Northwest Atlantic Fisheries Organization

Serial No. N433

NAFO SCR Doc. 81/IX/127

THIRD ANNUAL MEETING - SEPTEMBER 1981

The Use of Meristic Counts in Indicating Herring Stocks in the Gulf of Maine and Adjacent Waters

by

V. C. Anthony
Northeast Fisheries Center, National Marine Fisheries Service
Woods Hole, Massachusetts 02543, USA

Introduction

Research in the Northwest Atlantic on herring stock separation began on a very limited basis only after 1950. A study of parasites (Sindermann, 1957) during 1955 to 1957 provided some insight that two stocks might be present along the coast of Maine although no definitive conclusions were made. Sindermann found a high incidence of the myxosporidian, Kudoa clupeidae, in young herring from western Maine but none in herring from eastern Maine. Since the differences between eastern and western Maine in parasitized herring remained at age 2 and 3 Sindermann suggested that infected young herring from western Maine did not move eastward and that a separation existed between immature herring along the Maine coast at age 2 with an approximate transition zone from Cape Small to Mount Desert Island. Actually there was some indication of a slight eastward movement at age 2 but only to Penobscot Bay and this was very limited. The incidence of infection rose from 0 in Penobscot Bay at age 1 to 2% or 3% at age 2 compared with a percent incidence of about 25% at age 2 in Casco Bay. Incidence of this protozoan parasite in western Maine herring was reduced at age 2 and reduced still further at age 3. The 1954 and 1955 year classes had infections of myxosporidia of 56% and 43% at the end of age 1. The percent infection dropped to 34% and 22% for the two year classes by the end of age 2. Aquarium studies did not indicate a differential mortality between infected and uninfected herring and this was supported by the finding of similar proportions of "light", "moderate", and "heavy" infections of western Maine herring during both ages 1 and 2. Sindermann concluded that the populations of herring in western Maine were diluted by an influx of uninfected herring from eastern Maine or from offshore waters thereby reducing the percent of uninfected fish at age 2. If a migration occurs along the Maine coast, the incidence of parasitism by Kudoa clupeidae would suggest a movement from east to west, as very few infected fish were found in eastern Maine at any age.

Sindermann's work (1957) on the parasitism of young herring by larval nematodes (Anisakis sp.) also suggested the presence of 2 groups of herring along the Maine coast. Few herring of age 1 were infected with Anisakis sp. west of Penobscot Bay while the parasite was common east of Penobscot Bay especially east of Pleasant Bay and in Passamaquoddy Bay. The difference in frequency of occurrence of Anisakis sp. persisted between eastern and western Maine for a year class during the first two years of life in spite of a slight westward movement of parasitized herring.

The incidence of larval cestodes suggests that herring of age 2 found in the southern Gulf of Maine, Rhode Island and Connecticut areas do not migrate to the northern Gulf of Maine or to Nova Scotia. No larval cestodes were found in age 1 herring but age 2 herring and older contained this parasite from Penobscot Bay, Maine to Long Island, N.Y. The incidence of the parasite increased with decreasing latitude. Mature herring were examined from Georges Bank and they also contained larval cestodes. If herring migrated from the southern Gulf of Maine - Long Island, N.Y. area to the northern Gulf of Maine - Nova Scotia area the herring from the northern Gulf of Maine and Nova Scotia would have contained the parasite. The presence of this parasite does not preclude the possibility of migration from the southern Gulf of Maine to Georges Bank, however, or from northern Gulf of Maine to southern waters.

The first "conclusive evidence" of possible stock differences was presented by Sindermann and Mairs (1959) and Sindermann (1962) in what they called a major blood group system in Atlantic sea herring. This system consisted of two types: C-positive and C-negative. The cells of C-positive individuals were agglutinated by normal lobster serum, anti-herring immune sera produced in rabbits, or the extracts of certain strains of lima beans. The cells of C-negative individuals were not agglutinated by any of these reagents. The frequency of C-negative individuals was about 23% in immature herring in the western section of Maine but only about 29% in immature herring in the eastern section. This suggested that these groups of immature herring came from different spawning stocks, but no group of adult herring was found that contained more than 3 to 4% C-negative individuals. It was later found by Sindermann and Honey (1962-63, unpublished information) that a group of immature herring sampled in winter in western Maine contained no C-negative fish; on holding this group of herring at the laboratory, subsamples taken in the following summer and early fall average 38% C-negative. Similar studies continued by Ridgway (1969) indicated that herring became C-negative because of anemia. It was found that C-negative fish had a high frequency of immature red cells in their circulation and according to Ridgway, the work of Walter et al (1965) showed that the immature red cells of rats and chickens have different effective surface charges than mature red cells. Although the agglutinability of cells is known to be related to their surface charges (Pollock and Hager, 1965), Ridgway (1969) found that both C-negative and C-positive cells removed an identical fraction of antibody even though C-negatives are not agglutinated by the serum. Thus the C-negative class seems due to the existence of anemic fish containing a high percentage of immature red cells which will not agglutinate even though possessing the same antigenic makeup as the C-positive fish. This method, therefore, was discarded as a possible means of identifying stocks of herring.

Meristic characters were examined as a means of stock identification during the 1960's and some of the early results were presented in Anthony and Boyar (1968). Further analyses were presented in Anthony (1972) and Anthony and Waring (1980). This document presents some new information on the fixation times of meristic counts, and, thus the value of one meristic count over others, expands earlier discussions on changes in meristic count with age and year class and summarizes some results presented elsewhere for discussion purposes.

Figure 1 shows the areas I investigated in an attempt to discover stock differences within the Gulf of Maine. The Nova Scotia fishery began in the middle 1960's as a reduction fishery on spawning herring and changed over to a food fishery in the early 1970's. Purse seines and gill nets were used to catch herring in the fall that were spawning in the Lurcher and Trinity Shoals area. Gradually fishing expanded throughout the summer months as well. The Georges Bank and Jeffreys Ledge fisheries also were primarily for spawning herring for food purposes but they too expanded throughout the year. The coastal Maine and Passamaquoddy fisheries have been in existance since 1875 and are for young immature herring, mainly age 2. The early Cape Cod fishery was a trap fishery apparently harvesting both mature and immature migrating herring in limited quantities. In the late 1970's winter fisheries developed in Cape Cod Bay, on Stillwagen Bank and up to Jeffreys Ledge. A winter fishery has existed off Rhode Island for many years but has been dependent on migrations to this area which have not occurred in some years.

Materials and Methods

The examination of meristic counts is expensive, tedious and time consuming and, therefore, requires careful planning to achieve the proper testing of the hypotheses without being prohibitively expensive. The number of fish to examine for meristic counts was determined from scattered samples of meristic counts taken from herring during 1960. Figure 2 shows the curves of standard error ($S_{\bar{x}}$) against number of fish for dorsal and right pectoral fin rays and vertebral counts. The first 1,000 fish reduces the $S_{\bar{x}}$ by about 0.02 but an additional decrease of 0.01 requires a large increase in sample size. It appears that a proper study of meristic counts of herring should aim for a minimum of 1,000 fish for a given test area and year class of herring. This goal was sought through maximization of numbers of samples of small size, thus providing the best estimate of variability of meristic counts in the population.

Counts of fin rays (right pectoral and dorsal fins) and vertebrae were made with the aid of a low power (10X to 30X) dissecting microscope. Vertebral counts excluded the hypural plate. Fused vertebrae occurred in about 1% of the herring (determined from a randomly selected sample of 7,525) but were counted by using the neural spines (Figure 3). Vertebral columns in which individual vertebrae could not be distinguished were discarded. Otoliths provided age information according to Watson (196~~6~~4).

The reliability of a racial character partially depends on the coefficient of variation associated with the counting of each meristic character. Coefficients of variation (C.V.) were computed from samples chosen at random for five different areas (Table 1). The coefficients of variation varied from 3.13% to 4.37% for dorsal fin rays, 4.18% to

4.80% for right pectoral fin rays and 1.03% to 1.60% for vertebrae, and averaged 3.44% for dorsal, 4.39% for right pectoral and 1.27% for vertebrae. To detect reliably the same difference among test areas more fish need to be examined for right pectoral counts than for counts of vertebrae. Number of herring examined for vertebral and right pectoral counts are given in Tables 2 and 3 along with the mean counts by age, area and year class.

The Fixation of Meristic Counts

Meristic characters of fish are determined both by genetic (long term) and environmental (short term) means. The environmental effects have been well demonstrated by many studies on many species. The number of rays in a fin are apparently determined by the environment at the egg and/or early larval stages. Herring eggs are demersal and are, therefore subject to the vagaries of the environmental conditions existing on the ocean floor. Upon hatching, however, the larvae rise to the upper water layers and become pelagic where they are under the influence of the environmental conditions existing near the surface. The effect of the environments along the ocean bottom and ocean surface may be very different on the fixation of meristic counts. If the counts of several meristic characters are fixed at different stages of development, different environments may determine the counts of each meristic character. The order in which vertebral and fin ray counts are fixed should indicate which meristic characters are likely to be affected by which environment realizing that the order of fin fixation does not indicate *when* the counts were fixed.

In an attempt to establish the order of development of the fins of the Atlantic herring, 2 samples of herring larvae (Table 4) were stained with alizarin red S. The amount of stain that each fin absorbs is a function of the time in the stain and the amount of calcium deposited in that fin be= cause the bony portion of the fin absorbs the stain. Taning (1944, 1952) found with brown trout (*Salmo trutta trutta* L.) after approximately 4½ months that all fin rays were sufficiently ossified to be stained by alizarin S. Samples 1 and 2 were taken on March 7 and April 8, 1969, respectively from the upper Damariscotta River near Boothbay Harbor, Maine. Since the average month of spawning of Atlantic herring in the Gulf of Maine is September, larvae were about 5 and 6 months old. The rays of each of the dorsal, anal and right pectoral fins were counted which were partially stained. The vertebrae in all cases were fully stained indicating that ossification of the vertebrae occurs before all fin rays. Taning (1952) concluded from his work on the brown trout that "the number of vertebrae in our common fishes, such as cod, plaice, herring, etc., are certainly determined before the egg hatches."

Gabriel (1944) showed for Fundulus heteroclitus (L.) and Dannevig (1950) for Pleuronectes platessa (L.) that the number of vertebrae is also determined during incubation of the egg. Hempel and Blaxter (1961) reported that the myotome count of Atlantic herring is determined before hatching. Blaxter (1957), however, found that the myotome count increased between holding and absorption of the yolk sac and that myotome and vertebral count were related. Bückmann (1950) and Tester (1938) gave evidence that the number of vertebrae in herring is at least partially determined after the eggs have hatched.

Figures 4 and 5 show the results of the 2 samples examined. All curves were free hand fitted to the data. Each sample was stained separately so that the total quantity of stain absorbed varied among samples. The order at which the fins take up the stain is readily apparent. In Figure 4, (sample 1) the dorsal fin had all of its rays at least partially stained (and in most cases they were fully stained) by 29 mm total length. The pectoral fin, on the other hand, showed no stain at all in any fin ray. The anal fin showed a sharp increase in the numbers of rays containing some stain in larvae from 29 mm through 35 mm in total length. The rays of the dorsal fin may have been determined at a much smaller size than 29 mm and at a younger age than approximately 5 months. Bigelow and Schroeder (1953), in fact, gave 15-17 mm total length as the size at which the dorsal fin is formed. Blaxter (1963) indicated that the dorsal fin is formed at 13 - 14 mm in total length.

Figure 5 (Sample 2) shows that the anal fin was completely stained at about 32 or 33 mm and the pectoral fin was completely stained at about 50 mm in total length. Bigelow and Schroeder (1953) give 30 mm as the size when the anal fin is formed. These figures show the order in which ossification occurs and do not tell exactly at which size ossification occurs due to the variability in staining; but the rate of development of ossification should give an idea as to the total order of development of each fin. If the order of development of ossification is related to the order in which the fin ray counts are fixed, then Figures 4 and 5 give an indication of the order of fixation of the fin rays. It is clear from the figures that the dorsal fin shows evidence of ossification first, (after the vertebrae) followed by the anal and then the pectoral fin.

