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Variations in Vertebral Averages of Year-classes of Cod from Flemish Cap

by

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Introduction

It was demonstrated by several authors (Templeman 1962, 1974, 1979; Stanek MS 1968; Konstantinov MS 1967, 1970; Lear et al. MS 1979; Cross and Payne 1978) that cod on Flemish Cap formed a discrete stock differing in many respects from cod on the adjacent northeastern Grand Bank. The purpose of this paper is to investigate the significance of the variations in vertebral averages among year-classes of cod on the Flemish Cap during 1939-67, and whether temperature was responsible for these variations.

Cod on Flemish Cap spawn mainly during March with some spawning in February and in April-May (Templeman 1976). Larval stages are present by April over the central part of the bank (Serebryakov 1965). The late eggs and/or early larval stages, in one of which the numbers of vertebrae should be determined, are present on the Cap at least during March to June but mainly in March-April (see Templeman MS 1980 for further details). It has been demonstrated by various authors that lower temperaturs during egg stages and early larval development of fishes increase vertebral numbers, intermediate temperatures decrease vertebral numbers while high temperatures increase them (Taning 1944, 1952 for sea trout (Salmo trutta); Lindsay 1954 for paradise fish (Macropodus opercularis); Molander and Molander Swedmark 1950 for plaice (Pleuronectes platessa). Dannevig (1950) found that for plaice eggs developed between temperatures of 4.9 and 5.4°C, the average number of vertebrae decreased by 0.4 with only a 0.5°C increase in temperature. On the basis of these findings temperature data and temperature indicators for Flemish Cap and adjacent areas were compared with the vertebral averages of different year-classes of cod from Flemish Cap.

Methods and Materials

Vertebral columns of cod of the 1939-67 year-classes were collected from Flemish Cap (Fig. 1) during 1949-51, 1961-62, 1964 and 1968. Vertebral counts include the urostylar half-vertebrae as a vertebra. Ages were determined from otoliths. Only vertebral numbers of cod aged 1-10 yr were used, to eliminate errors caused by inaccurate age readings in fish older than 10 yr. Year-class data from samples of less than 9 fish (Table 1) were omitted from the analyses. Cod with fused vertebrae were not used in the vertebral averages.

Results and Discussion

Bartlett's test for homogeneity of variances (Sokal and Rohlf 1969) performed on 21 year-classes from 1940 to 1966, suggested that the variances around the vertebral averages were homogeneous. An analysis of variance on

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the same 21 samples indicated that the vertebral averages were significantly different ($P < .01$). Duncan's multiple range test (Kramer 1956) indicated that 18 of the samples were not significantly different at the .05 level (Table 2). The only samples statistically different from the 18 samples were the vertebral averages for the 1941, 1960 and 1966 year-classes.

Because the deeper temperatures over the Cap in March-April are usually approximately similar to those in late July (Templeman 1976), the St. John's Station, Flemish Cap sections for 1951-73 are probably useful indicators of temperature conditions in the March-June spawning and early larval period. Therefore the vertebral averages of cod of the 1953-54, 1956-66 year-classes were regressed against the late July temperatures in the corresponding years on Flemish Cap (in the area of 47°00'N. 45°00'W) for each of the following depths (M): 0, 10, 20, 30, 50, 75, 100, 125, 150, bottom (150-160) and the average temperature of the water column (0-150) (Table 3). Out of the foregoing 11 regressions only two were significant. They were as follows:

(1) $y = -0.1097 X + 55.9139$ ($r = -0.718$, $P < 0.01$)
where y = vertebral average
and x = temperature (°C) at 0m (surface) (Fig. 2)

(2) $y = -0.1391 X + 56.2050$ ($r = -0.553$, $P < 0.05$)
where y = vertebral average
and x = temperature (°C) at 10m. (Fig. 3)

The inverse relationship between temperature and vertebral numbers is consistent with that reported in the literature (Templeman 1962).

