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An hypothesis concerning the migration and distribution of Atlantic mackorel *(Scomber scombrus)*.

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Introduction

The Atlantic mackerel *(Scomber scombrus)*, is abundant in the coastal waters of the Canadian and American Atlantic from Chesapeake Bay to Newfoundland waters (Bigelow and Shroeder 1953 and Parsons 1970). It is also found in the northeast Atlantic from Spain to Norway. This species in the family *Scombridae* is of tropical origin and is the most northerly species of the genus *Scomber*. It is a pelagic fish designed for an efficient hydrodynamic performance and therefore is adapted well for its long distance migrations.

There are still many large gaps in the knowledge of the biology of mackerel. The earliest comprehensive works on the northwest Atlantic populations were done by Sette (1943 and 1950). On the basis of data collected from 1926 to 1935 he separated mackerel into northern and southern contingents. More recent works by Anderson (1973 and 1975a), MacKay (1967 and 1976), Moores et. al. (1975), Paciorkowski et. al. (1973) and Stobo and Hunt (1974) show that the more recent data substantiate and expand Sette's hypothesis. This species spawns in two separate areas, inshore from Long Island to Cape Cod (Sette 1943) and in the Magdalen Shallows (Arnold 1970). The northern group leaves the Gulf of St. Lawrence in the fall and migrates out to the edge of the continental shelf between Sable Island and Chesapeake Bay for the winter. It appears that at least some mixing of contingents occurs during this time.

The commercial catch from ICNAF Subareas 3, 4, 5 and 6 has increased rapidly from 6,831 M.T. in 1961 to 419,306 in 1973 (Anderson 1975a). Most of this was due to the increased winter fishery in subareas 5 and 6 by the foreign distant water fleets. Because of the possibility of mixing of northern and southern contingents in this area in winter, the biology of mackerel and the contingent interaction must be better understood in order to lay the groundwork for more comprehensive stock assessments and TAC allocations. This paper gives a preliminary assessment of the distribution, age and food of the mackerel found on the Scotian Shelf and Cape Cod area in the winter and the distribution of immature mackerel throughout the year.

Materials and methods

Sampling was done along the outer edge of the Scotian Shelf and Georges Bank from Cape Cod to the Gully, located northeast of Sable

Island (Fig. 1). One hundred and twenty-four sets using both the Engel bottom trawl and the diamond ten midwater trawl were used during the cruise (Fig. 2). The midwater trawl was used only when there was a strong midwater trace on the sonar. The cruise track followed a predetermined series of transects and sets were done on a regular basis or when sonar marks indicated the presence of fish. Tows were made at a speed of 3.5 knots with operations conducted around the clock. XBT casts and surface salinities were also done at each station.

Catches of mackerel (in numbers per metre of tow) were plotted for each station and catches of mackerel taken during groundfish cruises of the Fisheries and Marine Service (1958-1976) were also plotted. Isotherms were plotted using the bottom temperatures from each station.

All mackerel from the Scotian Shelf were measured (fork length) and then frozen. For the samples from Cape Cod that had greater than 100 individuals, a stratified subsample was measured and frozen. Somatic weight, stage of gonad (using an eight stage scale recommended to the Herring Committee of I.C.E.S., Parrish and Soville 1965) gonad weight, number of gill rakers and vertebrae counts were recorded and otoliths and stomachs were removed from each fish. The stomach contents were analysed in detail and a summary of the Scotian Shelf results are given.

Length versus weight and frequencies of lengths, maturity and preferred temperatures were plotted for the various locations sampled to determine geographical variation. Because the analysis of otoliths was not completed at the time of writing, year-classes were determined on the basis of length frequencies and the comparison of this data to old age-length keys made up for the same area. This data was then compared to commercial catch length frequencies and old research data from Canadian waters.

Results

The mackerel caught off Nova Scotia in November and December, 1976 were concentrated along the edge of the shelf from Brown's Bank to Sable Island (Fig. 3). The depth of the bottom at the areas where they were caught varied considerably but the average bottom depth where mackerel were caught on the Scotian Shelf was 62 F(113M). Distribution plots of the mackerel from past groundfish research cruises (1958-1976) also showed that they were concentrated at the edge of the shelf (Fig. 4, upper diagram). Most of these cruises were done in February and March showing that the distribution changed little over the winter months. However, mackerel were found over the whole of the Scotian Shelf in both shallow inland areas and deep offshore areas in the summer (Fig. 4, lower diagram). Relatively few mackerel were caught in each tow on the Scotian Shelf but the many tows that yielded mackerel along the shelf edge indicated that they either formed numerous small schools over a wide

area or they were not schooling at all but were dispersed over a wide area. More fish were caught in the bottom trawl or near bottom in the midwater trawl both day and night. No mackerel were caught between Brown's Bank and the Great South Channel but large concentrations were found inshore in the area just south of Cape Cod (Fig. 3).