Further evidence of the development of the fin rays of Atlantic herring is available from correlation coefficients of the counts between two meristic characters. Taning (1952) showed that the numbers of dorsal and pectoral fin rays of brown trout were positively correlated due to their times of fixation being close to one another. Recently, Templemen (1970) found a high correlation ($r = 0.71$, $P < 0.001$) between numbers of anal and dorsal fin rays in 173 specimens of the Greenland halibut (Reinhardtius hippoglossoides) from the northwest Atlantic. Such findings appear to be rare, however, especially in species of fish with a narrow range of fin ray counts. The Greenland halibut has from 90 - 107 dorsal fin rays and as great a variation of anal fin rays as from 62 to 84. Such a wide range of discrete data might be nearly normal and more capable of showing a statistically significant correlation than a species like herring which has a limited range in fin ray counts. For example, assume that some factor at the time of fin ray fixation, say, temperature, causes a 10% change in meristic count of both the Greenland halibut and the herring. Since the range of fin ray counts for halibut is 90 - 107 or 18 rays for the dorsal fin and 62 to 94 or 23 for the anal fin, a 10% change in count might be reflected in the count of rays by a change in 2 rays. The herring, on the other hand, varies over a range of 7 pectoral rays and 6 dorsal rays. A 10% change in meristics might not be reflected at all in this case. Therefore, correlated change in fin ray counts for Atlantic herring due to such things as environmental influences can be expected to be small. The correlation coefficients are very low but were surprisingly consistent in their relation to one another (Table 5). The correlation coefficients between the vertebral counts and the dorsal fin ray counts were noticeably higher then the coefficients for the vertebral and pectoral fin ray counts for all sections of the Maine coast and for each year class. The correlation coefficients between the vertebral and dorsal fin ray counts averaged over year classes 1961-1966 varied from 0.07 to 0.11 among sections of the Maine coast. The correlation coefficients for both combinations of vertebrae-pectoral and dorsal-pectoral were less than the correlation of vertebrae and dorsal counts. Considering the limited and discrete distributions of each meristic character it is surprising to obtain a correlation of even this magnitude. Counts of four meristic characters were taken on two year classes of adult herring (Table 6) which provide the same conclusion as the juvenile herring. Furthermore, the correlation of the anal fin rays with the dorsal fin rays was much greater than any two of the other meristic characters. Templemen (1970) found this to be the case with the Greenland halibut also. The average correlation coefficient for the anal and dorsal rays was 0.15 for vertebrae-dorsal and for vertebrae-anal 0.08, for anal-pectoral 0.07 for dorsal-pectoral 0.04 and for vertebrae-pectoral 0.04. If the vertebral count is established earliest of the four meristic characters then the correlation coefficients are additional evidence that the dorsal fin ray count is

established nearer to the time of fixation of the vertebral count than to the time of fixation of the pectoral fin ray count. The anal fin and dorsal fin rays are apparently fixed at about the same time. Since the fin ray counts are established after the vertebral counts this is further evidence that the right pectoral counts are formed later than the dorsal counts.

The Relationship of Meristic Counts to Surface Water Temperatures

To test the effect of water temperature on meristic counts, particularly the relation between surface water temperature and pectoral fin ray counts, the age 2 average meristic counts for year classes 1960-1966 were compared with the surface water temperature at the time of birth (Figure 8). The right pectoral fin ray counts along the Maine coast and from Passamaquoddy Bay, New Brunswick, increased significantly as the mean September temperature declined during the 1960's. In the one year in which the mean September temperature increased (1961) the right pectoral fin ray count declined. The pectoral fin ray count varied inversely for all year classes in all areas except in 1965. The right pectoral counts rose very sharply for the 1964 year class, dropped slightly in 1965 and rose again in 1966. The sharp increase in right pectoral counts occurred in western, central and eastern Maine but the count rose only slightly in Passamaquoddy Bay in 1964 implying a similar stock composition along the Maine coast which was different from the stock composition in Passamaquoddy Bay. The dorsal fin ray counts also rose while the mean September temperature was declining from 1961 to 1966. But, the dorsal ray count varied little from 1960 to 1963 as the water temperature rose and fell. The change in count occurred in all three areas along the coast of Maine and Passamaquoddy Bay in much the same way. Numbers of vertebrae generally increased from 1961 to 1965 and then declined in 1966. While the relation was inverse to surface water temperatures, it was not nearly so pronounced as for the pectoral and dorsal fin rays.

The correlation of these mean meristic counts at age 2 with temperatures is shown in Table 7. Rays of both fins are inversely significantly correlated with the mean September surface temperature taken at Boothbay Harbor, Maine, in the year of birth. The correlation coefficients were significant for all 4 areas for the pectoral fin and 3 areas for the dorsal fin. Vertebral counts were significantly correlated with surface water temperatures only in Passamaquoddy Bay. The birthplace of these fish and the exact time of birth is unknown so that correlation coefficients as high as these with Boothbay Harbor surface water temperatures is surprising.

These data demonstrate two things: 1) right pectoral and dorsal fin rays vary inversely with surface water temperatures and right pectoral fin rays appear to be the best discriminants of the three counts examined and 2) vertebral counts tend to vary inversely with surface water temperature but not significantly so and much less than pectoral and dorsal fin ray counts. These results tend to support the idea that because vertebral counts are formed first, perhaps, in the egg stage, that they may be more a function of bottom water temperature than surface water temperature although a relationship with surface water cannot be entirely excluded. Day (1957), in fact, reported that spring spawning herring from the east coast of Nova Scotia to the Gulf of St. Lawrence were more dependent on surface water temperature than on bottom water temperatures. There was no correlation between bottom temperatures in May and vertebral counts of these areas while a definite negative correlation existed between the vertebral counts and summer surface water (Figures 6 and 7).

Temperature Differences among Spawning Areas and Expected Meristic Differences

The average water temperatures at the surface and at 50 meters depth for 1940-1959 in the Gulf of Maine, Georges Bank area in September is given in Figure 9. While the data may be old, an averaged 20 year period should indicate both long term surface and bottom temperature differences that can be expected to produce meristic differences in stock characters. The average surface temperatures in September from the northern edge of Georges Bank where spawning occurs to the southwest Nova Scotia spawning grounds ranged from 12°C to 16°C whereas the water temperatures at 50 meters have only ranged from 11°C to about 12°C. Because of a 4 degree difference at the surface component to a 1 degree difference at 50 meters a meristic character fixed by the surface environment such as pectoral fin rays might be expected to vary more than a meristic character fixed by the ocean bottom environment such as vertebrae (ignoring for the moment the inherent characteristics of the meristic characters).

The average surface temperature in September between the southwestern portion of Maine to Georges Bank ranges only from 14°C to 16°C with the surface temperature on Jeffreys Ledge nearly the same as those occurring on Georges Bank. The range of average water temperature at 50 meters however, from southwestern Maine, and Jeffreys Ledge to Georges Bank was 8°C to 12°C. Because of a 2 degree difference at the surface compared to a 4 degree difference at 50 meters, a meristic character fixed by the ocean bottom environment might be expected to demonstrate stock differences between the western Gulf of Maine area and Georges Bank.

Since the greatest differences in surface water temperatures are between the spawning areas off southwestern Nova Scotia and Georges Bank, right pectoral fin ray counts can be expected to demonstrate stock differences it is questionable whether right pectoral fin ray counts can discriminate stock differences between Jeffreys Ledge and Georges Bank. Vertebral counts might be useful in this regard but the bottom temperatures are not greatly different and the vertebral counts are probably not entirely a function of bottom temperature.

Differences in Meristic Counts of Adult Herring

Figure 10 shows mean counts of pectoral and dorsal rays and vertebrae with two standard errors on either side of the mean for the Gulf of Maine; Georges Bank and adjacent areas for year classes 1958 and 1960-1966. Meristic counts were combined over all year classes and ages 4-8 for each area. The pectoral and vertebral counts of the adult herring indicate differences among areas. Inshore Maine and Canadian areas seem to be different from Georges Bank and Cape Cod herring, for example. This was also demonstrated with the adult herring of the 1958 and 1960 year classes by Anthony and Boyar (1968).

Adult herring from offshore Maine, Jeffreys Ledge and off Cape Ann, Massachusetts, seem to be intermediate in mean count between those from Maine-Nova Scotia areas and the Georges Bank-Cape Cod areas. The mean pectoral fin ray counts for herring found off Cape Ann agree with herring from Georges Bank although the sample size was small.

Analysis of variance tests were run for year classes 1958 through 1965 to test for mean differences between herring found in Nova Scotia, eastern Maine, western Maine, Cape Cod and Georges Bank. The tests were run for each year class for both the vertebral and right pectoral fin ray counts. The results are shown in Table 8. All tests were significant except the vertebrae for the 1962, 1964 and 1965 year classes and the right pectoral fin rays for the 1965 year class. As will be shown later, the meristic counts increased on Georges Bank markedly for the 1964 and 1965 year classes over the previous year classes and the stock differences were no longer apparent. Prior to the coming of the 1964 year class, however, the areas were generally different in meristic count among adults. Adjusted _t_-tests were conducted between all areas to determine those areas that may contain different stocks (or groups of herring. This test is explained in Scheffé (1950) and its use outlined in Anthony (1972). It is a planned comparison technique and avoids the wide intervals encountered with unplanned comparison techniques. When used to test for differences between means, the null hypothesis tends to be rejected more easily than with an unplanned comparison technique.

The probabilities that two areas contain fish with meristic counts that are not different are given in Table 9. The probabilities (P_i) that two areas do not differ were combined for the two meristic characters for each year class and over year classes for each meristic character where $-2 \sum_{i}^{I} \ln P_i$ is distributed as chi-square with twice as many degrees of freedom as there are P_i to be combined (Fisher, 1963). Disadvantages of combining in this way are that all four meristic counts are treated equally and that each P_i is treated as being independent. Also, one year class with a very low probability, such as <0.001 when combined with other year classes of much higher probabilities will produce a probability that is generally <0.05 for the entire set.

The data indicate that there is a Nova Scotia-Maine complex of herring that is different from a Georges Bank-Cape Cod complex. Herring from Nova Scotia and eastern Maine were not significantly different for any year class as was the case between herring from Georges Bank and Cape Cod. Herring from western Maine, eastern Maine and Nova Scotia, however, were generally significantly different from herring from Cape Cod and Georges Bank. Herring from western Maine seem to be somewhat intermediate between the Georges Bank-Cape Cod complex and the Nova Scotia and eastern Maine complex. Four of eight year classes had meristic counts that were significantly different between western Maine and Nova Scotia. Three of 7 year classes between eastern and western Maine were different.

Examination of Table 9 shows that year classes 1964 and 1965 do not generally reflect the same suggestion of stocks as mentioned above. The mean meristic counts for these two year classes were greater than for other year classes for the Georges Bank and Cape Cod area (Tables 2 and 3). Year classes 1958 through 1963 were very consistent in the suggestion of stock differences.

Change In Meristic Count With Age

A very interesting aspect of meristic counts of Atlantic herring is that the counts of the juvenile herring along the Maine coast do not agree with the counts of the adult herring caught in the same area. The right pectoral fin ray counts of mature herring (age 4 and older) are significantly greater than the counts of the age 2 herring which have provided the bulk of the herring in the Maine sardine fishery. Figure 11 shows the mean meristic counts of herring of the 1960 to 1965 year classes from the Maine coast and Passamaquoddy Bay, New Brunswick. The change in age of the right pectoral counts is striking, Except for ages 1 and 2 in western Maine the counts increased progressively with age. The differences were significant in nearly all cases. The increase in right pectoral fin ray counts is most pronounced in Passamaquoddy Bay and in eastern Maine. Although the dorsal and ventral counts showed little change in counts with age, the vertebral counts for Passamoquoddy Bay and eastern Maine did show slight changes for some ages; an increase from ages 1 and 2 to 3 and 4 for Passamoquoddy Bay and an increase from age 3 to 4 in eastern Maine. Iles (19) also reported the same low meristic counts in the New Brunswick juvenile fishery and presented evidence that these fish did not recruit to the Nova Scotia adult herring fishery.

Figure 12 compares mean right pectoral fin ray counts by age among areas of the Gulf of Maine and as far south as waters off Delaware. The lower figure shows the area differences already mentioned among older herring. The upper figure shows the increase in mean counts with age and the similarity of counts of age 1, 2 and 3 herring along the Maine and New Brunswick coasts with mean counts of older fish from Georges Bank, Cape Cod and areas southward. It is possible, therefore, that Maine juvenile herring could recruit to the Georges Bank or Jeffreys Ledge fisheries. It does not seem feasible that the juvenile herring with low pectoral counts that are caught in Maine waters spawn along the Maine or Nova Scotia coasts as adults.

Examination of Within-age Change in Meristic Counts

The change in meristic count among ages of immature herring could occur at any time of the year. As mentioned earlier there is a definite movement of herring into the coastal waters of Maine during the early summer months and an exodus of herring sometime in the fall. The most logical time for a change in meristic counts to appear is during the approximate eight months when the herring are not present along the coast. As the herring grow older they move inshore less and less until at age 4 they are only found among the offshore islands and beyond. It may be that as the herring grow older, different components of the population move to different areas. The young herring may be composed of several stocks which slowly begin to separate as the fish grow older. Such separation, however, may occur during the summer as well. It is commonly believed that the young herring move to the inshore Maine waters to feed and for this reason it seems unlikely that a mixture of stocks would separate and migrate during the feeding season. To examine the time of meristic count change I combined year classes 1960-1965 by adjusting each year class to the mean of the 1963 year class and plotted the change by weeks for ages 1-4 (Figure 13).

