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Meristic characteristics of Atlantic herring (*Clupea harengus harengus* L.) stocks in Newfoundland and adjacent waters

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Introduction

The fishery for Atlantic herring in Newfoundland waters increased spectacularly during the past decade. With the advent of a purse seine fishery, landings from the coastal waters of southwest Newfoundland (Cape Ray to Hermitage Bay) increased rapidly from less than 10,000 metric tons in 1965 to about 165,000 metric tons in 1969 (Hodder, 1971). Although over the years the bulk of the herring has been caught in the coastal waters of southern and western Newfoundland, herring appear seasonally in practically all bays and inlets around the Newfoundland coast and are fished to a limited extent in all areas.

The tremendous increase in fishing pressure on herring stocks frequenting the coastal waters of Newfoundland and adjacent areas, coupled with the possibility that the same stock or group of stocks was being fished at different times and places, emphasized the importance of identifying and delimiting the unit-stocks of herring which occur in the Newfoundland area. In January 1969 a study of the meristic characteristics of herring inhabiting Newfoundland and adjacent waters was undertaken to determine whether there are sufficient morphological differences between herring from the various areas to delineate separate stocks. This paper presents the results of that investigation, the primary objective being to determine whether the total herring stock in the Newfoundland area is a single, widely distributed population, the members of which intermingle freely and undertake extensive migrations along the coast, or whether it consists of a number of essentially discrete units or local stocks which intermingle to a limited extent, if at all.

Materials and Methods

Herring populations ranging from Gabarus Bay, Nova Scotia, in the south to the Strait of Belle Isle in the north including most coastal areas of Newfoundland (Fig. 1) were sampled during the period from January 1969 to July 1970. Herring samples, usually of 50 specimens but sometimes in multiples of 50, were collected from catches of purse seines, midwater trawls, gillnets and codtraps. Samples taken by purse seine are directly comparable with each other and may be regarded as representative of the schools from which they were obtained since the amount of selection by the gear is negligible. However, samples obtained from gillnets and codtraps cannot be regarded as completely representative of the size and age composition of the schools because of the selective action of these gears (Hodgson, 1933; Tester, 1935; Olsen, 1959).

The numbers of herring in each area from which meristic counts were obtained are listed in Table 1.

The length, sex, stage of maturity and weight of the fish were recorded and otoliths taken for subsequent age determination. The length used is the greatest total length measured from the tip of the lower jaw to the end of the longest lobe of the caudal fin with the lobe extending posteriorly in line with the body.

The age was recorded as the number of completedsummer (opaque) growth zones on the otolith. January 1 was selected as the arbitrary birth date; a fish is considered to be age I on January 1 following completion of the first summer's growth. Autumn-spawned herring would thus be several months older than spring-spawned herring of the same assigned age. Specimens of age X and greater were grouped into a X+ category.

Messieh (1969) and Hourston and Parsons (MS 1969) have questioned the validity of using otolith nucleus type as indicative of time of hatching for Northwest Atlantic herring. Because of the difficulty of determining time of hatching, in this study specimens were assigned to year-classes on the basis of spawning time. It is assumed that the vast majority of spring-spawning herring were hatched in the spring and autumn-spawning herring in the autumn. Parsons and Hodder (1971a) have shown that spring and autumn spawners differ greatly in meristic characteristics and Parsons (1972) has correctly classified from 79 to 91% of individual spring and autumn spawners to their respective spawning groups by means of a linear discriminant function based on three meristic characters. In this study an autumn-spawning herring of a certain age was assigned to the year-class immediately preceding that of a spring-spawning herring of the same assigned age.

Five meristic characters were examined in this study - the numbers of vertebrae, gill rakers on the first lower left gill arch and of pectoral, anal and dorsal fin rays. The gill rakers on the lower branch (hypobranchial and ceratobranchial) of the first left gill arch and the anal and left pectoral fin rays were counted with a binocular microscope. Vertebral counts, excluding the hypural plate, and dorsal fin-ray counts were determined from radiographs. All pectoral fin rays and all rakers on the lower limb of the first left gill arch, including rudimentary rakers and the raker in the bend of the arch, were counted. In the dorsal and anal fins all rays including rudimentary rays were counted; the last split rays originating from the same base were counted as one.

Results

A. Spawning season

Individual adult fish were assigned to spawning season on the basis of gonad development in relation to time of capture. Spring- and autumn-spawning herring differ markedly in the timing of the cycle of gonad development. Although the stage of maturity may not be a reliable indicator of spawning season in all cases, generally the distinction between the major spring- and autumn-spawning groups is clearcut; very few borderline cases were observed during the course of the present investigation.

In most areas (excluding Fortune Bay and Gabarus Bay) only small proportions of immature herring were present in the samples (Table 2). In those areas where virtually all adults belonged to one spawning group (e.g. Fortune Bay and Gabarus Bay) most of the immature herring were also assigned to the predominant spawning group since an examination of the otolith structure of these herring revealed that spring spawners could generally be separated from autumn spawners on the basis of the relative sizes of the first and second growth zones on the otolith (L. S. Parsons, unpublished data). However, no attempt was made to classify the few immature herring in areas where substantial proportions of both spring and autumn spawners were represented among the adults and these have been excluded from the data analyses which follow.

In most areas both spawning types were present but in varying proportions (Table 2). Herring caught in Gabarus Bay (northeast Nova Scotia) were virtually all (95.7%) autumn spawners. Autumn-spawning herring were predominant at Magdalen Islands and along southern Newfoundland west of Fortune Bay (73.6 and 71.8% respectively). Southeastern and eastern Newfoundland herring were primarily spring spawners. More than 90% of the herring in samples from Fortune Bay and Notre Dame Bay were definite spring spawners (93.2 and 96.4% respectively). Small proportions of late summer-early autumn spawners were found in the samples from Bonavista, Trinity and St. Mary's bays (22.8, 25.0 and 22.0% respectively); in Placentia Bay the proportion was somewhat higher (37.3%). Major spring spawnings occur in Fortune Bay in late April-early May, in Placentia and St. Mary's bays from the middle to the end of May and in Notre Dame Bay from mid-May to mid-June. These spawnings generally occur in shallow water (0-5 fathoms). Reports indicate that in recent years herring in Bonavista and Trinity bays have abandoned their traditional inshore spawning grounds and now spawn in deeper water (Parsons, 1970).

Spring and autumn spawners were present in approximately equal proportions in Conche samples but Quirpon herring were predominantly autumn spawners (61.4%). The large "Labrador-type" herring prevalent along the northwest coast of Newfoundland and in the southeastern Strait of Belle Isle during June and July were almost exclusively (94.0%) late summer-early autumn spawners. Hawke's Bay (northwest Newfoundland) herring were 53.4% spring spawners and 35.7% autumn spawners, the remainder being immature.

The proportions of spring spawners in Gabarus Bay and Strait of Belle Isle samples and autumn spawners in Fortune Bay and Notre Dame Bay samples were relatively insignificant (less than 7%). Hence, for the purpose of this study Gabarus Bay and Strait of Belle Isle herring are considered to be autumn spawners and Fortune Bay and Notre Dame Bay herring are considered to be spring spawners.

B. Meristic characteristics

Methods of analysis

For each type of statistical test employed a significance level of 0.01 was used except where otherwise stated.

Frequencies of vertebrae, gill rakers, and pectoral, anal and dorsal fin rays for samples from the same general areas were compared for spring and autumn spawners separately by analysis of variance adjusted for unequal sample sizes (Freund, Livermore and Miller, 1962) and calculation of F values within each area. No significant between-sample differences within areas were found for vertebrae, gill rakers, and pectoral and anal fin rays. Therefore, samples were combined for subsequent analyses involving these characters. There were, however, significant between-sample differences in dorsal fin-ray averages within several areas for both spring and autumn spawners.

To evaluate possible bias in meristic averages resulting from the different selective properties of the various gears employed in the collection of samples, correlation of meristic number with fish length was examined. Correlation coefficients relating meristic number to total length were calculated for spring and autumn spawners separately within each area and student's-t distribution was used to test the null hypothesis that there was no correlation between the two variables ($r = 0$).

Differences between means for spring and autumn spawners within each of the 9 areas where both spawning groups were present and differences between means for male and female herring in all areas (spring and autumn spawners separate) were tested for significance using student's-t test.

One-way analyses of variance adjusted for unequal sample sizes were performed to test year-class variation in meristic numbers within each area. Year-class comparisons based on very small numbers of fish in each category would be virtually meaningless. Therefore, a minimum number of specimens (25) equivalent to half the normal sample size (50) was arbitrarily chosen and only those year-classes which were represented in a particular area by at least 25 specimens were included in comparisons of year-class means within each area.

The combined data for each meristic character (spring and autumn spawners separate) were tested for differences among areas by analysis of variance. To test the individual differences ranked means of meristic numbers were compared using Duncan's new multiple range test (Steel and Torrie, 1960) modified for unequal sample sizes as proposed by Kramer (1956). In the tabular presentation of the results any two means included in the same bracket are similar but any two means not included in the same bracket are significantly different.

1. Numbers of vertebrae

(i) Variation with length

Both positive and negative correlations between vertebral numbers and total length were obtained (Table 3). The correlation coefficients differed significantly from zero in only 3 of 22 possible instances. The estimated population correlation coefficient (ρ) for spring spawners was 0.119 and for autumn spawners 0.059. According to Fukuhara et al. (1962) the expression 100 ρ^2 is an approximate measure of the variability in the observations for a particular character due to corresponding variability in length. For vertebral number this variability is 1.4% for spring spawners and only 0.3% for autumn spawners. It is evident from this that the correlation between length and vertebral number is negligible.

(ii) Variation between spawning groups and sexes

In five of the nine areas where both spawning groups were present spring spawners had a slightly higher vertebral average than autumn spawners but in the other four areas the situation was reversed (Table 4). The difference between spring and autumn spawners was significant in only one of the nine areas. Hence, it seemed reasonable to conclude that in general the difference between mean vertebral numbers of spring and autumn spawners from the same area is negligible and the two spawning groups were combined for area comparisons involving vertebral number.

Mean number of vertebrae was slightly higher for males than females in 14 instances and slightly higher for females than males in 8 instances (Table 5). Differences between the sexes were significant in only 2 of 22 possible instances. It was assumed that the observed significance was by chance only and the sexes were combined for subsequent vertebral comparisons.

