USE OF MERISTIC AND MORPHOMETRIC CHARACTERISTICS FOR THE DIFFERENTIATION OF ATLANTIC HERRING (CLUPEA HARENGUS HARENGUS LINNAEUS) STOCKS IN NEWFOUNDLAND AND ADJACENT WATERS

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Use of meristic and morphometric characteristics for the differentiation of Atlantic herring (*Clupea harengus harengus* Linnaeus) stocks in Newfoundland and adjacent waters

by

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A thesis presented to the Memorial University of Newfoundland in partial fulfilment of the requirements for the Degree of Master of Science in Biology.

ABSTRACT

Numbers of vertebrae, gill rakers, pectoral, anal and dorsal fin rays and the relative size of various body parts (orbit diameter, head, snout, postorbital and predorsal length) of herring from Newfoundland and adjacent areas were examined to ascertain the value of these characters for the differentiation of herring stocks in the Newfoundland area.

Spring and autumn spawners from the same area differ significantly in several morphological characteristics. 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. These meristic differences are related to water temperatures during larval development and to differences in developmental rates of spring- and autumn-hatched larvae. In most areas autumn spawners also have relatively larger heads, snouts, orbit diameters, postorbital and predorsal lengths than spring spawners. A linear discriminant function based on three meristic characters was used to correctly classify from 79 to 91% of individual southwest Newfoundland spring and autumn spawners to their respective spawning groups, which indicates that the amount of interchange between the two spawning groups is probably slight.

Sexual dimorphism in meristic and morphometric characteristics is negligible. Gill-raker number apparently increases with fish size in juvenile herring but not in adults. Correlation of the other meristic characters with fish length is negligible. Mean numbers of vertebrae and anal fin rays differ significantly between year-classes from the same locality in some instances. Dorsal fin-ray averages are unsatisfactory for stock separation, but mean numbers of pectoral and anal fin rays, gill rakers and vertebrae appear useful to varying degrees for this purpose.

Covariance comparisons of the log-log regressions of body parts on standard length revealed considerable heterogeneity in morphometric characteristics. Between-area differences are evident for all characters and all pairs of areas compared. Significant differences are found even between closely related stocks.

Both meristic and morphometric characters appear to be useful indicators of stock heterogeneity, but morphometric characters are less valuable than meristic characters and other methods for stock differentiation. Stock relationships indicated by the combined results of the meristic and morphometric comparisons agree in most instances with those suggested by other methods.

CONTENTS

I INTRODUCTION

A. Nature of the problem

The fishery for Atlantic herring, Clupea harengus harengus Linnaeus, in the Northwest Atlantic increased spectacularly during the past decade. Total landings increased from 180,000 metric tons in 1961 to the 950,000 tons level in 1968. In 1969 total herring landings declined slightly by about 70,000 tons from the 1968 figure of 950,000 tons. There was a further decline of 120,000 tons during 1970 (Anon., MS, 1971). The Canadian contribution to the Northwest Atlantic herring catches increased fivefold during the 1960's (Iles and Tibbo, MS, 1970). At present the Canadian herring fishery is concentrated in three main regions - the Bay of Fundy, the southern Gulf of St. Lawrence and the southwest coast of Newfoundland. Landings from the coastal waters of southwest Newfoundland (Cape Ray to Hermitage Bay) showed a dramatic increase from the early to the late 1960's. With the advent of a purse seine fishery along the south coast landings increased rapidly from less than 10,000 metric tons in 1965 to about 165,000 tons in 1969 (Hodder, MS, 1971).

The Newfoundland herring fishery prior to 1965 was primarily associated with the demand for herring as bait for the cod fishery and periodic demands for pickled herring products as food, especially during and just after the two World Wars (Hodder, 1967, 1970). During this period all of the herring were taken by gillnets and beach seines. Since 1966, however, most of the catch has been reduced to meal and oil. About 90% of the annual Newfoundland herring catch is presently utilized for reduction to meal and oil, despite a current increase in the quantities being processed for human consumption.

Although herring appear seasonally in practically all bays and inlets around the Newfoundland coast and are fished to a limited extent in all areas, over the years the bulk of the herring has been caught in the coastal waters of southern and western Newfoundland. This trend has intensified since the beginning of the purse seine fishery in the autumn of 1964. By 1968, 90% of the total landings originated in south coast waters. The herring concentrations on which the winter purse seine fishery is based appear along southwestern Newfoundland in late November and disappear again in April. Just prior to the start of the Newfoundland fishery, in late November, there is a short fishery near the Magdalen Islands, and in late April and May a similar fishery takes place in the vicinity of the Magdalen Islands after, the termination of the southwest Newfoundland fishery. From July to September there is a substantial summer fishery in the southwestern part of the Gulf of St. Lawrence. From these observations and information on the spatial and temporal distribution of catches along southwest Newfoundland, Hodder (1967, 1969) hypothesized a seasonal migration of herring between the autumn-spawning grounds of the southern Gulf of St. Lawrence and overwintering areas in the fjords of southwest Newfoundland.

The tremendous increase in fishing pressure on herring stocks inhabiting the coastal waters of Newfoundland and adjacent areas, coupled with the possibility that the same stock or group of stocks is being fished at different times and places, has emphasized the importance of identifying and delimiting the unit-stocks of herring which occur in the Newfoundland area. A variety of techniques have been utilized by fishery biologists for the differentiation of fish stocks. One of the most frequently used methods involves the comparison of morphological and physiological characteristics of fish from different areas. The value of certain parasites as natural biological "tags" in identifying fish from different areas has been demonstrated for several fish species (Templeman, Squires and Fleming, 1957; Sindermann, 1961; Templeman and Squires, 1960; Kabata, 1963; Margolis, 1963; Templeman and Fleming, 1963).

In recent years the application of immunogenic ~~immunogentical~~ and biochemical techniques to the study of fish populations has shown that significant variations exist in characteristics which probably are genetically controlled and not affected by environmental factors. The value of such techniques has also been established for many fish species (Cushing, 1952; Marr and Sprague, 1963; Sindermann, 1964; Frydenberg, Møller, Naevdal and Sick, 1965; Møller, 1966, 1968; Møller, Naevdal and Valen, 1967; Sick, 1961, 1965; Odense, Leung and Allen, 1966; de Ligny, 1969).

Although parasitological and biochemical studies of herring from Canadian Atlantic waters are now in progress, the present study concentrates on the use of meristic and morphometric characters only. This study was undertaken to determine whether there are sufficient morphological differences between herring from the various areas to delineate separate stocks. If the herring from the different regions intermingle freely, various physical characteristics should not differ to any great extent. An analysis and comparison of meristic numbers and body measurements was made, 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.

B. Previous research on herring in the Newfoundland area

Prior to 1965 research on the biology of herring in the Newfoundland area was sporadic. Hjort in 1914-15 investigated the biology of herring off the coast of Nova Scotia and in the Gulf of St. Lawrence including the west coast of Newfoundland. Lea (1919) examined herring samples from commercial catches in White Bay, Bonne Bay, Bay of Islands and St. George's Bay and concluded that Newfoundland herring could be distinguished from herring in other areas on the basis of differences in growth and year-class composition. Subsequent to his investigations no biological research on herring was undertaken until Tibbo (1956, 1957a) conducted studies of Newfoundland herring populations in 1942-44 and again in 1946-48, with emphasis on the south and west coasts where there were extensive herring fisheries at that time. Tibbo described four separate and distinct populations of herring located during spawning seasons in Bay of Islands, Fortune Bay, Placentia Bay and Notre Dame Bay. These were distinguished by differences in growth, diameter of the scales at the end of the first year of life, average vertebral counts and also by the length, age and year-class composition of the spawning aggregations. The fishery at that time was chiefly for large (32.4 to 36.4 cm) and old (7.4 to 13.0 years) herring.

There followed a lapse in herring research until 1957-58 when the Fisheries Research Board of Canada, assisted by the Industrial Development Branch of the Canadian Department of Fisheries, initiated exploratory fishing and herring research primarily along the south and west coasts (Olsen, 1959,1961). Olsen (1961) reported a rate of growth higher than that found by Tibbo in 1942-44; there was no significant difference in growth rate between the south coast and the region of Bay of Islands and Port au Port on the west coast. The most significant aspect of Olsen's study was the indication of an unusual spread in spawning time, with probable peaks in spring, autumn and winter, while prior to about 1950 Newfoundland herring were apparently all spring spawners (May-June)(Tibbo, 1956).

In 1965 the south coast fishery entered a period of rapid expansion with the advent of purse seiners and the utilization of herring for meal and oil. Humphreys (1966) carried out a study of south coast herring at the onset of the period of increased exploitation to serve as a basis for future comparisons. Mean length (33.0 cm) and mean age (8.2 years) were less than recorded during earlier investigations but growth rates had not changed appreciably. Humphreys concluded from the distribution of maturity stages in the samples he examined that the spawning season extends over the spring, summer and autumn months.

Pelagic fish research was reactivated at the St. John's Biological Station of the Fisheries Research Board of Canada in 1965. At the 1966 Canadian Atlantic Herring Fishery Conference Hodder (1967) reported the results of initial investigations and examined certain biological characteristics of herring from the south and west coasts. He was the first to suggest that the herring stocks which overwinter along southwest Newfoundland from late November to April probably exhibit a seasonal migration between autumn-spawning grounds in the southern Gulf of St. Lawrence and the overwintering areas of southwest Newfoundland. Since 1966 considerable effort has been directed towards the acquisition of catch and effort statistics and intensive sampling of seiner landings throughout the fishing season, with major emphasis being placed on the stocks which support the intensive winter fishery along southwest Newfoundland. Available statistics and information on the Newfoundland herring fishery to 1966 have been documented by Hodder (1967) and Hourston and Chaulk (MS, 1968). Hodder (1969,1970) has reviewed herring landings from 1967 to 1970 with particular emphasis on the distribution of the catches and their implications concerning migrations of the stocks. In recent years catches of herring in eastern and northern Newfoundland waters with traditional gears (gillnets, beach seines) have been insignificant compared with the large quantities caught in southwest Newfoundland waters by the mobile purse seiner fleet. For this reason research on the biology of eastern and northern Newfoundland herring stocks has been very limited. Parsons (1970) has summarized the available information on the biology, distribution and relative abundance of herring in these areas.

Hodder and Parsons (MS,1970) compared certain biological characteristics of Magdalen Islands and southwest Newfoundland herring and concluded that the winter fishery along southwest Newfoundland is largely dependent on herring concentrations which migrate eastward out of the southern part of the Gulf of St. Lawrence in the autumn. Subsequent tagging experiments conducted by the Fisheries Research Board's Biological Stations at St. John's, Newfoundland, and St. Andrew's, New Brunswick, utilizing internal metallic tags, have demonstrated extensive migrations of herring from southwest Newfoundland into the southern Gulf of St. Lawrence during the spring and a return migration from the southern Gulf to southwest Newfoundland during the autumn (Hodder and Winters, MS, 1970; Winters, 1970; MS, 1971; Beckett, MS, 1971). A preliminary study of the degree of infestation of southwest Newfoundland and southern Gulf of St. Lawrence herring with the larval nematode *Anisakis* also supports this conclusion and indicates that this parasite may be a useful indicator of herring stock heterogeneity in other areas (Parsons and Hodder, MS, 1971).

II. THE USE OF MERISTIC AND MORPHOMETRIC CHARACTERS IN FISH POPULATION STUDIES

A. Factors influencing the meristic and morphometric characteristics of fish

1. Meristic characters

At least two interpretations of the term "meristic" have been employed in the ichthyological literature. In the restricted sense the term applies only to those countable characters which appear to be anatomically associated with body somites or segments but generally it has been used synonymously with "numerical" or "capable of being counted". The more general usage, which encompasses gill rakers and pyloric caeca as well as vertebrae and dorsal and anal fin rays, is employed in the present study.

The use of meristic characters for the differentiation of stocks or populations of various fish species has been largely based on the premise that these characters exhibit plasticity under the influence of environmental conditions during the incubation period and early larval life (Schmidt, 1921; Vladykov, 1934; Tåning, 1944; Lindsey, 1954; Barlow, 1961). However, in the earliest days of racial investigations most investigators assumed that meristic differences were genetically determined. Heincke (1898) and Schnakenbeck (1931) were both of the opinion that meristic characters were inherited in herring. There are many reports in the literature based on observations from nature which indicate a negative correlation between temperature and meristic number. Numerous authors have shown that the number of meristic elements is progressively greater to the north in the Northern Hemisphere. Indeed, in both hemispheres there appears to be a good correlation between lower environmental temperatures and higher meristic numbers (Hubbs, 1926; Vladykov, 1934). Hubbs (1925) and Rounsefell (1930) found an increase in the mean vertebral count of Pacific herring, *Clupea harengus pallasii* Valenciennes, northwards along the North American coast. Rounsefell and Dahlgren (1932) obtained a significant negative correlation between mean vertebral count and average air temperature during the spawning months for herring in Prince William Sound, British Columbia. Tester (1937) obtained a similar negative correlation for herring in Jap Inlet, British Columbia, over a period of seven years but not in other inlets and found a gradation in mean vertebral count with latitude. He also showed a negative correlation between mean vertebral count and water temperature during the spawning season from 1926 to 1935 in Barkley Sound, British Columbia (Tester, 1938). Runnström (1941) reported a negative correlation between mean vertebral count and water temperature during the spawning season for spring-spawning herring from various regions in the northeast Atlantic. According to McHugh (1951) mean vertebral numbers of the northern anchovy, *Engraulis mordax* Girard, decrease from north to south along the Pacific coast of North America.

Most exceptions to this north-south cline in meristic counts have been associated with special local conditions, e.g. colder water currents to the south, differences in altitude in fresh-water systems, differences in time of spawning or salinity gradients (Barlow, 1961). Templeman (1948) found slightly higher mean vertebral numbers for capelin, *Mallotus villosus* (Müller), from the south coast of Newfoundland than for capelin from the more northerly east coast and Labrador. Tibbo (1956), for Atlantic herring in the Newfoundland area, reported that there was a tendency for mean vertebral number to decrease from south to north. He showed that the spawning period of Newfoundland herring becomes progressively later from south to north. He assumed that the temperature at spawning increases from south to north for these populations; hence, the more northerly fish may develop in higher temperatures than those farther south.

Laboratory experiments have generally confirmed this dependence of meristic number on temperature. Tåning (1944,1952), Blaxter (1958), Templeman and Pitt (1961), Barlow (1961) and Fowler (1970) have reviewed experimental studies of the influence of the environment on meristic number in various fish species. Only the more important features of this experimental evidence will be discussed here. Schmidt (1919, 1921) was the first to carry out experimental studies on the influence of environmental variables, particularly temperature, on meristic numbers in fish. He demonstrated significant differences in mean vertebral number among groups of brown trout, *Salmo trutta trutta* Linnaeus, maintained at different temperatures during embryonic development, and concluded that variation in vertebral number resulted from the selection of certain genotypes which produced fixed numbers of vertebrae. Gabriel (1944) found a continual decrease in vertebral number with increasing temperatures between 13.5 and 24.5°C during the development of killifish, *Fundulus heteroclitus* (Linnaeus). Dannevig (1950) showed a decrease of 0.4 vertebra for plaice, *Pleuronectes platessa* Linnaeus, with only ½°C increase in temperature. However, the number of elements in the dorsal fin of the guppy, *Lebistes reticulatus* (Peters), and the dorsal and anal fins of plaice decrease at lower temperatures (Schmidt, 1919; Molander and Molander-Swedmark, 1957). Hubbs (1924) reported that similar changes take place in the dorsal fin-ray numbers of two viviparous cyprinodonts. Ege (1942) concluded that the number of pectoral fin rays in the eelpout, *Zoarces viviparus* Linnaeus, is environmentally determined.

Several investigators have obtained experimental results which do not conform to the simple pattern of higher counts at low temperatures and lower counts at high temperatures. Experiments with salmonids (Schmidt, 1921; Tåning, 1944; Seymour, 1956,1959), plaice (Molander and Molander-Swedmark, 1957) and the genera *Macropodus*, *Channa* and *Oryzias* (Lindsey, 1954; Itazawa, 1959: Ali, 1962, respectively) have yielded a pattern of increased vertebral numbers at lower temperatures, decreased numbers at intermediate temperatures and higher counts again at higher temperatures. V- or U- shaped curves were obtained when vertebral numbers were plotted as a function of temperature. The intermediate temperature at which the lowest number is found is often the optimum identified by highest survival or most rapid growth (Fowler, 1970). Similar curves were obtained for the response of the fins to temperature changes but these were more complex.

Other environmental conditions, including oxygen and carbon dioxide tensions, salinity and light, may affect the determination of meristic numbers in fish. Tåning (1944, 1952) produced an increase in the number of vertebrae of sea trout by decreasing the pressure of either oxygen or carbon dioxide during development. Heuts (1947, 1949) demonstrated that both temperature and salinity influence the number of fin rays in the threespine stickleback, *Gasterosteus aculeatus* Linnaeus. Hempel and Blaxter (1961) obtained a positive correlation between salinity and mean myotome count in herring.

Forrester and Alderdice (1966) obtained similar results for cod. Dannevig (1932), working on cod, obtained results which indicated a possible inverse relationship between vertebral number and light intensity during development. McHugh (1954) found an inverse relationship between vertebral number and light intensity during embryonic development of the grunion, *Leuresthes tenuis* (Ayres). Lindsey (1958) reported that a 16-hour exposure to artifical light for the kokanee, *Oncorhynchus nerka* (Walbaum), yielded a significantly lower number of caudal vertebrae than an 8-hour exposure of the same intensity. Canagaratnam (MS, 1959) showed that development was accelerated by longer durations and higher intensities of light and that lower mean vertebral counts occurred under these conditions in salmon, *Oncorhynchus* spp.

The precise time of fixation of the meristic characters in Atlantic herring is not known. However, Tåning (1944, 1952) with *Salmo trutta trutta*, Gabriel (1944) with *Fundulus heteroclitus*, Dannevig (1950) with *Pleuronectes platessa*, Seymour (1959) with *Oncorhynchus tshawytscha* (Walbaum) and Garside (1966) with *Salvelinus fontinalis* (Mitchill) and *Salmo gairdneri* Richardson have shown that vertebral number in these species is determined during the incubation period of the fish egg. Hempel and Blaxter (1961) concluded that the myotome count of Atlantic herring is determined before hatching although Tester (1938) and Bückmann (1950) suggested that the number of vertebrae is at least partially determined after the eggs have hatched. Lindsey (1954), experimenting with the paradise fish, Macropodus opercularis (Linnaeus), which has a rapid development to the hatching stage, about 24 hours at 28°C, found that the caudal and hence the total vertebral numbers in the larvae were subject to change up to 11-12 days after hatching. Molander and Molander-Swedmark (1957) were able to change the vertebral and fin-ray numbers of plaice up to about 2 weeks after hatching. Tåning (1944, 1952) subjected sea trout embryos to temperature shifts and found that each meristic character has its own phenocritical or "super-sensitive" period - a period during development when a change in temperature is most effective in altering the final number of segments laid down. For vertebrae in sea trout Tåning found that this period occurred from about 145 day degrees (D°) to 165 D° - just before the development of eye pigment in the embryo. The phenocritical periods for determination of the number of vertebrae and, in part, the number of anal fin rays occur early in ontogeny and are relatively short. Dorsal and pectoral fins are formed later and have a longer phenocritical period; hence, they are influenced by environmental factors to a greater extent.

Hubbs (1926) suggested that the number of serial elements in fish is determined by developmental rate. He hypothesized that conditions which accelerate the developmental rate accelerate and accentuate the differentiating tendencies as well as growth. Retarding conditions, on the other hand, retard and reduce both differentiation and growth. Longer developmental periods, which may be induced by low temperatures or other agents which retard development, usually result in higher counts in meristic elements. Gabriel (1944) was the first investigator to correlate meristic number with a measure of the time of development which he took as the time from fertilization to the absorption of the yolk. There was a gradual increase in vertebral number with increased time of development and Gabriel concluded that vertebral number was related to developmental rate. Since then other investigators have related differences in vertebral number with different developmental temperatures but most of these have not utilized measurements of developmental time. Tåning (1944, 1952) and Marckmann (1954) measured metabolic development in terms of day-degrees (D^o) or thermal units. Both Barlow (1961) and Garside (1966) have criticized the use of "day-degrees" as a measurement of developmental time, based on the fact that the rate of embryonic development in fish is not a linear function of temperature over a wide range (Kinne and Kinne, 1962). Garside (1966) incubated the eggs of brook trout and rainbow trout at various constant levels of temperature and dissolved oxygen to test the hypothesis that vertebral number in fish is regulated within limits by the developmental rate. He determined the period of differentiation for vertebrae in terms of embryonic stages of development and plotted mean vertebral counts against developmental rates. The mean number of vertebrae in both species was inversely related to the rate of development expressed as the reciprocal of the number of days in the period of numerical determination of vertebrae in each species. Fowler (1970) has emphasized the necessity for further experimentation and study of the relationship between metabolic development and meristic number.

At least three explanations have been proposed for the occurrence of the V-shaped curves reported by several investigators. Lindsey (1954) suggested that two reciprocal mechanisms of control might be involved, one exhibiting dominance at lower temperatures with the other being dominant at higher temperatures. Garside (1966) has emphasized that, if such unspecified mechanisms do exist, they are apparently governed solely by temperature since other factors such as light and oxygen tension which affect developmental rate do so in only one direction i.e. decelerated development produces more vertebrae and accelerated development produces fewer vertebrae. Barlow (1961) proposed a model of the possible interaction between growth and differentiation in fish embryos which is in agreement with the original hypothesis put forth by Hubbs (1926) but yet accounts for the V-shaped curves. In this model growth of the embryo has a high temperature coefficient while differentiation of the vertebrae has a low temperature coefficient. Growth is retarded relatively more than differentiation of vertebrae at lower temperatures; hence, more vertebrae will form over a relatively longer period of time. Conversely, those meristic characters which decrease in numbers at low temperatures, e.g. dorsal fin rays in Lebistes reticulatus, probably have higher temperature coefficients than the growth of the embryo. In the instances of the V-shaped curves for different fins and vertebrae, the apex of the curve would be interpreted as showing the points of inflection of the temperature coefficients. Garside (1966) suggested that the V-shaped curves may result in part from different methods of counting vertebrae, arising from a lack of uniformity in defining and enumerating abnormal vertebrae, especially "complex" vertebrae, i.e. the neural arch and/or the haemal arch have been duplicated on a single centrum. According to McBride (1932) and Nelson (1953) the centrum is the basic unit since the first step in the differentiation of vertebrae is the investment of the notochord by tissue of the sclerotome which forms the centra. However, several investigators have used the number of neural and/or haemal arches as the vertebral count. Some have counted a complex vertebrae as a single unit while others have designated it as two vertebrae. Examination of the data of Molander and Molander-Swedmark (1957), who counted the complex vertebra as two if either arch was duplicated on a single centrum, reveals that increases in vertebral number at both high and low temperatures are accompanied by a considerable increase in the percentage frequency (36-50%) of fish with complex vertebrae. This, according to Garside, has considerably increased their mean vertebral counts at low and high temperatures, thereby accentuating if not creating the V-shape of the curves.

So far the discussion has been concentrated on the plasticity of meristic characters under the influence of environmental conditions. However, several investigators have shown a genetic as well as a phenotypic basis for meristic characters in various fish species (Barlow, 1961). The progeny of the killifish, Fundulus heteroclitus, with high vertebral numbers also have high vertebral numbers ~~counts~~ and similarly for those whose parents have low counts (Gabriel, 1944). The dorsal fin-ray counts of new-born guppies is high or low depending on the parentage (Schmidt, 1919; Svärdson, 1945). Hybrids between races of the same species commonly have intermediate numbers of meristic elements (Heuts, 1949; Svärdson, 1953; Hubbs, 1955). Several authors have shown that different races of species reared under comparable conditions differ in meristic characteristics (Mottley, 1937; Heuts, 1947, 1949; Seymour, 1959). Genetic determination of variation in meristic characters has also been deduced from comparisons of the nature of variation within a given year-class, between successive year-classes and between populations of the gobiidfish, Gillichthys mirabilis Cooper (Barlow, MS, 1958). Ege (1942) conducted transplantation experiments with Zoarces viviparous which indicated selection for fish with a particular number of vertebrae, the selection being for fish with the lower vertebral number. Schroeder (1965) concluded that dorsal fin-ray number in Mollienesia is controlled by polygenic inheritance. Recent experiments involving sibling comparisons have also demonstrated the influence of the genotype (Ali, 1962; Itazawa, 1959; Lindsey, 1962a,b). Hubbs (1928) recognized the possibly genetic nature of clines of meristic characters in fish species and suggested that differences in counts between geographically segregated populations are indications of adaptive change. He further suggested that species new to an area would be altered by the environment and that these differences, being associated with adaptive changes, would become genetically fixed. Barlow (1961) thought it probable that genetically reinforced differences exist in those species where the populations are somewhat isolated from one another.

The relative importance of genetic and phenotypic factors in the determination of gill-raker number in Atlantic herring is not known. Krefft (1958) suggested that gill-raker number is genetically fixed and concluded that late winter- and autumn-spawning herring of the eastern North Atlantic, which exhibit highly significant differences in mean gill-raker numbers, are two systematically well-defined subspecies. McCart and Andersen (1967) demonstrated plasticity in kokanee gill-raker number; kokanee reared in an artificial environment had a significantly lower number of gill rakers than their parents. Variation in number of gill rakers has been attributed to temperature variation by some authors (McHugh, 1951; Letaconnoux, 1954; Lee, 1965). However, Andreu (1969), in a comprehensive study of gill-raker variation in Sardina pilchardus (Walbaum), has shown that variation in gill-raker number is related to more complex ecological factors, in particular those connected with adaptative phenomena, especially with the optimum utilization of available food. He concluded that polymorphism in gill-raker number in this species is due to genetic differences accumulated with time through the process of natural selection. It has been shown that gill-raker numbers in freshwater coregonids of Sweden and in the Sardinian shad are, to a large extent, genetically determined (Svärdson, 1952; Cotiglia, 1963).

2. Morphometric characters

In addition to meristic structures other morphological characteristics of fish have been utilized for stock differentiation. Differences in the relative dimensions of various parts of the body have been widely used in fish systematic studies, to a lesser extent in racial or population studies and also in the study of the relative growth of body parts. Generally in fish systematic studies body dimensions are expressed in per cent ~~or per mille~~ of standard length. Usually only a few specimens are available to the systematist in which case regression analyses are not appropriate. Marr (1955), in a discussion of the use of morphometric data in systematic, racial and relative growth investigations, emphasized that the use of body diamensions expressed as per cent ~~or per mille~~ of standard length has in the past led to confusing or doubtful conclusions and recommended the wider use of regression analysis of original data in population studies, which usually involve larger numbers of specimens than systematic studies. Recently regression techniques have been widely employed in racial or population investigations e.g. Godsil (1948), Schaefer (1948), Schaefer and Walford (1950), Roedel (1952), Royce (1953, 1964), McCart (1965), Jean (1967), Yang, Nose and Hiyama (1969).

For many species it has been observed that certain body parts increase in relative size with the absolute size of the organism. The relationship of body part to body length can usually be described by one of three types of equations:

(1) $y = a + bx$ (rectilinear regression)

where y is the length of the body part, x is the body length, a (a constant) is the y-intercept and b (a constant) is the slope of the line. Such lines form a straight line on arithmetic coordinates.

(2) $y = pe^{kx}$ or $x = pe^{ky}$ (exponential regression) where y and x are the same as above, e is the base of natural logarithms, p (a constant) equals y when x is zero and k (a constant) is the percentage change in y per unit change in x.

(3) $y = bx^k$ (allometry equation)

This can be transformed logarithmically to

$$\log y = \log b + k \log x$$

where $\log b$ is a constant and k is the slope, which denotes the rate of change in form.

Many investigators have utilized the relative-growth method of analysis described by Huxley (1924, 1932) in recent population studies. This method consists essentially of plotting the logarithm of some dimension of a body component against the logarithm of a dimension of the whole body over a wide size range for the organism involved. Logarithmic plots of this nature generally exhibit a linear relationship over a wide range of body size. This linear logarithmic relationship indicates that the rate of change in body form is generally constant over the greater part of growth. The relative growth equation is represented by equation 3.

Martin (1949) has summarized the advantages of the relative-growth method of analysis as follows:

1. It takes cognizance of the multiplicative nature of growth.
2. The increased variance found with increasing body size is reduced to a level comparable with the variance found at small sizes by reducing variance to a percentage basis.
3. Development as a whole may be viewed in one picture.
4. The assessment of rate of change of form as well as change of form is facilitated.
5. A convenient method for the comparison of fish of different sizes but within the same growth stanza is provided.

Various attempts have been made to find a basis for the simple allometry relationship in the laws of time growth of organs and organisms or in simple postulates about growth. Reeve and Huxley (1945) examined several such explanations and concluded that the theoretical basis of the allometry formula is uncertain. Marr (1955) stated that the "rather wide use of the 'allometry equation' .... has been largely empirical........ There has been no satisfactory theoretical explanation of why the relative growth of body parts should follow any of the regression equations given above or any other for that matter."

A special terminology has been developed for describing the various types of relative-growth relationships. "Allometry" has been accepted as the general term for variation in relative growth from that which is constant. "Heterauxesis" is used to indicate ontogenetic allometry which involves the comparison of parts to a whole or to another part and comparisons between organisms of the same group but of different ages and sizes. "Allomorphosis" is used to indicate change of proportions with increase in size between adults of related groups or the comparison of a part at a definite age to parts or wholes of the same age but from different groups. The term "bradyauxesis" is used when a body part grows relatively more slowly ($k<1$) than the body as a whole. "Trachyauxesis" is used when the body part grows relatively faster than the body ($k>1$) and "isauxesis" or "isometry" when the growth rates of the body parts and the body are equal ($k=1$).

Martin (1949) investigated the mechanics of control of body form in fishes. Previous investigators had indicated a close correlation between rate of development and the relative size of many body parts of fish (Schmidt, 1919, 1921, 1930; Hubbs, 1926, 1934; Schultz, 1927; Rounsefell and Dahlgren, 1932; Tester, 1937). Northern races of a species generally have smaller heads, eyes, maxillaries and fins than southern races of the same species (Hubbs, 1926; Vladykov, 1934). Other authors had shown a correlation between body form and growth rate (Koelz, 1929; White, 1936; Tester, 1937; Hile, 1937; Svärdson, 1950).

Martin found that relative growth in fish is characterized by a series of growth stanzas, each with a different relative growth constant, generally with a sharp inflection at the transition from one stanza to the next. He cites examples of such relative growth curves for more than twenty species. Many species exhibit two growth inflections, one associated with ossification, the other being related to the onset of sexual maturity. A gradient of relative growth may be found along the body axis with the anterior parts generally growing more slowly and posterior parts faster than the body as a whole. (Hubbs, 1925; Shapiro, 1938). Differences in the relative size of body parts between fish of the same species result from changes in the timing of the inflections rather than the slopes of the lines (Martin, 1949).

Body form is not always negatively correlated with growth rate. Relatively smaller body parts have been found in slow-growing as well as fast-growing populations

(Wilder, 1947; Jean, 1967). Body form is correlated with the number of meristic elements (Hubbs, 1926; Tester, 1937; Jean, 1967) which in turn is correlated with rate of development. Hence, it would seem that body form is determined at an early stage in development. Martin (1949) concluded from experimental results that in general there is no causal connection between body form in fishes and either rate of development or subsequent growth rate although either of these processes may indirectly affect control of body form through their influence on body size at inflection. The direction of growth inflection and the sharpness of the angle or degree of inflection are as important as fish size at inflection in determining relative body dimensions at larger sizes. Martin also demonstrated that changes in body form may be produced through changes in slope of relative-growth lines induced by temperature or diet deficiency conditions as well as through changes at inflection.

B. Previous use of meristic and morphometric characters in herring racial investigations

1. Meristic characters

Heincke (1898) appears to have been the first to utilize meristic and morphometric characteristics for the differentiation of herring stocks. Since then European investigators have generally employed two meristic characters, the number of vertebrae and the number of keeled scales, to characterize different biological groups of herring. During the present century there have been extensive investigations of the variations in vertebral number of eastern North Atlantic herring, Clupea harengus harengus (Johansen, 1919, 1924; Schnakenbeck, 1937; Buchanan-Wollaston, 1933; Lissner, 1934; LeGall, 1935; Wood, 1936; Runnström, 1936, 1941; Fridriksson, 1944, 1958; Baxter, 1958; Cushing, 1958; Jensen, 1958; Zijlstra, 1958). Apart from a few early investigations (Thompson, 1917; Hubbs, 1925; Rounsefell, 1930; Tester, 1937), most population studies of the Pacific herring, Clupea harengus pallasii, have employed only vertebral counts. In general only one meristic character, namely, vertebral number, has been utilized in investigations of the stock interrelationships of western North Atlantic herring (Day, 1957a,b,c; Tibbo, 1956, 1957a,b,c; Jean, 1967).

