Northwest Atlantic Fisheries Organization

Serial No. N581

NAFO SCR Doc. 82/IX/75

FOURTH ANNUAL MEETING - SEPTEMBER 1982

Vertebral Averages of Juvenile Cod (*Gadus morhua*) from Eastern Newfoundland and Labrador as Indicators of Stock Origin

by

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ABSTRACT

Vertebral averages of juvenile cod collected during 1956-70 in the coastal bays of eastern Newfoundland and Labrador were used as indicators of stock origin. The samples of young of the year cod from eastern Newfoundland were mainly of the high "northern" type with some intermediate values around the Avalon area, indicative of the Avalon stock complex or of intermingling with it and the northern stock complex. The averages of the 1-year-old cod were mainly of the high "northern" type, except for intermediate values among the 1960 and 1961 year-classes. The averages of the 2-year-old cod were mainly of the high "northern" type typical of the 2J3KL cod stock complex. The vertebral averages of the 1960 and 1961 year-classes were generally lower than those of other year-classes. The low vertebral averages of the 1960 and 1961 year classes are attributed to water temperatures off Newfoundland and/or delayed spawning resulting in a possibly higher incubation temperature and hence a lowered vertebral number.

INTRODUCTION

The coastal bays of eastern Newfoundland are nursery areas for large numbers of cod fry. Large numbers of age 0+ cod (1400-4800 in different years) were obtained at various localities along eastern Newfoundland in September-October 1959-64 (Fleming MS 1963; Lear et al. MS 1980). These cod were obtained by beach seining, where beaches were suitable, in depths of 1-11 m but mainly in 4-6 m (overall average of 1959-64 was 4.8 m) (Lear et al. MS 1980).

It has been hypothesized by May (MS 1966) and Templeman (1979, 1981) that these are the progeny of the Labrador-east Newfoundland cod stock which spawns during March-May (mainly March-April) in deep water along the continental shelf off Labrador (2GHJ) (Templeman 1964, 1965; Dias 1965, 1967). Off Northeast Newfoundland (3K) spawning occurs as far south as Funk Island Bank during March but mainly April to early May and possibly June (Templeman 1965, 1979; Dias 1965). On the basis of egg surveys it is possible the greatest spawning occurs off northern Labrador (Div. 2G) (Serebryakov 1967). There is also some later spawning in June in the colder water of the deep channels and bays closer to the coast (Templeman 1964; Chrzan 1968). During recent tagging cruises in February-March 1978-81, prespawning concentrations of cod have been observed on Hamilton Bank, Funk Island Bank, Belle Isle Bank and north cape of the Grand Bank in depths in excess of 250 m and bottom temperatures about 3°C.

Based upon developmental periods from fertilization to hatching reported by Aspstein (1909), Templeman (1981) estimated that cod eggs spawned off northern Labrador (Div. 2G) in March-April would take 50-60 days to hatch in surface temperatures of -1.5°C to 0°C and those spawned on the slopes of Hamilton Bank (Div. 2J) in March-April about 40 days to hatch in temperatures of -1° to 1°C.

Templeman (1981) used an average velocity of about 10 miles per day for the Labrador Current based upon findings from Islelin (1930), Smith (1931), Kiilerich (1939), Buzdalin and Elizarov (1962), Templeman (1966), Serebryakov (1967) and Postolaky (MS 1975). Templeman (1981) estimated that at 10 miles/day the eggs spawned off northern Labrador would drift 500-600 miles southward to the area off southern Labrador. Eggs spawned on the slopes of Hamilton Bank would drift about 400 miles to the northern Grand Bank and the Avalon Peninsula. This hypothesis is consistent with the appearance of cod larvae in May off mid-Labrador and in April and May off southern Labrador (Serebryakov 1967). Various researchers have demonstrated that cod eggs and larvae are most common in the upper water layers mainly in the upper 25-30 m (McKenzie 1940; Wilborg 1948, 1950).

During the southward drift of the cod larvae over the Northeast Newfoundland Shelf they are carried shoreward by the shoreward sweep of the Labrador Current caused by the Coriolis force of the earth's rotation. These larvae are brought into the bays and inlets of eastern Newfoundland where they are found during September-October at modal lengths of 6-9 cm with some specimens as small as

3-4 cm long (Fleming MS 1963).

The spawning cod from which these larvae are postulated to be the progeny are the high-vertebral average cod of the Labrador-east Newfoundland cod stock complex. This stock has the highest average vertebral numbers of any cod stock in the Northwest Atlantic (Templeman 1962, 1981).

Templeman (1962, 1981) summarized the cod vertebral averages for stocks in the Northwest Atlantic. The vertebral averages of the cod stocks in the Newfoundland-Labrador area can be summarized as follows.

(1) The Labrador-east Newfoundland stock complex possesses high vertebral averages (54.8-55.3) and typically above 55. This stock is located from northern Labrador southward along eastern Newfoundland to the northern part of the Avalon Peninsula and to the northwestern slope of Grand Bank.

(2) The southern Grand Bank possesses lowest vertebral averages of the eastern Newfoundland area, typically below but occasionally above 54. This stock is located on the southern part of the Grand Bank mainly in Div. 3N and 3O.

(3) The Flemish Cap stock possesses intermediate vertebral averages which are different from those of the adjacent northeastern Grand Bank.

(4) The northern Gulf - western south coast of Newfoundland stock complex has typically low vertebral averages (around 54) where there is no intermingling with high-vertebral average cod. The intermediate and high-vertebral counts from the northeastern Gulf and the Strait of Belle Isle indicate incursions of schools of the Labrador-east Newfoundland stock (Templeman 1981).

In this paper to facilitate the discussion of results the following convention is made when describing vertebral averages: (1) High (54.8 or greater), (2) Low (less than 54.0), and (3) Intermediate (54.1 to 54.7).

The purpose of this paper is to analyze the vertebral averages of juvenile cod collected during 1957-70 in eastern Newfoundland and southern Labrador to test the following hypotheses:

(i) juvenile cod in the bays of eastern Newfoundland, southern Labrador and Strait of Belle Isle are of the high-vertebral average Labrador-east Newfoundland cod stock complex,

(ii) within a given bay or area the vertebral averages of different year-classes of juvenile cod are not significantly different,

(iii) vertebral averages of juvenile cod of the various areas sampled are not significantly different from each other.

Additionally an attempt is made to investigate the relationship of vertebral averages of cod and water temperatures of the upper water column off the Newfoundland east coast during the period of egg and larval development.

RELATIONSHIP BETWEEN AND VERTEBRAL AVERAGES AND WATER TEMPERATURES IN EASTERN NEWFOUNDLAND AND LABRADOR

Laboratory experiments by various researchers have repeatedly demonstrated that low and high temperatures during late egg and early larval developmental stages tend to produce higher vertebral numbers in fishes than intermediate temperatures: Taning (1944, 1952) for sea trout, Salmo trutta; Lindsay (1954) for paradise fish, Macropodus opercularis; and Molander and Molander-Swedmark (1957) for plaice, Pleuronectes platessa. The higher vertebral numbers caused by high temperatures are not always observed under experimental conditions and not as a rule evident in mature. The higher vertebral averages at high temperatures under experimental conditions may be a phenomenon caused by other factors which retard the development of the larvae and hence increase vertebral numbers. Fahy (1972, 1976) found that embryos of Fundulus majalis reared continuously in temperature regimes ranging from 13° to 32°C developed vertebral numbers which were on the average inversely related to temperature. Dannevig (1950) reported, that for plaice eggs developed at temperatures of 4.9°C and 5.4C°, that the average number of vertebrae in the resultant larvae was 0.4 lower at the higher temperature. Clark and Vladykov (1960) noted that there was an inverse relationship between average number of vertebrae in haddock, Melanogrammus aeglefinus, and surface temperature at spawning time for both the Northeast and Northwest Atlantic stocks. Brander (1979) indicated that there was an inverse relationship between surface water temperature during early development and mean vertebral number for cod populations throughout the North Atlantic. He also found that the vertebral averages for different year-classes of cod in the North Sea showed some dependence on water temperature, and suggested that year-class should be taken into account, where possible, when seeking evidence of stock separation.

Taning (1952) for sea trout reared at temperatures of 3° to 6°C stated that the phenocritical period in which the number of vertebrae was established occurred within 13-23 days after fertilization and long before hatching of the

egg. There was also a short supersensitive period of about 20 degree days (i.e. from 145 to 165D°) when the number of vertebrae was extremely sensitive to a change in temperature. The vertebral number of the paradise fish, Macropodus opercularis was subject to change up to 11-12 days after hatching (Lindsay 1954). The vertebral number of the European plaice, Pleuronectes platessa could be altered by changes in temperature up to a least two weeks after hatching (Molander and Molander-Swedmark 1957).