When it is considered that the amount of variation in vertebral averages is very small (18 of the 21 samples not significantly different from each other) and also that an r of 0.72 means that about 52% of this small amount of variation in vertebral averages can be explained by the sea surface temperature, it means overall there is not a great deal of variation in vertebral averages. A lack of data for some other years, in particular the year-class of 1941 which had an anomalous vertebral average, possibly prevents a higher correlation coefficient. Temperatures during April and May were obtained from the Marine Environmental Data Service, Ottawa for 4 grids around Flemish Cap (Fig. 1). There were sufficient temperature data for grids 3 and 4 for regression analyses with vertebral averages. The parameters used in the regressions were as follows: For grid 3 for April 1953-54, 1956-59 and 1961-65, the temperature (°C) at each depth level of 0, 10, 20, 30, 50, 75, 100, 125 and the average of 0-125 m depths were regressed against the vertebral average of the corresponding year class. No significant correlations were found. Similar regressions were run on grid 3 for May during 1953, 1956-60 and 1963-65 and on grid 4 during April 1954, 1956-59 and 1961-64 and grid 4 during May 1953, 1956-60 and 1963-64 data with no significant correlations found. Possibly the cause of lack of correlation may be the large area and the different locations where temperatures were taken each year, and the inclusion of data from areas not inhabited by the eggs and larvae, especially from south of the Cap over the deeper oceanic water.

A χ^2 test performed on 6 groups of year-classes to test the number of vertebral columns containing fused vertebrae indicated that there was no significant difference between year-classes in the proportion of fused vertebral columns. The overall average of vertebral columns containing fusions was 1.95%.

Thus there was a minimal amount of variation in vertebral averages among the 21 year-classes of cod produced during the period 1940-68. Of the average numbers of vertebrae of these 21 year-classes, 18 were similar and ranged from 53.52 to 53.87.

The differences in average numbers of vertebrae could not be explained very readily by differences in water temperatures prevailing in the years when the various year-classes were produced except in the two cases where significant correlations were found between the vertebral averages and temperaturs of the surface and 10 m. Except for the years 1941, 1960 and 1966 the factors responsible for determining the numbers of vertebrae during the egg or early larval stages of cod were generally similar and not subject to great variations and this is reflected in the homogenous variances around the vertebral averages for this period.

Acknowledgements

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Table 1. Vertebral averages and percentages of vertebral columns with fused vertebrae from Flemish Cap cod for the year-class 1939-47, 1951, 1953-67.

Year-class	No. vertebral columns in sample	Vertebral average	Standard deviation	No. vertebral columns with fused vertebrae	Total vertebral columns examined	Percent vertebral columns fused
1939	2	54.5000	0.7071	0	2	0.00
1940	9	54.5556	0.5270	0	9	0.00
1941	41	54.3659	0.6984	2	43	4.65
1942	37	54.5405	0.6910	0	37	0.00
1943	151	54.6689	0.7185	2	153	1.31
1944	69	54.6667	0.7410	3	72	4.17
1945	15	55.0000	0.9258	0	15	0.00
1946	158	54.6835	0.6686	5	163	3.07
1947	36	54.7778	0.7216	0	36	0.00
1951	2	55.0000	0.0000	0	2	0.00
1953	43	54.7209	0.7012	0	43	0.00
1954	52	54.6731	0.8098	0	52	0.00
1955	4	55.5000	1.0000	0	4	0.00
1956	85	54.7529	0.7385	2	87	2.30
1957	121	54.7355	0.7161	3	124	2.42
1958	203	54.5222	0.7334	5	208	2.40
1959	56	54.5179	0.7626	1	57	1.75
1960	71	54.3239	0.6923	1	72	1.39
1961	17	54.5294	0.5145	1	18	5.56
1962	92	54.5761	0.6669	2	94	2.13
1963	145	54.8690	0.6039	3	148	2.03
1964	37	54.6216	0.7941	0	37	0.00
1965	168	54.6726	0.7300	2	170	1.18
1966	22	54.0455	0.6530	0	22	0.00
1967	1	54.0000	-	0	1	0.00

Table 2. Results of Duncan's multiple range test on cod vertebral averages from Flemish Cap for 21 year-classes. Any group of means joined by a bracket indicates that they are not significantly different at the 0.05 level while any means not joined by a bracket indicates that they are significantly different at the 0.05 level.