(iii) Variation among year-classes and areas

Significant year-class heterogeneity was evident only in Notre Dame Bay where the 1961 year-class which had a mean vertebral number of 56.117 (60 specimens) differed significantly from the 1963 year-class which had a mean of 55.424 (328 specimens). Since no single year-class was adequately represented in all areas, area comparisons were performed with all year-classes pooled. For comparison with these results the 1963 year-class, which was best represented in all areas, was selected and area comparisons were also made based only on specimens belonging to this year-class.

Figure 2 shows mean vertebral numbers and two standard errors on each side of the mean for the various areas for the pooled year-classes (A) and the 1963 year-class only (B). Vertebral means (year-classes pooled) ranged from 55.497 for Gabarus Bay, Nova Scotia, to 55.877 for Fortune Bay, Newfoundland (Table 6). No geographic trend was evident. An analysis of variance of the vertebral frequencies revealed significant heterogeneity among areas. Duncan's new multiple range test indicated that Fortune Bay herring differ in mean vertebral number from herring in all other areas except Conche and Quirpon. Gabarus Bay fish differ in mean vertebral number from Fortune Bay, Conche, Quirpon, Hawke's Bay, Trinity Bay, St. Mary's Bay and Notre Dame Bay fish but are similar to all others (Table 7).

Vertebral comparisons based only on the 1963 year-class also indicated that Fortune Bay fish differ from all others except Conche and Quirpon. Notre Dame Bay fish also appear to be different from Quirpon and St. Mary's Bay fish. Although herring of the 1963 year-class from Hawke's Bay, Notre Dame, Bonavista and Trinity bays appear to have relatively low vertebral means whereas the means for Conche and Quirpon are relatively high, exceeded only by that for Fortune Bay, these differences are generally not statistically significant (at $p = 0.01$) probably because of the very small numbers of specimens involved in some areas.

(iv) Vertebral abnormalities

It is customary in meristic studies to exclude vertebral columns with fused vertebrae when computing means. In the present study such abnormal vertebral columns were noted so that the effect of their exclusion from the means could be studied. Of 5092 herring 108 (2.12%) possessed fused vertebrae. The frequency of abnormalities per fish (number of fish in parentheses) was 1(82), 2(20), 3(5) and 6(1). When each partially developed fused centrum was counted as one complete vertebra, the vertebral means based on fish with normal plus those with abnormal vertebrae were not significantly different (t-test) in any area from those means based only on fish with normal vertebrae. Hence, it appears that vertebral means are not significantly affected by inclusion or exclusion of the small number of vertebral columns with fused vertebrae.

Similar findings were reported by Ford and Bull (1926) for Atlantic herring and Templeman (1948, 1970) for capelin, *Mallotus villosus*, and Greenland halibut, *Reinhardtius hippoglossoides*. The percentages of fish with fused vertebrae in those studies are very similar to that found for Atlantic herring in the present study. Ford and Bull (1926) reported that 1.53% of their specimens had fused vertebrae. Templeman (1948, 1970) found 2.09 and 1.89% with fusions among capelin and Greenland halibut respectively. Pitt (1963) stated that an average of about 2% of American plaice, *Hippoglossoides platessoides*, had fused vertebrae. These percentages are much lower than that reported by McHugh (1942) for juvenile Pacific herring, *Clupea pallasii* (6.65%).

2. Numbers of gill rakers

(i) Variation with length

Both positive and negative correlations between gill-raker number and fish length were obtained (Table 3). The correlation coefficients differed significantly from the null hypothesis in only 2 (Fortune Bay and Placentia Bay spring spawners) of 22 possible instances. The estimated population correlation coefficient (ρ) for spring spawners was 0.167 and for autumn spawners 0.075. Overall variability in gill-raker number due to corresponding variability in length is 2.8% for spring spawners and 0.6% for autumn spawners. Scatter plots of gill-raker number against fish length indicated that gill-raker number increases with fish size in juvenile herring but there is no significant relationship between gill-raker number and length in adult herring. Therefore, all immature fish were excluded from the gill-raker frequencies for Fortune Bay and Placentia Bay spring spawners to eliminate any possible bias in area comparisons.

(ii) Variation between spawning groups and sexes

Autumn spawners had higher gill-raker averages than spring spawners in all nine areas where both spawning groups were present (Table 8). The differences were significant for all areas except Conche. These highly significant differences in mean gill-raker numbers necessitated the separation of spring and autumn spawners in subsequent analyses involving gill rakers.

Mean number of gill rakers was higher for males than females in 13 instances and higher for females than males in 9 instances (Table 9). Since these differences were not significant, males and females were combined for subsequent gill-raker comparisons.

(iii) Variation among year-classes and areas

There was evidence of significant year-class heterogeneity among spring spawners from both Fortune and Placentia bays. The observed significance was due to the relatively low gill-raker means for juvenile herring of the 1966 year-class which was well represented in the samples from these areas. Although the year-class means for Gabarus Bay did not differ significantly when tested by analysis of variance two-year-old fish of the 1967 year-class had a gill-raker average considerably lower than the averages for older fish belonging to the earlier year-classes. In all three instances the differences between year-classes were attributed to an increase in gill-raker number with fish size in juvenile herring and the lack of a significant relationship between gill-raker number and length in adult herring. Therefore, two-year-old herring of the 1967 year-class were excluded from the gill-raker frequencies for Gabarus Bay in addition to the exclusion of all immature fish from the gill-raker frequencies for Fortune Bay and Placentia Bay spring spawners. Since there was no evidence of year-class heterogeneity among adult herring, year-classes were pooled for area comparisons.

Figure 3 shows mean gill-raker numbers and two standard errors on each side of the mean for the various areas for spring and autumn spawners separately. Gill-raker means among spring spawners ranged from 47.036 for Magdalen Islands to 48.973 for Bonavista Bay (Table 8). Among autumn spawners the means ranged from 48.997 for Magdalen Islands to 49.655 for Gabarus Bay. Analyses of variance of the gill-raker frequencies showed significant heterogeneity among both spring and autumn spawners. Duncan's new multiple range test revealed that Magdalen Islands and southwestern Newfoundland spring-spawning herring differ in mean number of gill rakers from spring spawners in all other areas (Table 10). Spring spawners from eastern Newfoundland (Trinity Bay to Quirpon) and southeastern Newfoundland (St. Mary's, Placentia and Fortune bays) plus Hawke's Bay (northwest Newfoundland) form sets that are different from each other, fish from eastern Newfoundland having higher gill-raker averages than those from southeastern Newfoundland and Hawke's Bay which in turn have higher averages than southwest Newfoundland and Magdalen Islands fish. The gill-raker mean for southwest Newfoundland spring spawners is intermediate between those for Magdalen Islands and Hawke's Bay spring spawners and significantly different from both.

Among autumn spawners differences in mean numbers of gill rakers are much less evident. Autumn-spawning herring from Gabarus Bay which have the highest gill-raker average differ significantly from Magdalen Islands, Hawke's Bay and southwest Newfoundland autumn spawners which have the lowest gill-raker averages.

3. Numbers of pectoral fin rays

(i) Variation with length

Both positive and negative correlations between pectoral fin-ray number and fish length were derived (Table 3). The correlation coefficients differed significantly from zero in 7 of 22 possible instances, indicating a positive correlation between these two variables. However, the estimated population correlation coefficient (ρ) was only 0.123 for spring spawners and 0.129 for autumn spawners. Hence, the overall variability in pectoral fin-ray numbers due to corresponding variability in fish length is only 1.5% for spring spawners and 1.7% for autumn spawners from which it appears that the correlation between pectoral fin-ray number and fish length is negligible.

(ii) Variation between spawning groups and sexes

Autumn spawners had significantly higher pectoral fin-ray averages than spring spawners in all nine areas where both groups were represented (Table 11). Therefore, the two spawning groups were kept separate in subsequent analyses involving pectoral fin-ray numbers.

Mean number of pectoral fin rays was higher for males than females in 9 instances and higher for females than males in 13 instances (Table 12). Since these differences between the sexes were not significant, males and females were combined.

(iii) Variation among year-classes and areas

Since there was no evidence of significant year-class heterogeneity in pectoral fin-ray averages among either spring or autumn spawners, year-classes were pooled for area comparisons.

Figure 4 depicts mean pectoral fin-ray numbers and two standard errors on each side of the mean for the various areas for spring and autumn spawners separately. Mean numbers of pectoral fin rays among spring spawners ranged from 16.954 for Fortune Bay fish to 17.446 for St. Mary's Bay fish (Table 11). Among autumn spawners the means ranged from 18.418 for Quirpon fish to 18.622 for Trinity Bay fish. No geographic trend in mean pectoral numbers was evident among either spawning group. There was significant area heterogeneity among spring spawners but not among autumn spawners. Comparisons of the ranked means of pectoral fin rays for spring spawners by Duncan's new multiple range test indicated that Fortune Bay fish differ from those in all other areas (Table 13). St. Mary's Bay spring spawners are similar in mean pectoral fin-ray number to spring spawners from Hawke's Bay, Quirpon and Conche but differ significantly from those in all other areas. Notre Dame Bay spring spawners differ significantly from Conche, Quirpon and Hawke's Bay spring spawners as well as those from St. Mary's and Fortune bays.

4. Numbers of anal fin rays

(i) Variation with length

Both positive and negative correlations between anal fin-ray number and fish length were obtained (Table 3). Correlation coefficients differed significantly from the null hypothesis in only two instances. Since ρ was only 0.039 for spring spawners and 0.048 for autumn spawners, the variability in anal fin-ray numbers due to corresponding variability in length is only 0.2% for both spring and autumn spawners. Thus the correlation between anal fin-ray number and fish length is negligible.

(ii) Variation between spawning groups and sexes

In seven of the nine areas where both spawning groups were present autumn spawners had higher anal fin-ray averages than spring spawners (Table 14). For Magdalen Islands, southwest Newfoundland and Placentia Bay herring these differences were significant. Because of these differences spring- and autumn-spawning herring were treated separately in subsequent analyses involving anal fin-ray numbers.

Mean number of anal fin rays was higher for males than females in 7 instances and higher for females than males in 15 instances (Table 15) but the differences were not significant; therefore anal fin-ray data formales and females were combined.

