An Ecological Study of Mackerel *Scomber scombrus* (Linnaeus) in the Coastal Waters of Canada

by K.T. Mac Kay

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AN ECOLOGICAL STUDY OF MACKEREL, SCOMBER SCOMBRUS (LINNAEUS), IN THE COASTAL WATERS OF CANADA

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K. T. MacKay

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An Ecological Study of Mackerel, *Scomber scombrus* (Linnaeus), in the Coastal Waters of Canada

by

K. T. MacKay

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the requirements for the degree of
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ABSTRACT

Commercial catches of mackerel from coastal waters of eastern Canada and New England were sampled in 1965 and 1966 for length, age, meristic counts, sex, maturity and otolith annuli widths. Various tissue were analysed by vertical starch-gel electrophoresis for different enzymes and a tagging program was preformed. A length of 20 cm is reached by the first autumn. First spawning occurs at 30 cm(age II). Females are larger than males. The dominant 1959 year-class shows growth which is slower than the other year-classes and this may be related to competition in the first year. It's growth rate is similar to that of mackerel in the English Channel but much slower than for the 1923 year-class in New England waters. An apparent "Lee's phenomenon" was present. A "Walford plot" did not adequately describe the growth of the 1959 year-class. The dramatic fluctuations in abundance are caused by unequal survival of different year-classes which is related to fluctuating environmental conditions and inversely correlated with the numbers of spawners. In late May the main body of the northern population migrates from the vicinity of Georges Bank toward the coast of Nova Scotia and then into the Gulf of St. Lawrence to spawn and feed. The largest fish arrive first. In autumn the fish withdraw towards Georges Bank. Yearlings migrate in a similar pattern but appear a month later. No differences were found between the northern and southern populations and it is suggested that some of the year-classes found in the two areas belong to the same population. Three major isozymes of LDH are present in mackerel, and extra isozymes were found in brain, eye and kidney.

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I SYSTEMATIC POSITION, DESCRIPTION AND LIFE HISTROY OF THE MACKEREL

The Atlantic mackerel (Fig. 1), Scomber scomberus (Linnaeus 1758), is placed in the Order Perciformes (Berg 1947) or Percomorphi (Reagan 1929), Sub-order Scombroidei and the Family Scombridae, which is closely allied with the Family Thunnidae. Fraser-Brunner (1950) places only two species, Scomber scombrus and Scomber japonicus (Houttuyn), in the Genus Scomber whereas Matsui (1967) includes a third species, Scomber australasicus (Cuvier). Both authors consider the Atlantic chub mackerel, Scomber colias (Gmelin) to be synonymous with Scomber japonicus.

The following description of the Atlantic mackerel was compiled from Bigelow and Schroeder (1953) and Leim and Scott (1966). The body is elongate and fusiform, tapering to a narrow caudal peduncle bearing two short lateral keels but lacking the mid-lateral keel of the Thunnidae. The head is proportionately long (one quarter of standard length), the mouth is large extending to the level of the middle of the eye, each dentary, maxillary, vomer and palatine bone bearing a single row of small, slender teeth. The eye is partially covered by large, anterior and posterior masses forming the transparent adipose eyelids. The first of two dorsal fins originates at the level of the pectoral fin and is supported by 10 to 14 rather weak spines which can be adducted into the mid-dorsal groove; the second dorsal fin is approximately the same length as the first dorsal but only half as high and is supported by 12 (9 to 15) soft rays. The space between the two dorsal fins is twice the base length of the fins. Five (four to six) small finlets follow the second dorsal fin. The caudal fin is broad and deeply forked. The anal fin has one spiny ray and 12 (9 to 14) soft rays. It is followed by five (four to six) anal finlets similar in form to the dorsal finlets. The pectoral fins are located high on the side, a short distance behind the opercular opening; the pelvic fins are small and thoracic in position. The scales are small and the skin has a velvet texture. The lateral line is distinct and the air bladder is absent. The absence of the air bladder and the large space between the two dorsal fins distinguishes the Atlantic mackerel from the other Scombrids.

The upper surface of the body is a steel-blue colour with 23 to 33 dark, wavy bars, stopping about the midline. The pectoral fins are black or dusky, the dorsal and caudal fins are grey or dusky. The jaws and opercula are silvery, the lower sides are silvery and sometimes black spots are present, and the belly is silvery white.

Most adult mackerel measure 33 to 40 cm (13 to 16 in.) in fork length and weigh about 450 g (1 lb). Individuals as large as 56 cm (22 in.) and 1.8 kg (4 lb) are known. Bigelow and Schroeder (1953) indicate the largest recorded specimen weighed 3.4 kg (7.5 lb).

The Atlantic mackerel is found in the eastern coastal waters of the north Atlantic from Spain to Norway, in the Mediterranean and Black Sea and in the coastal waters of the northwest Atlantic from Cape Hatteras to the Gulf of St. Lawrence (Leim and Scott, 1966). Occasionally they occur in large numbers along the east coast of Newfoundland (Templeman and Fleming, 1953) and they have been reported sparingly from the Labrador coast (Leim and Scott, 1966).

The Atlantic mackerel in northern European waters is considered to be a separate race from the Atlantic mackerel in North American waters (Garstang, 1898). The Atlantic mackerel in North American waters has been separated into northern and southern populations termed 'contingents' by Sette (1950).

Mackerel is a schooling pelagic fish living in the coastal waters of the continental shelves. In North American waters they appear to undergo extensive latitudinal migrations which can be correlated with surface temperatures (Sette, 1950). They frequent the surface waters from spring to autumn but disappear from these waters in early winter and are assumed to overwinter at mid-depth near the edge of the continental shelf from Sable Island to Chesapeake Bay.

Mackerel spawn from late April through May south of Long Island. They spawn in May in Cape Cod Bay and in June and July in the Gulf of St. Lawrence. Some spawning occurs on the Atlantic coast of Nova Scotia; Sparks (1929) found eggs but no larvae, however, Martell (personal communication) reports both eggs and larvae were found in St. Margaret's Bay in 1967. The act of spawning has not been observed but is assumed to be simply a shedding of ova and sperm into the water. Mature females produce up to half a million eggs (Sette, 1943). The ova after fertilization vary somewhat in size, averaging 1.0 to 1.2 mm in diameter, each having a single small oil globule averaging

0.3 mm in diameter. The eggs are pelagic, floating in the surface waters above the thermocline. The rate of development is dependent on temperature being two days at 21 C and nine days at 12 C (Worley, 1933). Mackerel eggs hatch at temperatures as low as 9 C. The newly hatched larvae measure about 3.0 mm. Early growth is rapid, the larvae and post-larvae reaching a length of 10 mm in 26 days and 50 mm in 40 days at which size they appear to aggregate and form schools (Sette, 1943).

Mackerel feed on zooplankton, chiefly copepods, larval crustaceans, larval molluscs, and fish eggs and larvae. They also eat small fish and large crustaceans and Nilsson (1914) reported feeding on benthic invertebrates. Feeding behaviour involves both filtering and active pursuit.

II THE ENVIRONMENT OF THE ATLANTIC MACKEREL IN CANADIAN WATERS

(i) Submarine topography

The coastal waters of the Canadian Atlantic overlie a very broad continental shelf marked by the 100 fathom (183 m) contour which extends from 130 km offshore along northern Labrador to 330 km off southern Newfoundland where it has the greatest expanse of all continental shelves. The broad continental shelf west of the Grand Banks forms the Scotian Shelf and Georges Bank.

The continental shelf is cut by three distinct channels. These are from north to south, Hudson Strait, Laurentian Channel and Fundian Channel. These channels profoundly influence the oceanographic characteristics of the water overlying the shelf since they bring water of deeper oceanic origin close to the shore of the continent (Hachey, Hermann and Bailey, 1954). The Laurentian Channel is a deep trench delineated by the 200 m isobath which extends from the edge of the continental shelf almost to the mouth of the Saguenay River, with an arm, the Esquiman Channel, extending toward the Strait of Belle Isle along the northwest coast of Newfoundland. The Magdalen Shallows occupies the southern part of the Gulf of St. Lawrence.

(ii) Circulation of the water masses and their characteristics

The circulation of the water in the Northwest Atlantic of the Canadian coast is influenced by two major ocean currents, the Gulf Stream and the Labrador current (Fig. 2). The Labrador current is characterized by water of lower salinity and lower temperature than that of the Gulf Stream. The interaction of these two masses along with land drainage determines the circulation and physical characteristics of the water masses of the Canadian Atlantic. Four definite areas can be recognized. They are: (a) the Labrador-Newfoundland and Grand Banks area, (b) the Gulf of St. Lawrence, (c) the Scotian Shelf and Gulf of Maine, and (d) the Bay of Fundy (Fig. 3).

(a) Labrador-Newfoundland and Grand Banks area - The Labrador current which originates from the meeting of the Baffin Land current and the West Greenland current flows southward along the Labrador coast. The inshore branch has a lower salinity and lower temperature than the offshore branch. The inshore portion penetrates, at times, into the Gulf of St. Lawrence through the Strait of Belle Isle, and at times water from the Gulf of St. Lawrence moves outward through the Strait of Belle Isle joining the southern flow of the Labrador current along the eastern coast of Newfoundland. The Labrador current meets the northern edge of the Grand Banks, the offshore portion skirts the eastern margin of the Grand Banks and either flows westward towards the region of the Scotian Shelf or turns east to join with the Gulf Stream forming the North Atlantic drift. The inshore portion penetrates into the deep channel separating Newfoundland and the Grand Banks. It reaches the vicinity of St. Pierre Bank and may continue after some modifications and mixing towards the Laurentian Channel. The characteristic properties of the surface of this flow are modified by mixing but at intermediate depths it may be recognized by its low temperature. The surface temperature of the waters off southeastern Newfoundland ranges from a winter average minimum of -0.9 C to a summer average maximum of 12 to 14 C.

(b) Gulf of St. Lawrence - The Gulf of St. Lawrence is an important area for the spawning and development of mackerel (Sette, 1943) and for this reason a detailed description of some of the oceanographic features of this region is given.

The pattern of circulation of the surface waters of the Gulf of St. Lawrence is cyclonic (Fig. 2). From the south, water enters from the east, past Cape Ray and then flows along the west coast of Newfoundland. Part of this flow is deflected at the head of the deep Esquiman Channel, toward the north shore of the Gulf while the remainder continues northward to enter the circulation of the Strait of Belle Isle. The circulation of the Strait of Belle Isle consists of three variable components

(Hachey, 1961); a progressive inward movement of Labrador coastal water on the north side of the Strait, a progressive outward movement of Gulf of St. Lawrence water in the south side of the Strait, and a dominant flow which may be of Labrador coastal water inward or Gulf water outward.

Along the north shore of the Gulf there is a westward drift extending beyond the western end of Anticosti Island. The lower salinity water in the northwest corner of the Gulf, the result of mixing of fresh water discharge from the St. Lawrence Basin, with high salinity water in the estuary, flows along the Gaspe peninsula as the Gaspe current. Between Anticosti Island and Gaspe peninsula this current exceeds depths of 165 m (90 fathoms) and while constant in direction, it is subject to wide variations in strengths. Over the Magdalen Shallows the waters of the Gaspe current lose considerable velocity. The waters of the southern Gulf move eastward toward Cabot Strait forming the Cape Breton current, the main efflux from the Gulf of St. Lawrence.

Three layers of water are present in the Gulf of St. Lawrence in the summer (Lauzier, Trites and Hachey, 1957; Lauzier and Bailey, 1957; and Hachey, 1961): the surface layer, the intermediate layer and the deep layer. During the winter, the surface layer and the intermediate layer merge.

The deep layer is found only in the Laurentian and Esquiman Channels below 100 m and originates from the mixing of the Labrador current and 'slope water'. It has temperatures as high as 5.5 C and salinities greater than 34‰. There is no appreciable seasonal variation in temperature and salinity but the volume of this layer increases from spring to autumn.

The intermediate layer is defined (Lauzier and Bailey, 1957) as the layer of cold water bounded by the horizontal isotherm of 0 C. The lower isotherm is usually below 100 m while the upper isotherm ranges from 70 m to the surface, depending on the season. There is considerable seasonal variation in the thickness of the intermediate layer with a decrease in thickness occurring between spring and autumn. The intermediate layer forms the bottom layer over the Magdalen Shallows.

The surface layer reaches maximum thickness during winter when it merges with the intermediate layer. The spring and summer warming of the surface produces a sharp vertical temperature gradient declining one degree per metre. The thermocline is associated with a corresponding salinity gradient of 0.2‰ per metre. Because of the presence of this marked thermocline in summer, the surface layer is very stable with respect to the underlying layers and therefore offers considerable resistance to external forces which would tend to produce mixing. Lauzier (1957a) showed that when either north or south winds exceeding 24 km (15 miles) per hour lasts at least two days, a tilting of the thermocline results. This tilting is due to internal adjustment of water layers. This internal adjustment causes extreme variations in temperature and salinity, mainly at depth but also near the surface (Fig. 4). Blackford (1965) suggested that cyclonic gyres established by wind action also had significant upwelling effects on the thermocline beneath them.

The surface layer shows seasonal variation in depth, temperature and salinity, but during summer is homogenous as to temperature and salinity from the surface to the thermocline.

The thickness of the surface layer decreases from 100 m in winter when there is no intermediate temperature layer present, to 10 m in July and thickens to 15 m in August over the Magdalen Shallows. The vertical mixing associated with autumnal cooling proceeds at varying degrees in different areas causing regional variation in thickness, but eventually, when mixing and cooling are complete, the surface layer has merged again with the intermediate layer.

The surface layer varies seasonally in temperatures from -1.7 to 20 C (Appendix I), with the northern shore area having a reduced range. From January to March, the surface is normally covered by ice. Vernal warming is related to the ice distribution in late winter and results in temperatures from 2 to 12 C in June. The highest temperatures (in excess of 20 C) may occur in the Magdalen Shallows in July and August. Cooling commences in September, the main part of the Gulf having surface temperatures from 10 to 16 C. Between September and October, the temperature declines by approximately 4 C and then in November further cooling reduces the temperature to an average value of 4 C, varying from 2 C along the Gaspe coast to 9 C along the Cape Breton shore.

Salinity of the surface water decreases from a high value of 32‰ in spring to less than 30‰ and often as low as 26‰ in summer with lower values being recorded in bays and estuaries. Because of vertical mixing during autumnal cooling and lack of precipitation or runoff, the salinity of the surface layer increases to a range of 29‰ to 31‰. The minimum salinity over the Magdalen Shallows is reached from June to August which Lauzier (1957b) shows is related to the maximum discharge of the St. Lawrence River with a three-month lag.

(c) Scotian Shelf and Gulf of Maine - The Gulf Stream recognized by its high temperatures and high salinities, meanders as close as 425 km (230 nautical miles) and as far away as 780 km (420 nautical miles) from the coast of Nova Scotia. These meanderings have an indirect effect on the waters of the Scotian Shelf, due to the adjustments of the water masses that are associated with the changing position of the Gulf Stream.

At the confluence of the Labrador current and the Gulf Stream, the large scale mixing produces the 'slope water'. This influences the circulation of the Scotian Shelf both by gradual mixing and direct incursion onto the Shelf (Hachey, 1961).

The outward flow of water from the Gulf of St. Lawrence, the Cape Breton Current, spreads westward (Fig. 2) along the Shelf. The original characters of the water of the Gulf are lost by mixing with the more saline slope waters.

The circulation of the surface water of the Gulf of Maine shows an anticlockwise movement (Fig. 2) which takes the mixed water from the Bay of Fundy along the coast of Maine and mixes it with the discharges of several rivers. Some of this water flows past Cape Cod while the remainder follows the inshore edge of Georges Bank toward Nova Scotia. Some of it returns to the Bay of Fundy while the remainder discharges around the northern edge of Georges Bank (Hachey <u>et al</u>, 1954).

In summer, the waters of the Scotian Shelf and Gulf of

Maine are strongly stratified in temperature and salinity and form a three-layer system. This three-layer system is somewhat similar to that in the Gulf of St. Lawrence (Hachey, 1961).

The surface layer which may have a thickness of 75 m (40 fathoms) in summer, has a wide seasonal range of temperatures from 5 C to 20 C, and a salinity of less than 32‰. Inshore waters consist entirely of this layer. The intermediate layer which ranges between 30 m (17 fathoms) and 145 m (80 fathoms) in thickness, is characterized by temperatures less than 5 C to a low of 0 C, and salinities between 32.0‰ and 33.5‰. This layer is formed by the transport of water from the Labrador current and is continuous, at least during part of the year, with the similar layer in the Gulf of St. Lawrence.

The bottom layer which lies between the 50 fathom (90 m) and 100 fathom (183 m) contours has temperatures above 5 C, frequently as high as 8 C and at times due to incursion of slope water over the bottom of the shelf, it has temperatures as high as 12 C.

(d) Bay of Fundy - The circulation in the Bay of Fundy is generally cyclonic (Fig. 2). An inward movement of water along the coast of Nova Scotia from the Cape Sable area and from further offshore in the Gulf of Maine, constantly loses water to the New Brunswick side as it moves toward the head of the Bay. The movement along the coast of New Brunswick is westward and flows outward east of Grand Manan into the Gulf of Maine. The dominant feature of oceanographic conditions in the Bay of Fundy is the effect of strong tides which causes a complete mixing and produces a homogenous mass of water as to temperature and salinity. Seasonal changes in temperature and salinity in the Bay of Fundy are much less than in other parts of the Canadian Atlantic region.

III HISTORY OF THE FISHERY

(i) Annual commercial catch, 1876 to 1966

The commercial catch of mackerel in the Atlantic waters of North America has fluctuated widely. Fluctuations in the Canadian catch are shown in Figure 5.

The period from 1880 to 1884 was one of extraordinary abundance as indicated by both the Canadian and United States catches (Sette and Needler, 1934), with the highest recorded total catch of 233 million pounds occurring in 1884. The Canadian catch of 55 million then declined drastically to 8 million pounds in 1897. Subsequently there was a period of fluctuating relatively low catch culminating in the lowest recorded catch of 7 million pounds in 1910. This coincided with a drastic low point in the United States catch of only 3 million pounds. The Canadian catch then began a gradual increase fluctuating between 14 and 29 million pounds up to 1939 when it increased abruptly to 52 million pounds. The United States catch showed an eightfold increase between 1910 and 1926 which, as Sette (1950) showed, was the result of the successful survival of the 1923 year-class. From 1940 to 1959, the Canadian catch declined erratically to a low of 9 million pounds. The decrease from 28 million pounds in 1955 to a low point in 1959 may be partially accounted for by the fungus disease

Ichthyophonus (Ichthyosporidium) hoferi which between 1954 and 1957 decimated half the herring population in the Gulf of St. Lawrence (Sinderman, 1966). Mackerel stocks were also infected by the fungus and similar mass mortalities may have occurred. The catch since 1959 has gradually increased to 25 million pounds in 1966 which as shown in this study is the result of a successful 1959 year-class.

