

Vertebral Averages of Juvenile Cod, *Gadus morhua*, from Coastal Waters of Eastern Newfoundland and Labrador as Indicators of Stock Origin*

W. H. Lear and R. Wells

Department of Fisheries and Oceans, Fisheries Research Branch
Northwest Atlantic Fisheries Centre, P. O. Box 5667
St. John's, Newfoundland, Canada A1C 5X1

Abstract

Vertebral averages for juvenile Atlantic cod (age-groups 0, 1 and 2), collected during 1956-70 in coastal waters of Labrador and eastern Newfoundland, were used as indicators of stock origin. The averages were typically high (≥ 54.8) for most of the samples and within the range reported for adult cod of the Labrador-East Newfoundland stock which spawns offshore on the continental shelf. The consistently lower averages for the 1960 and 1961 year-classes may have resulted from delayed spawning and/or more favorable temperature conditions after spawning in these years. Occasional vertebral averages lower than 54.8 for other year-classes, particularly in the southern part of the surveyed area, evidently indicate intermingling with juveniles of the southern cod stock which typically have lower vertebral counts. The vertebral averages for age-groups 0 and 1 cod of the 1959 to 1969 year-classes from Notre Dame Bay were inversely correlated with mean temperatures of the 0-100 m water layer at a station in the Labrador Current off eastern Newfoundland.

Introduction

The coastal bays of eastern Newfoundland are nursery areas for cod fry, as indicated by the large numbers of juveniles caught at various locations along the coast during beach-seining operations in September-October 1959-64 (Fleming, MS 1963; Lear *et al.*, MS 1980). It was hypothesized by May (MS 1966) and Templeman (1979, 1981) that these cod are the progeny of the Labrador-East Newfoundland stock which spawns mainly during March-April on the continental shelf off Labrador and during April-May off northeastern Newfoundland (Templeman, 1964, 1965, 1979; Dias, 1965, 1967). From egg surveys of the area in the 1960's, Serebryakov (1967) concluded that the greatest spawning possibly occurs off northern Labrador. Spawning may also occur in June or later in the cold water of the deep channels and bays closer to the coast (Templeman, 1964; Chrzan, 1968). During cruises of Canadian research vessels in February-March 1978-81 primarily for cod tagging, prespawning concentrations of cod were observed on the slopes of Hamilton Bank, Belle Isle Bank, Funk Island Bank and northern Grand Bank in depths exceeding 250 m with bottom temperatures about 3°C (Unpubl. data, Northwest Atlantic Fisheries Centre, St. John's, Nfld).

From research by Apstein (1909) on developmental periods from fertilization of cod eggs to hatching of larvae at various temperatures, Templeman (1981) estimated that cod eggs spawned off northern Labrador would take 50-60 days to hatch in near-surface

temperatures of -1.5° to 0° C and those spawned on the slopes of Hamilton Bank would take about 40 days to hatch in temperatures of -1° to 1° C. He then used an average velocity of 10 naut. miles per day for the Labrador Current, based on the findings of various researchers (Iselin, 1930; Smith, 1931; Killerich, 1939; Buzdalin and Elizarov, 1962), to estimate that eggs spawned off northern Labrador would drift 500-600 miles southward to waters off southern Labrador by hatching time and those spawned on the slopes of Hamilton Bank would drift about 400 miles southward to the northern Grand Bank and southeastern Newfoundland. This hypothesis is consistent with the appearance of cod larvae off southern Labrador in April-May (Serebryakov, 1967). Wiborg (1948, 1950) observed that cod eggs are most common mainly in the upper 25-30 m of the water column.

The Labrador Current turns shoreward as it passes southward over the Northeast Newfoundland Shelf and is assumed to deposit large numbers of cod larvae in the bays and inlets of eastern Newfoundland, where juveniles (3-9 cm long) are found in September-October (Fleming, MS 1963). These juveniles are therefore postulated to be the progeny of adults of the Labrador-East Newfoundland stock, which is characterized by having the highest vertebral counts (54.8-55.3, typically above 55) of any cod stock in the Northwest Atlantic (Templeman, 1962, 1981). This paper attempts to test that hypothesis by analysis of vertebral numbers in juvenile cod (age-groups 0, 1 and 2) collected in coastal waters of eastern Newfoundland and southern Labrador during 1956-70 (Fig. 1).

* Based on a paper presented at the NAFO Special Session on "Stock Discrimination in Marine Fishes and Invertebrates of the Northwest Atlantic", held at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, during 8-10 September 1982.