(iii) Variation among year-classes and areas

Analyses of variance to test year-class variation in mean anal fin-ray numbers revealed significant year-class heterogeneity only among Placentia Bay spring spawners. Despite this heterogeneity area comparisons were performed with all year-classes pooled because of the wide fluctuations in year-class strength in the various areas and the fact that no single year-class was adequately represented in all areas. Area comparisons were also performed for spring spawners based only on specimens belonging to the 1963 year-class.

Mean numbers of anal fin rays among spring spawners (year-classes pooled) ranged from 17.598 for southwest Newfoundland herring to 18.026 for Bonavista Bay herring (Table 14). Among autumn spawners the means ranged from 17.929 for St. Mary's Bay fish to 18.300 for Magdalen Islands fish. Analyses of variance of anal fin-ray frequencies showed significant heterogeneity among both spring and autumn spawners. Duncan's new multiple range test indicated that among spring spawners fish from eastern and northwestern Newfoundland (Trinity Bay to Quirpon plus Hawke's Bay) and fish from southern Newfoundland and Magdalen Islands form two sets that appear to be different from each other (Table 16). Eastern Newfoundland and Hawke's Bay spring spawners have higher anal fin-ray averages than those from southern Newfoundland and Magdalen Islands. Comparisons based only on the 1963 year-class show greater similarity than those based on the pooled year-classes.

Fortune Bay herring of the 1963 year-class differ significantly from Bonavista Bay and Trinity Bay spring spawners of the same year-class (t-test).

Among autumn spawners Magdalen Islands fish differ significantly in mean number of anal fin rays from Gabarus Bay, Placentia Bay, St. Mary's Bay, Trinity Bay and Bonavista Bay autumn spawners. Autumn-spawning herring from the other areas are not significantly different from each other.

5. Numbers of dorsal fin rays

Dorsal fin-ray averages appear to be unsatisfactory for herring stock differentiation because there are significant differences between samples within several areas, and dorsal fin-ray counts, particularly of smaller fish, tend to be unreliable because of difficulties in distinguishing the first rudimentary ray. A small rather rounded bone was frequently present anterior to the first obvious rudimentary ray as found in *Oncorhynchus nerka* by Fukuhara et al. (1962) and in *Salmo salar* by Templeman (1967). If this bone was round and not elongated as in other rudimentary rays, it was not counted. However, checks by the author revealed differences between individuals in applying these criteria and even the same individuals experienced difficulty in distinguishing the first rudimentary ray consistently. Since these inconsistencies were an obvious source of variation in dorsal fin-ray averages, this character was discarded.

Discussion and Conclusions

In most Newfoundland areas and also in the southern Gulf of St. Lawrence two major spawning groups of herring occur, one spawning in spring and the other in late summer or autumn (Parsons, 1970; Parsons and Hodder, 1971a; Messieh and Tibbo, 1971). Spring-spawning herring are predominant in some areas and autumn spawners in others. These two spawning groups may be characterized as low- and high-temperature spawners respectively (Blaxter, 1958). Spring spawning generally occurs some time between late April and mid-June and late summer-autumn spawning in August-September. Evidence from other sources (Jean, 1956; Tibbo and Legaré, 1960; Das, MS 1968) indicates that in the Northwest Atlantic mean water temperature on the spawning grounds is approximately 5°C lower in the spring than it is in the autumn. Temperatures during spring spawning generally range from 2 to 12°C and during late summer-autumn spawning from 8 to 16°C.

Parsons and Hodder (1971a) have shown that spring- and autumn-spawning herring which overwinter along southwest Newfoundland exhibit distinct differences in mean numbers of fin rays and gill rakers and Messieh and Tibbo (1971) have reported similar fin-ray differences between spring and autumn spawners in the southern Gulf of St. Lawrence. The present study provides evidence that such differences are widespread, for spring- and autumn-spawning herring in practically all areas around Newfoundland differ in these meristic characteristics. Although there is generally no significant difference between mean vertebral numbers of spring and autumn spawners, mean numbers of gill rakers and of pectoral and anal fin rays are generally higher ($P < 0.01$) for autumn-spawning than for spring-spawning herring, with gill-raker and pectoral fin-ray numbers exhibiting the greatest degree of difference between spawning groups.

Parsons and Hodder (1971a) have related differences in the mean numbers of fin rays of spring- and autumn-spawning Atlantic herring to water temperatures during early development and to differences in the developmental rates of spring- and autumn-hatched larvae. Parsons (1972) has shown that from 79 to 91% of individual spring and autumn spawners can be correctly classified to their respective spawning groups by the use of a linear discriminant function based on three meristic characters, from which it is concluded that the vast majority of autumn spawners are the progeny of herring which spawned in the autumn and spring spawners of herring which spawned in the spring.

In view of the highly significant meristic differences between spawning groups within areas, it is necessary to consider spring and autumn spawners separately for between-area comparisons of all meristic characters except vertebral number. Comparisons of herring stocks in various regions have often been based solely on one meristic character, i.e. vertebral number. However, since meristic characters are susceptible during the early life history of individual fish to local environmental fluctuations, which may produce recognizable variations in some meristic characters but not in others, no single character is likely to be adequate to delineate the interrelationships of several stocks. The fact that spring- and autumn-spawning herring differ significantly in mean numbers of pectoral and anal fin rays and gill rakers, despite similarities in mean vertebral numbers, demonstrates the necessity for considering several characters in attempts at stock differentiation. Statistical comparisons of mean numbers of pectoral and anal fin rays, gill rakers and vertebrae indicate that all four meristic characters are useful to a limited degree for determining the interrelationships of herring stocks in the Newfoundland area. Gill-raker and anal fin-ray numbers appear to be the most useful.

Combined results for all four meristic characters indicate that southwest Newfoundland and Magdalen Islands spring-spawning herring differ from southeastern Newfoundland (Fortune, Placentia and St. Mary's bays) spring spawners which in turn are different from eastern Newfoundland (Trinity Bay to Quirpon) spring spawners. Southwest Newfoundland spring spawners have a gill-raker average which is intermediate between that for Magdalen Islands and Hawke's Bay spring spawners, indicating a possible mixing of spring spawners from more than one area along southwest Newfoundland. However, when all four characters are considered, it appears that Hawke's Bay spring spawners are relatively distinct from spring spawners to the south (southwest Newfoundland and Magdalen Islands) and the northeast (Quirpon and Conche). The distinct vertebral and pectoral fin-ray averages of Fortune Bay herring indicate that these herring probably do not intermingle to any great extent with those in adjoining areas. From their pectoral fin-ray average St. Mary's Bay spring spawners also appear to be relatively distinct from those in adjoining areas. There are no apparent meristic differences among spring spawners from Trinity, Bonavista and Notre Dame bays but Notre Dame Bay spring spawners differ significantly in mean number of pectoral fin rays from Conche, Quirpon and Hawke's Bay spring spawners, indicating that Notre Dame Bay spring spawners may be relatively distinct from those in more northern areas. Spring-spawning herring from Conche and Quirpon were similar in all meristic characteristics.

Fewer meristic differences are evident among autumn spawners than among spring spawners. Comparisons of mean vertebral numbers indicate that autumn spawners from Gabarus Bay in northeastern Nova Scotia, which have the lowest vertebral average (55.497), are different from Hawke's Bay, Quirpon, Conche, Notre Dame Bay and Trinity Bay herring. Gabarus Bay autumn spawners have the highest gill-raker average among autumn spawners and are significantly different from Magdalen Islands, southwest Newfoundland and Hawke's Bay autumn spawners, which have the lowest gill-raker averages (in order of increasing magnitude). Magdalen Islands autumn spawners are also significantly different in mean numbers of anal fin rays from Gabarus Bay and southeastern Newfoundland (Placentia, St. Mary's, Trinity and Bonavista bays) autumn spawners. These results suggest that autumn-spawning herring from northeastern Nova Scotia (Gabarus Bay) do not intermingle much with autumn spawners from southwest Newfoundland and the southern and northern Gulf of St. Lawrence. Magdalen Islands autumn spawners are similar in meristic characteristics to autumn spawners from southwest Newfoundland and Hawke's Bay but apparently intermix very little, if at all, with southeastern Newfoundland autumn spawners.

A negative correlation between mean vertebral number and water temperature has been shown previously for herring (Hubbs, 1925; Rounsefell and Dahlgren, 1932; Tester, 1938; Rünnstrom, 1941; Bückman, 1950). Tibbo (1956), from investigations conducted in 1942-44, found that the mean number of vertebrae tended to decrease from south to north in the Newfoundland area, which is the reverse of what is usually found elsewhere. He concluded that this was due to a progressive increase in temperature at spawning from south to north, development of Notre Dame Bay herring taking place later in the season at higher temperatures and being reflected in a lower mean number of vertebrae. Apart from Fortune Bay and Gabarus Bay herring vertebral means were similar throughout the area studied in the present investigation, with no geographic trend evident. Tibbo (1956) characterized three distinct herring populations on the basis of vertebral means. Labrador and Notre Dame Bay herring had similar relatively low mean numbers of vertebrae (55.459 and 55.429 respectively). Vertebral means of combined samples from those two areas differed significantly from the means for Bay of Islands (55.564) and Fortune Bay (55.779) which in turn were significantly different from each other. The vertebral mean for Placentia Bay (55.685) was statistically similar to the means for Fortune Bay and Bay of Islands. Although the mean number of vertebrae of Notre Dame Bay herring increased significantly from 1942-44 (55.429) to 1969-70 (55.672), in both periods Fortune Bay herring had the highest mean vertebral numbers in the Newfoundland area (55.779 and 55.877 respectively). Tibbo (1957a) reported a relatively high mean vertebral number of 55.772 for Fortune Bay herring during the 1946-48 period. Hodder (1967) also found a high vertebral mean (55.82) for Fortune Bay herring during 1965-66. From vertebral data reported by Anthony and Boyar (1968) for Gulf of Maine and adjacent Nova Scotian areas, Tibbo (1957b) for the Atlantic coast of Nova Scotia, and Day (1957a,b,c) and Tibbo (1957c) for the northern and southern Gulf of St. Lawrence, it appears that the present mean vertebral number of Fortune Bay herring (55.877) is matched only by that for herring from Ile Verte in the Estuary of the Gulf of St. Lawrence (55.883) and hence is among the highest in the Northwest Atlantic.

