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Fluctuations in the abundance of cod and some other commercial fishes on the Flemish Cap Bank

by

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Flemish Cap Bank is an isolated underwater elevation east of the Grand Newfoundland Bank. A deep trench, which is usually called "the way of icebergs", is stretched between them in a meridional direction. The area of the Flemish Cap Bank, outlined by 1000 m isobath, is equal to 48960 km^2. The minimal depth is 126 m.
The southern slope of the bank, cut by canyons, is steepest; steepness of this slope reaches 10–15° in some places.
The central part of the bank, with depth less than 170 m, is covered by sand with pebbles, gravel and shells; crabs (Hyas), bivalves (Pecten), ascidians dominate among bottom animals.
Slopes of the bank at depths exceeding 300 m are covered by sandy silt; coralls are abundant there, which sometimes present difficulties for the fishery by the bottom trawl. Coralls are especially abundant on the eastern and southern slopes of the bank.

As isolated elevation of sea bottom the Flemish Cap Bank was known long ago and it received its name ("Flemish Cap") for distinctive outlines. When the scheme of the regioning of the North-West Atlantic was in the process of development, the Flemish Cap Bank received index "3M" in the ICNAF system. The area covered by Division "3M" includes in addition to Flemish Cap Bank the adjacent vast spaces of the open ocean with depths down to 4000 m and more; the total area of Division 3M is about 408450 km^2.

Prior to 1956 no fishery was practically conducted on the Flemish

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Cap Bank (Table 1). In the summer of 1956 a Soviet big refrigerating trawler "Sverdlovsk" made a number of trawlings on the south-western slope of the bank in the result of which dense concentrations of beaked redfish, Sebastes mentella Travin,(with a small amount of golden redfish, S.marinus L., halibut, Hippoglossus hippoglossus (L.), cod and other valuable commercial fishes) were found at the depth of 400-550 m.

In the autumn of 1956 a small group of Soviet big refrigerating vessels started to operate there. In the spring of 1957 concentrations of spawning cod were recorded on the south-western slope of the bank. Since that time beaked redfish and cod became the main objects for the trawl fishery and regular fishery investigations on the Flemish Cap Bank.

Considerable changes in the total yield of fish and catch per fishing effort unit showed up vividly for the past years. The studying and predicting of such changes is important not only because the efficiency of the fleet operation on the Flemish Cap Bank could be increased but because it will foster solution of a number of general problems of the commercial sea fishery.

Flemish Cap Bank is an area extremely suitable for studying the influence of natural factors and fishery on the dynamics of of the abundance of fishes. Populations completely isolated from populations of the adjacent areas inhabit the Flemish Cap Bank. Consequently, neither their emigration nor migration can influence on the abundance of fishes on the Flemish Cap Bank. In other words, a closed biological system exists on the Flemish Cap Bank.

For example, tagging of cod proved that these fish never migrate from the Flemish Cap Bank to the adjacent Grand Newfoundland Bank and vice versa. Specimens released on the Flemish Cap Bank were recaptured only within its limits. This is confirmed by the data in Table 2. Isolation of the cod population of the Flemish Cap Bank is confirmed by the results of tagging as well, which were conducted by ichthyologists of Canada (Templeman,1974) and also by studying the parasite fauna (Postolaky, 1962; Templeman and Fleming, 1963), by comparing the number of vertebrae (Postolaky, 1962; Templeman, 1962), by data on the spawning and drift of eggs (Serebryakov, 1967).

There is a small population of haddock on the Flemish Cap Bank, which is also completely isolated from populations of other divisions of the Newfoundland Subarea, that was proved by V.P.Shestov (1970) after the analysis of the number of vertebrae. Judging by distribution of parasites of beaked redfish "... stock, which is mostly isolated, inhabit the Flemish Cap Bank" (Yanulov, 1962). There are reasons to suggest that American plaice and the rest of the commercial fishes form isolated populations on the Flemish Cap Bank.

The whole of the area of the bank is accessible for the fishery and observations the year throughout. Only in exceptionally rare cases (for example in the spring of 1973) the bank was partly covered by ice but not for long.