Superimposing the mackerel distribution plot over the chart of bottom temperatures for the sample area (Fig. 5) showed that the mackerel appear to be concentrated along the 9° C isopleth. This is confirmed by the data presented in Fig. 6. The Scotian Shelf mackerel were found in a relatively wide range of temperatures (5°C to 12°C) with a mean of 9.3°C while the Cape Cod mackerel were found in 10°C to 13°C waters with a mean of 11.2°C. This Cape Cod group was inshore in 34 F (65M) of water and they were formed into large midwater schools as was indicated by the sonar traces and the relatively large catches per tow.

Length frequencies were examined to note any size class variations from tow to tow, or from area to area. Analysis indicated that at stations where there were year-class 0 animals very few year-class II or older animals were present. Year-class I animals were found with both 0 and II+ mackerel but rarely at the same station. There was a distinct school year-class separation. In examining catch by area, a geographical separation of year-classes became apparent. A comparison of catches from the Sable Island area, the Emerald Bank area and the Brown's Bank area indicated little variation in length frequency distribution over the whole Scotian Shelf area (Fig. 7). There were predominantly year-class 0 (up to 21 cm.) and year-class I (up to 29 cm.) animals. Length frequencies of mackerel caught during the winter research cruises on the Scotian Shelf (January to March) showed a similar distribution of lengths. The increased mean length of 0 animals reflect growth between November and March (Fig. 8, lower diagram). However, in the Cape Cod samples the year-class 0 was missing completely (Fig. 8, upper diagram). No animals less than 22 cm. were caught in this area indicating the presence of only year-class I+. A further breakdown of catches from the Cape Cod area revealed that predominantly large animals, greater than 30 cm, were schooling in the shallows off Nantucket Island (20-25 F) and animals of 22 to 30 cm. length schooled separately just offshore in 35 to 45 F of water (Fig. 9). Length frequencies from the Gulf of St. Lawrence research cruises (Sept. 1970-1976) showed that yearlings (year-class I) were absent from this area in late summer (Fig. 10).

The gonad stages of the Scotian Shelf and Cape Cod animals were compared (Fig. 11). The maturity scale used is in 8 stages with stages I and II representing the immature (virgin) condition and stage III+ representing fish that have spawned at least once. The plot of length frequency of maturity for the different year-class 0 fish had gonads in stage I, year-class I fish with gonads in stage II, and year-classes II+ had mainly stage III, VII, and VIII. Those mackerel on the Scotian Shelf were almost all immature fish while the Cape Cod fish contained both virgin fish and those that had spawned at least once.

An examination of total weight versus fork length showed that there was no significant difference in the three areas of the Scotian Shelf (Fig. 12). The equations of the lines for the three areas are:

Sable Island - $W = 0.00432\ L^{3.248}$, coeff = 0.996

Emerald Bank - $W = 0.00498\ L^{3.215}$, coeff = 0.979

Brown's Bank - $W = 0.00383\ L^{3.274}$, coeff = 0.992

W = somatic weight
L = fork length

Those animals caught at Cape Cod were slightly longer for any given weight (Fig. 13). The equations for the lines are:

Scotian Shelf - $W = 0.00379\ L^{3.293}$, coeff = 0.987

Cape Cod - $W = 0.00756\ L^{3.0819}$, coeff = .967

The stomach contents from Scotian Shelf fish indicated that the mackerel were selectively feeding. A station by station analysis showed that stomach contents were significantly different where year-classes were mixed; there was selective feeding taking place within each year-class. In the year-class 0 animals about 60% of the euphausid species, *Thysanoessa inermis* and *Meganyctiphanes norvegia*, about 20% was the hyperiid amphipod, *Parathemisto sp.* and about 15-20% was unidentifiable. Other items found in small numbers were copepods (mainly *Calanus finmarchicus)*, fish larvae (mainly *blennoids and gadoids)*, the pteropod *Limacina sp.*, the octopus *Bathypolypus sp.* pelagic polychaetes and a terrestrial seed. In the year-class I animals, *Parathemiste sp.* was the dominant food (70-80% by weight of the stomach contents) with euphausids, copepods, pteropods, larval fish (including *Merrluccuis merluccius)*, decapod shrimps (mainly *Pandalus sp.)*, polychaetes and *Bathpolypus sp.* making up the remainder. In fish larger than 30 cm. much of the stomach content was very masticated but it appears that Parathemiste and fish larvae were the predominant food items. Twelve percent of all fish samples had empty stomachs.