MATERIALS AND METHODS

During 1956-70 juvenile cod (ages 0+ to 2 mainly and some 3-year-olds) were collected during regular small cod surveys (1959-64), inshore sampling trips (1956-60; 1965-70) and research vessel surveys in coastal bays of eastern Newfoundland and southern Labrador (Table 1, Fig. 1). All the samples were collected randomly as total catches or as randomly selected individuals of large catches which were subsampled.

The samples from St. Mary's Bay of the 1954-56 year-classes were obtained by lined otter trawl in depths of 95-132 m (Fig. 1). Samples from St. John's of the 1955-57 and 1959 year-classes were obtained by baited hook from a wharf in St. John's harbour. The samples from Twillingate, Lascie, Englee, St. Anthony, Quirpon, Red Bay, Battle Harbour, Venison Tickle and Port au Choix were taken during the summer either by baited hook or jigger spinner of the type used for trout angling. All other samples were obtained by beach seine as described by Lear et al. (MS 1980).

Examination of the material in the laboratory included extraction of the otoliths for age determination and removal of the flesh from the skeleton to facilitate counting the number of vertebrae. The smaller specimens were examined under the microscope to facilitate the counting of the vertebrae and to reduce the risk of errors in omitting vertebrae. The vertebrae from each specimen were initially counted twice by one person and an independent count was obtained by another person to serve as a check on the method and to reduce errors in counting. The vertebral counts were originally made according to the North American practice of omitting the urostylar half-vertebra. However, to conform with the European practice, the vertebral counts referred to in this paper include the urostylar half-vertebra as a vertebra. This enables easy comparison with the European material of Schmidt (1930) and Postolaky (1962) and with the results of Templeman (1981) and Lear et al. (1981).

Specimens with fused vertebrae were not included in the calculation of vertebral averages used in Tables 2-9. Ages were determined from otoliths and specimens were assigned to specific year-classes on the basis of age determination from otoliths.

For each of the ages 0+ (young of the year), 1, 2 and 3 year-old-cod from each area sampled (Tables 1-5), Levene's test of homogeneity of variances (Brown and Forsythe 1974b) were performed on the vertebral data for the various year-classes. These tests indicated that the variances of the vertebral averages were homogeneous within each area for each age group (p in each case greater than .05). Levene's test was also performed for each of the ages 0+, 1, 2 and 3-year-old cod from each year-class to test the homogeneity of variances among areas (Tables 6-9). For each age and year-class the variances of the vertebral averages were homogeneous among areas (P in each case greater than .05). One way analyses of variance and the Brown-Forsythe test (F*) were conducted on the vertebral averages of different year-classes by area for each of the ages 0+, 1, 2 and 3-year-old cod using the Biomedical Computer Program (BMDP7D) (Dixon and Brown 1979). In each case analyzed, the results of the ANOVA and F* statistic were identical or closely similar and yielded the same statistical decision regarding the significance of difference among average vertebral numbers.

Duncan's multiple range tests (Kramer 1956) were performed on the vertebral averages of year-classes which differed significantly within areas. Where an analysis of variance and/or Duncan's test revealed no significant differences between averages, this is shown in Tables 2-5 by those averages underscored by the same continuous line as for Area 1 in Table 2. Where two or more values are not underscored by the same line it indicates that these averages are significantly different at the .05 level as for Area 5 in Table 2. Tables 6-9 are presented in the same way to show similarities and differences among the vertebral averages of different areas by year-class.

In Fig. 2-5, the vertebral averages of each age group are presented by area. The highest vertebral averages which are not significantly different from each other at the .05 level, are combined for each age group and area and the significantly lower values, if any, are listed separately together with the specific year-classes combined in any one grouping.

An attempt was made to investigate the relationship between the vertebral averages of specific year-classes of juvenile cod from eastern Newfoundland and water temperatures in the upper water column. The largest range of data available, was from Notre Dame Bay, juvenile cod (0+, 1 and 2 year-olds combined) of the 1959 to 1969 year-classes (inclusive). The only long term monthly sea temperature data by depth was from station 27 (off Cape Spear) and which is considered to be an indication of temperatures prevailing in the Labrador Current water since station 27 is in the Avalon Channel through which the inner branch of the Labrador Current flows southward along the shores of the eastern Avalon Peninsula of Newfoundland.

RESULTS

VARIATIONS AMONG YEAR-CLASSES

Age 0+ (young of the year)

The vertebral averages of cod fry caught in St. Mary's Bay were of the intermediate cod high type (54.60 to 54.97) and were indicative of the Avalon stock complex or of intermingling of Avalon and Labrador-east Newfoundland stock. The samples from Trepassey Bay and Cape Broyle were all of the high Larador-east Newfoundland (hereafter called "northern") type. In Conception Bay the vertebral averages (55.00-55.24) were of the high northern type except for a small sample of the 1963 year-class which was atypically low (53.80) (Table 2, Fig. 2). At Rantem, Trinity Bay, all the vertebral averages were of the northern type (54.91-55.26). At Lockston, Trinity Bay, all except the 1960 year-class (54.50) were of the high northern type (55.00-55.43). At Chandler's Reach, Bonavista Bay, all the vertebral averages were of the high northern type (54.89-55.25). At Indian Bay, Bonavista Bay, the 1962, 1963 and 1964 year-clases were of the high northern type (54.91-55.30), while the 1961 average was intermediate (54.46) and the 1960 was low (53.93).

The vertebral averages of the cod fry from Gander Bay were mainly of the northern type (54.95-55.19) except the intermediate average of 54.67 for the 1959 year-class which was significantly different from the highest value of 55.19 for the 1962 year-class.

The averages for Bridgeport, Luke's Arm, Fortune Harbour, Springdale and Middle Arm, were all generally of the high northern type although the averages

for the 1960 year-class for Fortune Harbour and Springdale (54.59 and 54.55 respectively) and the 1963 year-class for Fortune Harbour (54.72) were of the intermediate type.

One-year-old-cod

The vertebral averages of the one-year-old cod from eastern Newfoundland, Labrador and the Strait of Belle Isle were of the high vertebral northern type with the exception of the 1960 year-class from St. Mary's Bay (54.63), Trepassey Bay (54.27), Conception Bay (54.02), Rantem, Trinity Bay (54.37), Lockston, Trinity Bay (54.05), Bridgeport (54.74), Fortune Harbour, Notre Dame Bay (54.14), Springdale (54.50) and the 1961 year-class from St. Mary's Bay (54.14), Trepassey Bay (54.73), Chandler's Reach, Bonavista Bay (54.41), Indian Bay (54.48), Fortune Harbour, Notre Dame Bay (54.11) (Table 3, Fig. 3) and the 1963 year-class from Indian Bay (54.65).

The samples from Indian Bay, Bonavista Bay varied from an intermediate value of 54.48 (1961 year-class) to a high of 54.90 (1959 year-class) which is the lower range of the northern type but the differences among the four year-classes compared were not signficantly different at the .05 level. There was one exceptionally high value of 55.68 for the 1959 year-class from St. John's (Table 3).

Two-year-old-cod

The vertebral averages of the two-year-old cod from St. Mary's Bay were in the low to intermediate range (53.80-54.71) (Table 4, Fig. 4). The two samples from St. John's were also of intermediate value (54.43 and 54.57) and were within the range of values reported by Templeman (1981) for adult cod sampled during 1961-71 at St. John's. The 1960 year-class averages for Conception Bay and Rantem, Trinity Bay were also low (54.05 and 53.92 respectively). The cod of the 1957 year-class from Conception Bay were of the high northern type (55.02). The averages from the Bridgeport area, Twillingate, Lascie, Englee, St. Anthony, Red Bay, Battle Harbour, and Venison Tickle were mainly all of the high vertebral northern type. Exceptions were the intermediate values of 54.74 from Englee (1963 year-class), 54.70 from St. Anthony (1966) and 54.73 for Battle Harbour (1961). As was the case for the 0+ and one-year-old cod, the 1960 year-class values for some areas (St. Mary's Bay, Conception Bay,

Rantem, Fortune Harbour and Middle Arm) were of low to intermediate value (53.80-54.30). The 1960 year-class for Springdale was of the high type (55.0). Other values of intermediate level were the averages for the 1959 year-class at Middle Arm (54.32), the 1966 year-class from Quirpon (54.46) and the 1963 year-class from Port au Choix (54.42).