Numerous investigators have demonstrated that the mean vertebral numbers of different year-classes of Atlantic herring from the same locality often differ so widely that differences between areas may merely reflect differences in year-class composition, e.g. Runnström, 1941;

Day, 1957c; Cushing, 1958; Zijlstra, 1958. However, Tibbo (1957a) did not find any significant year-class differences in mean vertebral numbers of herring from the south and west coasts of Newfoundland. Differences in vertebral averages of different year-classes from the same area have also been observed in the Pacific herring (Rounsefell and Dahlgren, 1932; Tester, 1937, 1938; McHugh, 1942). These authors found a negative correlation between vertebral averages and mean air temperatures during the spawning periods. It has also been observed in the Pacific herring that the larger fish of a year-class in many instances have a higher vertebral average than the smaller fish (Thompson, 1917; Hubbs, 1925; McHugh, 1942). Tester (1937), however, showed in comparisons of herring with 51-53 vertebrae that an increase of 1 vertebra was associated with a length gain of only 0.1 - 0.2 cm in fish about 19 cm long. In apparent contradiction of these observations, Ford (1930) found that the mean vertebral number of o-group herring at Plymouth decreased with increase in length. Templeman and Pitt (1961) drew attention to the fact that these Plymouth herring spawn from late September to March over a period with gradually declining temperatures. Hence, the herring resulting from early spawnings develop at higher temperatures, grow larger and have a lower mean vertebral number than those resulting from later spawnings which develop at lower temperatures.

Very little attention has been paid to fin-ray numbers in herring racial studies. Although Schnakenbeck (1927) showed that mean numbers of pectoral fin rays were useful for separating stocks of Atlantic herring, the significance of his findings was ignored until Dutt (1958) compared the mean pectoral fin-ray numbers of spring- and autumn-spawning herring from Kiel Bay in the western Baltic and found that autumn spawners had significantly higher pectoral fin-ray averages than spring spawners. Anthony and Boyar (1968) compared the pectoral, dorsal and anal fin-ray numbers of adult Atlantic herring from the Gulf of Maine and adjacent waters but did not investigate possible differences in fin-ray numbers between spawning groups. Apart from their study fin-ray numbers have been virtually ignored in studies of herring stocks in the western North Atlantic. Tester (1937) and McHugh (1954) were the only investigators to study the number of pectoral fin rays in Pacific herring but the usefulness of dorsal and anal fin-ray averages was examined by four investigators (Thompson, 1917; Hubbs, 1925; Rounsefell, 1930; McHugh, 1954).

Variation in numbers of gill rakers has been utilized for stock separation for several fish species e.g. northern anchovy, McHugh (1951); kokanee, Vernon (1957) and Nelson (1968); lake trout, Martin and Sandercock (1967); Mediterranean sardine, Andreu (1969). Gill-raker counts are often used for taxonomical purposes, especially to discriminate between closely related groups. Krefft (1954,1958) was apparently the first to investigate variation in gill-raker numbers in Atlantic herring. He found highly significant differences in the mean gill-raker numbers of autumn and late winter spawners. Since then several investigators have utilized gill-raker counts for the differentiation of Baltic herring stocks (Popiel, 1958; Strzyewska, 1969). McHugh (1954) was the only investigator to examine gill-raker numbers in studies of Pacific herring populations. Gill-raker counts have not been previously used for the differentiation of western North Atlantic herring stocks.

In many fish species the number of gill rakers is related to fish size. Krefft (1954,1958) showed that there is a positive correlation between gill-raker number and fish length in juvenile herring of northern Europe but the correlation is insignificant in adult herring. According to McHugh (1954) in Pacific herring the number of gill rakers is complete when the fish reach 100 mm in standard length.

2. Morphometric characters

Although morphometric characters have been frequently used in population studies of scombroid fishes, particularly the tunas (Godsil, 1948; Schaefer, 1948; Schaefer and Walford, 1950; Roedel, 1952; Royce, 1953, 1964; Yang, Nose and Hiyama, 1969), there have been very few attempts to characterize different biological groups of herring on the basis of the relative dimensions of various body parts. Apart from a few scattered observations by early European investigators, Popiel (1955), who examined the head lengths of certain groups of Baltic herring,was one of the first to utilize morphometric characters in European herring racial investigations. Muzinic and Parrish (1960) compared the head length - total length relationships among herring spawning in the northern (Banks) and southern (Downs) regions of the North Sea. They found a significant difference between the body proportions of the two spawning groups studied, the Scottish spawners having on the average a significantly greater head length than the East Anglican spawners. Differences were also detected between the sexes in both areas. The results of this preliminary analysis appeared to warrant a long-term more intensive study of the morphometric characteristics of herring from the main North

Sea spawning grounds. More recently, Burd (MS, 1969) applied principal component or cluster analysis to eight morphometric characters - preorbital, postorbital, caput, pectoral, predorsal, pelvic, preanal and cranial lengths. He found that multiple morphometric measurements did not satisfactorily discriminate between three samples of spawning herring from the Dogger, Sandettie and Flamborough fisheries. However, Pope and Hall (MS, 1970) concluded from a preliminary discriminant function analysis that these same characters, although of little value singly, were useful when combined to construct a linear discriminant function for separating the Buchan and Kobbergrund herring stocks.

Rounsefell (1930) and Tester (1937) examined certain relative body dimensions of Pacific herring. The only morphometric character used by Rounsefell (1930) was head length in relation to standard length. He found that in Alaskan herring there was a gradual decrease in the mean percentage head length with increase in body length. A similar decrease in mean percentage head length with increase in body length in British Columbia herring was reported by Tester (1937). He examined both head length and predorsal length in relation to standard length and concluded that there were no consistent differences between the sexes in these characters. He also found that fast-growing fish have relatively smaller heads than slow-growing older fish. Since growth rate is correlated with water temperature, Tester's results indicate that fish from cold water have larger heads than fish from warm water.

Jean (1967) compared herring from different regions in the Gulf of St. Lawrence on the basis of four morphometric characters - head length, snout length, orbit diameter and postorbital length. He found that herring from the relatively cold waters of Ile Vert had a slower growth rate and smaller snouts and heads than those from the warmer waters of Anse au Gascon. Sex differences were negligible. Jean's results agree with the generally accepted hypothesis that fish inhabiting colder waters have relatively smaller heads and other body parts than fish from warmer waters but do not conform to Tester's (1937) contention that fast-growing fish have relatively small heads.

III. MATERIALS AND METHODS

A. Source of samples

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. Samples, usually of 50 specimens each but sometimes in multiples of 50, were collected from landings at Newfoundland ports of herring caught in the commercial fisheries along the south coast of Newfoundland, in the southern Gulf of St. Lawrence near the Magdalen Islands, in Hawke's Bay on the northwest coast of Newfoundland and along northeastern Nova Scotia, and from research vessel catches during surveys of the coastal waters of southeastern, eastern and northern Newfoundland. Supplementary samples were obtained from catches by inshore fishermen,particularly in eastern and northern Newfoundland. Several types of gear were used to catch the herring. The southwest Newfoundland, Magdalen Islands and Hawke's Bay samples were caught by purse seiners and the Nova Scotian samples by midwater trawlers. Research vessel samples were caught in anchored gillnets set in coastal waters; each set consisted of a string of five nylon herring nets of different mesh sizes (2", 2¼", 2½", 2 3/4", 3"), 90 fathoms in length and 3 fathoms deep. Most of the samples provided by inshore fishermen were caught in gillnets generally with a mesh size of 2½ to 2 3/4 inches stretched measure, but some came from

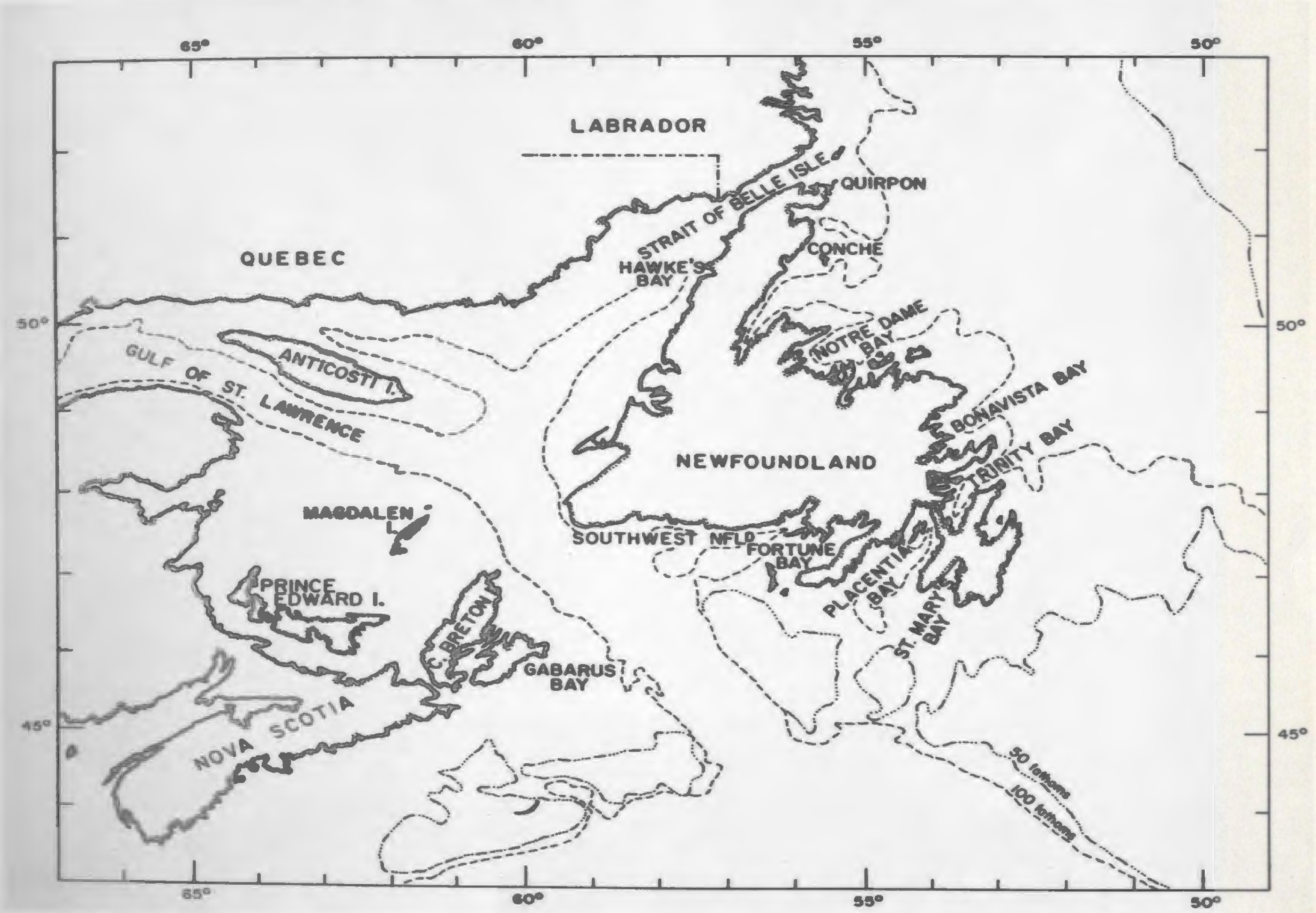

Fig. 1. Area map showing the localities and place names mentioned in the text.

incidental catches of herring in 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 representative of the herring schools because of the selective action of these gears (Hodgson, 1933; Tester, 1935, 1937; Olsen, 1959). Data on size and age compositions of herring in the various areas are presented but they are not strictly comparable except for those areas where all samples were derived from purse seine catches.

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

B. Sampling methods

All samples were thawed and examined after being kept in frozen storage for several weeks. Various length measurements were made on the thawed specimens using a measuring board similar to that described and illustrated by Rounsefell (1930) and employed by Tester (1937) and Jean (1967). All distances were measured in millimetres from the tip of the closed lower jaw to the various end points. These measurements were not of actual distances but rather of distances as projected on the millimetre scale of the board. All measurements were made by the author to eliminate between-individuals variation in methods of measuring. No corrections were made for shrinkage due to freezing.

The following body measurements were taken (Fig. 2):

Total length: distance from the tip of the closed lower jaw to the end of the longest lobe of the caudal fin with the lobe extending straight back in line with the body (greatest total length).

Standard length: distance from the tip of the closed lower jaw to the end of the silvery area on the caudal peduncle after the scales have been removed from that region.

Head length: distance from the tip of the closed lower jaw to the posterior margin of the operculum.

Snout length: distance from the tip of the closed lower jaw to the anterior margin of the orbit.

Orbit diameter: horizontal distance from the anterior to the posterior margin of the orbit.

Postorbital length: distance from the posterior

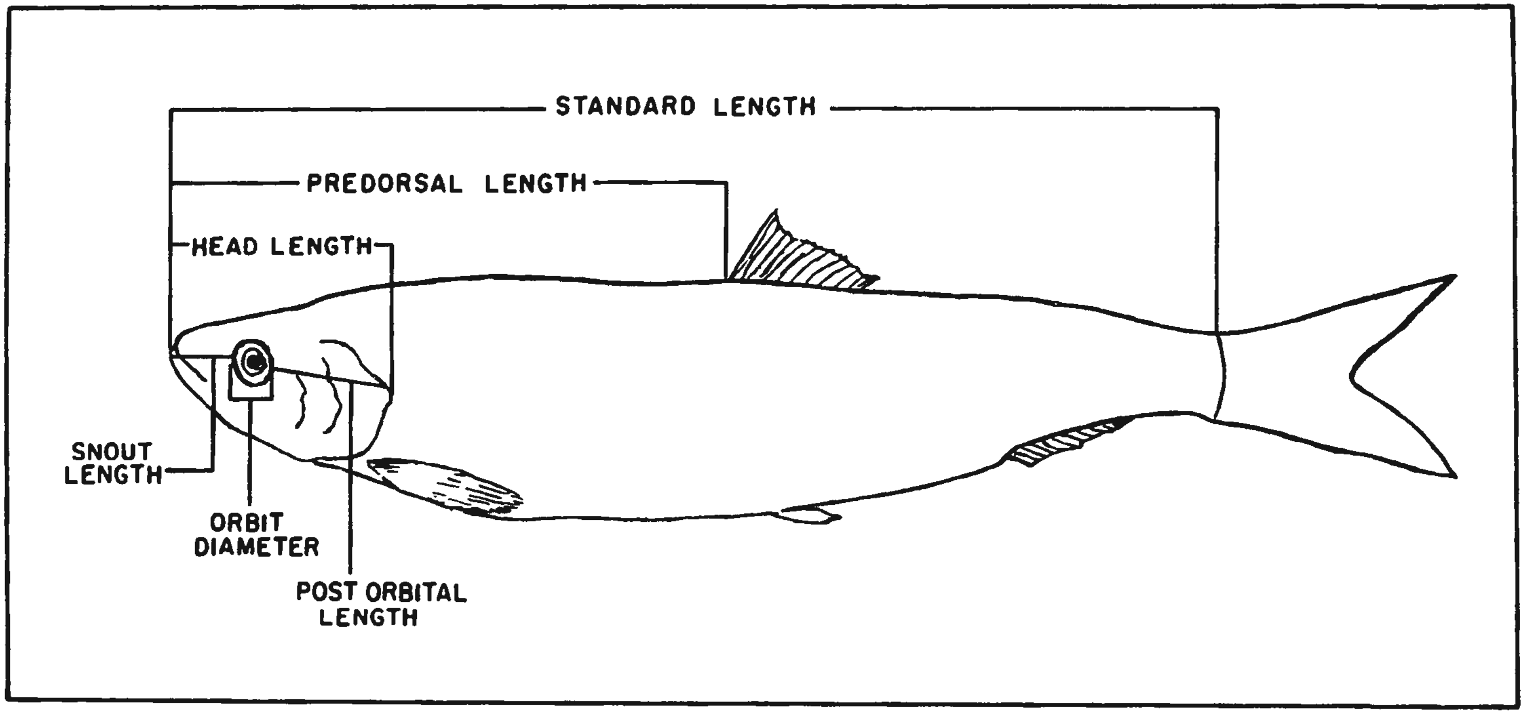

Fig. 2. Sketch of a herring showing the body measurements taken.

margin of the orbit to the posterior margin of the operculum.

Predorsal length: distance from the tip of the closed lower jaw to the base of the most anterior ray of the dorsal fin.

For comparisons of size compositions in the various areas total-length measurement data, recorded to the nearest millimetre, were grouped into 1-cm intervals ~~to the 0.5 cm below~~ (i.e. all lengths ranging from 310 to 319 mm were grouped into the 31-cm interval).

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 the use of a binocular microscope. The dorsal fin-ray and vertebral 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. Vertebral counts excluded the hypural plate.

The sex and stage of maturity of each specimen were also recorded and sagittal otoliths taken for subsequent age determination. The stage of maturity was determined by gross examination of gonads using the various stages of gonadal development as adopted by ICNAF (1964) (Table 2).

Age determinations were made from whole otoliths premounted in small circular depressions in otolith trays made of black plexiglass. A description of the tray and technique of otolith mounting is given by Watson (1965) and Hourston (MS, 1968). The age was recorded as the number of completed summer (opaque) growth zones on the otolith. January 1 was selected as the arbitrary birthdate; a fish is considered to be age I on January 1 following completion of the first summer's growth. Autumn-spawned herring will obviously be several months older than spring-spawned herring of the same assigned age. The degree of uncertainty for specimens of age X and greater was such that these were grouped into a X+ category. Such grouping of old herring is not unusual for Tibbo et al.(MS, 1969) used a similar grouping for Gulf of St. Lawrence herring and Boyar (1968) grouped all herring greater than age VIII into an VIII + category.

Messieh (1969) and Hourston and Parsons (MS, 1969) have questioned the validity of using otolith nucleus type as indicative of the time of hatching for Northwest Atlantic herring. Because of the difficulty of determining the 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. The degree of interchange between spawning groups is uncertain but the meristic differences between spring- and autumn-spawning herring reported here clearly indicate that spring- and autumn-spawning herring are not members of a homogeneous group but constitute relatively distinct breeding populations, the young of which develop at different times of the year under different environmental conditions. 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 age.

IV. RESULTS

A. Spawning season

Individual adult fish were assigned to spawning groups 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 (Unpublished data, St. John's Biological Station).

Gonads of autumn spawners which spawn in August-September remain in the resting or recovering stage (Stage VIII) throughout the autumn and winter, begin to develop during the late spring and mature progressively throughout the summer until spawning time. After spawning in May-June spring spawners spend most of the summer as recovering fish in the early stages of maturation. They begin to mature during the late summer and by November-December their gonads are well-developed (Stage IV), nearly ripe for spawning. Gonad development of spring spawners is thus far advanced long before spawning time but practically no maturation occurs during the winter. These fish ripen rapidly during the spring just before spawning. While 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. 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 this 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 (Parsons, in preparation). 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.

Table 3 shows the frequency and percentage of autumn and spring spawners in each area. In most areas both spawning groups were present but in varying proportions. Herring caught in Gabarus Bay, 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. Virtually all 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(Unpublished data, St. John's Biological Station). These spawnings generally occur in shallow water (0-5 fathoms). At spawning time "milky" water is usually visible in these areas and sometimes extends for miles. 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.

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 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 are 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. Size and year-class composition

Fig. 3 shows the percentage length compositions (greatest total length) of herring from the various areas by spawning group. Differences between spring and autumn spawners in the 9 areas where both spawning groups were present are obvious; in all instances autumn spawners were larger than spring spawners. With the exception of Gabarus Bay autumn spawners, which had greater proportions of intermediate- and smaller-sized fish (mean length 28.6 cm), the mean length among autumn spawners ranged from 33.0 cm for Hawke's Bay herring to 36.2 cm for Strait of Belle Isle herring. The frequency patterns for southwest Newfoundland and Magdalen Islands autumn spawners, which both had a mean length of 33.3 cm, were very similar. Except for herring from these two areas and Hawke's Bay, where there was a relatively high proportion of smaller- and intermediate-size fish, the mean lengths for autumn spawners from the other areas differed little - 34.8 to 36.2 cm. The mean length of spring spawners ranged from 30.5 cm for Placentia Bay herring to 32.8 cm for Trinity Bay and Quirpon herring,

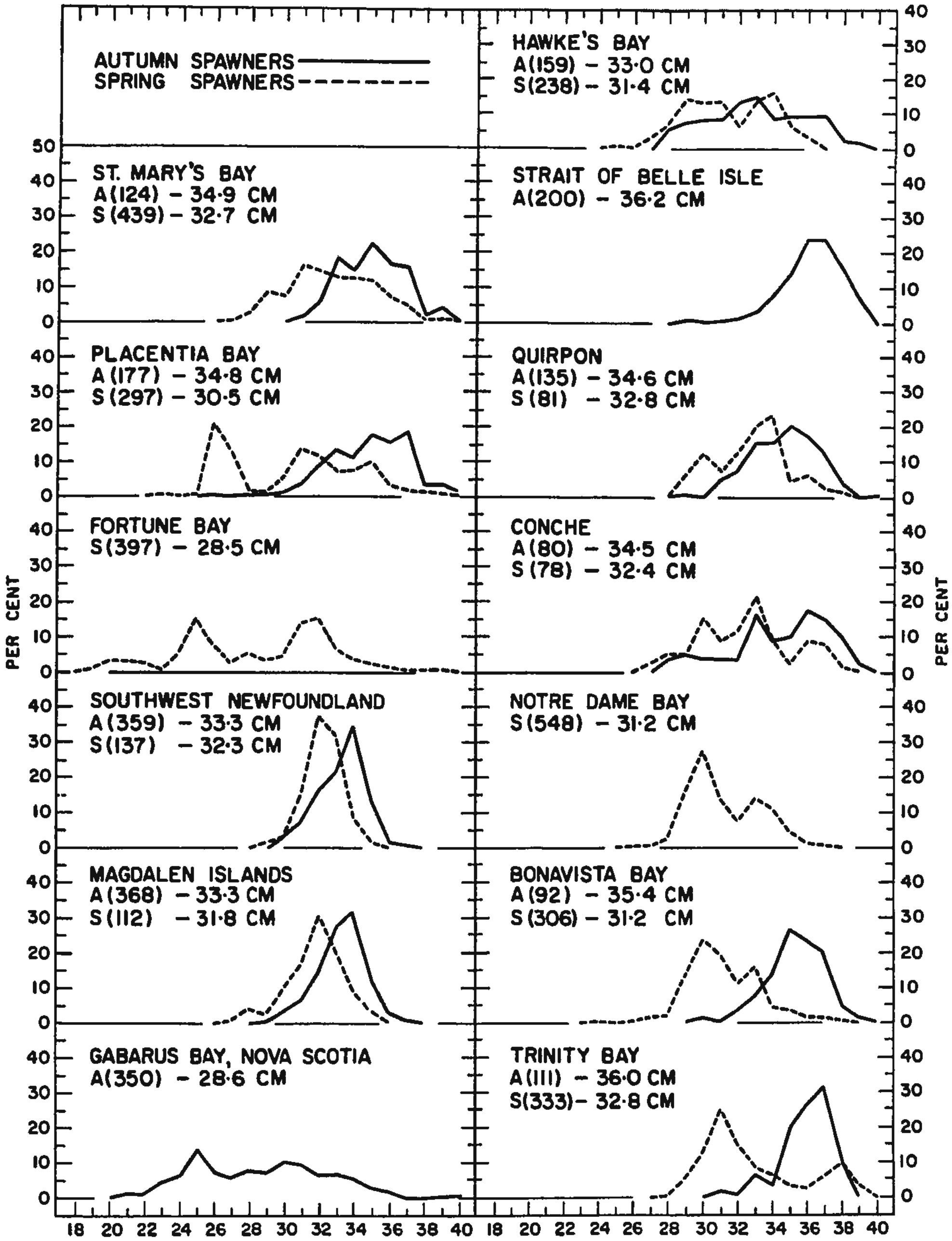

Fig. 3. Percentage length composition of herring from the various areas by spawning group. Numbers of fish measured are in parentheses.

with the exception of Fortune Bay spring spawners which had a higher proportion of smaller-sized fish (mean length 28.5 cm).

Fig. 4 illustrates the percentage year-class composition by spawning group for the various areas under consideration. Fish 10 years and older were grouped as 10+ and are shown in Fig. 4 as the 1960+ year-classes (year-classes preceding and including 1960) for spring spawners and the 1959+ year-classes (year-classes preceding and including 1959) for autumn spawners. The proportions of older age groups are much higher among autumn than among spring spawners. In all areas except Gabarus Bay the 1959+ year-classes were by far the dominant group among autumn spawners, ranging from 37.5% in Hawke's Bay samples to 83.5% in Strait of Belle Isle samples. In these areas no other year-class exceeded 20% of the total. There were relatively few older fish in Gabarus Bay; less than 10% belonged to the 1959+ year-classes and the 1960, 1961 and 1962 year-classes were poorly represented. The 1966 year-class was dominant (32.0%) as three year-olds in early 1970 and the 1963 year-class was also relatively strong (21.5%).

Between-area differences in year-class dominance were more evident among spring spawners than among autumn

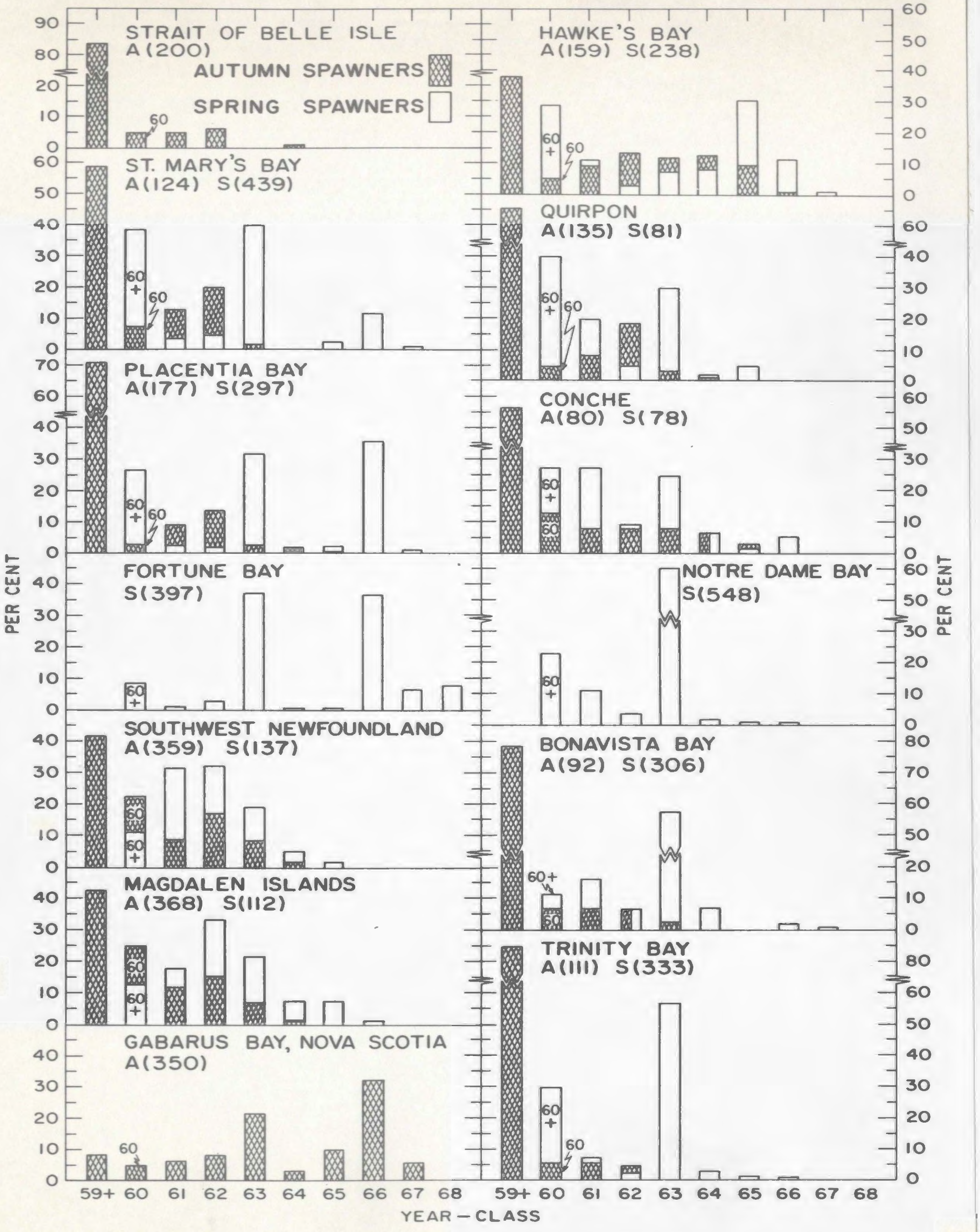

Fig. 4. Percentage year-class composition of herring from the various areas by spawning group. Numbers of fish aged are in parentheses.

spawners. There were relatively small proportions of older fish of the 1960+ year-classes in some areas, e.g. Fortune Bay, southwest Newfoundland, Magdalen Islands and Bonavista Bay. In other areas, e.g. St. Mary's Bay, Placentia Bay, Hawke's Bay, Quirpon and Conche, the 1960+ year-classes were relatively strong but were by no means as dominant among spring spawners as the 1959+ year-classes among autumn spawners. The 1961, 1962 and 1963 year-classes were dominant among both Magdalen Islands and southwest Newfoundland spring spawners. Apart from the 1960+ year-classes only two relatively strong year-classes were evident in the samples from Fortune, Placentia and St. Mary's bays. The 1963 and 1966 year-classes were both relatively strong (30 to 40% each) in Fortune and Placentia bays. The 1963 year-class was predominant in St. Mary's Bay (39.8%) whereas the 1966 year-class, although stronger than most others, comprised only 11.5% of the fish in the samples from this area. The 1963 year-class was very predominant (56.5 to 59.9%) among eastern Newfoundland (Trinity, Bonavista and Notre Dame bays) spring spawners and also strong (between 20 and 30%) among Conche and Quirpon spring spawners but the 1960+ and 1961 year-classes were also relatively strong in these latter two areas. The 1965 and 1960+ year-classes were predominant among Hawke's

Bay spring spawners but the 1963 year-class was relatively weak. Interestingly, the 1965 year-class which was very strong in Hawke's Bay was relatively insignificant in other areas. The dominance of the 1963 year-class among eastern Newfoundland spring spawners confirms good survival of the 1963 year-class predicted earlier from the abundance of 1-year-old juveniles in the summer of 1964 (Hodder, 1965).

C. Meristic characteristics

For each type of statistical test employed in this study 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 (Table 4). 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 the 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. This test however, does not reveal which areas are significantly different from each other. To test the individual differences ranked means of meristic numbers were compared using the 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 number and total length were obtained (Table 5). The correlation coefficients differed significantly from zero in only ~~3~~ 4 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 $100\rho^2$ is an approximate measure of the coefficient of variability in the observations for a particular character due to corresponding variability in length. For vertebral number this variability is 1.4 percent for spring spawners and only 0.3 percent 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

Vertebral frequencies, means, standard deviations and standard errors of spring- and autumn- spawning herring from the various areas are given in Table 6. 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. The difference between spring and autumn spawners was significant in only one of the nine areas; Trinity Bay autumn spawners had a significantly higher vertebral average than spring spawners. 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 7). Differences between the sexes were significant in only 2 of 22 possible instances. Both St. Mary's Bay and Quirpon male spring spawners had significantly higher mean vertebral numbers than females. 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 (Table 8) 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.

Fig. 5 shows mean vertebral numbers and two standard errors on each side of the mean for the various

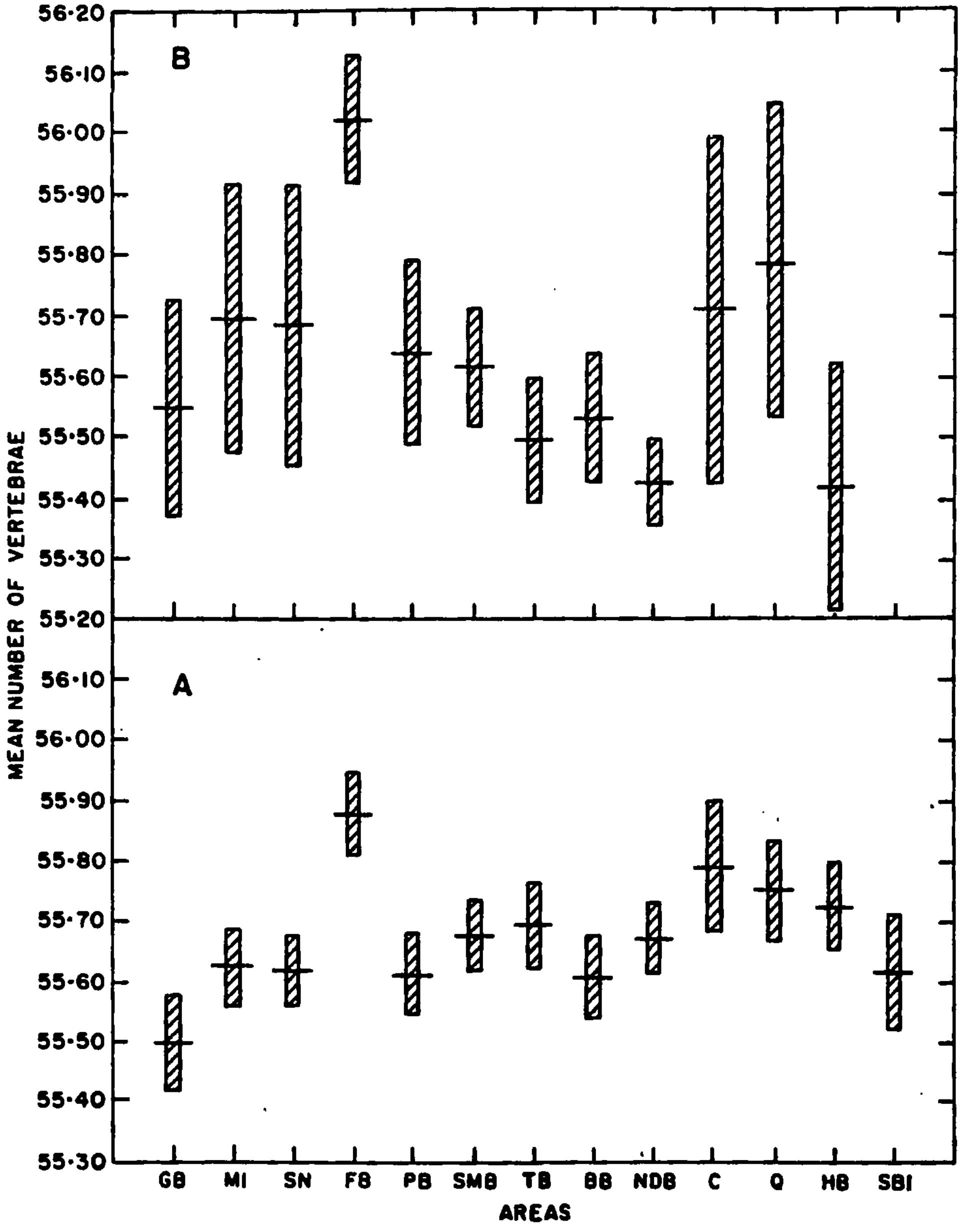

Fig. 5. Mean numbers of vertebrae by area (spring and autumn spawners combined) for the pooled year-classes (A) and the 1963 year-class only (B). (Horizontal lines indicate means; vertical bars indicate two standard errors on each side of the mean).

