.ru; taras@pinro.ru

Abstract

The present paper investigates a question of the relationship between dynamics of Greenland halibut catches and fluctuations in water temperature at different depths in the Flemish Cap area. Data obtained in the result of international research programs are used in the analysis.

Mean catches of Greenland halibut taken using the sampling trawl (individuals/trawl and kg/trawl) during summer trawl surveys by European Union are compared with data on the near-bottom water temperature. Their variability is estimated, correlation analysis of water temperature and catches by four depth intervals is made and significance of the relationships revealed is determined.

Results from the investigations bear out the existence of statistically significant relationship between fluctuations in the near-bottom water temperature and variations in the Greenland halibut catches in the Flemish Cap area. This relationship is the most pronounced in the depth range of 100 to 200 f. Water temperature have an effect on the Greenland halibut distribution on the Flemish Cap and thereby on the results of instrumental surveys.

Introduction

Many researchers examined changes in the behaviour of fish in relation to water temperature fluctuations. Temperature in the near-bottom layer, at which Greenland halibut occurred, varied from minus 1.5° to 8°C (Milinsky, 1944; Templeman, 1965; Shuntov, 1965; Bowering, 1984). On evidence from Bowering (1984) the largest catches of Greenland halibut were taken at temperature of 3-5°C. Investigations conducted by PINRO in 1970-80's in the area of the Baffin Island showed that increase of water temperature in this area led to decrease in density of the Greenland halibut concentrations on the continental slope and reduction in catch rates (Chumakov and Borovkov, 1986; Chumakov et al., 1987, 1992; Chumakov and Savvatimsky, 1987; Chumakov and Bowering, 1988). Thus, there are reasons to regard temperature as one of the factors influencing the formation of concentrations, catches and distribution of Greenland halibut.

EU surveys in the Flemish Cap area demonstrated more than twofold gradual decrease of CPUE in the period from 1998 to 2003 (Casas, 2004). Indices of abundance and biomass could have decreased because of the decline in the Greenland halibut stock. However, there is no reason to neglect the effect of environmental factors on fish distribution. The probability of such an effect grow considering the fact that oceanographic conditions in the bank area are formed in the result of interaction between the cold Labrador Current and warm North Atlantic Current. Therefore, temperature fluctuations and associated distribution of fish can be affected by currents. As the conditions change, concentrations can shift to areas that have not been covered by the survey. This may entail a reduction of the instrumental survey indices.

The objective of this paper is to reveal the relationship between distribution of Greenland halibut and water temperature in the Flemish Cap area. To attain the objective, the following tasks were identified:

1. To study temperature dynamics in the near-bottom layer by depth intervals based on Russian and available international oceanographic databases on the Flemish Cap for the period 1988-2002.
2. To analyze variations in mean catches of the Greenland halibut by the sampling trawl (individuals/tow and kg/tow) by depth in the Flemish Cap area using EC trawl surveys data for the period 1988-2002.
3. Based on the analysis, to estimate the relationship between Greenland halibut distribution and water temperature.

Materials and Methods

<u>Area stratification</u>. In the method currently used in the bottom trawl surveys, stratification of Div.3M includes the Flemish Cap with depth intervals as follows (Doubleday, 1981; Bishop, 1994):

Depth interval, fathom (f)	*70-80*	*81-100*	*101-140*	*141-200*	*201-300*	*301-400*	*401-500*	*501-600*	*601-700*	*701-800*
Depth interval, m	*127-146*	*147-182*	*183-255*	*256-364*	*365-546*	*547-728*	*729-910*	*911-1092*	*1093-1274*	*1275-1456*

<u>Data on temperature.</u> To conduct the research, information on near-bottom water temperature in the Flemish Cap area in spring and summer (April-July) for 1988-2002 was used. The source of information were databases as follows (Table 1):

1. Materials from Russian oceanographic surveys.
2. Information from AZMP (Atlantic Zone Monitoring Program, http://www.meds-sdmn.dfo-mpo.gc.ca) of the Department of Fisheries and Oceans of Canada – DFO.
3. Databases of the interactive World Ocean Atlas, 2001, published by The Ocean Climate Laboratory National Oceanographic Data Center, Silver Spring, MD 20910 with the support of The National Oceanic and Atmospheric Administration and U.S. Department of Commerce.