Three-year-old cod

The two samples from St. Mary's Bay had intermediate vertebral averages (54.05 and 54.51) (Table 5; Fig. 5). The vertebral averages from Englee, St. Anthony, and Quirpon were mainly of the higher northern type except for that of the 1965 year-class from St. Anthony which was intermediate (54.69).

VARIATION AMONG AREAS BY YEAR-CLASS

(0+) Young-of-the-year cod

The vertebral averages of the 1959 year-class from Conception Bay and Lockston were typical of the northern type (55.04 and 55.08) (Table 6). The value from Gander Bay was intermediate (54.67) and significantly different from the higher values.

The vertebral averages of the 1960 year-class from four of the six areas sampled varied from low to intermediate (53.93-54.59) from Lockston north to Springdale. For the 1960 year-class the averages for Cape Broyle and Conception Bay were highest (54.98 and 55.02 respectively).

Averages for the 1961 year-class groupings indicated that the young of the year were mainly of the high vertebral average northern type (54.89-55.80) except for two intermediate values of 54.46 and 54.60 from Indian Bay and St. Mary's Bay respectively. Only the extremely high value of 55.80 was significantly different from the other values.

The averages of the 1962 year-class samples were all of the higher northern type (54.90-55.56) from the 11 areas sampled although there were significant differences between the lowest and the highest values.

The averages of the 1963 year-class samples, with the exception of the low average of 53.80 from Conception Bay and the intermediate values of 54.72 and 54.73 from Fortune Harbour and St. Mary's Bay were of the higher average northern type (54.91-55.29). Although there were significant differences among these 11 averages, only the highest (55.29) average was significantly

higher than the lower average of 54.72 (with the exception of the Conception Bay average). The nine areas sampled for the 1964 year-class were not significantly different from each other and all possessed typically high vertebral averages (54.85-55.30).

One-year-old cod

In the areas sampled, the 1955, 1956, 1957, 1958, and 1959 year-classes possessed the high vertebral averages typical of the Labrador-eastern Newfoundland stocks with averages ranging from 54.75-55.68 (Table 7). The vertebral averages of the 1960 year-class from eight of the nine areas sampled were of low to intermediate values (54.02-54.74). The remaining area possessed a high vertebral average typical of the northern type (54.96). Similarly, the averages of the 1961 year-classes from five areas exhibited low to intermediate values (54.11-54.73) while the majority of the areas (six) possessed higher vertebral averages of the 2J3KL type (54.78-55.33). There were no significant differences among nine of the areas with averages ranging from 54.41 to 55.33.

All vertebral averages from the areas sampled for the 1962, 1963, 1965, 1966, 1967, 1968, and 1969 year-classes were of the high intermediate or the higher northern type (54.65-55.35) (Table 7). For the 1963 year-classes there were significant differences among the two lower values (54.65 and 54.75) and the highest value of 55.20.

Two-year-old cod

The vertebral averages of the 1955 year-class from St. Mary's Bay and St. John's were intermediate in value (54.40-54.43) (Table 8) while those of 1956 for the same areas were somewhat higher (54.57-54.71) but still intermediate. The averages of the 1957, 1961, 1963, 1964, 1965, 1967, and 1968 year-classes from the areas sampled (mainly east and northeast coast of Newfoundland) were of the higher 2J3KL type with ranges of 54.73 to 55.35. The 1959 year-class samples from Rantem, Fortune Harbour and Quirpon were of intermediate to high values (54.32-54.83). The 1960 year-class values of vertebral averages from the four areas (Rantem, Conception Bay, Fortune Harbour and Middle Arm) were low (53.92) to intermediate (54.05 to 54.30) with only one area, Springdale exhibiting a typically high northern average of 55.00.

The vertebral average for the 1962 year-class from St. Mary's Bay was of intermediate value (54.50) while that of Twillingate was of the high type (55.31). These ere significantly different from each other.

The average for the 1966 year-class from Port-au-Choix was of intermediate value (54.42) as were those of Quirpon (54.46) and St. Anthony (54.70). The values from samples collected at Twillingate, Lascie, and Englee were of the high northern type (54.96-55.16).

Three-year-old cod

The vertebral averages of 3-year-old cod of the 1954 and 1955 year-class groups from St. Mary's Bay were of the intermediate level (54.05-54.51) (Table 9).

The vertebral averages of the 1963 year-class from St. Anthony, the 1965 year-class from Englee, and Quirpon and the 1967 year-class from St. Anthony were higher values of the norther type (54.92-55.08). The 1965 year-class from St. Anthony was of the intermediate type (54.69) but not significantly different from the high value of 55.0.

RELATIONSHIP BETWEEN VERTEBRAL AVERAGE AND TEMPERATURE

The vertebral averages of juvenile cod from Notre Dame Bay of the 1959-69 year-classes were regressed against the average temperatures at station 27 for the 0-25 m, 0-50 m, 0-100 m, and 0-bottom for each of the months of March, April and May. No significant correlations resulted from this analysis. An inspection of the data indicated three anomalous points (1960, 1961 and 1968 year-classes (Fig. 6). The lower vertebral average for 1961 may be due to late spawning in that year. Templeman (1964) states that during 1961 many more cod than usual had not spawned before moving to the shallow inshore water since spawning was evidently delayed by cold water on the cod wintering grounds. Templeman (1964), Chrzan (1968) and Dias (1972) report that there is some spawning of the 2J3KL stock in June in the colder water of the deep channels and bank slopes closer to the coast. This probably also occurred during 1960 but there is no evidence to support this hypothesis. The high vertebral average of the 1968 year-class may be the result of the more southerly drift of more northerly spawned cod or of advanced spawning. Because of lack of evidence the assumed temperatures during development were not adjusted for the 1960 and 1968 year-classes. On the basis of the evidence for late spawning during 1961, the vertebral average of the 1961 year-class was regressed against the temperature of the water layers during June of that year. All the preceding regressions were run again using this adjustment. The only significant correlation ($P < .05$; $r = 0.67$) was that between the vertebral average of juvenile cod

from Notre Dame Bay (year-classes of 1959-69) and the average temperature in the upper water column (0-100 m) at station 27 (Fig. 6).

DISCUSSION AND CONCLUSIONS

The high vertebral averages of the 0+ (young-of-the-year) cod from eastern and southeastern Newfoundland, with the exceptions of the 1960 and 1961 year-classes in some areas, suggest that these are derived from the spawning of the Labrador-East Newfoundland cod stock. The low value of 53.80 from Conception Bay (1963 year-class) may reflect local spawning or a mixture with the Avalon stock. In St. Mary's Bay the intermediate value of 54.73 may suggest intermingling of northern and Avalon stock.

With the exception of the 1960 and 1961 year-classes, the vertebral avearages of 1-year-old cod from Venison Tickle, Labrador, southwards along the coast of Labrador, northeastern and southeastern Newfoundland as far as St. Mary's Bay, and including one sample from Port au Choix, were of the high northern type. The lower averages for the 1960 and 1961 year-classes may, as already discussed, be attributed to late spawning or conditions after spawning which favoured more rapid development of eggs and larvae which would tend to lower the vertebral averages. In southeastern Newfoundland there may also have been some intermingling of the northern juvenile cod with those of the Avalon stock which spawns as far north as the northwestern part of the Grand Bank (Templeman 1981). The vertebral averages of 2-year-old juvenile cod were generally of the high northern type. The sample from Port-au-Choix was intermediate probably indicative that they are of the Gulf of St. Lawrence origin. The similarly low value from Quirpon possibly represents a migration of juvenile Gulf cod as far north as Cape Bauld. The high values from St. Anthony, Englee, Lascie, Bridgeport and Twillingate were generally of the high northern type. There were intermediate values from Middle Arm (1960 year-class), Springdale (1958 year-class) Fortune Harbour (1959-60 year-classes), possibly indicative of local or late spawning or of intermingling with the northern segment of Avalon stock cod. Values around the Avalon Peninsula were generally low to intermediate except for that of the 1957 year-class from Conception Bay. In these areas the lower vertebral averages may be indicative that the 2-year-olds are of the Avalon stock of cod. It is possible that the 2-year-olds of the northern type may have begun to migrate northwards along the coast. This hypothesis is currently being tested by tagging of juvenile cod in the bays of

eastern Newfoundland.

The 3-year-old cod sampled at Quirpon, St. Anthony and Englee were of the high northern type. While those from St. Mary's Bay were intermediate suggesting Avalon stock origin.

Generally there were no significant differences among most of the year-classes within areas for the young-of-the year cod from eastern Newfoundland. Where differences did occur these were mainly samples of the 1960 or 1961 year-classes except for a small sample of 10 fish of the 1963 year-class from Conception Bay.

