Winter Distribution and Feeding of Mackerel on the Scotian Shelf and Outer Georges Bank with Reference to the Winter Distribution of Other Finfish Species

D.W. Kulka and W.T. Stobo

Marine Fish Division
Bedford Institute of Oceanography
Department of Fisheries and Oceans
Dartmouth, Nova Scotia
B2Y 4A2

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WINTER DISTRIBUTION AND FEEDING OF MACKEREL ON THE SCOTIAN SHELF AND OUTER GEORGES BANK WITH REFERENCE TO THE WINTER DISTRIBUTION OF OTHER FINFISH SPECIES

by

D.W. Kulka[1] and W.T. Stobo

Marine Fish Division

Department of Fisheries and Oceans

P.O. Box 1006

Dartmouth, Nova Scotia B2Y 4A2

[1]Research and Resource Services Directorate

Department of Fisheries and Oceans

P.O. Box 5667

St. John's, Newfoundland A1C 5X1

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ABSTRACT

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Results of a November-December, 1976, exploratory research vessel cruise for mackerel were plotted to show overwintering distribution on the Scotian Shelf and outer Georges Bank area. Mackerel of age groups 0 and 1 represented 92% of the catches on the Scotian Shelf and only 58% in the Cape Cod area. This occurrence suggests the whole of the northern spawning population does not migrate south of Cape Cod to overwinter, but rather a portion of this population, largely juveniles, overwinters on the Scotian Shelf. The mean length of Scotian Shelf 0-group mackerel was 6.3 cm shorter than those found off Cape Cod. The associated differences in the radius of the first otolith annulus shows promise as a means to distinguish between the northern and southern spawning contingents. Stomach content analyses indicated a dependence on euphausids by age group 0 animals and amphipods by older mackerel; fish (mainly larvae) comprised a maximum of 17% of identifiable contents.

The distribution by numbers of all other fish species caught are also plotted.

Key words: mackerel, finfish distribution, stomach contents, growth

RESUME

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Des cartes, illustrant la distribution hivernale du maquereau bleu sur le plàteau néo-écossais et autour du banc Georges, furent dessinées à partir des résultats d'une campagne exploratoire effectuée en novembre et décembre 1976 à bord d'un navire de recherche. Les maquereaux des groupes d'âge 0 et 1 représentaient 92 % des prises sur le plateau néo-écossais et seulement 58 % de celles de la région du cap Cod. Ceci donne à penser que toute la population reproductrice du nord n'émigre pas au sud du cap Cod pour y passer l'hiver. Une portion de cette population, en grande partie des juveniles, passerait l'hiver sur le plateau néo-écossais. Le groupe d'âge 0 du plateau néo-écossais avait une longueur moyenne inférieure de 6,3 cm à celle des poissons capturés au large du cap Cod. Cette différence se reflète dans le rayon du premier annulus des otolithes, ce qui semble prometteur comme moyen de différencier les contingents reproducteurs du nord et du sud. Les analyses des contenus stomacaux indiquent que les maquereaux du groupe d'âge 0 se nourrissent surtout d'euphausides, alors que les maquereaux plus âgés consomment principalement des amphipodes; les poissons (des larves en grande partie) constituent un maximum de 17 % des contenus identifiables.

Nous présentons également la distribution numérique de toutes les autres espèces de poissons capturées.

Mots-clés: maquereau, distribution des poissons, contenus stomacaux, croissance

INTRODUCTION

The Atlantic mackerel (Scomber scombrus) is abundant in Canadian and American coastal waters from Chesapeake Bay to Newfoundland (Bigelow and Schroeder, 1953; and Parsons, 1970). It constituted a very important Distant Water Fleet (DWF) and domestic fishery with catches increasing rapidly from 6,831 mt in 1961 to a high of 420,000 mt in 1973, then dropping to about 220,000 mt in 1976 just prior to the extension of jurisdiction over fisheries by Canada and the U.S.A. The extended jurisdiction essentially brought an end to the DWF involvement in the mackerel fishery.

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. The southern contingent spawns in the inshore area from Long Island to Cape Cod (Sette, 1943) and the northern contingent spawns in the Magdalen Shallows (Arnold, 1970). In the fall, the northern group leaves the Gulf of St. Lawrence and migrates out to the edge of the continental shelf between Sable Island and Chesapeake Bay for the winter but the details of this migration and the overwintering distribution of both northern and southern fish is still unclear. Because of the importance of the mackerel and the limited knowledge of geographical distribution over the winter, a survey was set up in 1976, concentrating mainly on the Scotian Shelf area. The cruise track covered an area from Sable Island to Martha's Vineyard (Fig. 1), excluding the Gulf of Maine.

There are other winter fisheries in this area, however, thus it is also important to obtain more data on general fish distribution during this time of year. Most of the previous work on marine fish distributions north of Cape Cod (Hare, 1977; Kohler, 1968; Scott, 1971 and Scott, 1976) were taken from summer cruises. There is very little distributional information available on winter distributions and assemblages of fish species in this area. Consequently documentation of potential bycatch problems during winter fisheries is not available.

This report then deals primarily with the distribution, lengths, weights, and food items of mackerel and also gives limited consideration to their otoliths, parasites, meristics, maturity and temperature preferences. It also presents the distribution of the other fish species caught during the cruise and the relative proportion of the dominant species.

MATERIALS AND METHODS

Sampling was conducted between Nov. 17 and Dec. 19, 1976 along the outer edge of the Scotian Shelf and Georges Bank from the Gully east of Sable Island (44°06'00"N, 58°40'00"W) to Cape Cod (40°04'30"N, 71°01'30"W) (Fig. 1). The cruise track followed a predetermined series of transects and a minimum number of sets were made daily with preference being given to making sets when sonar marks indicated the presence of fish. Tows were made at a speed of 3.5 knots, with operations conducted 24 hours a day. Several sets were made south of Cape Cod in order to ensure that the charter vessel and gear were capable of catching juvenile and adult mackerel. During this period the vessel restricted its operation to that area in which the Polish mackerel fleet was successfully trawling mackerel. XBT casts were made and surface salinity samples were taken at each station. A total of 124 sets using both the Engel bottom trawl (73 sets) and the Diamond Ten midwater trawl (51 sets) were made. The midwater trawl was used mostly in the area south of the Fundian Channel where there were strong midwater traces on the sonar.

Total sample weight for each species was taken and all species except invertebrates and skates were measured for fork length. When the catch of any one species exceeded 100 individuals in a single tow, a random sample of 100 fish was measured. Only for silver hake and flatfish were separate length frequencies for each sex taken. For subsequent silver hake stomach contents analysis, two stomachs per 1 cm size class per sex were placed in formalin. Whole mackerel (subsampled in large catches) were frozen and later in the lab, somatic weight, stage of gonad development (using an eight-stage scale recommended to the Herring Working Group of ICES) gonad weight, and numbers of gill rakers, pelvic fins and vertebrae were recorded, otoliths were taken, and stomachs were analysed.

Catches of all species (in numbers or kilograms per mile of tow) were plotted for each station. Contour maps of bottom temperature, temperature at gear, surface temperature and surface salinity from the present cruise were also plotted. Sonar traces of tows during which mackerel, herring, blueback herring, round herring, butterfish and squid were caught, were examined to see if individual species could be identified from the traces. Also plots showing proportions of mackerel, silver hake, cod, butterfish, blueback herring and redfish were examined to determine where species overlap could cause bycatch problems in winter fisheries.

Length-weight, otolith length-somatic length relationships, and frequencies of length maturity and preferred water temperature of mackerel were plotted and examined for the various locations sampled, to determine geographical variation in these parameters.

Age-length keys were derived and applied to the length frequencies to obtain the age structure of the population sampled. Stomach contents of the mackerel including parasites were broken into major taxonomic groups, counted and weighed, then plotted as percentages by weight of each group relative to mackerel length and age composition.

RESULTS AND DISCUSSION

An examination of surface salinities of the sample area (Fig. 2A) showed that there was an obvious east-west demarkation located over Browns Bank with salinities of 30 to 33% to the east and 33 to 34.5% to the west. Surface temperatures (Fig. 2B) were coolest to the north (2 to 5°C) but warmer along the southern edge of Georges Bank (11°C). Because most of the fish caught were bottom dwelling, or lived in mid to deep layers, the surface environment would probably have little or no effect on the faunal distribution. However, the wide range of temperatures at gear (Fig. 3A) and bottom temperatures (Fig. 3B) could have a considerable effect on the distribution of some of the species and this relationship is discussed separately for each species. The effect of the Gulf Stream can be seen along the shelf edge as eddies of warm water (10°C) pushing in just south of Browns and Emerald Banks. Correspondingly tongues of the cold Labrador current push down between the warm eddies along the Fundian Channel, LaHave and Sable Island Banks (8°C). The southern edge of Georges Bank however, is uniformly warm.