In addition to Canadian and United States catches, Russia has taken large quantities of mackerel in the International Commission for the Northwest Atlantic Fisheries (ICNAF) Convention area (Table I). All the Russian catches in 1966 were made by otter trawls towed by larger trawlers (over 1800 metric tons). The months of January to May yielded 70% of their catches, with the largest catch occurring in February. Most of these catches were made on the south and northwest slopes of Georges Bank (Day, personal communication).

(ii) Distribution of catch

Mackerel are caught in Canadian Atlantic waters from the Bay of Fundy to the Atlantic coast of Nova Scotia, throughout the Gulf of St. Lawrence, and periodically on the east coast of Newfoundland.

From 1957 to 1966, 45% of the commercial catch was taken from the waters of the Gulf of St. Lawrence and 55% from the waters of the Atlantic coast of Nova Scotia and the Bay of Fundy. The catches in Newfoundland waters have varied from zero in 1959 to a high of 2.2 million pounds in 1961. The 1961 catch was 18% of the Canadian total, with the largest catches being made on the east coast, particularly in Notre Dame Bay. This recent appearance of mackerel in the eastern coastal waters of Newfoundland has been related to a general warming of the surface waters (Templeman and Fleming, 1953).

The seasonal distribution of catch by area for the years 1924-1929 and 1957-1966 is shown in Figures 6a and 6b. A comparison of Figures 6a and 6b shows little change in the seasonal distribution of commercial catches in the past 40 years.

Mackerel are captured first in late May along the Atlantic coast of Nova Scotia with maximum catches occurring in June and smaller catches occurring from July through until December. Mackerel are caught in the Gulf of St. Lawrence from June to November with maximum catches occurring in June along the southern shore and Gaspe coast and in July along the North Shore. In August and September, large catches are made around the Magdalen Islands and Prince Edward Island while the maximum catch off the Cape Breton shore occurs in October. Along the east coast of Newfoundland, mackerel are caught from August to November with the maximum catch usually occurring in October. In the Bay of Fundy and around southwestern Nova Scotia, mackerel are taken from May to November with the largest catches occurring in July and August.

The seasonal distribution of catch is dependent on many factors, such as the type of gear, weather conditions, the pattern of other fisheries, and availability and behaviour of the fish. However, the seasonal distribution of the catch is suggestive of a pattern of migration and this, in conjunction with other evidence, enables the compiling of a scheme for migration.

(iii) Types of Gear used in the Fishery

Historically the oldest method of catching mackerel is by hook and line using minced fish as bait to attract the schools. In the middle of the 19th century, this was the main method of fishing for mackerel. This method is still used commercially around the Magdalen Islands and is the basis for one aspect of the tourist industry in Prince Edward Island. Elsewhere in the Gulf of St. Lawrence, hook and line is used to catch small quantities of mackerel for domestic consumption or bait.

Both fixed and drifting gill-nets were used to catch mackerel in the 19th century. Fixed gill-nets of 2½ to 3¼ in. (62.5 to 82.5 mm) stretched mesh are used along the coast of Nova Scotia, in Northumberland Strait and along the coast of Newfoundland. Drifting gill-nets are used off Alberton and in Egmont Bay, P. E. I., and in the Bay of Chaleur.

The capture of mackerel by purse seine was introduced in 1870 and became the main method of capture by fishermen of the United States. Canadian fishermen did not use purse seines until late in the 19th century. Purse seines are now used along the northern shore of Prince Edward Island and in the autumn along the Cape Breton shore of the Gulf of St. Lawrence. In 1965 and 1966, purse seines accounted for about one-third of the total catch.

Trap nets have been used on the Atlantic coast of Nova Scotia for at least 40 years. Trap nets are now in use at Cape Sable Island, Mahone Bay, St. Margaret's Bay, Little Harbour, Petit de Grat, St. Ann's Bay and Ingonish. Weirs or pole traps which are used in the Bay of Fundy sardine fishery occasionally capture mackerel. Trap nets and weirs in 1965 and 1966 accounted for about one-third of the total catch.

IV NATURE OF THE PROBLEM

Sette (1950) suggested that the North American mackerel was segregated into a northern and a southern population. To test this hypothesis, mackerel from the eastern coastal waters of Canada, and from the coastal waters of New England were sampled in 1965 and 1966 for length, age, sex and meristic counts. Fish from the two areas were then compared with respect to size and age composition, growth rate and meristic characteristics. In an attempt to find genetic differences between fish from the two areas, vertical starch-gel electrophoresis was used to compare enzyme pattern of tissues from fish representing the two populations.

Information concerning the migrations of mackerel was obtained by tagging and subsequent recapture, analysis of length frequencies and catch statistics, and interviews with persons associated with the mackerel fishery.

During the study of age composition, it became apparent that the year-class of 1959 was dominant. Length frequencies of samples from 1962 to 1964 (unpublished records, Fisheries Research Board, St. Andrews, N. B.), and for 1960 and 1961 from Bergeron (1961 and 1962) were employed for the calculation of the growth rate of this year-class and for comparison of it with growth rates of other year-classes in the fishery. In addition, axial width of each annular zone of the otolith was measured to enable a comparison of otolith growth with total growth. Some factors that may be responsible for the good survival of the 1959 year-class and the poor survival of subsequent year-classes are proposed.

V AGE AND GROWTH STUDIES

(i) Methods

(a) Body lengths - A random sample of 100 fish for length measurement was obtained from commercial catches landed at fishing ports between Yarmouth and Ingonish on the Atlantic Coast of Nova Scotia; from the Magdalen Islands, Prince Edward Island and Caraquet, N.B., in the Gulf of St. Lawrence; and in New England from Plum Island to Provincetown, Mass. In addition, samples of frozen mackerel were obtained from Rumson, N.J., and from the Gulf of Maine. As mackerel are usually packed indiscriminately into boxes of approximately 100 fish, a sample was taken from a single box. On occasions when the fish were not packed, a selection of fish of any particular size was avoided. Often when sampling gill-net catches, less than 100 fish were available while some other measurements contained more than 100 fish.

Lengths were determined using a standard measuring board of heavy plexiglass with a moveable arm. The measurement to the nearest millimeter was taken from the tip of the snout to the tip of the rays at the middle of the tail. This measurement corresponds to 'fork length', 'median length' and 'midcaudal length' of other authors (Ricker and Merriman, 1945).

Measurements of body lengths from 1962 to 1964 (unpublished records, Fisheries Research Board of Canada, St. Andrews,

N. B.) were in total lengths; that is, the length from the tip of the snout to the tip of the longest rays of the caudal fins when compressed. Fork lengths and total lengths were determined from 1017 fish in 1965 and 1966 and a conversion factor was calculated from these data. The relationship between fork length and total length was assumed to be linear; therefore, to obtain a conversion factor, the sum of fork lengths was divided by the sum of the total lengths. The conversion factor was then applied to the measurements of 1962 to 1964 and to the measurements of Bergeron (1961, 1962).

(b) Age-determination - Dermal scales of teleost fishes are often used for age determination (Rounsfell and Everhart, 1953) and have been used for Atlantic mackerel, Nilsson (1914) and Steven (1950). These scales, although easy to obtain, are deciduous and cause uncertainty as to the source of any scale when these fish are collected in groups. Otoliths are more difficult to obtain but have been found to be more reliable for use in age-determination of mackerel (Steven, 1950) and have been used throughout this study.

Three pairs of otoliths, the lapilli, the sagittae and the asterisci are found within the inner ear. These bones are enclosed in membranous sacs known respectively as utriculus, sacculus and lagena. The utriculus is found immediately lateral to the neurocranium and controls the postural responses. The sacculus and lagena, located in pits in the floor of the neurocranium are closely associated with hearing (Lowenstein, 1957). The sagitta, the largest of the otoliths has broader zones of opaque material with a higher content of organic material than the alternating zones of translucent material (Fitch, 1951). They have been found suitable for age-determination in the Pacific mackerel in the coastal waters of California (Fitch, 1951). The alternating zones have been also assumed to be annular zones in the Atlantic mackerel and have been used for age-determinations by Nilsson (1914), Steven (1950), and Sette (1950). Steven reports that more reliable readings were obtained from the blunt posterior end while the rostrum, the pointed anterior end, contained secondary markings. However, during the present survey the markings on the rostrum appeared to be the clearest and have been used as the prime source for age-determinations.

One sample of a 100 fish was obtained on the average of once a week from those sampled for body lengths. The otoliths were collected by making a transverse incision, posterior to the otolith through the head at the level of the first colour bar. Both sagittae were extracted from the sacculus using forceps. The sagittae were placed on the back of the hand and the casing was removed with forceps. Then, the pair of otoliths was placed in a numbered slot in a tray holding 100 otoliths and stored dry. Subsequently, the otoliths were removed from the holding tray and permanently mounted in depressions in black plexiglass using ethylene di-chloride (Watson, 1965). Pairs of otoliths from 50 fish were mounted on each plexiglass block with details of the collection inscribed on the block with white ink.

Counts of the annular opaque zones were made by stereoscopic observation of the otoliths immersed in 95% ethanol. Nuclei were omitted from the counts. Ages and year-classes (i. e., year of birth) were recorded without reference to the body length to avoid bias. Where there was doubt as to the accuracy of the age-determination due to indistinct or fused winter zones, the ages were not recorded. All otoliths were aged a second time without reference to the first readings. In addition to otoliths from the 1965 and 1966 study, a few otoliths were available from 1963 and these were mounted and examined in a similar manner.

(c) Otolith measurements - Widths of otoliths were measured with a stereoscopic microscope equipped with a drawing tube to superimpose the image of an otolith onto the image of co-ordinate paper with 1 mm graduations placed on a bench. The otolith was placed so that its longitudinal axis corresponded to that of the coordinate paper and measurements were made along the anterior-posterior axis of the otolith. The total length of the otolith was measured from the lower blunt edge to the tip of the rostrum, and each adjacent annulus was measured from the posterior distal part of the opaque zones to the anterior distal part of the same zone (Fig. 7). When one or more of the annuli were not clearly defined, they were not measured but the otolith was used in an assignment of age.

All otoliths from the 1963 samples were measured but the collection of otoliths from 1965 and 1966 were too numerous to permit measurements of all, so a sample was selected at random by drawing numbered cards.

Measurements of five otoliths, which were made with a graduated ocular lens were compared with those made using the drawing tube and coordinate paper. The measurements after correction for magnification were identical. Use of the drawing tube and coordinate paper was a more rapid and convenient technique.

Since the right otolith is larger than the left from the same individual in the Pacific mackerel (Kondo and Kuroda, 1966), both right and left otoliths from 33 fish were measured and the results indicated there was no difference between the left and right otolith in the Atlantic mackerel.

(ii) Results

(a) Body lengths - The mean lengths of 800 fish sampled from commercial catches during a four-day period June 6 to 9, 1965, in Halifax Co. and of 395 fish landed at Malpeque Harbour, P. E. I., are given in Table 2. Only the samples with the smallest and largest means from Halifax Co. are significantly different ($P < 0.05$) while the mean lengths of the samples from Malpeque Harbour do not differ significantly ($P > 0.05$). This indicates a high degree of homogeneity among the samples taken within a short period of time and at adjacent locations. This made it possible to assemble the length-frequencies into monthly groupings for different areas.

Selection of a relatively narrow size range of fish is a well known attribute of gill-nets (Leim, Tibbo and Day, 1957). Figure 8 shows that a gill-net of 3 in. stretched mesh captured larger mackerel than purse-seine gear on the same day near Malpeque Harbour (significant at $P < 0.05$). Such selectivity was not shown by 2 7/8 in. stretched mesh gill-nets in Halifax Co., June, 1965 (Table 2). The selective nature of gill-nets is not an important factor in the sampling procedure since only 10% of the samples in 1965 and 1966 was obtained from gill-nets. Trap nets, purse-seines and hook and line were all assumed to be non-selective within the size range of fish measured during this survey.

The conversion factor from total length to fork length was calculated to be FL = .916 TL (Appendix IIIa). To check the validity of the conversion factor, it was applied to the means of the samples with the largest and smallest lengths from which both total and fork lengths were available (Appendix IIIb). The difference between the measured and calculated fork length was only 1 mm for the smallest and 0.3 mm for the largest measurements. The conversion factor was then applied to the measurements of Bergeron (1961, 1962) and to the data for 1962 to 1964.

Length frequencies in monthly intervals for the different areas in Canadian waters for the years 1960 to 1966 are shown in Figure 9 and the detailed length frequencies are found in Appendix IV.

The largest group (group A) is present only in May and June, 1962, May, 1963, and May, 1964. This group makes up a decreasing per cent of length frequencies from 1962 to 1964 and disappears in 1965.

The persistent group (group B) is present in all samples between 1960 and 1966, except October, 1962, and August, 1965 and 1966, for Yarmouth Co., and is dominant in most of the length-frequencies.

A different group of small fish appears every year along the coast of southwest Nova Scotia but these do not appear to be distinct in following years. A group of very small fish (95 to 125 mm) was present in October, 1962, but this group was not found in succeeding years.

The mean lengths for May are significantly larger ($P<0.01$) than those for June in 1962 to 1966 for southwest Nova Scotia (Table 3). It is apparent from the length frequencies (Fig. 9) that this difference is due to the presence of larger fish of group B and a higher percentage of fish from group A. The length frequencies of fish found in southwest Nova Scotia in June are very similar to those found in the Gulf of St. Lawrence in July and the difference between the means is not significant ($P>0.05$).

The length frequencies for the coastal waters of New England for 1965 and 1966 are shown in Figure 10. The group which was found in September, 1965, (group E) is not apparent in the 1966 length frequencies. The group (group F) which was found at Provincetown in July was present again in September and the increase in size is assumed to represent growth. A group of small fish (group G) were sampled from New Jersey in September, 1966.

A comparison of the length frequencies for 1966 from Canadian waters with those from New England waters, shows the absence of group B from southern waters. Group F which was dominant around Provincetown in 1966 was also present in July and August along southwest Nova Scotia.

(b) Age-determination - Steven (1950) showed that age-determination from otoliths agreed with those of scales taken from mackerel captured off southwest England. He stated that the central opaque zone was deposited first and then followed by a narrow translucent zone formed during the first winter. This pattern of deposition was continued in subsequent years with the opaque zone being formed during the summer and the translucent zone during the winter.

Examination of otoliths taken in early July and again in September, 1966, showed an increase in the average width of the opaque zone during that period (Fig. 11b, c). Examination of length frequencies (Fig. 9) showed that one group (group B) had been dominant since 1960. This group of fish had identical measurements for the first four annuli on the otolith in 1965 and 1966. Further examination showed that in 1966 this group of fish (group B) had one more translucent zone than in 1965. This suggests that the translucent zone was formed during the winter and the opaque zone during the summer.

The otoliths from fish 135 to 175 mm in length, sampled in September, showed only an opaque nucleus and were assumed to be age 0 (Fig. 11a). The otoliths from the next size-group of fish 185 to 295 mm showed an opaque nucleus surrounded by a translucent zone and the beginning of an outer opaque zone (Fig. 11b, c). These fish were assumed to be age I. In subsequent years, an opaque zone was assumed to be formed during the summer, being noticeable first in late July and a translucent zone during the winter.

The increase in size with increasing age and the consistent agreement of ages of fish belonging to the dominant group sampled in 1963, 1965 and 1966 supports the validity of the use of otoliths in age-determination.

Estimates of age were made from 2550 otoliths and only 12% (309) of these were unreadable. There was close agreement between first and second age-determinations from the otoliths, 100% for otoliths which were assigned to age-class I, II and III, while for groups assigned higher ages there was approximately 90% agreement.

The distribution of year-classes sampled in 1965 and 1966 is given in Figure 12. In 1965, the 1959 year-class was dominant in samples taken in waters of the Atlantic coast of Nova Scotia in May and June and in the Gulf of St. Lawrence in July and August. In 1966, the 1959 year-class was dominant in samples from both areas. The samples from southwest Nova Scotia for July and August, 1965, showed that the 1964 year-class was dominant.

In samples from Massachusetts in 1966, trap-nets at Provincetown yielded only fish of the 1965 year-class. Samples from the purse-seine fishery near Provincetown and the sample taken by hook and line near Plum Island were dominated by the 1964 year-class. The sample from Rumson, N. J., taken in September, 1966, contained only fish-of-the-year.

The mean length of fish of the various year-classes sampled in 1963, 1965 and 1966 from Canadian waters and in 1965 and 1966 from New England waters are given in Tables 4 and 5. A detailed presentation of this data by area and month may be found in Appendix V. Examination of this data shows no apparent increase in length during summer in the samples from Canadian waters. This has allowed the combination of this monthly data and this is presented in Table 4.

(c) Otolith measurement - The mean widths of the successive annular zones on the otoliths from fish samples in Canadian waters in 1963, 1965 and 1966, and from New England waters in 1966 are given in Tables 6 and 7. The measurements of corresponding annular zones for fish which belonged to the 1959 year-class sampled in 1963, 1965 and 1966 are almost identical. The few otoliths measured from the 1960 year-class had similar successive annular zone widths to those of the 1959 year-class. The measurements of successive annular zones of the other year-classes were all larger than for the 1959 and 1960 year-classes. The 1965 year-class sampled in October from Canadian waters had the largest first annular zone.

The width of the first otolith annuli from Canadian and United States samples are compared in Table 8. The 1965 year-class from Canadian waters had significantly larger ($P < 0.05$) annuli than those from that year-class from Massachusetts. While the 1963 and 1964 year-classes did not differ significantly ($P > 0.05$). The other year-classes could not be compared because there were not sufficient numbers of fish from the southern samples.

VI SEX AND MATURITY STUDY

(i) Methods

The sex of 1748 fish sampled in 1965 and 1966 was determined by examination of the gonads during autopsy. The ovaries are yellow and the testes are grey to white. The gonads of immature fish could not be identified for sex. The stage of maturity was determined visually and classified into four stages (Table 9).

(ii) Results

The male to female sex ratio in 1965 was 52:48 (1131 fish) and in 1966, 49:51 (617 fish).

The data on stage of maturity (Table 10) show that in 1965 and 1966, fish sampled from the coastal waters of Nova Scotia from May to June 25 were almost all maturing, while none were ripe and running. The samples from the Gulf of St. Lawrence in 1965 showed that from July 12 to 20, 72% of the fish were spent, 24% were ripe and running, while only 2% were maturing. This indicates that spawning occurs in the Gulf of St. Lawrence in June and July.