Again for the 1-year-old cod the only differences among year-classes within areas were mainly from samples of the 1960 and 1961 year-classes. There were significant differences among year-classes within areas for only several areas, for the 2-year-old cod, again mainly the 1960 and 1961 year-classes. At St. Anthony there were no significant differences among year-classes of the 3-year-old cod.

For the young of the year and the 1-year-old cod there were significant differences among areas within most year-classes groupings but there was no evidence of a strong clinal trend in vertebral averages from south to north. A similar situation was evident from the vertebral aveages of the 2-year-old cod although differences were few and mainly resulted from a single outlying value. The differences among vertebral averages of different year-classes for cod from Notre Dame Bay were correlated with the water temperatures off eastern Newfoundland after adjustments were made for the anomalous value for 1961.

ACKNOWLEDGMENTS

The authors are indebted to Mr. A. M. Fleming who collected most of the juvenile cod data, to Mr. T. Collier, and the late Mr. C. J. Woodford who were responsible for most of the vertebral counting of the juvenile cod.

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Table 1. List of sampling localities and number of vertebral columns examined for the age groups 0+, 1, 2 and 3 year-old Atlantic cod (Gadus morhua) from coastal Newfoundland and Labrador for the year-classes of 1954-69.

Area code	Locality	Age 0+		Age 1		Age 2		Age 3	
		No.	Year-classes	No.	Year-classes	No.	Year-classes	No.	Year-classes
1	St. Mary's Bay	142	1961-63	266	1956; 1959-63	410	1955-56; 1960; 1962	92	1954-55
2	Trepassey	21	1963	200	1960-63	-	-	-	-
3	Cape Broyle	160	1960-63	186	1959-60; 1962-63	-	-	-	-
4	St. John's	-	-	306	1955-57; 1959	21	1955-56	-	-
5	Conception Bay	190	1959-63	425	1958-63	78	1957; 1960	-	-
6	Rantem, Trinity Bay	195	1961-64	175	1960-63	13	1960	-	-
7	Lockston, Trinity Bay	654	1959-64	186	1960-63	-	-	-	-
8	Chandlers Reach, Bonavista Bay	164	1961-64	157	1959; 1961; 1963	-	-	-	-
9	Indian Bay, Bonavista Bay	182	1960-64	107	1959; 1961-63	-	-	-	-
10	Gander Bay	161	1959; 1962-64	78	1962-63	-	-	-	-
11	Bridge Port, Luke's Arm, N.D. Bay	78	1962; 1964	156	1959-60; 1962-63	6	1959	-	-
12	Twillingate	-	-	362	1963; 1966-69	363	1962-63; 1965-66; 1968	-	-
13	Fortune Harbour	197	1960; 1962-64	166	1960-63	20	1959-60	-	-
14	Springdale	146	1960; 1962-64	199	1959-63	38	1959-60	-	-
15	Middle Arm, Green Bay	88	1963-64	137	1959; 1961-63	10	1960	-	-
16	LaScie	-	-	281	1967-68	205	1963; 1966-67	-	-
17	Englee	-	-	145	1967-68	319	1963; 1966-67	7	1965
18	St. Anthony	-	-	396	1965-68	649	1963-68	38	1963; 1965; 1967
19	Quirpon	-	-	-	-	26	1966	9	1965
20	Red Bay	-	-	59	1961	51	1967	-	-
21	Battle Harbour	-	-	48	1962	123	1957; 1961	-	-
22	Venison Tickle	-	-	22	1962	118	1957	-	-
23	Port Au Choix	-	-	20	1967	159	1966	-	-

Table 2. Results of analyses of variance and Duncan's Multiple Range Tests on vertebral averages of juvenile, age 0+, cod from various areas and of various year-classes.

Area	Year-class (number in sample) Vertebral average (standard error)					
1	1961 (10) 54.600 (.267)	1963 (56) 54.732 (.166)	1962 (76) 54.974 (.111)			
2	1963 (21) 55.048 (.223)					
3	1960 (50) 54.980 (.129)	1963 (53) 55.038 (.126)	1962 (47) 55.085 (.135)	1961 (10) 55.800 (.200)		
5	1963 (10) 53.800 (.327)	1961 (11) 55.000 (.234)	1960 (58) 55.017 (.103)	1959 (57) 55.035 (.112)	1962 (54) 55.241 (.135)	
6	1961 (42) 54.905 (.183)	1963 (46) 55.130 (.151)	1962 (56) 55.232 (.102)	1964 (51) 55.255 (.118)		
7	1960 (26) 54.500 (.159)	1963 (45) 55.000 (.152)	1961 (64) 55.047 (.125)	1959 (428) 55.077 (.043)	1964 (49) 55.143 (.140)	1962 (42) 55.429 (.145)
8	1961 (18) 54.889 (.159)	1963 (63) 54.937 (.106)	1964 (31) 55.129 (.111)	1962 (52) 55.250 (.106)		
9	1960 (83) 53.928 (.115)	1961 (13) 54.462 (.268)	1963 (34) 54.912 (.176)	1962 (29) 55.069 (.140)	1964 (23) 55.304 (.171)	
10	1959 (39) 54.667 (.177)	1964 (21) 54.952 (.146)	1963 (49) 55.041 (.109)	1962 (52) 55.192 (.117)		
11	1964 (27) 55.111 (.180)	1962 (51) 55.137 (.131)				
13	1960 (63) 54.587 (.149)	1963 (47) 54.723 (.182)	1962 (51) 54.902 (.132)	1964 (36) 55.056 (.169)		
14	1960 (51) 54.549 (.135)	1964 (20) 54.850 (.182)	1963 (27) 55.185 (.185)	1962 (48) 55.563 (.122)		
15	1964 (47) 55.128 (.108)	1963 (41) 55.293 (.112)				

Table 3. Results of analyses of variance and Duncan's Multiple Range Tests on vertebral averages of juvenile, age 1, cod from various areas and of various year-classes.

Area	Year-class (number in sample) Vertebral average (standard error)					
1	1961 (72) 54.139 (.151)	1960 (46) 54.630 (.147)	1963 (40) 54.800 (.135)	1962 (46) 54.935 (.157)	1956 (19) 55.105 (.252)	1959 (43) 55.139 (.131)
2	1960 (45) 54.267 (.157)	1961 (52) 54.731 (.158)	1963 (49) 54.959 (.116)	1962 (54) 55.056 (.148)		
3	1963 (25) 54.880 (.156)	1960 (51) 54.961 (.148)	1959 (64) 55.031 (.100)	1962 (46) 55.348 (.121)		
4	1955 (107) 55.168 (.097)	1957 (78) 55.256 (.090)	1956 (77) 55.429 (.088)	1959 (44) 55.682 (.133)		
5	1960 (48) 54.021 (.153)	1959 (48) 54.750 (.117)	1961 (30) 54.767 (.196)	1963 (52) 54.904 (.135)	1962 (45) 55.044 (.131)	1958 (202) 55.064 (.070)
6	1960 (46) 54.370 (.171)	1963 (51) 54.863 (.097)	1961 (28) 55.036 (.221)	1962 (50) 55.100 (.141)		
7	1960 (40) 54.050 (.164)	1963 (48) 54.792 (.119)	1961 (50) 54.920 (.117)	1962 (48) 55.000 (.133)		
8	1961 (49) 54.408 (.175)	1959 (56) 54.929 (.101)	1963 (52) 55.135 (.137)			
9	1961 (21) 54.476 (.203)	1963 (26) 54.654 (.135)	1962 (29) 54.862 (.209)	1959 (31) 54.903 (.182)		
10	1961 (34) 54.735 (.176)	1963 (44) 55.159 (.112)				
11	1960 (23) 54.739 (.211)	1963 (36) 54.750 (.166)	1962 (50) 55.100 (.125)	1959 (47) 55.234 (.126)		
12	1969 (19) 54.737 .274)	1966 (9) 55.111 (.261)	1967 (89) 55.112 (.079)	1963 (108) 55.204 (.069)	1968 (137) 55.248 (.065)	
13	1961 (37) 54.108 (.204)	1960 (35) 54.143 (.170)	1963 (46) 54.957 (.112)	1962 (48) 55.042 (.115)		
14	1960 (26) 54.500 (.114)	1961 (29) 54.931 (.156)	1959 (44) 55.091 (.162)	1962 (49) 55.122 (.132)	1963 (51) 55.176 (.104)	
15	1963 (41) 54.951 (.135)	1959 (44) 55.045 (.130)	1962 (46) 55.087 (.152)	1961 (6) 55.333 (.558)		
16	1967 (183) 54.945 (.055)	1968 (98) 55.153 (.087)				
17	1967 (62) 54.952 (.104)	1968 (83) 55.084 (.091)				
18	1967 (50) 54.800 (.146)	1965 (175) 55.011 (.060)	1968 (42) 55.143 (.143)	1966 (130) 55.169 (.075)		
20	1961 (59) 55.237 (.137)					
21	1962 (48) 55.313 (.108)					
22	1962 (22) 55.227 (.146)					
23	1967 (20) 55.000 (.178)					

Table 4. Results of analyses of variance and Duncan's Multiple Range Tests on vertebral averages of juvenile, age 2, cod from various areas and of various year-classes.