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 9). No geographic trend was evident. An analysis of variance of the vertebral frequencies showed significant heterogeneity among areas (Table 10). 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 (Table 11). 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~~ not demonstrably different from all others.

Vertebral comparisons based only on the 1963 year-class (Tables 11 and 12) 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, 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 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 fish 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 (Table 13). 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 these 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 5). 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

Gill-raker frequencies, means, standard deviations and standard errors of spring- and autumn-spawning herring from the various areas are given in Table 14. Autumn spawners had higher gill-raker averages than spring spawners in all nine areas where both spawning groups were present. 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 raker was higher for males than females in 13 instances and higher for females than males in 9 instances (Table 15). 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 (Table 16). 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 fish 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.

Fig. 6 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

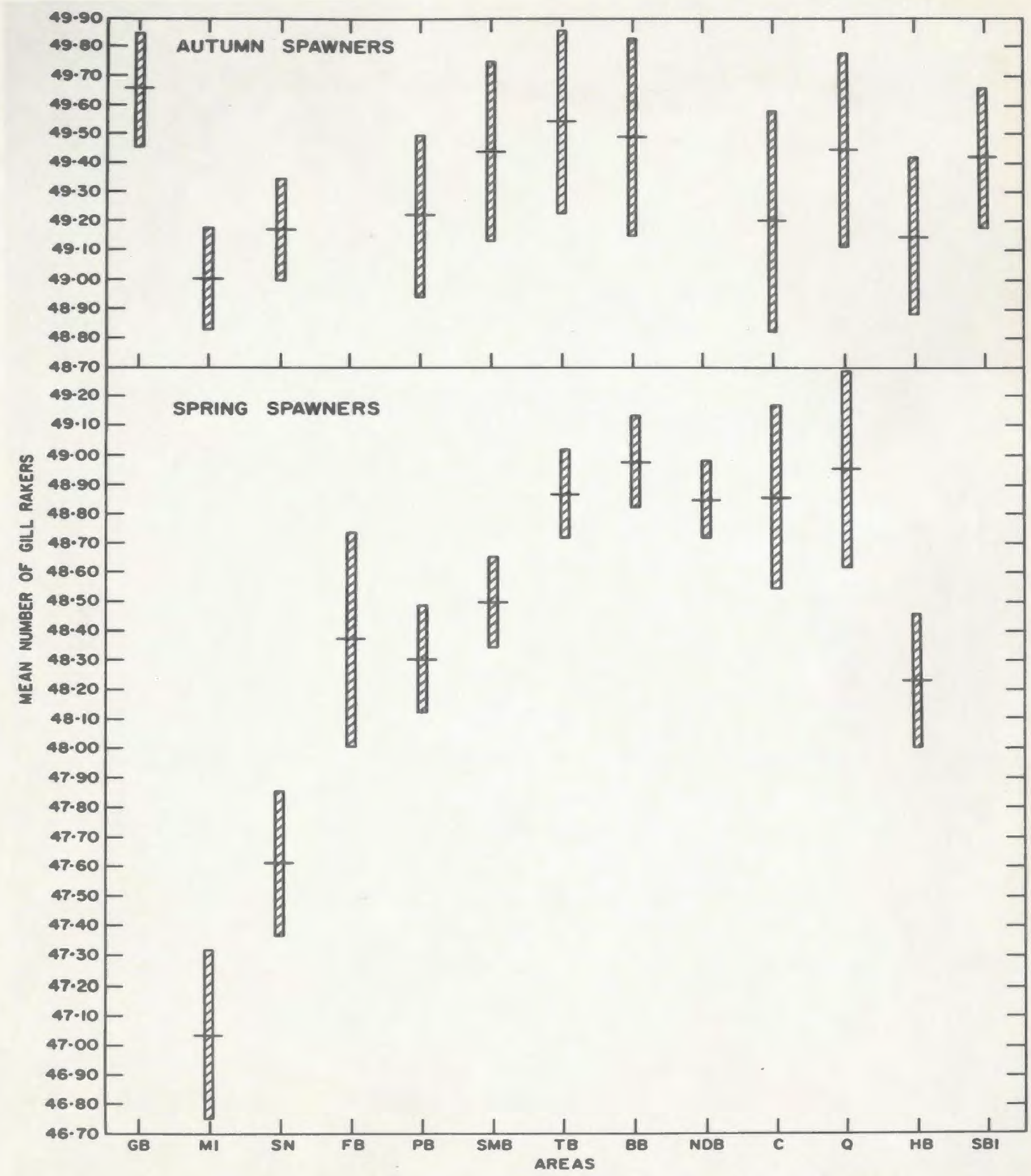

Fig. 6. Mean numbers of gill rakers by area and spawning group. (Horizontal lines indicate means; vertical bars indicate two standard errors on each side of the mean).

Bonavista Bay (Table 14). 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 (Table 17). 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 18). Spring spawners from eastern Newfoundland (Trinity Bay to Quirpon) and southeastern Newfoundland (St. Mary's, Placentia and Fortune bays) plus Hawke's Bay 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 among autumn spawners 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 obtained (Table 5). The correlation coefficients differed significantly from zero in 7 of 22 possible instances, indicating a positive correlation between the 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.

Table 19 gives the pectoral fin-ray frequencies, means, standard deviations and standard errors of spring- and autumn-spawning herring from the various areas. Autumn spawners had significantly higher pectoral fin-ray averages than spring spawners in all nine areas where both groups were represented. 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 20). 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 (Table 21), year-classes were pooled for area comparisons.

Fig. 7 shows 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 19). Among autumn spawners the means ranged from 18.418 for Quirpon fish to 18.622 for Trinity Bay fish. No geographic trend in pectoral means was evident among either spawning group. There was significant area heterogeneity among spring spawners but

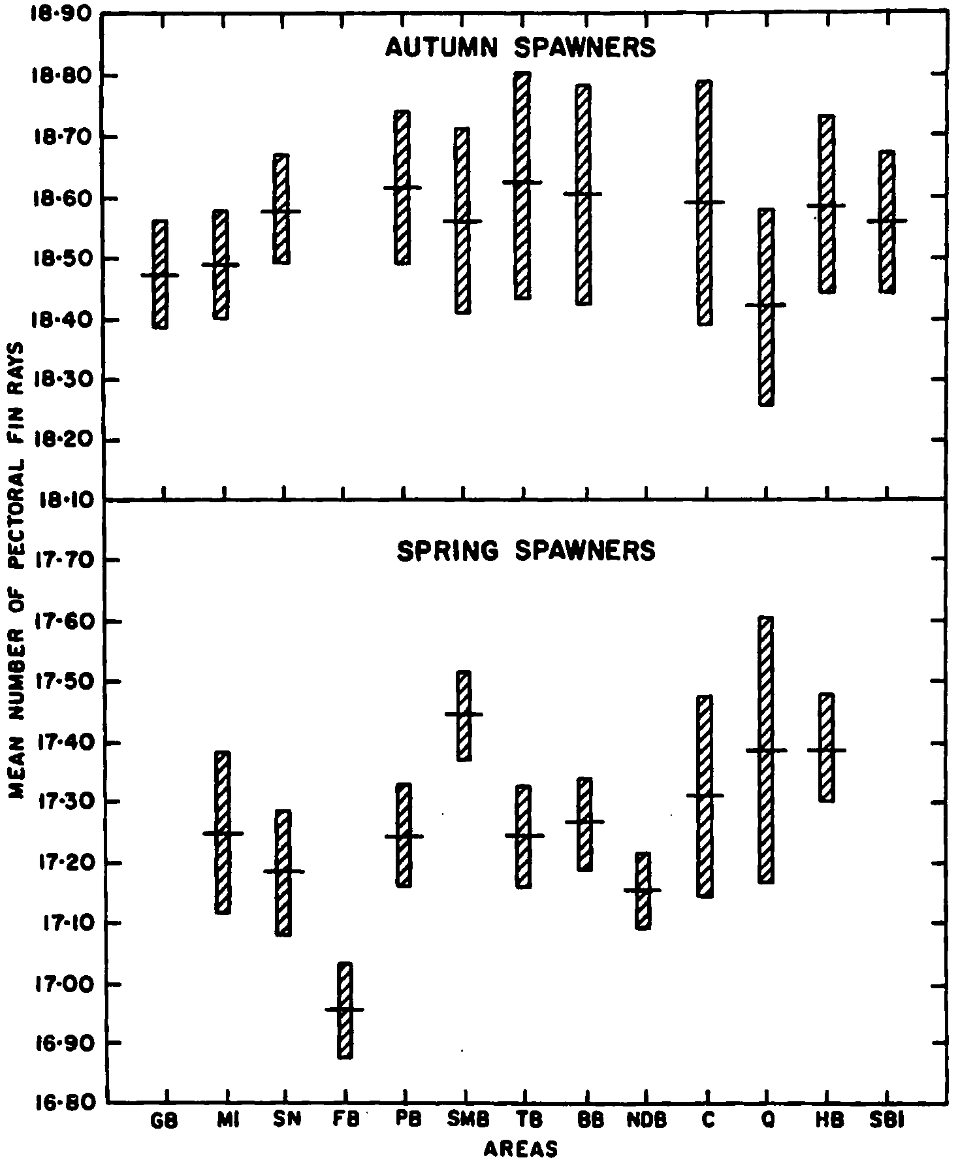

Fig. 7. Mean numbers of pectoral fin rays by area and spawning group. (Horizontal lines indicate means; vertical bars indicate two standard errors on each side of the mean).

not among autumn spawners (Table 22). 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 23). 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 derived (Table 5). The 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 lenght is only 0.2% for both spring and autumn spawners. Thus the correlation between anal fin-ray number and fish length is statistically negligible. However the fact that the correlations are generally positive for all meristic characters examined suggests some common fact. It may be that fish with fewer vertebrae, fin rays, etc., die off more rapidly during the course of their life history, possibly as an indirect effect of a correlation of growth rate and mortality.

(ii) Variation between spawning groups and sexes

Tabel 24 shows the anal fin-ray frequencies, means, standard deviations and standard errors of spring- and autumn-spawning herring from the various areas. In seven of the nine areas where both spawning groups were present autumn spawners had higher anal fin-ray averages than spring spawners. For Magdalen Islands, southwest Newfoundland and Placentia Bay 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 25) but the differences were not significant; consequently, anal fin-ray data for males 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 showed significant year-class heterogeneity only among Placentia Bay spring spawners (Table 26). Despite this heterogeneity area comparisons were made 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, which was best represented in all areas.

Figs. 8 and 9 show mean anal fin-ray numbers and two standard errors on each side of the mean for the various areas for the pooled year-classes and the 1963 year-class only (spring and autumn spawners separate). Mean numbers of anal fin rays among spring spawners (year-classes pooled) ranged from 17.598 for southwest Newfoundland fish to 18.026 for Bonavista Bay fish (Table 24). 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 (Table 27). 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 29). 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

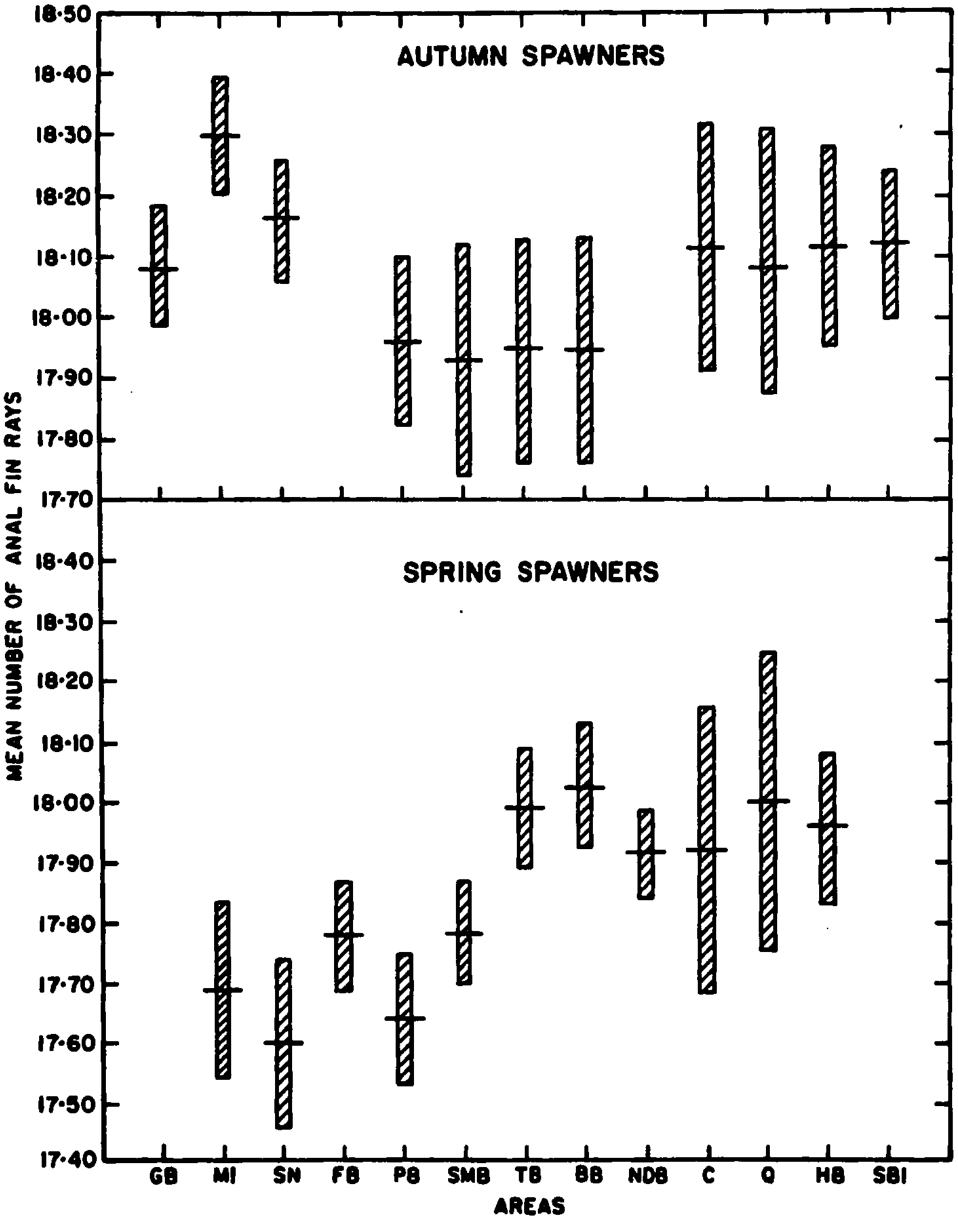

Fig. 8. Mean numbers of anal fin rays by area and spawning group-year-classes pooled. (Horizontal lines indicate means; vertical bars indicate two standard errors on each side of the mean).

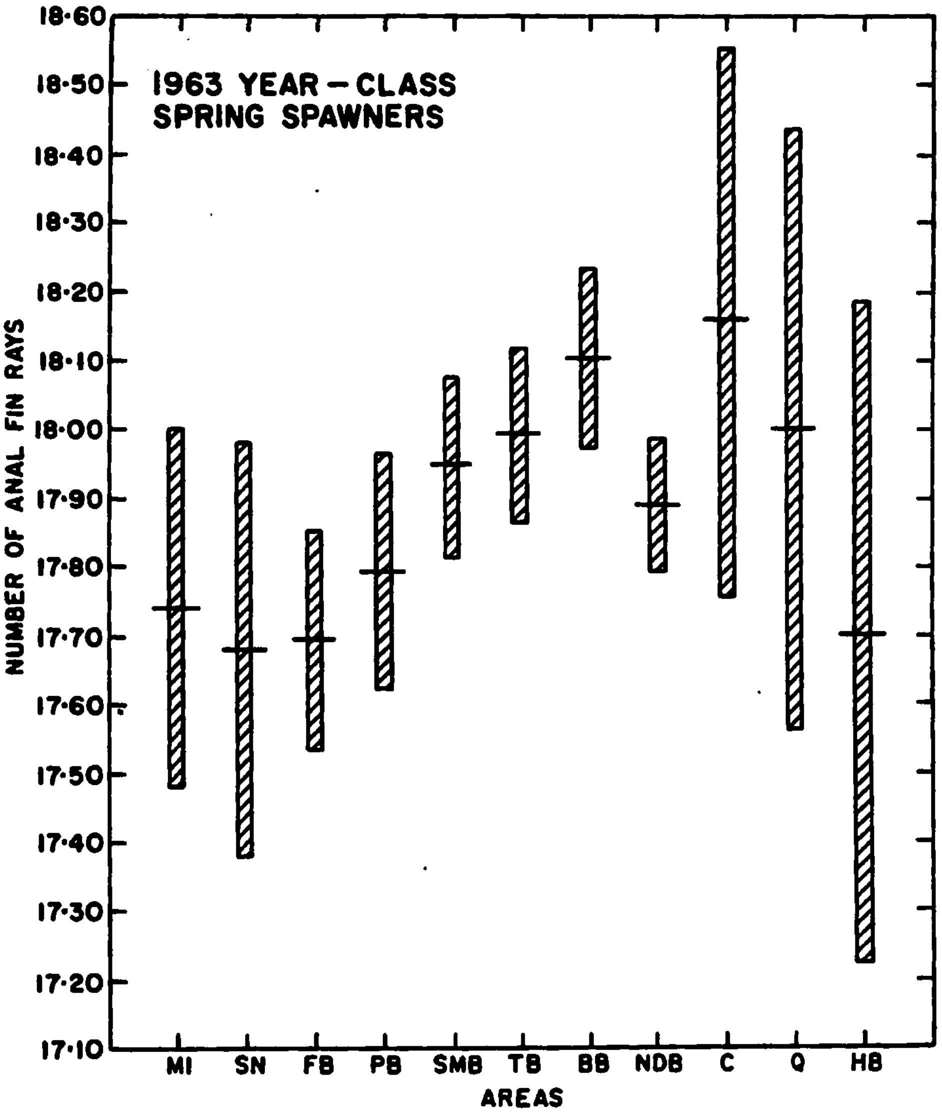

Fig. 9. Mean numbers of anal fin rays of spring spawners of the 1963 year-class. (Horizontal lines indicate means; vertical bars indicate two standard errors on each side of the mean).

year-class (Table 26) show greater similarity than those based on the pooled year-classes. Fortune Bay fish 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 other areas are not significantly different from one another.

5. Numbers of dorsal fin rays

Dorsal fin-ray averages appear to be unsatisfactory for herring stock differentiation since there are significant differences between samples within several areas (Table 4), 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 elogated 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.

6. Discriminant function analysis of spring and autumn spawners

To further evaluate the use of meristic characters as indices for racial separation, it is necessary to consider several characters simultaneously. Fisher (1936) derived the linear discriminant function, a multivariate statistical technique for classifying individuals to one of two populations. This technique has been widely used in recent years for discriminating between racial groups (Hill, 1959; Fukuhara et al., 1962; Kilambi, MS, 1965; Anas and Murai, 1969). Basically this method involves reducing a set of counts or measurements from an individual to a single value by which the individual can be classified as being from one group or the other. Detailed discussions of the statistical techniques employed in the construction of a discriminant function are given by Fisher (1936), Mahalanobis (1936), Rao (1952), Fukuhara, et al. (1962) and Andersen (1966).

Three meristic characters were used in the present discriminant function analyses - pectoral and anal fin rays and gill rakers. The main objective was to evaluate the usefulness of these meristic characters for classifying individual herring to their respective spawning groups. Discriminant analyses were made with the Multiple Discriminant Analysis Program (DISCR)for the IBM 1130 computer (Pienaar and Thomson, MS, 1967) as modified by E.J. Sandeman of the St. John's Biological Station.

A linear discriminant function was computed for 131 spring spawners and 343 autumn spawners from southwestern Newfoundland taken during late November-early December 1969. Means and differences between the means of the two spawning groups are given in Table 30. The discriminant function for these data is

$$y= 0.9157x_1 + 0.3420x_2 + 0.2110x_3$$

In this equation x_1, x_2, and x_3 represent the numbers of pectoral and anal fin rays and gill rakers respectively.

The estimated mean values of the coefficients of the discriminant function for the spring spawners ($\overline{y}_s$) and the autumn spawners ($\overline{y}_a$) were determined by substituting $\overline{x}_i$, the mean numbers of each of the three meristic characters for each spawning group, into the function. The values of $\overline{y}_s$ and $\overline{y}_a$ were 31.792 and 33.588 respectively. Therefore,in discriminating between the two spawning groups those fish with a value of y less than 32.690 were classified as spring spawners and those with values of y more than 32.690 were classified as autumn spawners. An analysis of variance revealed that differences between the two spawning groups were significant at less than the .001 level ($F_{3,470}$ = 129.34).

The variance of y is D^2 and is given by

$$D^2 = l_1 d_1 + l_2 d_2 + l_3 d_3$$

where l_1, l_2 and l_3 are the coefficients of the discriminant function and d_1, d_2 and d_3 are the differences between the estimated population means of the three characters (Table 30). The probability of correctly assigning an individual fish to its respective spawning group is equal to the probability that a normal deviate with mean zero and standard deviation of 1 will be less than or equal to $\frac{1}{2}D$ (Rao, 1952). Since D^2 in this instance is 1.796, the probability of misclassification is approximately 25.2%. This error of classification would be the proportion of spring spawners having y values less than 32.690 and the proportion of autumn spawners having y values more than 32.690.

This discriminant function was then used to classify individual fish in the original samples from which the function was derived and also to classify individuals in January 1969 and April 1970 samples from southwestern Newfoundland and November 1969 samples from the Magdalen Islands area. The resulting frequencies and percentages of y values above and below the critical value 32,690 (y_o) are shown in Table 31. The percentages of misclassification of autumn spawners in the January 1969 and April 1970 samples from southwestern Newfoundland and the November 1969 samples from Magdalen Islands were in close agreement with the percentage of misclassification of the southwestern Newfoundland autumn spawners used in the construction of the discriminant function. Percentages of misclassification of spring spawners in the January 1969 and April 1970 southwestern Newfoundland samples were very similar to that resulting from classification of the southwestern Newfoundland spring spawners upon which the function was based. The percentage of misclassification for Magdalen Islands spring spawners (9.3%) was even less than for those from southwestern Newfoundland.

The actual errors of misclassification for both spawning groups were in all instances less than the 25.2%

average error of misclassification inherent to the function. Percentages of correct classification ranged from 80.6 to 86.2 for autumn spawners and from 79.4 to 90.7 for spring spawners.

D. Morphometric characteristics

Graphical plots of the raw data indicated straight line relationships between standard length and all body parts examined; there were no obvious departures from linearity. It has been demonstrated for many species that the major growth inflection is related to the onset of sexual maturity after which the rate of relative growth is relatively constant (Debrosse, 1936; Mottley, 1936; Hamai, 1941; Wilder, 1952; Martin, 1949). Therefore, to avoid difficulties introduced by allometric growth, immature specimens were excluded from the data analyses. To ensure linearity and homogeneity of variance, the data were converted to common logarithms and log-log regressions of the various body parts on standard length were calculated. Differences in the regression coefficients (slopes) and adjusted means of the regression lines for individual samples, areas and spawning groups within areas were compared by analysis of covariance as described by Snedecor (1961). The F value derived from the ratio of mean square for regression coefficients to mean square within samples measures the significance of differences in slope of the regression lines. The significance of differences in adjusted means ~~(intercept)~~ is measured by the F value derived from the ratio of mean square for adjusted means to mean square for common regression. If the differences in slopes are significant, in which case the regression lines are not statistically parallel, differences in adjusted means have little meaning. Because of the relatively small size and irregular length distribution of the samples, only differences significant at the 0.01 level were considered to be valid.

1. Variation among samples

Log-log regressions of body parts on standard length were calculated separately for each sample for both spawning groups within each area. Between-sample differences were tested by analysis of covariance (Table 32). Differences in slopes were generally not significant (only 2 instances out of a possible 105). However, there were numerous instances of between-sample differences in adjusted means for all morphometric characters examined. Spring spawners in 3 out of 11 areas and autumn spawners in 4 out of 10 areas did not exhibit differences in either slopes or adjusted means. Despite between-sample differences within areas valid comparisons of populations can be made if the mean square difference among the samples is smaller than that between areas. Therefore, the variation between samples within areas was used to test the differences between the areas. For both spawning groups and all morphometric characters the mean square difference between areas exceeded the mean square difference between samples and in each instance the F value thus derived was statistically significant (Tables 33 and 34). Therefore, all samples within each area were pooled and regression lines computed for both spawning groups and both sexes within each area.

2. Head length and standard length

(i) Variation between spawning groups and sexes

Log-log regressions of head length on standard length were calculated for spring and autumn spawners within each of the eight areas* where both spawning groups were represented (Table 35). In seven of the eight areas autumn spawners had relatively larger heads at any particular standard length than spring spawners (Fig. 10 and 11). However, Conche spring spawners had relatively larger heads than autumn spawners. Covariance analyses to test the hypothesis that a common line can be utilized to express the head length-standard length relationship yielded significant F values for six of the eight areas (Table 35). Differences in slopes of the regression

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*Morphometric data were not available for St. Mary's Bay autumn spawners

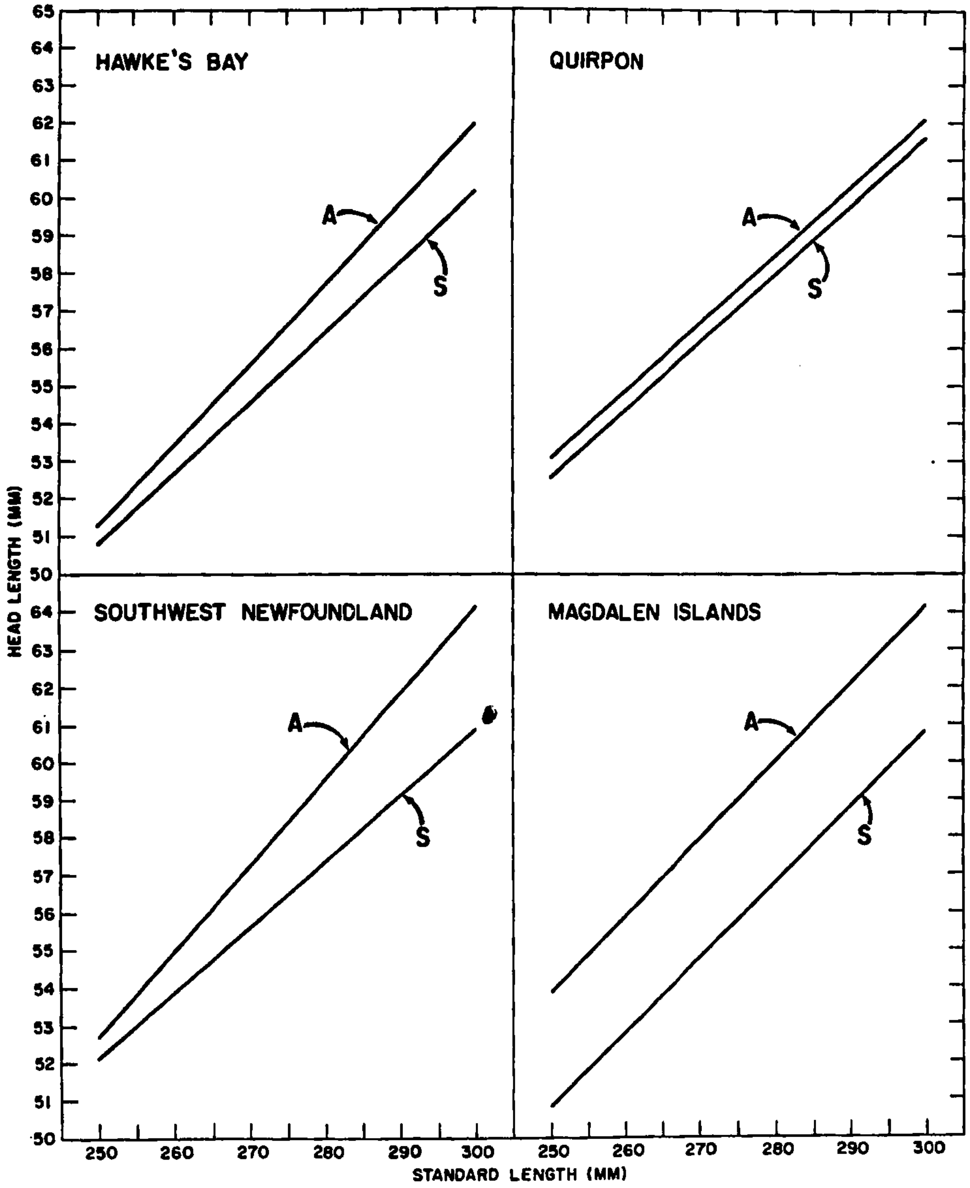

Fig. 10. Relation of head length to standard length for spring and autumn spawners from Hawke's Bay, Quirpon, southwest Newfoundland and Magdalen Islands.

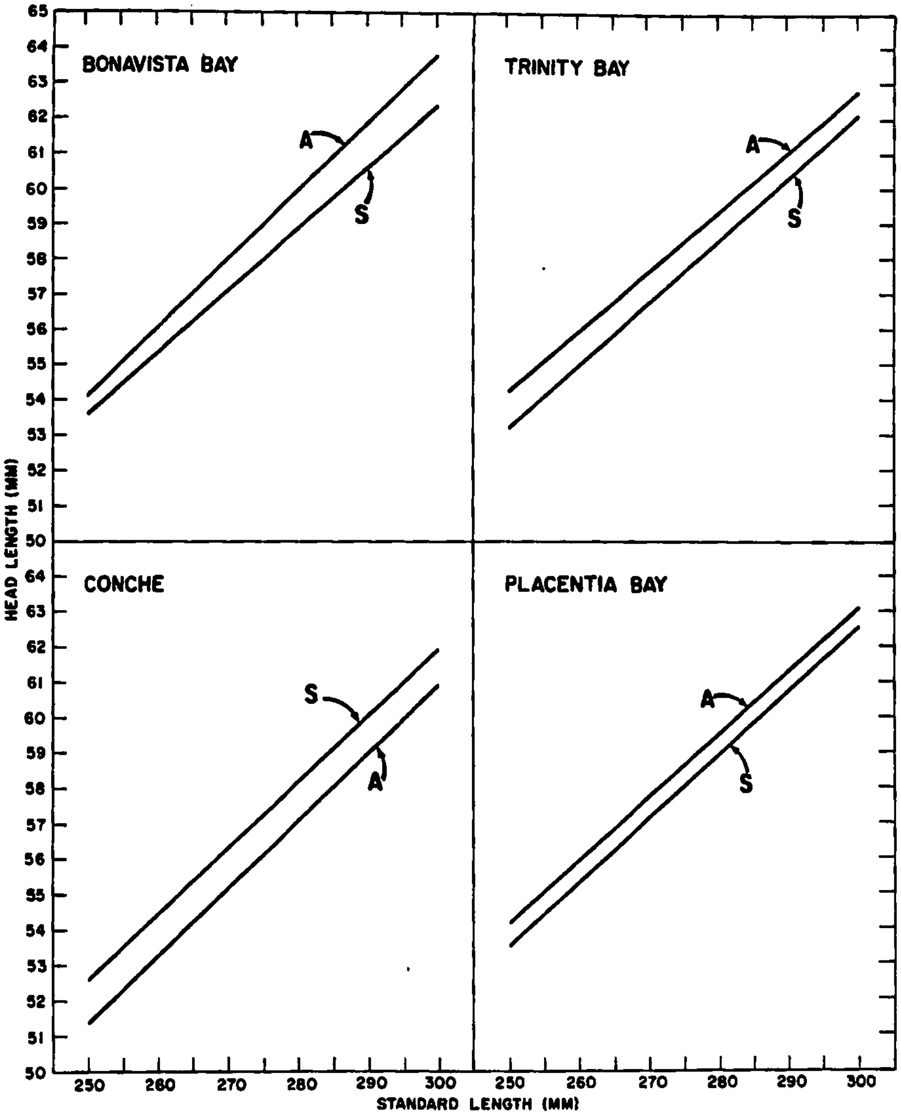

Fig. 11. Relation of head length to standard length for spring and autumn spawners from Bonavista Bay, Trinity Bay, Conche and Placentia Bay.

lines were significant between spring and autumn spawners from southwestern Newfoundland and Hawke's Bay. Adjusted means accounted for the significant differences between spring and autumn spawners from Magdalen Islands, Trinity Bay, Bonavista Bay and Conche. It was concluded that there are in general significant differences in relative head length between spring and autumn spawners. Therefore, the two spawning groups were treated separately in subsequent analyses.