In 1965, only one of the 510 fish of Age-I was mature while none of the Age-I fish were mature in 1966. Eight per cent of the Age-II fish were immature in 1965 while 18% were immature in 1966. None of the Age-III fish in 1965 were immature and only 3% of this age in 1966 were immature. Thus, first spawning in 1965 and 1966 occurred at Age-II with a few individuals not spawning until Age-III. The smallest mature fish (Age-II) were 275 and 289 mm long in 1965 and 1966, respectively. Both of these fish were males, whereas the smallest mature females were above 300 mm in both years.

Mean lengths were calculated separately for males and females (Table 11) and the difference between the means for the 1965 and 1966 samples were significant ($P \leq 0.05$), with the females being larger than the males. The females in the 1963 samples were also larger but the difference was not significant ($P > 0.05$). The difference between males and females in 1965 and 1966, although significant, was small when compared to the annual growth increment for these years. Because of this small difference and the absence of information on the sex of the samples for 1960 to 1962 and 1964, the length frequencies for the two sexes were combined in deriving the growth curves.

VII TAGGING STUDY

(i) Methods

A total of 2407 live mackerel obtained from the commercial fishery were tagged in 1966. The live fish were transferred directly from the capture gear into holding nets suspended in the water which allowed fish to be kept in good condition for at least an hour. Each fish was dipped from the retaining net and held gently at the head and tail in an upright position on the gunwale. The fish were marked with red Watson-Larsen tags, prepared in lots of 100, with each tag in a lot bearing the same code. If any lot was not completely used during a single day of tagging, the remainder of that lot was destroyed.

Two methods of application of the tag were employed (Fig. 13). In the first, a modified sewing needle with its contained tag was thrust through the skin between the first and second dorsal fins. After removal of the needle, the barbed tip was inserted into the opposite end of the hollow plastic shaft to form a ring. This operation was difficult to perform under field conditions but was used to mark 410 fish. In the second method of application, a hypodermic needle (No. 12) was used to insert the barbed end of the tag into the dorsal muscles just posterior to the first dorsal fin so that the barb of the tag hooked on the posterior fin rays of the first dorsal, then the needle was withdrawn.

Each fish was released immediately after the tag was applied. A reward of $1.00 was offered for the return of each tag and for information about the place and date of capture.

(ii) Results

The results of this tagging program during the summer of 1966 are given in Table 12, a more detailed tabulation of the results is found in Appendix VI.

The single recapture from the tagging at St. Johns Is., N. S., on June 9 was made in the vicinity of tagging, 13 days later. Three of the recaptures from the tagging at Clarkes Harbour on June 13 were made in the vicinity of the tagging from one to 27 days later. The other three recaptures were made along the coast of Cape Breton. One of these, taken 12 days later at Ingonish, was 660 km northeast of the release site while the other two were recaptured 29 days later and 500 km from the release site at Petit de Grat and West Arichat within a few km of each other. Five of the recaptures from the tagging at Clarkes Harbour on June 20 were within 24 km of the release point. The other recovery was questionable since the tag was found on board a swordfish longliner among bait which was believed to have come from St. Margaret's Bay.

All recaptures from the tagging at French Village, St. Margaret's Bay, on July 23 were made within the Bay. Fourteen recoveries were made within two days of tagging and these fish were released again. The remaining 11 recaptures were made from 4 to 78 days later.

There were only six recaptures from the tagging in the

Gulf of St. Lawrence near Malpeque Harbour, P. E. I., all within the vicinity of tagging.

VIII MERISTIC CHARACTERS

(i) Methods

(a) Vertebral numbers - Vertebral columns of 200 fish from the Atlantic coast of Nova Scotia were prepared by boiling the fish and removing the myomers. All units were counted except for the basi-occipital and the urostyle.

Radiographs of 54 fish captured at Provincetown, Mass., September 14, 1966, were obtained using the method of Bartlett and Haedrich (1966). The fish were covered by a mixture of one-half water and one-half ethyl alcohol, and the radiographs were taken at 50 ma, 30 kv, and 30 secs. Radiographs also were taken of 48 fish from Halifax, October 20, 1966, using exposures of 1/10 sec at 70 kv. The vertebrae were counted from the radiographs.

(b) Fin-ray and finlet counts - The rays of the second dorsal and of the anal fin were counted *in situ*. The first short spiny ray of the anal fin was not counted. The number of dorsal and anal finlets was determined by inspection. In some cases, the anterior finlet appeared to be joined to the second dorsal fin or anal fin and was counted as a part of the associated fin.

The samples used for the counts were obtained from the Atlantic coast of Nova Scotia, the Gulf of St. Lawrence, and Provincetown, Mass., in 1965 and 1966.

(ii) Results

(a) Vertebral numbers - Vertebral counts were obtained from 242 fish in Canadian waters and of these, 241 had 30 vertebrae while only one had 31 vertebrae. The radiographs of 54 fish from Provincetown, Mass. indicated that 52 had 30 vertebrae, one had 29 and one had 28 vertebrae. The difference in the mean number of vertebrae from mackerel of the northern and southern areas is not significant.

(b) Fin-ray and finlet counts - The mean counts of the fin rays and finlets are given in Tables 13, 14 and 15 and the frequency distributions are found in Appendix VII, a, b and c.

Both the samples from Provincetown, Mass., and the sample from Halifax, N. S., in 1966, belonged to the 1965 year-class. The difference between the mean counts of second dorsal rays from the two areas shows that the Provincetown sample had a significantly higher count than the Halifax sample ($P < 0.05$). The Provincetown sample also had significantly higher counts than any of the other samples ($P < 0.05$). The samples from the Atlantic coast of Nova Scotia in May and June had smaller mean counts for the second dorsal fin rays than the samples from the Gulf of St. Lawrence. ($P < 0.05$)

The mean counts of the rays of the anal fin and the counts of the dorsal and anal finlets did not differ significantly in any of the samples.

IX BIOCHEMICAL STUDIES

(i) Introduction

Lactate dehydrogenase (LDH), which catalizes the interconversion of pyruvate and lactate with the aid of the cofactor nicotinamide adenine dinucleotide (NAD), exists as a tetramer of two monomeric units A and B, controlled by separate gene loci (Markert, 1965). The combination of these monomers results in five multiple forms (LDH-1 to LDH-5) or isozymes, in mammals. The isozymes have species specific patterns and different concentrations of these isozymes are found in different tissues. LDH-1 consists of four B-monomers, LDH-5 consists of four A-monomers, whereas LDH-2, LDH-3 and LDH-4 consist of combinations of the A and B monomers (e. g.; LDH-2 is AB_3, LDH-3 is A_2B_2 and LDH-4 is A_3B). LDH-1 predominates in tissues richly supplied with oxygen while LDH-5 predominates in tissues subjected to periodic hypoxic conditions.

The five isozymes of LDH frequently show sub-banding. Markert (1965) has suggested three explanations: the existence of additional monomers under the control of further gene loci; the existence of permutations of the monomers within the five major bands (e. g.; a tetramer with a sequence ABAB might differ in mobility from a tetramer with the same subunit composition but with a different sequence ABBA); the existance of mutant alleles at any of the existing loci.

The LDH pattern of fish differs considerably from the mammalian pattern. Markert and Faulhaber (1965) studied 30 species of teleosts and found isozymes LDH-1, 2, 3, or 5 among the various species. The majority of the species, including the Atlantic mackerel possessed only two bands. An additional minor isozyme of LDH with a strong negative charge was found in eye tissue of most of the species.

Malate dehydrogenase (MDH) catalyzes the interconversion of pyruvate and malate with the aid of the cofactor NADP. Henderson (1966) found two isozymes of MDH in mice, one in the mitochondrial fraction of the heart muscle and the other in homogenate of liver. These isozymes are composed of subunits under genetic control.

Aspartate aminotransferase (AAT) occurs both as a bound and a soluble enzyme and has been shown by various workers (reviewed by Odense _et al_ 1966 a) to possess different electrophoretic mobility, molecular weight, solubility and pH optima. The mitochondrial and soluble forms of the enzyme in herring are under separate genetic control, and the soluble AAT is a dimer (Odense _et al_ 1966 a). The sub-banding in the soluble form was caused by a mutant allele.

The determination of the allele frequencies of mutant forms of the isozymes of cod (_Gadus morhua_) and herring (_Clupea harengus_) lactate dehydrogenase (LDH) and of herring aspartate aminotransferase (AAT), has been used to characterize populations of these species (Odense, Allen and Leung, 1966, b, c). In the hope that similar polymorphism would be found among mackerel enzymes, numerous enzyme systems (malate dehydrogenase (MDH), LDH, AAT and esterase) were examined by gel electrophoresis of tissue extracts followed by specific staining for enzyme activities.

(ii) Methods

Mackerel were collected in 1966 along the Atlantic coast of Nova Scotia and in the Gulf of St. Lawrence from May to October; and from Provincetown, Mass., and Rumson, N. J., in July and September. The appropriate organs were removed from fresh fish and either extracts were made immediately or frozen for later extraction; or the whole fish was frozen, the appropriate organs removed and extracts were made. The fish were also measured and the ages and sexes were determined.

Extracts of skeletal white muscle, skeletal red muscle, heart muscle, brain, eye, kidney, liver, spleen, intestine, gills, testes and ovaries were prepared by blending one part of the tissue with two parts of a 0.25 M sucrose and 0.001 M, EDTA (ethylenediaminetetraacetic acid) solution for one minute at 0 C in a Servall Omnimixer. After the preliminary work, a combined extract of heart and white skeletal muscle was used. The extracts were contrifuged at 12,000 g for 30 minutes and the supernatants were used directly for electrophoresis.

Electrophoresis of the extracts was performed by the vertical starch-gel procedure of Smithies (1955) using a tris-EDTA-borate buffer (Odense et al, 1966 a), consisting of 15.1 g tris (hydroxy-methyl) aminomethane (Tris), 1.5 g EDTA and 1.15 g boric acid made up to one liter with distilled water, adjusted to pH 8.6. The running time was 6 hours at a constant voltage of 400 and a current of 40-50 mA or 18 hours at 300 v at a current of 25-30 mA. Following electrophoresis, the starch blocks were sliced in half, stained and photographed using a Polaroid MP-3 camera.

The LDH bands were stained by incubation of a half-block in a staining mixture which was essentially that described by Dewey and Conklin (1960) and modified by Odense et al (1966 a) and which consisted of tris-HCl buffer, 0.2 M, pH 8.0, 12.5 ml;

sodium-L-lactate, 2.0 M, pH 7.0, 1.5 ml; p-nitro-blue tetrazolium salt (NBT), 0.5 mg/ml, 37.5 ml; phenazine methosulfate (PMS), 0.2%, 0.6 ml; nicotinamide-adenine-dinucleotide (NAD), 350 ml. The gels were developed from one to three hours depending on the LDH activity and washed in distilled water.

The procedure for the development of the MDH gels was similar to that used for LDH, with malic acid, 0.25 M, 1.5 ml being substituted for sodium-L-lactate.

The NAD-analog was used in place of NAD in the staining mixture for LDH and MDH in a few cases.

The AAT activity was detected by incubation of one-half the gel in a staining mixture described by Odense et al (1966 a). The staining mixture consisted of 25 ml of the buffered solution (containing 146.1 mg α ketoglutaric, 532.4 mg L-aspartic acid, 5.68 g sodium orthophosphate di-hydrogen (NaH_2PO_4), 2.0 g polyvinylpyrrolidone (PVP), 0.2 g EDTA, dissolved in water to make 200 ml of solution adjusted to pH 7.4; and 25 ml of a diazonium salt solution (consisting of 5 mg, 6-benzamide-4-methoxy-m-toluidine diazonium chloride per millimeter). The gels were incubated for 30 minutes to one hour and then washed in distilled water. When extracts from frozen tissues were used, pyridoxyl-5-phosphate was added to the extract prior to electrophoresis, to restore activity.

Esterase activity was determined by incubation of the starch gel in a staining mixture adapted from Lawrence, Melnick and Weiner (1960) containing tris-malate buffer, 0.1 M, pH 5.2, 50 ml; 8-hydroxy-quinolene glucuronide, 15 mg; and 20 mg, blue

RR salt. The starch-gels were developed from one to two hours and washed in distilled water.

The effect of temperature on the enzymes was tested by subjecting some of the extracts to temperatures of 20 C, 35 C and 50 C for 10 minutes prior to electrophoresis.

The starch-gels, following electrophoresis were tested for two additional enzymes, isocitric dehydrogenase and carbonic anhydrase.

The staining mixture for isocitric dehydrogenase consisted of the following components (Henderson, 1965): 45 ml, 0.2 M tris/HCl, pH 8.0; 5 ml, 1 mg/ml nitro-B-tetrazolium; 5 ml, 1.6 mg/ml, phenazine methosulfate; 3 ml, 0.1 M, sodium isocitrate; 1 ml, 10 mg/ml, NADP; and 0.2 ml, 0.25 M, $MnCl_2$.

The staining mixture for carbonic anhydrase consisted of a solution B (1 g sodium bicarbonate; 50 ml, 0.1 M sodium sulphate) which was added to solution A (1.0ml, 0.1 M cobalt sulphate; and 6 ml, 0.05 M sulphuric acid) and incubated for two hours, washed in distilled water for two minutes and then in a dilute solution of ammonium sulphite for one minute (after Pearse, 1961, p 914-915).

(iii) Results

Mackerel were found to have three main bands of LDH activity (Fig. 14) which correspond with LDH-1, 3 and 5 in the mammalian system. LDH-1 predominates in the heart, LDH-5 predominates in white skeletal muscle and LDH-3 appears as a much weaker band in both muscles and is often absent in extracts from frozen tissues. Skeletal red muscle, spleen, gill, ovary, kidney, brain and eye all showed the three main bands of LDH-1, 3 and 5.

When the NAD-analog was used, the LDH-5 appeared as a stronger band than LDH-1 while LDH-3 was not present.

The kidney showed an extra isozyme band which was strongly cathodic. This was also present in smaller concentrations in the liver and intestine where it was the only band present (Fig. 14). Temperatures of 50 C for 10 minutes did not destroy activity of this band, but activity was less after freezing. However, some activity was still present after a year storage at -15 C but this was destroyed by subsequent exposure to 35 C for 10 minutes after thawing. The LDH band from kidney reacted weakly with the NAD-analog.

The brain and eye also showed extra isozymes (Fig. 14). A strongly negative isozyme, LDH-e, which migrated rapidly towards the anode, and was prominent in the eye but also present in the brain. A band, LDH-b, which migrated slower than LDH-e but faster than LDH-1. It was prominent in the brain but also present in the eye and present in the heart as a faint band. The brain showed two additional bands; LDH-b_1, located between LDH-b and LDH-1, and LDH-be, located half way between LDH-b and LDH-e. A faint band of LDH-b_1 was also present in the eye and in addition two other faint bands (LDH-e_1 and LDH-e_2) were present in the eye very close to the main eye band, LDH-e.

Two main bands of MDH activity could be detected in extracts of heart and white skeletal muscle. A third strongly negative band was present in extracts from liver. A cathodic MDH band was found in extracts from kidney which corresponded with the LDH-k band.

The LDH activity of combined heart and muscle extracts of 127 mackerel from the northern area and 95 mackerel from the southern area, ranging in length from 135 to 395 mm, in age from 4 months to 7 years, and representing all stages of maturity and both sexes, was identical with no polymorphism demonstrated (Fig. 15). The LDH patterns from 10 kidneys from each area were identical, although the kidneys exhibited an additional band of LDH activity.

The patterns of MDH activity of combined heart and muscle extracts of 27 mackerel from the northern area and 50 from the southern area were all similar.

The bands of AAT activity were diffuse and difficult to identify but two bands representing the bound and soluble isozymes were present. Two bands of esterase activity were detected in extracts from heart and white skeletal muscles.

The bands of esterase and AAT activity were diffuse and not clearly defined but there was no apparent differences in the patterns of the combined heart and muscle extracts of these two enzymes from the two areas.

No activity was found for isocitric dehydrogenase or for carbonic dehydrogenase.

X DISCUSSION

(i) Age and growth

The first attempt to determine the age and growth of the Atlantic mackerel on the North American coast was made by Captain Atwood in 1856 (Bigelow and Schroeder, 1953). Fry measuring 50 mm were found in Massachusetts Bay in July about a month after the completion of spawning. In August they measured 90 to 115 mm, and in October 165 to 175 mm. All were considered to be fish hatched in that year. Bigelow and Schroeder (op. cit.) state that fish of the year average 200 to 230 mm in fork length in the autumn. The size of these fish varies from year to year. Fish sampled in November, 1927, measured 220 mm while in November, 1928, the length was 250 mm. Both sizes were assumed to be representative of fish in their first year. In the spring and early summer of the second year, the average length is 230 to 255 mm and by late autumn they have grown to about 305 to 330 mm and in some years to 355 mm. Age-I fish from different areas appear to grow at different rates. Mackerel taken in the Gulf of Maine are larger than those at Woods Hole, Mass., while they in turn are larger than those near Long Island, N. Y., (Sette, 1950).

The nature of age and growth of the Atlantic mackerel in European waters has been more controversial than for those in North American waters. Steven (1950) reviewed the two schools of thought. One of these, supported by Ehrenbaum (1923) and more recently by Le Gall (1939, 1950), places the length of the mackerel at the end of its first year of growth at 100 mm. The other, supported by Nilsson (1914) and Steven (1950), place the length at the end of the first season of growth at 200 mm. Evidence supporting the more rapid growth in the first year was supplied by Dannevig (from Steven, 1950), who showed growth to 150 mm by mid-September including a 25 mm increase in 25 days from early August to September 1.

Evidence from this study on the growth of mackerel during their first year is sparse. Attempts to capture fish-of-the-year in August, 1965, and 1966 using I-meter plankton nets and Issacs-Kidd trawls were unsuccessful. Fish of 130 to 190 mm are found occasionally along Cape Breton in the autumn (McCallum, 1925) but none were found during this survey. Fish obtained from Rumson, N. J., in September, 1966, averaged 143 mm in length; one fish of 180 mm was captured at Woods Hole, Mass., in September, 1966, and evidence from sportsfishermen indicated this size was common at that time. Six fish ranging in length from 159 to 200 mm were obtained from catches made by Albatross IV in October and November, 1966. All these fish were assumed to be fish-of-the-year (Age-0), as examination of the otoliths showed only an opaque nucleus. If mackerel reach only a length of 100 mm in the first year, occasional catches of small fish should occur the following spring and summer but this does not occur. The smallest fish taken in the spring and summer measured 165 mm but most of them are over 200 mm. Therefore, it is assumed that mackerel on the North American coast usually reach a length of around 200 mm by the first autumn. The very small fish (95 to 125 mm) measured in October, 1962, are an exception. These fish were not found in the length frequencies for the following years. In addition, the 1962 year-class was found subsequently to be a poor year-class. The slow growth of these fish may have resulted from the below average surface temperatures in the Gulf of St. Lawrence during 1962.