Thus, very favourable requisites exist for the use of the Flemish Cap Bank as natural ground for the fishery investigations and experiments. These requisites are the following:

a) Isolation of populations of commercial fishes and their relatively low abundance (compared with populations occupying vast areas on the continental shelf),

b) Fairly recent beginning of a regular fishery, practically unexploited stocks prior to 1956,

c) Accessibility of all the area of the bank for the fishery and investigations the year throughout.

At one time attention was drawn to these events by the author of the present report (Konstantinov, 1970, 1970 a). It was noted that an intensive trawl fishery for the spawning cod had affected their abundance and age composition; it was recommended to limit the annual yield. At present limitation of catches and quota fishing has become the practice of the fishery in the ICNAF Area.

However, growing intensity of the fishery can reduce the average catch per trawling hour only at one important condition: approximately constant annual recruitment to the fishing stock. Similarly, reduction in the intensity of the fishery can increase the fishing stock and average catch per fishing effort unit only in the case of stability of the annual recruitment. If sharp fluctuations in the strength of year classes are characteristic of the

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exploited stock, a regular relationship between intensity of the fishery and the stock state does not show up usually. Templeman and Gulland (1965) were absolutely right when they wrote: "In most fisheries, therefore, where there fluctuations in recruitment or other factors, independent of the amount of fishing it is difficult to predict what the absolute magnitude of the catch would be with any pattern of fishing, or to say that the catch in any particular year following some regulation (i.e. an increase of mesh size) will necessarily be greater than before regulation. What is possible is to determine that catches following some regulation will be greater than they would have been if the regulation had not been introduced".

Apparently in 1957-1967 the fishing stock of cod on the Flemish Cap Bank was recruited by year classes approximately equal by their strength. Therefore the growing intensity of the trawl fishery gave rise to the tendency for a decrease in the abundance and biomass of the stock. In susequent years, however, some very strong year classes originated: this was shown by the survey on determining the young cod abundance that was regularly conducted by Soviet ichthyologists in the Newfoundland Subarea. Most complete corrected data on determining the young abundance are available in "USSR Research Report, 1975" (Konstantinov and Noskov, 1976). Data relating to the Flemish Cap Bank cod are shown in Table 3. It is easily seen that the 1968 and especially 1973 and 1974 year classes are characterised by very high abundance. The last two year classes have just entered the fishing stock. The 1968 year class formely increased the stocks and yield of cod.

In the Table 4 the indices of the young cod abundance (which was determined when fishes are two years old) were correlated with the total yield of cod by all countries in that calendar year when cod of the given year class reached the age of 4 years and entered the fishing stock. It is readily seen that a close correlation (correlation coefficient $r = 0.57$) exists between the two compared values. It can be expressed by the equation

$$Y_i = 0.16\, n_{i-2} + 25.5 \qquad (1)$$

where

i - calendar year,

n - average number of the two-year-old cod caught per trawling hour by the trawl used during the survey,

Y - annual catch of cod by all countries (thousand tons)

When using equation (1) one can predict a probable yield of cod on the Flemish Cap Bank two years in advance. Thus, in 1977 the yield is to reach rather a high level:

$$Y_{1977} = 0.16\ n_{1975} + 25.5 = 0.16 \quad 350 + 25.5 = 81.5 \text{ thousand tons}$$

Needless to say, the possibility of such a yield caused by the sharply increasing stocks of cod will be realized only in the case of a corresponding increase of the limit.

Thus, under sharply pronounced fluctuations it is precisely these events that determine the abundance of any population exceeding the influence of all the rest of factors, including the fishery. The opinion of a decisive role of fluctuations was for the first time expressed by Hjort (1914, 1926) and now gains new and new corroborations. Thus, Pinhorn and Wells (1970) write about the cod of the southern part of the Grand Newfoundland Bank (Division 3NO) : "In this area recruitment can be quite variable, the survival rate of cod in one year being many times greater or lesser than in an adjacent year. Maximum sustained yield as estimated by Assessments Subcommittee of ICNAF in 1968 was 75 thousand tons and as estimated in this paper for 1963-66 data was 92-102 thousand tons. However, in 1967 the catch increased drastically to 220000 tons and in 1968 was still 160000 tons compared with about 80000 tons in 1963-66. Associated with this was a sharp increase in effort. This resulted from increased effort on the exceptionally good 1964 year class of cod when these fish were 3- and 4-year-old, respectively".