An account of the distribution of each species caught during the cruise is given below. The distributions of groundfish south of Cape Cod are probably inaccurate because the midwater trawl was primarily used in this area. However, distribution of pelagic species over the whole sample area and groundfish distributions north of Georges Bank are probably representative since the sonar traces indicated that generally, pelagic and groundfish species, were distributed close to the bottom on the Scotian Shelf.

SPECIES DISTRIBUTION

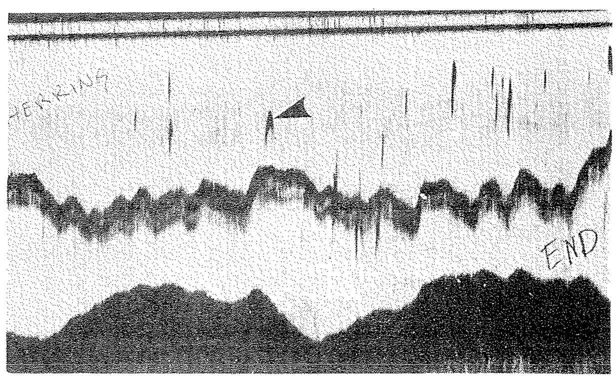
Spiny dogfish (Squalus acanthias) (Fig. 4). Both the midwater trawl and high opening Engel bottom trawl were effective in capturing dogfish, thus indicating a wide vertical distribution. Dogfish were found offshore, in the deeper basins on the Shelf and along the shelf edge in the area just south of Cape Cod. Here, large concentrations of adults were found in depths of 25 to 50 fms. in areas where the water was still warm. Juveniles, were found only along the edge of Georges Bank, almost completely separated geographically from the adults. They ranged in size from 28 to 46 cm (mean of 37 cm).

This species has been found to move south and offshore in the fall, to overwinter in deeper waters where the temperature exceeds 5°C (Leim and Scott, 1966). This is in agreement with the findings of the present cruise. It does appear however that some portion of this species may overwinter on the outer edges of the Scotian Shelf west of Sable Island Bank. Those fish present on Nantucket Shoals during November will probably move offshore as the water temperature decreases.

Thorny skate (Raja radiata) (Fig. 5). All skates caught were lumped under one classification, however the majority of catches were comprised almost solely of thorny skate. Catches were made mainly at stations located over the shallow areas, particularly Emerald, Western and Sable Island Banks. A similar distribution was found by Scott (1976) during summer cruises.

Blueback herring (Alosa aestivalis) (Fig. 6). This species was found only over the Nantucket Shoals except at a single location on Georges Bank. Midwater hauls on the Scotian Shelf revealed no blueback herring. The species apparently only ranges further north during the summer (Leim and Scott, 1966). Cooler waters on the Scotian Shelf probably limit the distribution of this more southern species. The mean length of these fish was 24.3 cm, with very little variance.

Atlantic herring (Clupea harengus harengus) (Fig. 7). Small numbers of herring were taken on Nantucket Shoals. Only two sets on the Scotian Shelf produced herring, both on Sable Island Bank. Small schools of this species on Sable Island Bank made a very distinctive U-shaped trace on the sonar paper as shown in the figure below. Such traces were seen no where else. Large schools of herring also display solid acoustical configurations (Stobo, unpublished) but these were not observed during this cruise.



Gaspereau (Alosa pseudoharengus) (Fig. 8). This species was taken in both bottom and midwater trawls and was common in the deeper areas of the Scotian Shelf. It was found in an average depth of 69 fms. The bulk of this species apparently overwinters offshore then moves into the coastal rivers in the spring to spawn (Leim and Scott, 1966).

Atlantic Argentine (Argentine silus) (Fig. 9). There appears to be little change in distribution of this species during the year. It was found mainly in slope waters or deep basins from Browns Bank to Sable Island Bank which is similar to the pattern found by Scott (1976) during summer cruises. The largest catches were made in depths greater than 90 fms.; smaller individuals of this species tended to be in shallower areas and geographically separate from the larger fish. Scott (1971) found that most argentines were caught in 100-150 fms. of water in the summer.

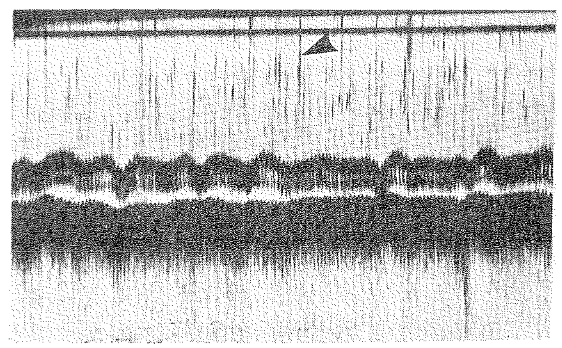
Cusk (Brosme brosme) (Fig. 10). This is essentially a deep water species which was concentrated mainly along the shelf edge southwest of the Emerald Bank area. This pattern suggests that they favour the deeper (50-150 fms.), warmer waters. Scott (1976) found a similar pattern during the summer cruise suggesting little change in distribution during the year.

Atlantic cod (Gadus morhua) (Fig. 11). Cod were widespread over the Scotian Shelf and Georges Bank and were found mainly on the banks in fairly shallow water. This pattern was similar to the summer distribution found by Scott (1976). The winter distribution of the Sable Island-Middle Bank stock and the Browns-LaHave stocks identified by Kohler (1968) appear to be quite similar to their summer distributions. Previous investigations show that cod migrations appear to be less extensive on the Scotian Shelf than in the Gulf of St. Lawrence or areas to the south (Leim and Scott, 1966). This species was not found in areas where the water temperatures exceeded 10°C. Catches were noticeably low in the two areas where the Gulf Stream eddies intruded onto the shelf.

Haddock (Melanogrammus aeglefinus) (Fig. 12). This species was also widespread over the Scotian Shelf in November-December with a large portion of the population concentrated over Browns, LaHave, Emerald and Western Banks. Few haddock however, were caught over the shallowest areas including Sable Island Bank. A portion of the population was found between the Banks in the deeper areas showing a slightly different pattern than the shallower summer distribution shown by Scott (1976). The present data agree with that compiled by Leim and Scott (1966) showing a movement to deep water by this species during the winter. Temperature appears to be quite important in determining distribution, as this species was not found in areas where the temperature was less than 7-8°C. Juvenile fish with a mean length of 15 cm were found in large numbers and were intermixed with the adults over the whole area.

Pollock (Pollachius virens) (Fig. 13). This species was distributed mainly in the areas between the banks with few catches in depths of less than 50 fms. This pattern is very similar to the summer pattern found by Scott (1976). Pollock from the Scotian Shelf have been found to migrate south in the winter (Leim and Scott, 1966) but the present study suggests that an appreciable portion can be found in the deeper areas of the Scotian Shelf in December and therefore may overwinter there. Most individuals caught were large adults.

Silver hake (Merluccius bilinearis) (Fig. 14). The distribution of this species appears to be governed mainly by temperature. On the Scotian Shelf, silver hake were located mainly in the warmer waters between the banks, at depths greater than 50 fms. However there were substantial numbers of hake in the shallow areas just south of Cape Cod where the water temperature was still high (9°C). In this area, they were intermixed in midwater with Atlantic herring, blueback herring, mackerel, dogfish and butterfish. The figure below shows schools of silver hake 5 to 20 fms off bottom in the Nantucket Shoals area, mixed with small numbers of other species. These schools probably moved offshore as the water temperature dropped. In the summer, the Scotian Shelf fish move onto the banks to spawn (Leim and Scott, 1966).



Length frequencies of catches in individual tows indicate extensive mixing of fish greater than 10 cm in length throughout the study area. Juveniles of about 5-10 cm in length however were found only at stations south of Browns Bank. The results of Hunt (1976a) indicate some segregation by size groups, however the present cruise gives little indication of this except with respect to these juveniles. Hunt also noted dense aggregations in the winter and a discontinuity in distribution at the Fundian Channel. This discontinuity was not noticeable in the present data.

A preliminary stomach content analysis involving 111 silver hake from various parts of the Scotian Shelf, Georges Bank and Nantucket Shoals was conducted. Approximately 22% had everted stomachs and though some food particles adhered to the stomach wall, these specimens were excluded from analysis. The remaining 87 stomachs (including 18 empty stomachs) were analysed for percent representation by major food items. The importance of each food item was as follows: 49% contained the euphausid species Meganyctiphanes norvegica and Thysanoessa inermis; 38% contained the shrimp

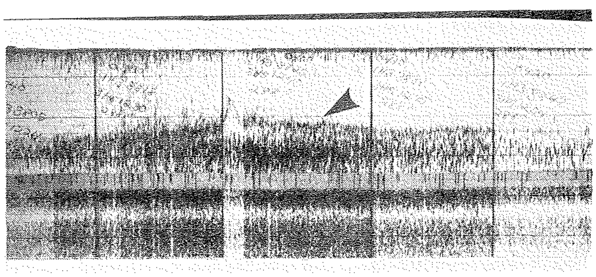
Pandalus sp., 13% contained juvenile silver hake (this was an important part of the diet in localized areas south of the Fundian Channel where the juveniles were concentrated); 2% contained small gadoid fish; 2% contained fish scales and 2% contained amphipods and polychaetes. These results are similar to the analysis of 103 stomachs conducted by J.S. Scott and reported by Hunt (1976b).