Log-log regressions of head length on standard length were then computed for the sexes within each spawning group for each area (Table 36). Significant sex differences were evident in only 2 of 21 possible instances; St. Mary's Bay male and female spring spawners differed in adjusted means and Placentia Bay male and female autumn spawners differed in slope. Therefore, sexual dimorphism in head length was considered negligible.

(ii) Variation among areas

Head length-standard length regression lines for all areas are shown in Figs. 12 and 13 for spring and autumn spawners respectively. Spring-spawning herring from Placentia, Bonavista and Trinity bays have the largest heads. Hawke's Bay spring spawners have the smallest heads followed in order of increasing size by Magdalen Islands and southwest Newfoundland spring spawners. Regression lines for spring

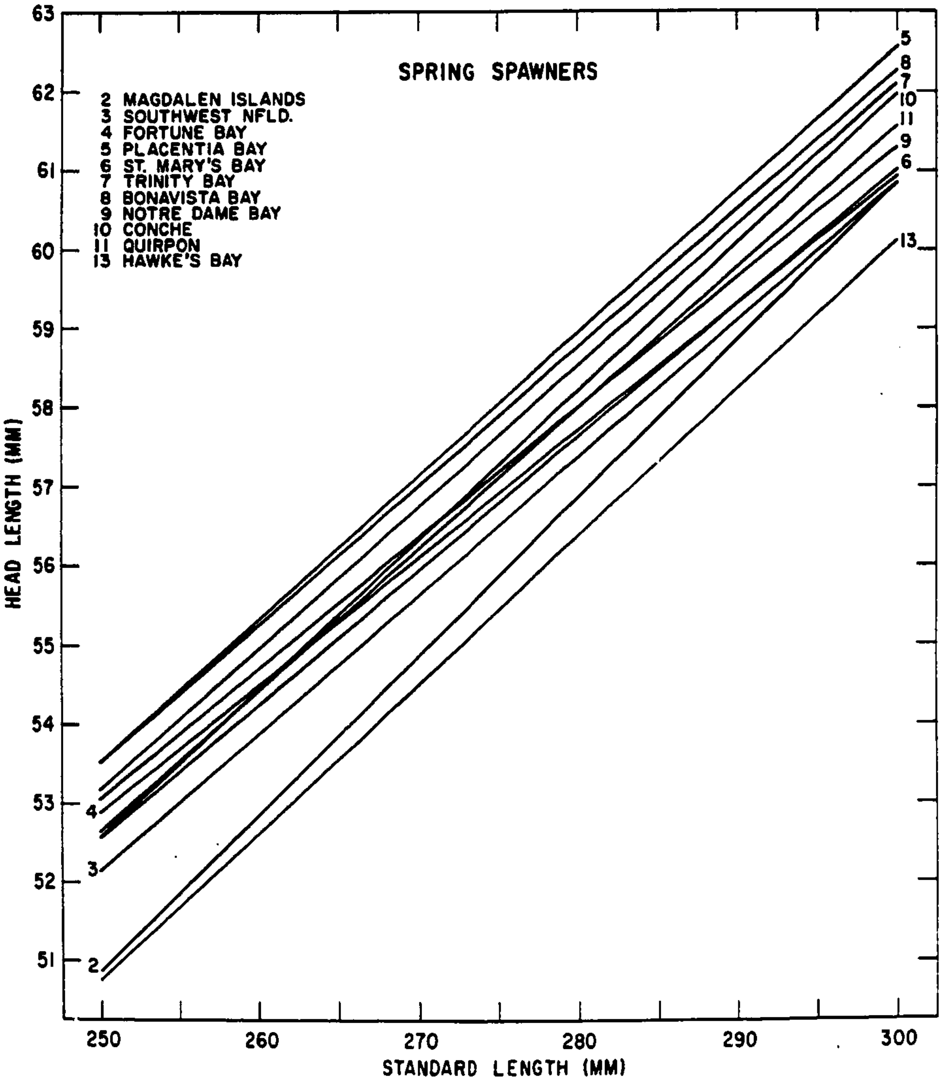

Fig. 12. Relation of head length to standard length for spring spawners in all areas.

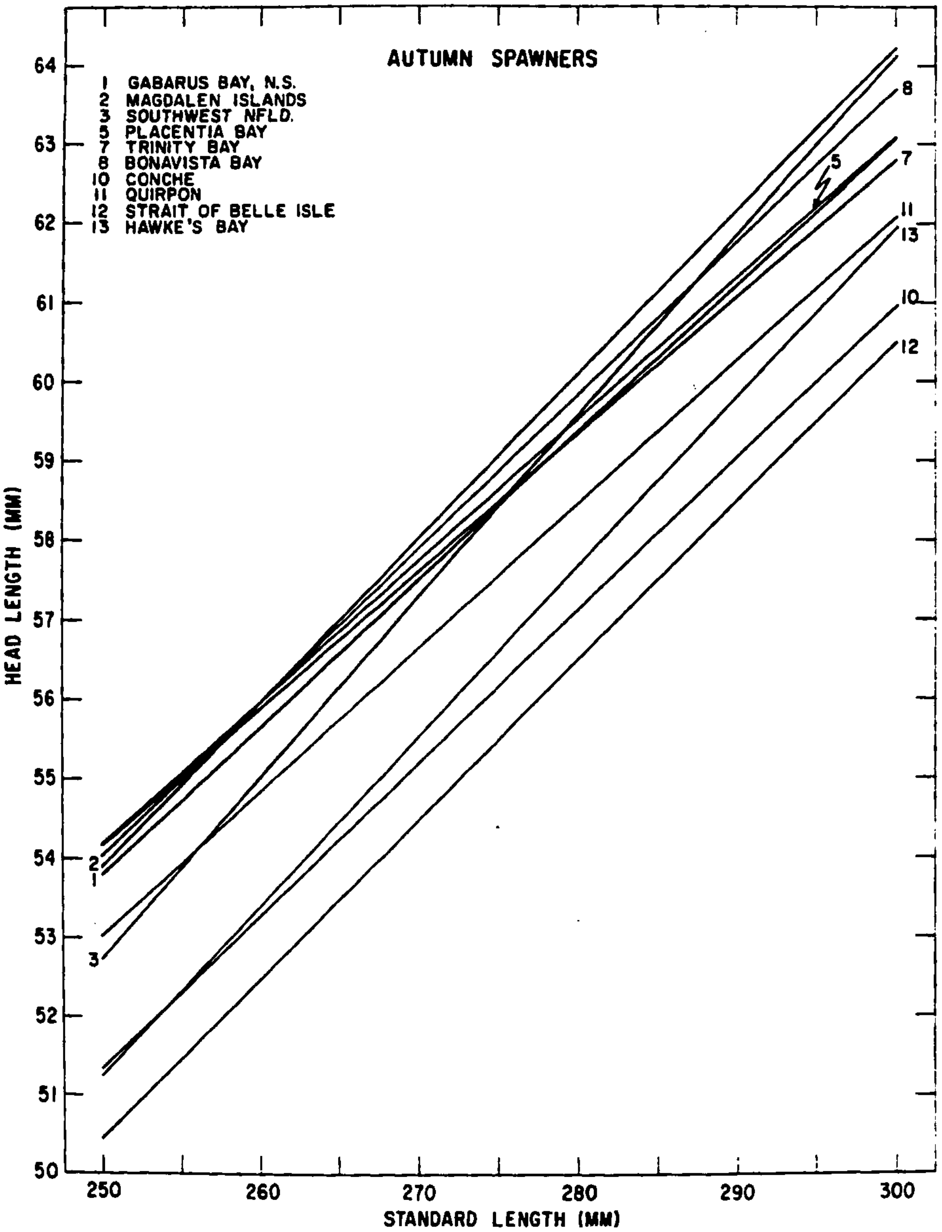

Fig. 13. Relation of head length to standard length for autumn spawners in all areas.

spawners from the other areas overlap considerably. Among autumn spawners Strait of Belle Isle herring have the smallest heads followed in order of increasing size by Conche, Hawke's Bay and Quirpon herring. Autumn spawners from Magdalen Islands, Bonavista Bay, Placentia Bay, Gabarus Bay, southwest Newfoundland and Trinity Bay have relatively larger heads. Regression lines for these latter areas exhibit considerable overlap, but there is a fair amount of spread between the lines for Strait of Belle Isle, Conche, Hawke's Bay and Quirpon.

There were highly significant differences among areas for both spring and autumn spawners in both slopes and adjusted means (Table 37). To test the significance of apparent differences in head length between areas, regression lines for pairs of geographically adjacent areas were compared for spring and autumn spawners separately (Tables 38 and 39).

Spring spawners

Spring spawners from Bonavista Bay were similar in head length to spring spawners from Trinity Bay but significantly different from Notre Dame Bay, Conche, St. Mary's Bay and Fortune Bay spring spawners. Trinity Bay spring spawners differed significantly from Notre Dame Bay, St. Mary's Bay, Placentia Bay and Fortune Bay spring spawners. In all these instances adjusted means account for the significant differences between areas. Notre Dame Bay spring spawners were similar in head length to Quirpon spring spawners but differed significantly in slope from Conche spring spawners and in adjusted means from Hawke's Bay as well as Bonavista Bay and Trinity Bay spring spawners. Although Conche spring spawners were significantly different from Notre Dame Bay, Bonavista Bay and Hawke's Bay spring spawners, they were similar in head length to spring-spawning herring from Quirpon. The latter in turn differed significantly in adjusted means from Hawke's Bay spring spawners which also differed significantly in adjusted means from Magdalen Islands and southwest Newfoundland spring spawners which were similar to each other. Southwest Newfoundland spring spawners were also similar in head length to Fortune Bay herring which in turn were similar to St. Mary's Bay spring spawners. Both Fortune Bay and St. Mary's Bay spring spawners were significantly different in adjusted means from Placentia Bay and Trinity Bay spring spawners.

Autumn spawners

Autumn-spawning herring from Trinity Bay were similar in head length to Placentia Bay autumn spawners but differed significantly in adjusted means from Bonavista Bay and Conche autumn spawners and differed significantly in slope from southwest Newfoundland autumn spawners. Bonavista Bay autumn spawners were similar in head length to Placentia Bay and southwest Newfoundland autumn spawners but differed significantly in adjusted means from Trinity Bay, Conche, Quirpon and Strait of Belle Isle autumn spawners. Conche autumn spawners also differed in adjusted means from Quirpon autumn spawners. Although they had larger heads, they were statistically similar to herring from the Strait of Belle Isle. Quirpon autumn spawners differed in adjusted means not only from Bonavista Bay and Conche but also from Strait of Belle Isle autumn spawners. They also differed in slope from Hawke's Bay autumn spawners. Strait of Belle Isle herring were significantly different in adjusted means from Quirpon, Hawke's Bay, Magdalen Islands, southwest Newfoundland and Gabarus Bay autumn spawners. Hawke's Bay autumn spawners differed significantly in adjusted means from Magdalen Islands, southwest Newfoundland and Gabarus Bay as well as Strait of Belle Isle autumn spawners. Magdalen Islands autumn-spawning herring differed significantly in adjusted means from Gabarus Bay autumn spawners but differed only slightly from southwest Newfoundland autumn spawners (F value of 9.96 is relatively small). Southwest Newfoundland autumn spawners differed significantly in slope from

Gabarus Bay, Placentia Bay and Trinity Bay autumn spawners.

3. Snout length and standard length

(i) Variation between spawning groups and sexes

Snout length-standard length regression lines for spring and autumn spawners in each area where both spawning groups were represented are illustrated in Fig. 14. In six of the eight areas autumn spawners had relatively larger snouts at any particular size than spring spawners. However, Conche spring spawners had relatively larger snouts than autumn spawners. The regression lines for Bonavista Bay spring- and autumn-spawning herring overlap. F values comparing spring and autumn spawners were significant for three of the eight areas (Table 40). Differences in adjusted means were significant between spring and autumn spawners from Magdalen Islands,southwest Newfoundland and Quirpon. In all three instances autumn spawners had relatively larger snouts than spring spawners. Because of these differences spring and autumn spawners were kept separate in subsequent analyses of the snout length-standard length relationship.

Since there was no evidence of sexual dimorphism in snout length (Table 41), the sexes were combined.

(ii) Variation among areas

Snout length-standard length regression lines

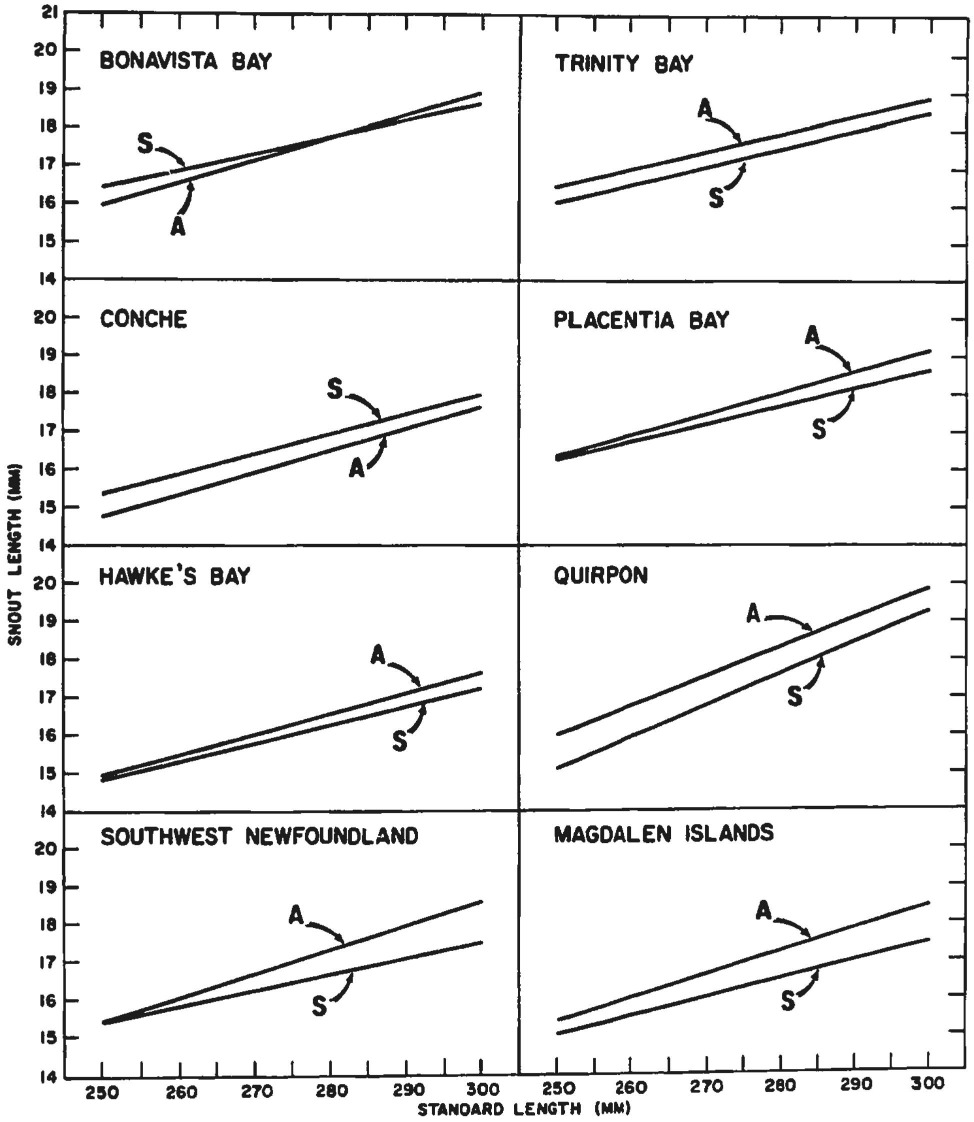

Fig. 14. Relation of snout length to standard length for spring and autumn spawners in each area.

for all areas are shown in Figs. 15 and 16 for spring and autumn spawners respectively. Spring-spawning herring from Bonavista and Placentia bays have the largest snouts and Hawke's Bay spring spawners the smallest followed in order of increasing size by Magdalen Islands and southwest Newfoundland spring spawners. Among autumn spawners herring from Quirpon, Placentia Bay, Trinity Bay and Bonavista Bay have the largest snouts. Conche autumn spawners have the smallest snouts followed in order of increasing size by Hawke's Bay and Strait of Belle Isle autumn spawners. Snout length in relation to standard length is intermediate in autumn-spawning herring from Gabarus Bay, southwest Newfoundland and Magdalen Islands.

Covariance comparisons of snout length-standard length regressions among all areas for spring and autumn spawners separately (Table 42) revealed significant differences in both slopes and adjusted means among spring spawners. Autumn spawners had similar slopes but differed significantly in adjusted means. To test the significance of apparent differences in snout length between areas, regression lines for pairs of geographically adjacent areas were compared for spring and autumn spawners separately (Tables 38 and 39).

Spring spawners

Trinity Bay spring spawners were similar in snout

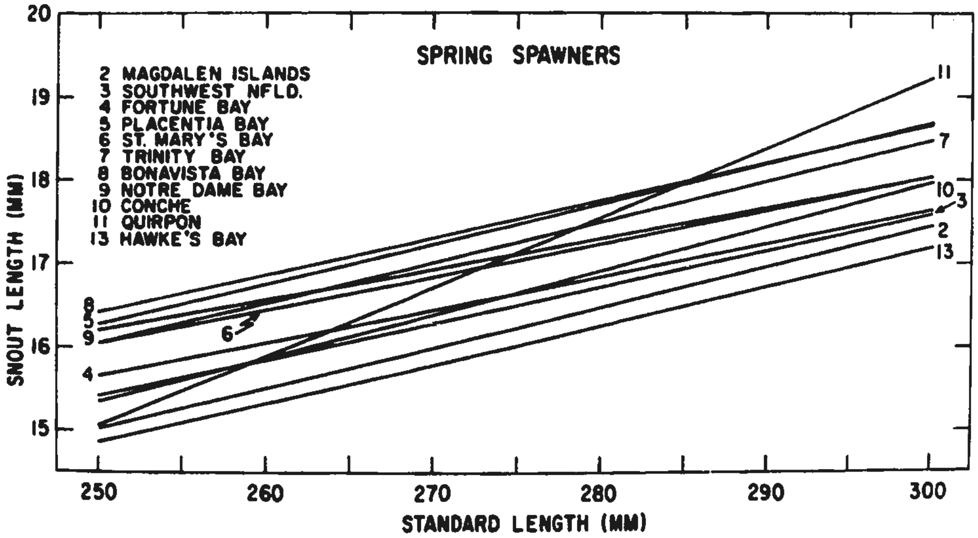

Fig. 15. Relation of snout length to standard length for spring spawners in all areas.

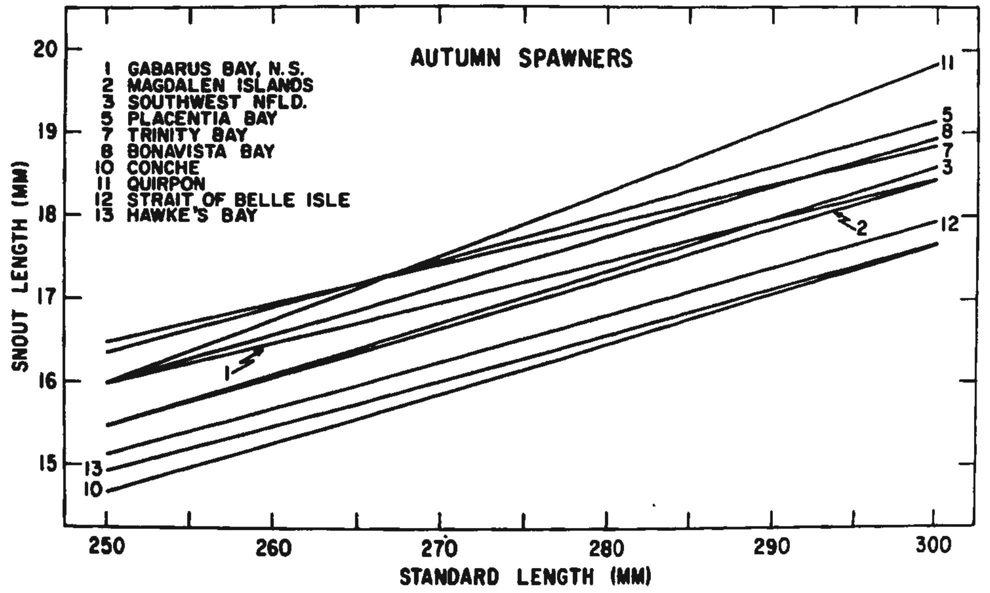

Fig. 16. Relation of snout length to standard length for autumn spawners in all areas.

length to spring-spawning herring from St. Mary's Bay but differed significantly in slope from Notre Dame Bay and in adjusted means from both Hawke's Bay and Bonavista Bay spring spawners. The latter were similar to spring spawners from Placentia Bay but differed significantly in adjusted means from Fortune Bay, St. Mary's Bay, Notre Dame Bay and Conche spring spawners. Spring spawners from Notre Dame Bay and Conche differed significantly in slope. Quirpon spring spawners differed significantly in slope from those in all other areas. Hawke's Bay spring spawners differed significantly in adjusted means from Conche and southwest Newfoundland spring spawners, but were similar to spring-spawning herring from Magdalen Islands, which were intermediate in snout length between spring spawners from Hawke's Bay and southwest Newfoundland and did not differ significantly from either. Southwest Newfoundland spring spawners were also similar in snout length to Fortune Bay herring which differed significantly in adjusted means from Placentia Bay, St. Mary's Bay, Trinity Bay and Bonavista Bay spring spawners. Placentia Bay spring spawners also differed significantly in slope from St. Mary's Bay spring spawners.

Autumn spawners

Autumn-spawning herring from Bonavista Bay were similar in snout length to Trinity Bay and Placentia Bay autumn spawners but differed significantly in adjusted means from Conche, Quirpon, Strait of Belle Isle and southwest Newfoundland autumn spawners. Trinity Bay autumn spawners were also similar in snout length to Placentia Bay and southwest Newfoundland autumn spawners but differed significantly in adjusted means from Conche autumn spawners, which in turn differed significantly in adjusted means from Quirpon autumn spawners but were similar to autumn spawners from the Strait of Belle Isle. Quirpon autumn spawners also differed significantly in adjusted means from autumn-spawning herring in other geographically adjacent areas such as the Strait of Belle Isle and Hawke's Bay. This is evident in Fig. 16 from which it is apparent that Conche, Hawke's Bay and the Strait of Belle Isle have the smallest snouts (in order of increasing size) whereas over most of the adult size range Quirpon autumn spawners tend to have the largest snouts. Covariance comparisons indicated that Strait of Belle Isle autumn spawners were similar in snout length to autumn spawners from both Conche and Hawke's Bay but differed significantly in adjusted means from Magdalen Islands, southwest Newfoundland and Gabarus Bay autumn spawners. Hawke's Bay autumn spawners differed significantly in adjusted means from Magdalen Islands, southwest Newfoundland and Gabarus Bay autumn spawners. Magdalen Islands autumn spawners also differed significantly in adjusted means from Gabarus Bay herring but were similar in snout length to autumn spawners from southwest Newfoundland. The latter were also similar to autumn spawners from Gabarus Bay and Trinity Bay but differed significantly in adjusted means from Placentia Bay autumn spawners.

4. Orbit diameter and standard length

(i) Variation between spawning groups and sexes

In six of the eight areas where both spawning groups were represented autumn spawners had relatively larger orbit diameters than spring spawners (Fig. 17) but F values were significant (in adjusted means) for only three areas (Table 43). Spring spawners at Conche and Quirpon had relatively larger orbit diameters than autumn spawners (Fig. 17) but the differences were not statistically significant. Because of the apparent tendency for autumn spawners to possess relatively larger orbit diameters than spring spawners, spring and autumn spawners were kept separate in subsequent analyses.

Covariance comparisons of the sexes within each spawning group in each area (Table 44) yielded no evidence of sexual dimorphism in orbit diameter.

(ii) Variation among areas

Orbit diameter-standard length regression lines

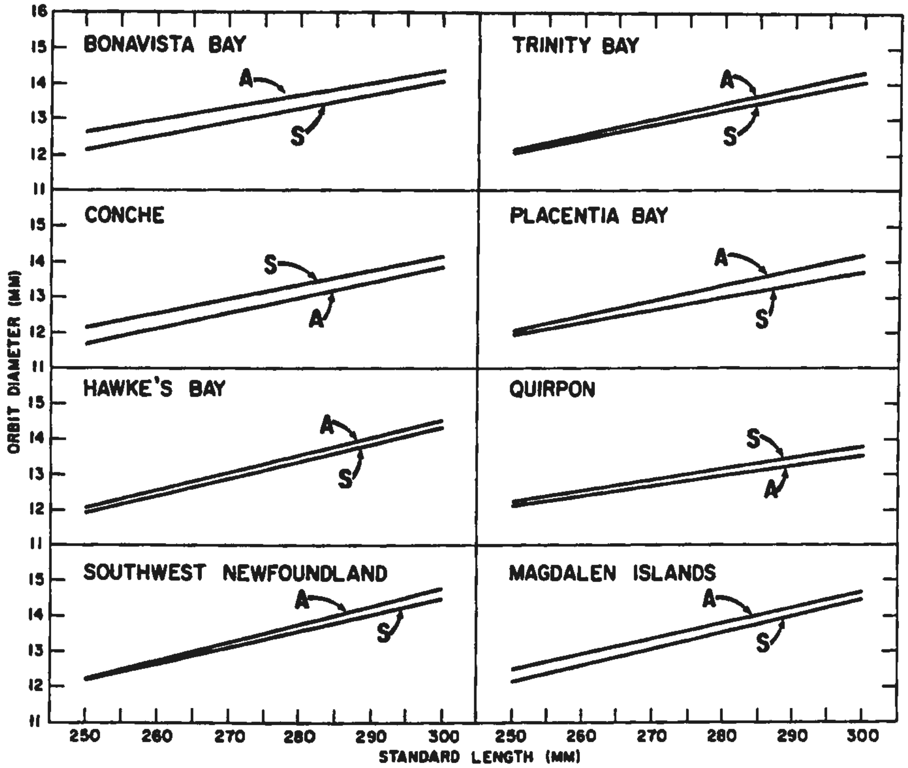

Fig. 17. Relation of orbit diameter to standard length for spring and autumn spawners in each area.

for all areas are shown in Figs. 18 and 19 for spring and autumn spawners respectively. There is considerable overlap of the regression lines for both spring and autumn spawners and no clearcut geographic trends are evident. Notre Dame Bay herring have the largest orbit diameters among spring spawners and Placentia Bay herring the smallest. Spring-spawning herring from southwest Newfoundland and Magdalen Islands appear to have similar relatively large orbit diameters exceeded only by Notre Dame Bay spring spawners. Herring from Quirpon and Conche have the smallest orbit diameters among autumn spawners. Regression lines for several areas including southwest Newfoundland and Magdalen Islands overlap near the top of the scale for autumn spawners.

Both spring and autumn spawners differed significantly in slopes and adjusted means of the orbit diameter-standard length regression lines (Table 45). F values comparing the regression lines for pairs of geographically adjacent areas are presented in Tables 38 and 39 for spring and autumn spawners respectively.

Spring spawners

Trinity Bay spring spawners were similar in orbit diameter to spring-spawning herring from Bonavista, Fortune and Placentia bays but differed significantly in

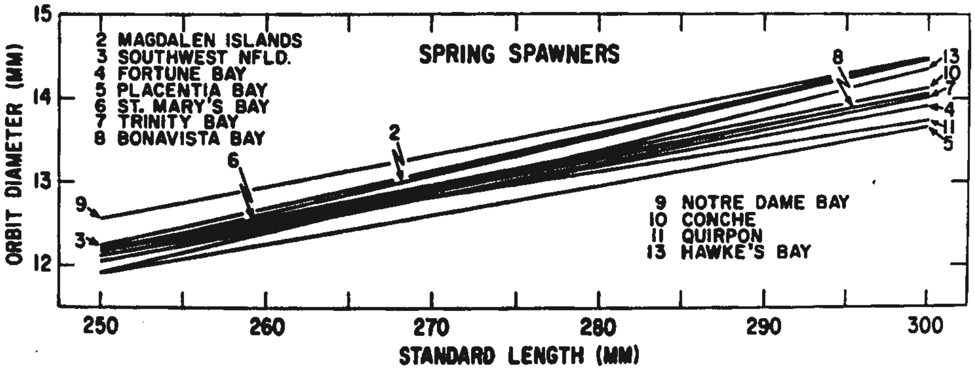

Fig. 18. Relation of orbit diameter to standard length for spring spawners in all areas.

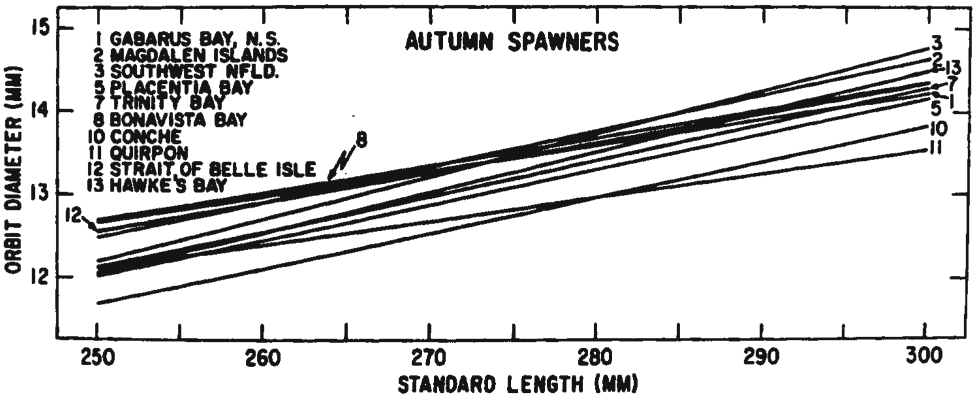

Fig. 19. Relation of orbit diameter to standard length for autumn spawners in all areas.

slope from Notre Dame Bay and in adjusted means from St. Mary's Bay spring spawners. Bonavista Bay spring spawners were also similar in orbit diameter to spring spawners from Fortune Bay, St. Mary's Bay and Conche but differed significantly in adjusted means from Notre Dame Bay spring spawners. The latter in turn differed significantly in adjusted means from Conche and Quirpon spring spawners. Conche spring spawners were similar in orbit diameter to spring spawners from Quirpon and Hawke's Bay but these differed significantly in slope. Hawke's Bay spring spawners were also similar in orbit diameter to spring-spawning herring from Magdalen Islands and southwest Newfoundland which were similar to each other. Southwest Newfoundland spring spawners differed significantly in adjusted means from Fortune Bay spring spawners but these were similar to spring-spawning herring from Placentia, St. Mary's and Trinity bays. Placentia and St. Mary's Bay spring spawners differed significantly in adjusted means.

Autumn spawners

Autumn-spawning herring from Trinity Bay were similar in orbit diameter to Bonavista Bay and Placentia Bay autumn spawners but differed significantly in adjusted means from Conche and southwest Newfoundland autumn spawners. Bonavista Bay autumn spawners were also similar in orbit diameter to autumn spawners from the Strait of Belle Isle but differed significantly in adjusted means from Conche, Quirpon, Placentia Bay and southwest Newfoundland autumn spawners. Conche autumn spawners also differed significantly in adjusted means from Strait of Belle Isle autumn spawners but were similar in orbit diameter to Quirpon autumn spawners. The latter in turn differed significantly in adjusted means from Strait of Belle Isle autumn spawners and in slope from Hawke's Bay autumn spawners. Strait of Belle Isle autumn spawners were similar in orbit diameter to autumn-spawning herring from Hawke's Bay and Gabarus Bay but differed significantly in adjusted means from Magdalen Islands and in slope from southwest Newfoundland autumn spawners. Autumn-spawning herring from Hawke's Bay differed significantly in adjusted means from both Magdalen Islands and southwest Newfoundland autumn spawners which were similar in orbit diameter. Gabarus Bay autumn spawners differed significantly in slope from Hawke's Bay, southwest Newfoundland and Magdalen Islands autumn spawners. Southwest Newfoundland autumn spawners also differed significantly in adjusted means from Placentia Bay autumn spawners.