Data on the near-bottom temperature were grouped by depth intervals according to Div. 3M stratification used in NAFO. For each depth range, mean water temperature in the near-bottom layer in spring and summer was calculated. Since data for 1997-1998 were lacking, mean temperature in the near-bottom layer for the above two years was estimated by interpolation between 1996 and 1999.

<u>Research survey data.</u> The paper uses data from annual EU bottom trawl surveys in Div. 3M for the period 1988-2002 (Vazques, 1989-1997, 1999-2002; Vazques et. al., 1998; Saborido-Rey, Vazques, 2003; Casas, 2004). All surveys were conducted using the standard stratified-random method applied in NAFO (Doubleday, 1981; Vazques, 1989; Bishop, 1994).

The surveys are carried out from the first ten days of July to the first ten days of August and last for about two weeks. A grid of trawl stations covers the depth range of 70 to 400 f. Most of results from these surveys were earlier published in papers to the NAFO Scientific Council Meeting June. Based on the data available, mean catches by the sampling trawl were calculated by depth intervals (individuals/trawl, kg/trawl).

<u>Statistical processing of data.</u> The relationship between near-bottom temperature and estimates of mean catches by the depth intervals was examined using correlation analysis. Closeness of the relationship was estimated using the Student's criterion from the table of significant correlation coefficients. According to the above criterion, significant correlation coefficient for the sample embracing 15 years corresponds to 0.51. Having estimated how close the relationship was, the significance of the relationship was tested using the bootstrap correlation coefficients.

Results and Discussion

Surveys conducted by EC on the Flemish Cap showed that Greenland halibut did not occur at depth less than 80 f. Juveniles were found in catches by the sampling trawl in the depth range of 80 to 100 f, but quite rare, and not in each survey. Therefore, we did not examine these two depth intervals.

The largest variability in the near-bottom temperature was observed in the depth range of 100-140 f and 140-200 f, where it varied from 2.9° to 4.4°C (Table 2). The lowest temperature in the first above mentioned depth range was registered in 1990, while in the second depth range it was recorded in 1990 and 1995. The highest values of the near-bottom temperature were observed in 1999 in both depth intervals. Dynamics of year-to-year variability in the water temperature near the bottom within these depth intervals showed a high similarity (Figure 1).

In the depths of 200 to 400 f, temperature fluctuations were not so great, ranging between 3.2 and 3.7°C. The lowest temperature in the 200-300 f depth interval was observed in 1993, while within 300-400 f layer it occurred in 1993 and 1996. The highest temperature in the depth range of 200-300 f was noted in 1988, 1999, 2001 and 2002. At the depths of 300-400 f, temperature was the highest in 2002. Year-to-year temperature dynamics in the two last depth intervals showed some similarity but not so high as noted for the depths of 100-200 f (Figure 1).

Variability of the near-bottom temperature decreased with depth (Table 2). The widest year-to-year fluctuations in temperature were registered for 100 -140 and 140-200 f depth intervals with variation coefficients being 11.1 and 7.0%, respectively. In the depth range of 200-300 and 300-400 f, the near-bottom temperature did not experience great variations; coefficients of variation were not high, 2.6 and 3.4%, respectively.

Variability in the mean values of catches went down with depth (Table 2). In the depth range of 100 to 140 f, the lowest catches in numbers and weight were taken in 1990 and 1994, while the largest they were in 1999 (Table 3, Figures 1 and 2). Within 140-200 f depth range, the lowest catches were observed in 1990, while the largest catches in numbers were taken in 1988 and in weight in 1999.

In the depths of 200-300 f, the lowest abundance was observed in 1989 and the lowest biomass was in the period 1988-1990. The highest abundance and biomass were recorded in 1998. In the depths of 300-400 f, minimum catches were taken in 1989, while the maximum ones in 1998.

As for the depth range of 100 to 200 f, coincidence of the years, when extremum values of temperatures and catches concurred (Table 3). Comparison of catches and water temperature permits us to infer that in these depths in the coldest years, indices of abundance and biomass are low. With the increase of water temperature, they grow and reach their maximum values. For the depths of 200-400 f such a relationship is not typical.

Significant values of correlation coefficients from 0.51 to 0.75 supporting the existence of the relationship between near-bottom temperature and catches were obtained from the depths of 100-300 f (Table 4). For the depth range of 300 to 400 f, the correlation was weak and such a relationship was not confirmed (R from 0.32 to 0.35).