Ages 3 and 4 show a great deal of variability even though the year classes are all adjusted to the 1963 year class. This is simply due to lack of data. The dotted lines represent the regression lines fitted to the data. Generally the slopes increase. When the slopes decrease it is because of a few aberrant data points. For western Maine, age 3, the unusually low counts during weeks 45-47 cause the negative slope and for Passamaquoddy Bay, age 4, the very low count in week 48 may have caused the minus slope. The mean values increased every year except between ages 1 and 2 for western Maine; and this was due to three unusually high values for weeks 31-34 in age 1. The meristic counts in western Maine increased little during ages 1 and 2; the count was slightly greater in age 3 (although decreasing during the season) and much greater at age 4. The meristic counts in Passamaquoddy Bay increased sharply during age 1, slightly during age 2 and were much higher at age 3. In all 3 areas of the Maine coast and in Passamaquoddy Bay, it was obvious that although the meristic counts tended to increase somewhat during the year that the big increase in meristic counts occurred between the fall and spring migrations.

A very interesting aspect of Figure 13 is the similar pectoral counts between the two areas lagged by one year; for ages 1 to 4 for Passamaquoddy the mean counts were 18.11, 18.22, 18.36 and 18.43. For Western Maine for ages 2 to 5 the counts were 18.11, 18.18, 18.36 and 18.43. One explanation is that certain herring with low meristic counts at age 2 leave Passamaquoddy Bay and move to the westward. The same movement may occur in western Maine but those fish might be replaced with herring from Passamaquoddy Bay.

Because of the possibility of an increase in meristic count with length within the season and not with time, tests were run to determine the nature of changes in meristic count with length. If a relationship existed, the larger herring would have the lower counts as they would be born first in the fall when the waters were warmer. Therefore, any relationship of meristic counts with length under these conditions would be inverse (negative slope). Ten fish were randomly selected for each one centimeter length group for each year class of each year and tested for differences in meristic count with size for a given year class at a given age. Regressions of meristic counts (vertebrae, dorsal and right pectoral fin rays) on total length were calculated for years 1963 through 1965 for year classes 1960 through 1964. Student t-tests indicated that only two regression lines of 27 had slopes significantly different from 0; the right pectoral counts of the 1961 and 1962 year classes and the slopes were both positive. I conclude, therefore, that fish present within a given year of a given year class of different lengths do not have different meristic counts.

Increase in meristic count with year classes

Figure 14 displays the mean right pectoral fin ray counts by year class, age and area for the coastal Maine area. These data clearly show the increase in pectoral ray counts with successive year classes. This was previously noted in Figure 8 for age 2 herring. Age 1 mean counts show this progression especially well. The mean right pectoral counts of age 1 herring in Passamaquoddy Bay increased from 17.93 to 18.68 in just six years. In every case for all areas the age 1 mean count increased over the previous year class. Only the 1961 and 1965 year classes failed to observe this trend as age 2 fish. The change was especially great beginning with the 1963 year class. In central and western Maine year classes 1960 through 1963 were fairly similar. If coastal Maine is a feeding area for many stocks of herring a reduction in the stock with low meristic counts would explain the change in mean meristic count and the reduction in catch as well.

The increase in pectoral fin ray counts by year class was especially striking for the Cape Cod and Georges Bank herring (Tables 2 and 3). The mean pectoral count for the Georges Bank fish for year classes 1958-1963 varied between 18.007 and 18.140 but the count for the 1964 year class was 18.258 and for the 1965 year class, 18.388. Limited data for the 1966-1968 year classes give estimates of 18.490, 18.338 and 18.400 respectively. These counts are very much greater than found for year classes prior to the 1964 year class. The same relative change also occurred for adult herring found off Cape Cod.

Summary

When the juvenile herring fishery along the Maine coast declined during the 1960's and heavy foreign fishing began on Georges Bank, the question of stock identification became very important. The analysis of meristic counts was one approach to solve the problem of stock identification. Previous research had indicated that bottom temperatures were associated with vertebral counts. Staining of herring indicated the order in which meristic counts were developed.

The vertebrae are formed first, the dorsal fin next, the anal fin third and the pectoral fins last. Therefore, since herring larvae are pelagic pectoral fin rays are most likely to be affected by surfact water temperature (Figure 8). The number of fin rays vary inversely to water temperatures within the range of water condition normally found in the Gulf of Maine area. The right pectoral fin appears to be the best stock discrimination of the 4 meristic characters examined. Differences in water temperature among the herring spawning sites in the Gulf of Maine and Georges Bank (Figure 9) indicated that these should be differences in environmentally induced characters such as meristic counts, especially between herring spawning off Nova Scotia and on Georges Bank.

Right pectoral fin ray counts may not descriminate between herring born in the southwestern Gulf of Maine area and Georges Bank but vertebral counts might due to the lack of differences in surface water temperatures and the 4 degree difference in bottom water temperatures. Examination of the 1958 and 1960 year classes of herring (Anthony and Boyar 1968) produced information that adult herring along the Maine coast had pectoral ray counts of around 18.45 which differed greatly with herring found on Georges Bank. Adult herring from Nova Scotia also were different from herring found on Georges Bank and in the Cape Cod area. These differences held through the 1963 year class, also, and two general complexes of spawning herring stocks were assumed; the Maine - Nova Scotia complex and the Georges Bank - Cape Cod complex. The Jeffreys Ledge - Stellwagen Banks spawning group may be a separate stock or racial group within one of the complexes. For both the right pectoral counts and the vertebral counts the Jeffreys Ledge and Stellwagen Banks areas were intermediate in counts between eastern Maine - Nova Scotia and Georges Bank - Cape Cod.

The same differences did not hold when juvenile herring were examined, however, (Figure 15). For year classes prior to 1964, the meristic counts agreed most closely to adult herring sampled from Georges Bank. I assume that herring born on Georges Bank return there to spawn and have low pectoral fin ray counts throughout their life. Herring which spawn along the Maine coast probably also return to their spawning ground and have high meristic counts. The difference in water temperature supports this explanation. The number of rays, vertebrae, etc., once determined at an early age do not change. Therefore, the young herring that subsequently spawn on Georges Bank must have low meristic counts and the young herring that subsequently spawn along the Maine coast must have high meristic counts. It is possible that the young herring along the

Maine coast prior to the 1964 year class subsequently recruited, at least in part, to the Georges Bank fishery although herring from Jeffreys Ledge may also have high pectoral fin ray counts. Examining the change in meristic counts of young herring on a week to week basis indicates that the major increase in meristic counts along the Maine and New Brunswick coasts, occurred between the fall and spring migrations, the change was either due to a winter mortality of herring with low counts or a change in stock composition from one year to the next. The amount of increase in meristic counts with age for a given year class for the right pectoral counts is considerable. It is doubtful whether a differential mortality could account for the great differences. The most logical explanation to the author is that the young herring with low meristic counts recruited away from the Maine and New Brunswick coasts to the adult stock with low pectoral counts. This stock could be from Jeffreys Ledge and south to Georges Bank. The large quantity of fish precludes recruiting to only Jeffreys Ledge, however. The young herring with high meristic counts which ultimately spawn along the Maine coast may also have been present in these inshore waters but if so were in much smaller numbers than herring which recruited elsewhere with the lower meristic counts.

Young herring (age 1 and 2) before 1969 are generally not found on Georges Bank. Herring begin to recruit to that area at age 3 which is also the age when the pectoral count begins to increase along the Maine coast. Recruitment is complete to Georges Bank by age 4 and 5 at which time the pectoral fin ray count of the herring along the Maine coast has reached a stationary level of around 18.40-18.50.

The pectoral fin-ray counts began to increase for successive year classes beginning with the 1964 year class, and no significant differences were apparent with subsequent year classes until the examination of meristic counts ceased in 1971 (Figure 15). A possible explanation of the increase in meristic counts beginning with the 1964 year class is the decrease in water temperature in all areas. The right pectoral fin-ray counts of herring at age 2 along the Maine coast and from Passamaquoddy Bay, New Brunswick, increased as the mean September temperature declined during the 1960s (Figure 15). As the water temperature decreased, the differences in temperature between the spawning areas also apparently diminished and there were no longer differences in fin-ray counts among the areas. whatever the cause in the increase of meristic counts of herring on Georges Bank meristic characters cannot be used to discriminate stocks until the adult spawning (Figure 15) fish show differences in counts. During the 1950's the water temperatures increased again and the environments of spawning areas within the Gulf of Maine and adjacent areas may be different again so that meristic counts may now be useful in discriminating stocks once more.

Literature Cited

Anthony, V.C. 1972. Population dynamics of the Atlantic herring in the Gulf of Maine. Ph.D. Thesis, Univ. Wash., 266 pp. (unpublished).

Anthony, V.C., and G. Waring. 1980. The assessment and management of the Georges Bank herring fishery. Rapp. P.-v. Réun. Cons. Int. Explor. Mer, 177: 72-111.

Anthony, V.C. and H.C. Boyar. 1968. Comparison of meristic characters of adult herring from the Gulf of Maine and adjacent waters. Int. Comm. Northw. Atlant. Fish., Spec. Publ. 5: 61-98.

Bigelow, H.B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish. Bull. U.S. 74: 88-100.

Blaxter, J.H.S. 1957. Herring rearing - III. The effect of temperature and other factors on myotome counts. Ibid., 1957, No. 1, 16 pp.

Blaxter, J.H.S. 1962. Herring Rearing - IV. Rearing beyond the yolksac stage. Mar. Res. No. 1, 18 p.

Bückmann, A. 1950. Die Untersuchungen der Biologischen Anstalt über die Ökologie der Heringsbrut in der sudlichen Nordsee, II. Helgöland, Wiss. Meeresunters. 3: 171-205.

Dannevig, A. 1950. The influence of the environment on number of vertebrae in plaice. Rep. Norwegian Fishery and Marine Investigation 9, 9 p.

Day, L.R. 1957. Populations of herring the northern Gulf of St. Lawrence . Bull. Fish. Res. Bd. Can., No. 111: 103-119.

Gabriel, M.L. 1944. Factors affecting the number and form of vertebrae in *Fundulus heteroclitus*. J. exp. Zool. 95: 105-147.

Hempel, G., and J.H.S. Blaxter. 1961.

Iles, D.

Pollack, W. and Hager, H.J. 1965. A pgysio-chemica study of hemagglutination. Soc. Int. Transfusion Sang. C.R.X. Congress Stockholm 4: 802-813.

Ridgway, G. 1969. Serological and biochemical studies of herring populations in the Gulf of Maine. Int. Council for Exploration of the Sea. Committee Memorandum No. 24: 1-13.

Scheffé, H. 1959. The analysis of variance. John Wiley and Sons, New York N.Y., 477 p.

Sindermann, C.J. 1957. Diseases of fishes of the western North Atlantic. VI. Geographic discontinuity of myxosporidiosis in immature sea herring. Maine Department Sea and Shore Fisheries, Research Bulletin No. 29, 20 p.

Sindermann, C.J. 1962. Serology of Atlantic clupeoid fishes. Amer. Nat. 96: 225-231.

Sindermann, C.J. and D.F. Mairs. 1959. A major blood group system in Atlantic sea herring. Copeia, 1959, No. 3, p. 228-232.

Taning, A.V. 1944. Experiments on meristics and other characters in fishes. I. On the influence of temperature on some meristic characters in sea trout and the fixation of these characters. Medd. Komm. Havunders. Fish., 11(3): 1-66.

Taning, A.V. 1952. Experimental study of meristic characters in fishes. Biological Review (Cambridge), 27(2): 169-193.

Templeman, W. 1970. Vertebral and other meristic characteristics of Greenland halibut, Reinhardtius hippoglossoides, from the northwest Atlantic. Jour. Fish. Res. Bd. Can. Vol. 27, No. 9, p. 1549-1562.

Tester, A.L. 1938. Variation in the mean vertebral count of herring (Clupea pallasii) with water temperature. J. Cons. Perm. int. Explor. Mer. Vol. 13, pp. 71-75.

Watson, J.E. 1964. Determining the age of young herring from their otoliths. Transactions American Fisheries Society, Vol. 93, No. 1, p. 11-20.

Walter, H., F. Selby, and R. Winge. 1965. Counter-current distribution of red blood cells of different ages and of different species. Fed. Proc. 24: No. 2, Part I, 542 (Abstract No. 2282).

Table 1. Estimates of coefficient of variation (C.V.) in percent for 2 year classes of herring from 5 locations.

	Vertebrae		Fin rays					
	Year Class		Right Pectoral Year Class		Dorsal Year Class		Anal Year Class	
	1958	1960	1958	1960	1958	1960	1958	1960
Nova Scotia	1.166	1.174	4.471	4.241	3.274	3.380	4.613	4.901
Eastern Maine	1.026	1.604	4.789	4.178	3.125	3.443	5.479	4.763
Western Maine	1.165	1.158	4.392	4.312	3.448	3.390	4.924	4.689
Cape Cod	1.372	1.444	4.522	4.520	3.428	3.172	4.737	3.852
Georges Bank	1.277	1.280	4.252	4.214	3.403	4.370	4.864	4.873
Total	6.006	6.660	22.426	21.465	16.768	17.755	24.617	23.078
Mean	1.201	1.332	4.485	4.293	3.336	3.551	4.923	4.616

Table 2 . Mean counts of Vertebrae and number of herring examined for year classes 1958-1967 for six areas.