5. Postorbital length and standard length

(i) Variation between spawning groups and sexes

In five of the eight areas where both spawning groups were represented autumn spawners had relatively larger postorbital lengths than spring spawners (Fig. 20). F values were significant in four of the five instances (Table 46). Adjusted means accounted for the differences between spawning groups at Magdalen Islands, along southwest Newfoundland and in Bonavista Bay. Hawke's Bay spring and autumn spawners differed significantly in slope. Conche spring spawners had relatively larger postorbital lengths than autumn spawners, but the difference was not statistically significant. The regression lines for spring and autumn spawners at Quirpon and in Placentia Bay overlap. Since there was an apparent tendency for autumn spawners to possess relatively larger postorbital lengths than spring spawners, the two spawning groups were treated separately in subsequent analyses of the postorbital length-standard length relationship.

Postorbital length-standard length regression lines for the sexes within each spawning group in each area were then compared by covariance analysis (Table 47). Hawke's Bay male and female spring spawners differed in adjusted means. Since a difference between the sexes was evident in only 1 of 21 possible instances, it was concluded that sexual dimorphism in postorbital length is negligible and the sexes were combined.

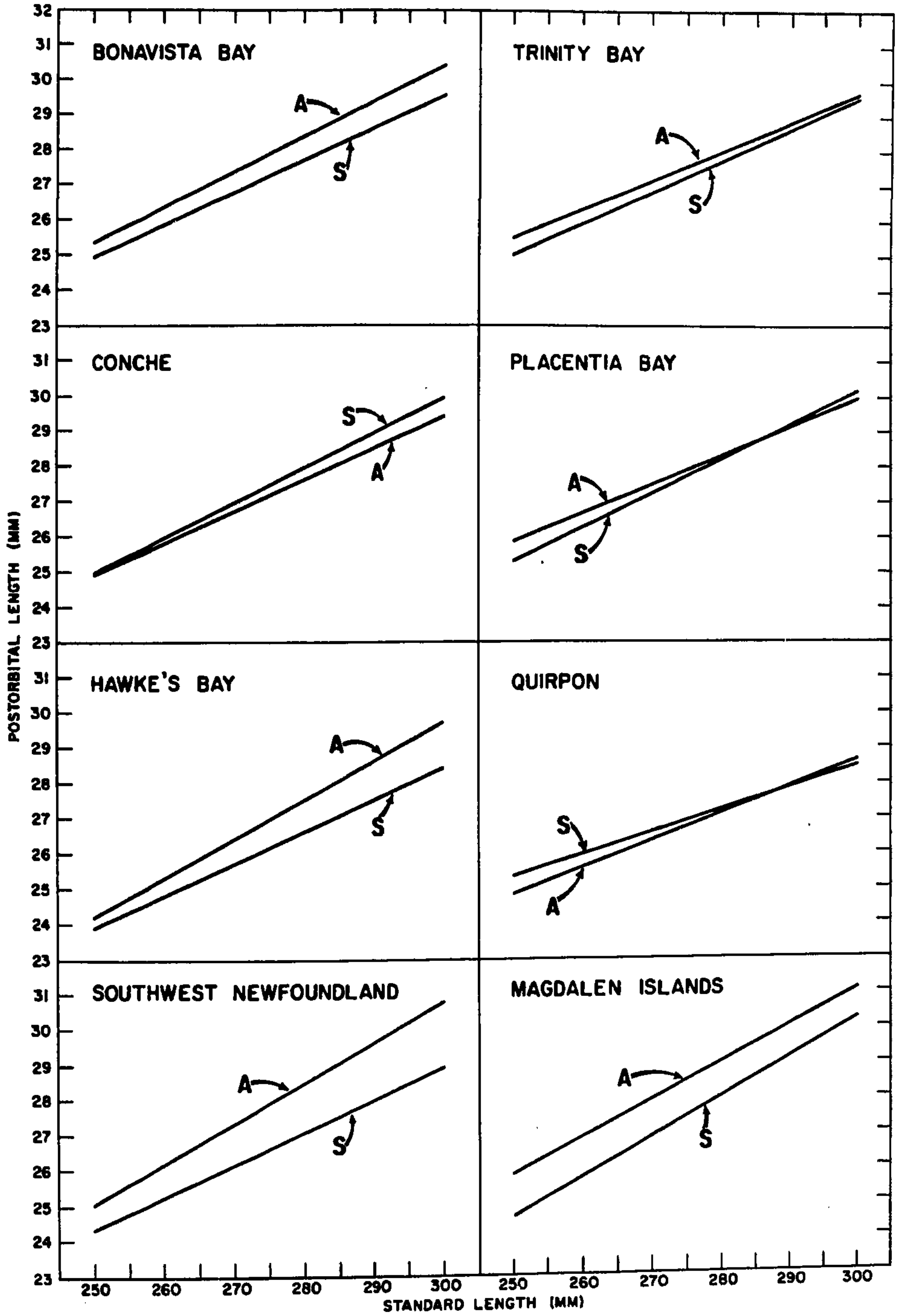

Fig. 20. Relation of postorbital length to standard length for spring and autumn spawners in each area.

(ii) Variation among areas

Postorbital length-standard length regression lines for all areas are illustrated in Figs. 21 and 22 for spring and autumn spawners respectively. No geographic trend in postorbital length is evident among spring spawners. Throughout most of the adult size range Placentia Bay spring spawners have the largest postorbital lengths and Hawke's Bay spring spawners the smallest. St. Mary's Bay, Notre Dame Bay and southwest Newfoundland spring spawners have relatively small postorbital lengths. Regression lines for spring spawners from other areas overlap considerably. Among autumn spawners there appears to be a tendency for herring from the more northerly areas to possess relatively small postorbital lengths. Strait of Belle Isle autumn spawners have the smallest postorbital lengths followed in order of increasing size by autumn spawners from Quirpon, Conche and Hawke's Bay, which exhibit considerable overlap. Magdalen Islands autumn spawners have the largest postorbital lengths and autumn-spawning herring from southwest Newfoundland also possess relatively large postorbital lengths. Autumn spawners from Gabarus Bay, the most southerly area, possess intermediate postorbital lengths.

Both spring and autumn spawners differed significantly in slopes and adjusted means of the postorbital

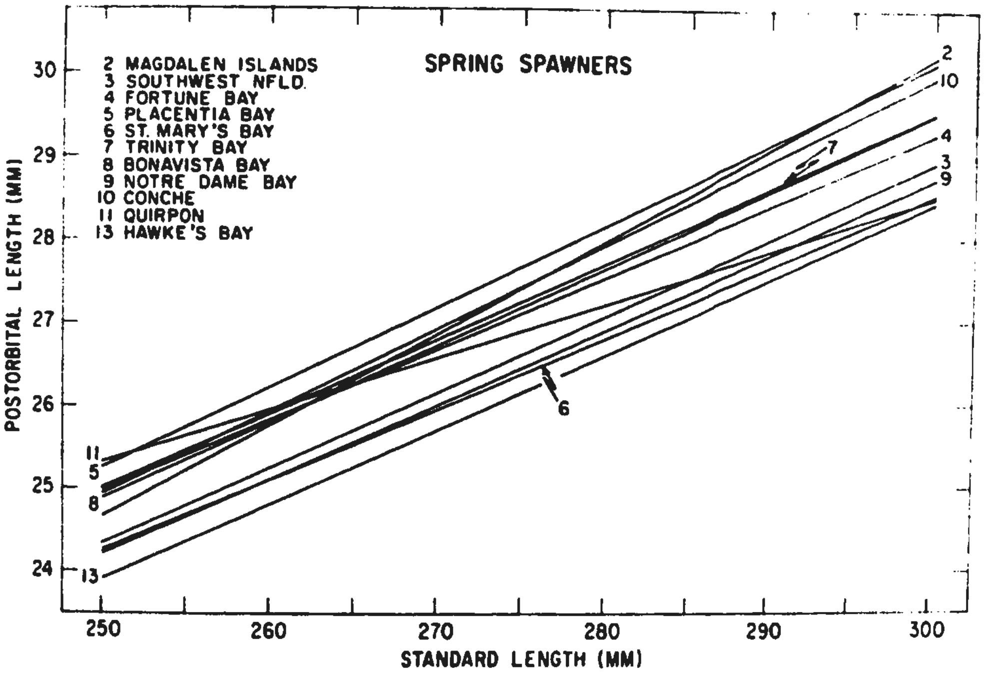

Fig. 21. Relation of postorbital length to standard length for spring spawners in all areas.

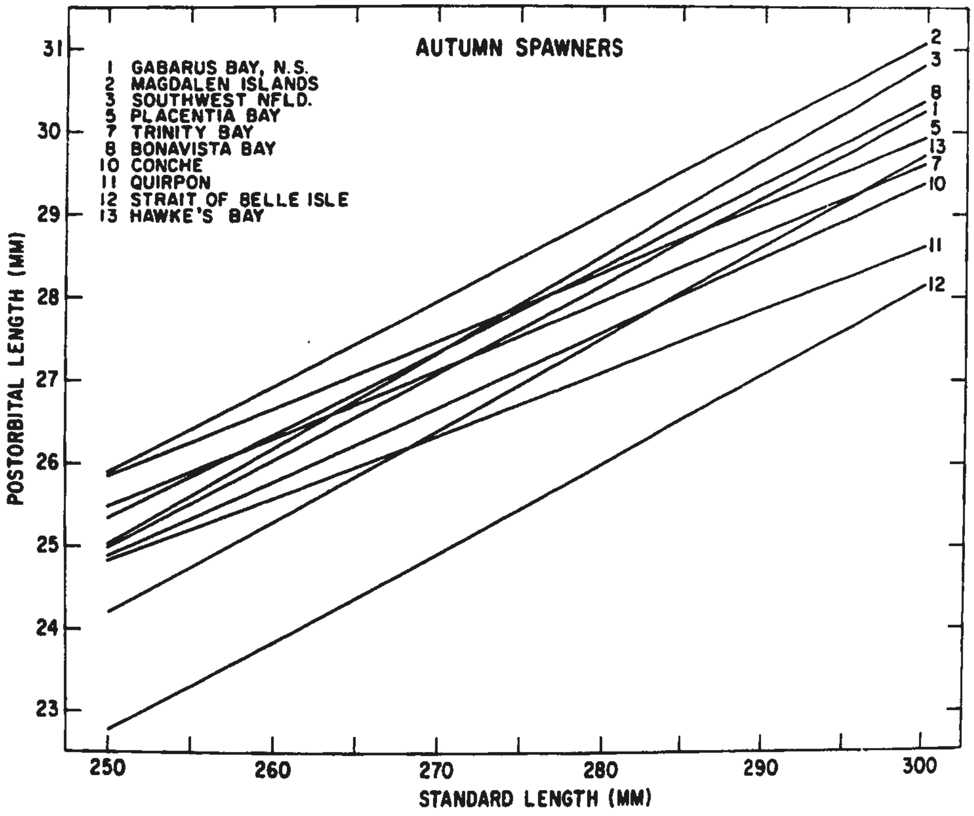

Fig. 22. Relation of postorbital length to standard length for autumn spawners in all areas.

length-standard length regression lines (Table 48). F values comparing the regression lines for pairs of geographically adjacent areas are given in Tables 38 and 39 for spring and autumn spawners respectively.

Spring spawners

Spring-spawning herring from Trinity Bay were similar in postorbital length to Bonavista Bay and Fortune Bay spring spawners but differed significantly in adjusted means from Notre Dame Bay, Placentia Bay and St. Mary's Bay spring spawners. Bonavista Bay spring spawners were also similar in postorbital length to spring spawners from Conche and Fortune Bay but differed significantly in adjusted means from Notre Dame Bay and St. Mary's Bay spring spawners. Notre Dame Bay spring spawners also differed significantly in adjusted means from Conche and in slope from Quirpon spring spawners. Conche spring spawners in turn differed significantly in adjusted means from Hawke's Bay spring spawners. Spring spawners from Quirpon differed significantly in slope from both Conche and Hawke's Bay spring spawners. Indeed, it is evident from Fig. 21 that Quirpon spring spawners differed in slope from spring spawners in all other areas. Hawke's Bay, Magdalen Islands and southwest Newfoundland spring spawners differed significantly in adjusted means from each other. Spring spawners from southwest Newfoundland also differed significantly in adjusted means from Fortune Bay spring spawners. Fortune Bay, Placentia Bay and St. Mary's Bay spring spawners differed significantly in adjusted means from each other.

Autumn spawners

Autumn-spawning herring from Trinity Bay were similar in postorbital length to Placentia Bay and Conche autumn spawners but differed significantly in adjusted means from Bonavista Bay and in slope from southwest Newfoundland autumn spawners. Bonavista Bay autumn spawners were similar in postorbital length to Placentia Bay and southwest Newfoundland autumn spawners but differed significantly in adjusted means from Conche, Quirpon and Strait of Belle Isle as well as Trinity Bay autumn spawners. Conche autumn spawners differed significantly in slope from Strait of Belle Isle autumn spawners and in adjusted means from Quirpon autumn spawners which in turn differed significantly in slope from both Strait of Belle Isle and Hawke's Bay autumn spawners. Autumn-spawning herring from the Strait of Belle Isle also differed significantly in adjusted means from Hawke's Bay, Magdalen Islands, southwest Newfoundland and Gabarus Bay autumn spawners. Similarly, Hawke's Bay autumn spawners differed significantly in adjusted means from Magdalen Islands, southwest Newfoundland and Gabarus Bay autumn spawners. Magdalen Islands and Gabarus Bay autumn spawners differed significantly in adjusted means. Southwest Newfoundland autumn spawners were similar in postorbital length to autumn spawners from Gabarus Bay but differed significantly in adjusted means from Magdalen Islands and in slope from Placentia Bay autumn spawners.

6. Predorsal length and standard length

(i) Variation between spawning groups and sexes

In four of the eight areas where both spawning groups were represented autumn spawners had relatively larger predorsal lengths than spring spawners throughout the adult size range (Fig. 23 and 24). Spring spawners from Hawke's Bay appeared to have slightly larger predorsal lengths than autumn spawners. The regression lines for spring and autumn spawners in the other three areas (Quirpon, Conche and Trinity Bay) overlap. In these instances the predorsal lengths of spring spawners were relatively larger than those of autumn spawners in smaller fish and relatively smaller in larger fish. Although F values were significant for only 2 of the 8 areas (Table 49), spring and autumn spawners were kept separate in subsequent analyses.

Predorsal length-standard length regression lines for the sexes within each spawning group in each area were compared by covariance analysis (Table 50). Difference between the sexes was evident in only 1 of 21 possible

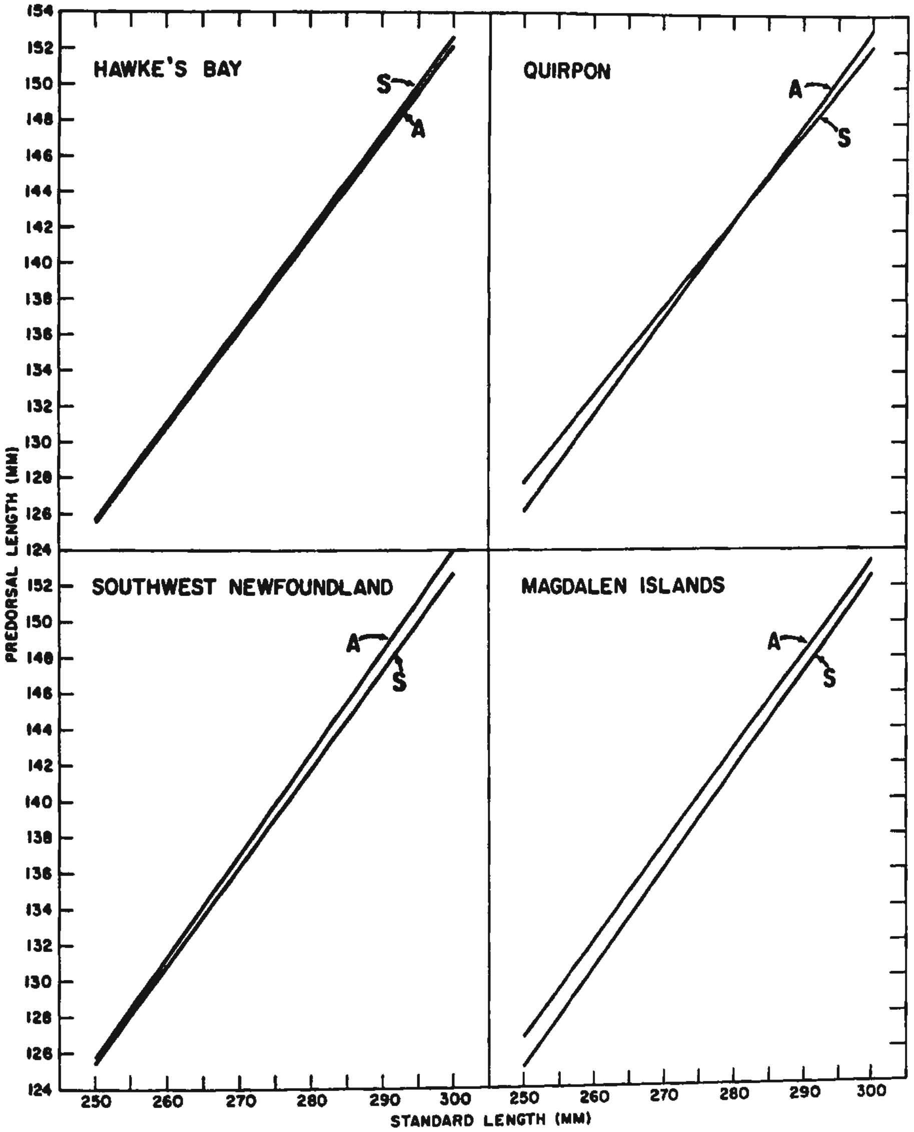

Fig. 23. Relation of predorsal length to standard length for spring and autumn spawners from Hawke's Bay, Quirpon, southwest Newfoundland and Magdalen Islands.

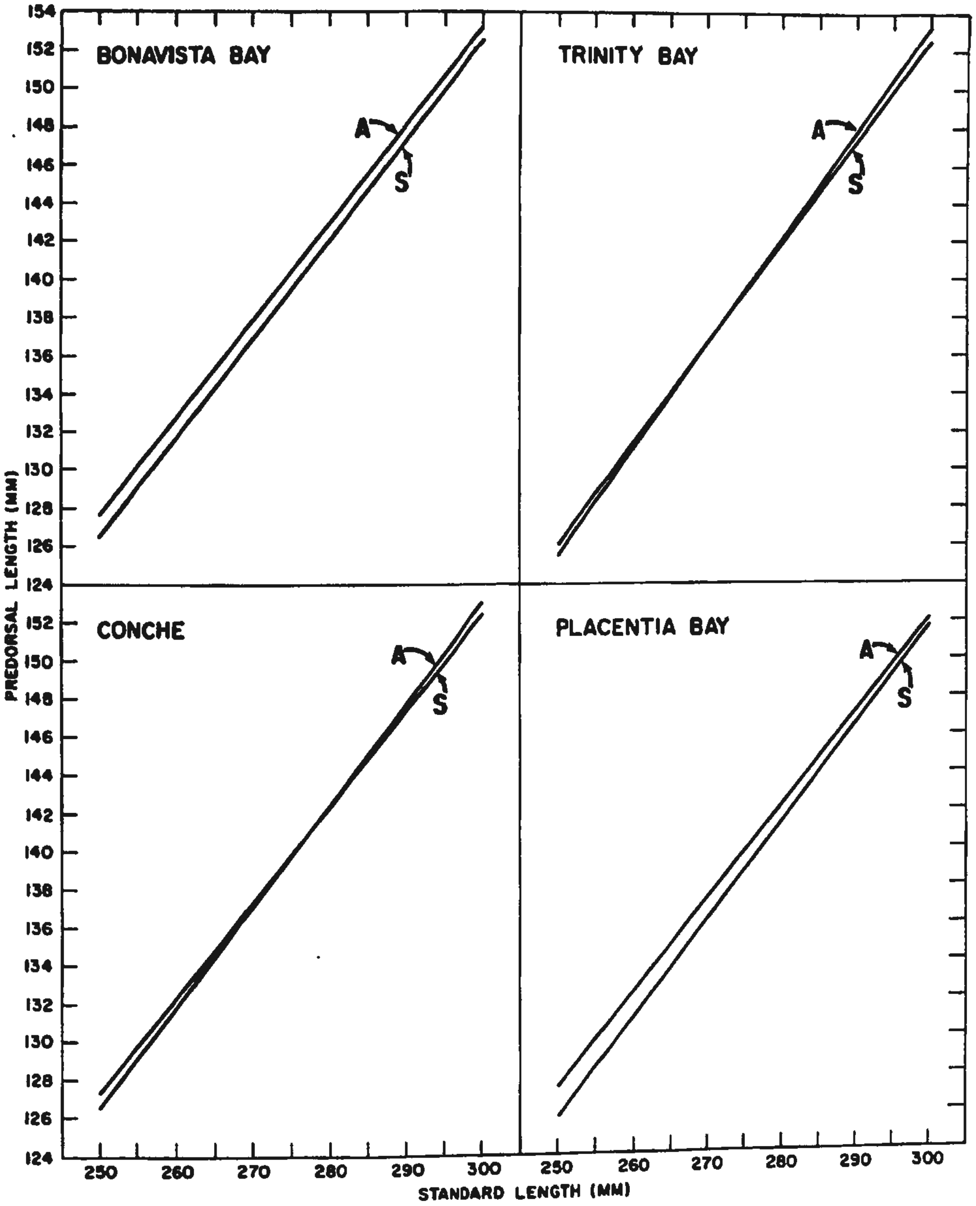

Fig. 24. Relation of predorsal length to standard length for spring and autumn spawners from Bonavista Bay, Trinity Bay, Conche and Placentia Bay.

instances; Quirpon male and female spring spawners differed in slope. Sexual dimorphism was considered negligible and the sexes were combined for area comparisons.

(ii) Variation among areas

Predorsal length-standard length regression lines for all areas are shown in Figs. 25 and 26 for spring and autumn spawners respectively. No geographic trend in predorsal length is evident among either spawning group. Notre Dame Bay and Conche herring have the largest predorsal lengths among spring spawners and Fortune Bay herring the smallest over most of the adult size range. Placentia Bay and southwest Newfoundland spring spawners also have relatively small predorsal lengths. Gabarus Bay herring have the largest predorsal lengths among autumn spawners and Hawke's Bay herring the smallest. Autumn spawners from the Strait of Belle Isle have relatively large predorsal lengths exceeded only by those from Gabarus Bay.

Covariance comparisons of predorsal length-standard length regressions among all areas for spring and autumn spawners separately (Table 51) revealed significant differences in slopes and adjusted means among both spring and autumn spawners. Differences in slope were barely significant at the 1% level ($F_{10,2250} = 2.50$ for $F_{.01} = 2.32$ and $F_{9,1693} = 2.42$ for $F_{.01} = 2.41$). To test the sig-

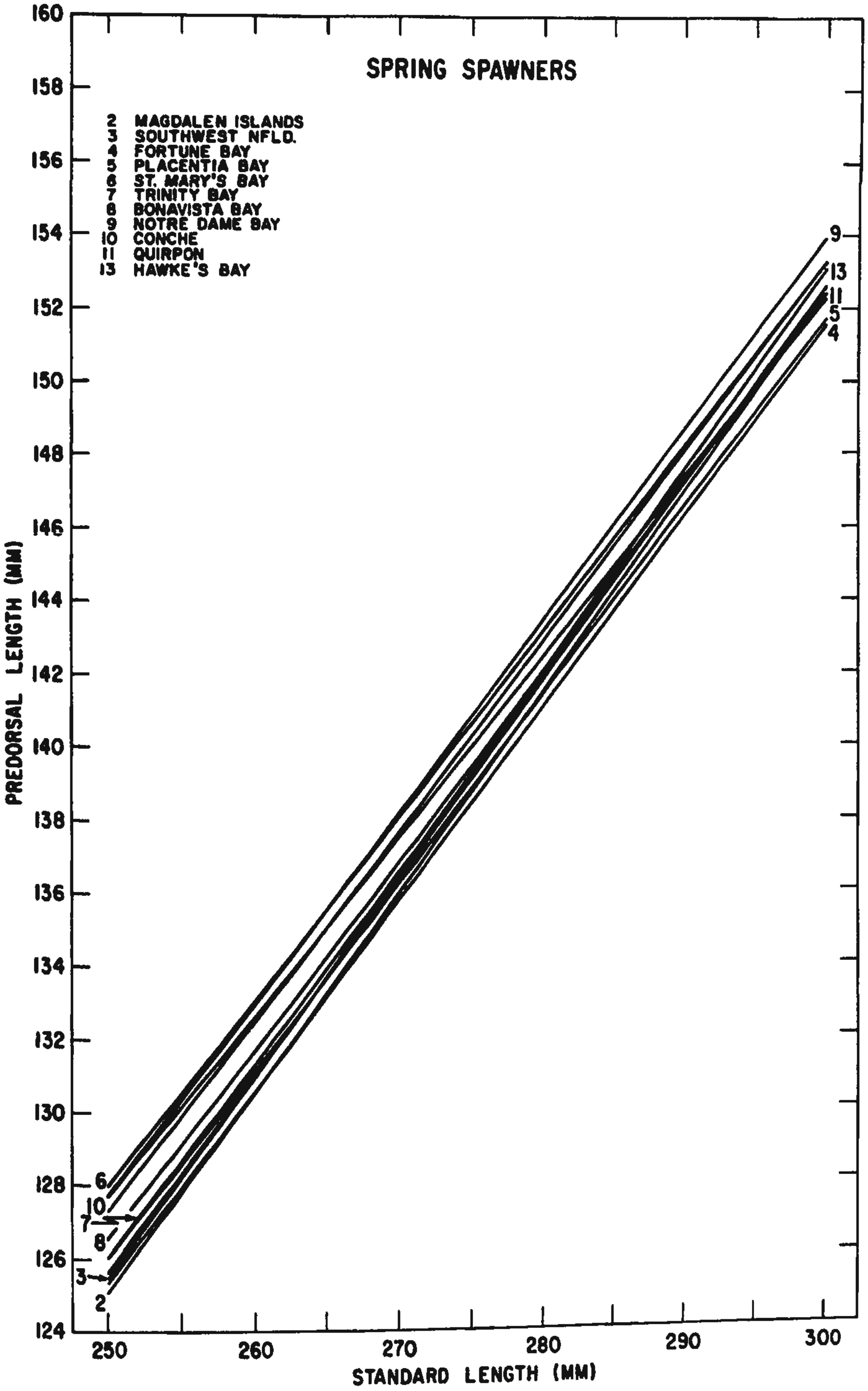

Fig. 25. Relation of predorsal length to standard length for spring spawners in all areas.

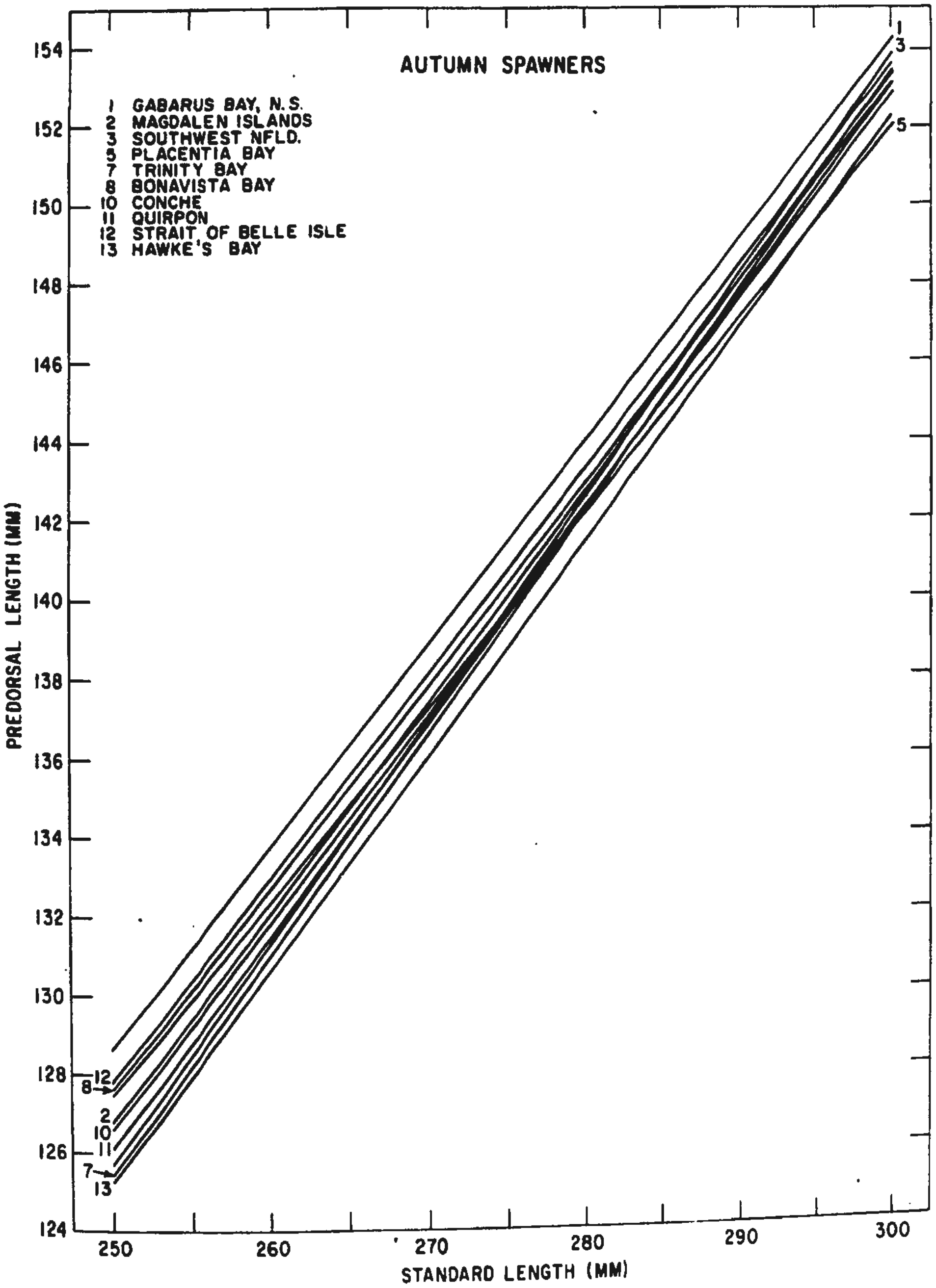

Fig. 26. Relation of predorsal length to standard length for autumn spawners in all areas.

nificance of apparent differences in predorsal length between areas, regression lines for pairs of geographically adjacent areas were compared for spring and autumn spawners separately (Tables 38 and 39).

Spring spawners

Spring-spawning herring from Trinity Bay were similar in predorsal length to Bonavista Bay and Placentia Bay spring spawners but differed significantly in adjusted means from those in Notre Dame Bay and Fortune Bay and in slope from those in St. Mary's Bay. Bonavista Bay spring spawners differed significantly in adjusted means from Notre Dame Bay, Conche, Fortune Bay and St. Mary's Bay spring spawners. Spring spawners from Notre Dame Bay were similar in predorsal length to those from Conche but differed significantly in adjusted means from those at Quirpon. Conche spring spawners were also similar in predorsal length to those from Quirpon and Hawke's Bay which in turn were similar to each other. Hawke's Bay spring spawners differed significantly in adjusted means from Madgalen Islands but were similar in predorsal length to those from southwest Newfoundland which in turn were similar to those from both Magdalen Islands and Fortune Bay. The latter differed significantly in adjusted means from Placentia Bay and in slope from St. Mary's Bay spring spawners. Placentia Bay spring spawners also differed significantly in adjusted means from St. Mary's Bay spring spawners.

Autumn spawners

Autumn-spawning herring from Trinity Bay were similar in predorsal length to those from Bonavista Bay, Conche and southwest Newfoundland but differed significantly in adjusted means from those in Placentia Bay. Bonavista Bay autumn spawners were also similar in predorsal length to those from Conche, Quirpon and Strait of Belle Isle but differed significantly in adjusted means from those in Placentia Bay and in slope from those along southwest Newfoundland. Conche autumn spawners in turn were similar in predorsal length to those from Quirpon and the Strait of Belle Isle, which were similar to each other. Quirpon autumn spawners were also similar in predorsal length to those in Hawke's Bay. Strait of Belle Isle autumn spawners were similar in predorsal length to those from Magdalen Islands and Gabarus Bay but differed significantly in adjusted means from those in Hawke's Bay and in slope from those which overwinter along southwest Newfoundland. Autumn spawners from Hawke's Bay also differed significantly in adjusted means from

Magdalen Islands, southwest Newfoundland and Gabarus Bay autumn spawners. Magdalen Islands and southwest Newfoundland autumn spawners were similar in predorsal length. Gabarus Bay autumn spawners differed significantly in adjusted means from those at Magdalen Islands and in slope from those along southwest Newfoundland. The latter differed significantly in slope from Placentia Bay autumn spawners.