Jean (1967) attributed the high vertebral average of Ile Verte herring to a negative correlation between vertebral number and water temperature, based on the premise that Ile Verte herring spawn and develop in very cold water. The consistently high vertebral averages of Fortune Bay herring may also be related to a relatively low temperature at spawning. Spring spawning in Fortune Bay usually occurs some time between mid-April and mid-May, mostly in early May, which is earlier than in most other Newfoundland areas (unpublished data, St. John's Biological Station). Hydrographic data indicate that in relatively shallow-water in Fortune Bay temperatures around the 20th of April generally range from 1.9°C at 10 m to 2.5°C at the surface. By the 20th of May bottom temperatures in 2-6 fathoms in the vicinity of the spawning grounds range from 2.5 to 3.8°C. Hence it seems likely that incubation temperatures could be as low as 2 to 4°C. It is possible that, as a result of the earlier spawning spring-spawned herring eggs in Fortune Bay develop and hatch at lower temperatures than in other Newfoundland areas where spawning is later (mid-May to mid-June) and temperatures at spawning may be higher. The available hydrographic data for most Newfoundland inshore areas is inadequate to permit valid comparisons of temperature at spawning in the various areas, but it is known that in 1970 bottom temperatures on the spawning grounds in St. Mary's Bay during and immediately after spawning in late May ranged from 4 to 10°C (G. H. Winters, personal communication).

Despite the lack of a geographic cline in vertebral means, the present results show geographic trends in the mean numbers of gill rakers and anal fin rays which appear to be correlated with water temperatures during early development. The period of fixation of gill-raker number in Atlantic herring is not known but is possibly related to complex ecological factors, in particular those connected with the optimum utilization of available food. It has been shown for several species that a correlation exists between gill-raker number and feeding habits (Reshetnikov, 1961; Martin and Sandercock, 1967). Although the precise time of fixation of the number of rays in the anal fin is also unknown, it probably occurs during the larval period since anal fin formation is completed at about 30 mm (Lebour, 1921).

A general negative correlation between the mean number of gill rakers and water temperature is readily apparent from the hydrography of the Newfoundland area. The frigid (< 0°C) portion of the Labrador Current of Arctic origin exerts the dominant hydrographic influence along the east coast of Newfoundland (Smith et al., 1937; Hachey et al., 1954; Templeman, 1966). To the north of the Grand Bank the Labrador Current divides, one branch passing through the Avalon Channel and along the coast southward toward Cape Race and the second flowing along the eastern slope of the Grand Bank. The volume of very cold water in the Labrador Current declines from north to south (May et al., 1965) and is less prominent along southeastern than along eastern Newfoundland. Its influence upon coastal hydrography is relatively weak west of Fortune Bay. A relatively warm current flows northward along the west coast of Newfoundland. A portion of this current flows out along the south shore of the Strait of Belle Isle, whereas a cold branch of the Labrador Current enters the Strait along its north shore.

Spring-spawning herring from the generally cold waters of eastern Newfoundland have higher gill-raker averages than spring spawners from southeastern Newfoundland where water temperatures are somewhat intermediate.

The lowest gill-raker averages occur along southwest Newfoundland and in the vicinity of the Magdalen Islands, generally warm areas which are relatively unaffected by the cold waters of the Labrador Current. The mean number of anal fin rays is also higher for eastern Newfoundland spring spawners than for spring spawners from southern Newfoundland and the Magdalen Islands. Hawke's Bay spring spawners are somewhat anomalous in that they are similar in mean number of gill rakers to southeastern Newfoundland spring spawners but are similar to eastern Newfoundland spring spawners in the mean number of anal fin rays. Despite the geographic trend in gill-raker and anal fin-ray averages among spring spawners, no such trend is evident among autumn spawners. It is possible that temperature conditions on the spawning grounds and in the larval nursery areas are more uniform throughout the Newfoundland area during the autumn than during the spring or early summer.

The results of the present study utilizing meristic differences as indicators of stock heterogeneity compare favourably with other methods of stock differentiation. Comparisons of other biological characteristics of herring from southwestern Newfoundland, Magdalen Islands, Banquereau, Canso Bank and Chedabucto Bay (Hodder and Parsons, 1971a,b; Parsons and Hodder, 1971b) and tagging results (Winters, 1970; MS 1971) have shown that the winter fishery along southwestern Newfoundland is largely dependent on herring that are not indigenous to that area but rather are derived from spring and autumn spawnings in the southern Gulf of St. Lawrence. This southwest Newfoundland-southern Gulf stock complex apparently does not intermix to any great extent with herring concentrations fished in winter by Canadian vessels in the Chedabucto Bay-Canso Bank area and by European vessels on Banquereau. Meristic comparisons indicate that the spring-spawning component of the southwest Newfoundland concentrations may also include an intermixture of herring which also frequent Hawke's Bay in northwest Newfoundland, since the gill-raker average for southwest Newfoundland spring spawners is intermediate between those for spring spawners from Magdalen Islands and Hawke's Bay. The recovery of 3 tags during the 1971 southwest Newfoundland winter fishery from the liberation of 3400 tagged herring at Hawke's Bay during December 1970 (G. H. Winters, personal communication) indicates some intermixture of Hawke's Bay herring with those which overwinter along southwest Newfoundland but this may be slight.

Despite the differences in pectoral fin-ray number between spring-spawning herring from Placentia and St. Mary's bays, previous evidence suggests that herring in these two bays belong, at least partially to the same stock. This was indicated by the migration of "red" herring, which had been exposed to phosphorus poisoning in Placentia Bay, into St. Mary's Bay in the spring of 1969 (Hodder, Parsons and Pippy, 1972).

Parsons and Hodder (1971b) have shown a distinct geographic variation in the incidence and intensity of infestation of adult herring from Canadian Atlantic waters with the larval nematode *Anisakis* Dujardin, 1845, which indicates that this parasite is valuable as a biological indicator of stock heterogeneity. Stock relationships suggested by meristic comparisons agree in most instances with those indicated by the level of infestation of herring in various areas with larval *Anisakis*.

Although meristic differences appear to be useful indicators of herring stock heterogeneity in Newfoundland and adjacent waters, the existence of significant morphological differences does not imply that no intermingling occurs between two areas but merely indicates that the samples were not derived from a single completely mixed stock. No one method is sufficient to completely delineate the degree of heterogeneity of fish stocks; conclusions regarding stock interrelationships should be based on a variety of techniques. Although morphological differences generally show stock heterogeneity within a broad area, only direct methods, i.e. tagging, will demonstrate actual intermixing between stocks. Tagging experiments are required to determine whether intermingling occurs between groups considered to be discrete on the basis of morphological characteristics.

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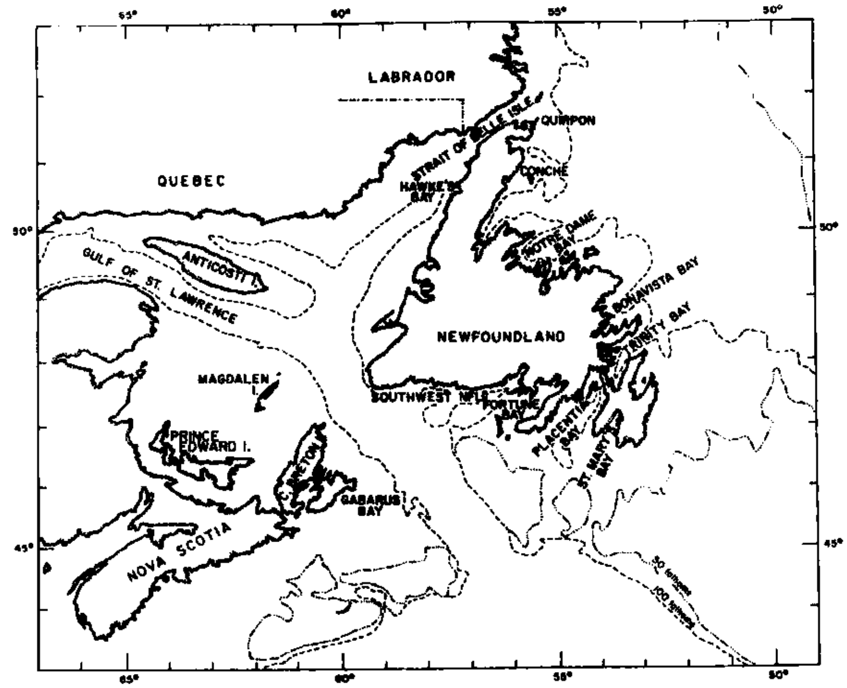

Fig. 1. Area map showing the localities and place names mentioned in the text.

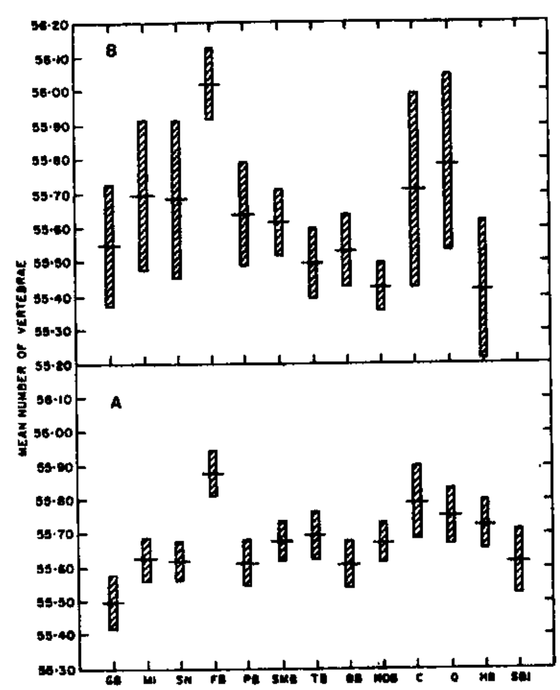

Fig. 2. Mean numbers of vertebrae by area (spring and autumn spawners combined) for the pooled year-classes (A) and the 1963 year-class only (B). (In Fig. 2-6 horizontal lines indicate means; vertical bars indicate two standard errors on each side of the mean.)