(ii) Sex, growth and maturity

Females were significantly larger than the males in the 1965 and 1966 samples. Garstang (1898) found that female mackerel were 4 mm larger than the males in waters off England. He explained the differences as a result of the cessation of growth in males. Nilsson (1914) and Bigelow and Schroeder (1953) claimed that the two sexes did not differ in length.

The sex ratio was 1.00 male to 1.05 females which agrees with Steven (1950). Nilsson (1914) found a 1.28 to 1.00 ratio in favour of males, while Garstang (1898) found a 1.00 to 1.17 ratio in favour of females.

Sexual maturity occurs in the third year (Age-II), at a size larger than 300 mm but a few mature males are smaller. Steven (1950) showed that the onset of sexual maturity coincided with a transition from fast to slow growth.

The sex ratio is approximately equal so the difference in size between the sexes cannot be attributed to a higher mortality of the larger males. The presence of a few smaller mature males at Age-II may indicate that the difference in length between the sexes is present prior to maturity, but the sex of immature fish is difficult to determine, so no information on the sex-length relationship for these fish is available. The difference in length between the sexes is not large and does not increase from year to year. Sette (1943) found a higher per cent of males than females spawn at Age-II. As the onset of sexual maturity decreases the growth rate, a higher per cent of immature females at Age-II could explain the larger average size of the females in subsequent years.

(iii) Growth curves

The 1959 year-class was found to be dominant in June along the Atlantic coast of Nova Scotia and in the Gulf of St. Lawrence from July to September in 1965 and 1966. This year-class can also be followed in length frequencies of samples taken from 1960 to 1964. The measurements for 1960 and 1961 (Bergeron, 1961, 1962) were taken in the Gulf of St. Lawrence while the measurements for 1962 to 1964 were taken in southwest Nova Scotia. The same length groups found off southwest Nova Scotia in June are found later in the Gulf of St. Lawrence and hence these length measurements can be used to derive a growth curve for the 1959 year-class. The mean lengths of the 1959 year-class for 1960 to 1964 were calculated from the length frequencies. The length frequencies for 1962 were clearly bimodal and the minimum frequency (345 mm) between the two modes was taken as the upper size limit of the 1959 year-class. The data from which the growth curve was derived are given in Appendix VII a and the resulting growth curve which is compared to those derived from otolith readings in 1965 and 1966 is shown in Figure 16. The 1959 year-class is smaller at each age than any of the subsequent year-classes.

Figure 17 compares the growth rate of the 1959 year-class with that of the 1923 year-class from New England waters (Sette, 1950), and with the growth curve obtained for mackerel from the southwest coast of England (Steven, 1950)(1). The

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(1) The measurements of Steven (1950) were converted from total length to fork length by FL=.915 TL. Steven (op cit) does not state what measurement was used but it is assumed that he used the standard measure prescribed by the International Commission for the Exploration of the Sea (ICES) which was total length (Anon. 1939).

1923 year-class from New England waters showed a much faster growth rate than any of the other growth curves. The growth curve of the 1959 year-class from Canadian waters was similar to that from English waters in the first two years. It showed a faster growth in the third year and a similar growth rate thereafter, but was larger at each age.

Information about the growth of fish is often obtained from scales or otoliths by using the measurements of the successive otolith annuli to back-calculate the lengths of the fish. A linear relationship between otolith annuli widths and body length was assumed. The resulting back-calculated lengths of the fish are shown in Figure 17. The back-calculated lengths at younger ages is smaller than for the actual measured lengths for those same ages for the 1959 year-class. This "Lee's phenomenon" (Ricker, 1958, p. 188) may be an artifical one, caused by the assumption of an incorrect relationship between the otolith annuli and the body length.

A graphic presentation of the relation $L_{t+1} = L\ (1+K) + bL_t$ from Walford (1946); where L_{t+1} is the length at any age $t+1$, L is the asymptotic or maximum length of the fish and K is the slope of the line; is shown in Figure 18. Growth conformed more or less to a straight line which was calculated by the method of least squares. This line intercepts the 45° construction line at 360 mm which represents the maximum length for the 1959 year-class from Canadian waters. The preliminary information from 1967 indicates that the mean length of this year-class is 355 mm in 1967 (Martell, personal communication). Paloheimo and Dickie

(1965) have recently suggested that the concept of asymptotic growth does not apply to many fish populations. The growth of the 1959 year-class of mackerel would suggest that the Walford plot does not adequately describe its growth.

(iv) Growth of the different year-classes

The 1966 year-class which was represented by only a few individuals, taken between September and October, ranged in size from 125 to 200 mm.

The 1965 year-class sampled in 1966 can be divided into three groups which are recognized by different lengths (Fig. 19). One group was sampled at Provincetown, Mass., another at Pubnico, N. S., and the third in St. Margaret's Bay, N. S. The group at Provincetown was sampled at the beginning of July and in mid-September. The measurements of the first annuli were identical for the two samplings indicating that they belonged to the same group of fish. Therefore, the 27 mm increase in fork length between July and September is a result of growth. No otoliths were available for the group from Pubnico but the increase in length with time indicates that the same group stays around Pubnico during the summer, and the increase represents growth. The July 6 sample is much smaller than the others while the August 4 sample is much larger and these may represent other groups which are migrating along the coast. In fact, the August 4 sample may have been the same group as the one in St. Margaret's Bay. The 1965 year-class from St. Margaret's Bay is larger than the other two groups. Tagging results from St. Margaret's Bay show that this group remains in the Bay throughout the summer.

The sample from Halifax in October may be from the same group found earlier in St. Margaret's Bay and if so, represents a 31 mm increase in length in three months. This sample also showed the largest first annulus of any year-class. The length of these Age-I fish was equal to the length of the 1959 year-class at Age-II, both measured in the autumn.

The 1964 year-class comprised 72% of the samples from southwest Nova Scotia and the Bay of Fundy during July and August, 1965, and 13% of the samples from southwest Nova Scotia and the Gulf of St. Lawrence in 1966. Growth in the first year, as indicated by the first annulus of the otoliths, was rapid. The difference in length between this year-class in 1965 and 1966 was 53 mm. This year-class was also present in samples from Massachusetts. The mean fork length and the mean length at the first annulus were not significantly different ($P > 0.05$) between this year-class in the two areas. The variability of this 1964 year-class, both from Canadian and United States waters, is larger than that of any of the other year-classes. This may indicate that the members of this year-class were spawned under more variable conditions than normal or that the spawning occurred over a longer time than usual.

The 1963 year-class is present in the length samples from southwest Nova Scotia in 1964. In 1965, it comprises 5% of the May and June samples from southwest Nova Scotia and 12% of the July and August samples from there and from the Gulf of St. Lawrence. In 1966, it comprised 6% of all the samples. The difference in length between 1965 and 1966 was 30 mm, showing rapid growth between Age-II and Age-III. This year-class was also present in samples from Massachusetts, but neither the mean fork length nor the mean width of the first annulus were significantly different ($P > 0.05$) than those of fish from Canadian waters.

The 1962 year-class may be the first progeny of the 1959 year-class. It forms less than 5% of the fish sampled in 1965 and 1966. It is obvious in the length frequencies from the October 1962 sampling as very small fish (95 to 125 mm). This year-class has been a poor one, perhaps due to below average temperatures in the Gulf of St. Lawrence in the year it was spawned.

The 1961 year-class comprises less than 10% of the samples in 1965 and 1966. This year-class first appears in the length frequencies in July, 1962, in southwest Nova Scotia. Graham (unpublished records) identifies these length frequencies, by age-determination from otoliths, as belonging to the 1961 year-class. The growth of this year-class has been faster than for that of the 1959 year-class. The 1961 year-class equalled the 1959 year-class in size in 1965 and 1966.

The 1960 year-class comprises 7% and 16% of the samples in 1965 and 1966, respectively. The length frequencies between 1960 and 1966 do not indicate the presence of this year-class but it may be masked by the dominant 1959 year-class. The mean fork length of this year-class and the mean widths of the first four otolith annuli are not significantly different ($P > 0.05$) than those of the 1959 year-class. The 1960 year-class either had almost identical growth to that of the 1959 year-class, an unlikely situation in view of the variation in both fork lengths and annuli widths shown by the other year-classes, or the 1960 year-class is an artifact, actually representing the 1959 year-class. The 1959 year-class showed very poor growth in 1962, probably as a result of lower surface temperatures. Observations while reading otoliths, suggested that the 1962 summer zone was difficult to determine and thus some 1959 year-class fish would be read as 1960 year-class fish. A smaller growth increment was not found when measuring the annulus but this may be due to the units of measurement being too coarse. The 1960 year-class was probably a poor year-class and is no longer present.

The 1959 year-class which has been dominant since 1960 comprised 70% of the May and June samples in 1965 and 44% of the samples in 1966. The mean fork lengths for each age and the mean widths of the successive annular rings on the otoliths are smaller than for any of the other year-classes, except for the 1960 year-class. The size of this year-class at Age-I was smaller than for the 1965 year-class but the growth rate was about equal (Fig. 19). The increase in size between Age-I and Age-II was large (35 mm) while the increase in size between Age-II and Age-III was small (6 mm). It has been shown earlier that first spawning normally occurs at Age-II and that this is accompanied by a transition from fast to slow growth. Thus, first spawning for this 1959 year-class may not have occurred until Age-III, in 1962. The surface temperatures for the Gulf of St. Lawrence in 1962 were below normal and this along with first spawning may have accounted for the poor growth in that year.

The slow growth of the 1959 year-class cannot be correlated with below average surface temperature or a poor crop of zooplankton. In fact, studies in the Bay of Chaleur showed that the zooplankton were more abundant in 1959 than any of the other six years during which the abundance of plankton was measured (Lacroix, 1965). The dominance of this year-class indicates that a large number of fish **was** present in this year. There is a suggestion, therefore, that growth may be density dependent.

(v) Recruitment

The fluctuation in abundance of the commercial catch of mackerel is very dramatic (Fig. 5). Various theories have been postulated to account for these fluctuations, including migration to Europe and overfishing, for which protective legislation was passed in Massachusetts as early as 1670 (Goode, 1870). Sette showed that fluctuations in abundance were the result of differences in survival of the various year-classes. The results of the present survey support Sette's theory, as the increase in catch since 1959 can be attributed to the successful survival of the 1959 year-class. While this year-class was successful, subsequent year-classes were not. The reasons for this are not clear but a few suggestions can be made.

The relative success of survival of a year-class may be dependent on the initial numbers of eggs spawned and the subsequent survival of the eggs and larvae, but for most marine species, including mackerel (Sette, 1943), it is the latter which is important. The commercial catch of mackerel in 1959 for Canadian waters was the smallest since 1910; also, fish which could have spawned in 1959 were scarce in the samples taken in subsequent years (Fig. 9). Thus, the success of the 1959 year-class may have been a result of the survival of a large proportion of larvae from a relatively small number of eggs.

Most of the spawning of the northern population occurs over the Magdalen Shallows in the Gulf of St. Lawrence. This area becomes strongly stratified as to temperature and salinity, with surface temperatures as high as 20 C. Worley (1933) showed that development and survival of mackerel eggs occurred only between 11 C and 20 C with 16 C being optimum under laboratory conditions. Sette (1943) found the eggs to be most abundant in the sea below 11 C. Worley (op cit) collected the eggs from water of 16 C and it appears that the high mortalities below 11 C were a result of the decrease in temperature from 16 C to 11 C. Thus, a sudden decrease in temperature such as occurs in the Magdalen Shallows, caused by oscillation of the thermocline induced by wind (Lauzier, 1957 a), would increase mortality of the eggs and perhaps also of the larvae. A sudden decrease in surface temperature did occur at Grande-Riviere in 1962 when the temperature dropped from 11 C to 6 C between July 19 and 20. If this condition was general throughout the northwest area of the Gulf of St. Lawrence, it could have been one of the factors responsible for the low recruitment of the 1962 year-class. In addition to these sudden decreases in temperature, Taylor, Bigelow and Graham (1957) using a three-year lag period have showed a positive correlation between mackerel landings and air temperatures. Thus, in years with below average surface temperatures or retarded spring warming, the development and growth of the eggs and larvae would be decreased, thus increasing the toll by predation on the vulnerable planktonic stages. The surface temperatures from

Entry Island for the summer of 1959 were normal whereas for 1962 they were one to two degrees below normal (Appendix III). This below-average temperature may also have contributed to the poor survival of the 1962 year-class.

McCallum (1925) showed that normal development occurred at salinities as low as 19.6‰. The lowering of salinities caused by precipitation and surface run-off, in addition to the usual spring incursion from the St. Lawrence River, thus would not affect directly the survival of eggs and larvae. However, it could affect their survival indirectly by lowering the density of the surface layer and causing the eggs to sink to the sub-surface waters where the cooler temperature would slow growth and development.

The abundance of zooplankton is an important factor in the survival of mackerel larvae (Sette, 1943). Information from the Bay of Chaleur indicates that the crop of zooplankton was more abundant in 1959 than in any of the years 1955, 1960 to 1962 and 1964. However, it is not known if this represents the general condition throughout the Gulf. An unusually large crop of plankton was correlated with successful recruitment of five species of fish in Lake Erie (Scott, 1950). Evidence from other animals which have pelagic larvae and spawn in the Magdalen Shallows suggests that the successful recruitment of mackerel was not paralled by lobster (Scarratt, 1963), plaice or cod (Powles and Kohler, personal communication).

Sette (1943) showed that prolonged winds from abnormal directions were responsible for the poor survival of the 1932 year-class in the southern population by drifting the larvae away from the plankton-rich nursery areas. Prolonged southerly or southwesterly winds in the Gulf of St. Lawrence would cause the eggs and larvae to move to the cooler and less productive Laurentian Channel and Gaspe coast, thus decreasing survival.

In addition to the environmental factors influencing the recruitment of mackerel, density-dependent causes of mortality among eggs and larvae may be important in survival of a year-class. Ricker (1954) suggests that a combination of density-dependent mortality with the mortality caused by environmental factors could account for the marked oscillation in mackerel abundance. The high production of recruits by a small number of spawning adults in 1959 and the low production of recruits by a large number of spawners in subsequent years, fits the theory of density-dependence. Indeed, in mackerel there is a generally recognized inverse correlation between the numbers of spawners and the success of recruitment (Bigelow and Schroeder, 1953). The two factors which may be responsible for density-dependence of recruitment in mackerel, are cannibalism and competition for food.

Mackerel have been reported to feed on eggs and larvae of various species of fish, and small mackerel (Bigelow and Schroeder, 1953). They feed by both somewhat passive pharyngeal filtering and by active pursuit of prey. Goode (1884) claimed that mackerel in the Gulf of St. Lawrence do not feed during the spawning period because they could not be taken on hooks at that time. However, during the present study spawning mackerel were captured on hooks and underwater observations plus inspection of stomach contents of purse-seine caught mackerel showed that they were feeding on zooplankton during and immediately after spawning. Thus, passive cannibalism of eggs and larvae by adult fish may occur and in years of abundance of adults could be a significant factor in mortality of eggs and larvae.

Competition may also be significant in controlling survival of a year-class. The 1959 year-class grew more slowly than the other year-classes in the first year as a result of competition within the year-class, in spite of the apparent abundance of zooplankton. Thus, especially in years of low abundance of zooplankton, this within year-class competition may be an important factor in determining success of recruitment.

(vi) Distribution and migration of the mackerel in Canadian waters

(a) Migration of adults - The disappearance of the mackerel from the surface waters during the winter has long been the subject of controversy, especially among Canadian and United States biologists in the latter decades of the 19th century. United States biologists claimed that the schools of mackerel migrated in the autumn to southern waters near Cape Hatteras where they overwintered, then with the warming of the waters in the spring, they moved northward as far as the Gulf of St. Lawrence, and hence United States fishermen should have the right to follow the fish into the Gulf of St. Lawrence and fish there. Canadian biologists, however, quoting records of winter catches of mackerel, stated that the mackerel moved seaward in the autumn, overwintered just offshore, and returned to coastal waters during spring warming and hence United States fishermen did not have the right to fish in the Gulf of St. Lawrence (Goode, 1884). The Treaty of Washington, 1873, granted United States fishermen the right to fish in the Gulf of St. Lawrence, but in 1877 the Halifax Commission determined that the government of the United States should provide financial compensation for the privilege of fishing in the Gulf. This controversy existed until Sette (1950) plotted the records of occasional winter catches, then suggested that these mackerel pass the winter at mid-depths in water around 7C, along the edge of the continental shelf from Sable Island to Cape Hatteras. Recent catches of mackerel by Russian fishermen from 1964 to 1966 indicated that there are large quantities of mackerel in the winter on the south and northwest slopes of Georges Bank (ICNAF, Dartmouth, N. S., unpublished records).

From 1926 to 1935 Sette (1950) analyzed a considerable quantity of length measurements from commercial catches and combined this with the results from tagging experiments to indicate the existance of two populations ('contingents') described as 'northern' and 'southern' with discrete spawning areas in the Gulf of St. Lawrence and from Cape Hatteras to Long Island, respectively. Sette also outlined their different patterns of migration (Fig. 20).

The southern population passed the winter in an area south of that for the northern one. Early in April, the southern population appears between Cape Hatteras and Delaware Bay moving inshore, then joined by additional schools from offshore it moves north and east, spawning in May between the coast of New Jersey and Long Island. They then move around Cape Cod to occupy the western half of the Gulf of Maine in summer. The autumn withdrawal occurs in October, with the schools often proceeding as far south as Block Island, R. I., before disappearing from the surface waters.

The northern population, after passing the winter along the continental slope, approaches the coast of southern New England in late May, mixes temporarily with the southern population, then moves to the northwest and is joined by additional schools from offshore. This newly constituted aggregation migrates along the coast of Nova Scotia and into the Gulf of St. Lawrence where it spawns in June and July. Parts of this sometimes remains along the Atlantic coast of Maine, Nova Scotia and Cape Breton Island. In September and October, the northern population withdraws from the Gulf of St. Lawrence, moves southward along the coast of Nova Scotia and through the Gulf of Maine from October to December where a brief mixing of the two populations occurs. The northern population leaves the Gulf of Maine near Cape Cod in December.

The analysis of length measurements, the results of tagging, observations of the seasonal distribution of catch and comments made by fishermen during the present study all tend to support the pattern of migration for the northern population as suggested by Sette (1950), and answer some of the previously unresolved problems concerning the migration of this northern population.

The first mackerel sampled from southwest Nova Scotia in late May are larger than those in June. This results from the presence of larger fish (1959 year-class and older) in May than in June. During migrations, mackerel tend to form schools, the individuals of which are of uniform size and this in turn is related to swimming speed (Sette, 1950). The larger fish swim more rapidly than the smaller ones and would arrive first on the coast of Nova Scotia.