During stomach content analysis it became apparent that only year-class I+ animals contained stomach parasites (nematodes). None had yet become established in the young of the year.

Vertebrae and gillraker counts comparing the Cape Cod and Scotian Shelf animals were inconclusive and were not useful in separating year-classes.

Conclusions

It has been established that a portion of the mackerel population spawns in the Gulf of St. Lawrence in June following a long migration from the wintering grounds on the edge of the shelf south of Georges Bank. These mackerel then perform a reverse migration out of the Gulf passing over the Scotian Shelf on their way south. Previously there was sparse data indicating that some of the mackerel might be over-wintering along the edge of the Scotian Shelf (Sette 1950, Moores et. al. 1974 and MacKay 1976) but to this point it was only speculative. Water temperatures are also suitable for mackerel along the edge of the Scotian Shelf, northeast to Sable Island. The data from the November 1976 cruise showed that, in fact, mackerel were found along the edge of the Scotian Shelf from Brown's Bank to Sable Island and the 1958-1976 mackerel by catch of groundfish research cruises confirmed that they do overwinter in this area. This means that a certain portion of the northern contingent splits from the main population during the southward migration and overwinters near the bottom in 60 F of water along the shelf edge where the water temperature is about 9°C. The mackerel do not form large schools at this time. Until now it was uncertain how much of the northern contingent overwintered in S.A. 4, but the current data showed that these animals were almost exclusively young of the year and yearlings. This means that the northern contingent had a distinct geographical year-class separation in the winter, with the reminder of the stock (year-class I+) probably overwintering in S.A.'s 5 and 6. Recent tagging experiments done by Beckett et. al. (1974) and Parsons and Moores (1974) indicated that at least part of the northern contingent does migrate from S.A. 4 to S.A.'s 5 and 6. This implies, then, that the two youngest year-classes, in not moving south were not vunerable to the intensive S.A. 5 and 6 offshore fishery carried on from November through May as the older year classes are. The 1970 to 1976 length frequency research data and the 1973 to 1976 commercial length frequencies from the Gulf of St. Lawrence indicates that the year-class I animals were almost completely missing from the samples. Only in 1960 and 1968 did the data presented by Bergeron (1961) and MacKay (1976) show substantial numbers of yearlings in the Gulf of St. Lawrence. In other years few yearlings were recorded by these two authors in this area. Year-class I mackerel, in general stayed out of the Gulf in the summer. MacKenzie (1930) noted that the appearance

of yearlings inshore along the Atlantic coast of Nova Scotia is a regular summer occurrence. Commercial trap data from 4X, 4W and to some extent 4VN for recent years confirms the occurrence of yearlings inshore along outer Nova Scotia in the summer. The 1959 and 1967 year-classes were exceptionally strong and the presence of the yearlings of these two large year-classes in the Gulf of St. Lawrence in summer (1960 and 1968) probably represents a spilling over of the abundant yearlings into this area. For weaker year-classes there tended to be a poorer representation of the subsequent yearlings in 4VN and 4T.

This means that mackerel spawned in the Gulf of St. Lawrence move out of the Gulf in the fall and appear to migrate only as far as the outer Scotian Shelf. They overwinter in this area offshore, then disperse inshore in the spring and remain along the outer Nova Scotia coast during their second summer. MacKay (1976) found that most of the mackerel mature and spawn for the first time in their third summer but with a small number, maturing during their second and fourth summer. Those mackerel (year-class 0 and I) that remain on the Scotian Shelf throughout the year are immature and this area is, in effect, a nursery ground for the juvenile portion of the northern contingent mackerel. The diet of mackerel changes throughout the life cycle.