White hake (Urophysis tenuis) (Fig. 15). The distribution of this species in November-December was similar to that found by Scott (1976) during the summer cruises, therefore, there is probably little or no seasonal movement. Most white hake were caught in areas between the banks and at the edge of the Shelf in depths greater than 50 fms. Depth appeared to be the main controlling factor in distribution.

Atlantic mackerel (Scomber scombrus) (Fig. 16). This species shows two distinct areas of concentration. The Scotian Shelf group, located from Browns Bank to Sable Island along the Shelf edge is separated by much of Georges Bank from the Cape Cod group located over the Nantucket Shoals. A detailed analysis of distribution and aspects of the biology of this species are discussed in a later section.

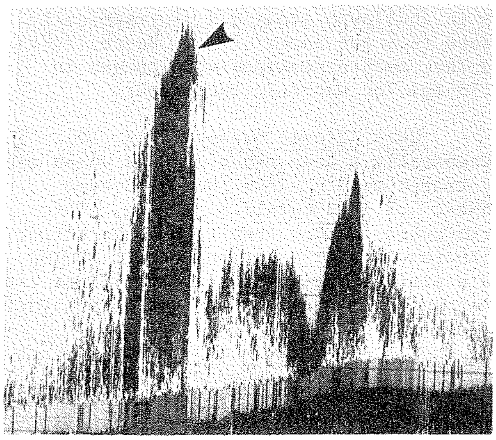
Atlantic wolffish (Anarhichas lupus) (Fig. 17). This species was distributed in the shallow areas of the Scotian Shelf on Browns, LaHave, Emerald and Western Banks. Depth appears to be the main factor governing distribution and there appears to be little change from the summer distribution shown by Scott (1976). Individuals ranged in size from 25 to 100 cm.

Butterfish (Poronotus triacanthus) (Fig. 18). This species was found south of Cape Cod only in the Nantucket Shoals area and along the southern Georges Bank in a fairly wide range of depths. Sonar traces, similar to that in the figure below, showed that this species was near bottom (10 to 15 fms.) in vast schools or aggregations covering many square miles. Leim and Scott (1966) state that butterfish schools



frequent shallow, sandy areas in the warm months then move into deeper areas in the winter. This species was probably just starting to move offshore in November. Temperature appears to be the controlling factor for this more southern species.

Redfish (Sebastes marinus) (Fig. 19). This species was concentrated in the deep basins, channels and along the continental slope. Sonar traces of redfish, similar to that in the figure below, were common along the slope. Redfish appear to stay in deep waters where the temperatures are relatively



constant and show little seasonal movement. The same distribution was observed during November-December as that shown by Scott (1976) for the summer. Juvenile redfish (mean length of 10 cm) were caught in large numbers along the slope south of Browns Bank.

Sea Raven (Hemitripterus americanus) (Fig. 20). This species was found only in small numbers on the Banks in shallow areas. Depth, rather than temperature, probably effects the distribution. Summer distribution as shown by Scott (1976) is virtually the same as that found during this cruise.

Longhorn Sculpin (Myoxocephalus octodecim spinosus) (Fig. 21). The distribution of this species was similar to that of the sea raven generally being found only in shallow water. This species also shows little difference between its summer and winter distribution.

Witch (Glyptocephalus cynoglossus) (Fig. 22). Scott (1976) showed that this species is spread over a wide variety of depths from the Laurentian Channel to the shoals of Sable Island. In the present survey, it seemed to be restricted mainly to the deeper areas off the banks and along the slopes. No specimens were caught southwest of Emerald Basin. This species probably moves into the deeper areas in the winter in response to cooler water temperatures occurring on the banks during winter.

Plaice (Hippoglossoides platessoides) (Fig. 23). Plaice are also quite widely distributed in the summer but are found in greatest numbers over the banks in the area northeast of Western Bank (Scott, 1976). A similar pattern was observed during the November-December cruise with only one haul of those made west of Emerald Bank catching plaice.

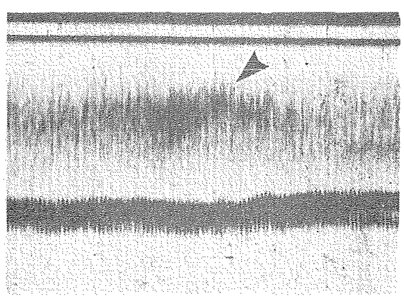
Halibut (Hippoglossus hippoglossus) (Fig. 24). Halibut are more southerly than the previous two flatfish species (Leim and Scott, 1966) and were found only in small numbers. They were concentrated mainly on Western, Emerald, LaHave, Browns and Georges Banks. They were not found in the colder water of Sable Island Bank and appeared to prefer areas shallower than 60 fms.

Yellowtail (Limanda ferruginea) (Fig. 25). This species was widely distributed over the banks in depths less than 50 fms. The major concentration of this species occurred on Sable Island Bank which is similar to the summer distribution shown by Scott (1976). Specimens were, however, taken as far south as the Nantucket Shoals, and there was evidence of a concentration on Georges Bank.

Other flatfish (Fig. 26). These species were found only in small numbers in the sampled area. Fourspot flounder (Paralichthys oblongus) and summer flounder (Paralichthys dentatus) were restricted to the most southerly portions of the sampled area. Winter flounder (Pseudopleuronectes americanus) and windowpane (Scophthalmus aquosus) were found over the whole area on the banks.

Monkfish (Lophius americanus) (Fig. 27). This large species was caught in small numbers over a wide range of depths. Its summer distribution as shown by Scott (1976) indicates a similar range in both summer and winter.

Squid (Loligo paelei and Illex illecebrosus). (Fig. 28). Squid were not examined as two separate species. Large numbers were caught in the deeper, slope waters from Emerald Bank to southern Georges Bank. Depth appears to be an important factor influencing their distribution. Young squid, probably Loligo paelei, since it is the more southerly of the two species, were found in large concentrations along the southern edge of Georges Bank from the slope south of Cape Cod to Lydonia Canyon. Sonar traces, such as that in the figure below, indicated that the young squid were distributed over a wide area. The average mantle length of these squid was 7 cm, and they were geographically separate from the adults (average length of 23 cm) which were common from Lydonia Canyon northward. A squid cruise done by Mesnil (1977) in the same area south of Nantucket Shoals during the same time of year also yielded small individuals of Loligo (4-14 cm long) thus agreeing with our 1976 data.



Other species (Fig. 29). This group of species was caught only in restricted areas or in small numbers during the November-December cruise. Atlantic round herring (Etrumeus sadina), Menhaden (Brevoortia tyrannus), smooth dogfish (Mustelus canis), and northern sea robin (Prionotus carolinus) were at the northern limit of their range (Leim and Scott, 1966) in the southern portion of the study area. American snipe eel (Nemichthys scolopaceous) and longtooth anglemouth (Gonostoma clongatum) were two mesopelagic species caught in the slope waters. The gear used could not reach the depths inhabited by the bulk of these small, deep-dwelling species however and the results are not representative. Shad (Alosa sapidissima), longfin hake (Urophysis chesteri), cunner (Tautogolabrus adspersus), mailed sculpin (Triglops murrayi), and ocean pout (Macrozoarces americanus) occurred in small numbers on the more northern banks.

SPECIES INTERMIX

There is generally very little information available to evaluate species intermix problems in the Northwest Atlantic and even less information on such intermixing during the winter. Knowledge of seasonal overlap in distribution is important in order to address bycatch problems in a variety of international and domestic fisheries. Figures 30-36 show the relative proportions in the catches for a variety of species which are commercially important and under catch regulation. These cases are those in which, in the opinion of the authors, the intermix of two species could cause potential bycatch problems.

The data indicate that there is considerable distributional overlap between mackerel, butterfish, and blueback herring in the area just south of Cape Cod (Figs. 30 and 31). However, this situation probably only lasts for a short time in the early winter while mackerel are still in the inshore areas. The overlap may not persist once the mackerel move into deeper offshore waters. Silver hake and mackerel also overlap in this same area south of Cape Cod (Fig. 32), and they were also caught in the same hauls on the outer portion of the Scotian Shelf. Due to the apparently small quantities of mackerel on the Scotian Shelf during winter, there would probably be only a limited bycatch of mackerel in a winter fishery in that area. In the Cape Cod area, the offshore movement of mackerel after December would probably limit the intermix situation to early winter south of Cape Cod.