Mackerel which are captured in May and early June along the southwest coast of Nova Scotia are assumed to move eastward along the coast and then into the Gulf of St. Lawrence. The length-frequency distributions for 1965 and 1966 show that mackerel found on the Atlantic coast of Nova Scotia in June are similar to those found in the Gulf of St. Lawrence in July (Fig. 9). Three of the nine fish recaptured in the tagging study in southwest Nova Scotia in June, 1966, had migrated to Cape Breton. Two of these were recaptured on the same day near Arichat within 8 km of each other, 500 km from the point of release. It is probable that these fish had migrated in the same school. The other six recaptured fish showed that some schools remain along the southwest coast of Nova Scotia. These tagging results agree with the tagging study conducted by the Atlantic Biological Station, St. Andrews, N. B., in June of 1925 to 1928 in southwest Nova Scotia (Anon, 1931, Sette, 1950, and unpublished records Fisheries Research Board, St. Andrews, N. B.). Of the 53 recaptures in the first three months of that study, 37 showed migration northeast as far as Cape Breton. Only one fish was recaptured from the Gulf of St. Lawrence. The remainder were recaptured in the vicinity (10), along the coast of Maine (4) and one in the Bay of Fundy. This indicates that some fish remain around southwestern Nova Scotia and in the northern Gulf of Maine during the summer. The paucity of tagging returns in the Gulf of St. Lawrence from the tagging (1925 to 1928 and June, 1966) in southwestern Nova Scotia indicates that the fish which are found first along the coast of southwest Nova Scotia may be an inshore branch of the main body of migrating schools which remain on the Atlantic coast of Nova Scotia or migrate into the Gulf of St. Lawrence. If so, they must remain in an area or areas where there is no commercial fishery. Comments from fishermen indicate that the largest spring catches are made in the first or second week of June.

Mackerel which are found at the head of St. Margaret's Bay in July all tend to remain within the Bay until October as shown by the results of the tagging performed there in 1966. However, this was not the case with fish tagged on June 30, 1927, at the mouth of the Bay. Only one of the nine returns in the first three months was within the area of tagging, six had moved to Cape Breton as far as Ingonish and two were found in the Gulf of St. Lawrence.

The tagging program in the Gulf of St. Lawrence in 1966 yielded only 0.3% returns, all near the point of release. This low percentage of recaptures may indicate a large population of fish in the Gulf. The tagging carried out in August, 1925, from the Magdalen Islands yielded one recapture near Prince Edward Island in September, 1925.

In the tagging study in 1925 to 1928, 30% of the tagged fish were recaptured from United States waters (Sette, 1950). These returns confirmed the pattern of migrations proposed by Sette. No recaptures from the tagging in 1966 were made in the coastal waters of the United States. This absence of returns is not unexpected, since the catch of mackerel in the United States has decreased drastically in recent years and was only 13% of the Canadian catch in 1966 (Table I) whereas from 1925 to 1928 it was four times greater than the Canadian catch (Sette and Needler, 1934).

There were five returns from the tagging in June, 1927, at St. Margaret's Bay during the summer of 1928 from New Jersey to Cape Cod after the northern population had left this area. Sette (1950) claims these were stragglers which were injured by the tag attached around the caudal peduncle, and thus were unable to remain with their schools. An alternate suggestion which he mentions but discounts, is that some members of the northern population in one year may join the southern population in another year. This seems to have some validity since these stragglers represent 33% of the recaptures from that tagging. Tagging studies in other localities in Canadian waters did not yield returns during the following summers in the area normally occupied by the southern population. Thus, mixing between the populations may occur but is not a general occurrence.

The movement of mackerel within the Gulf of St. Lawrence cannot be determined from the few tagging returns from there but the monthly statistics of commercial catches suggests the following movements. Local concentrations appear along the southern shore and the Gaspe coast in July, along the north shore in August, and around the Magdalen Islands and Prince Edward Island in August and September. In October, the schools are located along Cape Breton Island suggesting that the mackerel are leaving the Gulf through Cabot Strait. In years of above average surface temperatures, they may move along the east coast of Newfoundland.

In addition to the information on the spatial distribution of the mackerel, the following general information on the nature of the migration was determined.

The movement of the northern population to the Gulf of St. Lawrence in spring is a spawning migration as indicated by the information on stage of maturity. The mackerel along the Atlantic coast of Nova Scotia in June are ripening, whereas those in the Gulf of St. Lawrence are spawning or spent in July. Casual examination of stomach contents indicate that this spawning migration was accompanied by feeding.

The swimming speed of fish-of-the-year in captivity has been demonstrated to be 11 km/hr while that of yearlings is 21 km/hr. One fish in the present tagging study (1966) travelled 660 km in 12 days for an average swimming speed of 2.1 km/hr. Two returns from the tagging study at St. Margaret's Bay in 1927, showed rapid movement through considerable distances; one travelled 290 km in 5 days and the other travelled 485 km in 7 days, giving average speeds of 2.1 km/hr and 2.5 km/hr, respectively.

The uniformity of size composition within schools disappears during the summer feeding in the Gulf of St. Lawrence. Observations of purse-seine catches show all sizes are present in one school. Underwater observations of a school encircled in a purse-seine showed that not only were the different sizes of mackerel integrated into one school, but there were other species of pelagic fish, herring (Clupea harengus), gaspereau (Alosa pseudoharengus), and shad (Alosa sapidissima), in the same school.

In summary then, the spring movement of mackerel is a spawning migration during which the fish are also feeding. The fish move along the coast of Nova Scotia and into the Gulf of St. Lawrence. The largest fish arrive first, in late May. The main schools usually appear in early June. Those which arrive along the southwest coast of Nova Scotia probably represent a branch from the main body of fish and some of these may move westward and stay in the northern part of the Gulf of Maine, others may remain in coastal waters of southwest Nova Scotia for the entire summer, and others may migrate northeastward along the coast of Nova Scotia with some or all entering the Gulf of St. Lawrence. Some mackerel stay along the Atlantic coast of Nova Scotia all summer and those which enter St. Margaret's Bay in July remain there until autumn.

The main body of fish spawn in the Gulf of St. Lawrence over the Magdalen Shallows. After spawning, they disperse and are found throughout the Gulf being more concentrated in the northern part in August, and around the Magdalen Islands and Prince Edward Island in September. The main body leaves the Gulf via Cabot Strait in October and if the water temperatures on the east coast of Newfoundland are above average, some schools will move northward along the east coast. The mackerel schools have left all of these areas in December and are assumed to pass the winter in the vicinity of Georges Bank.

(b) Migration of immature fish - Attempts to capture fish-of-the-year in August in 1965 and 1966 were unsuccessful and information on their migration could not be determined.

Age-I fish or 'tinkers' (fishermen's term for yearling mackerel, 220 to 290 mm) from the southern population migrate separately from the adult fish and arrive in the Gulf of Maine about a month later than the larger fish (Sette, 1950). These fish appear along southwestern Nova Scotia and in St. Margaret's Bay in July and then remain until October. The appearance of yearlings along the Atlantic coast of Nova Scotia is a regular occurrence (MacKenzie, 1930) which fishermen describe as a summer run of 'tinker' mackerel. The mean lengths of yearling fish in samples taken in 1966 is different at Pubnico and St. Margaret's Bay. This agrees with Sette (1950) who found different size yearlings in different areas. A few yearlings were found in the Gulf of St. Lawrence in 1966 and fishermen in Prince Edward Island stated that they captured some schools of 'tinkers' in July, 1966. Bergeron (1961) shows that yearling mackerel of the 1959 year-class were common around the Magdalen Islands in 1960.

In summary then, the yearlings follow a similar pattern of migration to the adults but they appear a month later. They remain along the coast of Nova Scotia, often in large schools, particularly around Pubnico and in St. Margaret's Bay, occasionally entering the Bay of Fundy. They may reach as far as the Gulf of St. Lawrence in years when they are particularily abundant. The migration in the autumn is assumed to be similar to that of the adults, leaving Canadian waters in September and October and passing the winter near Georges Bank.

(c) Factors which may influence the migration of mackerel - The start of the spring migration probably is regulated by the increasing photoperiod with subsequent control by temperature. The recent appearance of mackerel on the east coast of Newfoundland in autumn coincides with higher than average temperatures (Templeman and Flemming, 1953), suggesting that the migratory movements are simply a response to temperature. Galtsoff (1924) showed that the autumn migration of the Atlantic mackerel in the Black Sea in autumn is related to a sudden drop in surface temperature, but is independent of the temperature at which this drop occurs. This migration also is independent of salinity. A similar situation may occur in the Gulf of St. Lawrence as fishermen claim that strong winds in the autumn (which would increase mixing, thus lowering surface temperatures) cause the fish to disappear.

(vii) Population study

Sette (1950), after analyzing samples from commercial catches of mackerel over a 10-year period, was able to separate the Atlantic mackerel from the coastal waters of North America into northern and southern populations (Fig. 21).

Differences in length and age composition of samples from the northern and southern areas were apparent in 1966. The 1959 year-class was dominant in the northern population, while the 1965 year-class appeared to be dominant in the southern population. However, the samples from the southern population were obtained mainly from inshore traps at Provincetown, Mass., where Sette (1950) has shown there is a concentration of smaller and younger fish during summer and early autumn. Thus, the dominance of the 1965 year-class may not represent the true age composition of this population. Only one sample was obtained from the offshore purse-seine fishery at Provincetown and in this the 1964 year-class was dominant with the 1963 year-class next. Only two fish of the 1959 year-class were present in this sample of 100 fish. The difference between the length and age composition of the two populations may indicate a difference between them, but the paucity of samples from offshore for the southern population makes this comparison uncertain.

The average fork length of fish belonging to the 1962, 1963 and 1964 year-classes sampled in the summer of 1966 did not differ significantly ($P > 0.05$) in the two areas. In addition, the width of the first annular zone on the otolith did not differ significantly for these year-classes from the two areas. The 1965 year-class has already been shown to consist of at least three different length groups. The group from the southern area is intermediate in size between the two groups found in the northern area. Thus, the difference in size in this 1965 year-class does not indicate a difference between the populations.

The study of meristic characters failed to show significant differences ($P > 0.05$) between the samples from the northern and southern areas for the number of anal fin rays, dorsal finlets or anal finlets. The counts of the dorsal fin rays did show a significant difference between fish from the two areas but a significant difference was also shown by fish of the northern area sampled on the Atlantic coast of Nova Scotia and in the Gulf of St. Lawrence, yet these fish belong to the same northern population.

Evidence from the biochemical study fails to indicate any genetic differences between the populations. The lack of polymorphism in the LDH pattern of mackerel is unusual as polymorphism has been demonstrated in herring and cod by Odense _et al_ (1966 b, c) and in pollack (_Pollochius virens_), haddock (_Melanogrammus aeglefinus_), tomcod (_Microgadus tomcod_), and the Atlantic salmon (_Salmo salar_) by Odense (personal communication). There was no polymorphism in the other enzymes tested in mackerel in this survey. The lack of polymorphism of the enzymes in mackerel may indicate that they are genetically very stable.

In summary, differences were found in the length and age composition of the two populations, but these differences may be the result of inadequate sampling of the southern population. A difference was found for the counts of the rays of the second dorsal fin, between the two populations, but a similar difference was also found within the northern population. No differences were found in the other meristic characters. The enzyme patterns of the two populations were not different indicating that the populations are not genetically distinct.

The lack of differences in growth rate of the 1962, 1963 and 1964 year-classes from the two areas does not conform to the existance of two populations, especially in view of the differences that exist between different year-classes. This similarity of growth rate suggests that these year-classes are actually members of the same population. As already mentioned (in discussion of migration), mixing of the populations may occur (i. e., members of one population in one year may be found in the other population in another year). This mixing could happen if the spring spawning migration was controlled mainly by temperature. Rapid vernal warming could cause the waters in the Gulf of Maine to reach a suitable temperature for mackerel spawning before the slower-moving schools destined for the northern area had left the Gulf of Maine. These schools would then stay there during the late spring and summer, spawning and feeding.

(viii) Biochemical study

Mackerel were found to have three major isozymes corresponding to the mammalian LDH-1, 3 and 5. Markert and Faulhaber (1965) found only two main isozymes LDH-1 and 5 but the disappearance of the LDH-3 band after storage at -15 C could account for their findings.

The bands of minor isozymes found in kidney, eye and brain are probably separate from the main system of isozymes and under separate genetic control, similar to the extra isozyme of LDH found in the sperm of many mammals and birds (Blanco, Zinkham and Kupchyk, 1964). Extra isozymes from the brain and eye have been found in other fish (Markert and Faulhaber, 1965; Odense, personal communication). These extra isozymes from brain and eye may be part of the same system with the minor bands being different combinations on the LDH-b and LDH-e sub-units. Kohn (personal communication) found isozymes in mackerel eye which corresponded to the LDH-b and e. She also found that retinal dehydrogenase (RDH) activity was located in the same place on the starch-gel as LDH-b.

The extra LDH isozyme band in the kidney appears to use malate as a substrate. This extra isozyme may represent a non-specific dehydrogenase.

The weak bands of LDH activity present in samples of frozen tissue (Fig. 15) may be permutations of the monomers within the three major bands caused by alterations in the tetramer structure.

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Table 1

Catches of mackerel in the waters of ICNAF Convention, 1964 to 1966[1], by Canada, Russia and the United States, in metric tons (1 metric ton equals 2204.6 lb)

Year	Canada	Russia	United States
1964	10,786	680	1,264
1965	10,991	2,877	1,469
1966	11,675	6,680	1,501

[1]From ICNAF Statistical Bulletin 1964, 1965 and 1966 (in press)

Table 2. Mean fork length in mm of mackerel sampled from commercial catches in Halifax County, N.S. 6-9 June, 1965, and from Malpeque Harbour, P.E.I., 30 July to 1 August, 1966.

Year	Date	Location	Gear	Sample Size	Mean	Standard Dev.
1965	6 June	Indian Harbour	Trap	100	347	11.3
1965	7 June	French Village	Trap	100	353	12.3
1965	7 June	Indian Harbour	Trap	100	349	12.7
1965	7 June	Peggy's Cove	Trap	100	348	14.0
1965	8 June	Indian Harbour	Trap	100	348	12.0
1965	8 June	Peggy's Cove	Trap	100	346	12.9
1965	9 June	East Jeddore	2-7/8 gill net	100	349	14.4
1965	9 June	Murphy's Cove	2-7/8 gill net	100	347	11.1
1966	30 July	Malpeque Hbr.	Purse-seine	100	354	11.8
1966	30 July	Malpeque Hbr.	Purse-seine	100	350	15.1
1966	31 July	Malpeque Hbr.	Purse-seine	99	354	11.1
1966	1 Aug.	Malpeque Hbr.	Purse-seine	96	354	12.1

Table 3. Mean fork lengths in mm of fish sampled in May and June from the southwest coast of Nova Scotia (4X) and in July in the Gulf of St. Lawrence (4T), from 1962 to 1966.

Year	1962		1963		1964		1965			1966	
ICNAF District	4X		4X		4X		4X		4T	4X	4T
Month	May	June	May	June	May	June	May	June	July	June	July
Number	172	688	242	280	143	475	304	2148	1012	816	487
Mean	363	333	354	320	354	330	365	350	350	354	353
Standard Deviation	±33.4	±35	±16.4	±12.2	±18.3	±14.3	±15.9	±13.0	±14.0	±24.1	±20.2

Table 4. Mean fork length and standard deviation of different year-classes of mackerel sampled from Canadian waters in 1963, 1965 and 1966 (number of fish in parentheses).

Year-Class	Fork length in mm			
	1963 June-Aug.	1965 June-Aug.	1966 June-Sept.	1966 October
1965	- -	- -	276 ± 11.1 (12)	280 ± 8.3 (117)
1964	- -	266 ± 13.8 (510)	319 ± 12.2 (20)	323 ± 11.1 (16)
1963	- -	318 ± 12.1 (146)	345 ± 8.4 (35)	- -
1962	266 ± 17.3 (14)	338 ± 11.3 (69)	353 ± 10.0 (23)	- -
1961	316 ± 9.3 (28)	345 ± 10.0 (84)	358 ± 9.9 (40)	- -
1960	- -	348 ± 11.2 (107)	357 ± 9.7 (96)	- -
1959	327 ± 17.1 (39)	349 ± 11.9 (607)	356 ± 10.8 (282)	- -

Table 6. Mean widths of the successive otolith annuli and mean fork lengths of the mackerel from which they were taken, sampled in Canadian waters in 1963, 1965 and 1966 and standard deviation.

Year-Class	Date	Age	Mean fork length mm	No.	Mean widths at successive annuli mm O_1	O_2	O_3	O_4	O_5	O_6	O_7
1959	June 1963	IV	327 ±17.1	39	2.5 ±.17	3.6 ±.35	4.1 ±.38	4.3 ±.41	- -	- -	- -
1959	May-Aug. 1965	VI	349 ±16.8	103	2.6 ±.27	3.7 ±.40	4.2 ±.58	4.4 ±.40	4.7 ±.48	4.9 ±.50	- -
1959	June-Sept. 1966	VII	362 ±10.8	67	2.5 ±.30	3.6 ±.35	4.2 ±.40	4.4 ±.43	4.7 ±.43	4.9 ±.44	5.1 ±.45
1960	June-July 1965	V	342 ±13.0	4	2.5 ±.20	3.6 ±.13	4.2 ±.17	4.4 ±.20	4.7 ±.40		
1960	June-Aug. 1966	VI	352 ±11.0	5	2.6 ±.29	3.6 ±.22	4.1 ±.27	4.3 ±.32	4.6 ±.36	4.9 ±.38	
1961	June-July 1963	II	316 ± 9.3	28	2.9 ±.25	3.9 ±.23	4.2 ±.30				
1961	June-July 1965	IV	346 ±10.4	9	3.1 ±.21	4.1 ±.29	4.6 ±.35	4.9 ±.38			
1962	July-Aug. 1963	I	266 ±17.3	14	3.0 ±.34	3.8 ±.42					
1963	June-July 1965	II	320 ±11.7	12	2.9 ±.23	4.3 ±.23					
1963	July-Aug. 1966	III	346 ±10.8	17	2.9 ±.33	4.0 ±.41	4.4 ±.45	4.7 ±.49			
1964	July-Aug. 1965	I	268 ± 7.2	51	3.1 ±.45	3.8 ±.4					
1964	July-Aug. 1966	II	320 ±10.4	24	3.3 ±.6	4.2 ±.35	4.4 ±.42				
1964	October 1966	II	323 ±11.3	16	3.1 ±.54	4.2 ±.47	4.7 ±.39				
1965	October 1966	I	279 ± 8.6	79	3.5 ±.26	4.2 ±.34					

Table 5. Mean fork length and standard deviation of different year-classes of mackerel sampled from United States waters in 1966 (number of fish in parenth ses)

Year-Class	Fork length in mm	
	1966 July	1966 Sept.
1966	-	143 ± 9.7 (96)
1965	231 ± 12.1 (142) 25	258 ± 8.4 (150)
1964	316 ± 12.5 (85)	-
1963	342 ± 10.4 (39)	-
1962	359 ± 9.9 (18)	-
1961	362 ± 17.4 (5)	-
1960	368 ± 20.5 (2)	-
1959	367 ± 11.3 (2)	-

Table 7. Mean widths of the successive otolith annuli and the mean fork lengths of the mackerel from which they were taken, and standard deviations, of samples from United States waters in 1966.