		YEAR CLASS									
		1958		1959		1960		1961		1962	
Area	Year	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
Nova Scotia	1962	55.528	53								
	1963	55.583	283			55.406	133				
	1964	55.473	129			55.491	291				
	1965										
	1966	55.708	72	55.516	124	55.488	320	55.405	227	55.484	64
	1967			55.541	207	55.521	317	55.493	365	55.419	74
	1968					55.507	136	55.482	166	55.391	184
Weighted average		55.568	537	55.532	331	55.491	1197	55.464	758	55.416	322
East	1962					55.438	192				
	1963					55.390	1003	55.320	2620	55.429	539
	1964	55.342	38			55.503	738	55.359	209	55.394	1974
	1965	55.387	31			55.466	678	55.667	15	55.388	165
	1966					55.625	16	55.214	14	55.276	29
	1967					55.545	11	55.513	39	55.552	29
	1968										
Weighted average		55.362	69			55.447	2638	55.327	2897	55.401	2736
West	1962					55.258	570				
	1963	55.592	211			55.460	1575	55.335	2846	55.310	371
	1964					55.387	377	55.302	265	55.379	4067
	1965	55.550	111			55.476	401			55.332	271
	1966	55.337	86	55.533	135	55.443	296	55.429	168	55.457	92
	1967			55.258	97	55.477	130	55.375	144	55.402	87
	1968					55.405	37	55.245	49	55.354	48
Weighted average		55.527	408	55.418	232	55.418	3386	55.337	3472	55.373	4936
Jeffreys Ledge-Stellwagen Bank											
	1966	55.318	44	55.411	73	55.407	91	55.342	38	55.455	11
	1967			55.370	27	55.237	38	55.250	28	55.385	13
	1968					55.407	145	55.374	249	55.451	215
	1969							55.336	241	55.347	193
	1970									55.391	179
Weighted average		55.318	44	55.400	100	55.383	274	55.353	656	55.399	611
Cape Cod	1963	55.355	169								
	1964	55.230	152			55.331	296				
	1965					55.349	361				
	1966	55.400	30	55.349	43	55.375	152	55.374	123	55.259	54
	1967			55.273	22	55.410	78	55.312	77	55.348	66
	1968					55.222	18	55.381	21		
	1969							55.727	11	55.351	37
	1970										
Weighted average		55.305	351	55.323	65	55.350	905	55.371	232	55.318	157
Georges Bank	1963	55.279	265			55.334	389				
	1964	55.344	157			55.376	532				
	1965	55.176	51			55.335	632				
	1966	55.393	28	55.306	49	55.377	459	55.306	565	55.268	194
	1967			55.217	23	55.328	134	55.283	343	55.316	98
	1968					55.389	36	55.413	150	55.372	226
Weighted average		55.295	501	55.278	72	55.354	2182	55.314	1058	55.322	518

Table 2. Mean counts of Vertebrae and number of herring examined for year classes 1958-1967 for six areas.(cont.)

Area	Year	YEAR CLASS 1963 Mean	N	1964 Mean	N	1965 Mean	N	1966 Mean	N	1967 Mean	N
Nova Scotia	1962										
	1963										
	1964										
	1965										
	1966	55.182	11								
	1967	55.445	155	55.455	11						
	1968	55.366	377	55.354	277	55.478	46				
Weighted average		55.385	543	55.358	288	55.478	46				
East	1962										
	1963										
	1964										
	1965	55.374	3811								
	1966	55.363	946	55.397	880	55.535	99				
	1967	55.495	206	55.416	250	55.403	1165	55.397	136		
	1968	55.217	60			55.342	284	55.327	1991	55.052	77
Weighted average		55.375	5023	55.401	1130	55.400	1548	55.331	2127	55.052	77
West	1962										
	1963										
	1964	55.423	575								
	1965	55.392	2305	55.466	378						
	1966	55.393	509	55.469	1318	55.555	137				
	1967	55.449	205	55.415	381	55.504	840				
	1968	55.490	98	55.509	106	55.396	351	55.395	1046	55.446	74
Weighted average		55.403	3692	55.439	542	55.481	1328	55.395	1046	55.446	74
Jeffreys Ledge-Stellwagen Bank	1966										
	1967										
	1968	55.396	96	55.293	41	55.529	17				
	1969	55.471	85	55.636	33	55.150	20	55.358	120		
	1970	55.379	161	55.450	140	55.375	96	55.392	125	55.271	59
Weighted average		55.407	342	55.449	214	55.361	133	55.375	245	55.271	59
Cape Cod	1963										
	1964										
	1965										
	1966	55.368	38								
	1967	55.435	85	55.553	85	55.400	15				
	1968	55.283	53	55.388	85	55.365	96	55.461	102		
	1969	55.329	70	55.465	99	55.426	101	55.332	371		
	1970			55.300	10	55.400	15	55.429	14		
Weighted average		55.362	246	55.462	279	55.397	227	55.362	487		
Georges Bank	1963										
	1964										
	1965										
	1966	55.268	71								
	1967	55.224	76	55.308	13						
	1968	55.344	157	55.400	60	55.531	32				
Weighted average		55.296	304	55.384	73	55.531	32				

Table 3. Mean counts of Right Pectoral fin rays of herring examined for year classes 1958-1969 for six areas.

		YEAR CLASS											
		1958		1959		1960		1961		1962		1963	
Area	Year	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
Nova Scotia	1962	18.472	53										
	1963	18.481	283			18.263	133						
	1964	18.504	129			18.385	291						
	1965												
	1966	18.347	72	18.500	124	18.544	320	18.507	227	18.406	64	18.000	11
	1967			18.517	207	18.577	317	18.455	365	18.243	74	18.155	155
	1968					18.610	136	18.518	166	18.321	184	18.422	377
	1969							18.495	93	18.500	132	18.418	292
	1970									18.393	89	18.396	106
Weighted Average		18.468	537	18.323	331	18.490	1,197	18.486	851	18.376	543	18.369	941
East	1962					18.151	192						
	1963					18.282	1,002	18.013	2,617	17.876	540		
	1964	18.290	38			18.461	738	18.168	208	18.116	1,977		
	1965	18.678	31			18.456	678	18.667	15	18.158	165	18.187	3,812
	1966					18.313	16	18.786	61	18.517	29	18.287	946
	1967					18.636	11	18.769	39	18.414	29	18.330	206
	1968											18.517	60
	1969							18.477	44	18.191	68	18.439	132
	1970									18.630	81	18.457	92
Weighted Average		18.464	69			18.369	2,637	18.060	2,984	18.097	2,889	18.225	5,248
West	1962					18.032	570						
	1963	18.427	211			18.167	1,584	17.978	2,852	17.970	371		
	1964					18.337	377	18.098	266	18.038	4,062	18.122	574
	1965	18.378	111			18.399	401			17.934	271	18.106	2,304
	1966	18.419	86	18.230	135	18.324	296	18.274	168	18.337	92	18.189	509
	1967			18.144	97	18.254	130	18.215	144	18.322	87	18.376	205
	1968					18.081	37	18.225	49	18.313	48	18.439	98
	1969							18.162	259	18.175	251	18.212	203
	1970									18.215	316	18.389	311
Weighted Average		18.412	408	18.194	232	18.207	3,395	18.025	3,738	18.057	5,498	18.165	4,204
Jeffreys Ledge	1966	18.227	44	18.151	73	18.220	91	17.974	38	17.818	11		
-Stellwagen	1967			18.519	27	18.263	38	18.250	28	18.231	13		
Bank	1968					18.207	145	18.193	249	18.135	215	18.479	96
	1969							18.116	241	18.204	193	18.224	85
	1970									18.156	179	18.342	161
	1971											18.295	163
Weighted Average		18.227	44	18.250	100	18.219	274	18.148	556	18.159	611	18.333	505
Cape Cod	1962												
	1963	18.142	169										
	1964	18.040	152			18.189	296						
	1965					18.213	361						
	1966	18.233	30	18.116	43	18.158	152	18.098	123	18.185	54	18.026	38
	1967			18.409	22	18.154	78	17.922	77	18.076	66	18.071	85
	1968					18.056	18	18.238	21			18.170	53
	1969							18.091	11	17.919	37	18.171	70
	1970												
Weighted Average		18.106	351	18.215	65	18.188	905	18.052	232	18.076	157	18.114	246
Georges Bank	1962												
	1963	18.034	265			18.026	389						
	1964	18.178	157			18.263	532						
	1965	18.177	51			18.101	632						
	1966	17.714	28	17.980	49	18.146	459	17.961	565	17.974	194	18.225	71
	1967			18.261	23	18.090	134	18.035	343	17.929	98	18.132	76
	1968					18.333	36	18.107	150	18.071	226	17.955	157
	1969							18.105	19	18.211	38	18.053	38
	1970									17.960	25	17.714	35
Weighted Average		18.076	501	18.070	72	18.140	2,182	18.007	1,077	18.019	581	18.029	377

Table 3. Mean counts of Right Pectoral fin rays of herring examined for year classes 1958-1969 for six areas. (cont.)

		YEAR CLASS											
		1964		1965		1966		1967		1968		1969	
Area	Year	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
Nova Scotia	1967	18.455	11										
	1968	18.531	277	18.217	46								
	1969	18.309	220	18.077	78	18.467	135						
	1970	18.245	94	18.634	101	18.591	105	18.438	16				
Weighted Average		18.404	602	18.356	225	18.521	240	18.438	16				
East	1966	18.408	880	18.263	99								
	1967	18.344	250	18.250	1,165	18.537	136						
	1968			18.299	284	18.509	1,991	18.520	77				
	1969	18.646	65	18.433	67	18.382	505	18.388	1,792	18.435	46		
	1970	18.391	110	18.593	113	18.544	182	18.541	183	18.500	398	18.224	125
Weighted Average		18.406	1,305	18.288	1,728	18.490	2,814	18.407	2,052	18.493	444	18.224	125
West	1965	18.252	377										
	1966	18.364	1,318	18.350	137								
	1967	18.373	381	18.355	840								
	1968	18.547	106	18.333	351	18.484	1,046	18.473	74				
	1969	18.248	161	18.262	187	18.430	928	18.323	316	18.133	15		
	1970	18.354	288	18.405	284	18.518	411	18.469	531	18.527	328		
Weighted Average		18.348	2,631	18.349	1,799	18.469	2,385	18.419	921	18.510	343		
Jeffreys Ledge	1968	18.317	41	18.353	17								
-Stellwagen	1969	18.515	33	18.350	20	18.500	120						
Bank	1970	18.343	140	18.427	96	18.520	125	18.305	59	18.429	21		
	1971	18.345	209	18.415	229	18.394	165	18.509	112	18.402	102	18.500	10
Weighted Average		18.355	423	18.412	362	18.463	410	18.439	171	18.407	123	18.500	10
Cape Cod	1967	18.212	85	18.533	15								
	1968	18.459	85	18.281	96	18.520	102						
	1969	18.202	99	18.248	101	18.469	371						
	1970	18.500	10	18.667	15	18.500	14						
Weighted Average		18.294	279	18.308	227	18.481	487						
Georges Bank	1967	17.923	13										
	1968	18.367	60	18.563	32								
	1969	18.304	46	18.222	36								
	1970	18.167	48	18.391	105	18.490	304	18.338	136	18.400	80		
Weighted Average		18.258	167	18.388	173	18.490	304	18.338	136	18.400	80		

Table 4. Number of fin rays of the dorsal, right pectoral and anal fins showing some stain*.

Sample Number 1					Sample Number 2				
	Total	Number of stained rays				Total	Number of stained rays		
Fish Number	length (cm)	Dorsal fin	Anal fin	Pectoral fin	Fish Number	length (cm)	Dorsal fin	Anal fin	Pectoral fin
1	34	19	9	0	1	39	20	17	6
2	29	18	5	0	2	41	19	17	8
3	31	17	15	0	3	38	18	17	6
4	38	19	17	0	4	39	19	18	7
5	29	17	0	0	5	34	19	--	3
6	29	17	0	0	6	42	18	17	10
7	29	17	6	0	7	39	18	17	5
8	32	17	15	0	8	39	19	19	9
9	39	19	18	0	9	33	18	16	0
10	34	19	17	0	10	34	19	17	2
11	34	19	10	0	11	34	19	18	2
12	34	18	18	0	12	39	19	19	9
13	32	17	--	0	13	40	19	18	12
14	34	18	11	0	14	37	19	17	4
15	33	18	10	0	15	39	18	17	8
16	39	19	17	0	16	36	19	17	2
17	32	17	9	0	17	44	20	18	15
18	38	18	17	0	18	45	19	18	13
19	35	18	16	0	19	35	20	17	5
20	30	18	0	0	20	36	19	19	3
21	35	19	9	0	21	31	18	17	0
22	32	19	18	0	22	38	20	17	8
23	31	17	10	0	23	37	19	18	6
24	33	18	0	0	24	37	18	17	5
25	37	18	17	0	25	38	19	17	8
26	35	18	12	0	26	33	18	17	0
27	32	18	--	0	27	43	21	18	13
28	33	18	12	0	28	41	18	16	11
29	37	19	17	0	29	41	20	18	12
30	35	19	16	0	30	40	19	19	12
					31	36	19	18	3
					32	40	19	17	6
					33	40	20	18	8
					34	37	19	17	8
					35	42	20	20	8
					36	40	18	17	8
					37	40	19	18	9

*For all fish, the dorsal fin rays contained the most stain per ray followed by the anal and the pectoral fins, in that order.