This case has been considered in more detail by the author of the present paper (Konstantinov, 1976).

A similar sharp increment of stocks and catch of cod, like that observed in Division 3NO in 1967-1968, will take place on the Flemish Cap Bank in 1977-1978. In both cases the increment is due to analogous causes.

In the previous papers (Konstantinov, 1971, 1972) the author has expressed an opinion that in the southern part of the Newfoundland Subarea the reproduction of cod is favoured by a decrease in water temperature (compared with long-term mean). In essence, the Grand Newfoundland Bank is the southern boundary of the fishery area of cod. Despite the fact that cod are met with further south - as far as the coast of North Carolina (Wise, 1958) - this fish does not serve as the primary object for the fishery there. Therefore, an anomalous cooling of water masses in the southern Grand Bank approaches environmental conditions of cod to optimum ones, i.e. to those typical of the central part of the area of distribution.

The foregoing refers both to the Flemish Cap Bank cod (Konstantinov, 1975) and to cod of North Sea (Dickson, Pope, Holden, 1974; Daan, 1975; Southward, Butler, Pennycuik, 1975). Thus, cooling of water masses in the North Sea in 1950-1970 sharply increased stocks and catches of cod (as well as haddock and other arcto-boreal fishes).

The strength of herring year classes off Alaska is adversely affected by decreased (compared with long-term mean) water temperature but the latter favours origin of rich year classes off British Columbia (Tester, 1948).

Laboratory experiments showed that at a comparatively low water temperature (about 2°C), the mortality of developing eggs of cod is minimal and the length of hatching larvae is maximal (Laurence, Rogers, 1976).

Water temperatures on standard hydrological section 4-A, somewhat further south-west of the Flemish Cap Bank, as well as strength of the 1968-1975 year classes of cod (according to data on determining the young abundance at the age of one year) are shown in Table 5. Relationship between the compared indices can be expressed by the following equation:

$$N_i = -65.6\ t_{i-1} + 166.6 \qquad (2)$$

where

i - calendar year,
t - water temperature (in °C) on hydrological section 4-A in May,
N - average number of one-year-old cod caught on the Flemish Cap Bank per trawling hour by the trawl used during investigations.

Mass spawning of cod occurs on the south-western slope of the bank from February to April, with the peak in March (Mankevich and Prokhorov, 1962). Conditions which are observed in the nearest months after spawning are important for the survival and development of the spawned out eggs and larvae.

Relationship between water temperature in May and strength of a year class of cod is very close; correlation coefficient r =-0.83. Using equation (2), one can predict the abundance of the young, which in turn makes it possible to foresee the future yield of adult cod.

Abundance of spawning fishes and the quantity of spawned out eggs do not have a pronounced effect on the strength of year classes. Cod catches on the Flemish Cap Bank in March (when mainly spawning cod are exploited by the fishery) and the abundance index of the year-class appeared in the given calendar year (according to the results of determining the abundance of two-year-olds) are correlated in Table 6. There are no agreement between the yield of the spawning cod (and hence between the level of their stocks) on the one hand and the abundance of the appeared fry on the other hand. Thus, comparatively small quantity of cod were caught in March 1973; their concentration distributed over extremely small area. Meanwhile it is in 1973 that the strongest year class appeared.

The strength of the year classes is determined by the conditions of development of eggs, larvae and fry not only in the Flemish Cap Bank cod but in some other commercial sea fishes; but it practically does not depend on the number of fishes taking part in the spawning (Messtorff, 1959; Hempel, 1964; Gulland, 1965; Templeman, 1965, 1972; Cushing, 1968; Sonina, 1969; Tveit, 1971; Grauman, 1973; Hylen and Dragesund, 1973; Jones, 1973; Mikhman and Mikhailov, 1973; Ponomarenko, 1973).