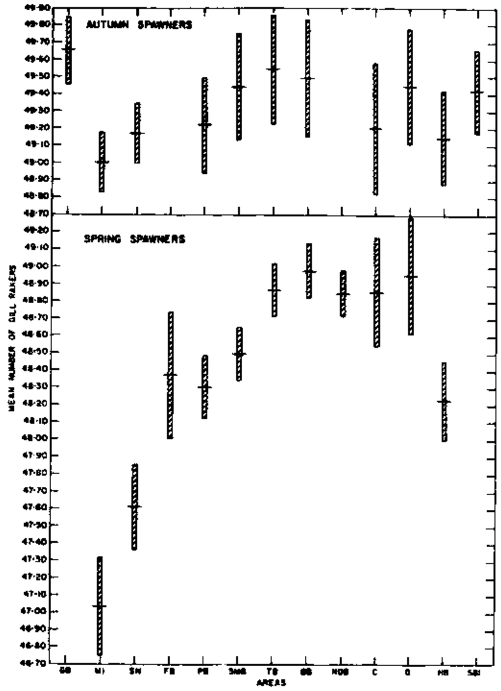

Fig. 3. Mean numbers of gill rakers by area and spawning group.

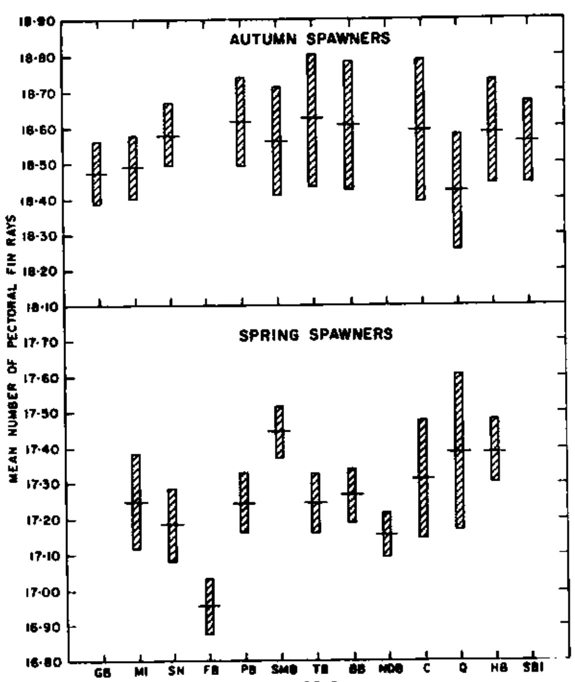

Fig. 4. Mean numbers of pectoral fin rays by area and spawning group.

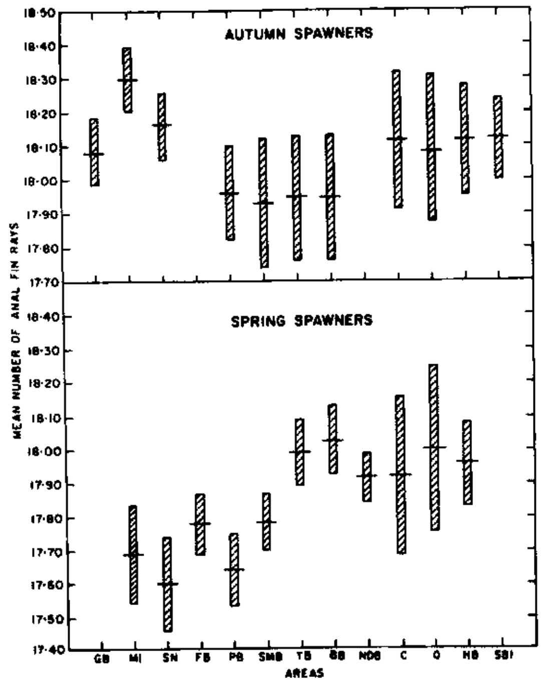

Fig. 5. Mean numbers of anal fin rays by area and spawning group (year-classes pooled).

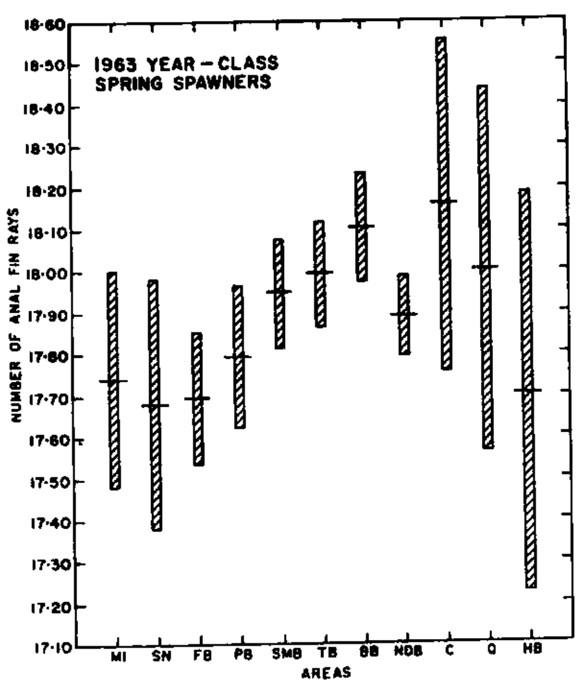

Fig. 6. Mean numbers of anal fin rays of spring spawners of the 1963 year-class by area.

Table 1. Numbers of herring in each area from which meristic counts were obtained (S = Spring spawners; A = Autumn spawners).

Area code	Locality and spawning group		No. of specimens
1	Gabarus Bay, N.S.	(A)	350
2	Magdalen Islands	(S)	112
	" "	(A)	368
3	Southwest Nfld.	(S)	137
	" "	(A)	359
4	Fortune Bay	(S)	397
5	Placentia Bay	(S)	297
	" "	(A)	177
6	St. Mary's Bay	(S)	417
	" " "	(A)	122
7	Trinity Bay	(S)	333
	" "	(A)	110
8	Bonavista Bay	(S)	306
	" "	(A)	92
9	Notre Dame Bay	(S)	548
10	Conche	(S)	77
	"	(A)	80
11	Quirpon	(S)	81
	"	(A)	135
12	Strait of Belle Isle	(A)	200
13	Hawke's Bay	(S)	238
	" "	(A)	159
			5095

Table 2. Frequency and percentage of autumn and spring spawners in the various areas.

Areas	Frequency			Percentage		
	Autumn spawners	Spring spawners	Immatures*	Autumn spawners	Spring spawners	Immatures*
Gabarus Bay, N.S.	335	14	1	95.7	4.0	0.3
Magdalen Islands	368	112	20	73.6	22.4	4.0
Southwestern Nfld.	359	137	4	71.8	27.4	0.8
Fortune Bay	370	27	...	93.2	6.8	
Placentia Bay	177	297	1	37.3	62.5	0.2
St. Mary's Bay	124	439		22.0	78.0	
Trinity Bay	111	333		25.0	75.0	
Bonavista Bay	92	306	6	22.8	75.7	1.5
Notre Dame Bay	20	528		3.6	96.4	
Conche	80	78	16	46.0	44.8	9.2
Quirpon	135	81	4	61.4	36.8	1.8
Strait of Belle Isle	188	12		94.0	6.0	
Hawke's Bay	159	238	49	35.7	53.4	10.9

*Includes only those immature herring which have not been assigned to either spawning group.

Table 3. Correlation coefficients of each meristic character with length. Numbers of fish are in parentheses.

(A double asterisk indicates significance at the 1% level.)

Areas	Vertebrae	Gill rakers	Pectoral fin rays	Anal fin rays	Dorsal fin rays
		Spring spawners			
Magdalen Islands	-0.128 (112)	0.221 (110)	0.065 (112)	0.260**(110)	0.102 (107)
Southwestern Nfld.	0.138 (137)	0.156 (136)	0.016 (137)	0.017 (132)	-0.053 (127)
Fortune Bay	0.053 (397)	0.485**(392)	0.210**(394)	0.087 (395)	0.159**(363)
Placentia Bay	0.140 (296)	0.256**(283)	0.220**(294)	0.191**(255)	0.137 (289)
St. Mary's Bay	0.228**(417)	-0.034 (415)	0.271**(413)	-0.137 (392)	-0.022 (385)
Trinity Bay	0.261**(333)	-0.059 (320)	0.128 (331)	-0.065 (332)	-0.055 (319)
Bonavista Bay	0.193**(304)	0.041 (301)	0.111 (303)	-0.050 (302)	0.021 (296)
Notre Dame Bay	0.378**(548)	-0.008 (525)	-0.038 (544)	0.003 (541)	0.039 (517)
Conche	0.065 (77)	0.080 (75)	0.177 (74)	-0.027 (75)	0.065 (74)
Quirpon	-0.073 (80)	0.054 (80)	0.127 (79)	0.140 (75)	0.005 (77)
Hawke's Bay	0.039 (238)	0.106 (236)	0.039 (237)	0.061 (238)	0.020 (211)
ρ*	0.119	0.167	0.123	0.039	0.061
ρ^2	0.014	0.028	0.015	0.002	0.004
		Autumn spawners			
Gabarus Bay, N.S.	0.115 (350)	0.132 (338)	0.106 (350)	0.125 (349)	0.106 (316)
Magdalen Islands	-0.013 (368)	-0.002 (364)	0.116 (366)	0.041 (367)	0.012 (352)
Southwestern Nfld.	-0.046 (359)	0.078 (349)	0.047 (359)	-0.073 (353)	0.130 (340)
Placentia Bay	0.023 (177)	0.089 (165)	0.158 (177)	-0.150 (144)	0.129 (174)
St. Mary's Bay	0.126 (124)	0.024 (121)	-0.067 (120)	0.031 (100)	0.059 (123)
Trinity Bay	0.138 (110)	0.024 (109)	0.052 (111)	-0.069 (111)	0.146 (105)
Bonavista Bay	-0.070 (91)	-0.050 (86)	0.074 (90)	0.009 (89)	-0.007 (86)
Conche	0.151 (75)	-0.023 (75)	0.380**(80)	0.105 (80)	0.432**(67)
Quirpon	0.024 (135)	-0.002 (134)	0.240**(134)	-0.090 (129)	0.209 (124)
Strait of Belle Isle	0.037 (200)	0.168 (197)	0.212**(200)	0.126 (199)	0.135 (184)
Hawke's Bay	0.115 (159)	0.123 (157)	0.240**(159)	0.180 (156)	-0.089 (150)
ρ*	0.059	0.075	0.129	0.048	0.093
ρ^2	0.003	0.006	0.017	0.002	0.009

*ρ is an estimated population correlation coefficient (null hypothesis: $\rho = 0$).