The most significant relationship (R from 0.71 to 0.74) both in numbers and weight was revealed only for the depths between 100 and 140 f. In the depth range of 140 to 200 f, the significance of the relationship between catches and temperature was verified only for catch in numbers (R=0.75). Checking of the revealed relationship using the bootstrap method showed that all estimates were within the interval of 0.4-1.0 that supported the correlation of this relationship.

It was found that the highest significance of the relationship with correlation coefficients ranging between 0.71 and 0.75 was characteristic of parameters with the highest variation coefficients from 88.0 to 107.4% (Tables 2 and 4).

For the depth range of 300-400 f, such a relationship was not verified. Taking into account that variations in water temperature within this depth range are minor it may be suggested that small fluctuations in water temperature at these depths do not affect strongly the density of concentrations.

Conclusion

Results from the research based on the analysis of data for 15 years support the assumption that there is the statistically significant relationship between fluctuations of near-bottom temperature and variations in Greenland halibut catches in the Flemish Cap area. This relationship is the most prominent in the depth range between 100 and 200 f.

Water temperature has an effect on the Greenland halibut distribution in the Flemish Cap area, and thus, on the results from instrumental surveys.

It is worth noting that so far data series is not complete enough. First of all, it refers to data on the near-bottom temperature. In this relation, the results obtained should be considered provisional.

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Table 1. Sources of oceanographic data used to estimate mean near-bottom water temperature.

Year	Data source					Note
	Russian oceanographic surveys			World Ocean Atlas 2001	AZMP	
	name of vessel	side number	cruise number			
1988	Persey-III	BMRT-1202	40			
1989	Persey-III	BMRT-1202	43			
1990	Persey-III	BMRT-1202	48			
1991	Vilnyus	PST-1362	35	+		
1992	Kapitan Shaitanov	PST-1366	27			
1993	Vilnyus	PST-1362	43	+		
1994				+		
1995				+		
1996				+		
1997						Interpolation on
1998						estimates of 1996 and 1999
1999					+	
2000					+	
2001	Mozdok	PST-1360	1		+	
2002	Remoyfjord	SRTMK-1466	1		+	

Table 2. Variability by depth in mean the near-bottom water temperature and in mean catches taken by the sampling trawl. Flemish Cap, 1988-2002.

Depth range, f	Near-bottom water temperature, °C			Coefficient of variation of mean values, %		
	minimum	maximum	max-min	near-bottom water temperature	catches	
					ind./tow	kg/ tow
100-140	2.9	4.4	1.5	11,1	100,4	107,8
140-200	3.3	4.2	0.9	7,0	79,0	88,0
200-300	3.4	3.7	0.3	2,6	73,1	60,3
300-400	3.2	3.6	0.4	3,4	36,8	26,1

Table 3. Extremum values of mean near-bottom temperature and mean catches taken by the sampling trawl, in numbers and weight, given by depth. Flemish Cap, 1988-2002.

Depth range, f	**Minimum**		**Maximum**	
	Near-bottom temperature			
	t, °C	year	t, °C	year
100-140	2.9	**1990**	4.4	**1999**
140-200	3.3	**1990**, 1995	4.2	**1999**
200-300	3.4	1993	3.7	1988, 1999, 2001, 2002
300-400	3.2	1993, 1996	3.6	2002
	Mean catch in numbers			
	ind/trawl	year	in/трал	year
100-140	0.2	**1990**, 1994	17.2	**1999**
140-200	0.9	**1990**	58.4	1998
200-300	6.5	1989	84.2	1998
300-400	18.2	1989	101.0	1998
	Mean catch in weight			
	kg/trawl	year	kg/trawl	year
100-140	⩽0.1	**1990**, 1994	7.5	**1999**
140-200	0.9	**1990**	27.6	**1999**
200-300	7.4-7.8	1988-1990	54.0	1998
300-400	22.5	1989	66.8	1998

Note: Underlined are years when minimum and maximum values of mean catches concurred with years of temperature extremums.

TABLE 4. Correlation coefficients of mean catches by the sampling trawl, in numbers and weight, and mean values of water temperature in the near-bottom layer, by depth. Flemish Cap, 1988-2002.