Year-class	Sample number	Vertebral average	No. in sample
1966	(21)	54.0455	22
1960	(20)	54.3239	71
1941	(19)	54.3659	41
1959	(18)	54.5179	56
1958	(17)	54.5222	203
1961	(16)	54.5294	17
1942	(15)	54.5405	37
1940	(14)	54.5556	9
1962	(13)	54.5761	92
1964	(12)	54.6216	37
1944	(11)	54.6667	69
1943	(10)	54.6689	151
1965	(9)	54.6726	168
1954	(8)	54.6731	52
1946	(7)	54.6835	158
1953	(6)	54.7209	43
1957	(5)	54.7355	121
1956	(4)	54.7529	85
1947	(3)	54.7778	36
1963	(2)	54.8690	145
1945	(1)	55.0000	15

Table 3. Temperatures (°C) at various depth intervals (m) from the vicinty of 47°00'N, 45°00"W on Flemish Cap during July 25-August 1, 1953-54, 1956-66, and which were used in regression analyses with cod vertebral averages.

Depth (m)	July 26 1953	July 26 1954	Aug. 1 1956	Aug. 1 1957	July 29 1958	July 27 1959	July 23-27 1960	July 25 1961	July 26 1962	July 29 1963	July 25 1964	July 23-25 1965	July 27 1966
0	11.99	13.58	11.59	11.38	10.54	11.30	13.10	12.20	11.30	10.70	12.70	11.80	15.70
10	11.43	12.28	11.04	11.32	10.45	11.19	13.30	11.87	11.12	10.69	12.68	11.80	12.58
20	10.86	10.98	10.49	11.26	10.36	9.94	12.80	11.63	10.54	10.67	12.58	9.70	9.04
30	9.72	9.24	9.23	9.95	10.22	8.15	9.60	10.36	9.85	6.59	7.03	8.40	7.81
50	6.29	4.90	5.29	4.82	9.81	4.93	5.80	3.83	6.58	4.76	4.81	5.40	5.82
75	4.04	4.04	3.96	3.71	4.98	3.25	3.80	3.49	6.65	3.76	4.40	4.30	5.02
100	4.75	3.74	3.64	3.08	4.59	2.85	3.50	3.44	4.13	3.39	3.94	4.20	4.59
125	3.93	3.80	3.48	3.05	4.20	2.87	3.45	3.49	4.64	3.22	3.80	4.10	4.50
150	3.12	3.86	3.15	3.01	3.81	2.89	3.40	3.54	4.14	3.57	3.71	4.00	4.41
Bottom	3.02 (153m)	3.87 (154m)	3.25 (160m)	3.01 (152m)	3.72 (156m)	2.90 (158m)	3.40 (160m)	3.56 (158m)	4.05 (155m)	3.69 (155m)	3.71 (155m)	4.00 (155m)	4.41 (150m)
A(0-150)	7.35	7.38	6.87	5.73	7.66	6.37	7.64	7.09	7.66	6.37	7.29	7.08	7.72