Table 5. Partial correlation coefficients of 3 meristic characters of juvenile herring.

Area	Meristic Characters*	Year Class 1961	1962	1963	1964	1965	1966	Mean
Western Maine	VD	0.07	0.11	0.07	0.09	0.06	0.01	0.07
	DP	0.07	0.07	0.00	-0.01	0.02	0.00	0.02
	VP	0.00	0.06	0.01	0.08	0.07	0.06	0.05
Central Maine	VD	0.03	0.11	0.09	0.06	0.14	0.12	0.09
	DP	0.08	0.06	0.03	0.04	0.07	-0.01	0.04
	VP	0.02	0.00	0.04	0.00	0.00	0.07	0.02
Eastern Maine	VD	0.07	0.08	0.09	0.10	0.08	0.03	0.07
	DP	0.09	0.11	0.01	0.06	0.02	0.04	0.05
	VP	0.03	0.07	0.05	0.04	0.00	0.04	0.04
Passamaquoddy Bay	VD	0.06	0.13	0.09	0.17	0.13	0.07	0.11
	DP	0.13	0.06	-0.02	-0.01	0.07	0.03	0.04
	VP	0.02	0.08	0.02	0.02	0.00	0.04	0.03

*VP = correlation of vertebral and right pectoral counts with effects of third variable, dorsal ray counts, held constant. VD and DP are similar.

Table 6. Correlation coefficients of 4 meristic characters of adult herring.

Areas	Meristic characters*	Year class 1958	1960	Mean
Nova Scotia	DA	0.21	0.16	0.18
	VD	0.10	0.08	0.09
	PA	0.11	0.12	0.12
	VA	0.13	0.10	0.12
	PD	0.06	0.05	0.06
	VP	0.09	0.12	0.10
Eastern Maine	DA	0.12	0.11	0.12
	VD	0.13	0.08	0.10
	PA	0.09	0.01	0.05
	VA	0.10	0.12	0.11
	PD	0.07	-0.01	0.03
	VP	-0.02	0.03	0.00
Western Maine	DA	0.21	0.12	0.16
	VD	0.05	0.07	0.06
	PA	0.07	0.06	0.06
	VA	0.08	0.04	0.06
	PD	-0.02	0.04	0.01
	VP	-0.03	0.05	0.01
Southern New England (Connecticut to Maine)	DA	0.12	0.13	0.12
	VD	0.10	0.10	0.10
	PA	0.08	0.07	0.08
	VA	0.03	-0.01	0.01
	PD	0.08	0.01	0.04
	VP	0.00	0.01	0.01
Georges Bank	DA	0.18	0.17	0.18
	VD	-0.05	0.17	0.06
	PA	0.04	0.06	0.05
	VA	0.12	0.07	0.10
	PD	0.05	0.02	0.04
	VP	0.10	0.06	0.08

*DA = correlation of dorsal and anal fin rays, VD = correlation of vertebrae and dorsal fin ray counts, etc.

Table 7. Correlation of mean meristic counts of age 2 Atlantic herring with mean September temperatures at Boothbay Harbor, Maine at time of birth.

Area	Vertebrae		Right Pectoral Fin		Dorsal Fin	
	r	n	r	n	r	n
Western Maine	-0.53	7	-0.84*	7	-0.89**	7
Central Maine	-0.46	7	-0.78*	7	-0.81*	7
Eastern Maine	-0.28	7	-0.83*	7	-0.60	7
Passamaquoddy Bay, New Brunswick	-0.79*	7	-0.85*	7	-0.80*	7
Total	-0.30	28	-0.77**	28	-0.71**	28

* indicates significance at the 5% level
** indicates significance at the 1% level

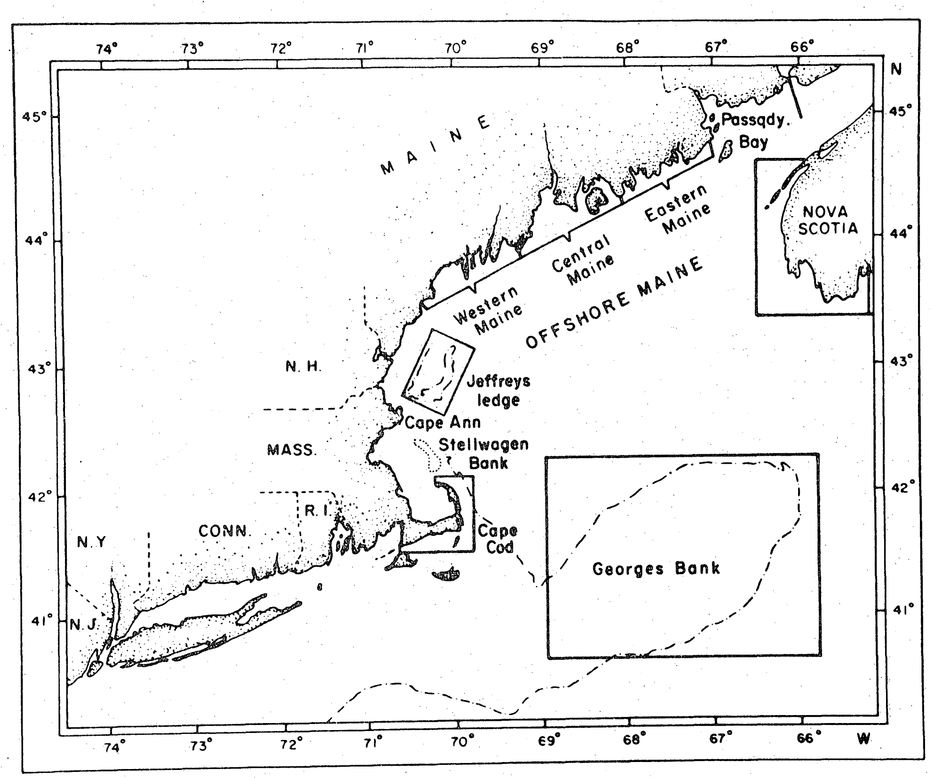

Figure 1. Areas investigated for the determination of racial differences among Atlantic herring.

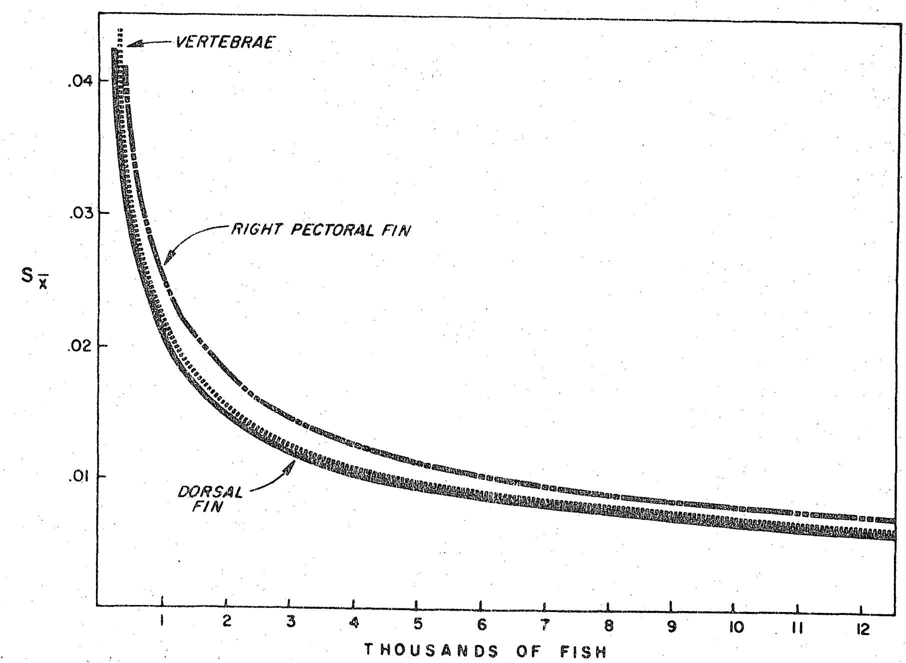

Figure 2. Standard error against sample size for fin rays and vertebral counts of herring.

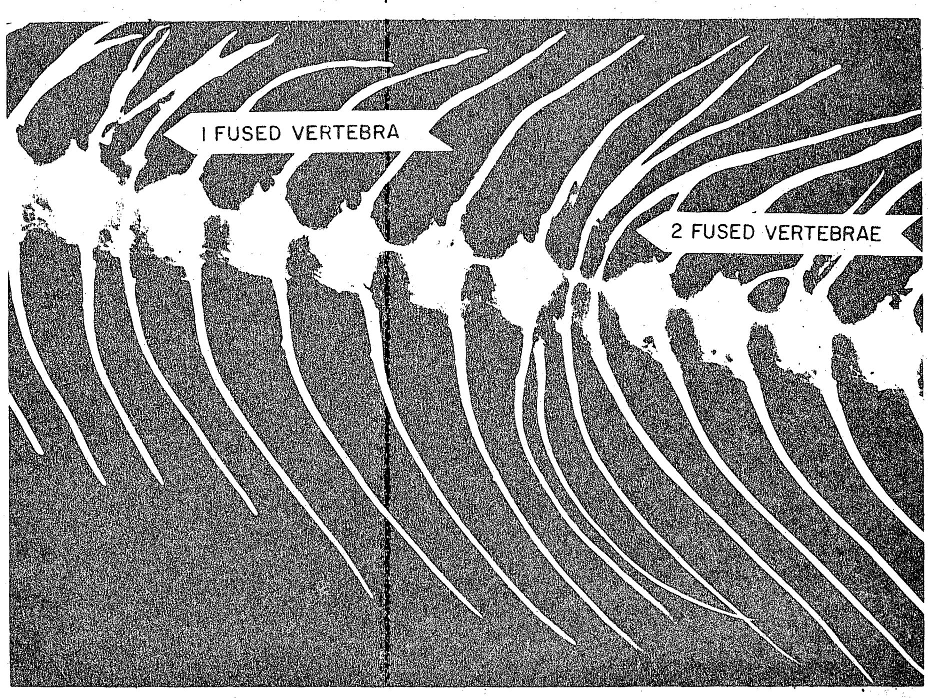

Figure 3. Fused vertebrae are occasionally encountered in Atlantic herring.

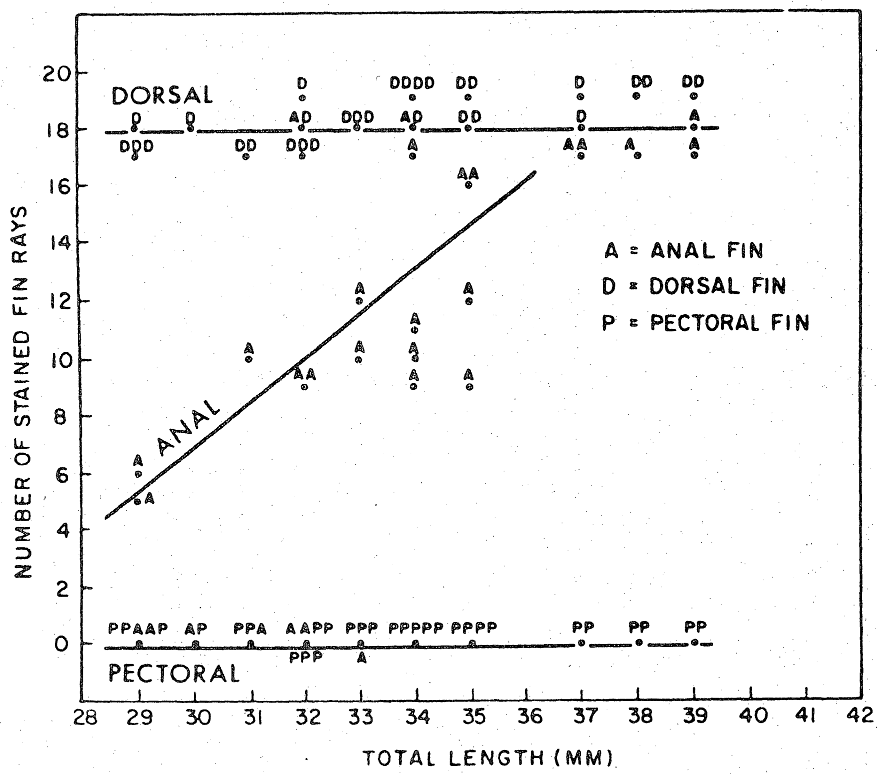

Figure 4. Results of staining dorsal, anal, and right pectoral fin rays of Atlantic herring (Sample 1).