With the help of total trawl survey which is regularly conducted by Soviet ichthyologists in the Newfoundland Subarea beginning in 1971 it has been possible to confirm that the abundance of the cod year classes on the Flemish Cap Bank increased. As seen from Table 7, the abundance and biomass of the Flemish Cap Bank cod increase.

Abundance and biomass indices of beaked redfish and American plaice for the Flemish Cap Bank are given in Table 7. Data of the total trawl survey are in good agreement with the results of the fishery, for example, with the total yield of the above fishes (Table 8).

It has been also possible with the help of the total trawl survey to evaluate the absolute biomass of these species for which approximate coefficients of catchability of the bottom trawl are known (Serebrov, 1973). For example, it was calculated that in 1974 on the Flemish Cap Bank the American plaice abundance was equal to 140.5 million specimens, and biomass made up 84.3 thousand tons, fishes of non-commercial sizes including (Chekhova, 1975). In future, when the coefficients of catchability of the bottom trawl are improved both for cod and redfish, it will be also possible to determine their biomass by the method of direct assessment.

It is difficult to say with full assurance which year classes of beaked redfish turned out to be especially strong and favoured the increment of the population on the Flemish Cap Bank. Determining the abundance of the young would not have helped to solve this problem because it is not easy to identify the species of redfish at the first years of life. S.mentella Travin, Sebastes marinus L. and probably S.fasciatus Storer are abundant on the Flemish Cap Bank (Barsukov, 1968; Barsukov and Zakirov, 1972). When analyzing catches of young redfish it is not possible to sort them out quickly and correctly according to species. Determination of the age of adult redfish also do not give sufficiently reliable results.

The total trawl survey does not make it possible to estimate the stocks of the beaked redfish with the same accuracy as the stocks of cod or American plaice are evaluated because beaked redfish distribute at such depths which are not covered by the trawlings during the survey. Besides beaked redfish more often keep in the pelagic layer than typical "bottom fishes" and this hampers the accurate assessment of their stocks with the help of the bottom trawl.

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Table 1. Total catch of fish on the Flemish Cap Bank in 1953-1975.

Year	Catch, thousand tons	Year	Catch, thousand tons
1953	0,1	1965	98,3
1954	0,5	1966	41,6
1955	0,8	1967	38,3
1956	0,1	1968	39,3
1957	51,5	1969	24,4
1958	60,2	1970	21,5
1959	63,7	1971	34,4
1960	21,7	1972	101,3
1961	39,4	1973	48,1
1962	24,0	1974	64,6
1963	40,8	1975	41,7
1964	57,9		

Table 2. Returns of cod tagged and released on the Flemish Cap Bank by Soviet Research vessels in 1961-1968.

Released				Number of tag	Recaptures			
Date	Positions N	Positions W	Length of cod (cm)		Country	Date	Positions N	Positions W
23 Mar 1961	46°39'	45°52'	58	7927	USSR	28 Jun 1961	46°50'	46°05'
23 Mar 1961	46°39'	45°52'	58	7931	France	14 May 1964	46°30'	46°30'
12 Mar 1963	45°26'	45°30'	52	7733	Spain	22 Aug 1963	45°26'	45°30'
14 Mar 1963	46°30'	45°33'	59	20053	France	9 Aug 1963	46°30'	46°00'
14 Mar 1963	46°28'	45°53'	52	21769	Spain	20 Aug 1963	46°26'	45°30'
27 Feb 1965	46°38'	46°06'	53	26925	USSR	5 May 1965	46°50'	45°45'
28 Feb 1965	46°34'	45°47'	73	35081	USSR	10 Jun 1965	46°41'	45°33'
28 Feb 1965	46°34'	45°47'	75	35087	USSR	5 Aug 1965	46°30'	45°15'
28 Feb 1965	46°34'	45°47'	56	35099	USSR	2 Jun 1965	46°50'	45°45'
27 Feb 1965	46°39'8	46°13'9	60	35097	USSR	30 May 1965	47°58'	45°03'
28 Feb 1965	46°34'9	45°47'4	63	35048	Poland	21 Nov 1965	47°43'	44°43'
11 Dec 1966	46°59'	45°35'	58	106282	Norway	2 Jan 1968	47°00'	45°00'
11 Dec 1966	46°59'	45°35'	59	106219	Portugal	15 Mar 1967	46°28'	45°23'
12 Dec 1966	46°53'	45°29'	64	106345	England	22 Aug 1967	46°30'	45°40'
12 Dec 1966	46°55'	45°31'	65	106389	Norway	8 Oct 1968	47°00'	45°00'
9 Apr 1968	46°33'	45°55'	57	177672	Portugal	7 Mar 1969	46°30'	45°00'