Year-Class	Date	Age	Mean Fork Length	Number	Mean widths at successive annuli O_1	O_2	O_3	O_4
1962	July 1966	IV	362 ±7.5	12	2.9 ± .31	4.0 ± .35	4.6 ± .28	4.7 ± .32
1963	July 1966	III	345 ±12.0	22	2.9 ± .39	4.1 ± .36	4.4 ± .44	
1964	July 1966	II	318 ±12.0	64	3.2 ± .54	4.2 ± .63		
1965	July 1966	I	232 ±13.6	79	3.1 ± .37	3.6 ± .38		
1965	Sept. 1966	I	257 ± 8.6	39	3.1 ± .27	3.8 ± .63		
1966	Sept. 1966	0	143 ± 9.7	19	3.0 ± .24			

Table 8. Mean widths at the first annulus of otoliths from Canadian and United States waters sampled in 1966.

Year-Class	Location	Month	Number	Mean Width at O_1	Standard Deviation
1965	Canada	October	79	3.5	± .26
	United States	July	39	3.1	± .27
1964	Canada	July-Aug.	24	3.3	± .60
		October	16	3.1	± .54
	United States	July	64	3.2	± .54
1963	Canada	July-Aug.	17	2.9	± .33
	United States	July	22	2.9	± .39

Table 9

Classification system used to determine the stage of maturity of mackerel sampled in 1965 and 1966

Symbol	Stage of Maturity	Description
A	Immature	gonads, small translucent or small opaque; no superficial distinction between sexes
B	Maturing	the testes enlarged, white; the ovaries enlarged, granular to translucent with spots
C	Ripe and running	similar to maturing but sperm or eggs expressed by slight pressure on the abdomen
D	Spent	testes are loose and hemorrhaging; ovaries loose and containing residual eggs; often both testes and ovaries are atrophying

Table 10

Stage of maturity in various locations along the Atlantic coast of Nova Scotia, in the Gulf of St. Lawrence and the coast of Massachusetts in 1965 and 1966

Date	Location	Stage of Maturity Immature	Maturing	Ripe and Running	Spent
May-June 1965	Southwest coast of Nova Scotia	1	638	-	-
May-June 1966	Southwest coast of Nova Scotia	7	369	-	-
June 1965	Ingonish, N. S.	7	92	-	-
July 1965	Yarmouth Co., N. S.	154	146	-	-
August 1965	Bay of Fundy	197	-	-	-
July 1965	Gulf of St. Lawrence	4	5	47	141
August 1965	Caraquet, N. B.	-	-	-	100
July 1966	St. Margaret's Bay, N. S.	2	-	-	16
August 1966	Malpeque Hbr., P. E. I.	13	-	-	234
October 1966	Halifax, N. S.	120	-	-	20
July 1966	Massachusetts	148	5	40	107
September 1966	Massachusetts	100	-	-	-

Table 11

Fork length of male and female mackerel sampled in Canadian waters in 1963(1), 1965 and 1966

Year	Sex	Number	Mean	Standard Error
1963	Females	97	325	± 2.0
1963	Males	114	323	± 1.8
1965	Females	539	349	± .56
1965	Males	592	344	± .61
1966	Females	255	356	± .81
1966	Males	244	353	± .76

(1) Data for 1963 were obtained from unpublished records, Fisheries Research board of Canada, St. Andrews, N. B.

Table 12

Results of 1966 tagging study in which 2407 mackerel were marked and released along the Atlantic coast of Nova Scotia and in the Gulf of St. Lawrence

Date	Location	Number Tagged	Number Recaptured	Per Cent Recaptured	Maximum distance from tagging site
June 9	St. Johns Is., Yarmouth Co., N. S.	50	1	2	4 km
June 13	Clarkes Hbr., Shelburne Co., N. S.	85	6	7	660 km
June 20	Clarkes Hbr., Shelburne Co., N. S.	75	5	7	24 km
July 23	St. Margaret's Bay, Halifax Co., N. S.	100	25	25	15 km
August 8-10	Malpeque Hbr., Prince Co., P. E. I.	697	6	1	45 km
September 21-22	Malpeque Hbr., Prince Co., P. E. I.	1400	0	0	-

Table 13

Mean counts of rays of the second dorsal fin from various localities in Canadian and United States waters in 1965 and 1966

Date	Location	Number	Mean	Standard Deviation
May-June 1965	Atlantic coast of Nova Scotia	448	11.66	± 0.62
July-Sept. 1965-1966	Gulf of St. Lawrence	450	11.78	± 0.56
August 1965	Bay of Fundy	100	11.86	± 0.64
October 1966	Halifax, N. S.	48	11.69	± 0.69
September 1966	Provincetown, Mass.	154	11.87	± 0.58

Table 14

Mean counts of rays of the anal fin from various locations in Canadian and United States waters in 1965 and 1966

Date	Location	Number	Mean	Standard Deviation
May-June 1965	Atlantic coast of Nova Scotia	447	11.77	± 0.53
August-September 1965-1966	Gulf of St. Lawrence	349	11.83	± 0.50
August 1965	Bay of Fundy	100	11.74	± 0.45
October 1966	Halifax, N. S.	48	11.80	± 0.38
September 1966	Provincetown, Mass.	54	11.92	± 0.61

Table 15

Mean counts of dorsal and anal finlets from various locations in Canadian and United States locations in 1965 and 1966

Date	Location	Finlet	Number	Mean	Standard Deviation
June 1965	Atlantic coast of Nova Scotia	Dorsal	200	5.0	± 0.26
		Anal	100	5.0	± 0.22
July-September 1965-1966	Gulf of St. Lawrence	Dorsal	449	5.0	± 0.25
		Anal	450	5.0	± 0.25
October 1966	Halifax, N. S.	Dorsal	48	5.1	± 0.44
		Anal	48	5.0	± 0.26
September 1966	Provincetown, Mass.	Dorsal	100	5.0	± 0.20
		Anal	100	5.0	± 0.28

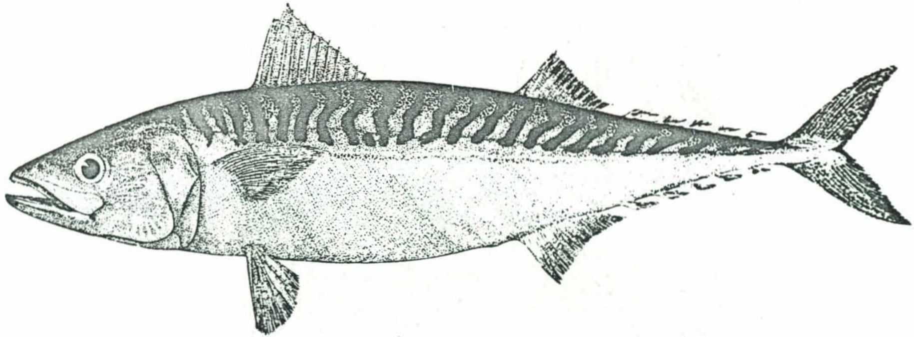


FIGURE 1. The Atlantic mackerel, Scomber scombrus (after Leim and Scott, 1966).

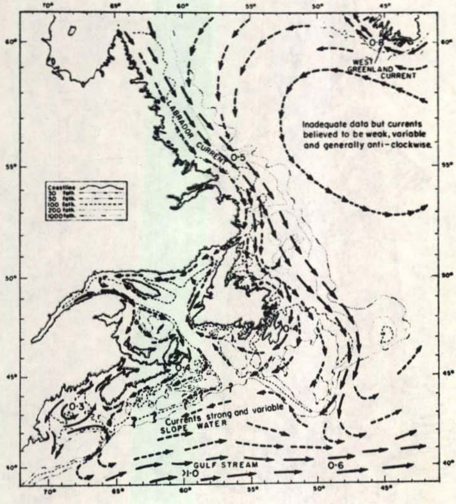


FIGURE 2. Chart of the surface waters of the Northwest Atlantic during spring and summer, showing current flow (after Templeman, 1966).

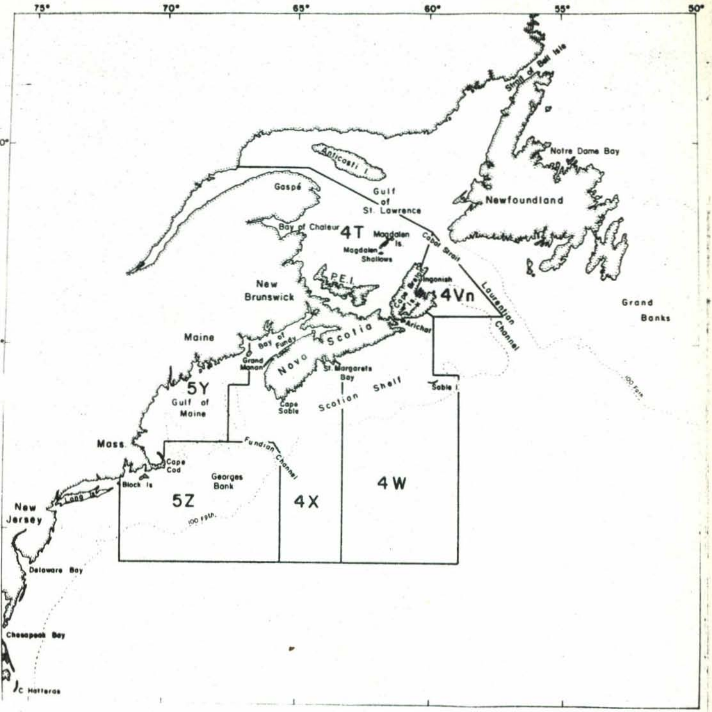


FIGURE 3. Chart of the Canadian Atlantic region showing the ICNAF statistical districts and the general area covered in this study.

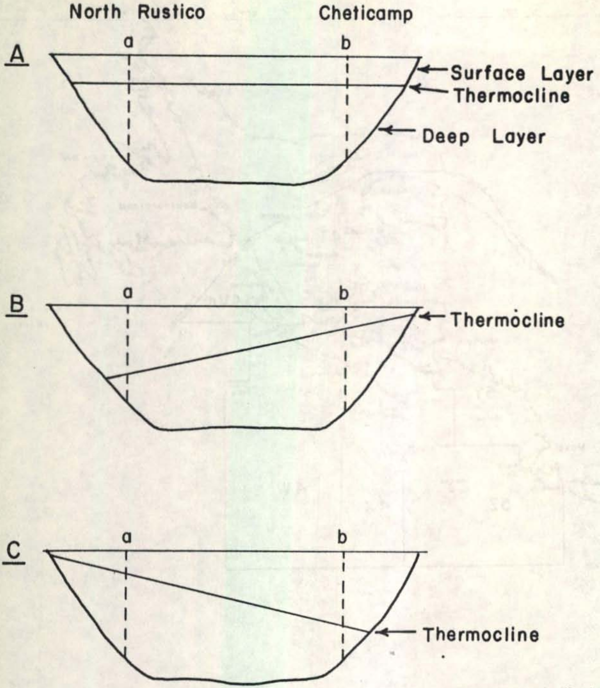


FIGURE 4. Theoretical section between North Rustico and Cheticamp in the Gulf of St. Lawrence, under different conditions: (A) no motion, (B) northerly wind (toward the viewer) resulting in warm surface water close to the bottom at North Rustico and cold bottom water near the surface at Cheticamp, and (C) southerly wind (away from the viewer) resulting in the reverse effect to a northerly wind (redrawn from Lauzier, 1957a).

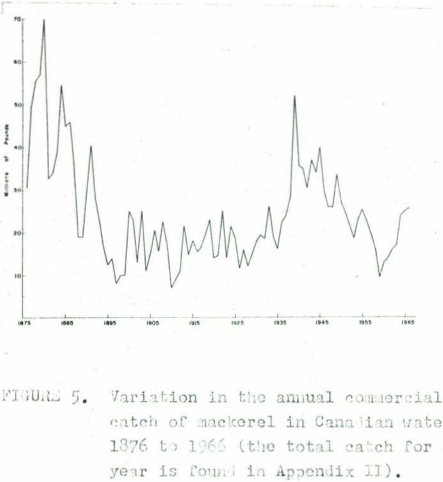
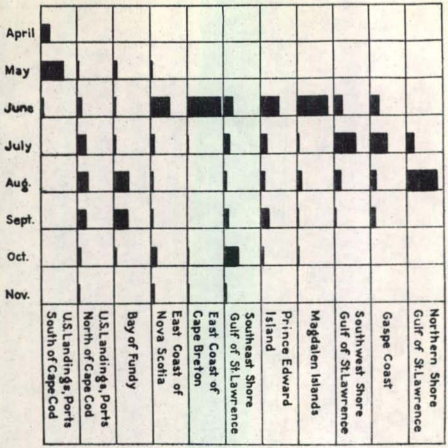


FIGURE 5. Variation in the annual commercial catch of mackerel in Canadian waters, 1876 to 1966 (the total catch for each year is found in Appendix II).

(a)



(b)

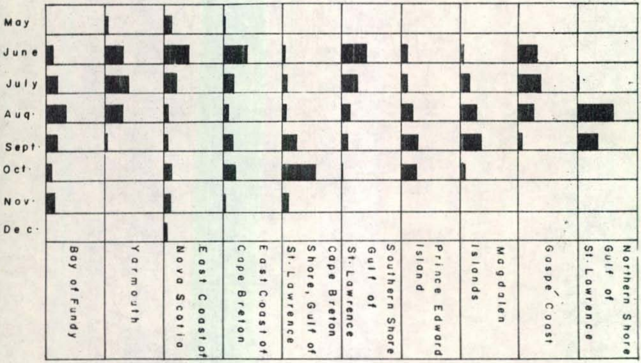


FIGURE 6. Seasonal distribution of commercial catch of mackerel; (a) 1924 to 1929 (after Sette and Needler, 1934), (b) 1957 to 1966 (from Canadian Fisheries Statistics, Preliminary Monthly Tabulations, Dominion Bureau of Statistics).

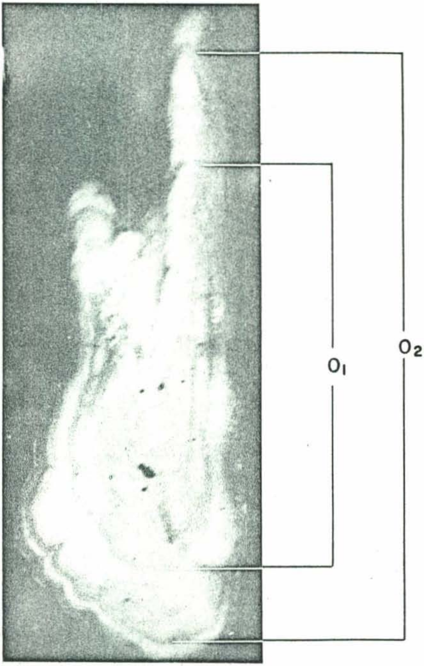


FIGURE 7. Otolith from Age-II mackerel showing measurement of otolith annuli; O_1 is the width of the otolith annulus formed during the first year, O_2 is the total width of the annulus at the end of the second year.

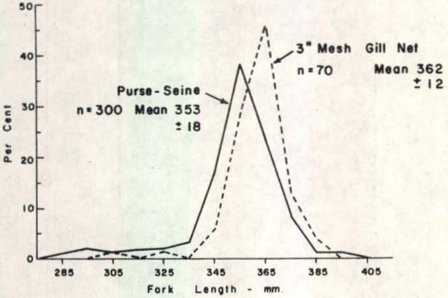


FIGURE 8. Length-frequency distributions of mackerel sampled from commercial catches by a purse-seine net and a gill-net of 3 in. stretched mesh at Malpeque Hbr., P.E.I., September 21 and 22, 1966.

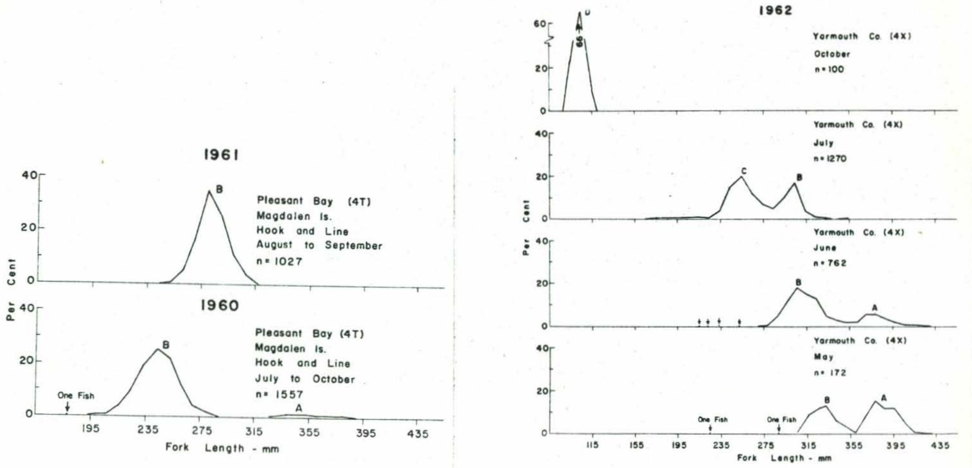


FIGURE 9. Length-frequency distributions of mackerel sampled in Canadian waters from 1960 to 1966 by month and area (ICNAF statistical districts in parenthesis). The peaks are lettered to enable identification of them in the text; 1960 and 1961 after Bergeron (1961 and 1962), 1962 to 1964 from unpublished records Biological Station, St. Andrews, N.B.