Arnold (1970) found that the larvae (5 to 20 mm) in the Gulf of St. Lawrence ate, in order of importance, copepods, cladocerans, fish larvae, other crustaceans and invertebrate eggs. Year-class 0 animals that have migrated to the outer Scotian Shelf eat larger particles, in order of importance, euphausids, hyperid amphipods, and fish larvae. The year-class I animals of the Scotian Shelf eat smaller particles primarily hyperid amphipods and some euphausids. MacKay (1976) found that the older year-classes again reduce preferred particle size and eat mainly copepods, larval crustaceans, fish eggs, and a few larger euphausids and shrimps.

There appears to be a certain amount of interaction between the older year-classes of the northern contingent and the southern contingent in the winter, however, this pattern is still not clear. Data from the present study and that of Anderson and Almeida (1976) showed a distinct year-class separation from school to school but a great deal more research is needed to determine the detailed community structure of mackerel in S.A.'s 5 and 6. This data sheds some light on the status of the northern contingent immatures but much more research is required before mackerel stock assessment and TAC allocations can be down with any degree of certainty.

Acknowledgments

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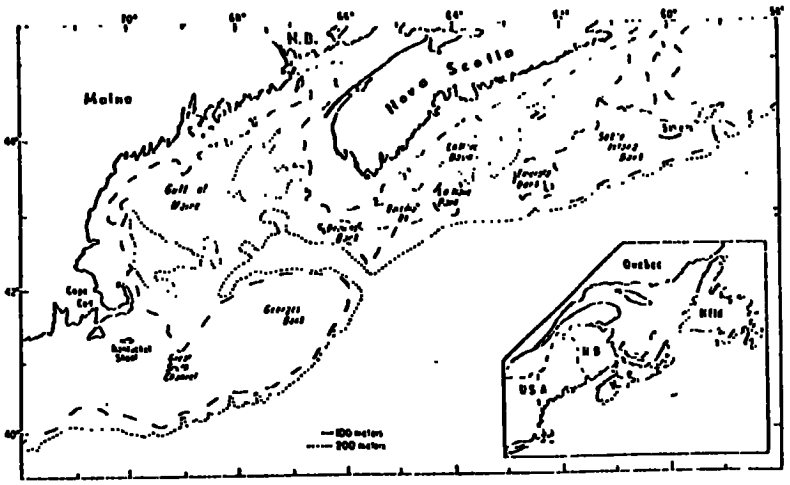

Fig. 1. Chart of the Scotian Shelf and Georges Bank showing depth contours.

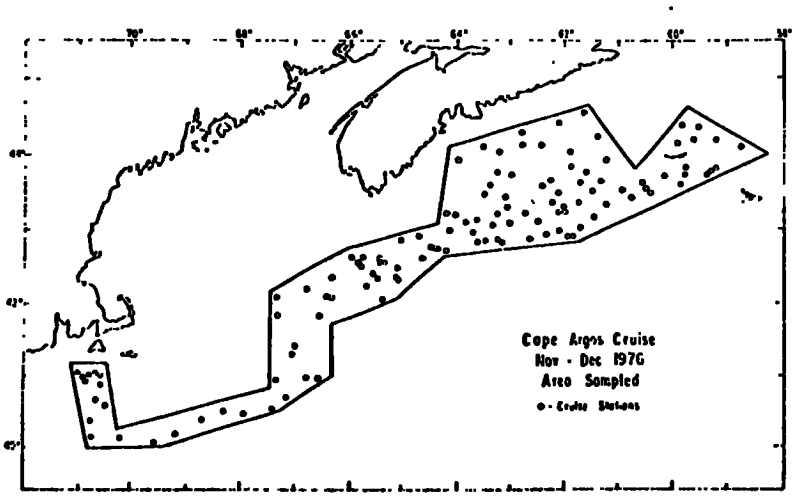

Fig. 2. Chart of the Scotian Shelf and Georges Bank showing the stations sampled, Nov. - Dec. 1976.