Table 3. Abundance of young cod of different year classes on the Flemish Cap Bank.

Year class	Average number of specimens per trawling hour by the trawl used during investigations		
	One-year-olds	Two-year-olds	Three-year-olds
1961			6
1962		7	29
1963	0	6	14
1964	0	1	14
1965	3	2	9
1966	0	0	13
1967	0	13	20
1968	10	106	58
1969	0	2	2
1970	0	1	1
1971	22	87	3
1972	3	29	22
1973	303	350	568
1974	133	50	
1975	5		

Table 4. Strength of year classes and catch of cod on the Flemish Cap Bank

Year of determining the abundance of the young	Average catch of two-year-olds per trawling hour	Year of the fishery	Catch of cod, thousand tons
1964	7	1966	29,0
1965	6	1967	37,1
1966	1	1968	33,9
1967	2	1969	22,1
1968	0	1970	18,0
1969	13	1971	24,6
1970	106	1972	56,8
1971	2	1973	22,9
1972	1	1974	24,9
1973	87	1975	22,4

Table 5. Water temperature on hydrological section 4-A between 45°57'N,48°30'W and 45°20'N,47°22'W and abundance of one-year-old cod on the Flemish Cap Bank.

Year of measuring the water temperature	Hydrological vessel	Date	Water temperature in the 0-200 m layer (°C)	Year of determining the abundance of the young	Catch of one-year-old cod per trawling hour by the trawl used during investigations
1968	"Rossiya"	16 May	2,04	1969	10
1969	"Rossiya"	15 May	3,93	1970	0
1970	"Protsion"	22 May	2,40	1971	0
1971	"Protsion"	18 May	1,92	1972	22
1972	"Protsion"	19 May	1,37	1973	3
1973	"Protsion"	19 May	-0,80	1974	303
1974	"Gemma"	22 May	0,61	1975	133
1975	"Evergreen"	31 May	1,58	1976	5
1976	"Perseus III"	11 May	0,68	1977	

Table 6. Catch of cod on the Flemish Cap Bank in March and strength of the 1962-1974 year classes.