Area	Year-class (number in sample) Vertebral average (standard error)					
1	1960 (5) 53.800 (.374)	1955 (315) 54.400 (.068)	1962 (8) 54.500 (.327)	1956 (82) 54.707 (.130)		
4	1955 (14) 54.429 (.251)	1956 (7) 54.571 (.202)				
5	1960 (22) 54.045 (.242)	1957 (56) 55.018 (.136)				
6	1960 (13) 53.923 (.265)					
11	1959 (6) 54.833 (.307)					
12	1965 (115) 54.983 (.086)	1963 (64) 55.109 (.078)	1966 (55) 55.164 (.121)	1968 (90) 55.300 (.098)	1962 (39) 55.308 (.098)	
13	1960 (7) 54.143 (.340)	1959 (13) 54.615 (.213)				
14	1959 (19) 54.316 (.230)	1960 (19) 55.000 (.202)				
15	1960 (10) 54.300 (.260)					
16	1963 (99) 54.889 (.8)	1966 (91) 54.956 (.087)	1967 (15) 55.200 (.145)			
17	1963 (93) 54.742 (.079)	1966 (50) 54.960 (.121)	1967 (176) 54.994 (.063)			
18	1966 (92) 54.696 (.103)	1967 (98) 54.888 (.069)	1968 (86) 54.895 (.091)	1963 (194) 54.923 (.053)	1964 (55) 55.018 (.102)	1965 (124) 55.089 (.078)
19	1966 (26) 54.462 (.216)					
20	1967 (51) 55.118 (.124)					
21	1961 (11) 54.727 (.141)	1957 (112) 55.304 (.084)				
22	1957 (118) 55.347 (.077)					
23	1966 (159) 54.421 (.099)					

Table 5. Results of analyses of variance and Duncan's Multiple Range Tests on vertebral averages of juvenile, age 3, cod from various areas and of various year-classes.

Area	Year-class (number in sample) Vertebral average (standard error)		
1	1954 (57) 54.053 (.140)	1955 (35) 54.514 (.202)	
17	1965 (7) 55.000 (.218)		
18	1965 (13) 54.692 (.328)	1967 (12) 54.917 (.229)	1963 (13) 55.077 (.178)
19	1965 (9) 55.000 (.236)		

Table 6. Results of analyses of variance and Duncan's Multiple Range Tests on vertebral averages of juvenile, age 0+, cod of various year-classes from various areas.

Year-class	Area (number in sample) Vertebral average (standard error)											
1959	10 (39) 54.667 (.177)	5 (57) 55.035 (.112)	7 (428) 55.077 (.043)									
1960	9 (83) 53.928 (.115)	7 (26) 54.500 (.159)	14 (51) 54.549 (.135)	13 (63) 54.587 (.149)	3 (50) 54.980 (.129)	5 (58) 55.017 (.103)						
1961	9 (13) 54.462 (.268)	1 (10) 54.600 (.267)	8 (18) 54.889 (.159)	6 (42) 54.905 (.183)	5 (11) 55.000 (.234)	7 (64) 55.047 (.125)	3 (10) 55.800 (.200)					
1962	13 (51) 54.902 (.132)	1 (76) 54.974 (.111)	9 (29) 55.069 (.140)	3 (47) 55.085 (.135)	11 (51) 55.137 (.131)	10 (52) 55.192 (.117)	6 (56) 55.232 (.102)	5 (54) 55.241 (.135)	8 (52) 55.250 (.106)	7 (42) 55.429 (.145)	14 (48) 55.562 (.122)	
1963	5 (10) 53.800 (.327)	13 (47) 54.723 (.182)	1 (56) 54.732 (.166)	9 (34) 54.912 (.176)	8 (63) 54.937 (.106)	7 (45) 55.000 (.152)	3 (53) 55.038 (.126)	10 (49) 55.041 (.109)	2 (21) 55.048 (.223)	6 (46) 55.130 (.151)	14 (27) 55.185 (.185)	15 (41) 55.293 (.112)
1964	14 (20) 54.850 (.182)	10 (21) 54.952 (.146)	13 (36) 55.056 (.169)	11 (27) 55.111 (.180)	15 (47) 55.128 (.108)	8 (31) 55.129 (.111)	7 (49) 55.143 (.140)	6 (51) 55.255 (.118)	9 (23) 55.304 (.171)			

Table 7. Results of analyses of variance and Duncan's Multiple Range Tests on vertebral averages of juvenile, age 1, cod of various year-classes from various areas.

Year-class	Area (number in sample) Vertebral average (standard error)														
1955	4 (107) 55.168 (.097)														
1956	1 (19) 55.105 (.252)	4 (77) 55.429 (.088)													
1957	4 (78) 55.256 (.090)														
1958	5 (202) 55.064 (.070)														
1959	5 (48) 54.750 (.117)	9 (31) 54.903 (.182)	8 (56) 54.929 (.101)	3 (64) 55.031 (.100)	15 (44) 55.045 (.130)	14 (44) 55.091 (.162)	1 (43) 55.140 (.131)	11 (47) 55.234 (.126)	4 (44) 55.682 (.133)						
1960	5 (48) 54.021 (.153)	7 (40) 54.050 (.164)	13 (35) 54.143 (.170)	2 (45) 54.267 (.157)	6 (46) 54.370 (.171)	14 (26) 54.500 (.114)	1 (46) 54.630 (.147)	11 (23) 54.739 (.211)	3 (51) 54.961 (.148)						
1961	13 (37) 54.108 (.204)	1 (72) 54.139 (.151)	8 (49) 54.408 (.175)	9 (21) 54.476 (.203)	2 (52) 54.731 (.158)	5 (30) 54.767 (.196)	7 (50) 54.920 (.117)	14 (29) 54.931 (.156)	6 (28) 55.036 (.221)	20 (59) 55.237 (.137)	15 (6) 55.333 (.558)				
1962	10 (34) 54.735 (.176)	9 (29) 54.862 (.209)	1 (46) 54.935 (.157)	13 (48) 55.042 (.115)	5 (45) 55.044 (.131)	2 (54) 55.056 (.148)	15 (46) 55.087 (.152)	7 (48) 55.000 (.133)	6 (50) 55.100 (.141)	11 (50) 55.100 (.125)	14 (49) 55.122 (.132)	22 (22) 55.227 (.146)	21 (48) 55.312 (.108)	3 (46) 55.348 (.121)	
1963	9 (26) 55.654 (.135)	11 (36) 54.750 (.166)	7 (48) 54.792 (.119)	1 (40) 54.800 (.135)	6 (51) 54.863 (.097)	3 (25) 54.880 (.156)	5 (52) 54.904 (.135)	15 (41) 54.951 (.135)	13 (46) 54.957 (.112)	2 (49) 54.959 (.116)	8 (52) 55.135 (.137)	10 (44) 55.159 (.112)	14 (51) 55.176 (.104)	12 (108) 55.204 (.069)	
1965	18 (175) 55.011 (.060)														
1966	12 (9) 55.111 (.261)	18 (130) 55.169 (.075)													
1967	18 (50) 54.800 (.146)	16 (183) 54.945 (.055)	17 (62) 54.952 (.104)	23 (20) 55.000 (.178)	12 (89) 55.112 (.079)										
1968	17 (83) 55.084 (.091)	18 (42) 55.143 (.143)	16 (98) 55.153 (.089)	12 (137) 55.248 (.065)											
1969	12 (19) 54.737 (.274)														

Table 8. Results of analyses of variance and Duncan's Multiple Range Tests on vertebral averages of juvenile, age 2, cod of various year-classes from various areas.