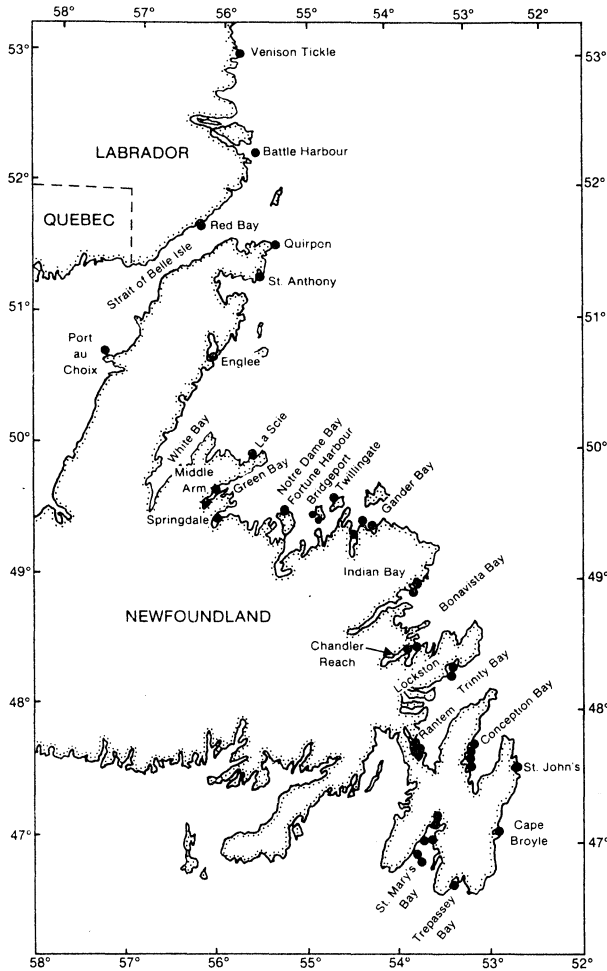


Fig. 1. Map of Newfoundland and Labrador showing sampling locations and place names mentioned in the text.

Material and Methods

Large numbers of juvenile cod were collected in shallow areas (usually <10 m) of bays and inlets from St. Mary's Bay northward along the coast of Newfoundland to Venison Tickle in Labrador (Table 1). The samples were either total catches or random subsamples of large catches. Juveniles sampled during 1959-64 in areas 1-15 (except 4 and 12) were caught in September-October by a small Danish seine with mesh sizes of 15 mm in the wings and belly, 11 mm in the lengthening piece and 9 mm in the codend which had a 4-mm mesh nylon liner. At each locality the seine was set near a suitable beach, free of obstructions, in depths mainly of 4-6 m and hauled toward the beach. Samples from area 4 (St. John's) in 1956-60 were obtained during August-September by baited hook from a wharf in the harbor. The samples from St. Mary's Bay (area 1) in 1957 and 1958 were obtained during April-May in 92-132 m by otter trawl with a small-mesh

TABLE 1. Locations and years of sampling and numbers of specimens examined for this study of vertebral numbers in juvenile cod from coastal waters of eastern Newfoundland and Labrador.

Area No.	Locality (Fig. 1)	Years of Sampling	No. by age-group			
			0	1	2	Total
1	St. Mary's Bay	1957-64	142	266	410	818
2	Trepassey	1961-64	21	200	—	221
3	Cape Broyle	1960-64	160	186	—	346
4	St. John's	1956-60	—	306	21	327
5	Conception Bay	1959-64	190	425	78	693
6	Rantern	1961-64	195	175	13	383
7	Lockston	1959-64	654	186	—	840
8	Chandler's Reach	1960-64	164	157	—	321
9	Indian Bay	1960-64	182	107	—	289
10	Gander Bay	1959-64	161	78	—	239
11	Bridgeport	1960-64	78	156	6	240
12	Twillingate	1964-70	—	362	363	725
13	Fortune Harbour	1960-64	197	166	20	383
14	Springdale	1960-64	146	199	38	383
15	Middle Arm	1960-64	88	137	10	235
16	Lascie	1965-69	—	281	205	486
17	Englee	1965-69	—	145	319	464
18	St. Anthony	1965-70	—	396	649	1,045
19	Quirpon	1968	—	—	26	26
20	Red Bay	1962,69	—	59	51	110
21	Battle Harbour	1959,63	—	48	123	171
22	Venison Tickle	1959,63	—	22	118	140
23	Port au Choix	1968	—	20	159	179

liner in the codend. Samples from area 12 and 16-23 in various years during 1959-70 were obtained in July-September with baited hook or 3-hook spinner of the type used for trout fishing.

Examination of the material in the laboratory included extraction of otoliths for age determination and the removal of flesh from the skeletons to facilitate counting the number of vertebrae. The smallest specimens (mainly age-group 0) were examined under a binocular microscope. To enable comparison with the results of Schmidt (1930), Postolaky (1962), Lear *et al.* (1981) and Templeman (1981), the vertebral counts in this paper follow the European practice of including the urostylar half-vertebra as a vertebra. Specimens with fused vertebrae were not included in the calculation of averages. The young cod were assigned to year-classes on the basis of ages determined from otoliths.

For each of the age-groups (0, 1 and 2) of cod, applications of Levene's test of homogeneity of variances (Brown and Forsythe, 1974) to the vertebral averages indicated that the variances were homogeneous among both year-classes and areas. Consequently, one-way analysis of variance (ANOVA) and the Brown-Forsythe test (F^*) were conducted on the vertebral averages of different year-classes by area for each age-group by utilizing the Biomedical Computer Program (BMDP7D) (Dixon and Brown, 1979). For each

case analyzed, the results of ANOVA and F^* were similar and yielded the same statistical decisions regarding significance of differences among vertebral averages. Use of Duncan's multiple range test (Kramer, 1956) revealed the vertebral averages which were significantly lower than others for an area, and these are indicated by asterisks in Tables 2-4.