On the Scotian Shelf, but not south of Cape Cod, there was some overlap between silver hake, redfish, argentine, and cod. The overlap between silver hake and redfish (Fig. 33) appears to be primarily in the deeper basins on the inner portion of the Scotian Shelf; that with argentine (Fig. 34) mainly in the deeper areas of the Shelf to the north end of, and between, Western and LaHave Banks; while the overlap with cod (Fig. 35) appears to be more widespread over the whole Shelf. There also appears to be a considerable overlap between cod and redfish (Fig. 36) in the basins of the Scotian Shelf, but relatively little overlap with argentine. Since major cod and silver hake fisheries occur on the Scotian Shelf, winter bycatch problems could occur.

MACKEREL BIOLOGY

Distribution

The mackerel caught off Nova Scotia in November-December were concentrated along the edge of the shelf from Brown's Bank to Sable Island. The depth of the bottom in areas where they were caught varied considerably but the average bottom depth for the Scotian Shelf mackerel catches was 62 fms. Although no general groundfish survey programs have been conducted during the winter, various specialized cruises have been conducted during the period 1958-1976. The catches of mackerel, during these various winter cruises and the annual summer groundfish cruises were summarized and the results are given in Figure 37. None of these cruises, considered separately are representative of fish distribution on the Scotian Shelf but the composite picture indicates that mackerel are generally concentrated along the edge of the shelf during winter (Fig. 37A). Most of these cruises were carried out in February or March, indicating little change in distribution over the winter months when compared to the present cruise (see Fig. 16). However, during the summer groundfish surveys, mackerel have been found over the whole of the Scotian Shelf in both shallow inshore areas and deep offshore areas (Fig. 37B). During the 1976 winter survey, 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 rather were dispersed over a wide area. Mackerel were normally caught in the bottom trawl and more were caught in the midwater trawl when it was towed close to the bottom than when towed in midwater. No differences were observed in vertical distribution between day and night tows. These data suggest a near bottom existence during that time of year.

No mackerel were caught between Browns Bank and the Great South Channel but large concentrations were found inshore in the area just south of Cape Cod. These concentrations were found at a mean depth of 34 fms. and formed large midwater schools.

Mackerel appear to avoid cooler waters and temperature seems to be one of the controlling factors determining their distributions and movements. Although Scotian Shelf mackerel were found in a relatively wide range of temperatures (5-12°C) with a mean of 9.3°C, over 92% of those caught were in areas where the temperature exceeded 8°C. Cape Cod mackerel were found in warmer waters (10-13°C) with a mean temperature of 11.2°C (Fig. 38). The temperatures with which the mackerel are associated in the two areas differ possibly because on the Scotian Shelf overwintering temperatures have been reached while off Cape Cod the water may not have cooled sufficiently to cause movement into the deeper offshore area. Anderson and Almeida (1976) showed from the U.S. spring surveys (March-May) that mackerel from Georges Bank south are found offshore during late winter. If both sets of data are representative of population distribution, they suggest that the mackerel taken from the inshore area near Cape Cod in November-December probably move offshore as the water temperature in that area drops.

Length/age analysis

Analysis of length frequencies of mackerel from the various areas revealed a geographical separation of year-classes. An age-length key (Table 1) for the Scotian Shelf group was derived and applied to the length frequencies of the Scotian Shelf animals (Fig. 39) to show relative proportions of age-groups. There were predominantly age-group 0 (up to 21 cm) and age-group 1 (up to 29 cm) animals present here. A comparison of catches from the Sable Island area, the Emerald Bank area, and Browns Bank area indicated little variation in this pattern over the whole Scotian Shelf (Fig. 40), although sample sizes are very small. The length frequencies of mackerel caught during the winter research cruises in this area (January-March, 1959-1976) are similar to the present data (Fig. 39). The slightly higher mean length of the research cruise data could be caused by size variation in different years and by slight growth of the mackerel from December to March. The length frequencies of the mackerel from the Cape Cod area, however, show a very different pattern (Fig. 39). No animals less than 20.5 cm were caught in this area. An age-length key derived from present cruise data (Table 2) applied to the length frequencies showed that the first two year-classes of the Cape Cod fish were considerably different in length from those of the Scotian Shelf. The mean length of age-group 0 Scotian Shelf fish (16.6 cm) was 6.3 cm shorter than those found off Cape Cod (22.9 cm). The age-group 1 animals (24.8 cm) of the Scotian Shelf were only 1.8 cm smaller than those off Cape Cod (26.6 cm), showing remarkable compensatory growth assuming the pattern is the same every year. The age-group 2 animals were almost the same length from both areas (Scotian Shelf - 29.6 cm and Cape Cod - 30.7 cm). It is possible then that the smaller age-group 0 animals found on the Scotian Shelf are those that were spawned in the Gulf of St. Lawrence in June and part of July (Sette 1943; Arnold 1970). The larger age-group 0 animals from Cape Cod are probably spawned in this area or south in April and May (Sette 1943). Consequently, they would have had two months longer to grow than the northern group and would be expected to be larger in November of their first year of life. By the end of their second year, however, the Gulf of St. Lawrence group (northern contingent) appears to have compensated by growing at a higher rate.

A further breakdown of catches from Cape Cod revealed that predominantly large animals (greater than 30 cm, age-groups 2+) were schooling in 20-25 fms. of water over the Nantucket Shoals while animals (22-30 cm, age-groups 0 and 1) tended to school separately just south of this area in 35-45 fms. of water (Fig. 41). Anderson and Almeida (1976) also showed a distinct year-class schooling in the population of mackerel overwintering offshore but they did not find a distinct pattern in inshore-offshore size class distribution as we found off Cape Cod in November-December. It is possible then that the younger fish (age-groups 0 and 1) move offshore first in the late fall and are then followed by the older year-classes migrating to the overwintering area.

No mackerel less than 20.5 cm in length were found in the Cape Cod area; however, an examination of length frequencies of winter commercial catches from south of Georges Bank for several years revealed substantial numbers of individuals less than 20 cm (fork length). This may indicate that a portion of the Gulf of St. Lawrence spawned 0 and 1 age-groups overwinter in the south as well as the Scotian Shelf. Alternatively, this discrepancy may indicate that these winter survey samples from the Cape Cod area were not representative of the overwintering population in that area, or merely illustrates year-to-year variation in length-at-age.

Otolith growth

With the considerable size difference exhibited between the age-group 0 northern and southern contingents of mackerel, it is possible that there would be a corresponding difference in the size of the otoliths at this age. If so, then in older fish, the radius of the 0 ring in the otoliths of fish from the two components should differ, and this difference should provide a method for separating the contingents in areas where the two mix.

Utilizing samples from the Cape Cod portion of the cruise, a total of 288 mackerel were used to test the feasibility of such an analysis. Measurements of the otolith were taken to obtain total otolith radius, T (maximum distance from the nucleus to the posterior edge; Fig. 42). Along this line the radii for age-groups 0 and 2 annuli were also taken.

The ability to discriminate between fish from the northern and southern contingents by otolith annuli can occur only if otolith growth is proportional to growth in length. Regression of T on fork length of the 288 mackerel gave the following relationship:

otolith length = 0.00514 fork length + 0.25756
r = 0.95

The high correlation associated with this relationship indicates that the total otolith radius is linearly related to the fork length and this relationship occurs regardless of fish length or area from which it was taken.

In order to reduce the effect of individual growth variation in the analysis, a ratio of the radii of age-group 0 to age-group 2 was used. The resultant distribution frequency of ratios (Fig. 43) indicates a definite bimodality. Since the radius for southern contingent age-group 0 fish is greater than that for the northern contingent, while age-group 2 radii are of similar length, two modes should be expected using the above ratio with the mode to the right representing the southern contingent.

This bimodality however, resulted from samples involving fish of several ages, and detailed examination of the data indicated that older fish tended to have a greater age-group 0/2 radii ratio. Thus the increase of this ratio with age could at least have partially caused the bimodality in Fig. 43. Unfortunately not enough specimens were taken from the cruise to examine each year-class separately and thus determine year-class affect.

These age-group 0 radius differences in otolith annuli appears to have some value in separating northern and southern contingent fish. However, before conclusions can be drawn, baseline data must first be obtained by examining the otoliths of the two contingents when they are geographically separate, during the spawning season, and comparisons must be made on a single year-class basis.

Length-weight relationship

An examination of total weight versus fork length showed that there was no significant difference in various parts of the Scotian Shelf. The equations of the relationships for the three areas are:

Sable Island	$W = 0.00432L^{3.248}$
	$R^2 = 0.99$
Emerald Bank	$W = 0.00498L^{3.215}$
	$R^2 = 0.98$
Brown's Bank	$W = 0.00383L^{3.274}$
	$R^2 = 0.99$

where W = total weight, L = fork length.