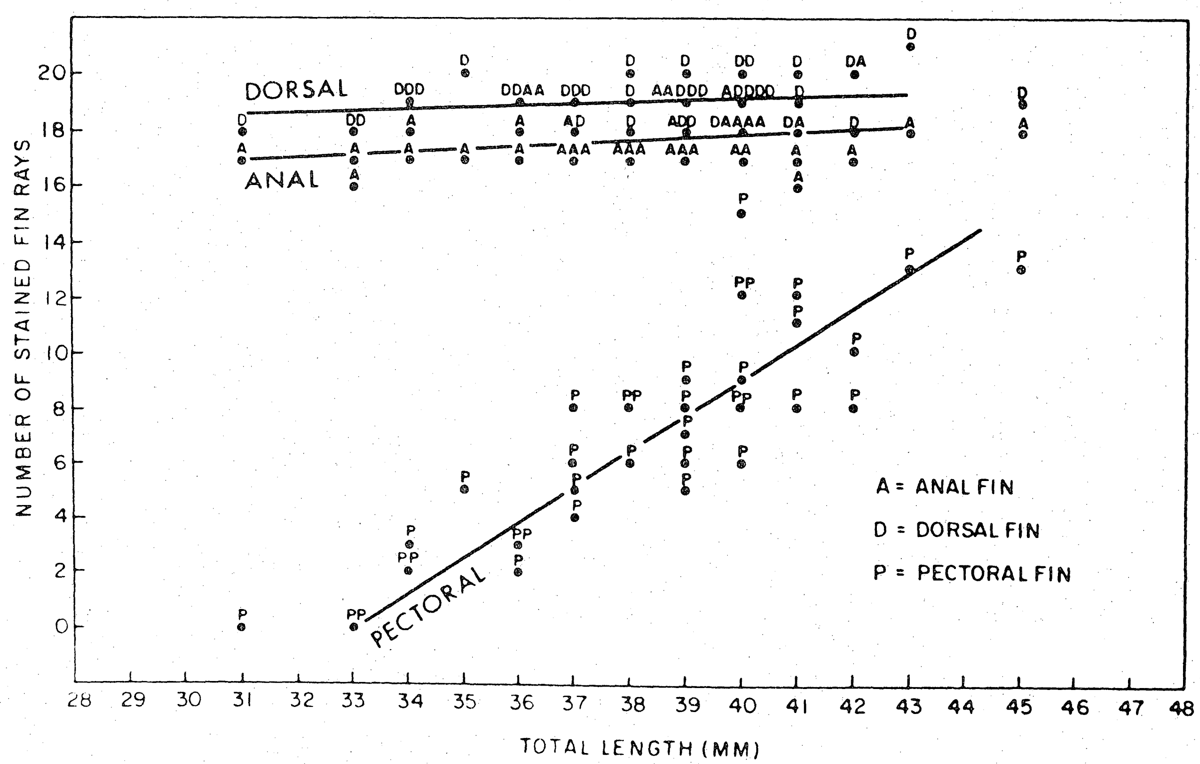

Figure 5. Results of staining dorsal, anal, and right pectoral fin rays of Atlantic herring (Sample 2).

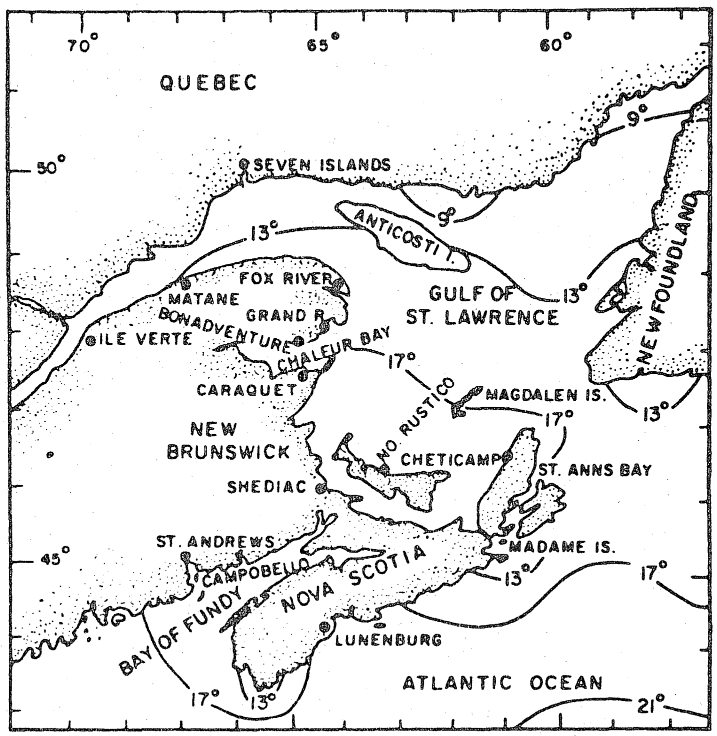

Figure 6. Average summer surface water temperatures in the Canadian Atlantic waters (from Day, 1957; p. 167).

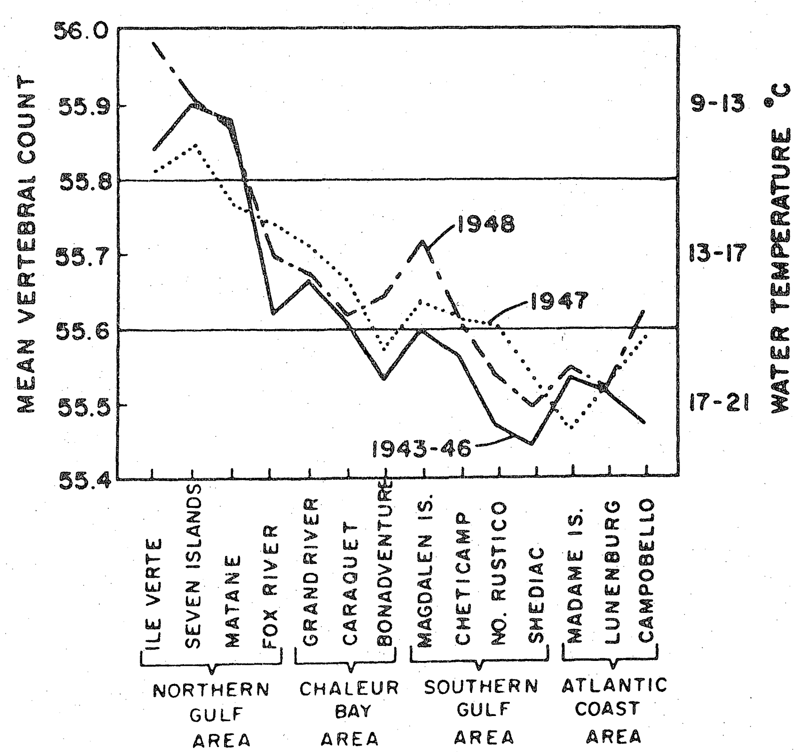

Figure 7. Mean total vertebral numbers for 1943-1946, 1947, 1948 in relation to summer surface water temperatures for areas in Canadian Atlantic waters (from Day, 1957, p. 169).

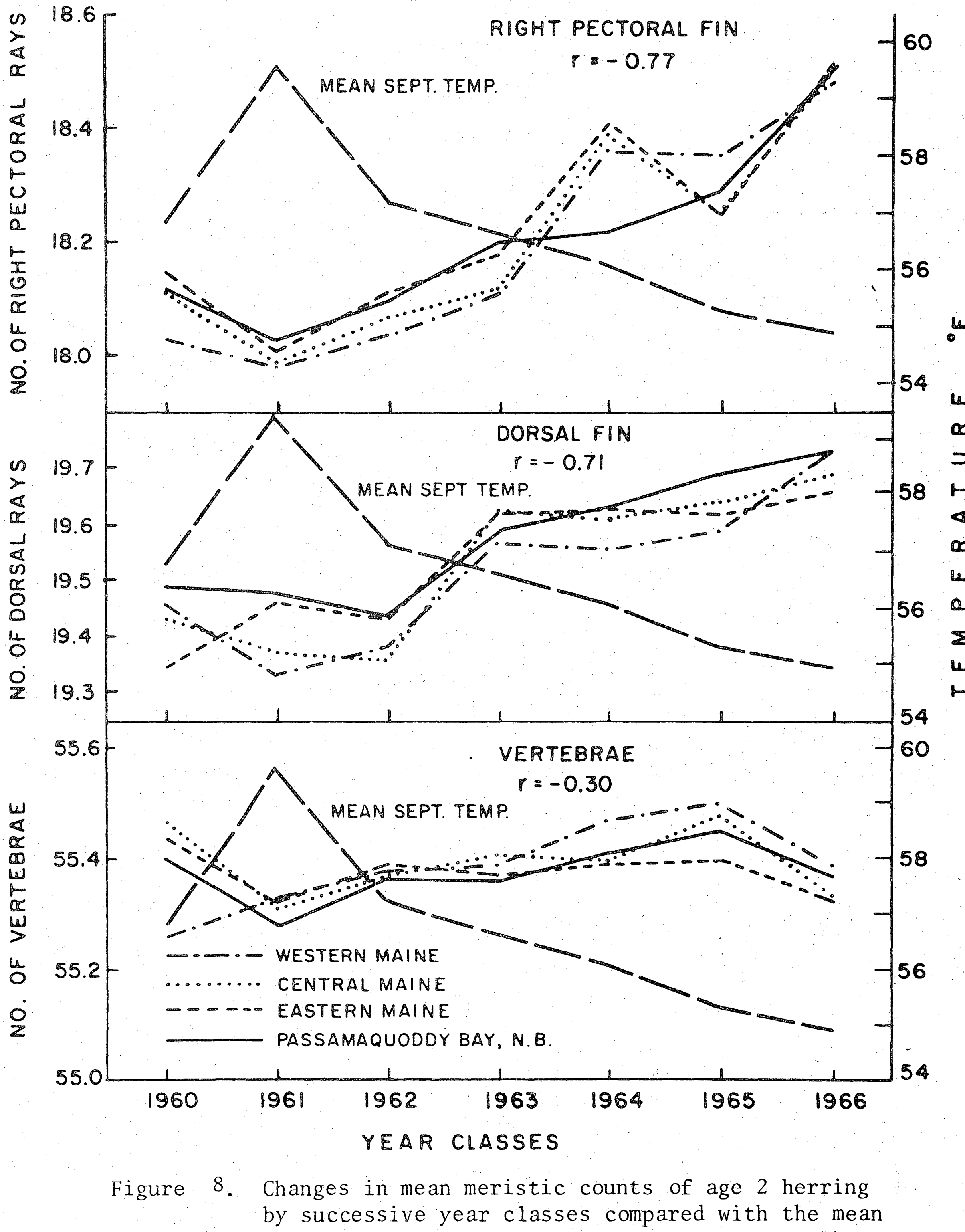

Figure 8. Changes in mean meristic counts of age 2 herring by successive year classes compared with the mean surface water September temperatures at Boothbay Harbor, Maine.