In the light of the findings of Templeman (1981) for cod of Newfoundland and adjacent waters, the following convention is used in this paper to facilitate discussion of vertebral averages for juvenile cod: (a) **low** (≤ 54.0 vertebrae), (b) **intermediate** (54.1-54.7), and (c) **high or northern type** (≥ 54.8 vertebrae).

The longest series of cod vertebral data available to investigate the possible effect of variable environmental conditions on vertebral numbers were the averages for the 1956-69 year-classes from Notre Dame Bay (areas 10-15). The only long-term monthly temperature data by depth for the east coast of Newfoundland were those of Station 27 in the Avalon Channel off St. John's (Akenhead, MS 1983). These data are considered to be indicative of temperature conditions prevailing in the upper 100 m of the Labrador Current, because the shoreward branch of this current passes through the Avalon Channel after flowing southward along Labrador and eastern Newfoundland.

Results

Variation among year-classes by area

Age-group 0 cod (Table 2). Vertebral averages of cod fry caught in St. Mary's Bay (area 1) were intermediate to high (54.60-54.97), being indicative of the Avalon stock complex or intermingling of the Avalon stock and the Labrador-East Newfoundland stock (the vertebral averages for the latter stock being commonly referred to as the "northern type"). The samples from Trepassey and Cape Broyle (areas 2 and 3) were all of the northern type. In Conception Bay (area 5), the averages (55.0-55.24) were of the northern type except a small sample of the 1963 year-class which had an atypically low value (53.80). In Trinity Bay (areas 6 and 7), the averages were of the northern type (54.91-55.43) except that for the 1960 year-class (54.50). In Bonavista Bay (areas 8 and 9), the averages were of the northern type (54.89-55.30) in seven of nine samples, intermediate (54.46) for a small sample of the 1961 year-class, and low (53.93) for the 1960 year-class. In Gander Bay (area 10), the averages were mainly of the northern type (54.95-55.19) except an intermediate one (54.67) for the 1959 year-class. In Notre Dame Bay (areas 11-15), the averages were high in nine samples (54.85-55.56) and intermediate in the remaining three (54.55-54.72). Middle Arm (area 15)

TABLE 2. Vertebral averages, standard errors and sample sizes for age-group 0 cod of the 1959-64 year-classes from various coastal areas of Newfoundland and Labrador defined in Table 1. (Asterisks indicate averages are significantly lower than other averages for an area.)

Area Ref.	Vertebral average, standard error and sample size by year-class					
	1959	1960	1961	1962	1963	1964
1	—	—	54.60 0.27 10	54.97 0.11 76	54.73 0.17 56	—
2	—	—	—	—	55.05 0.22 21	—
3	—	54.98 0.13 50	55.80 0.20 10	55.09 0.14 47	55.04 0.13 53	—
5	55.04 0.11 57	55.02 0.10 58	55.00 0.23 11	55.24 0.14 54	53.80* 0.33 10	—
6	—	—	54.91 0.18 42	55.23 0.10 56	55.13 0.15 46	55.26 0.12 51
7	55.08 0.04 428	54.50* 0.16 26	55.05 0.13 64	55.43 0.15 42	55.00 0.15 45	55.14 0.14 49
8	—	—	54.89 0.16 18	55.25 0.11 52	54.94 0.11 63	55.13 0.11 31
9	—	53.93* 0.12 83	54.46* 0.27 13	55.07 0.14 29	54.91 0.18 34	55.30 0.17 23
10	54.67* 0.18 39	—	—	55.19 0.12 52	55.04 0.11 49	54.95 0.15 21
11	—	—	—	55.14 0.13 51	—	55.11 0.18 27
13	—	54.59 0.15 63	—	54.90 0.13 51	54.72 0.18 47	55.06 0.17 36
14	—	54.55* 0.14 51	—	55.56 0.12 48	55.19 0.19 27	54.85* 0.18 20
15	—	—	—	—	55.29 0.11 41	55.13 0.11 47

was the northern limit of beach-seining surveys during 1959-64, and the sampling gears used north of this area would not normally catch age-group 0 cod.

Age-group 1 cod (Table 3). In the southernmost samples from St. Mary's Bay and Trepassey (areas 1 and 2), vertebral averages for four samples of the 1960 and 1961 year-classes were intermediate (54.14-54.73), and the remaining six samples had high averages (54.80-55.14) which were near the lower part of the range defined for northern type fish. The averages

TABLE 3. Vertebral averages, (standard errors and sample sizes) for age-group 1 cod of the 1955-63 and 1965-69 year-classes from various coastal areas of Newfoundland and Labrador defined in Table 1. (Asterisks indicate averages are significantly lower than other averages for an area.)