Correlation coefficient	**Correlation coefficients by depth**			
	100-140 f	**140-200 f**	**200-300 f**	**300-400 f**
Correlation coefficient in numbers	***0,74***	**0,53**	**0,51**	0,32
Correlation coefficient in weight	***0,71***	***0,75***	**0,52**	0,35

Note:

1. Underlined are correlation coefficients of significant values.
2. The highest correlation coefficients, which significance was confirmed after checking by the bootstrap method are typed in italic

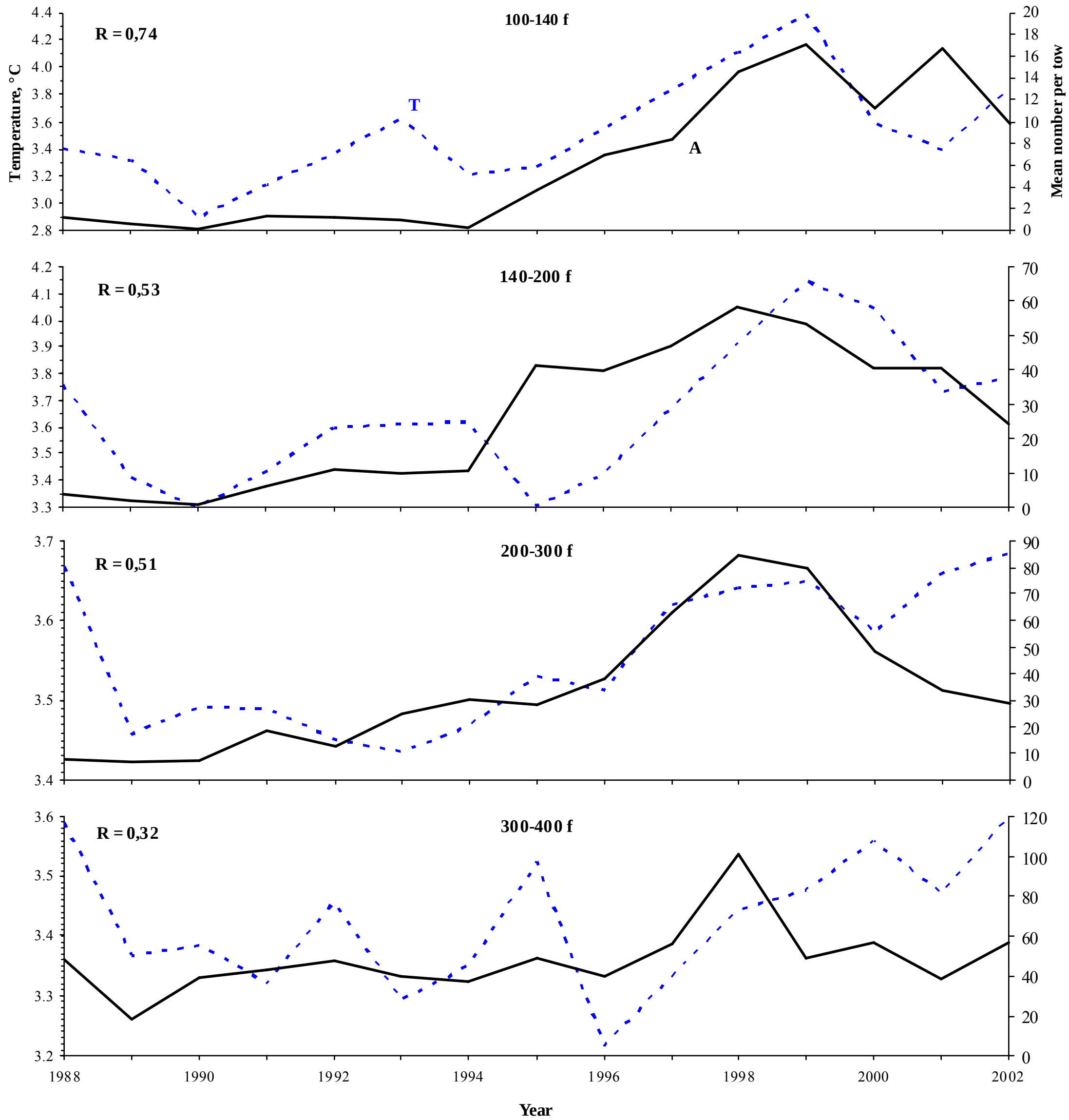

Figure. 1. Dynamics of mean water temperature in the near-bottom layer (T) and mean catches by sampling trawl in numbers (A) by four depth intervals. Flemish Cap, 1988-2002.