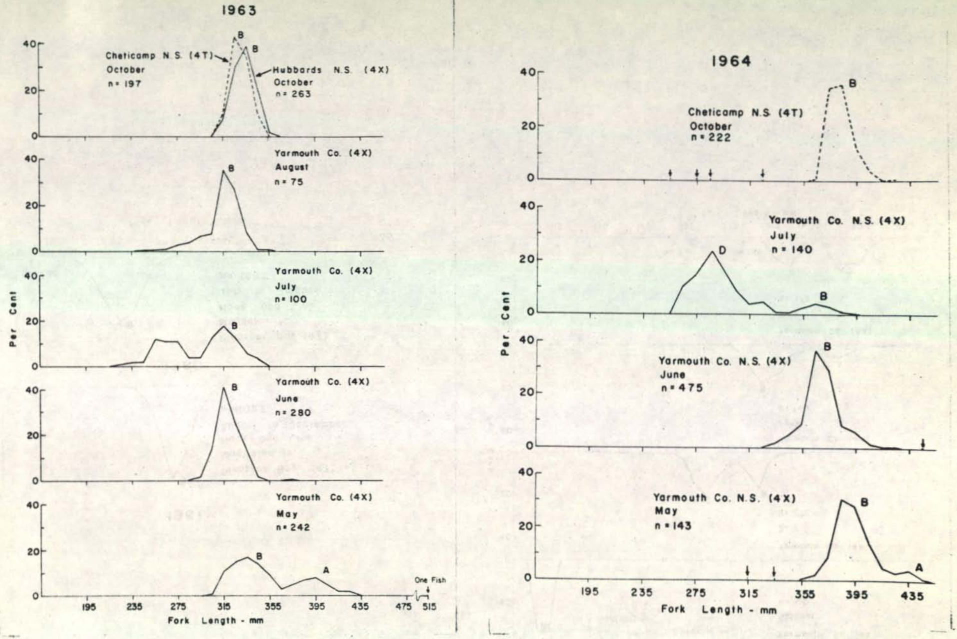


FIGURE 9 (continued).

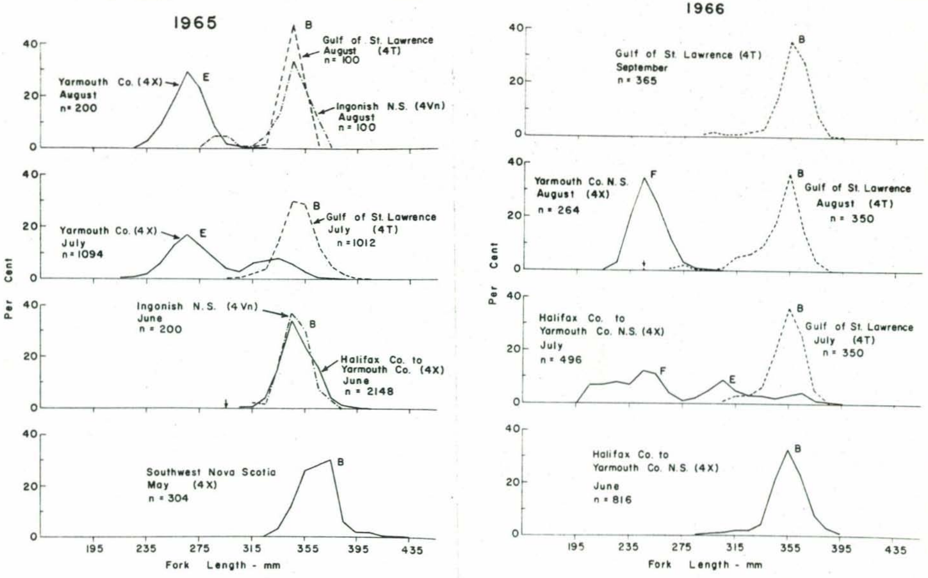


FIGURE 9 (continued)

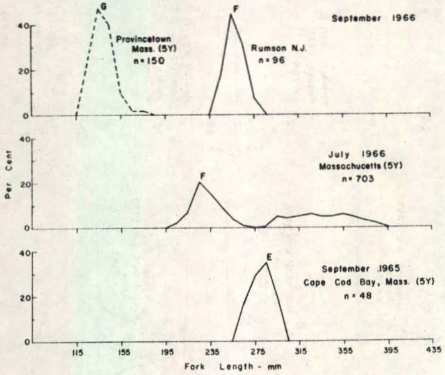


FIGURE 10. Length-frequency distributions of mackerel sampled in United States waters in 1965 and 1966 by month and area (ICNAF statistical districts in parenthesis). The peaks are lettered to enable identification of them in the text.

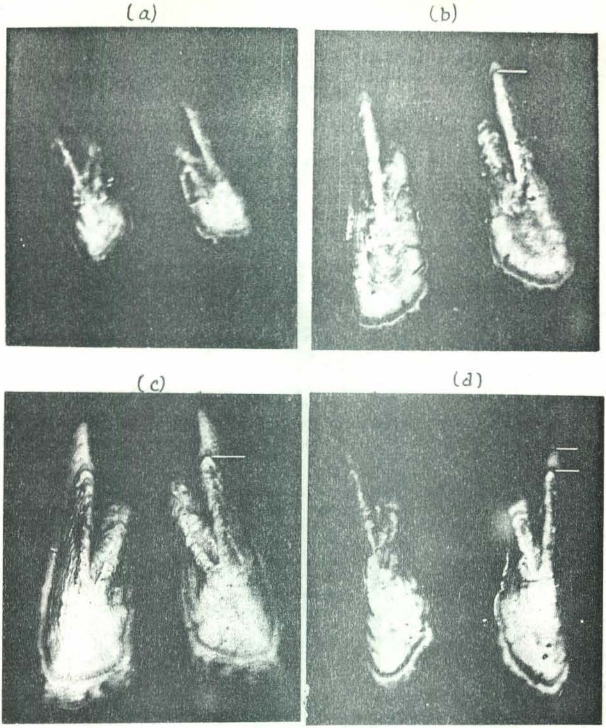


FIGURE 11. Otoliths from mackerel of different ages and lengths: (a) Age-0 (September), 136 mm; (b) Age-I (June), 232 mm; (c) Age-I (September), 251 mm; (d) Age-II (July), 322 mm; (e) Age-III (June), 348 mm; (f) Age-IV (August), 359 mm; (g) Age-V (August), 362 mm; (h) Age-VI (August), 355 mm; and (i) Age-VII (August), 366 mm.

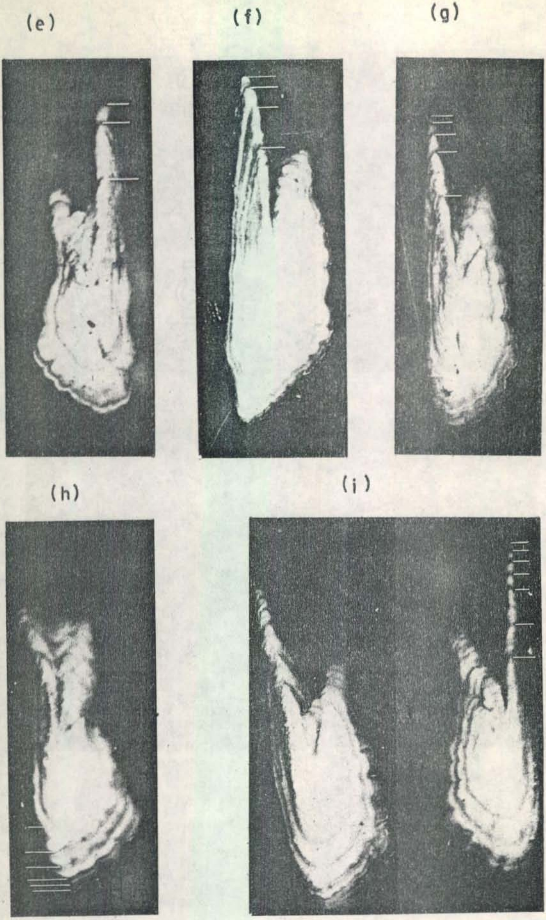


FIGURE 11 (continued)

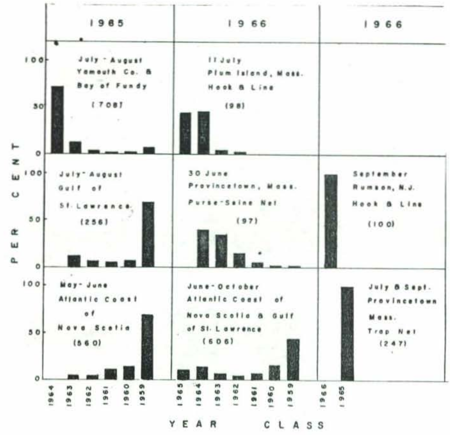


FIGURE 12. Per cent composition of year-classes of mackerel sampled from Canadian and United States waters in 1965 and 1966.

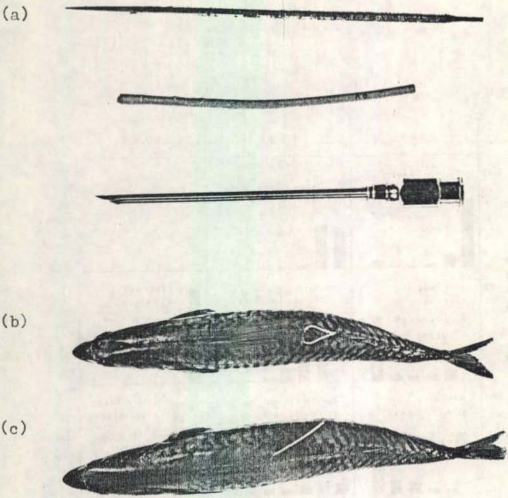


FIGURE 13. Illustration of the apparatus and method of tagging mackerel: (a) top - a modified large sewing needle used to apply the tag as a dart, middle - a Watson-Larsen tag, bottom - a loaded No. 12 hypodermic needle used to apply the tag as a dart; (b) the Watson-Larsen tag applied as a ring between the two dorsal fins; and (c) the Watson-Larsen tag applied as a barb, hooked under the last rays of the first dorsal fin.

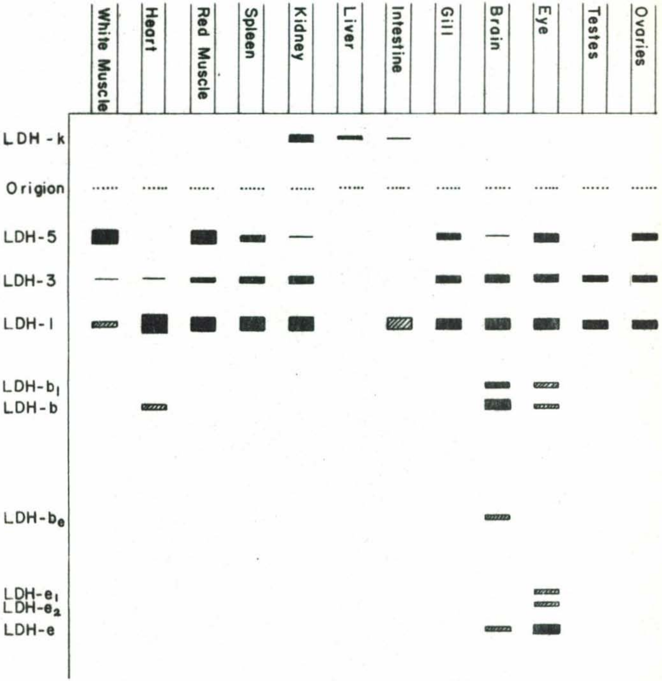


FIGURE 14. Activity of lactate dehydrogenase (LDH) from different organs of the Atlantic mackerel as determined by starch-gel electrophoresis.

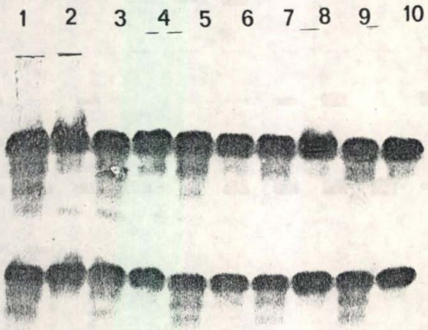


FIGURE 15. Lactate dehydrogenase (LDH) activity of mackerel after starch-gel electrophoresis for 18 hours at 300 v on 16% starch. Odd-numbered slots, heart and white muscle extracts from Pubnico, N.S., June 3, 1966, and even-numbered slots, heart and white muscle extracts from Provincetown, Mass., June 30, 1966.

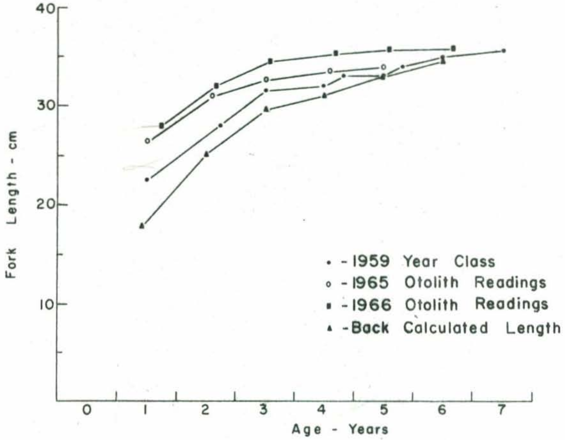


FIGURE 16. Growth curve of the 1959 year-class of mackerel sampled from Canadian Atlantic waters compared to the growth curve derived from the back-calculation of otoliths from the 1959 year-class, sampled in 1966, and to the growth curves derived from the age-determinations using otoliths sampled in 1965 and 1966.

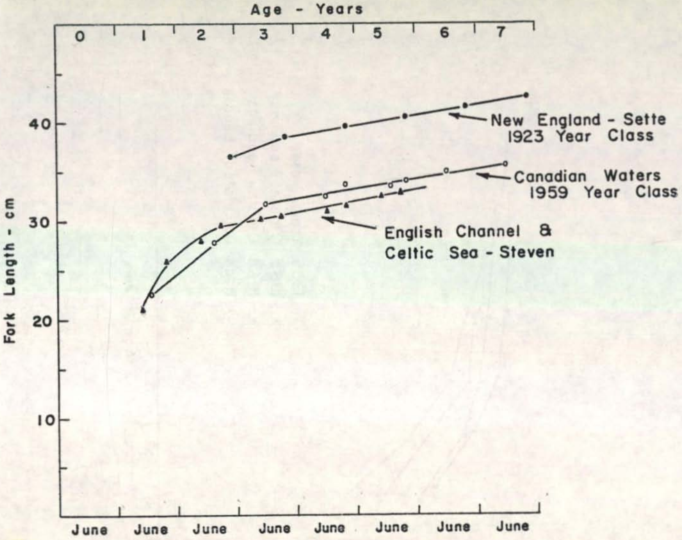


FIGURE.17. Growth curve of the 1959 year-class of Atlantic mackerel from Canadian waters compared with the 1923 year-class from southern New England waters (Bigelow and Schroeder, 1953), and with the growth curve of mackerel from the southwest coast of England (Steven, 1950).

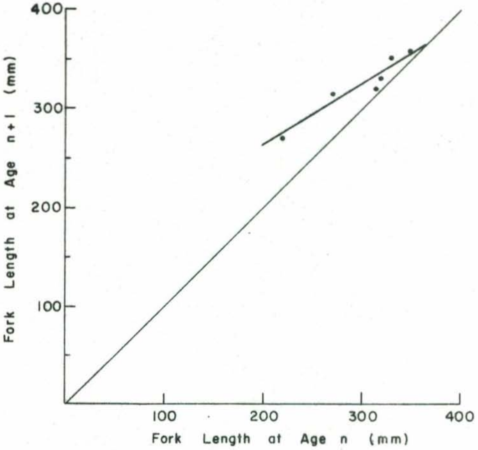


FIGURE 18. Straight-line growth transformation (Walford plot) of the Atlantic mackerel for the 1959 year-class. Fork lengths at age n are plotted against length one year later (n + 1).

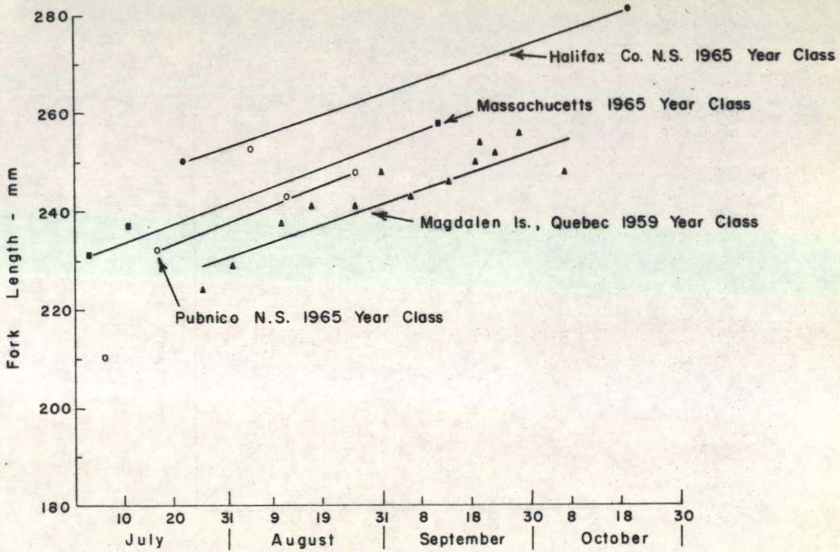


FIGURE 19. Growth of the Atlantic mackerel during the second year from four localities and belonging to the 1965 and 1959 year-classes.

(a)

(b)

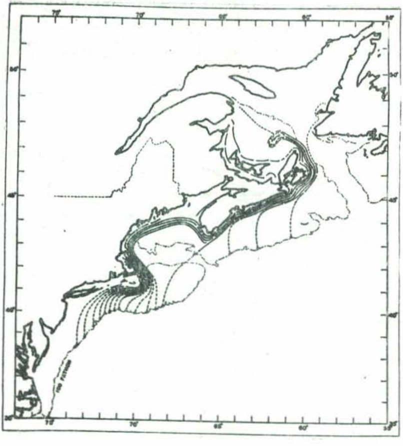


FIGURE 20. Diagramatic representation of the spring (a) and autumn migration (b), after Sette (1950).

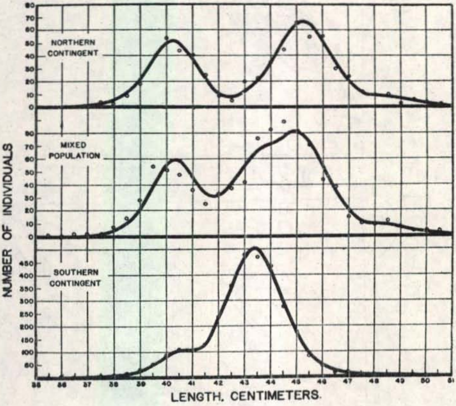


FIGURE 21. Length-frequencies representing the southern and northern populations, and the mixed population which results during the spring and autumn migration, after Sette (1950).

Monthly average surface temperatures from Grande Rivière[1] for 1958-65 and Entry Island[2] for 1958-66.