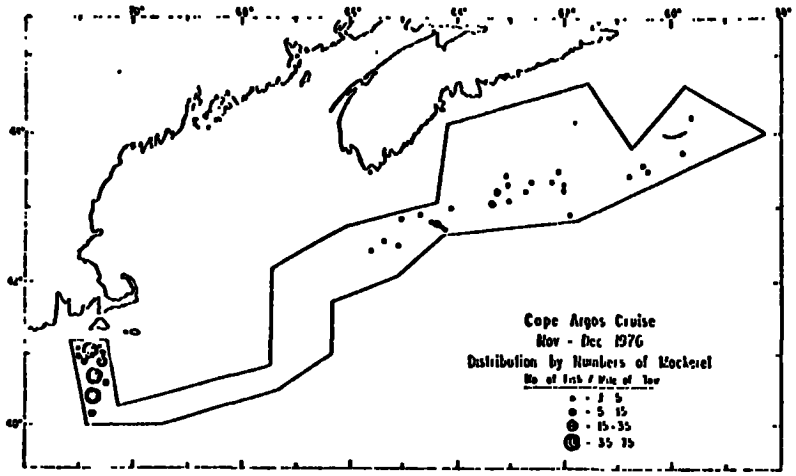

Fig. 3. Chart of the Scotian Shelf and Georges Bank showing the distribution of Atlantic mackerel, Nov. - Dec. 1976.

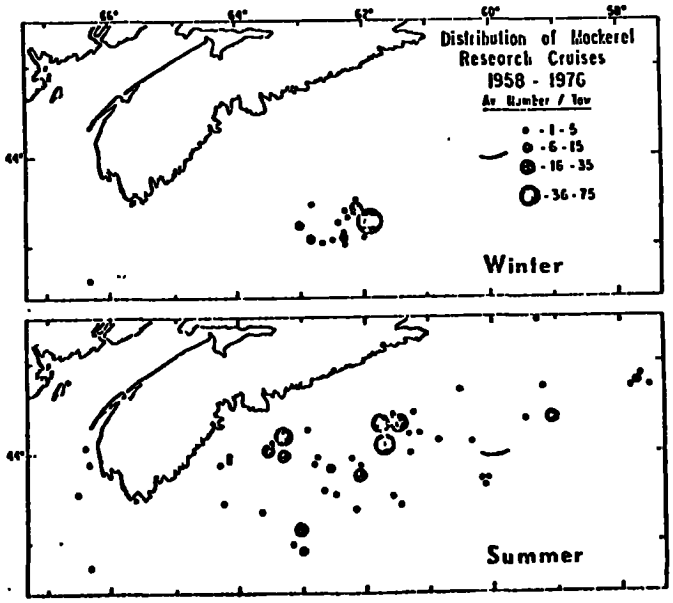

Fig. 4. Chart of the Scotian Shelf showing the distribution of mackerel in winter (upper) and summer (lower). Data is from groundfish cruises of the Fisheries and Marine Service, 1958-1976.

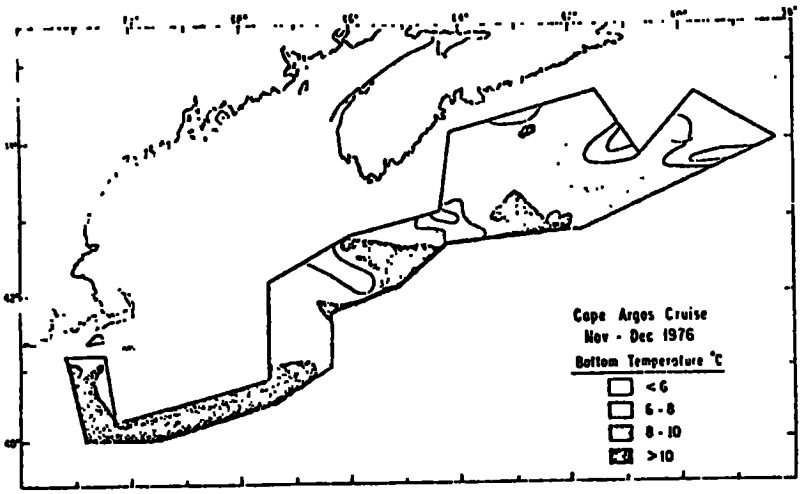

Fig. 5. Chart of the Scotian Shelf and Georges Bank showing bottom water temperatures in Nov. - Mar. 1976.