Area	Vertebral average, standard error and sample size by year-class													
	1955	1956	1957	1958	1959	1960	1961	1962	1963	1965	1966	1967	1968	1969
1	—	55.11 0.25 19	—	—	55.14 0.13 43	54.63 0.15 46	54.14* 0.15 72	54.94 0.16 46	54.80 0.14 40	—	—	—	—	—
2	—	—	—	—	—	54.27* 0.16 45	54.73 0.16 52	55.06 0.15 54	54.96 0.12 49	—	—	—	—	—
3	—	—	—	—	55.03 0.10 64	54.96 0.15 51	—	55.35 0.12 46	54.88 0.16 25	—	—	—	—	—
4	55.17 0.10 107	55.43 0.09 77	55.26 0.09 78	—	55.68 0.13 44	—	—	—	—	—	—	—	—	—
5	—	—	—	55.06 0.07 202	54.75 0.12 48	54.02* 0.15 48	54.77 0.20 30	55.04 0.13 45	54.90 0.14 52	—	—	—	—	—
6	—	—	—	—	—	54.37* 0.17 46	55.04 0.22 28	55.10 0.14 50	54.86 0.10 51	—	—	—	—	—
7	—	—	—	—	—	54.05* 0.16 40	54.92 0.12 50	55.00 0.13 48	54.79 0.12 48	—	—	—	—	—
8	—	—	—	—	54.93 0.10 56	—	54.41* 0.18 49	—	55.14 0.14 52	—	—	—	—	—
9	—	—	—	—	54.90 0.18 31	—	54.48 0.20 21	54.86 0.21 29	54.65 0.14 26	—	—	—	—	—
10	—	—	—	—	—	—	—	54.74* 0.18 34	55.16 0.11 44	—	—	—	—	—
11	—	—	—	—	55.23 0.13 47	54.74 0.21 23	—	55.10 0.13 50	54.75 0.17 36	—	—	—	—	—
12	—	—	—	—	—	—	—	—	55.20 0.07 108	—	55.11 0.26 9	55.11 0.08 89	55.25 0.07 137	54.74 0.27 19
13	—	—	—	—	—	54.14* 0.17 35	54.11* 0.20 37	55.04 0.12 48	54.96 0.11 46	—	—	—	—	—
14	—	—	—	—	55.09 0.16 44	54.50* 0.11 26	54.93 0.16 29	55.12 0.13 49	55.18 0.10 51	—	—	—	—	—
15	—	—	—	—	55.05 0.13 44	—	55.33 0.56 6	55.09 0.15 46	54.95 0.14 41	—	—	—	—	—
16	—	—	—	—	—	—	—	—	—	—	—	54.95 0.06 183	55.15 0.09 98	—
17	—	—	—	—	—	—	—	—	—	—	—	54.95 0.10 62	55.08 0.09 83	—
18	—	—	—	—	—	—	—	—	—	55.01 0.06 175	55.17 0.08 130	54.80 0.15 50	55.14 0.14 42	—

TABLE 3. (continued).

Area	Vertebral average, standard error and sample size by year-class													
	1955	1956	1957	1958	1959	1960	1961	1962	1963	1965	1966	1967	1968	1969
20	—	—	—	—	—	—	55.24 0.14 59	—	—	—	—	—	—	—
21	—	—	—	—	—	—	—	55.31 0.11 48	—	—	—	—	—	—
22	—	—	—	—	—	—	—	55.23 0.15 22	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	55.00 0.18 20	—	—

for samples from Cape Broyle and St. John's (areas 3 and 4) were all of the northern type (54.88–55.68), the value for the 1959 year-class in the St. John's sample (55.68) being exceptionally high. In Conception and Trinity bays (areas 5–7), the averages were typically near the lower part of the range for northern fish (54.78–55.06) except the low intermediate values for the 1960 year-class (54.02–54.37) and a high intermediate value (54.75) for the 1959 year-class. In Bonavista Bay (areas 8 and 9), the averages were high in four samples (54.86–55.14) and intermediate in three samples (54.41–54.65). In Gander Bay and Notre Dame Bay (areas 10–15) the averages were generally of the northern type (54.75–55.33) except those for the 1960 and 1961 year-classes (54.11–54.74), the low values for samples from Fortune Harbour (area 13) being significantly lower than other averages for the region. The averages for samples from all sampling sites north of Notre Dame Bay including Port au Choix (areas 16–23) were all representative of northern type fish (54.80–55.53).

Age-group 2 cod (Table 4). Vertebral averages for samples from St. Mary's Bay and St. John's (areas 1 and 4) ranged from low to intermediate (53.80–54.71), the intermediate values for two samples from St. John's being within the range of averages reported by Templeman (1981) for adult cod sampled during 1961–71 in the area. In Conception and Trinity bays (areas 5 and 6), the averages for the 1960 year-class were quite low (53.92, 54.05), whereas that for the 1957 year-class was much higher (55.02). In Notre Dame Bay (areas 11–15), the averages for the 1959 and 1960 year-classes were mostly intermediate (54.14–54.62) with two values (54.83, 55.00) being representative of northern type fish, whereas all five averages for the 1962–68 year-classes were high (54.98–55.31). In the northern sampling locations (areas 16–23), intermediate averages (54.42–54.74) were evident in five of 13 samples of age-group 2 fish, whereas all averages for age-group 1

cod were of the northern type (Table 3). High averages (54.89–55.35) occurred in the remaining 13 samples of age-group 2 cod from these northern localities.