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Table 4. Vertebral numbers of autumn- and spring-spawning Atlantic herring from various Newfoundland and adjacent areas. (The double asterisk indicates significance at the 1% level.)

Areas	Autumn												Spring												Autumn sp.-Spring sp.
	50	53	54	55	56	57	58	59	NO	AVE	SD	SE	52	53	54	55	56	57	58	59	NO	AVE	SD	SE	
Gabarus Bay, N.S.		3	15	160	150	21	1		350	55.497	0.725	0.039													
Magdalen Islands			13	139	193	22	1		368	55.617	0.666	0.035			4	44	51	13			112	55.652	0.732	0.069	-0.035
Southwestern Nfld.			6	150	181	22			359	55.610	0.628	0.033	1		2	52	72	10			137	55.635	0.706	0.060	-0.025
Fortune Bay															5	101	233	54	4		397	55.877	0.683	0.034	
Placentia Bay	1		2	73	83	16	2		177	55.644	0.821	0.062			8	127	141	19	1	1	297	55.599	0.696	0.040	0.045
St. Mary's Bay			1	42	66	12	1		122	55.754	0.672	0.061		1	13	152	215	35	1		417	55.655	0.697	0.034	0.099
Trinity Bay			1	36	59	9	3	2	110	55.845	0.837	0.080		1	10	129	164	24	5		333	55.646	0.737	0.040	0.199**
Bonavista Bay			3	32	48	8	1		92	55.696	0.722	0.075			11	129	144	21	1		306	55.582	0.688	0.039	0.114
Notre Dame Bay															12	219	256	59	2		548	55.672	0.709	0.030	
Concne			1	27	37	10			75	55.747	0.699	0.081				23	44	10			77	55.831	0.637	0.073	-0.084
Quirpon			1	42	82	10			135	55.748	0.595	0.051				29	44	7	1		81	55.753	0.662	0.074	-0.005
Strait of Belle Isle			5	81	100	12	2		200	55.625	0.683	0.048													
Hawke's Bay			2	57	92	7	1		159	55.673	0.611	0.048		2	5	77	122	28	4		238	55.761	0.783	0.051	-0.088

Table 5. Vertebral numbers of male and female Atlantic herring from various Newfoundland and adjacent areas. (The double asterisk indicates significance at the 1% level.)

Area and spawning group		Male													Female											Male-Female
		50	52	53	54	55	56	57	58	59	NO	AVE	SD	SE	53	54	55	56	57	58	59	NO	AVE	SD	SE	
Gabarus Bay	(A)			2	7	64	59	8			140	55.457	0.743	0.063	1	8	96	91	13	1		210	55.524	0.713	0.049	-0.067
Magdalen Islands	(S)					16	21	5			42	55.738	0.665	0.103		4	28	30	8			70	55.600	0.769	0.092	0.138
" "	(A)				7	55	77	5			144	55.556	0.645	0.054		6	84	116	17	1		224	55.656	0.678	0.045	-0.100
SW Newfoundland	(S)		1		2	23	45	8			79	55.709	0.787	0.089			29	27	2			58	55.534	0.569	0.075	0.175
"	(A)				3	71	87	12			173	55.624	0.641	0.049		3	79	94	10			186	55.597	0.618	0.045	0.027
Fortune Bay	(S)				3	57	110	25	3		198	55.838	0.715	0.051		2	43	119	29	1		194	55.918	0.655	0.047	-0.080
Placentia Bay	(S)				3	62	73	15	1	1	1[illegible]5	55.690	0.752	0.060		5	65	68	4			142	55.500	0.616	0.052	0.190
" "	(A)				1	42	45	9	1		99	55.606	0.901	0.091		1	31	38	7	1		78	55.692	0.708	0.080	-0.086
St. Mary's Bay	(S)			1	7	78	94	10			190	55.553	0.678	0.049		6	74	121	25	1		227	55.740	0.703	0.047	-0.187**
" "	(A)				1	25	31	3			60	55.600	0.616	0.080			18	36	9	1		64	55.891	0.693	0.087	-0.291
Trinity Bay	(S)				7	69	81	9	1		167	55.569	0.690	0.053	1	3	60	83	15	4		166	55.723	0.776	0.060	-0.154
" "	(A)				1	16	31	4	2	1	55	55.873	0.862	0.116			20	28	5	1	1	55	55.818	0.819	0.110	0.055
Bonavista Bay	(S)				3	61	63	11			138	55.594	0.669	0.057		8	68	81	10	1		168	55.571	0.706	0.054	0.023
" "	(A)				1	11	24	4			40	55.775	0.660	0.104		2	21	24	4	1		52	55.635	0.768	0.106	0.140
Notre Dame Bay	(S)				4	110	131	32			277	55.690	0.690	0.041		8	109	125	27	2		271	55.653	0.729	0.044	0.037
Conche	(S)					13	27	6			46	55.848	0.631	0.093			10	17	4			31	55.806	0.654	0.118	0.042
"	(A)				1	15	17	9			42	55.810	0.804	0.124			12	20	1			33	55.667	0.540	0.094	0.143
Quirpon	(S)					9	24	5	1		39	55.949	0.686	0.110			20	20	2			42	55.571	0.590	0.091	0.379**
"	(A)					15	41	5			61	55.836	0.553	0.071		1	27	41	5			74	55.676	0.622	0.072	0.160
Strait Belle Isle	(A)				2	40	59	5	1		107	55.654	0.646	0.062		3	41	41	7	1		93	55.591	0.726	0.075	0.063
Hawke's Bay	(S)			2	1	43	69	17	3		135	55.793	0.811	0.070		4	34	53	11	1		103	55.718	0.746	0.074	0.075
" "	(A)					25	36	3			64	55.656	0.570	0.071		2	32	56	4	1		95	55.684	0.640	0.066	-0.028

A = Autumn; S = Spring

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Table 6. Vertebral numbers of Atlantic herring from various Newfoundland and adjacent areas.
(Autumn and spring spawners combined.)

Areas	50	51	52	53	54	55	56	57	58	59	No.	Ave.	SD	SE
Gabarus Bay, N.S.				3	15	160	150	21	1		350	55.497	0.725	0.039
Magdalen Islands					17	183	244	35	1		480	55.625	0.682	0.031
Southwestern Nfld.			1		8	202	253	32			496	55.617	0.650	0.029
Fortune Bay					5	101	233	54	4		397	55.877	0.683	0.034
Placentia Bay	1				10	200	224	35	3	1	474	55.616	0.744	0.034
St. Mary's Bay				1	14	194	281	47	2		539	55.677	0.692	0.030
Trinity Bay				1	11	165	223	33	8	2	443	55.695	0.767	0.036
Bonavista Bay					14	161	192	29	2		398	55.608	0.697	0.035
Notre Dame Bay					12	219	256	59	2		548	55.672	0.709	0.030
Conche					1	50	81	20			152	55.789	0.667	0.054
Quirpon					1	71	126	17	1		216	55.750	0.619	0.042
Strait of Belle Isle					5	81	100	12	2		200	55.615	0.683	0.048
Hawke's Bay				2	7	134	214	35	5		397	55.725	0.720	0.036

Table 7. Results of the Duncan new multiple range test applied to the ranked mean numbers of vertebrae (spring and autumn spawners combined) of herring from various Newfoundland and adjacent areas. (Any two means not included in the same bracket are significantly different; any two means included in the same bracket are not significantly different.)

Pooled year-classes		1963 year-class	
Area	Mean	Area	Mean
Fortune Bay	55.877	Fortune Bay	56.020
Conche	55.789	Quirpon	55.786
Quirpon	55.750	Conche	55.708
Hawke's Bay	55.725	Magdalen Islands	55.694
Trinity Bay	55.695	Southwest Nfld.	55.684
St. Mary's Bay	55.677	Placentia Bay	55.639
Notre Dame Bay	55.672	St. Mary's Bay	55.614
Magdalen Islands	55.625	Gabarus Bay, N.S.	55.547
Southwest Nfld.	55.617	Bonavista Bay	55.531
Placentia Bay	55.616	Trinity Bay	55.495
Strait of Belle Isle	55.615	Notre Dame Bay	55.424
Bonavista Bay	55.608	Hawke's Bay	55.417
Gabarus Bay, N.S.	55.497		

Table 8. Gill-raker numbers of autumn- and spring-spawning Atlantic herring from various Newfoundland and adjacent areas. (The double asterisk indicates significance at the 1% level.)

Areas	Autumn																
	43	44	45	46	47	48	49	50	51	52	53	54	55	NO	AVE	SD	SE
Gabarus Bay, N.S.			3	9	12	39	73	71	44	28	6	5		290	49.655	1.676	0.098
Magdalen Islands			3	22	36	77	93	74	33	21	2	3		364	48.997	1.634	0.086
Southwestern Nfld.		1	2	11	42	66	77	84	40	18	6		2	349	49.166	1.656	0.087
Fortune Bay																	
Placentia Bay		2	1	5	17	33	35	36	19	11	5	1		165	49.218	1.781	0.139
St. Mary's Bay		1	1	3	9	15	32	28	20	6	3	1		119	49.437	1.676	0.154
Trinity Bay				5	17	17	23	25	19	10	3			109	49.511	1.658	0.159
Bonavista Bay		1		1	5	13	25	20	13	5	3			86	49.488	1.577	0.170
Notre Dame Bay																	
Conche			2	2	6	15	16	19	8	7				75	49.200	1.644	0.190
Quirpon		1	3	5	10	23	26	24	20	19	2		1	134	49.448	1.933	0.167
Strait of Belle Isle		1		3	19	40	46	34	29	18	6	1		197	49.421	1.699	0.121
Hawke's Bay	1		2	7	14	27	41	34	17	11	3			157	49.146	1.716	0.137

Areas	Spring															Autumn sp.- Spring sp.
	43	44	45	46	47	48	49	50	51	52	53	NO	AVE	SD	SE	
Gabarus Bay, N.S.																
Magdalen Islands	1	4	10	24	30	24	13	2	2			110	47.036	1.490	0.142	1.961**
Southwestern Nfld.			12	20	28	39	25	10	2			136	47.610	1.436	0.123	1.556**
Fortune Bay			5	9	17	26	8	16	2	4	3	100	48.370	1.798	0.180	
Placentia Bay			3	7	36	40	45	32	14	4	1	182	48.621	1.503	0.111	0.597**
St. Mary's Bay	1	1	12	28	57	106	107	65	27	10	1	415	48.494	1.577	0.077	0.943**
Trinity Bay			2	7	40	78	98	59	25	10	1	320	48.863	1.362	0.076	0.678**
Bonavista Bay			1	7	32	66	98	61	25	8	3	301	48.973	1.359	0.078	0.515**
Notre Dame Bay			6	20	73	118	132	109	48	16	3	525	48.842	1.492	0.065	
Conche				2	11	17	22	14	7	2		75	48.853	1.363	0.157	0.347
Quirpon				2	10	23	20	11	9	4	1	80	48.950	1.509	0.169	0.498**
Strait of Belle Isle																
Hawke's Bay	2	3	8	23	42	53	48	37	15	4	1	236	48.229	1.740	0.113	0.917**

Table 9. Gill-raker numbers of male and female Atlantic herring from various Newfoundland and adjacent areas.