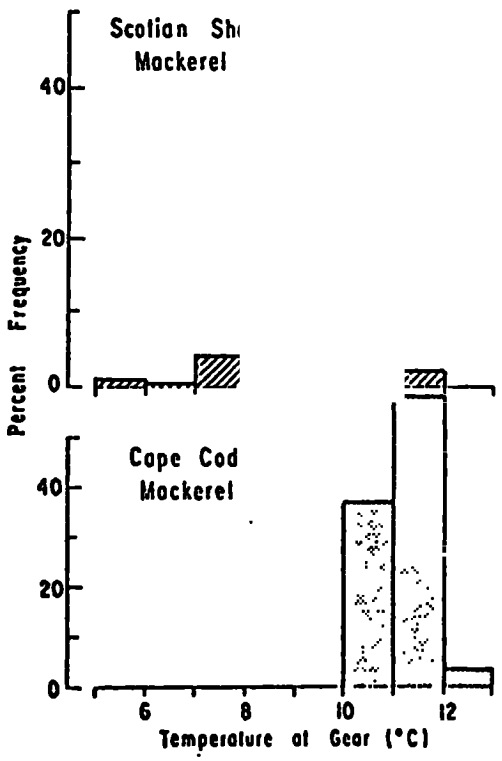

Fig. 6. Percent frequency of mackerel on the Scotian Shelf and Cape Cod showing temperatures at which these animals were found.

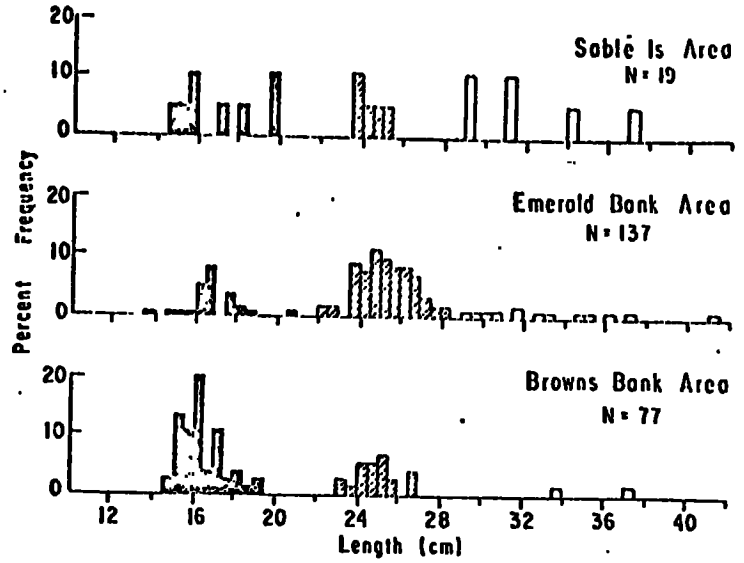

Fig. 7. Length frequency histograms of mackerel from three areas of the Scotian Shelf. Black bars represent year-class 0 animals, stippled bars represent year-class I animals and white bars represent II+ animals.

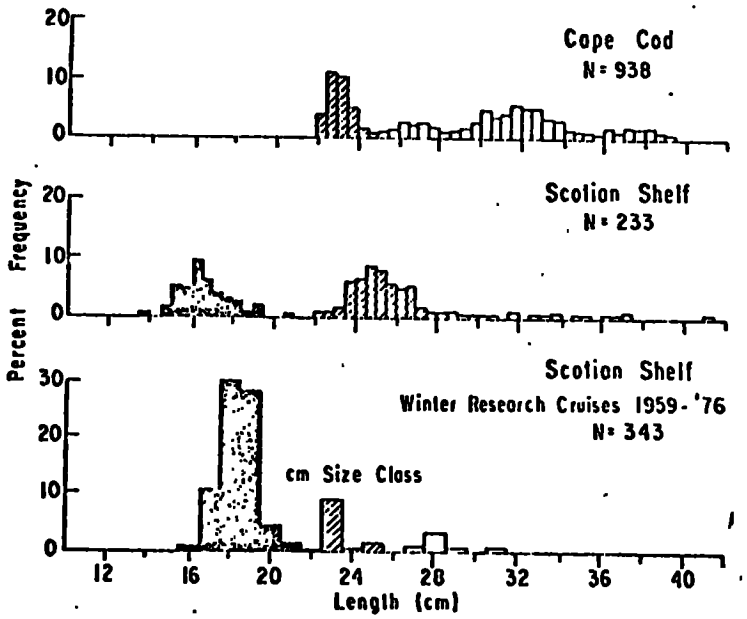

Fig. 8. Length frequencies of: mackerel caught in 1976 off Cape Cod (upper diagram), mackerel caught in 1976 on the Scotian Shelf (middle diagram), and mackerel caught, 1958-1976 on the Scotian Shelf (lower diagram).