Variation among areas by year-class

The irregular nature of sampling throughout the period and the lack of data for some year-classes in various areas make it difficult to assess variation in vertebral averages among areas for all year-classes. However, some general conclusions can be drawn in cases where certain year-classes were sampled over a wide range of areas. There is no evidence of a trend in vertebral averages of age-group 0 cod of the 1962 and 1963 year-classes from St. Mary's Bay (area 1) to Notre Dame Bay (areas 10–15), with intermediate values of 54.73 and 54.72 occurring in areas 1 and 13 respectively (Table 2). Likewise, there is no evidence of a trend in vertebral averages for age-group 1 cod of the 1959–63 year-classes from area 1 to area 15 (Table 3). Vertebral averages of the 1961 and 1962 year-classes in areas 20–22 (55.23–55.31) were generally higher than in the southern areas, although occasional high values occurred in the latter region (e.g. 55.35 in area 3 and 55.33 in area 15).

To examine further the possibility of a south-north trend, it seemed appropriate to group the data from south to north as follows: (a) St. Mary's Bay to St. John's (areas 1–4) which represent that part of south-eastern Newfoundland where mixing with the southern (low vertebral-count) cod stocks is likely; (b) Conception, Trinity and Bonavista bays into which larvae are carried by the Labrador Current and to which juveniles may possibly migrate from southern waters; (c) the Notre Dame Bay region from Gander Bay to Middle Arm (areas 10–15) which face northward and contain inlets suitable as nursery grounds for larvae and juveniles; and (d) the northern areas from LaScie to Venison Tickle where high vertebral averages would be

TABLE 4. Vertebral averages, standard errors, and sample sizes for age-group 2 cod of the 1955-57, and 1959-68 year-classes from various coastal areas of Newfoundland and Labrador defined in Table 1. (Asterisks indicate averages are significantly lower than other averages for an area.)

Area	Vertebral average, standard error and sample size by year-class												
	1955	1956	1957	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
1	54.40 0.07 315	54.71 0.13 82	—	—	53.80 0.37 5	—	54.50 0.33 8	—	—	—	—	—	—
4	54.43 0.25 14	54.57 0.20 7	—	—	—	—	—	—	—	—	—	—	—
5	—	—	55.02 0.14 56	—	54.05 0.24 22	—	—	—	—	—	—	—	—
6	—	—	—	—	53.92 0.27 13	—	—	—	—	—	—	—	—
11	—	—	—	54.83 0.31 6	—	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	55.31 0.10 39	55.11 0.08 64	—	54.98 0.09 115	55.16 0.12 55	—	55.30 0.10 90
13	—	—	—	54.62 0.21 13	54.14 0.34 7	—	—	—	—	—	—	—	—
14	—	—	—	54.32* 0.23 19	55.00 0.20 19	—	—	—	—	—	—	—	—
15	—	—	—	—	54.30 0.26 10	—	—	—	—	—	—	—	—
16	—	—	—	—	—	—	—	54.89 0.08 99	—	—	54.96 0.09 91	55.20 0.15 15	—
17	—	—	—	—	—	—	—	54.74 0.08 93	—	—	54.96 0.12 50	54.99 0.06 176	—
18	—	—	—	—	—	—	—	54.92 0.05 194	55.02 0.10 55	55.09 0.08 124	54.70* 0.10 92	54.89 0.07 98	54.90 0.09 86
19	—	—	—	—	—	—	—	—	—	—	54.46 0.22 26	—	—
20	—	—	—	—	—	—	—	—	—	—	—	55.12 0.12 51	—
21	—	—	55.30 0.08 112	—	—	54.73* 0.14 11	—	—	—	—	—	—	—
22	—	—	55.35 0.08 118	—	—	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	54.42 0.10 159	—	—

expected to prevail except for some intermixing with fish of intermediate vertebral counts from the Gulf of St. Lawrence (Table 5).

For age-groups 0 and 1, vertebral averages were mainly of the northern type in all regions except for the 1960 and 1961 year-classes which exhibited persist-

TABLE 5. Vertebral averages for age-groups 0+1 and 2 cod of the 1955–69 year-classes for four regions from south to north along eastern Newfoundland. (Numbers of specimens in parentheses.)

Year-class	Vertebral averages by grouped areas			
	Areas 1–4	Areas 5–9	Areas 10–15	Areas 16–23
Age-groups 0+1 (Tables 2-3)				
1955	55.17(107)	—	—	—
1956	55.37 (96)	—	—	—
1957	55.26 (78)	—	—	—
1958	—	55.06(202)	—	—
1959	55.25(151)	55.03(620)	55.02(174)	—
1960	54.72(192)	54.20(301)	54.51(198)	—
1961	54.50(144)	54.82(326)	54.54 (72)	55.24 (59)
1962	55.07(269)	55.15(405)	55.11(429)	55.28 (70)
1963	54.90(244)	54.91(427)	55.06(490)	—
1964	—	55.20(154)	55.05(151)	—
1965	—	—	—	55.01(175)
1966	—	—	55.11 (9)	55.17(130)
1967	—	—	55.11 (89)	54.93(315)
1968	—	—	55.25(137)	55.12(223)
1969	—	—	54.74 (19)	—
Age-group 2 (Table 4)				
1955	54.40(329)	—	—	—
1956	54.70 (89)	—	—	—
1957	—	55.02 (56)	—	55.33(230)
1959	—	—	54.50 (38)	—
1960	53.80 (5)	54.00 (35)	54.64 (36)	—
1961	—	—	—	54.73 (11)
1962	54.50 (8)	—	55.31 (39)	—
1963	—	—	55.11 (64)	54.87(386)
1964	—	—	—	55.02 (55)
1965	—	—	54.98(115)	55.09(124)
1966	—	—	55.16 (55)	54.67(418)
1967	—	—	—	54.99(340)
1968	—	—	55.30 (90)	54.90 (86)