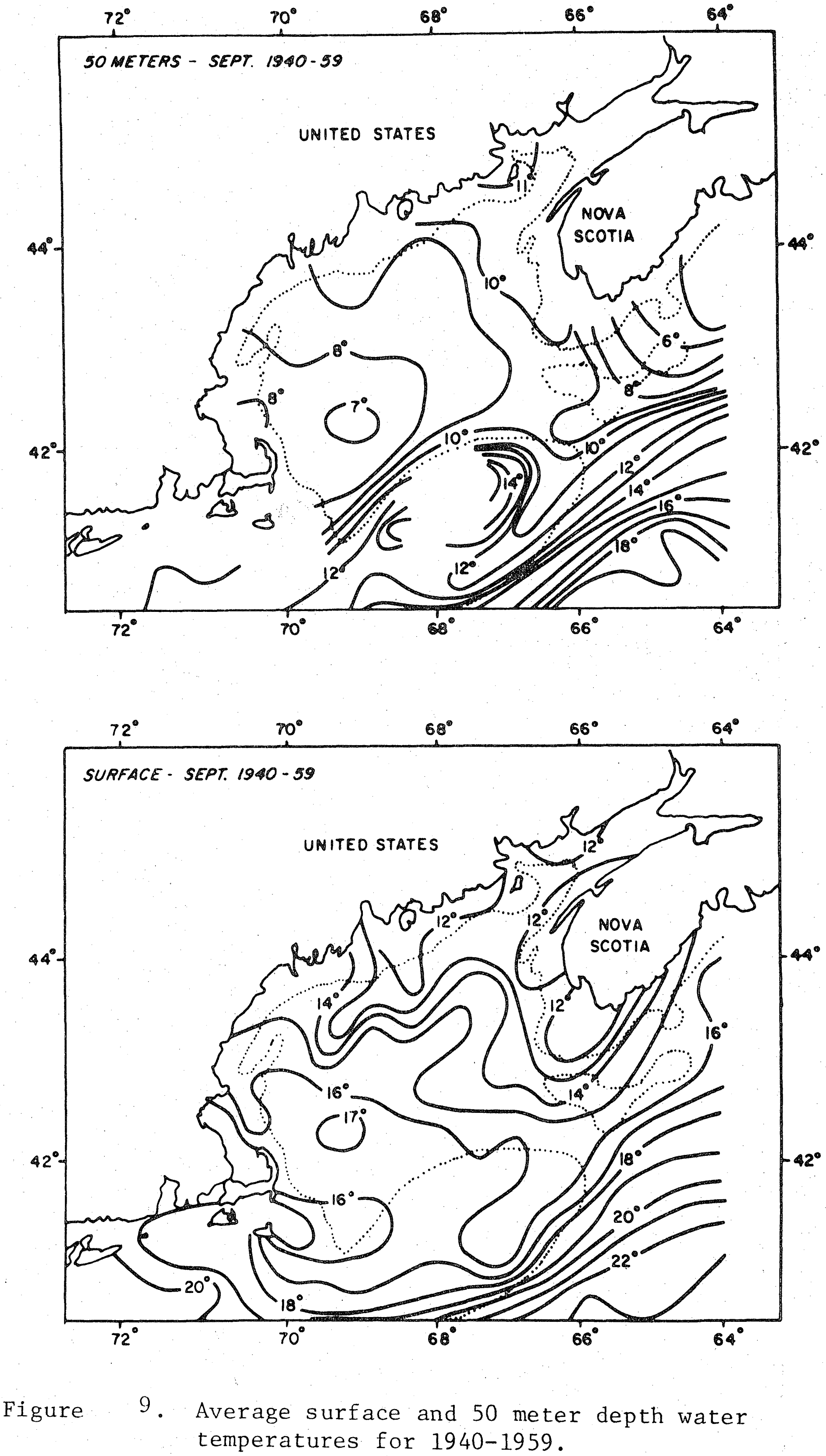

Figure 9. Average surface and 50 meter depth water temperatures for 1940-1959.

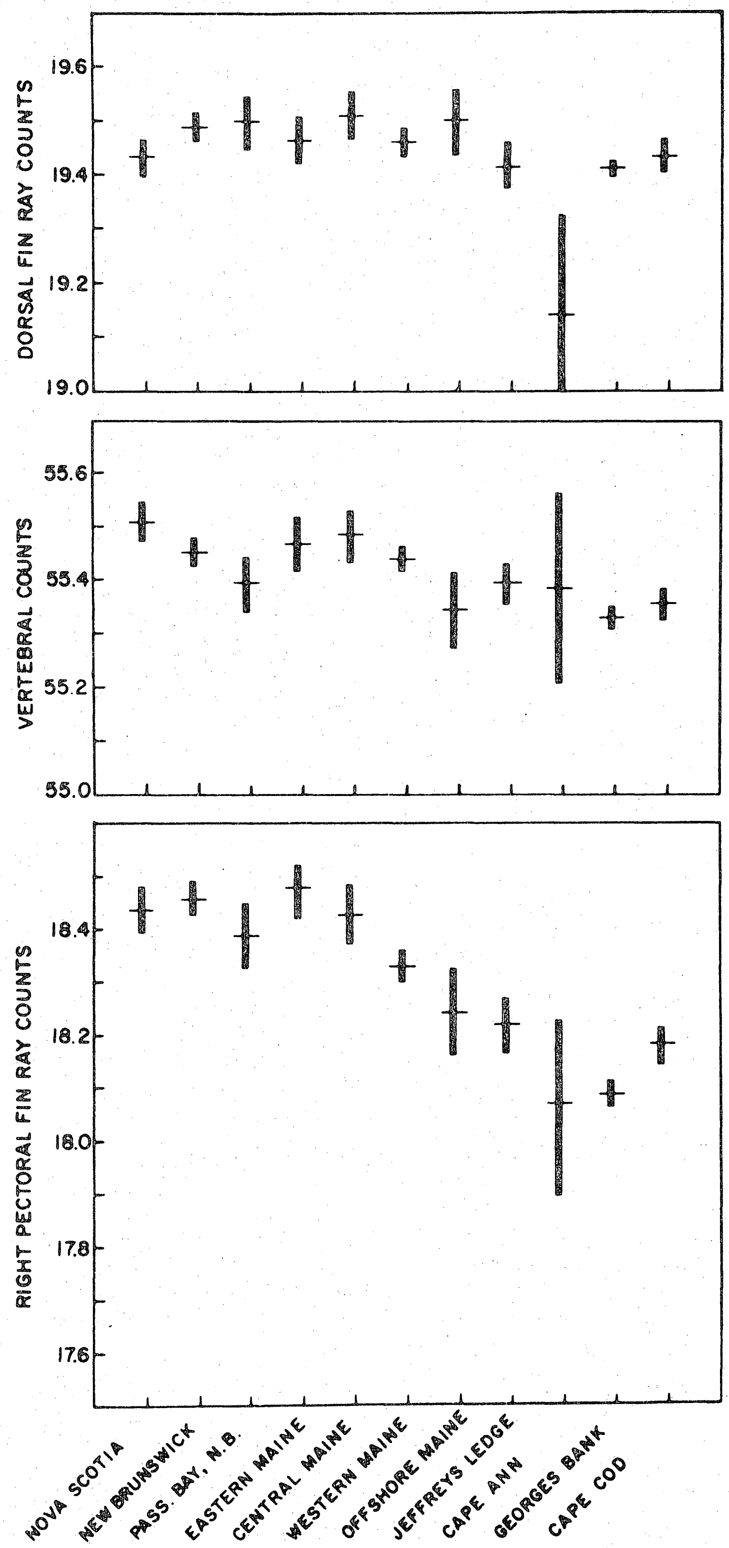

Figure 10. Meristic counts of adult herring from various areas plus and minus two standard errors.

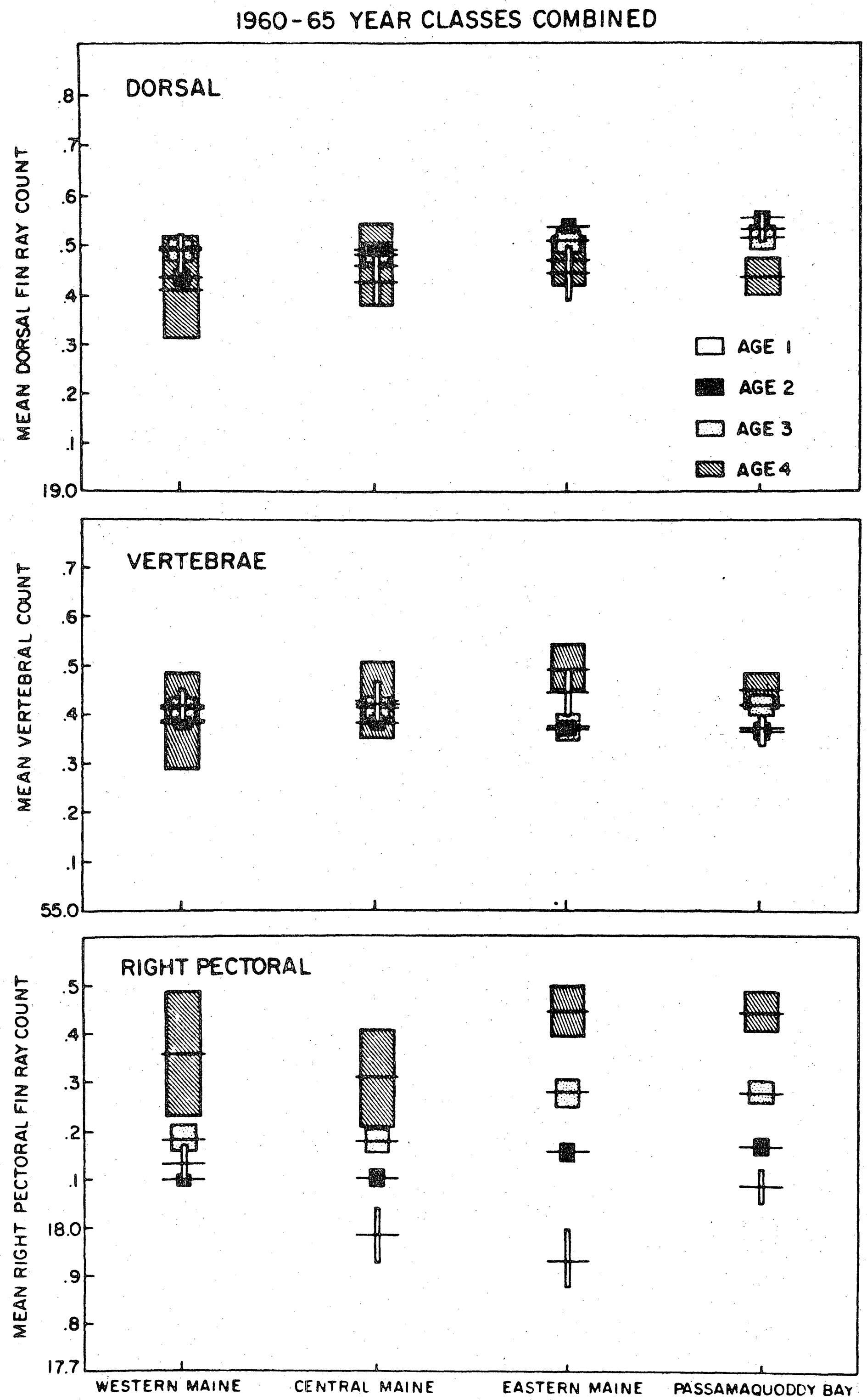

Figure 11. Change in meristic counts of young herring by age along the Maine coast.

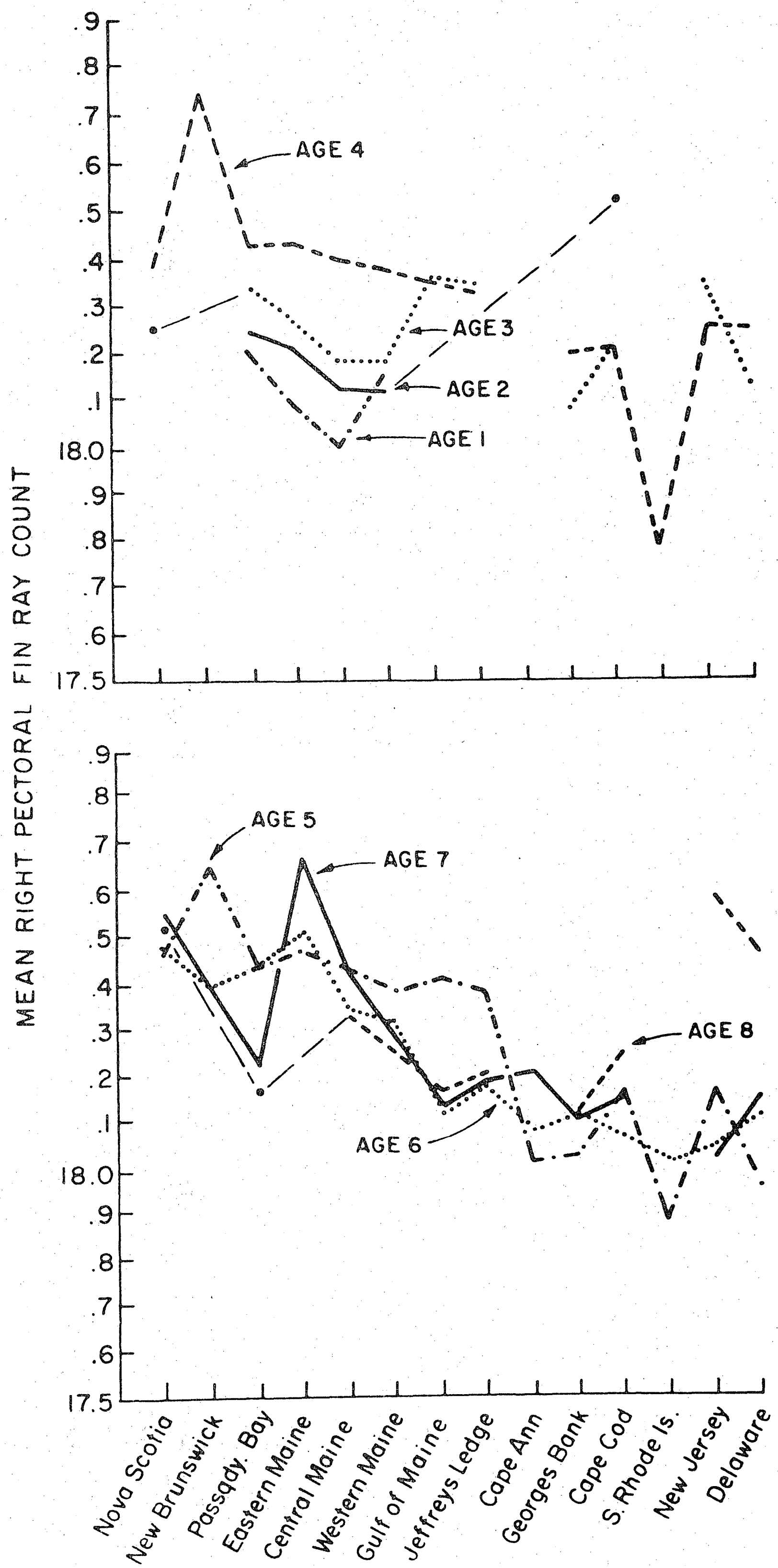

Figure 12. Comparison of mean right pectoral fin ray counts by age among areas of the Northwest Atlantic.