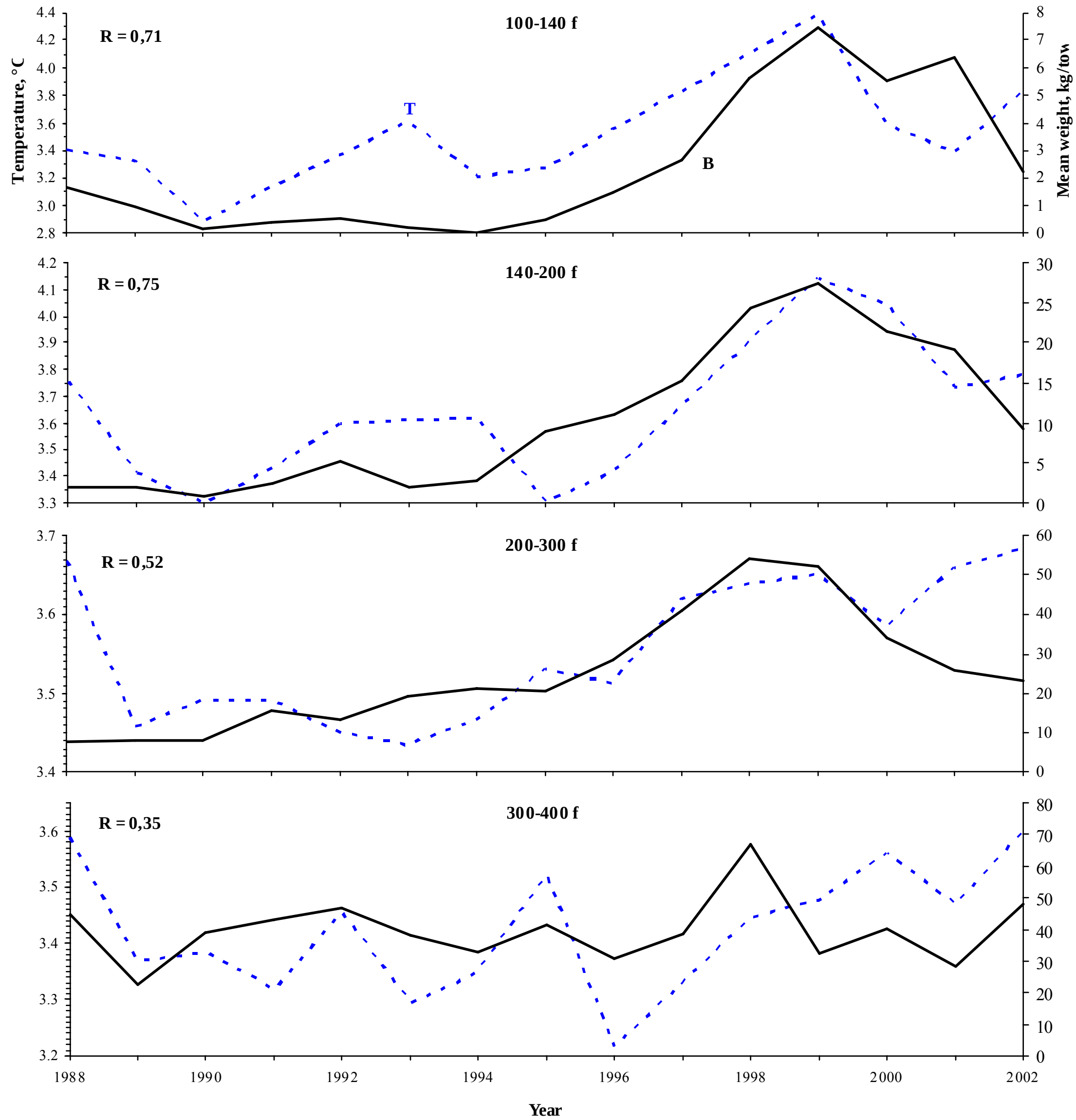

Figure. 2. Dynamics of mean water temperature in the near-bottom layer (T) and mean catches by sampling trawl in weight (B) by four depth intervals. Flemish Cap, 1988-2002.