ently low averages in three of the four regions (Table 5). For those year-classes common to two or more regions, there is no evidence of a south-north trend except the 1961 year-class with a considerably higher vertebral average in areas 16–23 (55.24) than in the other three areas (54.50–54.82).

For age-group 2, there is a tendency for the averages in the two southern regions to be lower than those in the northern regions, but the evidence is scanty due to small sample sizes for some year-classes and the paucity of data for year-classes common to all regions. The prevalence of lower-than-normal vertebral averages for age-groups 0+1 of the 1960 and 1961 year-classes was also apparent for age-group 2 of the 1960 year-class in the three regions from southeastern Newfoundland to Notre Dame Bay.

Vertebral numbers and water temperature

To examine the relationship between vertebral numbers in juvenile cod and water temperature off eastern Newfoundland, vertebral averages of the 1959–64 and 1966–69 year-classes (age-groups 0 and 1) from Notre Dame Bay (areas 10–15) were regressed

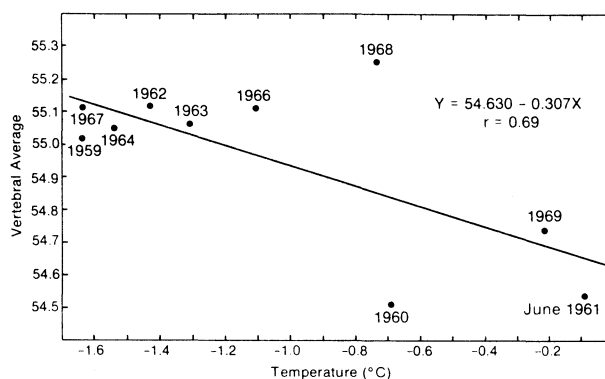


Fig. 2. Regression of vertebral averages of ages 0+1 cod of the 1959–64 and 1966–69 year-classes in Notre Dame Bay (areas 10–15) against average water temperature in 0–100 m at Station 27 off St. John's in March (June temperature used for 1961).

against average water temperatures at Station 27 off St. John's for 0–25 m, 0–50 m, 0–100 m and 0–160 m in each of March, April and May, which encompass the period of egg and early larval development in cod off Labrador and eastern Newfoundland. No significant correlations resulted from these analyses, presumably due largely to three anomalous points (1960, 1961 and 1968 year-classes) (Fig. 2).

Templeman (1964), Chrzan (1968) and Dias (1972) have noted that, although major spawning of cod usually occurs in late winter and early spring on the off-shore banks, some spawning may occur as late as June in the deep channels and on the slopes of banks closer to the coast. In fact, Templeman (1964) stated that spawning was evidently delayed in 1961 because many more cod than usual had not spawned before moving to shallow coastal waters. This may have occurred also in 1960 but there are no observations to support the hypothesis. Likewise, there are no observations that would explain the high vertebral average for the 1968 year-class. Taking account of the evidence for late spawning in 1961, regressions were performed utilizing average water temperatures of the 0–100 m layer in March for the vertebral averages of the 1959–60 and 1962–69 year-classes and in April, May and June for the vertebral average of the 1961 year-class. The only significant correlation ($r = 0.69$, $P < 0.05$) was that based on the use of average water temperature in June relative to the vertebral average for the 1961 year-class (Fig. 2).

Discussion and Conclusion

The high vertebral averages for age-group 0 cod of eastern and southeastern Newfoundland, except some intermediate values for the 1960 and 1961 year-classes in some areas, indicate that these fish are derived mainly from the spawning of the Labrador-East Newfoundland cod stock with typically high vertebral

numbers. The low average of 53.80 for the 1963 year-class in Conception Bay may reflect late local spawning or an influx of low vertebral-count fish from southern spawning grounds, and the intermediate value of 54.73 for the 1963 year-class in St. Mary's Bay may reflect the intermingling of young from the northern and southern stocks.

With the exception of the 1960 and 1961 year-classes, vertebral averages of age-group 1 cod throughout the region from Labrador to southeastern Newfoundland, including the sample from Port au Choix, were generally indicative of northern type fish (≥ 54.8 vertebrae). The lower averages for the 1960 and 1961 year-classes may have resulted from delayed spawning of adults or conditions after spawning which favored more rapid development of eggs and larvae. According to Templeman (1964) spawning was evidently delayed in 1961 by cold water on the offshore spawning grounds because many more cod than usual had not spawned before their spring migration to coastal waters. In southeastern Newfoundland areas, there may have been some intermingling of northern juveniles with those of the Avalon stock complex which may spawn as far north as the northwestern slope of the Grand Bank (Templeman, 1981).