Year-class	Area (number in sample) Vertebral average (standard error)					
1955	1 (315) 54.400 (.068)	4 (14) 54.429 (.251)				
1956	4 (7) 54.571 (.202)	1 (82) 54.707 (.130)				
1957	5 (56) 55.018 (.136)	21 (112) 55.304 (.084)	22 (118) 55.347 (.077)			
1959	14 (19) 54.316 (.230)	13 (13) 54.615 (.213)	11 (6) 54.833 (.307)			
1960	1 (5) 53.800 (.374)	6 (13) 53.923 (.265)	5 (22) 54.045 (.242)	13 (7) 54.143 (.340)	15 (10) 54.300 (.260)	14 (19) 55.000 (.202)
1961	21 (11) 54.727 (.141)					
1962	1 (8) 54.500 (.327)	12 (39) 55.308 (.098)				
1963	17 (93) 54.742 (.079)	16 (99) 54.889 (.078)	18 (194) 54.923 (.053)	12 (64) 55.109 (.078)		
1964	18 (55) 55.018 (.102)					
1965	12 (115) 54.983 (.086)	18 (124) 55.089 (.078)				
1966	23 (159) 54.421 (.099)	19 (26) 54.462 (.216)	18 (92) 54.696 (.103)	16 (91) 54.956 (.087)	17 (50) 54.960 (.121)	12 (55) 55.164 (.121)
1967	18 (98) 54.888 (.069)	17 (176) 54.994 (.063)	20 (51) 55.118 (.124)	16 (15) 55.200 (.145)		
1968	18 (86) 54.895 (.091)	12 (90) 55.300 (.098)				

Table 9. Results of analyses of variance and Duncan's Multiple Range Tests on vertebral averages of juvenile, age 3, cod of variance year-classes from various areas.

Year-class	Area (number in sample) Vertebral average (standard error)		
1954	1 (57) 54.053 (.140)		
1955	1 (35) 54.514 (.202)		
1963	18 (13) 55.077 (.178)		
1965	18 (13) 54.692 (.328)	17 (7) 55.000 (.218)	19 (9) 55.000 (.236)
1967	18 (12) 54.917 (.229)		

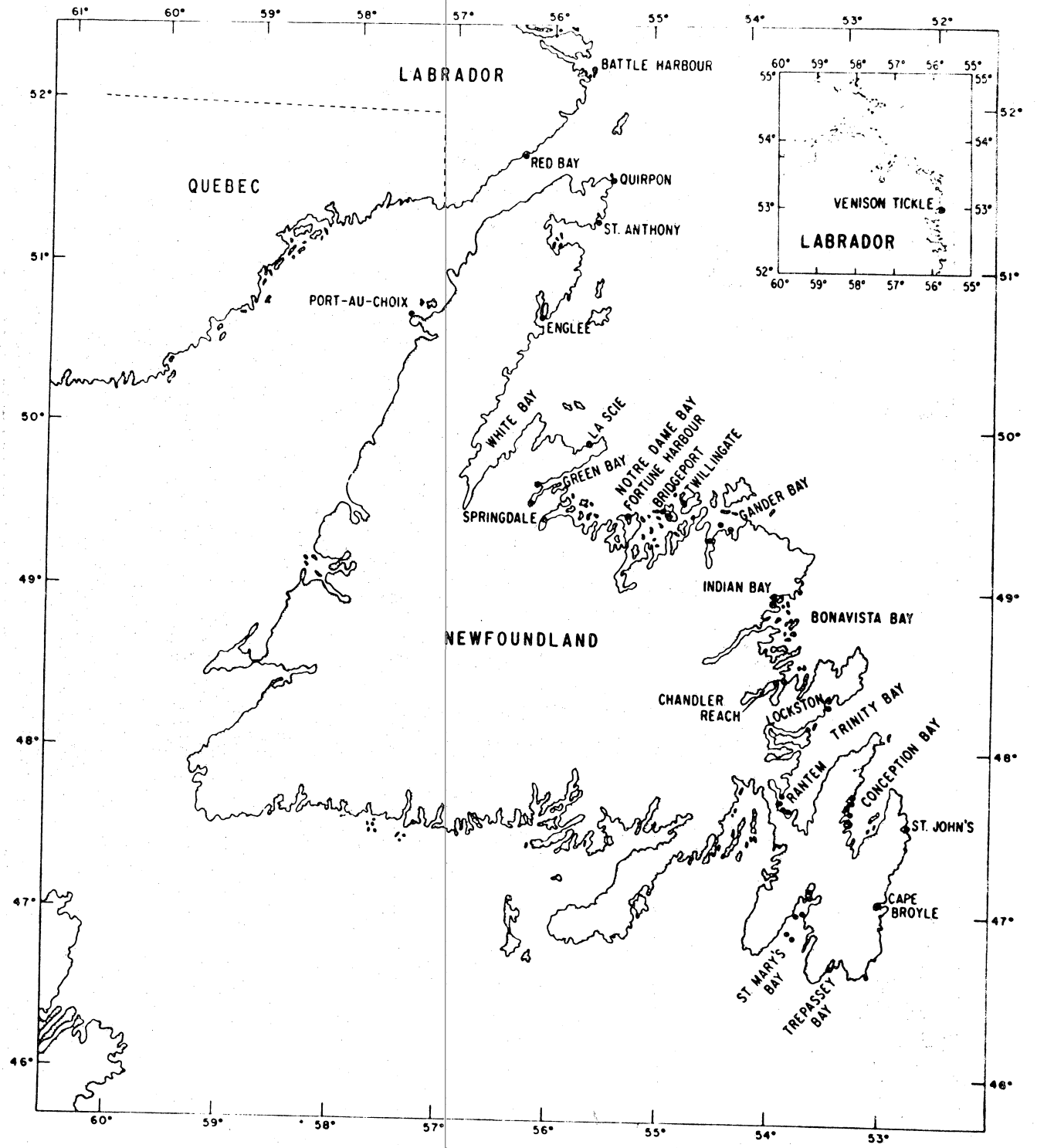

Fig. 1. Area map of Newfoundland and Labrador (inset) showing sampling locations and place names mentioned in the text.

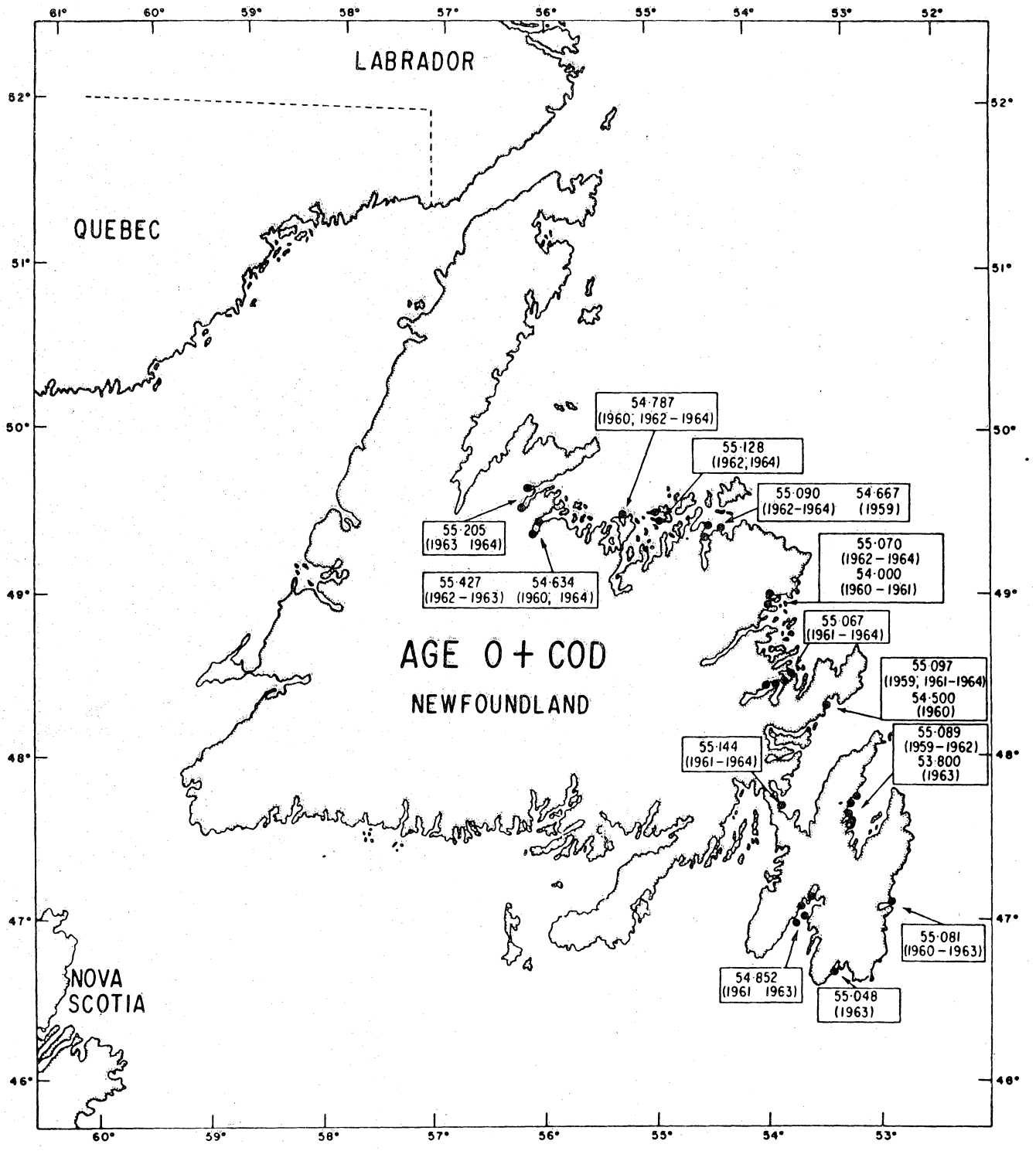

Fig. 2. Vertebral averages of 0+ (young-of-the-year) cod from various localities in eastern Newfoundland grouped by year-classes.