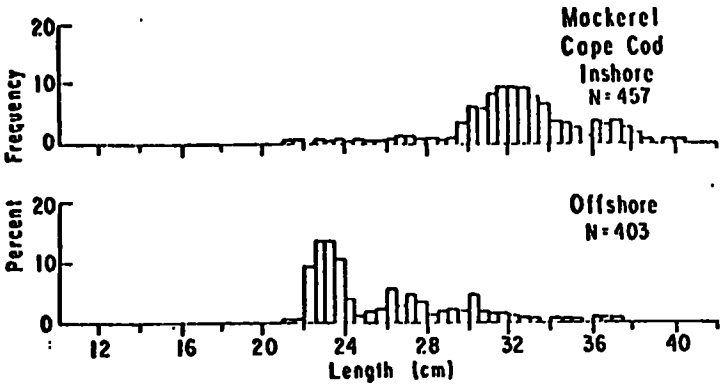

Fig. 9. Length frequencies of: mackerel schooling in the inshore shallows (upper diagram), and those schooling offshore in 35 to 45 F. of water (lower diagram).

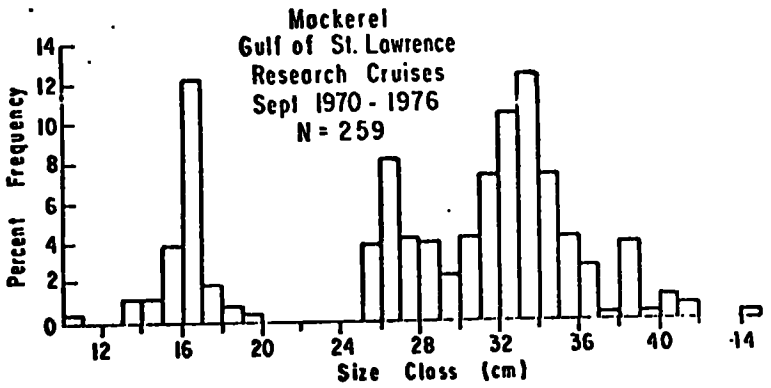

Fig. 10. Length frequencies of mackerel from the Gulf of St. Lawrence in late summer, 1970-76.

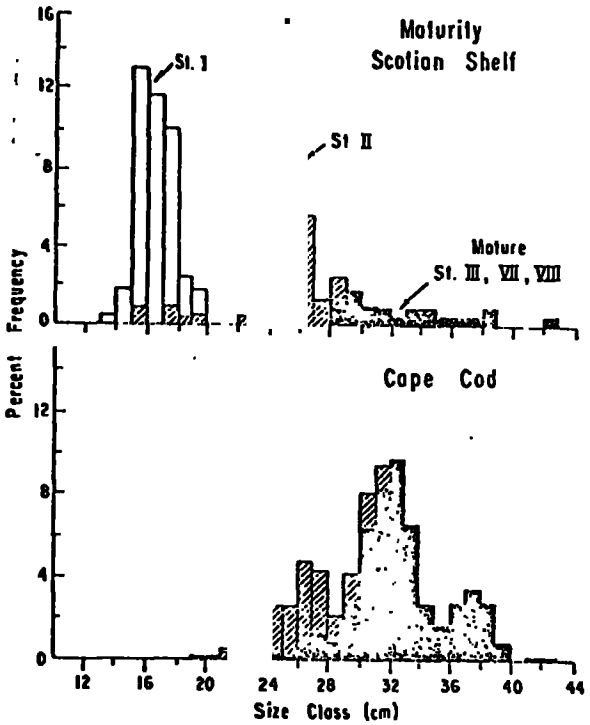

Fig. 11. Length frequencies showing gonad maturity for: Scotian Shelf mackerel (upper diagram), and Cape Cod mackerel (lower diagram).