7. Summary of area comparisons - all morphometric characters

Spring spawners

Spring spawners from Trinity Bay differed only in snout length from those in Bonavista Bay but differed significantly in orbit diameter, head, postorbital and predorsal length from those in St. Mary's Bay, in head, snout and postorbital length from those in Placentia Bay and in head, snout and predorsal length from those in Fortune Bay. Bonavista Bay spring spawners differed significantly in head, snout and predorsal length from those in Fortune Bay and at Conche and in head, snout, postorbital and predorsal length from those in St. Mary's Bay. Spring spawners from Notre Dame Bay differed in all five characters from those in Bonavista Bay and Trinity Bay; they also differed in orbit diameter, head, snout and postorbital length from Conche spring spawners and in orbit diameter, snout, postorbital and predorsal length from those at Quirpon. Conche and Quirpon spring spawners differed only in snout and postorbital length but those at Conche differed in head, snout and postorbital length from Hawke's Bay spring spawners while those at Quirpon and in Hawke's Bay differed in orbit diameter, head, snout and postorbital length. Spring spawners from Hawke's Bay also differed in head, postorbital and predorsal length from those at Magdalen Islands and in head, snout and postorbital length from those along southwest Newfoundland. The latter differed only in postorbital length from Magdalen Islands and in orbit diameter and postorbital length from Fortune Bay spring spawners. Those from Fortune Bay in turn differed in head, snout, postorbital and predorsal length from Placentia Bay spring spawners and in snout, postorbital and predorsal length from those in St. Mary's Bay. Placentia Bay and St. Mary's Bay spring spawners differed in all five characters.

Autumn spawners

Autumn-spawning herring from Trinity Bay differed only in predorsal length from Placentia Bay and in head and postorbital length from Bonavista Bay autumn spawners. They also differed in orbit diameter, head and snout length from Conche and in orbit diameter, head and postorbital length from those along southwest Newfoundland. Bonavista Bay autumn spawners differed only in orbit diameter and predorsal length from those in Placentia Bay but differed in orbit diameter, head, snout and postorbital length from those at Conche and Quirpon. They also differed in head, snout and postorbital length from Strait of Belle Isle autumn spawners and in orbit diameter, snout and predorsal length from those along southwest Newfoundland. Conche autumn spawners differed from those in the Strait of Belle Isle only in orbit diameter and postorbital length but differed from those at Quirpon in head, snout and postorbital length. Those from Quirpon differed from both Strait of Belle Isle and Hawke's Bay autumn spawners in orbit diameter, head, snout and postorbital length. Strait of Belle Isle autumn spawners differed in head, postorbital and predorsal length from those in Hawke's Bay, in diameter, head, snout and postorbital length from those at Magdalen Islands, in head, snout and postorbital length from those in Gabarus Bay and in all five characters from those along southwest Newfoundland. Hawke's Bay autumn spawners differed from those at Magdalen Islands, along southwest Newfoundland and in Gabarus Bay in all five characters. Magdalen Islands autumn spawners differed only in head and postorbital length from those along southwest Newfoundland but differed in orbit diameter, head, postorbital and predorsal length from those in Gabarus Bay. The latter differed in orbit diameter, head, and predorsal length from southwest Newfoundland autumn spawners which in turn differed in orbit diameter, head and postorbital length from those in Trinity Bay and in all five characters from those in Placentia Bay.

V. 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. 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. Bottom temperatures on the spawning grounds in St. Mary's Bay, Newfoundland, during spawning in late May generally range from 4 to 10°C (G.H. Winters, personal communication).

The present study provides evidence that spring- and autumn-spawning herring from the same area differ in several morphological characteristics. Although there is no statistically 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. In most areas autumn spawners also have relatively larger heads and snouts and relatively larger orbit diameters and postorbital and predorsal lengths in relation to standard length than spring spawners.

Meristic characters exhibit plasticity under the influence of environmental factors, especially temperature, during the incubation period and early larval life. Although the relative importance of genetic and phenotypic factors in the determination of gill-raker number is not known, fin-ray fixation apparently occurs during the larval stage. Tåning (1944) reported that the period of fixation for the anal fin in brown trout, Salmo trutta trutta, begins in the egg stage but continues after hatching. Subsequently the dorsal and then the pectoral fins are formed. Bigelow and Schroeder (1953) gave 15-17 mm and Blaxter (1962) gave 13-14 mm as the lengths at which the dorsal fin is formed in Atlantic herring. The anal fin is first evident at about 16 mm (Blaxter, 1962) and completed at about 30 mm (Lebour, 1921, Bigelow and Schroeder, 1953).

Although herring eggs develop at lower temperatures in the spring (May-June) than in the autumn (August-September), spring-hatched larvae develop under more favourable environmental conditions during their first months than autumn-hatched larvae. Fig. 27 shows the mean monthly sea surface temperatures in the southern Gulf of St. Lawrence for the period from 1963 to 1967 (Anon., 1963-67). It is evident that spring-hatched larvae develop under conditions of increasing water temperatures while autumn-hatched larvae develop during a period when water temperatures are declining. Thus temperatures at the time of fin-ray fixation are probably

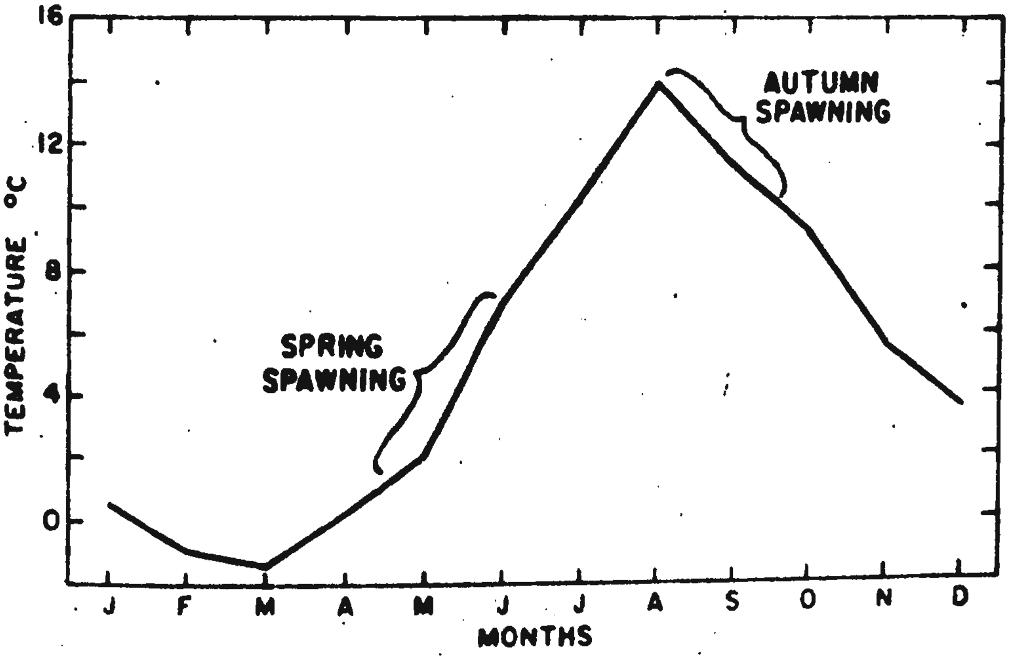

Fig. 27. Mean monthly sea surface temperatures in the southern Gulf of St. Lawrence, 1963-67.

higher for spring-hatched larvae than for autumn-hatched larvae. Hubbs (1926) hypothesized that the number of meristic elements in fish is determined by developmental rate. Longer developmental periods, which may be induced by low temperatures or other agents which retard development, usually result in higher meristic counts and vice versa. Jean (1956) has shown that autumn-hatched herring larvae grow at a slower rate and have a longer developmental period than spring-hatched larvae. Hence, autumn-hatched larvae would be expected to have higher mean fin-ray numbers than spring-hatched larvae.

Jean (1956) reported that spring- and autumn-spawning herring at Grande-Riviere, Quebec, were identical with respect to vertebral number and head length. From these similarities and the overlap of ratios of the first and second growth zones on the scales, he concluded that each spawning population was a mixture of fish hatched in the spring and fish hatched in the autumn. Despite the similarity of mean vertebral numbers of spring and autumn spawners in the present study, there were distinct differences in the mean numbers of pectoral and anal fin rays and gill rakers. If the spring- and autumn-spawning populations were both made up of fish hatched in the spring and fish hatched in the autumn, these morphological characters should be very similar, especially if spring- and autumn-hatched fish were present in about the same proportions among spring spawners and among autumn spawners. The observed differences in fin-ray numbers between spring and autumn spawners correlate with differences in developmental rates of spring- and autumn-hatched larvae. This correlation between the higher mean fin-ray numbers of autumn spawners and the longer developmental period of autumn-hatched larvae, on the one hand, and the lower mean fin-ray numbers of spring spawners and the shorter developmental period of spring-hatched larvae, on the other, indicates that spring- and autumn-spawning herring, which intermix during the overwintering and feeding periods but segregate at spawning time, are not members of a homogeneous group but constitute distinct breeding populations which developed at different times of the year under different environmental conditions. From 79 to 91 percent 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 - pectoral and anal fin rays and gill rakers. This clearly demonstrates 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. The amount of interchange between the two spawning groups is probably slight.

Martin (1949) demonstrated that early development is important in the determination of the relative size of the body parts of fish and that temperature and diet during the early growth period result in differences in body form. Since data on the influence of these environmental factors on body form in herring are lacking, it is not possible to relate these factors to the morphometric differences between spring- and autumn-spawning herring. However, it is possible that these differences are due to differences in the size at which these herring attain sexual maturity and spawn for the first time. If spring spawners mature earlier than autumn spawners, as is suggested by available data, differences in the size at growth inflection would account for the tendency for adult autumn spawners to possess relatively larger body parts than adult spring spawners.

Although both meristic and morphometric differences between the two spawning groups appear to be controlled mainly by the environment during early development, Blaxter (1958) has presented evidence which suggests that the difference in spawning season is genetical and is based on different responses to the environment. In an earlier paper Blaxter (1956) reported that under experimental conditions spring-spawned eggs were markedly inviable at autumn-spawning temperatures. He concluded that in typical spring- and autumn-spawning herring groups reproductive isolation exists, although a slight amount of interchange occurs, and suggested that spring and autumn spawners may be referred to as different sibling species using the main criterion of difference in breeding season.

In view of the highly significant meristic and morphometric differences between spawning groups within areas, it is necessary to consider spring and autumn spawners separately for between-area comparisons of all meristic and morphometric 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 sufficient to delineate the interrelationships of several stocks. In the present study it was found that, despite similarities in mean vertebral numbers, spring- and autumn-spawning herring differ significantly in mean numbers of pectoral and anal fin rays and gill rakers. This finding 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 varying degrees for determining the interrelationships of herring stocks in the Newfoundland area. Gill-raker and anal fin-ray averages 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, from all four characters 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 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. However, Notre Dame Bay spring spawners differ significantly in the 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 are similar in all meristic characteristics examined.

Fewer meristic differences are evident among autumn spawners than among spring spawners. Comparisons of mean vertebral numbers indicate that autumn spawners from Gabarus Bay, 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 intermingle 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, 1937, 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 statistically 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 averages. 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 these 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. Reports from Fishery Officers of the Canadian Department of Fisheries and Forestry over the past several years indicate that 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 meters to 2.5°C at the surface (V.M. Hodder, personal communication). 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 temperatures 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 study shows geographic trends in the mean numbers of gill raker and anal fin rays, which appear to be correlated with water temperature during early development. We have seen previously that the period of fixation of gill-raker number in Atlantic herring is unknown 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 area under consideration. 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; Dunbar, 1951; Bailey and Hachey, 1951; 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.

Herring from Newfoundland and adjacent waters exhibit considerable heterogeneity in morphometric as well as meristic characteristics. Between-area differences are evident for all morphometric characters and all pairs of areas compared for at least one character. Some areas differ in all morphometric characteristics but for other paired area comparisons the results are much more complex. Mayr, Linsley and Usinger (1953), Royce (1953,1957,1964) and Ahlstrom (1957) have shown that statistically significant morphometric differences can be found commonly even between the most closely related natural populations. Such statistical differences have been found so consistently that Royce (1953) concluded that, even with samples from closely related stocks, highly significant statistical differences could always be found by increasing the size of the sample or by considering enough characters. Groups considered to be distinct on the basis of morphometric studies have been found to exhibit considerable intermixture when tagging experiments were performed. Although the highly significant morphometric differences between herring stocks in Newfoundland and adjacent waters help to establish that herring from the various areas do not belong to a single completely mixed population, it is more difficult to determine from these differences which stocks are distinct and which intermingle freely. The author has not yet attempted to apply cluster analysis using the technique of principal components to these morphometric data but further analyses along these lines may shed additional light on the degree of intermixture between stocks.

For the present it is assumed that the number of morphometric characters in which two groups differ is probably a crude measure of the degree of intermingling between the two areas. However, since it has been shown for other species that significant differences in morphometric characteristics can be found even between closely related populations, differences in only one or two of the five characters are probably insufficient to establish that the samples were drawn from different population. Autumn-spawning herring from the Magdalen Islands and southwest Newfoundland differ in two morphometric characters - head and postorbital length - and spring spawners from these areas also differ in postorbital length. Despite these morphometric differences tagging results have shown that herring which overwinter along southwest Newfoundland represent the overwintering phase of a stock complex with spawns and feeds in the southern Gulf of St. Lawrence (Hodder and Winters, MS, 1970; Winters, 1970; MS, 1971; Beckett, MS, 1971). Nonetheless, the differences in head length and postorbital length must be considered as "significant" as any other, on the basis of their observed probabilities. It is possible that several groups of herring that are thoroughly mixed in winter along southwest

Newfoundland sort themselves out when they migrate to their spawning grounds in the southern Gulf of St. Lawrence.

Herring from areas which differ in all five morphometric characters examined probably belong to relatively discrete stocks which intermingle very little. On this basis Hawke's Bay autumn spawners differ from southwest Newfoundland, Magdalen Islands and Gabarus Bay autumn spawners and southwest Newfoundland autumn spawners also differ from Placentia Bay and Strait of Belle Isle autumn spawners. Spring-spawning herring from Notre Dame Bay differ in all five characters from Bonavista Bay and Trinity Bay spring spawners and Placentia Bay spring spawners differ in all five characters from St. Mary's Bay spring spawners. Bonavista Bay autumn spawners differ from southwest Newfoundland autumn spawners in all three of the characters considered useful - snout length, orbit diameter and predorsal length. Notre Dame Bay and Quirpon spring spawners also differ in these three characters.

Herring from areas which differ in two of these three characters may also belong to relatively discrete stocks. On this basis spring-spawning herring from Bonavista Bay differ from St. Mary's Bay, Fortune Bay and Conche spring spawners. St. Mary's Bay, Trinity Bay and Fortune Bay spring spawners differ from each other. Fortune Bay spring spawners also differ from Placentia Bay spring spawners and Notre Dame Bay spring spawners differ from Conche spring spawners. Spring-spawning herring from Quirpon differ from Hawke's Bay spring spawners which in turn differ from southwest Newfoundland spring spawners. Autumn-spawning herring from Bonavista Bay differ from Conche, Quirpon and Placentia Bay autumn spawners. Conche autumn spawners also differ from Trinity Bay autumn spawners while Quirpon autumn spawners differ from Hawke's Bay and Strait of Belle Isle autumn spawners. The latter also differ from Magdalen Islands autumn spawners. Gabarus Bay autumn spawners differ from both southwest Newfoundland and Magdalen Islands autumn spawners. Differences in only one of snout length, orbit diameter and predorsal length may also be indicative of significant heterogeneity among areas, but there is far greater likelihood of error when basing conclusions on only one character.

Fish inhabiting colder waters tend to have relatively smaller heads and other body parts than fish from warmer waters (Rounsefell, 1930; Hubbs, 1940; Martin, 1949; Barlow, 1961). These smaller body parts are usually correlated with higher meristic counts for these populations (Martin, 1949; Barlow, 1961). Jean (1967), from investigations in 1943-44, found that herring from the relatively cold waters of Ile Verte in the Estuary of the Gulf of St. Lawrence had a slower growth rate and smaller snouts and heads than those from the warmer waters of Anse au Gascon. In the present study no clearcut geographic trend in either of the morphometric characters is evident among spring spawners. No geographic trend in snout or predorsal length is evident among autumn spawners, but autumn spawners from more northerly areas, e.g. Strait of Belle Isle, Quirpon, Conche and Hawke's Bay, tend to have smaller heads, orbit diameters and postorbital lengths than those from more southerly areas, e.g. Magdalen Islands and southwest Newfoundland (Figs. 13,16 and 19). Herring in these northern areas inhabit generally colder waters than those along southwest Newfoundland and in the southern Gulf of St. Lawrence.

Combined results of the meristic and morphometric comparisons suggest the following stock relationships. Herring fished at Magdalen Islands and along southwest Newfoundland apparently belong to the same stock complex, the winter fishery along southwest Newfoundland being largely dependent on herring concentrations which migrate eastward out of the southern part of the Gulf of St. Lawrence in the autumn. It is possible, however, 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. Autumn-spawning herring from northeastern Nova Scotia (Gabarus Bay-Chedabucto Bay area) do not appear to intermingle with Magdalen Islands and southwest Newfoundland herring. Both spring and autumn spawners from Hawke's Bay appear to be relatively distinct from the southern Gulf - southwest Newfoundland stock complex. Hawke's Bay autumn spawners do not differ significantly in meristic and morphometric characteristics from Strait of Belle Isle autumn spawners. It is probable that the large old autumn-spawning herring which appear during the summer in the southern Strait of Belle Isle represent an older portion of the same autumn-spawning stock which occurs during the autumn in Hawke's Bay. Herring from these two areas differ significantly from spring- and autumn-spawning herring which occur seasonally in the vicinity of Quirpon and Conche in northeast Newfoundland. Quirpon and Conche herring probably belong to the same stock complex. Notre Dame Bay spring spawners differ from spring spawners to the north and south and apparently constitute a relatively discrete spring-spawning population. Samples of spring-spawning herring from Bonavista and Trinity bays are similar in meristic and morphometric characteristics; it is probable that one stock of spring spawners frequents both bays. Autumn spawners from these two bays are also similar. Considerable meristic and morphometric differences indicate that spring spawners from Fortune, Placentia and St. Mary's bays represent relatively discrete stocks, despite their geographic proximity. Certainly the available evidence strongly suggests that Fortune Bay spring spawners do not intermingle much with those in adjoining areas.

Despite the meristic and morphometric differences 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, 1971). It is possible that the migration of "red" herring at that time was an unnatural one, prompted by behavioral changes resulting from the phosphorus poisoning. At any rate the migration of a portion of the Placentia Bay herring stock into St. Mary's Bay at that time does not preclude the possibility that normally two relatively discrete stocks frequent these bays. The existence of significant morphological differences, on the other hand, does not imply that no intermingling occurs between the two areas but does indicate that the samples of spring spawners from these two bays were not derived from a single completely mixed spring-spawning stock. However, autumn spawners from these bays are similar and probably belong to one autumn-spawning stock. The relationship of the autumn spawners in Placentia and St. Mary's bays to those which occur in Bonavista and Trinity bays is still uncertain; they may belong to the same stock.

The results of the present study, utilizing meristic and morphometric differences as indicators of stock heterogeneity, yield conclusions essentially the same as those derived by other methods. From comparisons of certain biological characteristics, including size, age and maturity composition, of herring taken at Magdalen Islands just prior to the start of the Newfoundland fishery in the autumn of 1969 and in the coastal waters of southwest Newfoundland shortly thereafter, Hodder and Parsons (MS, 1970) concluded that Magdalen Islands and southwest Newfoundland herring belong to the same stock complex, which spawns and feeds in the southern Gulf of St. Lawrence and overwinters in the fjords of southwest Newfoundland. Herring were tagged in the coastal waters of southwest Newfoundland in early March, 1970, and after the termination of the Newfoundland fishery in mid-April substantial recaptures were made at Magdalen Islands (Hodder and Winters, MS, 1970) and as far west as the Gaspé Peninsula (Winters, 1970; MS, 1971), confirming the westward movement of the herring schools after they leave the Newfoundland coast in the spring. Substantial numbers of herring tagged at Magdalen Islands and in the Chaleur Bay - Gaspé area during the spring and summer of 1970 were recaptured along southwest Newfoundland during the winter fishery of 1970-71 (Beckett, MS, 1971), confirming the eastward migration of herring from the southern Gulf of St. Lawrence to southwest Newfoundland during the autumn. The recovery of only 3 tags in the 1971 winter fishery along southwest Newfoundland from the liberation of 3400 tagged herring at Hawke's Bay in northwestern Newfoundland during December 1970 (G.H. Winters, personal communication) indicates that the degree of intermixture of Hawke's Bay herring with those which overwinter along southwest Newfoundland is probably slight.

Parsons and Hodder (MS,1971) 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 indicated by the level of infestation of herring in various areas with larval Anisakis (Parsons and Hodder, MS, 1971) agree in most instances with those suggested by meristic and morphometric comparisons. The similarity in incidence of Anisakis infestation of herring fished near Magdalen Islands in the autumn (29%), herring from southwest Newfoundland in winter (30%), herring fished between Cape Breton and Magdalen Islands in the spring (29%) and near Chaleur Bay - Gaspé during the summer (25%) provides further evidence of a seasonal migration of herring eastward from the southern Gulf of St. Lawrence in the autumn to overwintering areas along southwest Newfoundland and westward again into the Gulf in the spring. The present study of meristic and morphometric characteristics similarly shows that the winter fishery along southwest Newfoundland is largely dependent on herring which are not indigenous to that area but rather are derived from spring and autumn spawnings in the southern Gulf.

The incidence of infestation of herring from northeastern Nova Scotia (Gabarus Bay) with larval Anisakis

(64%) is more than twice that for southwest Newfoundland and the southern Gulf of St. Lawrence, the intensity of infestation (average number of nematodes per fish examined) being four times as large. Differences both in Anisakis infestation and meristic and morphometric characteristics indicate that herring from this area do not intermingle to any great extent with the southern Gulf - southwest Newfoundland stock complex. Differences in nematode abundance as well as meristic and morphometric characteristics suggest that herring along the northwest coast of Newfoundland (Hawke's Bay area) are also relatively distinct from the southern Gulf - southwest Newfoundland stock complex. The level of nematode infestation and the similarity in meristic and morphometric characteristics both indicate that herring which occur during the summer in the Strait of Belle Isle probably represent an older portion of the same stock which occurs in Hawke's Bay.

The low incidence of larval nematodes at all ages in spring-spawning herring from Notre Dame Bay (8%) suggests that this herring stock is relatively discrete, although it probably intermingles to a limited extent with herring to the north and south in White Bay and Bonavista Bay respectively. We have seen that Notre Dame Bay spring spawners also differ in meristic and morphometric characteristics from those in adjoining areas. The higher nematode abundance in Fortune Bay herring (43% incidence and 1.1 nematodes per fish) compared with southwest Newfoundland herring (30% incidence and 0.5 nematodes per fish) indicates that Fortune Bay herring, which are almost exclusively spring spawners, are probably relatively distinct from the stock complex which overwinters along southwest Newfoundland. The available meristic and morphometric evidence also indicates that Fortune Bay herring constitute a distinct stock.

Although spring-spawning herring from Placentia and St. Mary's bays differ in certain meristic and morphometric characteristics, the similarity of the incidence and intensity of infestation of herring from these bays with larval <u>Anisakis</u> suggests that the samples from these two bays were derived from the same stock, which was also indicated by the migration of "red" herring from Placentia Bay into St. Mary's Bay in the spring of 1969.

From the results of the present study it is apparent that both meristic and morphometric characters are useful indicators of stock heterogeneity but morphometric characters are probably less useful than meristic characters and larval <u>Anisakis</u> for determining the degree of intermingling of herring populations, since significant morphometric differences are found even between closely related populations. It is generally recognized that no one method is sufficient to accurately delineate the degree of heterogeneity of fish stocks. Conclusions regarding stock interrelationships should be based on a variety of techniques. In recent years immunogenetical and biochemical studies of Northeast Atlantic herring have been made by de Ligny (1962), Zenkin (1969), and Naevdal (1969, 1970). Sindermann and Mairs (1959) and Sindermann (1962) differentiated immature herring stocks in the Gulf of Maine on the basis of variations in the frequencies of certain blood groups. Studies of serum antigens in herring samples collected throughout the North American Atlantic coastal region also indicated heterogeneity in the local stocks (DiCapua, 1966). Ridgway, Sherburne and Lewis (1970) detected differences in the frequencies of esterase polymorphisms in Georges Bank and Western Maine herring, confirming the conclusion of Anthony and Boyar (1968), based on meristic data, that these subpopulations are separate. Polymorphisms in the enzymes lactate dehydrogenase (LDH) and aspartate aminotransferase (AAT) of herring from Canadian Atlantic coastal areas, excluding Newfoundland, were described by Odense, Allen and Leung (1966). Studies of these enzyme variants in herring from various Canadian areas including Newfoundland, to determine population interrelationships, are presently in progress at the Fisheries Research Board's Technological Laboratory in Halifax, Nova Scotia (P.H. Odense, personal communication). These studies may provide valuable information about the degree of genetic differentiation and taxonomic status of herring groups present in Canadian Atlantic waters.

Although meristic and morphometric differences generally show stock heterogeneity within a broad area, only direct methods, i.e. tagging, will demonstrate the actual amount of intermixing between stocks. Returns from taggings of over 80,000 herring along southwest Newfoundland and in the southern Gulf of St. Lawrence have confirmed that the fisheries in these areas occur on the same stock complex, as was indicated by similarities in meristic and morphometric characteristics and the degree of infestation with larval Anisakis. Further tagging experiments in other areas are required to determine whether intermingling occurs between groups considered to be discrete on the basis of morphological characteristics.

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VIII. TABLES

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

Area	Locality and		Number of specimens	
code	spawning group		Meristics	Morphometrics
1	Gabarus Bay, N.S.	(A)	350	146
2	Magdalen Islands	(S)	112	107
	" "	(A)	368	373
3	Southwest Nfld.	(S)	137	141
	" "	(A)	359	348
4	Fortune Bay	(S)	397	219
5	Placentia Bay	(S)	297	76
	" "	(A)	177	49
6	St. Mary's Bay	(S)	417	244
	" " "	(A)	122	-
7	Trinity Bay	(S)	333	322
	" "	(A)	110	105
8	Bonavista Bay	(S)	306	334
	" "	(A)	92	150
9	Notre Dame Bay	(S)	548	431
10	Conche	(S)	77	73
	"	(A)	80	74
11	Quirpon	(S)	81	82
	"	(A)	135	133
12	Strait of Belle Isle	(A)	200	195
13	Hawke's Bay	(S)	238	243
	" "	(A)	159	141
			5095	3986

Table 2. Gonadal stages and the description of the gonads and eggs of herring in the various stages. Descriptions are from the official ICNAF definition.

Stage	Males	Females
I	Virgin herring. Testes very small, threadlike, whitish or grey-brown.	Virgin herring. Gonads very small 2-3 mm broad, ovaries wine red.
II	Virgin herring with small sexual organs. Width of testes about 3-8 mm and reddish grey in colour.	Virgin herring with small sexual organs. Width of ovaries about 3-8 mm, eggs not visible to naked eye but can be seen with a magnifying glass.
III	Testes occupying about half of ventral cavity. Width of testes between 1 and 2 cm. Reddish grey or greyish.	Ovaries occupying about half of ventral cavity, width of ovaries between 1 and 2 cm. Eggs small but can be distinguished with naked eye, orange in colour.
IV	Testes almost as long as body cavity. Testes whitish.	Ovaries almost as long as body cavity. Eggs larger, varying in size, opaque, orange or pale yellow.
V	Testes fill body cavity, testes milk white. Sperm do not flow but can be extruded by pressure.	Ovaries fill body cavity. Yellowish in colour. Eggs large, round; some transparent but do not flow.
VI	Testes ripe, testes white and sperm flowing freely.	Ovaries ripe. Eggs transparent and flowing freely.
VII	Spent herring. Testes bloodshot but may contain remains of sperm.	Spent herring. Ovaries baggy and bloodshot, empty or containing only a few residual eggs.
VIII	Recovering spents. Testes firm and larger than virgin herring on Stage II. Walls of testes striated; blood vessels prominent, testes wine red in colour. (This stage passes into Stage III.)	Recovering spents. Ovaries firm and larger than virgin herring on Stage II. Eggs not visible to naked eye. Walls of ovary striated, blood vessels prominent, ovaries wine red in colour. (This stage passes into Stage III.)

Table 3. 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 4. Summary of one-way analysis of variance tests between samples within each area (spring and autumn spawners separate) for numbers of vertebrae, gill rakers, pectoral, anal and dorsal fin rays. (A double asterisk indicates significance at the 1% level.)

Area	Vertebral No.		Gill-raker No.		Pectoral fin-ray No.		Anal fin-ray No.		Dorsal fin-ray No.	
	d.f.	F	d.f.	F	d.f.	F	d.f.	F	d.f.	F
Spring spawners										
Magdalen Islands	8,103	0.77	8,101	1.32	8,103	0.97	8,101	2.14	8,98	2.55
Southwestern Nfld.	9,127	0.82	9,126	1.39	9,127	1.83	9,124	1.12	9,119	0.59
Fortune Bay	4,392	0.49	4,385	0.96	4,389	0.76	4,390	0.90	4,358	6.02
Placentia Bay	5,291	1.08	5,278	1.05	5,289	2.13	5,251	1.84	5,284	1.72
St. Mary's Bay	6,410	0.77	6,408	1.29	6,406	1.57	6,385	1.66	6,377	1.97
Trinity Bay	6,326	1.19	6,313	0.81	6,324	0.45	6,325	1.92	6,317	0.89
Bonavista Bay	9,296	0.61	9,291	1.22	9,295	1.21	9,294	0.94	9,288	1.23
Notre Dame Bay	5,542	1.34	5,519	1.60	5,538	2.34	5,535	0.38	5,511	0.74
Conche	3,73	0.67	3,71	0.38	3,70	0.63	3,71	0.35	3,70	0.39
Quirpon	4,76	0.22	4,75	0.48	4,75	1.83	4,71	1.65	4,73	1.05
Hawke's Bay	8,229	0.85	8,227	1.57	8,228	0.58	8,229	0.93	8,202	0.80
Autumn spawners										
Gabarus Bay, N.S.	2,347	0.08	2,335	0.29	2,347	1.24	2,346	3.05	2,313	0.59
Magdalen Islands	8,359	1.08	8,355	0.79	8,357	1.53	8,358	0.93	8,343	3.14**
Southwestern Nfld.	9,349	0.32	9,339	0.64	9,347	1.97	9,341	0.60	9,328	1.71
Placentia Bay	5,171	2.75	5,159	1.13	5,161	2.65	5,139	0.92	5,174	1.74
St. Mary's Bay	5,116	0.32	5,113	1.74	5,112	1.30	5,92	1.46	5,115	3.39**
Trinity Bay	4,104	1.23	4,103	3.06	4,105	0.89	4,105	1.73	4,100	0.16
Bonavista Bay	6,86	0.49	6,80	0.95	6,85	1.71	6,83	0.40	6,82	0.86
Conche	4,70	0.33	4,70	0.55	4,75	1.62	4,75	0.60	4,62	3.85**
Quirpon	5,129	1.04	5,128	1.03	5,128	0.15	5,123	0.98	5,118	3.39**
Strait of Belle Isle	3,196	1.92	3,193	0.87	3,196	2.31	3,195	0.66	3,180	2.43
Hawke's Bay	8,150	1.15	8,148	1.19	8,150	1.60	8,147	1.35	8,141	1.01

Table 5. 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: $\rho = 0$).

Table 6. 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	
Conche			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 7. 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	155	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

Table 8. Analysis of variance of numbers of vertebrae for spring and autumn spawners separately by year-class. (The double asterisk indicates significance at the 1% level.)

Locality	Source of variation	d.f.	Mean square	F
	Spring spawners			
Southwestern Nfld.	Between 1961, 1962 and 1963 year-classes within groups	2 110	0.1400 0.5051	0.28
Fortune Bay	Between 1963 and 1966 year-classes within groups	1 235	2.3600 0.4252	5.55
Placentia Bay	Between 1963 and 1966 year-classes within groups	1 196	0.9100 0.5184	1.76
Bonavista Bay	Between 1961 and 1963 year-classes within groups	1 222	0.6300 0.4627	1.36
Notre Dame Bay	Between 1961 and 1963 year-classes within groups	1 386	24.3600 0.3841	63.42**
Hawke's Bay	Between 1961, 1965 and 1966 year-classes within groups	2 122	1.5100 0.5716	2.64
	Autumn spawners			
Gabarus Bay, N.S.	Between 1962, 1963, 1965 and 1966 year-classes within groups	3 247	0.6500 0.5130	1.27
Magdalen Islands	Between 1960, 1961, 1962 and 1963 year-classes within groups	3 212	0.4667 0.4266	1.09
Southwestern Nfld.	Between 1960, 1961, 1962 and 1963 year-classes within groups	3 201	0.8300 0.9357	0.89

Table 9. 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 10A. Analysis of variance of numbers of vertebrae among areas - spawning groups, samples, year-classes and sexes pooled. (The double asterisk indicates significance at the 1% level.)

Source of variation	Degrees of freedom	Mean square	F
Between localities	10	3.8140	7.77**
Within localities	5079	0.4913	

At df 10 and ∞ : F(.01) = 2.32

Table 10B. Analysis of variance of numbers of vertebrae among areas based on the 1963 year-class - spawning groups, samples and sexes pooled. (The double asterisk indicates significance at the 1% level.)

Source of variation	Degrees of freedom	Mean square	F
Between localities	11	3.8736	8.44**
Within localities	1365	0.4592	

At df 11 and ∞ : F(.01) = 2.24

Table 11. 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 12. Vertebral numbers of Atlantic herring of the 1963 year-class from various Newfoundland and adjacent areas (autumn and spring spawners combined).