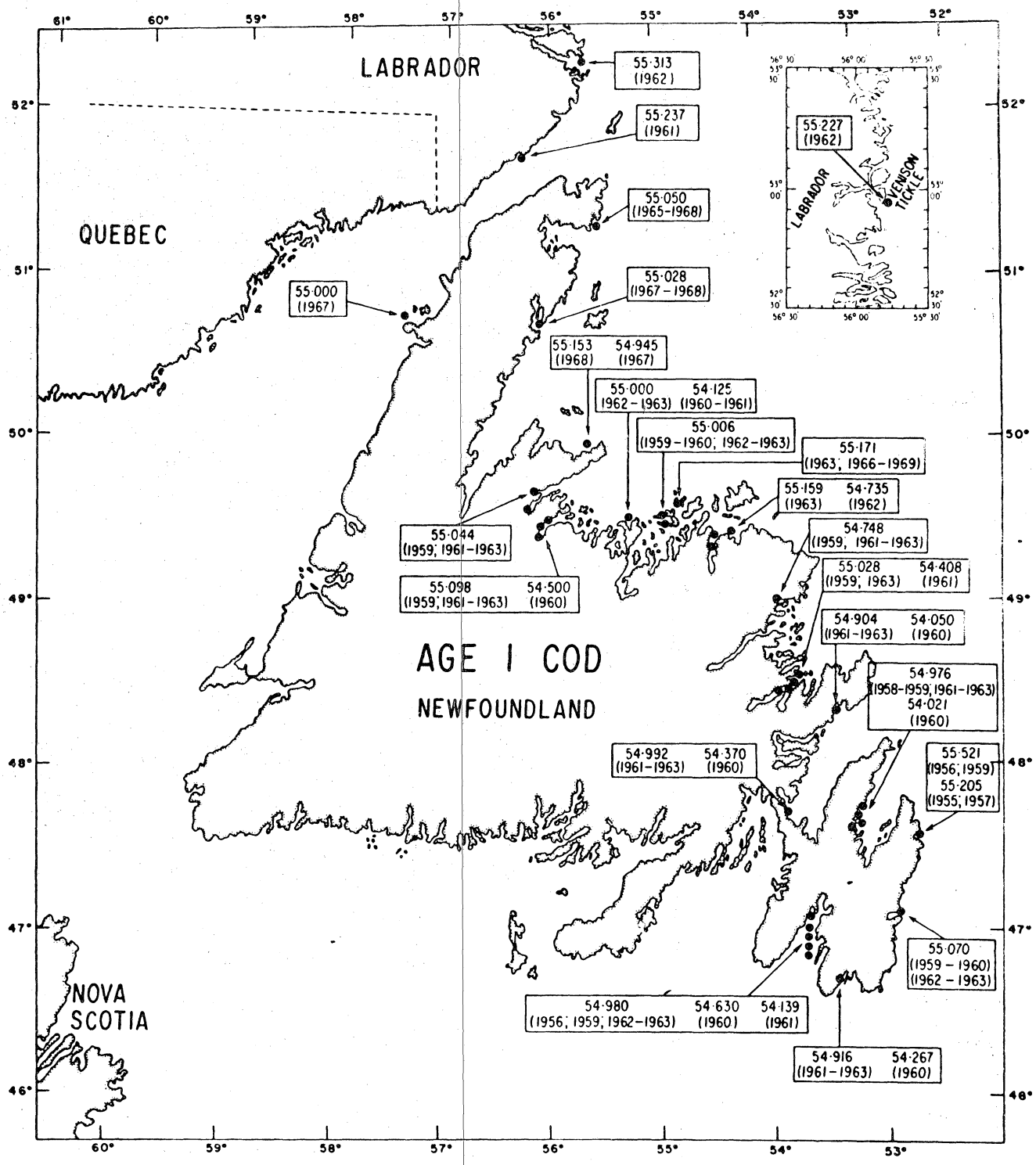

Fig. 3. Vertebral averages of 1-year old cod from various localities in eastern Newfoundland and Labrador grouped by year classes of similar values.

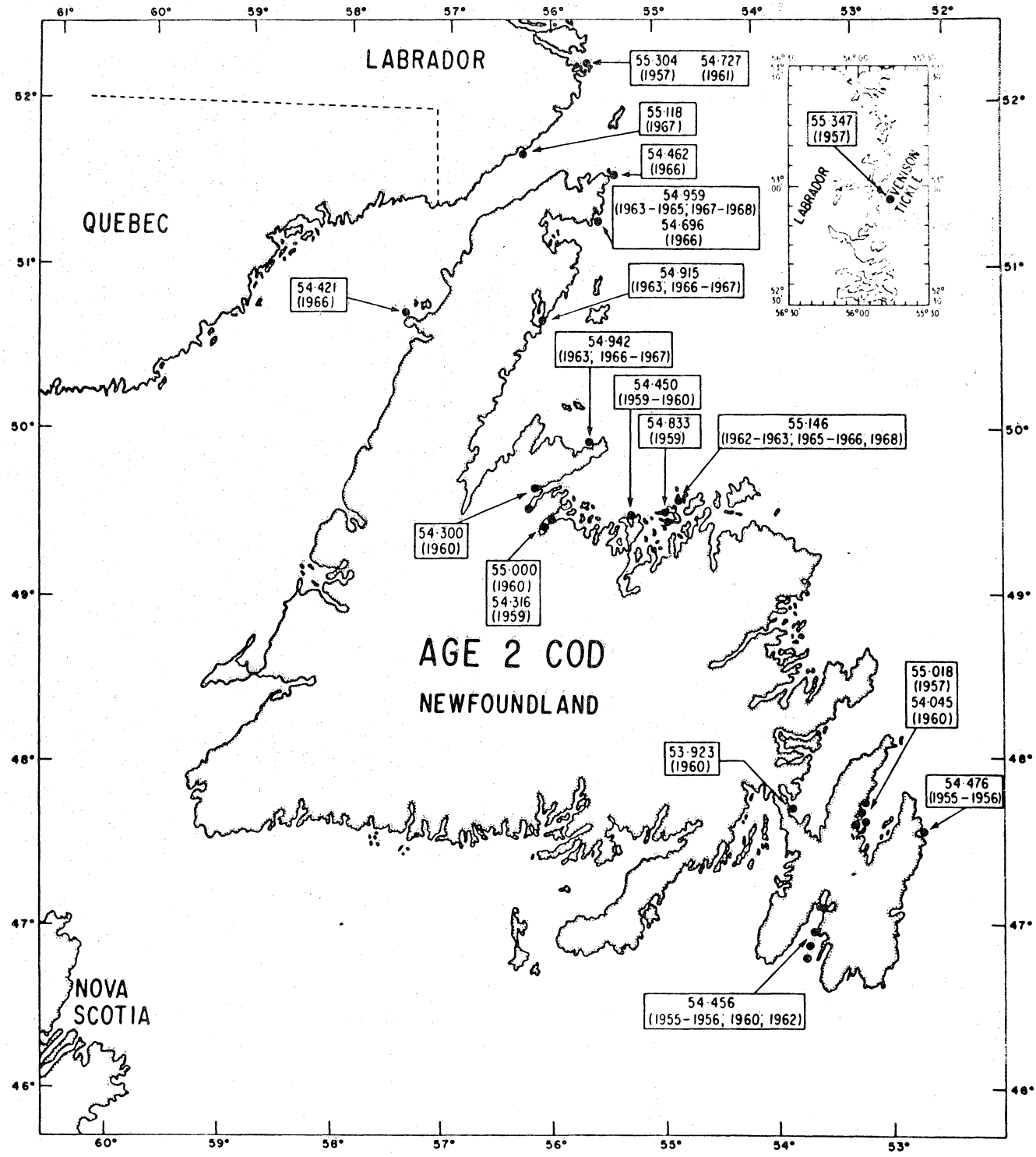

Fig. 4. Vertebral averages of 2 year old cod from various localities in eastern Newfoundland and Labrador grouped by year classes.