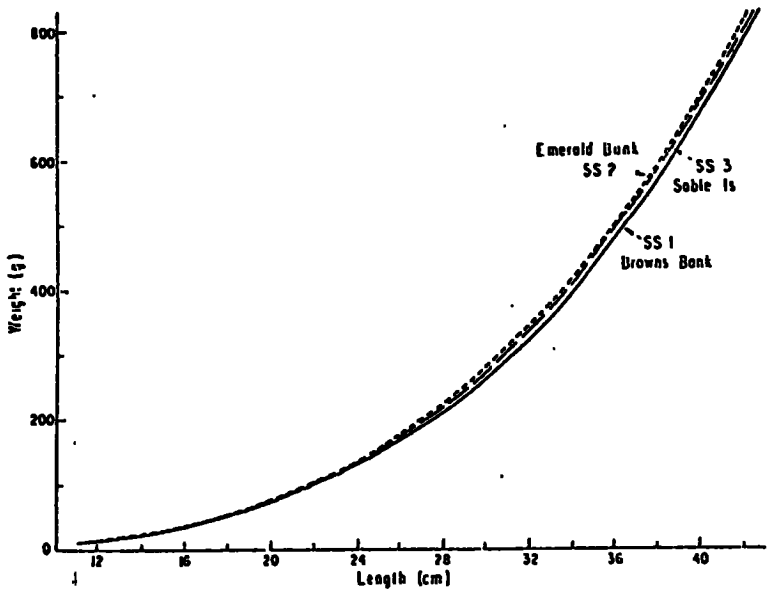

Fig. 12. Lines of best fit for weight versus length for mackerel caught off Sable Island, at Emerald Bank and at Browns Bank.

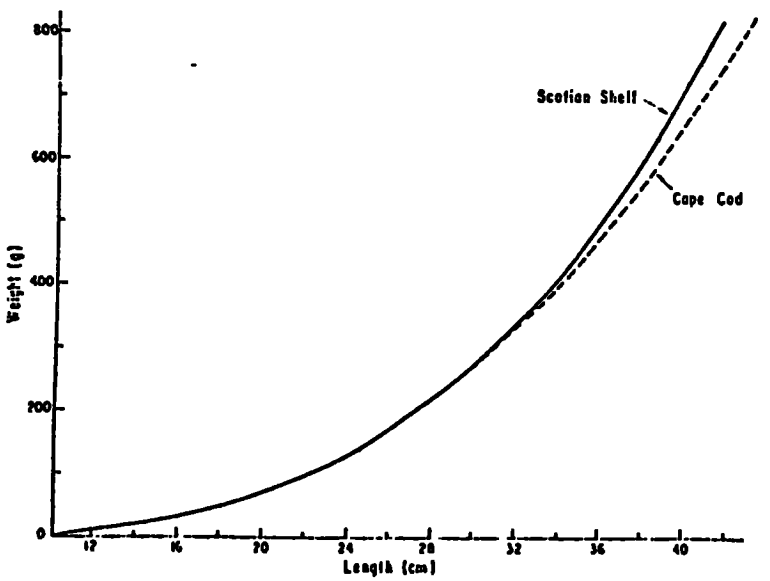

Fig. 13. Lines of best fit for weight versus length for mackerel caught on the Scotian Shelf and off Cape Cod.

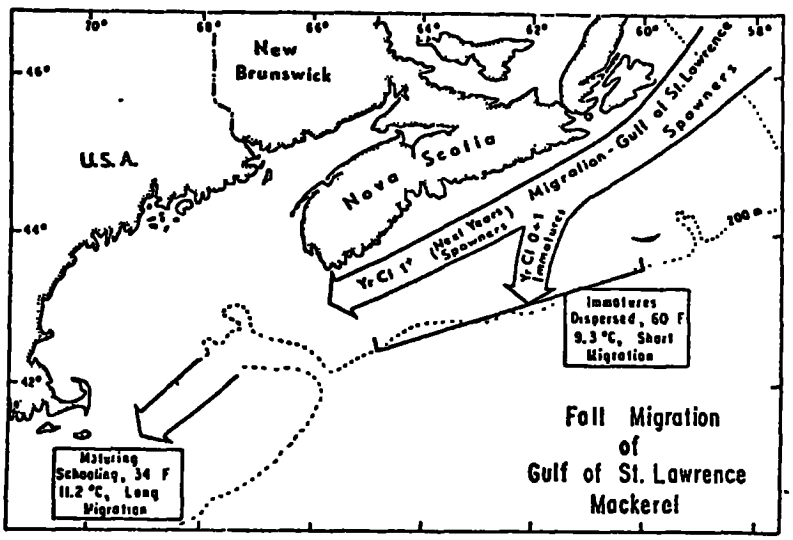

Fig. 14. Movement of mackerel along the Scotian Shelf in the fall and the winter conditions on the Scotian Shelf and at Cape Cod.