For age-group 2 cod, apart from the low to intermediate vertebral averages for the 1960 and 1961 year-classes throughout the region and the comparatively low values for samples from St. Mary's Bay and St. John's (areas 1 and 4), those for most year-classes and areas were generally of the northern type. The intermediate value for the Port au Choix (area 23) sample indicates that the cod were of Gulf of St. Lawrence origin. The similarly low value for the Quirpon sample (area 19) is possibly indicative of migration of juvenile cod from the Gulf of St. Lawrence through the Strait of Belle. Low to intermediate values for samples from the Avalon Peninsula northward to Notre Dame Bay may indicate local or late spawning or intermingling with the northern segment of the Avalon stock complex. The absence of high averages for age-group 2 cod in the southern areas (1-11), except one sample from Conception Bay, may indicate that many of the 2-year-old juveniles, which were derived from northern spawning, had migrated northward from their nursery grounds along the southern part of eastern Newfoundland, leaving these areas inhabited mainly by 2-year-old juveniles of the southern stocks. This hypothesis is currently being tested by the tagging of juvenile cod in the bays of eastern Newfoundland.

For cod of age-groups 0 and 1 which are less likely to undertake extensive migrations from nursery areas where they were deposited as larvae, there is no evidence of a south to north trend in vertebral averages despite considerable variation within year-classes and areas in the ungrouped data. Combination of the data

(weighted) by year-classes, to reflect vertebral averages for age-groups 0 and 1 cod in four major areas from southeastern Newfoundland to Labrador, shows a reasonably consistent pattern with similarly high vertebral averages in cod from the four regions despite the proximity of the southernmost region to the Avalon, Grand Bank and St. Pierre Bank stocks of cod which have lower vertebral numbers (Templeman, 1981). Therefore, the evidence is that most of the juvenile cod, which utilize bays and inlets of eastern Newfoundland as nursery areas, are the progeny of high vertebral-count adults which constitute the Labrador-East Newfoundland stock.

Much of the evidence for inverse relationships between vertebral numbers in fish and water temperature over the ranges of temperature usually present in natural habitats has accrued from laboratory experiments: e.g. Tåning (1944, 1952) for sea trout, *Salmo trutta*; Lindsay (1954) for paradise fish, *Macropodus opercularis*; Dannevig (1950) and Molander and Molander-Swedmark (1957) for the European plaice, *Pleuronectes platessa*; and Fahy (1972, 1976) for haddock, *Melanogrammus aeglefinus*, and Brander (1979) for cod noted that there is an inverse relationship between mean vertebral numbers and surface water temperature at spawning time and during egg and early larval development for populations in the North Atlantic. The attempt in this paper to correlate vertebral averages for juvenile cod from one region of eastern Newfoundland with water temperatures during spawning time also resulted in an inverse relationship for the short time-series of data available. Since the mean temperatures were derived from observations at a station in the Labrador Current somewhat remote from the areas where spawning occurs, the two outlying points for the 1960 and 1968 year-classes may reflect spatial or temporal changes in spawning or a combination of both, with consequent egg development occurring at temperatures different from those of the Labrador Current at the station off St. John's.

Acknowledgements

The authors are indebted to A. M. Fleming who collected most of the data on juvenile cod, and to T. Collier and the late C. J. Woodford who did most of the vertebral counts.

References

- AKENHEAD, S. A. MS 1983. Mean temperature and salinities from an ocean climate station by Newfoundland. *NAFO SCR Doc.*, No. 30, Serial No. N682, 28 p.
- APSTEIN, C. 1909. Die bestimmung des alters pelagisch lebender fischeier. *Mitt. Dtsch. Seefisch.*, **25**: 363-373.
- BRANDER, K. 1979. The relationship between vertebral number and