Areas	52	53	54	55	56	57	58	59	NO	AVE	SD	SE
Gabarus Bay, N.S.		1	3	32	33	5	1		75	55.547	0.7586	0.088
Magdalen Islands			2	18	22	7			49	55.694	0.7693	0.110
Southwestern Nfld.	1		1	20	27	8			57	55.684	0.8693	0.115
Fortune Bay				28	89	29	1		147	56.020	0.6460	0.053
Placentia Bay			2	42	44	8	1		97	55.639	0.7526	0.076
St. Mary's Bay			3	70	88	10			171	55.614	0.6256	0.048
Trinity Bay		1	9	81	91	5	1		188	55.495	0.6821	0.050
Bonavista Bay			7	81	78	10	1		177	55.531	0.6912	0.052
Conche			1	7	14	2			24	55.708	0.6903	0.141
Quirpon				10	14	4			28	55.786	0.6862	0.130
Hawke's Bay			1	20	14	1			36	55.417	0.6036	0.101
Notre Dame Bay			11	178	128	11			328	55.424	0.6160	0.034

Table 13. Comparison of vertebral means based on fish with normal plus those with abnormal vertebrae with those based only on fish with normal vertebrae (S = Spring spawners; A = Autumn spawners).

Area and spawning group		Normal plus abnormal vertebrae Mean ± SE	Normal vertebrae only Mean ± SE
Gabarus Bay, N.S.	(A)	55.497 ± .039	55.493 ± .039
Magdalen Islands	(S)	55.652 ± .069	55.645 ± .069
" "	(A)	55.617 ± .035	55.620 ± .035
Southwest Nfld.	(S)	55.635 ± .060	55.677 ± .054
" "	(A)	55.610 ± .033	55.597 ± .033
Fortune Bay	(S)	55.877 ± .034	55.879 ± .035
Placentia Bay	(S)	-	55.599 ± .040
" "	(A)	55.644 ± .062	55.651 ± .062
St. Mary's Bay	(S)	55.655 ± .034	55.672 ± .034
" " "	(A)	55.754 ± .061	55.730 ± .059
Trinity Bay	(S)	55.646 ± .040	55.650 ± .040
" "	(A)	55.845 ± .080	55.796 ± .073
Bonavista Bay	(S)	55.582 ± .039	55.593 ± .040
" "	(A)	55.696 ± .075	55.678 ± .072
Notre Dame Bay	(S)	55.672 ± .030	55.680 ± .030
Conche	(S)	55.831 ± .073	55.838 ± .075
"	(A)	55.747 ± .081	55.726 ± .081
Quirpon	(S)	55.753 ± .074	55.772 ± .074
"	(A)	55.748 ± .051	55.752 ± .052
Strait of Belle Isle	(A)	55.625 ± .048	55.625 ± .048
Hawke's Bay	(S)	55.761 ± .051	55.772 ± .050
" "	(A)	55.673 ± .048	55.669 ± .050

Table 14. 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																	Spring															Autumn sp.- Spring sp.
	43	44	45	46	47	48	49	50	51	52	53	54	55	NO	AVE	SD	SE	43	44	45	46	47	48	49	50	51	52	53	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	1	4	10	24	30	24	13	2	2			110	47.036	1.490	0.142	1.961**
Southwestern Nfld.		1	2	11	42	66	77	84	40	18	6		2	349	49.166	1.656	0.087			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		2	1	5	17	33	35	36	19	11	5	1		165	49.218	1.781	0.139			3	7	36	40	45	32	14	4	1	182	48.621	1.503	0.111	0.597**
St. Mary's Bay		1	1	3	9	15	32	28	20	6	3	1		119	49.437	1.676	0.154	1	1	12	28	57	106	107	65	27	10	1	415	48.494	1.577	0.077	0.943**
Trinity Bay				5	17	17	23	25	19	10	3			109	49.511	1.658	0.159			2	7	40	78	98	59	25	10	1	320	48.863	1.362	0.076	0.678**
Bonavista Bay		1		1	5	13	25	20	13	5	3			86	49.488	1.577	0.170			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	2	6	15	16	19	8	7				75	49.200	1.644	0.190				2	11	17	22	14	7	2		75	48.853	1.363	0.157	0.347
Quirpon		1	3	5	10	23	26	24	20	19	2		1	134	49.448	1.933	0.167				2	10	23	20	11	9	4	1	80	48.950	1.509	0.169	0.498**
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	2	3	8	23	42	53	48	37	15	4	1	236	48.229	1.740	0.113	0.917**

Table 15. Gill-raker numbers of male and female Atlantic herring from various Newfoundland and adjacent areas.

Area and spawning group		Male																	Female																	Male-Female
		43	44	45	46	47	48	49	50	51	52	53	54	55	NO	AVE	SD	SE	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			4	11	11	30	47	51	30	13	3	4		204	49.397	1.777	0.124	0.222
Magdalen Islands	(S)		1	1	12	14	6	5	1	1					41	47.146	1.370	0.214	1	3	9	12	16	18	8	1	1					69	46.971	1.5622	0.188	0.175
" "	(A)			2	6	15	31	35	29	9	12	1	3		143	49.105	1.759	0.147			1	16	21	46	58	45	24	9	1			221	48.928	1.5475	0.104	0.277
SW Newfoundland	(S)			7	14	12	24	14	7	1					79	47.620	1.479	0.166			5	6	16	15	11	3	1					57	47.596	1.387	0.184	0.024
"	(A)			2	6	24	34	40	36	16	8	2		2	170	49.024	1.706	0.131		1		5	18	32	37	48	24	10	4			179	49.302	1.600	0.120	-0.278
Fortune Bay	(S)		1	13	27	41	42	39	21	9	2	2			197	47.942	1.701	0.121		4	7	23	44	50	33	16	7	5	2			191	47.939	1.705	0.123	0.003
Placentia Bay	(S)			8	8	34	33	29	24	8	2				146	48.240	1.573	0.130			1	9	30	41	28	17	9	2	1			138	48.370	1.455	0.124	-0.130
" "	(A)		1		2	8	20	19	27	13	4				94	49.191	1.490	0.154		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)			7	10	20	59	48	31	11	4				190	48.516	1.468	0.107	1	1	5	18	37	47	59	34	16	6	1			225	48.476	1.642	0.109	0.040
" "	(A)		1	1	2	7	7	17	10	9	2	2	1		59	49.186	1.916	0.249				1	2	8	16	18	11	4	1	1		62	49.742	1.459	0.185	-0.556
Trinity Bay	(S)			1	2	21	29	54	35	13	4				159	48.950	1.306	0.104			1	5	19	49	44	24	12	6	1			161	48.776	1.414	0.111	0.174
" "	(A)				2	5	8	15	9	11	2	3			55	49.455	1.687	0.227				3	2	9	8	16	8	8				54	49.630	1.640	0.223	-0.175
Bonavista Bay	(S)				3	13	36	46	22	15	1				136	48.882	1.230	0.105			1	4	19	30	52	39	10	7	3			165	49.048	1.456	0.113	-0.166
" "	(A)		1			2	4	12	8	9		2			38	49.553	1.655	0.269				1	3	9	13	12	4	5	1			48	49.438	1.529	0.221	0.115
Notre Dame Bay	(S)				13	40	65	57	59	20	10	1			265	48.808	1.479	0.091			6	7	33	53	75	50	28	6	2			260	48.877	1.507	0.093	-0.069
Conche	(S)					7	10	15	8	4	1				45	48.889	1.265	0.189				2	4	7	7	6	3	1				30	48.800	1.518	0.277	0.089
"	(A)			1		3	8	10	11	4	3				40	49.250	1.498	0.237			1	2	3	7	6	8	4	4				35	49.143	1.817	0.307	0.107
Quirpon	(S)					6	9	10	4	5	3	1			38	49.158	1.636	0.265				2	4	14	10	7	4	1				42	48.762	1.376	0.212	0.396
"	(A)			1	1	7	13	7	12	9	9	2			61	49.508	1.876	0.240		1	2	4	3	10	19	12	11	10			1	73	49.397	1.991	0.233	0.111
Strait Belle Isle	(S)		1		1	11	25	23	15	17	10	2	1		106	49.349	1.746	0.170				2	8	15	23	19	12	8	4			91	49.505	1.649	0.173	-0.156
Hawkes Bay	(S)	1	1	4	12	25	29	32	16	10	4	1			135	48.333	1.749	0.151	1	2	4	11	17	24	16	21	5					101	48.089	1.727	0.172	0.244
" "	(A)	1		1	5	6	14	17	11	3	5	1			64	48.766	1.849	0.231			1	2	4	13	24	23	14	6	2			93	49.409	1.576	0.163	-0.643

A = Autumn; S = Spring

Table 16. Analysis of variance of numbers of gill rakers for spring and autumn spawners separately by year-class. (The double asterisk indicates significance at the 1% level.)

Locality	Source of variation	d.f.	Mean square	F
	Spring spawners			
Southwestern Nfld.	Between 1961, 1962 and 1963 year-classes within groups	2 109	2.7350 2.0729	1.32
Fortune Bay	Between 1963 and 1966 year-classes within groups	1 233	224.2700 2.0329	110.32**
Placentia Bay	Between 1963 and 1966 year-classes within groups	1 189	53.0900 2.0887	25.42**
Bonavista Bay	Between 1961 and 1963 year-classes within groups	1 218	1.1600 1.8267	0.64
Notre Dame Bay	Between 1961 and 1963 year-classes within groups	1 371	5.8400 2.2129	2.64
Hawke's Bay	Between 1961, 1965 and 1966 year-classes within groups	2 121	6.6050 2.7559	2.40
	Autumn spawners			
Gabarus Bay, N.S.	Between 1962, 1963, 1965 and 1966 year-classes within groups	3 237	5.5900 2.8930	1.93
Magdalen Islands	Between 1960, 1961, 1962 and 1963 year-classes within groups	3 210	2.5267 2.7225	0.93
Southwestern Nfld.	Between 1960, 1961, 1962 and 1963 year-classes within groups	3 194	0.0100 2.6336	0.004

Table 17. Analysis of variance of numbers of gill rakers among areas for spring and autumn spawners separately - samples, year-classes and sexes pooled. (The double asterisk indicates significance at the 1% level.)

Spawning group	Source of variation	Degrees of freedom	Mean square	F
Spring	Between localities	10	55.1020	24.20**
spawners	Within localities	2469	2.2772	

At df 10 and ∞ : F(.01) = 2.32

Spawning group	Source of variation	Degrees of freedom	Mean square	F
Autumn	Between localities	10	7.3560	2.51**
spawners	Within localities	2082	2.9263	

At df 10 and ∞ : F(.01) = 2.32

Table 18. 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 19. 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 20. Pectoral fin-ray numbers of male and female Atlantic herring from various Newfoundland and adjacent areas.

Area and spawning group	Male											Female												Male-Female
	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 (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

Table 21. Analysis of variance of numbers of pectoral fin rays for spring and autumn spawners separately by year-class.

Locality	Source of variation	d.f.	Mean square	F
	Spring spawners			
Southwestern Nfld.	Between 1961, 1962 and 1963 year-classes	2	0.0800	0.21
	within groups	110	0.3722	
Fortune Bay	Between 1963 and 1966 year-classes	1	1.1700	2.81
	within groups	234	0.4170	
Placentia Bay	Between 1963 and 1966 year-classes	1	0.0300	0.08
	within groups	195	0.3823	
Bonavista Bay	Between 1961 and 1963 year-classes	1	0.1300	0.29
	within groups	221	0.4489	
Notre Dame Bay	Between 1961 and 1963 year-classes	1	1.9900	4.91
	within groups	383	0.4054	
Hawke's Bay	Between 1961, 1965 and 1966 year-classes	2	0.1350	0.33
	within groups	121	0.4080	
	Autumn spawners			
Gabarus Bay, N.S.	Between 1962, 1963, 1965 and 1966 year-classes	3	0.6267	0.94
	within groups	247	0.6675	
Magdalen Islands	Between 1960, 1961, 1962 and 1963 year-classes	3	0.6833	0.94
	within groups	211	0.7250	
Southwestern Nfld.	Between 1960, 1961, 1962 and 1963 year-classes	3	1.3433	1.66
	within groups	201	0.8113	

Table 22. Analysis of variance of numbers of pectoral fin rays among areas for spring and autumn spawners separately - samples, year-classes and sexes pooled. (The double asterisk indicates significance at the 1% level.)

Spawning group	Source of variation	Degrees of freedom	Mean square	F
Spring	Between localities	10	6.1480	11.32**
spawners	Within localities	2911	0.5429	
	At df 10 and ∞ : F(.01) = 2.32			
Autumn	Between localities	10	0.8910	1.22
spawners	Within localities	2134	0.7315	

At df 10 and ∞ : F(.01) = 2.32

Table 23. 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 24. 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

Table 25. Anal fin-ray numbers of male and female Atlantic herring from various Newfoundland and adjacent areas.

Area and spawning group		Male											Female											Male-Female
		15	16	17	18	19	20	21	NO	AVE	SD	SE	15	16	17	18	19	20	21	NO	AVE	SD	SE	
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

Table 26. Analysis of variance of numbers of anal fin rays for spring and autumn spawners separately by year-class. (The double asterisk indicates significance at the 1% level.)

Locality	Source of variation	d.f.	Mean square	F
	Spring spawners			
Southwestern Nfld.	Between 1961, 1962 and 1963 year-classes	2	1.5450	2.51
	within groups	105	0.6150	
Fortune Bay	Between 1963 and 1966 year-classes	1	0.3500	0.44
	within groups	235	0.7976	
Placentia Bay	Between 1963 and 1966 year-classes	1	5.7500	7.99**
	within groups	177	0.7192	
Bonavista Bay	Between 1961 and 1963 year-classes	1	0.4100	0.55
	within groups	221	0.7518	
Notre Dame Bay	Between 1961 and 1963 year-classes	1	0.6300	0.90
	within groups	381	0.7034	
Hawke's Bay	Between 1961, 1965 and 1966 year-classes	2	0.4400	0.44
	within groups	122	1.0050	
	Autumn spawners			
Gabarus Bay, N.S.	Between 1962, 1963, 1965 and 1966 year-classes	3	0.0567	0.07
	within groups	246	0.7693	
Magdalen Islands	Between 1960, 1961, 1962 and 1963 year-classes	3	0.8733	1.09
	within groups	212	0.7990	
Southwestern Nfld.	Between 1960, 1961, 1962 and 1963 year-classes	3	1.1000	1.36
	within groups	197	0.8099	

Table 27A. Analysis of variance of numbers of anal fin rays among areas for spring and autumn spawners separately - samples, year-classes and sexes pooled. (The double asterisk indicates significance at the 1% level.)

Spawning group	Source of variation	Degrees of freedom	Mean square	F
Spring	Between localities	10	4.9130	6.48**
spawners	Within localities	2850	0.7581	
Autumn	Between localities	10	2.6640	3.29**
spawners	Within localities	2065	0.8102	

At df 10 and ∞ : F(.01) = 2.32

Table 27B. Analysis of variance of numbers of anal fin rays among areas for spring spawners based on the 1963 year-class - samples and sexes pooled. (The double asterisk indicates significance at the 1% level.)

Source of variation	Degrees of freedom	Mean square	F
Between localities	10	2.0060	2.72**
Within localities	1171	0.7372	

At df 10 and ∞ : F(.01) = 2.32

Table 28. Anal fin-ray numbers of spring-spawning Atlantic herring of the 1963 year-class from various Newfoundland and adjacent areas.

Areas	15	16	17	18	19	20	NO	AVE	SD	SE
Magdalen Islands			8	13	2		23	17.739	0.6192	0.129
Southwestern Nfld.		2	6	15	2		25	17.680	0.7483	0.150
Fortune Bay	1	16	40	62	26	2	147	17.694	0.9552	0.079
Placentia Bay		1	29	40	10	2	82	17.793	0.7656	0.085
St. Mary's Bay		7	36	84	35	3	165	17.945	0.8209	0.064
Trinity Bay	1	7	41	86	48	4	187	17.989	0.8737	0.064
Bonavista Bay		2	39	82	41	10	174	18.103	0.8539	0.065
Notre Dame Bay	1	11	90	149	65	7	323	17.889	0.8475	0.047
Conche			5	8	4	2	19	18.158	0.9582	0.220
Quirpon		1	5	8	5	1	20	18.000	0.9733	0.218
Hawke's Bay		1	7	6	2	1	17	17.706	0.9852	0.239

Table 29. 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

Table 30. Means and differences between means for autumn and spring spawners from Southwestern Newfoundland (November-December 1969).

Character	Mean for autumn spawners	Mean for spring spawners	Difference
Pectoral fin rays (X_1)	18.57143	17.18321	1.38822
Anal fin rays (X_2)	18.14869	17.59542	0.55327
Gill rakers (X_3)	49.16327	47.57252	1.59075

Table 31. Frequency and percentage of the values (Y) of the discriminant function above and below the critical value 32.68958 (Y_0) for autumn and spring spawners from Southwestern Newfoundland and Magdalen Islands.

Area and time of capture	Spawning[1] group	Classification matrix				
		Frequency			Percent	
		$Y>Y_0$[2]	$Y<Y_0$[3]	Total	$Y>Y_0$[2]	$Y<Y_0$[3]
Southwestern Nfld. (November-December 1969)[4]	Autumn	287	56	343	83.7	16.3
	Spring	18	113	131	13.7	86.3
Southwestern Nfld. (January 1969)	Autumn	47	11	58	81.0	19.0
	Spring	8	34	42	19.0	81.0
Southwestern Nfld. (April 1970)	Autumn	56	9	65	86.2	13.8
	Spring	7	27	34	20.6	79.4
Magdalen Islands (November 1969)	Autumn	290	70	360	80.6	19.4
	Spring	10	98	108	9.3	90.7

[1] Based on gonad maturity
[2] Classified as autumn spawners
[3] Classified as spring spawners
[4] Source data for discriminant function

Table 32. Covariance comparisons of the log-log regressions of various body parts on standard length between samples within each area for spring and autumn spawners separately. (A double asterisk indicates significance at the 1% level.)

Area	d.f. Slopes F	d.f. Adj Means F	Head length		Snout length		Orbit diameter		Postorbital length		Predorsal length	
			Slopes F	Adj Means F	Slopes F	Adj Means F	Slopes F	Adj Means F	Slopes F	Adj Means F	Slopes F	Adj Means F
					Spring spawners							
Magdalen Islands	8,89	8,97	0.57	0.38	0.49	1.79	0.78	1.40	0.91	0.74	0.64	1.69
Southwest Nfld.	9,121	9,130	1.54	1.63	0.30	3.70**	1.32	1.60	1.07	1.38	0.72	1.19
Fortune Bay	3,207	3,211	0.70	20.47**	3.19	21.91**	0.95	4.24**	1.92	8.72**	1.75	1.01
Placentia Bay	1,72	1,73	0.00	0.40	0.11	2.68	0.01	0.00	0.11	4.18	0.00	0.10
St. Mary's Bay	2,240	2,241	3.92	0.84	0.25	1.18	0.02	4.18	4.68	8.81**	6.72**	13.54**
Trinity Bay	6,303	6,309	0.90	3.99**	1.05	5.21**	1.12	1.42	0.45	4.59**	1.14	4.52**
Bonavista Bay	9,310	9,319	1.01	6.76**	0.70	10.41**	0.55	2.51	1.48	10.76**	0.98	1.63
Notre Dame Bay	4,421	4,425	0.63	5.51**	0.87	4.40**	1.93	4.78**	1.57	9.59**	0.95	3.78**
Conche	3,65	3,68	1.10	1.24	0.41	0.17	0.62	3.39	1.00	2.89	2.76	0.14
Quirpon	3,71	3,74	4.67**	1.58	0.80	24.43**	1.55	2.26	2.87	15.88**	1.96	2.54
Hawke's Bay	8,225	8,233	1.47	5.77**	2.39	2.66**	0.60	3.28**	0.63	2.54	1.01	3.36**
					Autumn spawners							
Gabarus Bay, N.S.	1,142	1,143	1.00	0.06	0.93	0.08	0.00	1.17	0.33	0.65	1.22	0.29
Magdalen Islands	8,355	8,363	0.60	3.67**	0.61	9.53**	0.20	2.73**	0.50	1.03	0.64	1.26
Southwest Nfld.	9,328	9,337	0.94	4.67**	1.07	3.59**	1.34	2.59	1.23	3.63**	0.93	1.16
Placentia Bay	1,45	1,46	0.48	0.01	2.42	0.98	0.11	2.40	0.05	2.27	0.88	0.32
Trinity Bay	4,90	4,94	0.57	0.16	2.91	0.62	1.48	0.76	2.41	0.76	1.00	0.56
Bonavista Bay	7,132	7,139	2.31	3.25**	0.48	7.97**	1.57	3.52**	1.56	0.93	0.95	0.83
Conche	4,64	4,68	2.32	2.17	0.49	4.87**	2.90	0.67	1.19	1.21	1.79	2.00
Quirpon	5,121	5,126	2.38	1.75	0.67	21.55**	1.16	5.74**	1.99	7.00**	0.92	3.92**
Strait of Belle Isle	3,187	3,190	1.70	2.15	4.36**	6.15**	0.19	1.68	0.39	0.22	0.15	3.03
Hawke's Bay	8,123	8,131	0.80	0.95	0.28	1.91	1.66	1.57	0.70	0.58	1.72	0.66

Table 33. Covariance statistics comparing locality differences in the log-log regressions of body part on standard length for spring spawners with differences between samples within localities. (A double asterisk indicates significance at the 1% level.)

Body part	Source of variation	d.f.	Sum of squares	Mean square	F
Head length	Differences between localities	20	7.7911×10^{-2}	3.8956×10^{-3}	8.75**
	Differences between samples	112	4.9843×10^{-2}	4.4503×10^{-4}	
Snout length	Differences between localities	20	3.9983×10^{-1}	1.9992×10^{-2}	9.03**
	Differences between samples	112	2.4792×10^{-1}	2.2135×10^{-3}	
Orbit diameter	Differences between localities	20	1.1232×10^{-1}	5.6158×10^{-3}	5.32**
	Differences between samples	112	1.1831×10^{-1}	1.0563×10^{-3}	
Postorbital length	Differences between localities	20	1.2995×10^{-1}	6.4976×10^{-3}	5.76**
	Differences between samples	112	1.2636×10^{-1}	1.1282×10^{-3}	
Predorsal length	Differences between localities	20	1.8732×10^{-2}	9.3659×10^{-4}	8.84**
	Differences between samples	112	1.1865×10^{-2}	1.0593×10^{-4}	

At df 20 and 100, F(.01) = 2.06

Table 34. Covariance statistics comparing locality differences in the log-log regressions of body part on standard length for autumn spawners with differences between samples within localities. (A double asterisk indicates significance at the 1% level.)

Body part	Source of variation	d.f.	Sum of squares	Mean square	F
Head length	Differences between localities	18	1.1880×10^{-1}	6.5999×10^{-3}	23.35**
	Differences between samples	100	2.8268×10^{-1}	2.8268×10^{-4}	
Snout length	Differences between localities	18	2.8980×10^{-1}	1.6100×10^{-2}	8.35**
	Differences between samples	100	1.9281×10^{-1}	1.9281×10^{-3}	
Orbit diameter	Differences between localities	18	1.6772×10^{-1}	9.3176×10^{-3}	7.49**
	Differences between samples	100	1.2441×10^{-1}	1.2441×10^{-3}	
Postorbital length	Differences between localities	18	2.7807×10^{-1}	1.5449×10^{-2}	27.76**
	Differences between samples	100	5.5646×10^{-2}	5.5646×10^{-4}	
Predorsal length	Differences between localities	18	7.3092×10^{-3}	4.0607×10^{-4}	5.22**
	Differences between samples	100	7.7754×10^{-3}	7.7754×10^{-5}	

At df 16 and 100, F(.01) = 2.19

Table 35. Covariance statistics comparing the log-log regressions of head length on standard length for spring and autumn spawners within each area. (The double asterisk indicates significance at the 1% level.)

Area and spawning group		No. of specimens	Regression coef., k	Intercept log b	Correlation coef., r	St. error of estimate	Covariance analysis	
							Slopes F	Adjusted means F
Magdalen Islands	(S)	107	0.9847	-0.6458	0.850	0.013	0.15	107.70**
" "	(A)	373	0.9593	-0.5688	0.832	0.012		
Southwest Nfld.	(S)	141	0.8479	-0.3159	0.698	0.012	7.79**	143.66**
" "	(A)	348	1.0764	-0.8591	0.832	0.012		
Placentia Bay	(S)	76	0.8583	-0.3297	0.956	0.013	0.07	2.70
" "	(A)	49	0.8393	-0.2779	0.870	0.015		
Trinity Bay	(S)	322	0.8503	-0.3132	0.933	0.012	0.32	10.05**
" "	(A)	105	0.8131	-0.2162	0.844	0.009		
Bonavista Bay	(S)	330	0.8316	-0.2656	0.892	0.013	1.46	34.84**
" "	(A)	150	0.9058	-0.4394	0.789	0.013		
Conche	(S)	73	0.9026	-0.4435	0.933	0.013	0.51	14.39**
"	(A)	74	0.9421	-0.5487	0.949	0.012		
Quirpon	(S)	82	0.8607	-0.3425	0.903	0.012	0.01	2.96
"	(A)	133	0.8671	-0.3547	0.843	0.014		
Hawke's Bay	(S)	243	0.9275	-0.5184	0.920	0.014	7.29**	39.01**
" "	(A)	141	1.0377	-0.7786	0.943	0.013		
Fortune Bay	(S)	217	0.7806	-0.1484	0.921	0.015		
St. Mary's Bay	(S)	244	0.8139	-0.2308	0.934	0.010		
Notre Dame Bay	(S)	431	0.7914	-0.1730	0.896	0.010		
Gabarus Bay, N.S.	(A)	146	0.8719	-0.3600	0.940	0.010		
Strait of Belle Isle	(A)	195	0.9962	-0.6860	0.868	0.011		

A = Autumn; S = Spring

Table 36. Comparisons of the log-log regressions of head length on standard length by analysis of covariance for the sexes within each spawning group for each area. (A double asterisk indicates significance at the 1% level.)

Area	Mean squares		Slopes	Mean squares		Adjusted means
	Within	Reg. Coef.	F	Common	Adjusted means	F
			Spring spawners			
Magdalen Islands	1.6720 x 10^{-4}	5.3487 x 10^{-8}	0.00	1.6560 x 10^{-4}	2.9471 x 10^{-4}	1.78
Southwest Nfld.	1.5198 x 10^{-4}	5.5013 x 10^{-5}	0.36	1.5128 x 10^{-4}	7.8202 x 10^{-4}	5.17
Placentia Bay	1.7459 x 10^{-4}	1.9087 x 10^{-5}	0.11	1.7246 x 10^{-4}	4.0856 x 10^{-4}	2.37
Trinity Bay	1.5157 x 10^{-4}	5.0855 x 10^{-4}	3.36	1.5269 x 10^{-4}	7.1157 x 10^{-5}	0.47
Bonavista Bay	1.6586 x 10^{-4}	5.6712 x 10^{-6}	0.03	1.6537 x 10^{-4}	6.7517 x 10^{-4}	4.08
Conche	1.7037 x 10^{-4}	1.6619 x 10^{-7}	0.00	1.6794 x 10^{-4}	1.4651 x 10^{-4}	0.87
Quirpon	1.3967 x 10^{-4}	2.4103 x 10^{-4}	1.73	1.4095 x 10^{-4}	4.4484 x 10^{-4}	3.16
Hawke's Bay	1.8673 x 10^{-4}	5.1765 x 10^{-7}	0.00	1.8595 x 10^{-4}	3.8615 x 10^{-4}	2.08
Fortune Bay	2.2321 x 10^{-4}	2.1926 x 10^{-4}	0.98	2.2319 x 10^{-4}	2.8748 x 10^{-4}	1.29
St. Mary's Bay	1.0786 x 10^{-4}	9.3062 x 10^{-7}	0.01	1.0742 x 10^{-4}	7.3053 x 10^{-4}	6.80**
Notre Dame Bay	1.0551 x 10^{-4}	5.4993 x 10^{-5}	0.52	1.0539 x 10^{-4}	5.0630 x 10^{-4}	4.80
			Autumn spawners			
Magdalen Islands	1.5346 x 10^{-4}	3.2157 x 10^{-4}	2.10	1.5391 x 10^{-4}	1.1540 x 10^{-4}	0.75
Southwest Nfld.	1.4566 x 10^{-4}	8.4355 x 10^{-5}	0.58	1.4549 x 10^{-4}	1.6761 x 10^{-4}	1.15
Placentia Bay	1.8273 x 10^{-4}	1.3288 x 10^{-3}	7.27**	2.0765 x 10^{-4}	7.0107 x 10^{-4}	3.38
Trinity Bay	8.7260 x 10^{-5}	2.1469 x 10^{-4}	2.46	8.8509 x 10^{-5}	1.8619 x 10^{-4}	2.10
Bonavista Bay	1.7622 x 10^{-4}	2.2122 x 10^{-5}	0.13	1.7517 x 10^{-4}	7.4033 x 10^{-4}	4.23
Conche	1.4930 x 10^{-4}	1.1574 x 10^{-5}	0.08	1.4736 x 10^{-4}	2.0802 x 10^{-5}	0.14
Quirpon	1.9255 x 10^{-4}	2.6414 x 10^{-4}	1.37	1.9311 x 10^{-4}	8.2781 x 10^{-5}	0.43
Hawke's Bay	1.6452 x 10^{-4}	1.4104 x 10^{-6}	0.01	1.6334 x 10^{-4}	8.0337 x 10^{-6}	0.05
Strait of Belle Isle	1.2835 x 10^{-4}	2.4601 x 10^{-4}	1.92	1.2897 x 10^{-4}	3.3157 x 10^{-4}	2.57
Gabarus Bay, N.S.	1.0778 x 10^{-4}	7.0439 x 10^{-5}	0.65	1.0752 x 10^{-4}	1.1511 x 10^{-5}	0.11

Table 37. Covariance comparisons of the log-log regressions of head length on standard length among all areas for spring and autumn spawners separately.

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

Test	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Among areas spring spawners	Within Samples	2244	3.4448×10^{-1}	1.5351×10^{-4}	4.03**
	Reg. Coefficients	10	6.1829×10^{-3}	6.1829×10^{-4}	
	Common Regression	2254	3.5067×10^{-1}	1.5557×10^{-4}	46.11**
	Adjusted Means	10	7.1728×10^{-2}	7.1728×10^{-3}	
	Total	2264	4.2239×10^{-1}		

At df 10 and ∞ : F(.01) = 2.32

Test	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Among areas autumn spawners	Within Samples	1694	2.5208×10^{-1}	1.4881×10^{-4}	4.37**
	Reg. Coefficients	9	5.8523×10^{-3}	6.5025×10^{-4}	
	Common Regression	1703	2.5793×10^{-1}	1.5146×10^{-4}	82.86**
	Adjusted Means	9	1.1295×10^{-1}	1.2549×10^{-2}	
	Total	1712	3.7088×10^{-1}		

At df 9 and ∞ : F(.01) = 2.41

Table 38. Covariance comparisons of the log-log regressions of various body parts on standard length between pairs of areas for spring spawners. (The double asterisk indicates significance at the 1% level.)

Area comparisons (spring spawners)	Head length		Snout length		Orbit diameter		Postorbital length		Predorsal length	
	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F
Bonavista Bay vs Trinity Bay	0.40	3.76	1.63	12.12**	0.11	1.09	0.14	0.48	1.99	0.47
Bonavista Bay vs Notre Dame Bay	1.84	39.33**	4.66	36.57**	0.26	66.57**	0.01	76.24**	0.00	73.61**
Bonavista Bay vs St. Mary's Bay	0.32	60.43**	0.94	31.01**	1.73	4.91	0.68	48.61**	4.42	48.19**
Bonavista Bay vs Conche	2.24	7.60**	2.63	45.81**	0.04	0.26	0.88	2.00	0.00	8.06**
Bonavista Bay vs Fortune Bay	2.49	26.56**	0.56	71.29**	0.72	0.23	1.68	0.00	1.18	21.99**
Notre Dame Bay vs Conche	7.92**	0.42	14.67**	23.92**	0.35	17.90**	1.11	52.74**	0.00	3.52
Notre Dame Bay vs Quirpon	2.38	0.03	79.62**	4.35	1.64	42.19**	14.73**	5.30	4.55	11.25**
Notre Dame Bay vs Trinity Bay	4.93	16.49**	15.86**	4.22	0.90	84.56**	0.29	91.04**	2.25	74.76**
Conche vs Quirpon	0.46	0.67	12.53**	11.03**	1.59	2.34	12.57**	10.76**	2.77	1.04
Conche vs Hawke's Bay	0.25	61.77**	0.22	20.51**	4.27	0.02	0.39	61.35**	0.11	4.97
Quirpon vs Hawke's Bay	1.40	49.42**	18.87**	68.92**	10.76**	4.78	12.96**	12.24**	4.33	1.15
Hawke's Bay vs Magdalen Islands	0.74	59.52**	0.01	2.47	0.40	3.49	2.33	74.15**	1.78	7.46**
Hawke's Bay vs Southwest Nfld.	0.94	33.54**	0.25	16.31**	0.33	6.68	0.02	12.14**	0.69	2.22
Magdalen Islands vs Southwest Nfld.	2.08	5.87	0.25	4.00	0.00	0.35	1.33	27.48**	0.04	1.02

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Table 38. Cont'd.