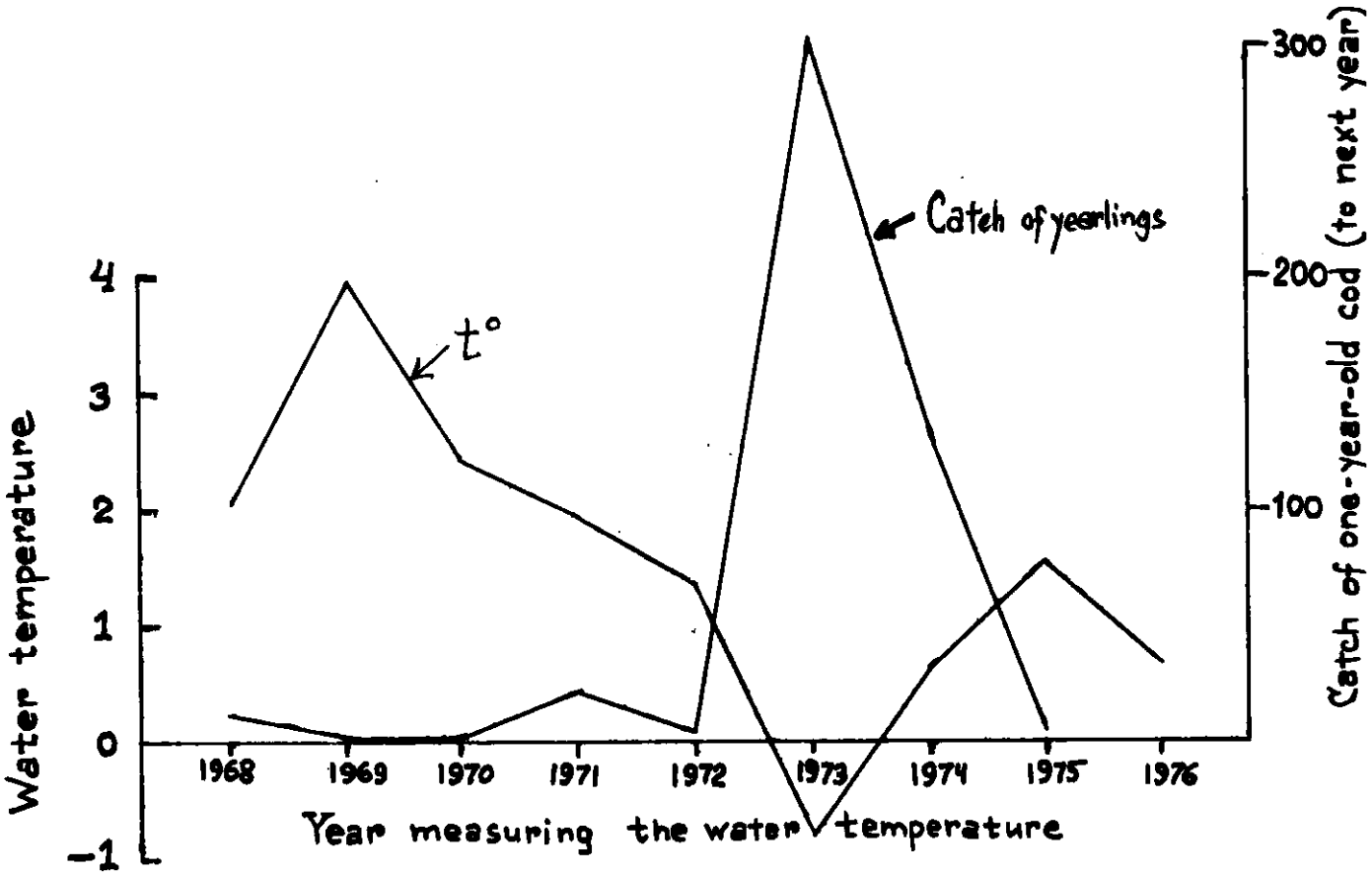
Year of the fishery	Catch of cod in March, thousand tons	Year of determining the abundance of the young	Average number of two-year-old cod per trawling hour by the trawl used during investigations
1962	0,1	1964	7
1963	25,8	1965	6
1964	10,6	1966	1
1965	0,1	1967	2
1966	3,9	1968	0
1967	19,1	1969	13
1968	17,4	1970	106
1969	14,7	1971	2
1970	10,5	1972	1
1971	13,1	1973	87
1972	7,1	1974	29
1973	2,5	1975	350
1974	1,6	1976	50

Table 7. Average catch of some commercial species per trawling hour by the trawl used during investigations on the Flemish Cap Bank.

Year	Cod		Beaked redfish		American plaice	
	Number of specimens	Weight, kg	Number of specimens	Weight, kg	Number of specimens	Weight, kg
1971	77	69	66	13	38	26
1972	66	75	449	194	41	22
1973	108	46	484	117	55	37
1974	346	51	314	89	93	74
1975	550	121	516	163	93	53
1976	693	296	103	48	169	127

Table 8. Catch of cod, redfish and American plaice on the Flemish Cap Bank in 1971-1975 (Thousand tons)

Year	Cod	Redfish	American plaice
1971	24,5	8,0	1,1
1972	56,8	41,9	0,9
1973	22,9	22,4	0,5
1974	24,9	34,7	1,9
1975	22,4	16,1	1,7


Water temperature
4
3
2
1
0
−1
t°
Catch of yearlings
300
200
100
Catch of one-year-old cod (to next year)
1968
1969
1970
1971
1972
1973
1974
1975
1976
Year measuring the water temperature