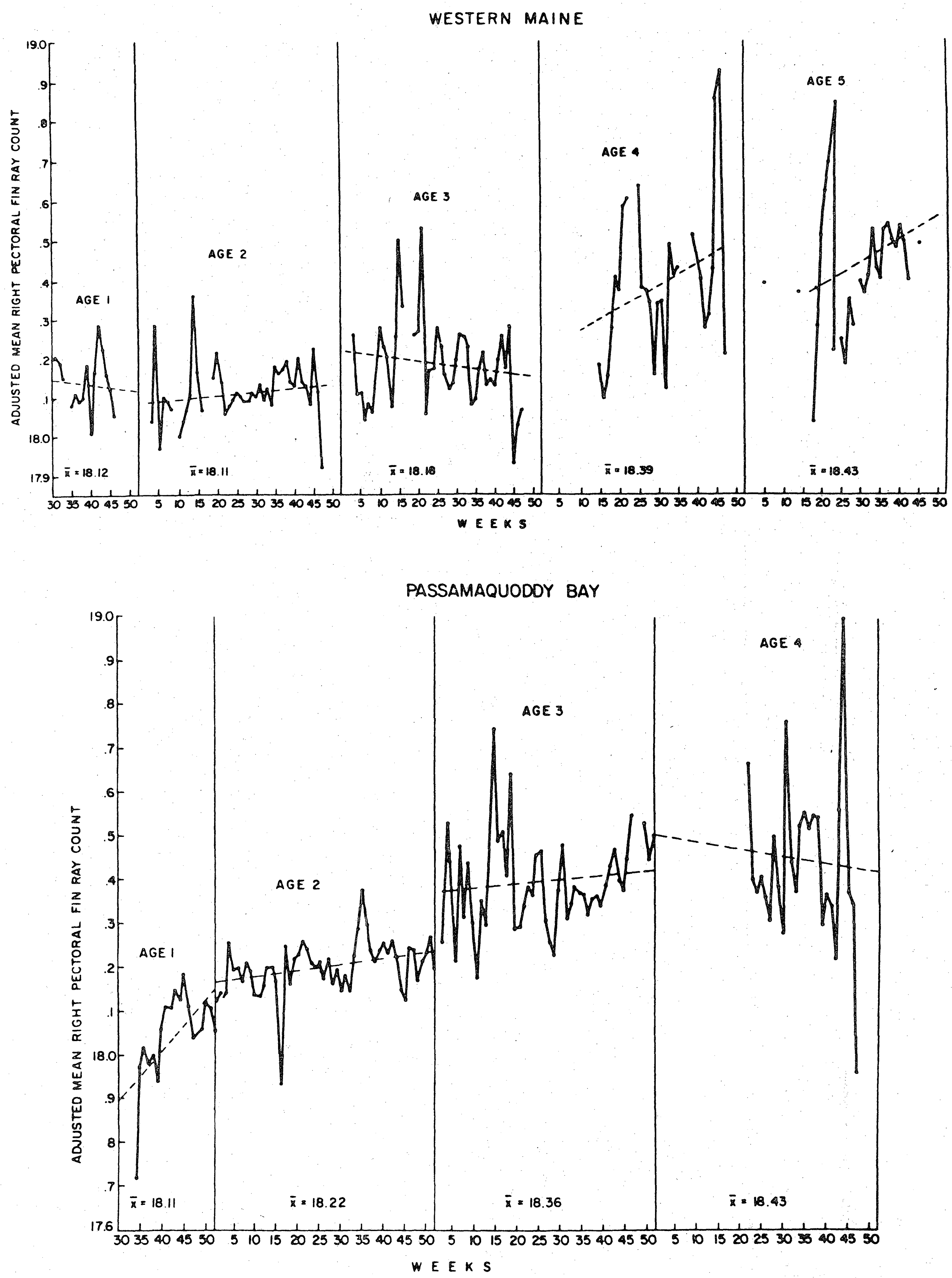

Figure 13. Change in adjusted mean right pectoral fin ray count with time for Western Maine and Passamaquoddy Bay, N.B.

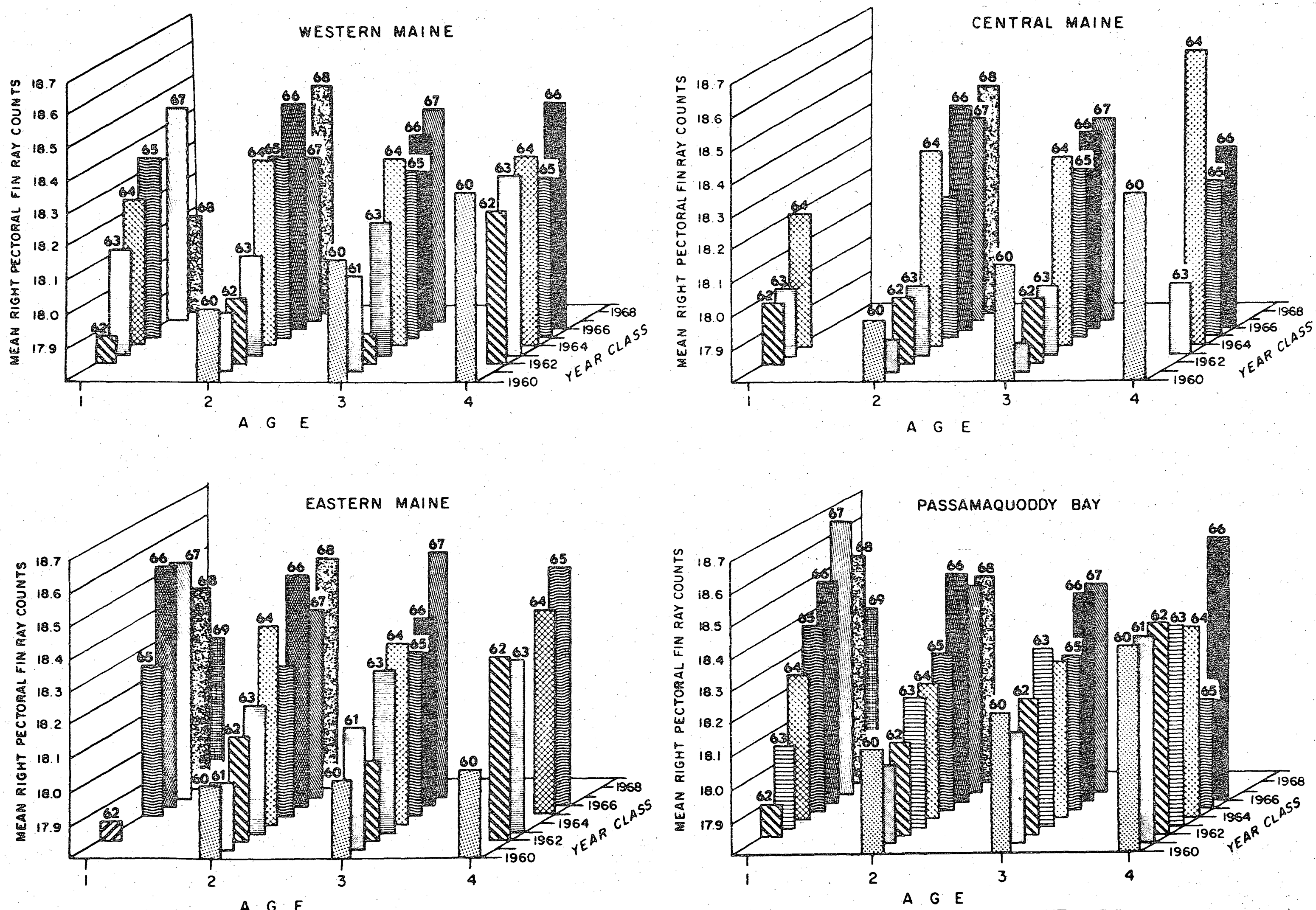

Figure 14. Mean right pectoral fin ray counts by age, year class and area of the Maine coast.

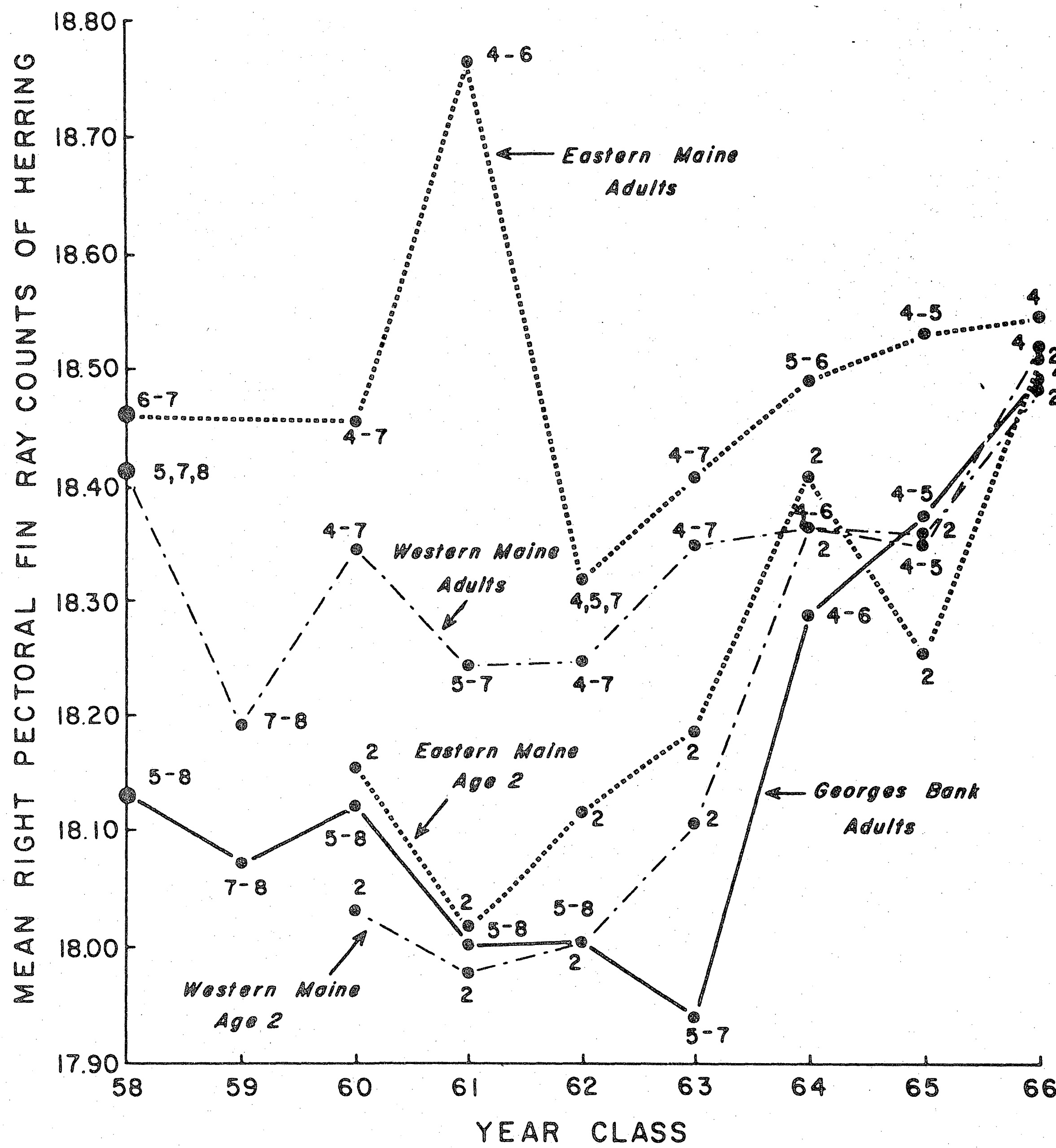

Figure 15. Right pectoral fin ray counts of adult and juvenile herring from eastern and western Maine compared with adult herring counts from Georges Bank. The ages of herring examined are given beside each data point (from Anthony and Waring 1980).