Those animals caught off Cape Cod were slightly longer than the Scotian Shelf mackerel for any given weight (Fig. 44). The equations for these two lines are:

Scotian Shelf	$W = 0.00379L^{3.293}$
	$R^2 = 0.99$
Cape Cod	$W = 0.00756L^{3.082}$
	$R^2 = 0.97$

Sexual maturity

The stage of maturity of the gonads are presented in Fig. 45. Stage I and II represent the immature (virgin) condition while the majority of fish with stage III+ gonads have spawned at least once. Comparison of Figures 40 and 41 show that for both Scotian Shelf and Cape Cod age-group 0 and 1 fish were mainly immature while the older year-classes were VII and VIII. The data show that the majority of mackerel spawn for the first time in their third year as has been indicated previously (MacKay 1976).

Stomach contents

A stomach content analysis of 199 fish collected from the Scotian Shelf showed a great deal of selectivity of food items between year-classes. Figure 46 shows a breakdown of the diet by year-class. Age-group 0 animals ate mainly euphausids (47% by weight of the diet). Meganyctiphanes norvegic was the dominant species with Thysanoessa inermis making up the bulk of the rest of this group. Twenty-two percent of the diet consisted of the hyperid amphipod Parathemisto sp., 7% consisted of fish larvae (mainly blennoids and gadoids), 1% consisted of copepods (mainly Calanus sp. and Labidocera aestiva), pelagic snails (Limacina sp.) and the amphipod Hyperia sp. The rest of the stomach contents, 23%, were too digested for identification and 16% of the stomachs examined were empty. In age-group 1 animals the hyperid amphipod Parathemisto sp. was the dominant food item representing 69% of the content by weight, with larval fish (including Merluccius bilinearis) representing 14% and the remainder consisting of euphausids, decapods (Pandalus sp.), polychaetes (mainly Nereis pelagica), Limacina sp. and the octopus Bathypolypus sp. Fifteen percent of the contents was unidentifiable. In animals age-group 2 and older, the amphipod Parathemisto sp. still dominated in the contents at 62%, fish larvae at 17% and the remainder consisted of euphausids, copepods, and Limacina sp. Nineteen percent of the content was unidentifiable and 14% of the stomachs were empty.

As expected, the weight of the stomach content increased with the size of the animal. The small age-group 0 animals had an average stomach content weight of 0.582 g, the larger age-group 1 had a weight of 1.498 g, and age-group II+ had a weight of 3.743 g.

The percent weight of each category of food item in the stomachs examined was plotted for each centimeter size group of fish length (Fig. 47). This diagram shows that the euphausids were found almost strictly in the stomachs of fish less than 19 cm (age-group 0) while the smaller amphipods gradually increased in importance as the size of the fish increased. Amphipods were found as a food item of fish in all size categories.

It became apparent that there was a definite particle size selection in mackerel. To illustrate this, a relationship was first derived between stomach content weight and volume (volumetric displacement of water) using the contents of 86 mackerel stomachs (Fig. 48). The stomach contents were then converted to a volume measure using the derived relationship (volume = 1.0268 weight + 0.0778, $R^2 = 0.99$) and the average particle size derived by dividing the volume of the stomach contents by the number of particles in that stomach. Next a ratio of the average food particle size to the size in length of the fish from which the stomach was removed was calculated. This produced a value of particle size per unit length of fish (cc/cm) and the results were as follows: 5.04×10^{-4} for year-class 0 animals; 2.14×10^{-4} for year-class I animals; and 3.10×10^{-4} for year-class II+ animals. This shows that the year-class 0 animals select considerably larger size particles per unit of body length (size) than do the older year-classes. This could be a mechanism by which mackerel can utilize a wider variety of food items in a restricted area.

As well, a preliminary study of the stomach contents of 42 mackerel from the Cape Cod area showed that copepods (mainly Calanus sp.) were the dominant food item in this area, with amphipods (Parathemisto sp. and Hyperia sp.), euphausids, decapods, Limacina sp., fish larvae, hydrozoans, and possibly chaetognaths making up the remainder of the diet.

There have been few studies in the past dealing with the diet of mackerel but Arnold (1970) found that the larvae (5-20 mm) in the Gulf of St. Lawrence ate, in order of importance, copepods, cladocerans, fish larvae, other crustaceans, and invertebrate eggs. MacKay (1976) found that the older year-classes in the Gulf ate smaller food particles, consuming mainly copepods, larval crustaceans, fish eggs, and only a few euphausids and shrimps. The results of Maurer and Bowman (1975), Bowman et al. (1976), and Maurer (1976) for mackerel from the New England area are similar to the findings of this report with copepods, Limacina sp. euphausids, and amphipods as the main part of the diet; however, stomach contents were not analyzed with respect to size or year-classes in these papers.

Parasites

Nematode parasites from the stomachs of the Scotian Shelf mackerel were counted and a comparison of extensiveness of infection between age-groups revealed that only 4.3% of the fish were infected in age-group 0 while 86.1% and

7.1% were infected in age-group I and age-group II+ respectively. The intensity of the infection was 0.2 worms per fish in age-group 0, 0.97 in age-group I, and 0.36 in age-group II+. Only 14 age-group II+ fish were examined and this may be part of the reason why this group had lower counts than age-group I fish. The larval nematodes found in mackerel by Isakov (1976) were identified as Anisakis sp. This is probably the same species encountered here.

Meristics

Vertebrae, pelvic fins, and pectoral fins were counted for both Scotian Shelf and Cape Cod fish. The fin counts showed very little variation and the vertebrae counts were consistently 30. As in almost all scombroids, the meristic counts were not useful in separating populations because of the low variation in the meristics of this family of fish.

Acoustics

Acoustics for locating and quantifying mackerel schools during the November-December cruise proved to be of little use because of the mixing of the mackerel with schools of other species (Fig. 49). The mackerel tended to be masked by the other species present and no characteristic mackerel trace was apparent. During this time of year the mackerel could probably be most easily located by looking for the schools of butterfish, blueback herring, round herring, and silver hake with which it associates.

SUMMARY

It has been established that a portion of the mackerel population spawns in the Gulf of St. Lawrence following a migration from the more southerly offshore wintering grounds. A few mackerel were thought to remain on the Scotian Shelf (Sette 1950; Moores et al. 1975) rather than migrating further south to Georges Bank and the area south of Cape Cod. Previously, there was almost no data available as to the distribution or biology of the mackerel that might have stayed in the Scotian Shelf area. This report shows that a portion of age-groups 0 and 1 mackerel in fact do stay on the Scotian Shelf, splitting off from the southward migrating group and overwintering in the deep, warm water of the shelf edge. They then return inshore and into the Gulf of St. Lawrence in the spring.

This preliminary investigation sheds some light on a period of the mackerel life history but much more work is needed to understand the total biology of this species.

REFERENCES

Anderson, E.D. and F. Almeida. 1976. Distribution of Atlantic mackerel in ICNAF Subarea 5 and Statistical Area 6 based on research vessel spring trawl surveys, 1968-1975. Int. Comm. Northw. Atl. Fish. Res. Doc. 75/15.

Arnold, P.W. 1970. Spawning and aspects of the early life history of the Atlantic mackerel Scomber scombrus L., in the Gulf of St. Lawrence. B.Sc. thesis, Acadia University.

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish. and Wildlife Serv., Fish. Bull. 74, Vol. 53.

Bowman, R.E., R.O. Maurer, Jr., and J.A. Murhpy. 1976. Stomach contents of twenty-nine species from five regions in the Northwest Atlantic - Data Report. Northeast Fishery Centre Lab. Ref. No. 76-10, Woods Hole, Mass.

Hare, G.M. 1977. Atlas of the major Atlantic coast fish and invertebrate resources adjacent to the Canada-United States boundary area. Fish. Mar. Serv. Res. Dev. Tech. Rept. 681.

Hunt, J.J. 1976a. Age, growth and distribution of silver hake (Merluclus bilinearis) from modal analysis of length frequencies. Int. Comm. Northwest Atl. Fish. Res. Doc. 76/164.

1976b. A revised assessment of the 4VWX silver hake fishery incorporating preliminary 1976 data. Int. Comm. Northw. Atl. Fish. Res. Doc. 76/160.

Isakov, V.I. 1976. On the results of biological studies on mackerel from the Northwest Atlantic. Int. Comm. Northw. Atl. Fish. Res. Doc. 76/52.

Kohler, A.C. 1968. Fish stocks in ICNAF Subarea 4. Int. Comm. Northw. Atl. Fish. Res. Doc. 68/61.

Leim, A.H. and W.B. Scott. 1966. Fishes of the Atlantic coast of Canada. Fish. Res. Bd. Can. Bull. No. 155.

MacKay, K.T. 1976. Population biology and aspects of energy use of the northern population of Atlantic mackerel, Scomber scombrus L. PhD. Thesis Dalhousie University.

Maurer, R.O. and R.E. Bowman. 1975. Food habits of marine fishes of the northwest Atlantic - Data Report. Northeast Fish Centre Lab Ref. No. 75-03, Woods Hole, Mass.

Mesnil, B. 1977. Growth and life cycle of squid, Loligo pealei and Illex illecebrosus from the Northwest Atlantic. Int. Comm. Northw. Atl. Fish. Res. Doc. 76/65.