Grande Rivière

Year / Month	1958	1959	1960	1961	1962	1963	1964	1965	Average 1958-65	Average 1936-62
Jan.	-1.0	-1.3	-1.4	-1.6	-0.7	0.1	-1.4	-1.2	-1.1	-1.1
Feb.	-1.5	-1.6	-1.4	-1.7	-1.8	-0.2	-1.5	-1.2	-1.4	-1.5
March	-0.7	-1.4	-1.4	-1.3	-0.9	-0.3	-1.3	-0.7	-1.0	-1.2
April	1.1	1.0	-0.2	0.3	0.6	0.4	0.2	-0.1	0.4	0.5
May	4.7	4.3	4.6	3.8	3.9	3.9	4.3	3.6	4.1	4.1
June	7.9	7.9	10.3	8.1	9.1	9.3	8.4	8.3	8.7	8.8
July	12.6	13.5	13.0	12.7	10.7	13.1	12.6	12.2	12.6	12.9
Aug.	13.5	14.4	12.6	13.7	13.2	14.2	12.8	13.0	13.4	13.9
Sept.	10.6	12.7	10.5	11.2	11.3	10.9	10.8	10.7	11.1	11.4
Oct.	7.1	8.0	6.7	8.4	8.5	7.5	7.0	5.9	7.4	7.5
Nov.	3.8	3.6	3.2	4.9	4.5	4.5	2.8	2.3	3.7	4.0
Dec.	-0.3	0.4	0.4	2.3	1.4	1.0	0.1	0.0	0.7	0.8

Entry Island

	1958	1959	1960	1961	1962	1963	1964	1965	1966	Average 1958-66	Average 1930-62
May	6.7	6.3	7.4	2.4	5.0	4.5	4.9	5.0	5.5	5.3	4.9
June	10.5	9.4	12.2	7.5	9.0	10.5	9.4	9.4	11.1	9.9	9.8
July	14.9	14.2	17.3	14.2	13.3		14.5	15.1	14.8	14.8	14.9
Aug.	16.7	17.3	18.4	17.5	15.5		16.1	17.2	18.2	17.1	17.2
Sept.	14.2	14.7	14.8	15.8	13.7	12.8	13.9	13.7	14.2	14.2	14.8
Oct.	9.4	9.9	9.3	11.8	10.0	9.8	9.7	8.6	9.5	9.8	10.0
Nov.	-	5.8	5.3	7.0	5.4	-	3.8	3.2	5.9	5.2	5.2
Dec.	-	1.7	-	-	-	-	-0.7	0.3	2.9	-	-

[1] from Rapport Annuel 1958 to 1965. Station de Biologie Marine. Grande Rivière, Quebec Ministere de la Chasse et des Pecheries

[2] from unpublished records Fisheries Research Board, Biological Station, St. Andrews, N.B.

APPENDIX II

Canadian Catch of Mackerel[1]

Year	Total catch in 000 lbs	Year	Total catch in 000 lbs
1876	31,362	1921	14,555
1877	49,556	1922	25,122
1878	55,409	1923	14,175
1879	57,316	1924	21,559
1880	70,331	1925	18,766
1881	32,412	1926	11,549
1882	34,293	1927	15,880
1883	38,632	1928	12,376
1884	54,534	1929	15,276
1885	44,720	1930	17,847
1886	45,832	1931	19,625
1887	36,195	1932	17,845
1888	18,953	1933	26,332
1889	19,064	1934	19,082
1890	29,440	1935	16,050
1891	40,557	1936	22,764
1892	28,161	1937	23,916
1893	22,536	1938	28,557
1894	17,329	1939	52,065
1895	12,734	1940	35,735
1896	13,757	1941	35,113
1897	8,342	1942	30,308
1898	10,150	1943	37,086
1899	10,381	1944	34,287
1900	25,210	1945	40,207
1901	23,155	1946	29,518
1902	13,075	1947	25,991
1903	25,032	1948	25,876
1904	11,036	1949	33,523
1905	15,055	1950	27,230
1906	20,527	1951	24,742
1907	15,438	1952	21,991
1908	22,747	1953	18,458
1909	16,419	1954	25,512
1910	6,980	1955*	28,118
1911	9,013	1956	22,449
1912	10,798	1957	19,690
1913	21,546	1958	16,147
1914	14,372	1959	9,451
1915	18,098	1960	13,138
1916	15,608	1961	14,118
1917	16,706	1962	16,167
1918	19,678	1963	17,039
1919	22,988	1964	23,90[illegible]
1920	14,235	1965	24,846
		1966	25,741

*The total catch before 1955 excludes Newfoundland while the total catch from 1955 on includes Newfoundland

[1] 1876-1930 total after Sette and Needler (1934)
1931-1966 totals from Canadian Fisheries Statistics (Annual Review)
1931-1966 - Dominion Bureau of Statistics

APPENDIX III

(a)

Mean fork length and mean total lengths of samples used in calculating the conversion factor

Date	Location	Sample size	Mean fork length	Mean total length	Conversion factor
25/6/65	St. Annes Pt, N.S.	90	339.8	373.8	.910
15/9/65	Cape Cod Bay, Mass.	50	281.6	307.9	.915
25/5/66 to 20/6/66	South-west Nova Scotia	383	356.3	388.9	.916
30/6/66 to 11/7/66	Provincetown, Mass.	398	270	294	.918
1/8/66	Gulf of St. Lawrence	96	353.8	388.3	.911

(b)

Measured total and fork lengths, and calculated fork lengths in mm of the smallest and largest samples from which both fork and total lengths were available

Date	Location	Sample size	Mean measured total length	Mean measured fork length	Calculated fork length	Difference
Sept. 1966	Rumson, N.J.	96	154.09	142	141	1
9 June 1966	St. Johns Is. N.S.	100	393.3	360.5	360.2	.3

Fork length frequencies for 1962 to 1966 by month and ICNAF Statistical District.

Year	1962[1]				1963[1]						1964[1]				1965									1966									
Statistical Districts	4X				4X					4T	4X			4T	4X				$4V_n$		4T		5X	4X				4T			5Y		Rumson, N.J.[2]
Month	5	6	7	10	5	6	7	8	10	10	5	6	7	10	5	6	7	8	6	8	7	8	9	6	7	8	10	7	8	9	7	9	9
Fork Length																																	
95				23																													
105				66																													
115				10																													
125				1																													
135																																	45
145																																	38
155																																	9
165			3																														2
175			6																														2
185			6																												1		
195			7																												1		
205			9																						34						14		
215		1	12											1			5								36	1					45		
225	1	2	7				1						15				14								42	28					141		
235		1	49				2						21	1			23	6							37	175					108		
245			188				2	1					33	1			67	20							60	292			2		63	25	
255		1	260				12	1					24				146	40							57	209			0		26	66	
265		1	151				11	1					13				189	61					8		21	102	8		4		9	47	
275		1	92				11	2			1		5				145	47		1			14		7	21	54		8			12	
285	1	9	59			2	4	3				1	7	1			92	19		5			17	1	10	4	35			3	4		
295		55	128			6	4	5			1	10	2			1	39	4		5	1		9	8	32	4	22		1	7	13		
305	2	133	219		3	38	13	6	1			24	2			9	33	2		1	4			7	44	1	3	6	3	5	26		
315	13	125	51		26	116	18	27	22	19	1	45	4			10	64	1	4	1	24	1	1	14	31		14	14	18	5	32		

[1]The 1962 to 1964 fork length frequencies calculated from total length by FL = .916 TL. These length frequencies obtained from unpublished records Fisheries Research Board of Canada, St. Andrews, N.B.

[2]Rumson, N.J., is outside the ICNAF Convention Area

Year	1962[1]				1963[1]						1964[1]				1965									1966									
Statistical Districts	4X				4X					4T	4X			4T	4X				$4V_n$		4T		5X	4X				4T			5Y		
Month	5	6	7	10	5	6	7	8	10	10	5	6	7	10	5	6	7	8	6	8	7	8	9	6	7	8	10	7	8	9	7	9	9
Fork Length																																	
325	18	103	12		36	70	13	20	79	86	3	176	6	21		77	73	1	3	5	37	2	1	16	17		22	14	21	6	38		
335	24	51	6		42	36	6	7	102	72	13	140	4	78	8	343	85		33	14	150	25		33	13		20	27	33	10	32		
345	9	17	0		34	8	3	1	52	19	44	39	2	79	37	733	70		75	34	307	48		173	12		9	99	62	55	34		
355	4	17	5		22	1		1	6	1	40	28	1	29	77	511	36		61	22	290	22		272	16		20	174	128	132	42		
365	6	24			8	1			1		20	7		8	85	344	8		17	11	129	2		188	18		31	121	55	103	35		
375	22	43			11	2					7	2		1	60	92	3		6	1	50			68	6		20	26	13	32	21		
385	29	50			18						5	2		2	19	19	1		1		16			23	3		6	6	1	5	12		
395	27	30			20						6	0	1		7	7	1				3			6						2	2		
405	11	11			12						2	1			6	2					1			5							1		
415	3	5			4										2																		
425	1	5			5										2																1		
435	1	2													1																		
445		1																															
515					1																												
Total	172	688	1270	100	242	280	100	75	263	197	143	475	140	222	304	2148	1094	200	200	100	1012	100	50	816	496	837	264	487	350	365	701	150	96

APPENDIX V

Mean fork length and number of mackerel (in parentheses) of different year-classes, by monthly intervals and area for 1965 and 1966.

Year Class	1966	1965			1964				1963					1962					1961					
Age	0	I			I	II			II		III			III		IV			IV			V		
Year Sampled	1966	1966			1965	1966			1965		1966			1965		1966			1965			1966		
ICNAF Area	Rumson, N.J.[1]	4T	4X	5Y	4X	4X	4T	5Y	4X	4T	4X	4T	5Y	4X	4T	4X	4T	5Y	4X	$4V_n$	4T	4X	4T	5Y
Month																								
May														355 (1)					362 (7)					
June						315 (24)			325 (30)		339 (8)			339 (22)		349 (11)			343 (46)	344 (7)		357 (22)		
July				232 (142)	268 (312)	319 (18)		317 (85)	316 (87)	321 (24)			344 (37)	336 (35)	339 (7)			361 (18)	342 (11)		349 (8)			365 (5)
Aug.		277 (12)			265 (194)		322 (25)		308 (3)	321 (24)		350 (22)		325 (1)	335 (3)						343 (4)		365 (6)	
Sept.	142 (96)			258 (150)			317 (5)					347 (6)					358 (9)						360 (12)	
Oct.			281 (118)			319 (22)										350 (2)	362 (3)					365 (3)		

[1] Rumson, N.J. is outside the ICNAF Convention Area.

Year Class		1960						1959						1958
Age		V			VI			VI			VII			VIII
Year Sampled		1965			1966			1965			1966			1966
ICNAF Area	Rumson, N.J.[1]	4X	$4V_n$	4T	4X	4T	5Y	4X	$4V_n$	4T	4X	4T	5Y	4T
Month														
May		359 (16)						362 (51)						
June		348 (67)	354 (9)		357 (60)			351 (279)	351 (67)		357 (160)			
July		342 (3)		349 (12)			370 (2)	346 (45)		349 (106)		357 (58)	365 (2)	
Aug.				343 (6)		358 (23)				345 (75)		357 (42)		355 (3)
Sept.						358 (13)								
Oct.					355 (2)									

APPENDIX VI

Date, location, number of fish tagged and date and location of recaptures of 2407 mackerel tagged on the Atlantic coast of Nova Scotia and in the Gulf of St. Lawrence in 1966.

Tagging				Recaptures		
Date	Location	Symbol	no.	Date	no.	Location
June 9	St. Johns Is, Shelburne Co. N.S.	A_1	50	June 22	1	Lear Is., Yarmouth Co., N.S.
June 13	Clarks Harbour Shelburne Co. N.S.	A_2	85	June 14	1	Clarks Harbour Shelburne Co., N.S.
				June 17	1	Bon Portage Shelburne Co., N.S.
				June 29	1	Ingonish Victoria Co., N.S.
				July 15	1	Petit de Grat Richmond Co., N.S.
				July 15	1	West Arichat Richmond Co., N.S.
June 20	Clarks Harbour	A_3	75	June	1	St. Margarets Bay,[1] N.S.
				June 22	1	Cape Negro, Shelburne Co., N.S.
				June 27	1	Charlesville, Shelburne Co., N.S.
				July 1	1	Charlesville Shelburne Co., N.S.
				July 7	1	St. Johns Is. Shelburne Co., N.S.
July 23	St. Margarets Bay Halifax Co., N.S.	A_4	100	July 24 to 25	14	St. Margarets Bay, NS
				July 27	2	St. Margarets Bay, NS
				Aug. 1		St. Margarets Bay, NS
				Aug. 15	3	St. Margarets Bay, NS
				Aug. 17	1	St. Margarets Bay, NS
				Aug. 23	1	St. Margarets Bay, NS
				Sept. 5	1	St. Margarets Bay, NS
				Oct. 8	1	St. Margarets Bay, NS

[1] recovered from a frozen fish in bait used by a longliner; the fish was reported to have come from St. Margarets Bay

APPENDIX VI (continued)

Tagging				Recaptures		
Date	Location	Symbol	no.	Date	no.	Location
Aug. 8	Malpeque Harbour, P.E.I.	A_5	100	Aug. 19	1	Alberton, P.E.I.
				Aug. 27	1	Alberton, P.E.I.
				Sept. 3	1	Alberton, P.E.I.
Aug. 8	Malpeque Harbour	A_7	100	Aug. 27	1	Alberton, P.E.I.
Aug. 9	Malpeque Harbour	A_6	97	Aug. 10	1	Malpeque, P.E.I.
Aug.10	Malpeque Harbour	A_8- A_{10}	300	-	0	
Aug.10	Malpeque Harbour	A_{11}	100	Aug. 11	1	Malpeque, P.E.I.
Sept.21	Malpeque Harbour	A_{12}- A_{20}	900		0	
Sept.22	Malpeque Harbour	A_{21}- A_{25}	300		0	

APPENDIX VII (a)

Fork length in mm of mackerel of the 1959 year-class from various sources for the Gulf of St. Lawrence (ICNAF Statistical Area 4T), the Atlantic coast of Cape Breton (ICNAF Statistical Area $4V_n$) and southern Atlantic coast of Nova Scotia (4X).

Year	Date	ICNAF Area	Number	Mean	Source
1960	July	4T	100	224	Bergeron (1961)
1960	August	4T	368	243	Bergeron (1961)
1960	September	4T	670	250	Bergeron (1961)
1960	July to September	4T	1481	244	Bergeron (1961)
1961	August to September	4T	1027	282	Bergeron (1962)
1962	June	4X	513	316	length frequencies
1963	June	4X	280	320	length frequencies
1963	October	4X	263	333	length frequencies
1963	October	4T	197	330	length frequencies
1964	June	4X	474	330	length frequencies
1964	October	4T	218	342	length frequencies
1965	June	4X	279	351	otoliths
1965	June	$4V_n$	67	351	otoliths
1965	July	4T	106	349	otoliths
1965	August	4T	75	345	otoliths
1965	June to August	4X, $4V_n$, and 4T	4249	349.	length frequencies
1966	June	4X	160	357	otoliths
1966	August	4T	78	357	otoliths
1966	September	4T	42	357	otoliths
1966	June to September	4X and 4T	1107	355	length frequencies

APPENDIX VII

(b)

Average size in mm of mackerel from the 1923 year-class measured in the autumn of 1925 to 1930, from the waters of New England (after Bigelow and Schroeder, 1953).

Year Sampled	1925	1926	1927	1928	1929	1930
Age	II	III	IV	V	VI	VII
Measured length	365	385	395	405	415	425

(c)

Fork length calculated from total length measurements of mackerel from the S.W. coast of England (Steven, 1950).

Age	I		II		III		IV		V		VI	
Date	May	Sept.	May	Sept.	May	Sept.	May	Sept.	May	Sept.	May	Sept.
TL	238	286	306	321	330	333	341	346	355	559	362	
FL	218	262	280	294	302	305	312	317	325	329	332	

APPENDIX VIII

(a)

Frequency distribution of counts of rays of the second dorsal fin in various locations from Canadian and United States waters in 1965 and 1966.

Date	Location	Number of Rays 9	10	11	12	13	14	number of samples
May 27 1965	Woods Harbour, Shelb. Co., N.S.		5	35	54	6		100
June 1-15, 1965	Yarmouth and Lunenburg, N.S.		6	42	97	5		150
June 15-30, 1965	Yarmouth and Ingonish, N.S.		9	51	133	5		198
July 1 to Aug.15/65	Gulf of St. Lawrence		9	58	215	18	1	301
Aug. 10 1966	Malpeque, P.E.I.		1	17	78	4		100
Sept.22 1966	Malpeque, P.E.I.		2	10	35	2		49
Aug. 5 1965	Passamaquoddy Bay, N.B.	1	0	21	69	8	1	100
Oct. 22 1966	Halifax, N.S.		2	16	26	4		48
Sept. 10 1966	Provincetown, Mass.		2	11	83	4		100
Sept. 14* 1966	Provincetown, Mass.	1	2	8	37	6		54

*second dorsal fin ray counts were obtained from radiographs

APPENDIX VIII

(b)

Frequency distributions of counts of rays of the anal fin in various locations from Canadian and United States waters in 1965 and 1966.

Date	Location	Number of rays 9	10	11	12	13	14	number of samples
May 27 1965	Woods Harbour Shelb. Co., N.S.		6	23	70	1		100
June 1-15, 1965	Yarmouth and Lunenburg, N.S.		1	24	117	8		150
June 15-30, 1965	Yarmouth to Ingonish, N.S.		2	50	140	5		197
July 1-Aug.15/65	Gulf of St. Lawrence		6	46	237	9	1	299
Sept. 22 1966	Malpeque, P.E.I.		1	11	38			50
Aug. 5 1965	Passamaquoddy Bay, N.B.	1	2	12	83	2		100
Oct. 22 1966	Halifax, N.S.			7	39	2		48
Sept.14* 1966	Provincetown, Mass.		3	3	43	5		54

*anal fin ray counts were obtained from radiographs

APPENDIX VIII

(c)

Frequency distribution of counts of finlets in various locations from Canadian and United States waters in 1965 and 1966.

Date	Location		Number of finlets 4	5	6	number in sample
June 15-30/65	Yarmouth to Ingonish, N.S.	Dorsal	6	187	7	200
		Anal	5	95	0	100
July 1-Aug.15/65	Gulf of St. Lawrence	Dorsal	12	281	6	299
		Anal	12	282	6	300
Aug.10/66	Malpeque, P.E.I.	Dorsal	4	94	2	100
		Anal	4	94	2	100
Sept.22/66	Malpeque, P.E.I.	Dorsal	1	49		50
		Anal	-	50		50
Oct. 22/66	Halifax, N.S.	Dorsal	2	39	7	48
		Anal	2	45	1	48
Sept.10/66	Provincetown, Mass.	Dorsal	2	96	2	100
		Anal	6	92	2	100

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