Male

Area and spawning group		43	44	45	46	47	48	49	50	51	52	53	54	55	NO	AVE	SD	SE
Gabarus Bay	(A)			2	8	5	17	31	27	23	16	4	1		134	49.619	1.822	0.157
Magdalen Islands	(S)		1	1	12	14	6	5	1	1					41	47.146	1.370	0.214
" "	(A)			2	6	15	31	35	29	9	12	1	3		143	49.105	1.759	0.147
SW Newfoundland	(S)			7	14	12	24	14	7	1					79	47.620	1.479	0.166
"	(A)			2	6	24	34	40	36	16	8	2		2	170	49.024	1.706	0.131
Fortune Bay	(S)		1	13	27	41	42	39	21	9	2	2			197	47.942	1.701	0.121
Placentia Bay	(S)			8	8	34	33	29	24	8	2				146	48.240	1.573	0.130
" "	(A)		1		2	8	20	19	27	13	4				94	49.191	1.490	0.154
St. Mary's Bay	(S)			7	10	20	59	48	31	11	4				190	48.516	1.468	0.107
" "	(A)		1	1	2	7	7	17	10	9	2	2	1		59	49.186	1.916	0.249
Trinity Bay	(S)			1	2	21	29	54	35	13	4				159	48.950	1.306	0.104
" "	(A)				2	5	8	15	9	11	2	3			55	49.455	1.687	0.227
Bonavista Bay	(S)				3	13	36	46	22	15	1				136	48.882	1.230	0.105
" "	(A)		1			2	4	12	8	9		2			38	49.553	1.655	0.269
Notre Dame Bay	(S)				13	40	65	57	59	20	10	1			265	48.808	1.479	0.091
Conche	(S)					7	10	15	8	4	1				45	48.889	1.265	0.189
"	(A)			1		3	8	10	11	4	3				40	49.250	1.498	0.237
Quirpon	(S)					6	9	10	4	5	3	1			38	49.158	1.636	0.265
"	(A)			1	1	7	13	7	12	9	9	2			61	49.508	1.876	0.240
Strait Belle Isle	(S)		1		1	11	25	23	15	17	10	2	1		106	49.349	1.746	0.170
Hawkes Bay	(S)	1	1	4	12	25	29	32	16	10	4	1			135	48.333	1.749	0.151
" "	(A)	1		1	5	6	14	17	11	3	5	1			64	48.766	1.849	0.231

Female

Area and spawning group		43	44	45	46	47	48	49	50	51	52	53	54	55	NO	AVE	SD	SE	Male-Female
Gabarus Bay	(A)			4	11	11	30	47	51	30	13	3	4		204	49.397	1.777	0.124	0.222
Magdalen Islands	(S)	1	3	9	12	16	18	8	1	1					69	46.971	1.5622	0.188	0.175
" "	(A)			1	16	21	46	58	45	24	9	1			221	48.928	1.5475	0.104	0.277
SW Newfoundland	(S)			5	6	16	15	11	3	1					57	47.596	1.387	0.184	0.024
"	(A)		1		5	18	32	37	48	24	10	4			179	49.302	1.600	0.120	-0.278
Fortune Bay	(S)		4	7	23	44	50	33	16	7	5	2			191	47.939	1.705	0.123	0.003
Placentia Bay	(S)			1	9	30	41	28	17	9	2	1			138	48.370	1.455	0.124	-0.130
" "	(A)		1	1	3	9	13	16	9	6	7	5	1		71	49.254	2.116	0.251	-0.063
St. Mary's Bay	(S)	1	1	5	18	37	47	59	34	16	6	1			225	48.476	1.642	0.109	0.040
" "	(A)				1	2	8	16	18	11	4	1	1		62	49.742	1.459	0.185	-0.556
Trinity Bay	(S)			1	5	19	49	44	24	12	6	1			161	48.776	1.414	0.111	0.174
" "	(A)				3	2	9	8	16	8	8				54	49.630	1.640	0.223	-0.175
Bonavista Bay	(S)			1	4	19	30	52	39	10	7	3			165	49.048	1.456	0.113	-0.166
" "	(A)				1	3	9	13	12	4	5	1			48	49.438	1.529	0.221	0.115
Notre Dame Bay	(S)			6	7	33	53	75	50	28	6	2			260	48.877	1.507	0.093	-0.069
Conche	(S)				2	4	7	7	6	3	1				30	48.800	1.518	0.277	0.089
"	(A)			1	2	3	7	6	8	4	4				35	49.143	1.817	0.307	0.107
Quirpon	(S)				2	4	14	10	7	4	1				42	48.762	1.376	0.212	0.396
"	(A)		1	2	4	3	10	19	12	11	10			1	73	49.397	1.991	0.233	0.111
Strait Belle Isle	(S)				2	8	15	23	19	12	8	4			91	49.505	1.649	0.173	-0.156
Hawkes Bay	(S)	1	2	4	11	17	24	16	21	5					101	48.089	1.727	0.172	0.244
" "	(A)			1	2	4	13	24	23	14	6	2			93	49.409	1.576	0.163	-0.643

A = Autumn; S = Spring

Table 10. Results of the Duncan new multiple range test applied to the ranked mean number of gill rakers of herring from various Newfoundland and adjacent areas (based on pooled year-classes).

Spring spawners		Autumn spawners	
Area	Mean	Area	Mean
Bonavista Bay	48.973	Gabarus Bay, N.S.	49.655
Quirpon	48.950	Trinity Bay	49.541
Trinity Bay	48.863	Bonavista Bay	49.488
Conche	48.853	Quirpon	49.448
Notre Dame Bay	48.842	St. Mary's Bay	49.437
Placentia Bay	48.621	Strait of Belle Isle	49.421
St. Mary's Bay	48.494	Placentia Bay	49.218
Fortune Bay	48.370	Conche	49.200
Hawke's Bay	48.229	Southwest Nfld.	49.166
Southwest Nfld.	47.610	Hawke's Bay	49.146
Magdalen Islands	47.036	Magdalen Islands	48.997

Table 11. Pectoral fin-ray numbers of autumn- and spring-spawning Atlantic herring from various Newfoundland and adjacent areas. (The double asterisk indicates significance at the 1% level.)

Areas	Autumn											Spring												Autumn sp.-Spring sp.
	15	16	17	18	19	20	21	NO	AVE	SD	SE	13	15	16	17	18	19	20	21	NO	AVE	SD	SE	
Gabarus Bay, N.S.		2	34	144	138	30	2	350	18.474	0.828	0.044													
Magdalen Islands		6	33	136	158	33		366	18.489	0.843	0.044		1	9	68	29	5			112	17.250	0.704	0.067	1.239**
Southwestern Nfld.		2	31	128	156	39	3	359	18.579	0.848	0.045			13	88	34	2			137	17.182	0.609	0.052	1.397**
Fortune Bay													3	103	216	56	13	3		394	16.954	0.796	0.040	
Placentia Bay		1	12	64	79	19	2	177	18.616	0.832	0.063			37	160	87	10	1		295	17.247	0.726	0.042	1.369**
St. Mary's Bay			7	46	48	16	1	118	18.559	0.822	0.076			26	201	164	20	2		413	17.446	0.707	0.035	1.113**
Trinity Bay		1	11	37	44	16	2	111	18.622	0.944	0.090	1	1	35	189	90	13	2		331	17.245	0.769	0.042	1.377**
Bonavista Bay		1	5	36	37	11	1	91	18.604	0.855	0.090		1	25	183	87	7	1	1	305	17.266	0.697	0.039	1.338**
Notre Dame Bay													2	79	319	124	18	1	1	544	17.154	0.737	0.032	
Conche		1	9	22	38	10		80	18.588	0.896	0.100			8	38	25	3			74	17.311	0.720	0.084	1.277**
Quirpon	1	1	17	52	49	13	1	134	18.418	0.936	0.081		1	11	36	22	9		1	80	17.388	0.987	0.110	1.030**
Strait of Belle Isle		2	13	78	87	19	1	200	18.555	0.813	0.057													
Hawke's Bay		1	16	56	62	23	1	159	18.585	0.902	0.072			18	118	93	7	1		237	17.388	0.690	0.045	1.197**

Table 12. Pectoral fin-ray numbers of male and female Atlantic herring from various Newfoundland and adjacent areas.