Moores, J.A., G.H. Winters and L.S. Parsons. 1975. Migration and biological characteristics of Atlantic mackerel (Scombrus scombrus) occurring in Newfoundland waters. J. Fish. Res. Bd. Canada 32: 1347-1357.

Parsons, L.S. 1970. Northern range extension of the Atlantic mackerel, Scombrus scombrus, to Black Island, Labrador. J. Fish. Res. Bd. Canada 27: 610-613.

Scott, J.S. 1971. Abundance of groundfishes on the Scotian Shelf. Fish. Res. Bd. Canada Tech. Rept. 260.

1976. Summary of distribution of groundfish on the Scotian Shelf. 1970-1974. Fish Res. Bd. Canada Tech. Rept. No. 635.

Sette, O.E. 1943. Biology of the Atlantic mackerel (Scombrus scombrus) of North America Part I. Early history. U.S. Fish. Wildlife Serv. Bull. 38(50).

1950. Biology of the Atlantic mackerel (Scomber scombrus) of North America Part II. Migrations and habits. J.S. Fish. Wildlife Bull. 49(51).

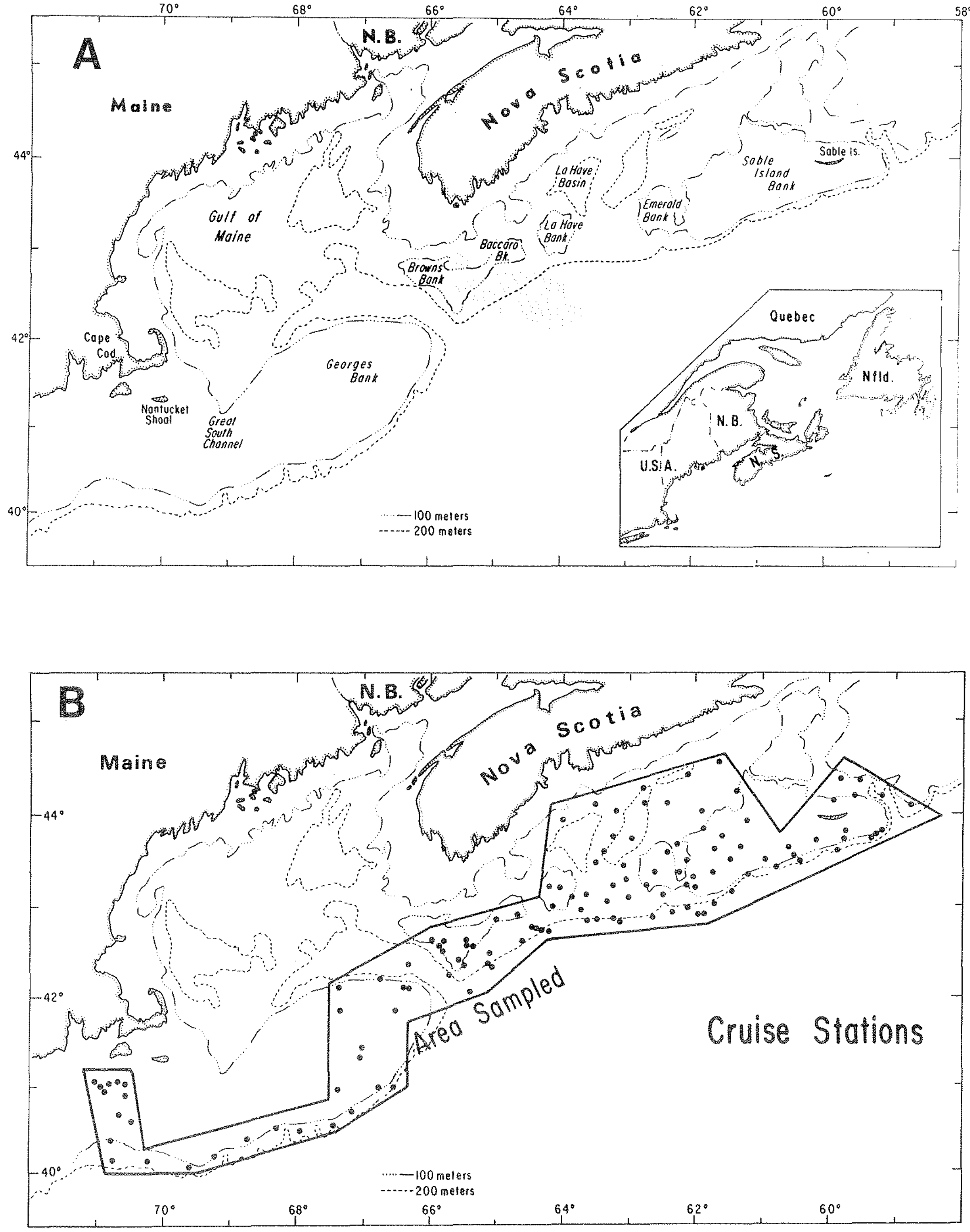


Fig. 1. Chart of the Scotian Shelf and Georges Bank showing: (A) depth contours; and (B) stations sampled, Nov. - Dec. 1976.

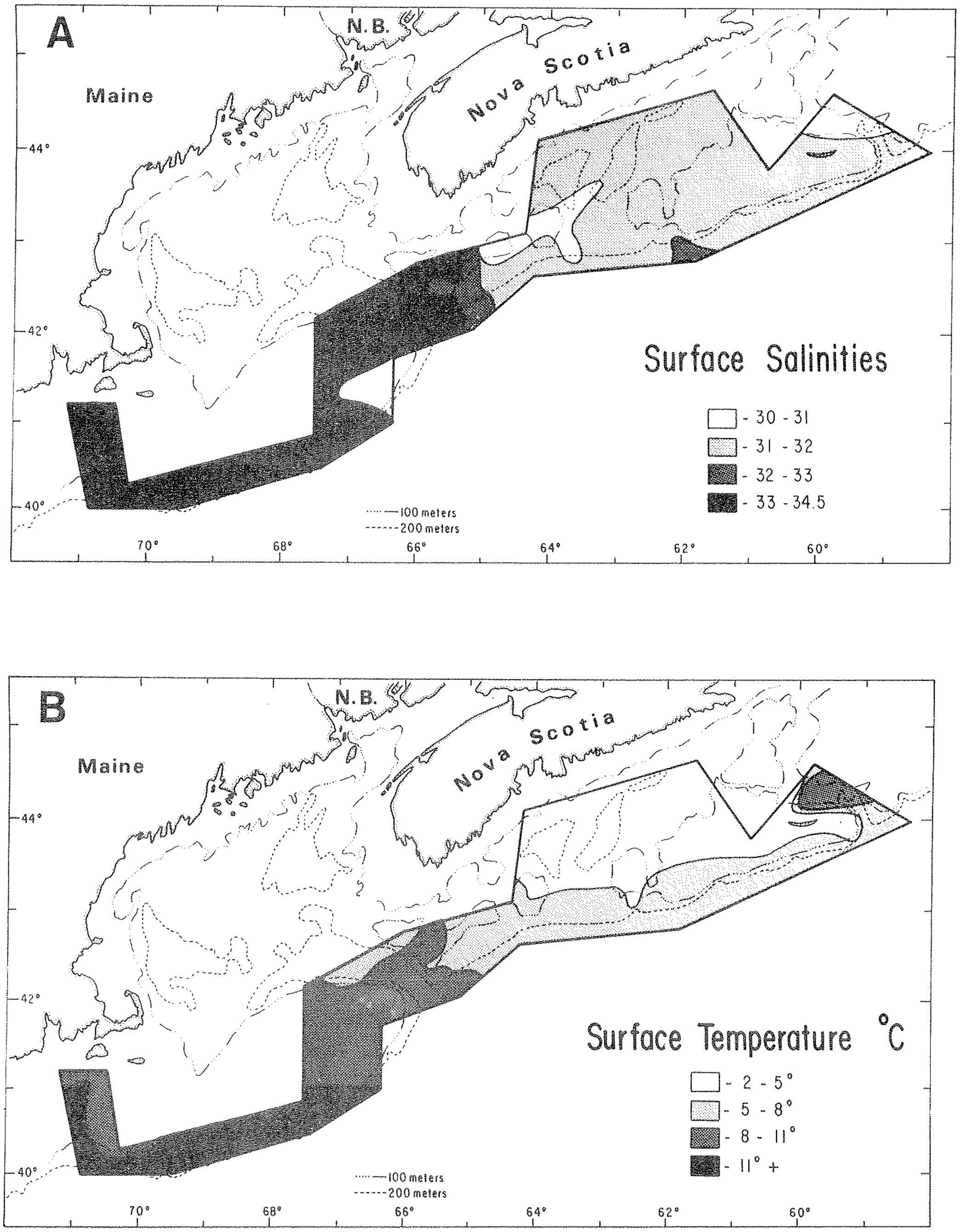
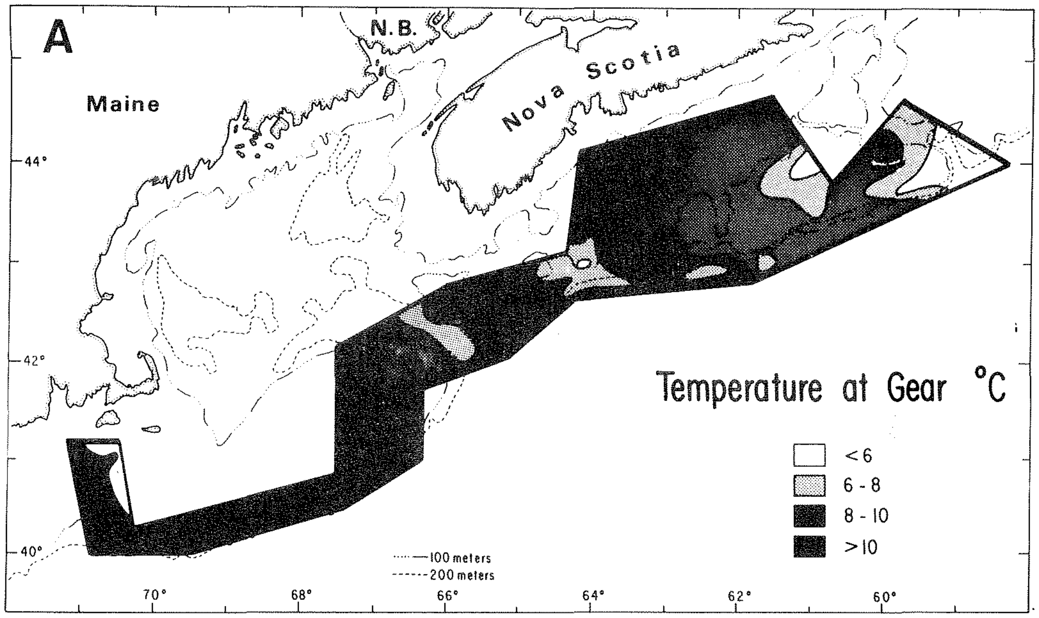