Area comparisons (spring spawners)	Head length		Snout length		Orbit diameter		Postorbital length		Predorsal length	
	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F
Southwest Nfld. vs Fortune Bay	0.62	3.50	0.13	1.40	1.31	13.18**	0.38	11.41**	0.47	5.05
Fortune Bay vs Placentia Bay	10.13	25.29**	6.63	42.90**	2.65	1.77	2.60	7.35**	1.53	6.96**
Fortune Bay vs St. Mary's Bay	1.15	2.76	0.02	18.36**	5.92	4.17	0.19	46.48**	11.49**	149.63**
Fortune Bay vs Trinity Bay	5.99	12.31**	4.37	29.72**	1.87	0.12	1.23	0.82	0.16	9.58**
Placentia Bay vs St. Mary's Bay	5.58	63.59**	11.54**	24.67**	0.38	12.86**	1.25	79.61**	4.21	49.13**
Placentia Bay vs Trinity Bay	1.40	14.28**	0.88	15.25**	0.21	0.41	0.41	7.13**	2.41	0.33
St. Mary's Bay vs Trinity Bay	1.68	30.33**	6.11	3.59	1.32	12.45**	0.32	60.36**	12.69**	46.63**

Table 39. Covariance comparisons of the log-log regressions of various body parts on standard length between pairs of areas for autumn spawners.

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

Area comparisons (autumn spawners)	Head length		Snout length		Orbit diameter		Postorbital length		Predorsal length	
	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F
Bonavista Bay vs Trinity Bay	1.26	21.55**	1.73	3.11	1.58	0.01	1.67	24.25**	3.50	3.10
Bonavista Bay vs Conche	0.28	107.92**	0.33	66.50**	2.68	14.97**	0.72	30.81**	0.73	0.08
Bonavista Bay vs Quirpon	0.26	49.25**	2.59	36.73**	0.20	54.79**	2.95	96.97**	2.06	0.45
Bonavista Bay vs Strait of Belle Isle	1.70	250.47**	0.00	85.29**	0.15	0.07	3.26	256.55**	0.05	4.11
Bonavista Bay vs Placentia Bay	0.12	4.76	1.04	0.14	1.55	7.50**	0.30	2.53	0.34	6.75**
Bonavista Bay vs Southwest Nfld.	6.44	2.07	0.36	9.50**	6.91**	11.93**	2.35	6.41	7.73**	4.38
Conche vs Trinity Bay	3.86	52.71**	4.22	46.25**	0.04	12.93**	0.68	2.74	1.70	1.76
Conche vs Quirpon	1.49	18.91**	1.61	136.20**	5.19	3.70	1.66	11.50**	0.57	0.35
Conche vs Strait of Belle Isle	0.99	2.80	0.59	3.16	2.87	19.00**	12.43**	53.96**	0.51	2.71
Quirpon vs Strait of Belle Isle	4.28	48.85**	3.96	226.78**	0.95	77.87**	14.95**	2.72	1.93	0.60
Quirpon vs Hawke's Bay	9.10**	1.86	4.97	169.05**	10.07**	48.84**	12.72**	21.11**	0.00	5.33
Strait of Belle Isle vs Hawke's Bay	0.64	41.75**	0.03	4.78	6.39	2.00	0.27	95.16**	3.09	11.36**
Strait of Belle Isle vs Magdalen Islands	0.47	316.02**	0.08	19.09**	1.45	8.78**	4.93	426.61**	0.89	0.93
Strait of Belle Isle vs Southwest Nfld.	1.99	298.55**	0.56	30.06**	7.37**	15.30**	0.16	364.02**	8.17**	0.37
Strait of Belle Isle vs Gabarus Bay, N.S.	6.62	110.22**	2.39	14.17**	1.32	0.89	2.75	164.07**	0.00	5.82

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Table 39. Cont'd.

Area comparisons (autumn spawners)	Head length		Snout length		Orbit diameter		Postorbital length		Predorsal length	
	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F	Slopes F	Adj. means F
Hawke's Bay vs Magdalen Islands	3.01	198.79**	0.30	52.83**	1.96	9.01**	3.69	143.98**	0.78	17.20**
Hawke's Bay vs Southwest Nfld.	0.62	141.06**	1.06	68.97**	0.09	8.19**	0.01	71.00**	2.00	21.32**
Hawke's Bay vs Gabarus Bay, N.S.	16.47**	79.51**	2.16	60.69**	18.14**	1.99	1.37	24.51**	4.72	78.98**
Magdalen Islands vs Gabarus Bay, N.S.	3.97	18.30**	4.07	4.85	6.91**	3.26	0.62	43.63**	1.30	36.10**
Magdalen Islands vs Southwest Nfld.	5.27	9.96**	0.27	1.52	2.51	0.17	3.67	28.64**	4.50	0.06
Gabarus Bay, N.S. vs Southwest Nfld.	18.62**	2.06	5.97	1.54	18.66**	1.96	1.60	4.79	11.48**	42.72**
Southwest Nfld. vs Placentia Bay	11.26**	1.49	1.36	17.03**	1.16	17.61**	11.54**	6.40	11.73**	7.20**
Southwest Nfld. vs Trinity Bay	13.34**	35.50**	4.19	1.68	0.90	19.32**	8.76**	49.89**	0.03	1.75
Placentia Bay vs Trinity Bay	1.08	1.15	0.70	2.07	0.16	5.08	1.07	3.23	2.95	10.21**

Table 40. Covariance statistics comparing the log-log regressions of snout length on standard length for spring and autumn spawners within each area. (The double asterisk indicates significance at the 1% level.)

Area and spawning group		No. of specimens	Regression coef., k	Intercept log b	Correlation coef., r	St. error of estimate	Covariance analysis	
							Slopes F	Adjusted means F
Magdalen Islands	(S)	107	0.8148	-0.7769	0.532	0.027	1.14	43.52**
" "	(A)	373	0.9576	-1.1064	0.607	0.024		
Southwest Nfld.	(S)	141	0.7155	-0.5277	0.370	0.026	3.29	34.53**
" "	(A)	348	1.0094	-1.2312	0.587	0.023		
Placentia Bay	(S)	76	0.7632	-0.6181	0.868	0.022	0.63	1.70
" "	(A)	49	0.8547	-0.8356	0.765	0.022		
Trinity Bay	(S)	321	0.7711	-0.6433	0.785	0.023	0.18	5.79
" "	(A)	105	0.7183	-0.5054	0.546	0.020		
Bonavista Bay	(S)	332	0.7000	-0.4629	0.653	0.025	3.88	3.50
" "	(A)	150	0.9314	-1.0296	0.570	0.025		
Conche	(S)	73	0.8481	-0.8463	0.781	0.025	2.02	5.69
"	(A)	74	1.0101	-1.2550	0.828	0.026		
Quirpon	(S)	82	1.3238	-1.9956	0.806	0.028	0.87	11.60**
"	(A)	133	1.1809	-1.6280	0.698	0.030		
Hawke's Bay	(S)	243	0.7999	-0.7458	0.698	0.028	1.59	5.51
" "	(A)	141	0.9080	-1.0026	0.759	0.027		
Fortune Bay	(S)	217	0.6503	-0.3643	0.668	0.033		
St. Mary's Bay	(S)	243	0.6416	-0.3327	0.736	0.020		
Notre Dame Bay	(S)	431	0.6416	-0.3327	0.736	0.017		
Gabarus Bay, N.S.	(A)	146	0.7830	-0.6740	0.777	0.021		
Strait of Belle Isle	(A)	195	0.9272	-1.0432	0.653	0.022		

A = Autumn; S = Spring

Table 41. Comparisons of the log-log regressions of snout length on standard length by analysis of covariance for the sexes within each spawning group for each area. (A double asterisk indicates significance at the 1% level.)

Area	Mean squares		Slopes	Mean squares		Adjusted means
	Within	Reg. Coef.	F	Common	Adjusted means	F
			Spring spawners			
Magdalen Islands	7.6942 x 10^{-4}	1.8389 x 10^{-5}	0.02	7.6220 x 10^{-4}	6.6153 x 10^{-5}	0.09
Southwest Nfld.	6.7249 x 10^{-4}	1.4067 x 10^{-5}	0.02	6.6772 x 10^{-4}	3.4853 x 10^{-4}	0.52
Placentia Bay	4.6988 x 10^{-4}	1.2464 x 10^{-3}	2.65	4.8052 x 10^{-4}	5.0536 x 10^{-5}	0.11
Trinity Bay	5.2231 x 10^{-4}	5.8484 x 10^{-4}	1.12	5.2251 x 10^{-4}	7.5993 x 10^{-5}	0.15
Bonavista Bay	6.0592 x 10^{-4}	6.6832 x 10^{-4}	1.10	6.0611 x 10^{-4}	4.0536 x 10^{-3}	6.69
Conche	6.3787 x 10^{-4}	1.1178 x 10^{-3}	1.75	6.4473 x 10^{-4}	5.5187 x 10^{-8}	0.00
Quirpon	8.1635 x 10^{-4}	4.2208 x 10^{-6}	0.01	8.0607 x 10^{-4}	1.2305 x 10^{-3}	1.53
Hawke's Bay	8.0689 x 10^{-4}	2.3567 x 10^{-4}	0.29	8.0451 x 10^{-4}	9.0889 x 10^{-4}	1.13
Fortune Bay	1.0685 x 10^{-3}	1.2673 x 10^{-4}	0.12	1.0641 x 10^{-3}	5.3291 x 10^{-5}	0.05
St. Mary's Bay	3.9435 x 10^{-4}	6.1503 x 10^{-4}	1.56	3.9527 x 10^{-4}	5.5329 x 10^{-5}	0.14
Notre Dame Bay	3.0413 x 10^{-4}	1.3536 x 10^{-5}	0.04	3.0345 x 10^{-4}	4.5731 x 10^{-4}	1.51
			Autumn spawners			
Magdalen Islands	5.8882 x 10^{-4}	3.0272 x 10^{-6}	0.01	5.8724 x 10^{-4}	2.8766 x 10^{-3}	4.90
Southwest Nfld.	5.5010 x 10^{-4}	3.5387 x 10^{-4}	0.64	5.4953 x 10^{-4}	2.1329 x 10^{-4}	0.39
Placentia Bay	5.0252 x 10^{-4}	7.0560 x 10^{-4}	1.40	5.0694 x 10^{-4}	1.0822 x 10^{-4}	0.21
Trinity Bay	3.9934 x 10^{-4}	8.2853 x 10^{-5}	0.21	3.9624 x 10^{-4}	1.6075 x 10^{-3}	4.06
Bonavista Bay	6.4838 x 10^{-4}	8.5553 x 10^{-6}	0.01	6.4403 x 10^{-4}	8.2710 x 10^{-4}	1.28
Conche	7.1172 x 10^{-4}	2.8282 x 10^{-4}	0.40	7.0568 x 10^{-4}	2.2300 x 10^{-4}	0.32
Quirpon	9.2528 x 10^{-4}	1.2018 x 10^{-3}	1.30	9.2741 x 10^{-4}	9.1830 x 10^{-6}	0.01
Hawke's Bay	7.5044 x 10^{-4}	4.6679 x 10^{-6}	0.01	7.4503 x 10^{-4}	1.6303 x 10^{-4}	0.02
Strait of Belle Isle	4.6153 x 10^{-4}	1.2731 x 10^{-4}	0.28	4.5979 x 10^{-4}	1.0481 x 10^{-3}	2.28
Gabarus Bay, N.S.	4.2945 x 10^{-4}	4.1507 x 10^{-4}	0.97	4.2935 x 10^{-4}	5.2509 x 10^{-8}	0.00

Table 42. Covariance comparisons of the log-log regressions of snout length on standard length among all areas for spring and autumn spawners separately. (The double asterisk indicates significance at the 1% level.)

Test	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Among areas spring spawners	Within Samples	2244	1.3337	5.9434×10^{-4}	6.69**
	Reg. Coefficients	10	3.9765×10^{-2}	3.9765×10^{-3}	
	Common Regression	2254	1.3735	6.0935×10^{-4}	59.09**
	Adjusted Means	10	3.6007×10^{-1}	3.6007×10^{-2}	
	Total	2264	1.7335		

At df 10 and ∞ : F(.01) = 2.32

Test	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Among areas autumn spawners	Within Samples	1694	9.9536×10^{-1}	5.8758×10^{-4}	2.22
	Reg. Coefficients	9	1.1758×10^{-2}	1.3064×10^{-3}	
	Common Regression	1703	1.0071	5.9138×10^{-4}	52.24**
	Adjusted Means	9	2.7805×10^{-1}	3.0894×10^{-2}	
	Total	1712	1.2852		

At df 9 and ∞ : F(.01) = 2.41

Table 43. Covariance statistics comparing the log-log regressions of orbit diameter on standard length for spring and autumn spawners within each area. (The double asterisk indicates significance at the 1% level.)

Area and spawning group		No. of specimens	Regression coef., K	Intercept log b	Correlation coef., r	St. error of estimate	Covariance analysis Slopes F	Covariance analysis Adjusted means F
Magdalen Islands	(S)	107	0.9436	-1.1772	0.597	0.027	0.23	7.39**
" "	(A)	373	0.8762	-1.0044	0.544	0.026		
Southwest Nfld.	(S)	141	0.9341	-1.1520	0.454	0.026	0.43	2.10
" "	(A)	348	1.0412	-1.4102	0.597	0.024		
Placentia Bay	(S)	76	0.7609	-0.7489	0.821	0.026	0.80	3.16
" "	(A)	49	0.8917	-1.0579	0.679	0.030		
Trinity Bay	(S)	321	0.8248	-0.8963	0.796	0.024	0.40	10.11**
" "	(A)	105	0.9055	-1.0880	0.635	0.020		
Bonavista Bay	(S)	332	0.8052	-0.8466	0.690	0.026	0.88	7.76**
" "	(A)	150	0.6890	-0.5496	0.426	0.028		
Conche	(S)	73	0.8231	-0.8885	0.752	0.027	0.80	5.68
"	(A)	74	0.9338	-1.1720	0.778	0.029		
Quirpon	(S)	82	0.6533	-0.4796	0.574	0.027	0.06	2.16
"	(A)	133	0.6172	-0.3971	0.452	0.030		
Hawke's Bay	(S)	243	1.0285	-1.3898	0.798	0.027	0.04	1.72
" "	(A)	141	1.0116	-1.3445	0.783	0.028		
Fortune Bay	(S)	217	0.7540	-0.7235	0.799	0.025		
St. Mary's Bay	(S)	243	0.8845	-1.0342	0.852	0.018		
Notre Dame Bay	(S)	431	0.7747	-0.7584	0.691	0.021		
Gabarus Bay, N.S.	(A)	146	0.6306	-0.4084	0.675	0.022		
Strait of Belle Isle	(A)	195	0.7424	-0.6816	0.565	0.022		

A = Autumn; S = Spring

Table 44. Comparisons of the log-log regressions of orbit diameter on standard length by analysis of covariance for the sexes within each spawning group for each area. (A double asterisk indicates significance at the 1% level.)

Area	Mean squares		Slopes	Mean squares		Adjusted means
	Within	Reg. Coef.	F	Common	Adjusted means	F
			Spring spawners			
Magdalen Islands	7.1890×10^{-4}	9.1668×10^{-4}	1.28	7.2081×10^{-4}	1.0431×10^{-3}	1.45
Southwest Nfld.	6.9005×10^{-4}	1.2982×10^{-5}	0.02	6.8514×10^{-4}	1.5353×10^{-3}	2.24
Placentia Bay	7.0366×10^{-4}	7.7105×10^{-4}	1.10	7.0458×10^{-4}	1.9680×10^{-4}	0.28
Trinity Bay	5.5472×10^{-4}	4.8897×10^{-4}	0.88	5.5451×10^{-4}	3.3522×10^{-4}	0.60
Bonavista Bay	6.7050×10^{-4}	3.7557×10^{-7}	0.00	6.6847×10^{-4}	4.2095×10^{-4}	0.63
Conche	7.3337×10^{-4}	4.1697×10^{-4}	0.57	7.2885×10^{-4}	8.6260×10^{-6}	0.01
Quirpon	7.6431×10^{-4}	1.3554×10^{-5}	0.02	7.5480×10^{-4}	1.9344×10^{-5}	0.03
Hawke's Bay	7.2295×10^{-4}	1.4939×10^{-3}	2.07	7.2616×10^{-4}	1.4739×10^{-4}	0.20
Fortune Bay	6.5237×10^{-4}	5.1806×10^{-4}	0.79	6.5174×10^{-4}	6.3938×10^{-5}	0.10
St. Mary's Bay	3.2702×10^{-4}	1.0451×10^{-3}	3.20	3.3002×10^{-4}	1.0715×10^{-3}	3.25
Notre Dame Bay	4.5428×10^{-4}	3.1050×10^{-7}	0.00	4.5322×10^{-4}	1.1376×10^{-3}	2.51
			Autumn spawners			
Magdalen Islands	6.9149×10^{-4}	3.0356×10^{-4}	0.44	6.9044×10^{-4}	1.3234×10^{-4}	0.19
Southwest Nfld.	5.4693×10^{-4}	4.8063×10^{-4}	0.88	5.4673×10^{-4}	2.9393×10^{-3}	5.38
Placentia Bay	8.6505×10^{-4}	5.4982×10^{-4}	0.64	8.5819×10^{-4}	2.4484×10^{-3}	2.85
Trinity Bay	4.1170×10^{-4}	1.5124×10^{-4}	0.37	4.0915×10^{-4}	1.0104×10^{-4}	0.25
Bonavista Bay	7.7136×10^{-4}	5.3063×10^{-4}	0.69	7.6972×10^{-4}	6.0662×10^{-4}	0.79
Conche	8.7388×10^{-4}	6.1065×10^{-5}	0.07	8.6243×10^{-4}	1.9339×10^{-5}	0.02
Quirpon	9.4193×10^{-4}	5.3430×10^{-5}	0.06	9.3510×10^{-4}	2.0067×10^{-5}	0.02
Hawke's Bay	7.9536×10^{-4}	4.9430×10^{-7}	0.00	7.8960×10^{-4}	3.0637×10^{-5}	0.04
Strait of Belle Isle	4.7440×10^{-4}	2.3976×10^{-7}	0.00	4.7193×10^{-4}	2.9145×10^{-4}	0.62
Gabarus Bay, N.S.	5.0299×10^{-4}	4.4878×10^{-5}	0.09	4.9979×10^{-4}	1.3446×10^{-3}	2.69

Table 45. Covariance comparisons of the log-log regressions of orbit diameter on standard length among all areas for spring and autumn spawners separately.

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

Test	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Among areas spring spawners	Within Samples	2244	1.3208	5.8858×10^{-4}	3.35**
	Reg. Coefficients	10	1.9729×10^{-2}	1.9729×10^{-3}	
	Common Regression	2254	1.3405	5.9472×10^{-4}	15.57**
	Adjusted Means	10	9.2587×10^{-2}	9.2587×10^{-3}	
	Total	2264	1.4331		

At df 10 and ∞ : F(.01) = 2.32

Test	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Among areas autumn spawners	Within Samples	1694	1.1002	6.4948×10^{-4}	3.95**
	Reg. Coefficients	9	2.3064×10^{-2}	2.5627×10^{-3}	
	Common Regression	1703	1.1233	6.5959×10^{-4}	24.37**
	Adjusted Means	9	1.4465×10^{-1}	1.6073×10^{-2}	
	Total	1712	1.2679		

At df 9 and ∞ : F(.01) = 2.41

Table 46. Covariance statistics comparing the log-log regressions of postorbital length on standard length for spring and autumn spawners within each area. (The double asterisk indicates significance at the 1% level.)

Area and spawning group		No. of specimens	Regression coef., k	Intercept log b	Correlation coef., r	St. error of estimate	Covariance analysis	
							Slopes F	Adjusted means F
Magdalen Islands	(S)	107	1.1041	-1.2549	0.789	0.018	1.22	60.36**
" "	(A)	373	1.0000	-0.9848	0.741	0.018		
Southwest Nfld.	(S)	141	0.9421	-0.8724	0.578	0.019	2.78	128.23**
" "	(A)	348	1.1368	-1.3274	0.754	0.017		
Placentia Bay	(S)	76	0.9653	-0.9119	0.924	0.020	2.28	0.10
" "	(A)	49	0.8017	-0.5096	0.752	0.022		
Trinity Bay	(S)	321	0.9134	-0.7921	0.872	0.019	0.59	0.34
" "	(A)	105	0.8346	-0.5948	0.710	0.015		
Bonavista Bay	(S)	329	0.9310	-0.8361	0.802	0.021	0.40	21.53**
" "	(A)	150	0.9924	-0.9757	0.699	0.019		
Conche	(S)	73	1.0023	-1.0062	0.905	0.018	1.60	5.09
"	(A)	74	0.9114	-0.7895	0.920	0.015		
Quirpon	(S)	82	0.6458	-0.1448	0.647	0.022	1.14	0.00
"	(A)	133	0.7792	-0.4735	0.611	0.025		
Hawke's Bay	(S)	243	0.9578	-0.9181	0.859	0.020	7.67**	33.92**
" "	(A)	141	1.1282	-1.3214	0.885	0.021		
Fortune Bay	(S)	215	0.8666	-0.6801	0.883	0.021		
St. Mary's Bay	(S)	243	0.8875	-0.7429	0.852	0.018		
Notre Dame Bay	(S)	431	0.9363	-0.8610	0.824	0.017		
Gabarus Bay, N.S.	(A)	146	1.0506	-1.1204	0.899	0.017		
Strait of Belle Isle	(A)	195	1.1684	-1.4444	0.831	0.016		

A = Autumn; S = Spring

Table 47. Comparisons of the log-log regressions of postorbital length on standard length by analysis of covariance for the sexes within each spawning group for each area. (A double asterisk indicates significance at the 1% level.)

Area	Mean squares		Slopes	Mean squares		Adjusted means
	Within	Reg. Coef.	F	Common	Adjusted means	F
			Spring spawners			
Magdalen Islands	3.3549×10^{-4}	2.5424×10^{-4}	0.76	3.3471×10^{-4}	1.4975×10^{-4}	0.45
Southwest Nfld.	3.5202×10^{-4}	2.0435×10^{-4}	0.58	3.5095×10^{-4}	2.2103×10^{-3}	6.30
Placentia Bay	3.8232×10^{-4}	7.8048×10^{-4}	2.04	3.8777×10^{-4}	1.0644×10^{-3}	2.74
Trinity Bay	3.6498×10^{-4}	2.0373×10^{-3}	5.58	3.7024×10^{-4}	4.1070×10^{-4}	1.11
Bonavista Bay	4.5621×10^{-4}	7.9387×10^{-5}	0.17	4.5505×10^{-4}	3.8379×10^{-5}	0.08
Conche	3.0748×10^{-4}	2.0389×10^{-4}	0.66	3.0600×10^{-4}	4.1913×10^{-4}	1.37
Quirpon	4.9017×10^{-4}	9.4593×10^{-4}	1.93	4.9594×10^{-4}	5.8393×10^{-4}	1.18
Hawke's Bay	3.7420×10^{-4}	7.1769×10^{-5}	0.19	3.7294×10^{-4}	4.4578×10^{-3}	11.95**
Fortune Bay	4.2737×10^{-4}	9.7443×10^{-4}	2.28	4.2995×10^{-4}	7.4565×10^{-4}	1.73
St. Mary's Bay	3.2865×10^{-4}	9.0658×10^{-4}	2.76	3.3106×10^{-4}	1.5198×10^{-3}	4.59
Notre Dame Bay	2.8633×10^{-4}	2.0976×10^{-4}	0.73	2.8616×10^{-4}	2.6561×10^{-4}	0.93
			Autumn spawners			
Magdalen Islands	3.0730×10^{-4}	8.2697×10^{-4}	2.69	3.0870×10^{-4}	2.2918×10^{-4}	0.74
Southwest Nfld.	2.7515×10^{-4}	1.1949×10^{-3}	4.34	2.7781×10^{-4}	2.6384×10^{-5}	0.09
Placentia Bay	4.2608×10^{-4}	2.4128×10^{-3}	5.66	4.6927×10^{-4}	6.9470×10^{-4}	1.48
Trinity Bay	2.2978×10^{-4}	3.8200×10^{-4}	1.66	2.3128×10^{-4}	3.0247×10^{-6}	0.01
Bonavista Bay	3.7018×10^{-4}	7.8991×10^{-7}	0.00	3.6767×10^{-4}	7.0829×10^{-4}	1.93
Conche	2.2519×10^{-4}	3.7696×10^{-4}	1.67	2.2733×10^{-4}	5.0239×10^{-6}	0.02
Quirpon	6.4097×10^{-4}	2.3563×10^{-4}	0.37	6.3785×10^{-4}	6.1102×10^{-4}	0.96
Hawke's Bay	4.3278×10^{-4}	1.2124×10^{-6}	0.00	4.2965×10^{-4}	2.6971×10^{-7}	0.00
Strait of Belle Isle	2.4321×10^{-4}	7.2000×10^{-4}	2.96	2.4569×10^{-4}	9.6947×10^{-5}	0.39
Gabarus Bay, N.S.	2.7794×10^{-4}	6.4838×10^{-5}	0.23	2.7645×10^{-4}	6.5203×10^{-4}	2.36

Table 48. Covariance comparisons of the log-log regressions of postorbital length on standard length among all areas for spring and autumn spawners separately. (The double asterisk indicates significance at the 1% level.)

Test	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Among areas spring spawners	Within Samples	2239	8.3268×10^{-1}	3.7190×10^{-4}	2.65**
	Reg. Coefficients	10	9.8559×10^{-3}	9.8559×10^{-4}	
	Common Regression	2249	8.4253×10^{-1}	3.7463×10^{-4}	32.06**
	Adjusted Means	10	1.2010×10^{-1}	1.2010×10^{-2}	
	Total	2259	9.6263×10^{-1}		

At df 10 and ∞ : F(.01) = 2.32

Test	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Among areas autumn spawners	Within Samples	1694	5.5737×10^{-1}	3.2903×10^{-4}	4.93**
	Reg. Coefficients	9	1.4588×10^{-2}	1.6209×10^{-3}	
	Common Regression	1703	5.7196×10^{-1}	3.3586×10^{-4}	87.17**
	Adjusted Means	9	2.6349×10^{-1}	2.9276×10^{-2}	
	Total	1712	8.3545×10^{-1}		

At df 9 and ∞ : F(.01) = 2.41

Table 49. Covariance statistics comparing the log-log regressions of predorsal length on standard length for spring and autumn spawners within each area. (The double asterisk indicates significance at the 1% level.)

Area and spawning group		No. of specimens	Regression coef., k	Intercept log b	Correlation coef., r	St. error of estimate	Covariance analysis Slopes F	Covariance analysis Adjusted means F
Magdalen Islands	(S)	107	1.0879	-0.5116	0.947	0.008	1.16	16.93**
" "	(A)	373	1.0418	-0.3951	0.928	0.008		
Southwest Nfld.	(S)	141	1.0757	-0.4808	0.890	0.008	0.46	7.63**
" "	(A)	348	1.1099	-0.5621	0.932	0.007		
Placentia Bay	(S)	76	1.0179	-0.3405	0.986	0.009	1.34	1.33
" "	(A)	49	0.9661	-0.2112	0.964	0.008		
Trinity Bay	(S)	322	1.0498	-0.4169	0.977	0.009	1.20	6.78
" "	(A)	105	1.1017	-0.5432	0.926	0.008		
Bonavista Bay	(S)	334	1.0227	-0.3504	0.970	0.008	0.43	3.89
" "	(A)	149	0.9984	-0.2883	0.925	0.008		
Conche	(S)	73	1.0234	-0.3494	0.980	0.008	0.10	1.31
"	(A)	74	1.0347	-0.3787	0.979	0.008		
Quirpon	(S)	82	0.9618	-0.1998	0.969	0.007	5.76	0.72
"	(A)	133	1.0652	-0.4534	0.948	0.009		
Hawke's Bay	(S)	243	1.0336	-0.3765	0.974	0.008	1.81	4.69
" "	(A)	141	1.0674	-0.4614	0.978	0.008		
Fortune Bay	(S)	219	1.0427	-0.4023	0.986	0.008		
St. Mary's Bay	(S)	244	0.9807	-0.2441	0.977	0.007		
Notre Dame Bay	(S)	431	1.0230	-0.3467	0.970	0.007		
Gabarus Bay, N.S.	(A)	146	1.0085	-0.3087	0.975	0.007		
Strait of Belle Isle	(A)	195	1.0084	-0.3114	0.936	0.008		

A = Autumn; S = Spring

Table 50. Comparisons of the log-log regressions of predorsal length on standard length by analysis of covariance for the sexes within each spawning group for each area. (A double asterisk indicates significance at the 1% level.)

Area	Mean squares		Slopes	Mean squares		Adjusted means
	Within	Reg. Coef.	F	Common	Adjusted means	F
			Spring spawners			
Magdalen Islands	6.1297×10^{-5}	6.3638×10^{-5}	1.04	6.1319×10^{-5}	1.1196×10^{-6}	0.02
Southwest Nfld.	6.2582×10^{-5}	8.1973×10^{-5}	1.31	6.2722×10^{-5}	5.4789×10^{-5}	0.87
Placentia Bay	7.5867×10^{-5}	4.3039×10^{-5}	0.57	7.5417×10^{-5}	1.1639×10^{-4}	1.54
Trinity Bay	7.3532×10^{-5}	1.1448×10^{-6}	0.02	7.3305×10^{-5}	1.4990×10^{-5}	0.20
Bonavista Bay	6.2287×10^{-5}	1.0254×10^{-4}	1.65	6.2408×10^{-5}	9.2671×10^{-6}	0.15
Conche	5.7852×10^{-5}	1.3016×10^{-4}	2.25	5.8885×10^{-5}	3.9080×10^{-5}	0.66
Quirpon	4.8088×10^{-5}	4.0586×10^{-4}	8.44**	5.2617×10^{-5}	2.4507×10^{-5}	0.47
Hawke's Bay	6.9647×10^{-5}	4.7290×10^{-5}	0.68	6.9554×10^{-5}	2.6316×10^{-4}	3.78
Fortune Bay	6.0996×10^{-5}	1.4666×10^{-5}	0.24	6.0781×10^{-5}	2.6551×10^{-4}	4.37
St. Mary's Bay	5.1413×10^{-5}	1.3226×10^{-5}	0.26	5.1255×10^{-5}	1.2714×10^{-4}	2.48
Notre Dame Bay	4.4437×10^{-5}	3.2556×10^{-6}	0.07	4.4340×10^{-5}	2.0840×10^{-4}	4.70
			Autumn spawners			
Magdalen Islands	6.5366×10^{-5}	1.3089×10^{-4}	2.00	6.5543×10^{-5}	2.9935×10^{-5}	0.46
Southwest Nfld.	5.2454×10^{-5}	1.1492×10^{-4}	2.19	5.2635×10^{-5}	8.2128×10^{-5}	1.56
Placentia Bay	6.9489×10^{-5}	4.6998×10^{-5}	0.68	6.9000×10^{-5}	1.0587×10^{-6}	0.02
Trinity Bay	6.8228×10^{-5}	7.7956×10^{-5}	1.14	6.8323×10^{-5}	4.1280×10^{-5}	0.60
Bonavista Bay	6.0667×10^{-5}	7.6382×10^{-5}	1.26	6.0775×10^{-5}	9.5255×10^{-7}	0.02
Conche	6.9507×10^{-5}	1.8752×10^{-4}	2.70	7.1169×10^{-5}	7.5603×10^{-6}	0.11
Quirpon	7.9315×10^{-5}	2.1388×10^{-4}	2.70	8.0350×10^{-5}	1.6014×10^{-5}	0.20
Hawke's Bay	6.3782×10^{-5}	3.5536×10^{-5}	0.56	6.3578×10^{-5}	3.3433×10^{-6}	0.05
Strait of Belle Isle	5.7682×10^{-5}	5.6927×10^{-5}	0.99	5.7678×10^{-5}	6.6198×10^{-5}	1.15
Gabarus Bay, N.S.	5.5859×10^{-5}	2.9512×10^{-5}	0.53	5.5675×10^{-5}	1.0559×10^{-6}	0.02

Table 51. Covariance comparisons of the log-log regressions of predorsal length on standard length among all areas for spring and autumn spawners separately. (The double asterisk indicates significance at the 1% level.)

Test	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Among areas spring spawners	Within Samples	2250	1.3513×10^{-1}	6.0060×10^{-5}	2.50**
	Reg. Coefficients	10	1.4999×10^{-3}	1.4999×10^{-4}	
	Common Regression	2260	1.3663×10^{-1}	6.0458×10^{-5}	28.50**
	Adjusted Means	10	1.7232×10^{-2}	1.7232×10^{-3}	
	Total	2270	1.5387×10^{-1}		

At df 10 and ∞ : F(.01) = 2.32

Among areas autumn spawners	Within Samples	1693	1.0498×10^{-1}	6.2010×10^{-5}	2.42**
	Reg. Coefficients	9	1.3529×10^{-3}	1.5032×10^{-4}	
	Common Regression	1702	1.0634×10^{-1}	6.2477×10^{-5}	10.59**
	Adjusted Means	9	5.9563×10^{-3}	6.6181×10^{-4}	
	Total	1711	1.1229×10^{-1}		

At df 9 and ∞ : F(.01) = 2.41

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