- water temperature in cod. *ICES J. Cons.*, **38**: 286-292.
- BROWN, M. B., and A. B. FORSYTHE. 1974. Robust tests for the equality of variances. *J. Amer. Stat. Assoc.*, **69**: 364-367.
- BUZDALIN, Y. I., and A. A. ELIZAROV. 1962. Hydrological conditions in the Newfoundland banks and Labrador areas in 1960. In Soviet fisheries investigations in the Northwest Atlantic, VNIRO-PINRO, Moscow, p. 152-168. (Transl. for U.S. Dept. Int. and Nat. Sci. Found., Washington, D. C., by Israel Prog. Sci. Transl., 1963.)
- CHRZAN, F. 1968. Polish research report, 1967. *ICNAF Redbook 1968*, Part III: 75-84.
- CLARK, J. R., and V. D. VLADYKOV. 1960. Definition of haddock stocks of the northwestern Atlantic. *Fish. Bull. U.S.*, **60**: 283-296.
- DANNEVIG, A. 1950. The influence of the environment on numbers of vertebrae in plaice. *Fiskeridir. Skr. (Fisk.)*, **9**(9): :6 p.
- DIAS, M. L. 1965. Portuguese research report, 1964. *ICNAF Redbook 1965*, Part II: 95-102.
1967. Portuguese research report, 1966. *ICNAF Redbook 1967*, Part II: 90-106.
1972. Portuguese research report, 1971. *ICNAF Redbook 1972*, Part II: 71-78.
- DIXON, W. J., and M. B. BROWN (ed.). 1979. Biomedical computer programs, P-series. Univ. Calif. Press, Los Angeles, 880 p.
- FAHY, W. G. 1972. Influences of temperature change on number of vertebrae and caudal fin rays in *Fundulus majalis* (Walbaum). *ICES J. Cons.*, **34**: 217-231.
1976. The morphological time of fixation of the total number of vertebrae in *Fundulus majalis* (Walbaum). *ICES J. Cons.*, **36**: 243-250.
- FLEMING, A. M. MS 1963. Baby cod survey, 1962. *Fish. Res. Bd. Canada, Rep. Biol. Sta., St. John's, Newfoundland for 1962-63*, App. No. 5.
- ISELIN, C. 1930. A report on the coastal waters of Labrador, based on exploration by the *Chance* during the summer of 1926. *Proc. Amer. Acad. Arts Sci.*, **66**(1): 1-37.
- KILLERICH, A. B. 1939. A theoretical treatment of the hydrographical observation material, Godthaab Expedition, 1928. *Medd. om Grönland*, **78**(5), 149 p.
- KRAMER, C. Y. 1956. Extension of multiple range test to group means with unequal numbers of replications. *Biometrics*, **12**: 307-310.
- LEAR, W. H., A. M. FLEMING, and R. WELLS. MS 1980. Results of small cod surveys in eastern Newfoundland during 1959-64. *NAFO SCR Doc.*, No. 144, Ser. No. N218, 11 p.
- LEAR, W. H., R. WELLS, and W. TEMPLEMAN. 1981. Variation in vertebral averages for year-classes of Atlantic cod, *Gadus morhua*, on Flemish Cap. *J. Northw. Atl. Fish. Sci.*, **2**: 57-60.
- LINDSAY, C. C. 1954. Temperature-controlled meristic variation in the paradise fish, *Macropodus opercularis* (L.). *Can. J. Zool.*, **32**: 87-98.
- MAY, A. W. MS 1966. Biology and fishery of Atlantic cod (*Gadus morhua* L.) from Labrador. Ph. D. thesis, McGill University, Montreal, March 1966, 225 p.
- MOLANDER, A. R., and M. MOLANDER-SWEDMARK. 1957. Experimental investigations on variations in plaice (*Pleuronectes platessa* L.). *Rep. Inst. Mar. Res., Lysekil (Biol.)*, No. 7, 45 p.
- POSTOLAKY, A. I. 1962. Biology of the Labrador and Newfoundland cod. In Soviet fisheries investigations in the Northwest Atlantic, VNIRO-PINRO, Moscow, p. 152-168. (Transl. for U.S. Dept. Int. and Nat. Sci. Found., Washington, D. C., by Israel Prog. Sci. Transl., 1963.)
- SCHMIDT, J. 1930. The Atlantic cod (*Gadus callarias* L.) and local races of the same. In Racial investigations. No. X, C. R. Lab., Carlsberg, **18**(6), 71 p.
- SEREBRYAKOV, V. P. 1967. Cod reproduction in the Northwest Atlantic. *Tr. PINRO*, **20**: 205-242. (Fish. Res. Bd. Canada Transl. Ser., No. 1133, 1968.)
- SMITH, E. H. 1931. Arctic ice, with special reference to its distribution in the North Atlantic Ocean. The Marion expedition to Davis Strait and Baffin Bay, 1928: scientific results. *Bull. U.S. Coast Guard*, **19**(3): 221 p.
- TÄNING, Å. V. 1944. Experiments on meristic and other characters in fishes. 1. On the influence of temperature on some meristic characters in sea trout and the fixation period of these characters. *Medd. Komm. Dan. Fisk., Havunders, Ser. Fisk.*, **11**(3): 1-66.
1952. Experimental study of meristic characters in fishes. *Biol. Rev.*, **27**: 169-193.
- TEMPLEMAN, W. 1962. Divisions of cod stocks in the Northwest Atlantic. *ICNAF Redbook 1962*, Part III: 79-129.
1964. Canadian research report, 1963. A. Subareas 2 and 3. *ICNAF Redbook 1964*, Part II: 3-21.
1965. Canadian research report, 1964. A. Subareas 2 and 3. *ICNAF Redbook 1965*, Part II: 3-20.
1979. Migrations and intermingling of stocks of Atlantic cod, *Gadus morhua*, of the Newfoundland and adjacent areas from tagging in 1962-66. *ICNAF Res. Bull.*, **4**: 5-50.
1981. Vertebral numbers in Atlantic cod, *Gadus morhua*, of the Newfoundland and adjacent areas, 1947-71, and their use for delineating cod stocks. *J. Northw. Atl. Fish. Sci.*, **2**: 21-45.
- WIBORG, K. F. 1948. Investigations of cod larvae in the coastal waters of northern Norway: occurrence of cod larvae, and occurrence of food organisms in the stomach contents and in the sea. *Fiskeridir. Skr. (Havunders.)* **9**(3): 1-27.
1950. The occurrence of fish eggs and larvae along the coast of northern Norway during April-June 1948 and 1949. *ICES Ann. Biol.*, **6**: 12-16.