Fig. 2. Contour maps of the area sampled showing (A) surface salinity; and (B) surface temperature



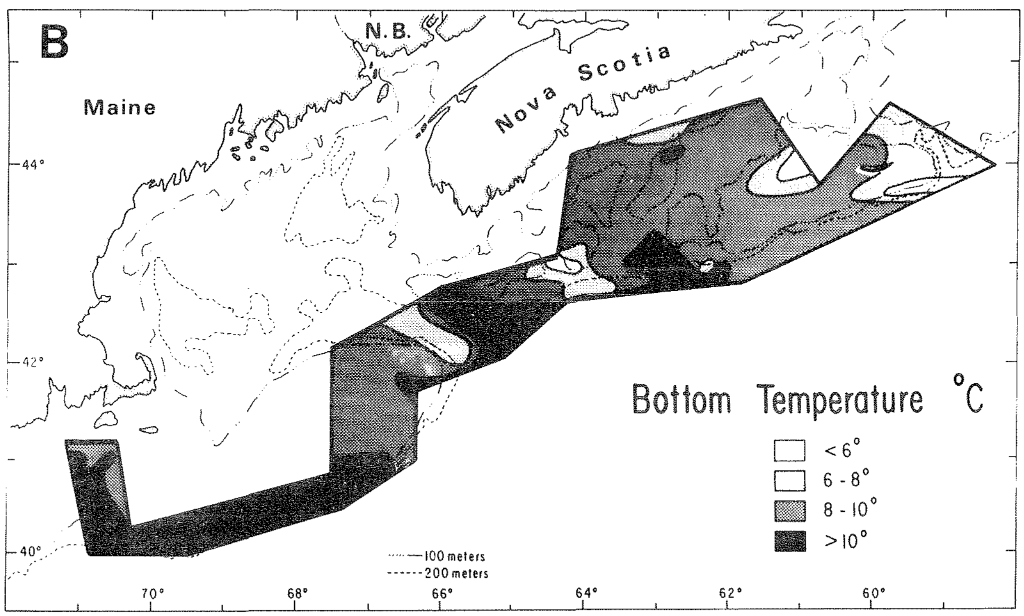


Fig. 3. Contour maps of the area sampled showing (A) temperature at gear; and (B) bottom temperature.

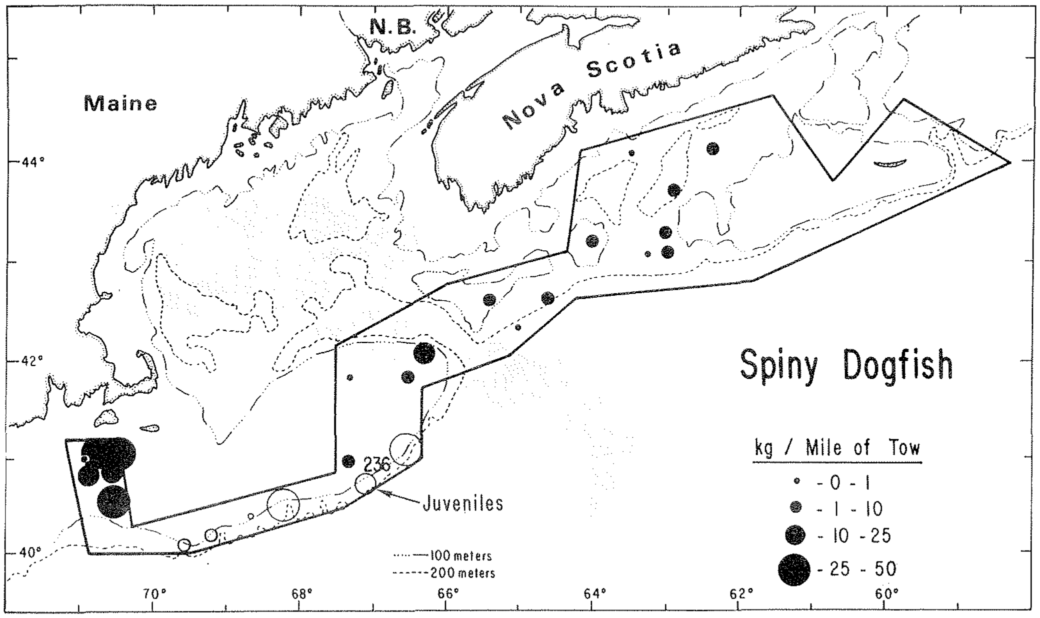


Fig. 4. Chart of the sample area showing the distribution of: Spiny dogfish (<u>Squalus acanthias</u>). The open circles indicate set locations where only juveniles were caught and refer to the numbers/mile of tow; the actual number of juveniles caught is indicated for one set in which the catch exceeded the designated categories.

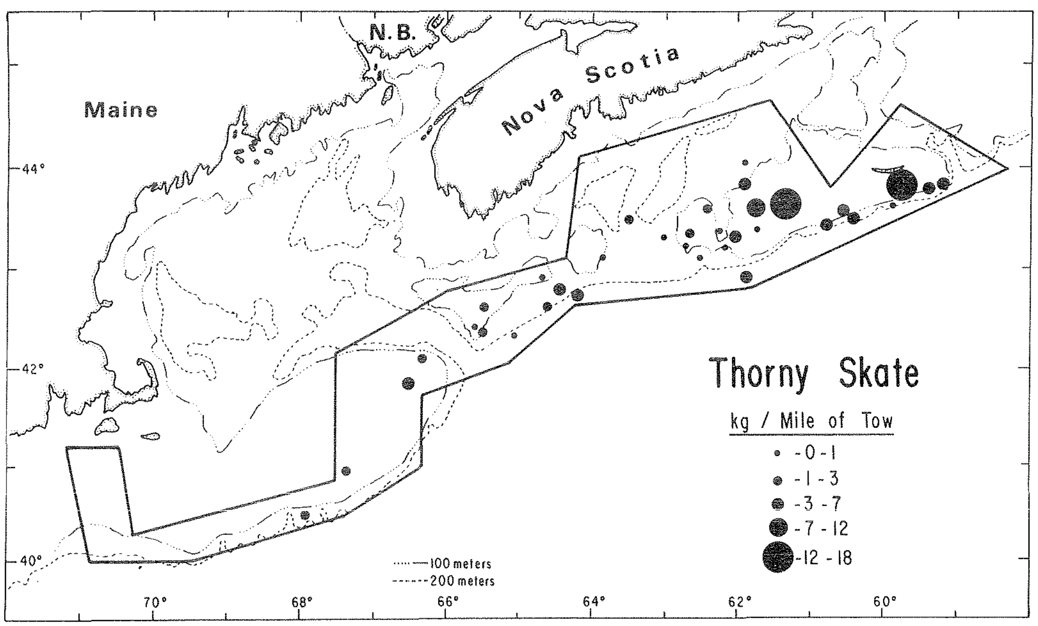


Fig. 5. Chart of the sample area showing the distribution of thorny skate (<u>Raja radiata</u>).