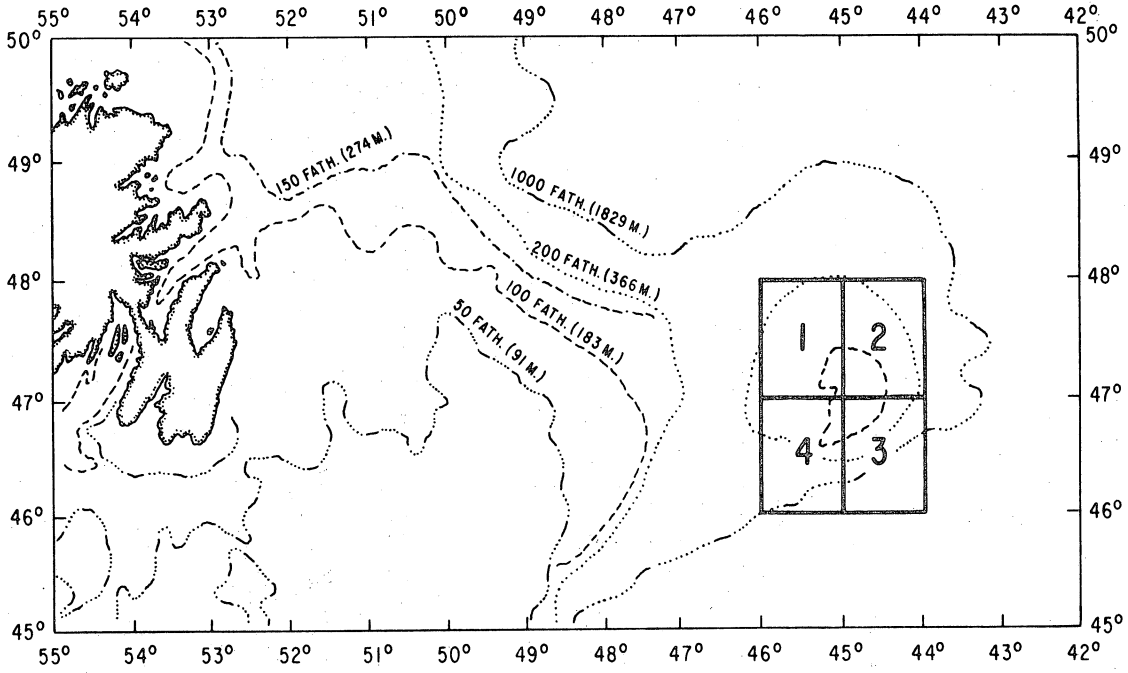

Fig. 1. Area map showing location Flemish Cap and the four grids on Flemish Cap from which temperature data were analyzed.

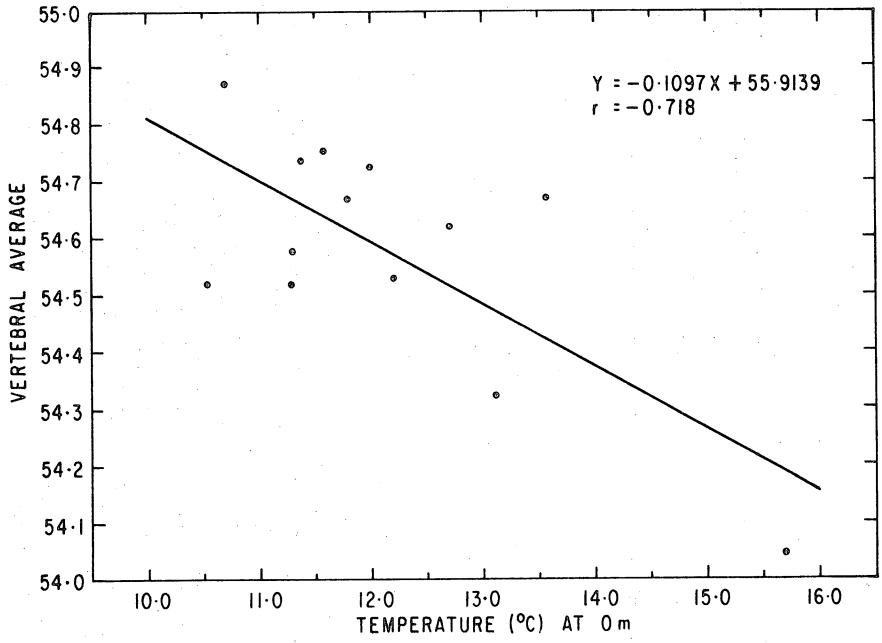

Fig. 2. Regression of vertebral average of Flemish Cap cod of the 1953-54, 1956-66 year-classes versus the sea surface temperature (°C) during late July on Flemish Cap.

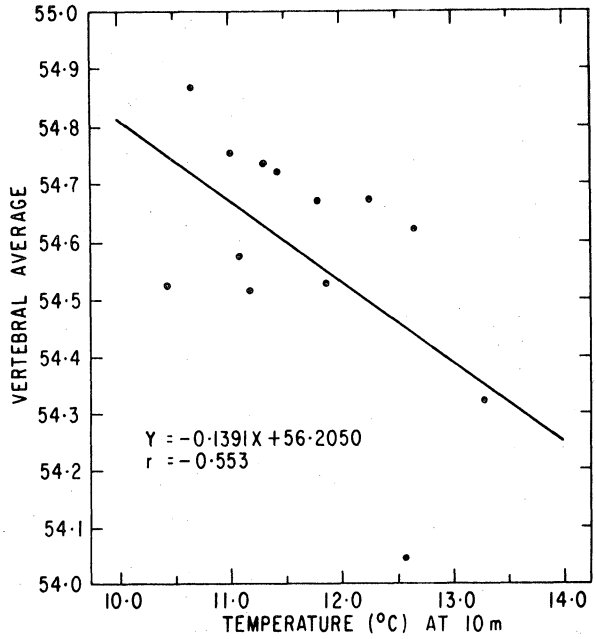

Fig. 3. Regression of vertebral averages of Flemish Cap cod for the 1953-54, 1956-66 year-classes versus the temperature at 10 m during late July on Flemish Cap.