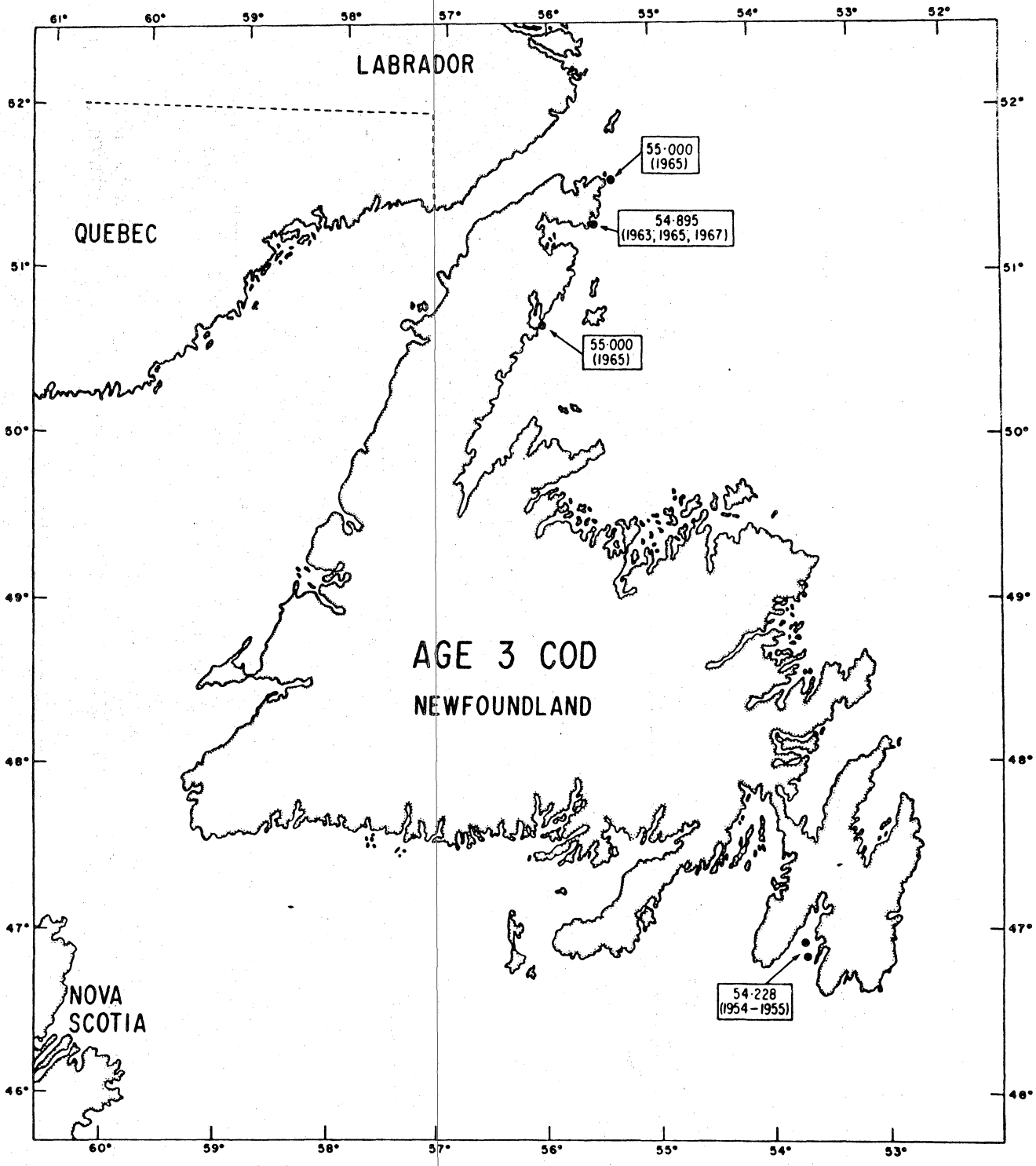

Fig. 5. Vertebral averages of 3-year-old cod from various localities in eastern Newfoundland grouped by year-classes.

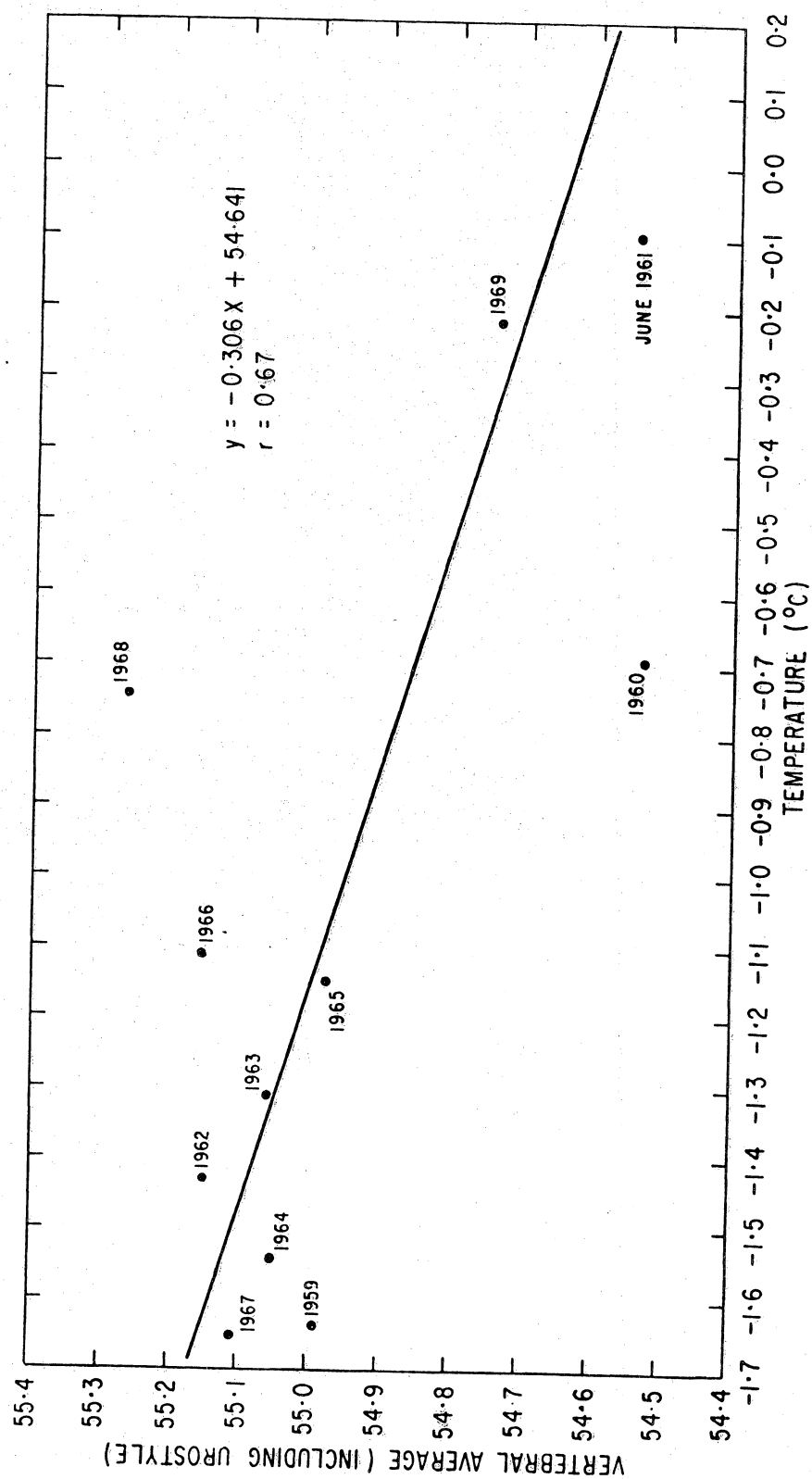

Fig. 6. Regression of vertebral average of juvenile cod of the year classes of 1959-69 from Notre Dame Bay versus the water temperatures (averaged throughout the upper 100 m) at Station 27 during March (except for 1961, when the June average was used).