Area and spawning group		Male 15	16	17	18	19	20	21	NO	AVE	SD	SE	Female 13	15	16	17	18	19	20	21	NO	AVE	SD	SE	Male-Female
Gabarus Bay	(A)			15	59	53	12	1	140	18.464	0.826	0.070			2	19	85	85	18	1	210	18.481	0.831	0.057	-0.017
Magdalen Islands	(S)		4	24	12	2			42	17.286	0.708	0.109		1	5	44	17	3			70	17.229	0.705	0.084	0.057
" "	(A)		3	11	58	59	12		143	18.462	0.837	0.070			3	22	78	99	21		223	18.507	0.848	0.057	-0.045
SW Newfoundland	(S)		11	50	16	2			79	17.114	0.660	0.074			2	38	18				58	17.276	0.523	0.069	-0.162
"	(A)		1	10	70	70	21	1	173	18.595	0.820	0.062			1	21	58	86	18	2	186	18.565	0.875	0.064	0.030
Fortune Bay	(S)	1	55	112	23	7			198	16.899	0.740	0.053		2	47	103	32	6	3		193	17.010	0.848	0.061	-0.111
Placentia Bay	(S)		18	84	44	7			153	17.261	0.723	0.058			19	76	43	3	1		142	17.232	0.731	0.061	0.029
" "	(A)			3	39	45	10	2	99	18.687	0.778	0.078			1	9	25	34	9		78	18.526	0.893	0.101	0.161
St. Mary's Bay	(S)		14	98	67	10	1		190	17.400	0.726	0.053			12	103	97	10	1		223	17.484	0.690	0.046	-0.084
" "	(A)			3	23	24	7	1	58	18.655	0.828	0.109				4	23	26	9		62	18.645	0.811	0.103	0.010
Trinity Bay	(S)		20	94	44	7	1		166	17.247	0.742	0.058	1	1	15	95	46	6	1		165	17.242	0.797	0.062	0.005
" "	(A)		1	7	19	19	10		56	18.536	0.990	0.132				4	18	25	6	2	55	18.709	0.896	0.121	-0.173
Bonavista Bay	(S)		11	78	43	5			137	17.307	0.670	0.057		1	14	105	44	2	1	1	168	17.232	0.717	0.055	0.075
" "	(A)			3	16	17	4		40	18.550	0.783	0.124			1	2	20	20	7	1	51	18.647	0.913	0.128	-0.097
Notre Dame Bay	(S)	1	40	164	59	11		1	276	17.156	0.754	0.045		1	39	155	65	7	1		268	17.153	0.721	0.044	0.003
Conche	(S)		5	25	11	3			44	17.273	0.758	0.114			3	13	14				30	17.367	0.669	0.122	-0.094
"	(A)		1	5	12	22	5		45	18.556	0.918	0.137				4	10	16	5		35	18.629	0.877	0.148	-0.073
Quirpon	(S)	1	7	19	8	3		1	39	17.231	1.087	0.174			4	17	14	6			41	17.537	0.869	0.136	-0.306
"	(A)			10	28	17	6		61	18.311	0.867	0.111		1	1	7	24	32	7	1	73	18.507	0.988	0.116	-0.196
Strait Belle Isle	(A)		1	2	43	47	13	1	107	18.673	0.786	0.076			1	11	35	40	6		93	18.419	0.825	0.086	0.254
Hawke's Bay	(S)		12	68	51	3			134	17.336	0.671	0.058			6	50	42	4	1		103	17.456	0.711	0.070	-0.120
" "	(A)			7	29	18	9	1	64	18.500	0.926	0.116			1	9	27	44	14		95	18.642	0.886	0.091	-0.142

A = Autumn; S = Spring

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Table 13. Results of the Duncan new multiple range test applied to the ranked mean numbers of pectoral fin rays of spring-spawning herring from various Newfoundland and adjacent areas (based on pooled year-classes).

Spring spawners	
Area	Mean
St. Mary's Bay	17.446
Hawke's Bay	17.388
Quirpon	17.388
Conche	17.311
Bonavista Bay	17.266
Magdalen Islands	17.250
Placentia Bay	17.247
Trinity Bay	17.245
Southwest Nfld.	17.182
Notre Dame Bay	17.154
Fortune Bay	16.954

Table 14. Anal fin-ray numbers of autumn- and spring-spawning Atlantic herring from various Newfoundland and adjacent areas. (The double asterisk indicates significance at the 1% level.)

Areas	Autumn											Spring											Autumn sp.- Spring sp.
	15	16	17	18	19	20	21	NO	AVE	SD	SE	15	16	17	18	19	20	21	NO	AVE	SD	SE	
Gabarus Bay, N.S.		10	75	155	96	12	1	349	18.080	0.874	0.047												
Magdalen Islands	1	2	63	155	115	28	3	367	18.300	0.907	0.047		7	35	53	15			110	17.691	0.763	0.073	0.609**
Southwestern Nfld.	1	8	67	153	106	16	2	353	18.164	0.902	0.048		10	49	58	14	1		132	17.598	0.798	0.069	0.566**
Fortune Bay												2	26	114	176	70	7		395	17.777	0.893	0.045	
Placentia Bay	1	3	34	71	33	2		144	17.958	0.818	0.068	1	20	86	117	27	5		256	17.641	0.861	0.054	0.317**
St. Mary's Bay		5	27	40	22	4		98	17.929	0.933	0.094	1	22	117	190	65	7		402	17.783	0.849	0.042	0.146
Trinity Bay	1	4	31	43	28	4		111	17.946	0.952	0.090	1	12	75	155	80	8	1	332	17.991	0.874	0.048	-0.045
Bonavista Bay		5	19	44	20	2		90	17.944	0.866	0.091		6	73	149	60	15	1	304	18.026	0.863	0.050	-0.082
Notre Dame Bay												1	15	145	261	105	14		541	17.917	0.829	0.036	
Conche		2	16	38	21	1	2	80	18.113	0.914	0.102		4	23	28	16	3	1	75	17.920	1.021	0.117	0.193
Quirpon		5	28	55	34	6	1	129	18.085	0.944	0.109		4	21	30	14	6	1	76	18.000	1.058	0.122	0.085
Strait of Belle Isle		1	46	88	56	8		199	18.121	0.826	0.059												
Hawke's Bay		7	35	61	40	12	1	156	18.115	1.009	0.081	2	12	55	101	61	7		238	17.958	0.940	0.061	0.157

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Table 15. Anal fin-ray numbers of male and female Atlantic herring from various Newfoundland and adjacent areas.

Area and spawning group		Male 15	16	17	18	19	20	21	NO	AVE	SD	SE	Female 15	16	17	18	19	20	21	NO	AVE	SD	SE	Male-Female
Gabarus Bay	(A)		4	32	66	32	5		139	18.014	0.851	0.072		6	43	89	64	7	1	210	18.124	0.888	0.061	-0.110
Magdalen Islands	(S)			19	14	9			42	17.762	0.790	0.122		7	16	39	6			68	17.647	0.787	0.095	0.115
" "	(A)		2	21	69	37	12	2	143	18.294	0.918	0.077	1		42	86	78	16	1	224	18.304	0.902	0.060	-0.010
SW Newfoundland	(S)		6	26	35	9	1		77	17.649	0.839	0.100		4	23	23	5			55	17.527	0.766	0.103	0.122
"	(A)	1	4	37	70	53	6	1	172	18.116	0.923	0.070		4	30	83	53	10	1	181	18.210	0.882	0.066	-0.094
Fortune Bay	(S)	2	14	57	83	38	3		197	17.761	0.931	0.066		10	55	92	32	4		193	17.819	0.847	0.061	-0.058
Placentia Bay	(S)	1	5	45	63	19	1		134	17.724	0.808	0.070		15	41	54	8	4		122	17.549	0.910	0.082	0.175
" "	(A)		1	20	39	16	1		77	17.948	0.759	0.087	1	2	14	32	17	1		67	17.970	0.887	0.108	-0.022
St. Mary's Bay	(S)	1	8	65	81	28	4		187	17.743	0.860	0.063		14	52	99	37	3		205	17.820	0.858	0.060	-0.077
" "	(A)		3	14	18	11	3		49	17.939	1.008	0.144		2	14	22	11	2		51	17.941	0.904	0.127	-0.002
Trinity Bay	(S)		7	42	75	40	2	1	167	17.946	0.873	0.068	1	5	33	80	40	6		165	18.036	0.876	0.068	-0.090
" "	(A)		2	18	19	16	1		56	17.929	0.912	0.122	1	2	13	24	12	3		55	17.964	0.999	0.135	-0.035
Bonavista Bay	(S)		3	29	70	31	4		137	18.029	0.804	0.069		3	44	79	29	11	1	167	18.024	0.911	0.071	0.005
" "	(A)		2	7	20	11			40	18.000	0.816	0.129		3	12	24	9	2		50	17.900	0.909	0.129	0.100
Notre Dame Bay	(S)	1	9	77	126	54	5		272	17.875	0.841	0.051		6	68	135	51	9		269	17.959	0.816	0.050	-0.084
Conche	(S)		3	15	15	12			45	17.800	0.919	0.137		1	8	13	4	3	1	30	18.100	1.125	0.205	-0.300
"	(A)		1	10	21	11	1	1	45	18.089	0.925	0.138		1	6	17	10		1	35	18.143	0.912	0.154	-0.054
Quirpon	(S)		1	10	17	8	1		37	17.946	0.848	0.139		3	11	13	6	5	1	39	18.051	1.234	0.198	-0.105
"	(A)		1	14	27	15	2	1	60	18.100	0.915	0.118		4	14	28	19	4		69	18.072	0.975	0.117	0.028
Strait Belle Isle	(A)		1	22	45	33	6		107	18.196	0.863	0.083			24	43	23	2		92	18.033	0.777	0.081	0.163
Hawke's Bay	(S)	2	8	29	56	36	4		135	17.948	0.987	0.085		4	26	45	25	3		103	17.971	0.880	0.087	-0.023
" "	(A)		5	11	24	14	7		61	18.115	1.097	0.140		2	24	37	26	5	1	95	18.116	0.955	0.098	-0.001

A = Autumn; S = Spring

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Table 16. Results of the Duncan new multiple range test applied to the ranked mean numbers of anal fin rays of herring from various Newfoundland and adjacent areas (based on pooled year-classes).

Spring spawners		Autumn spawners	
Area	Mean	Area	Mean
Bonavista Bay	18.026	Magdalen Islands	18.300
Quirpon	18.000	Southwest Nfld.	18.164
Trinity Bay	17.991	Strait of Belle Isle	18.121
Hawke's Bay	17.958	Hawke's Bay	18.115
Conche	17.920	Conche	18.113
Notre Dame Bay	17.917	Quirpon	18.085
St. Mary's Bay	17.783	Gabarus Bay, N.S.	18.080
Fortune Bay	17.777	Placentia Bay	17.958
Magdalen Islands	17.691	Trinity Bay	17.946
Placentia Bay	17.641	Bonavista Bay	17.944
Southwest Nfld.	17.598	St. Mary's Bay	17.929