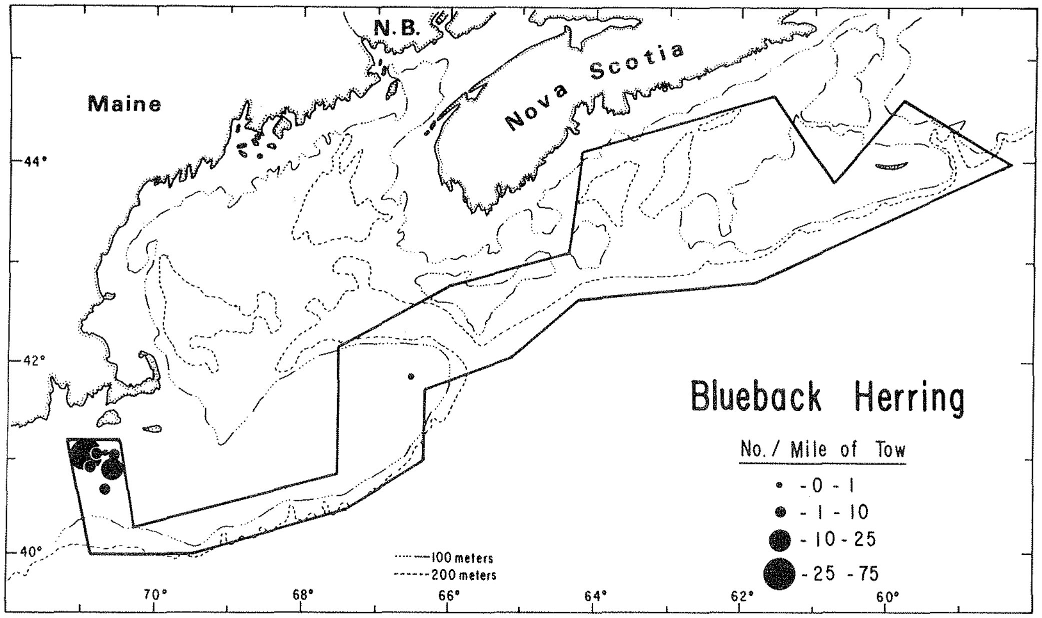


Fig. 6. Chart of the sample area showing the distribution of blueback herring.

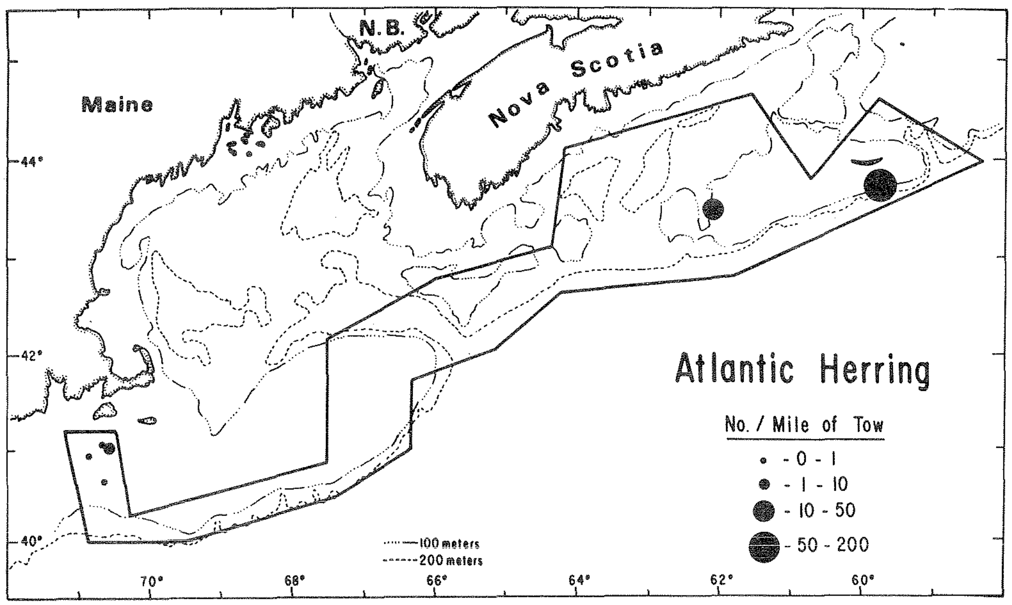


Fig. 7. Chart of the sample area showing the distribution of Atlantic herring.

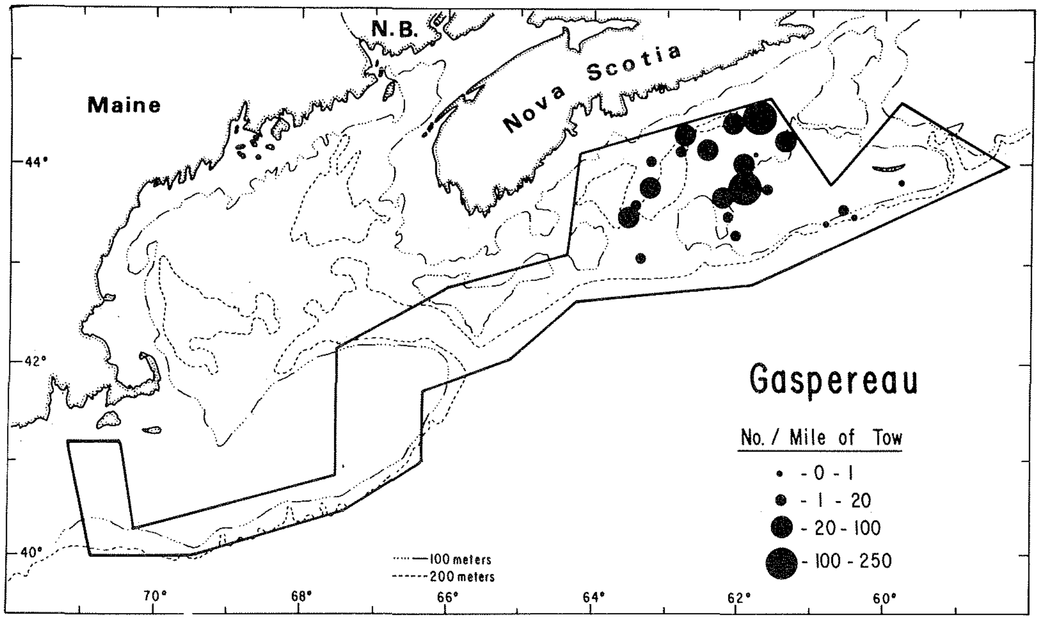


Fig. 8. Chart of the sample area showing the distribution of gaspereau.

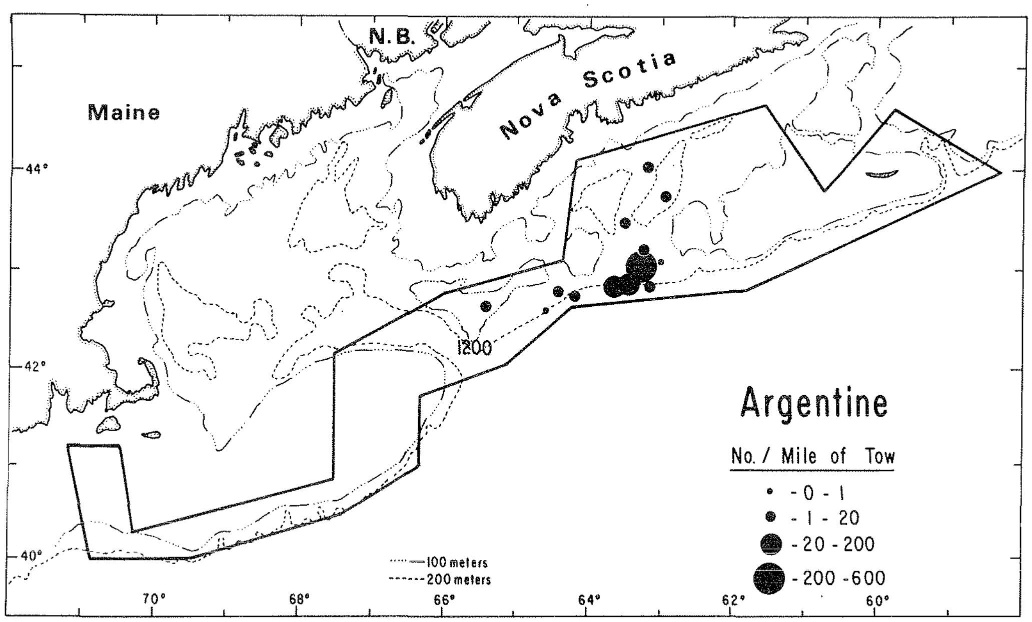


Fig. 9. Chart of the sample area showing the distribution of argentine. The actual number of argentine caught is indicated for one set in which the catch exceeded the designated categories.

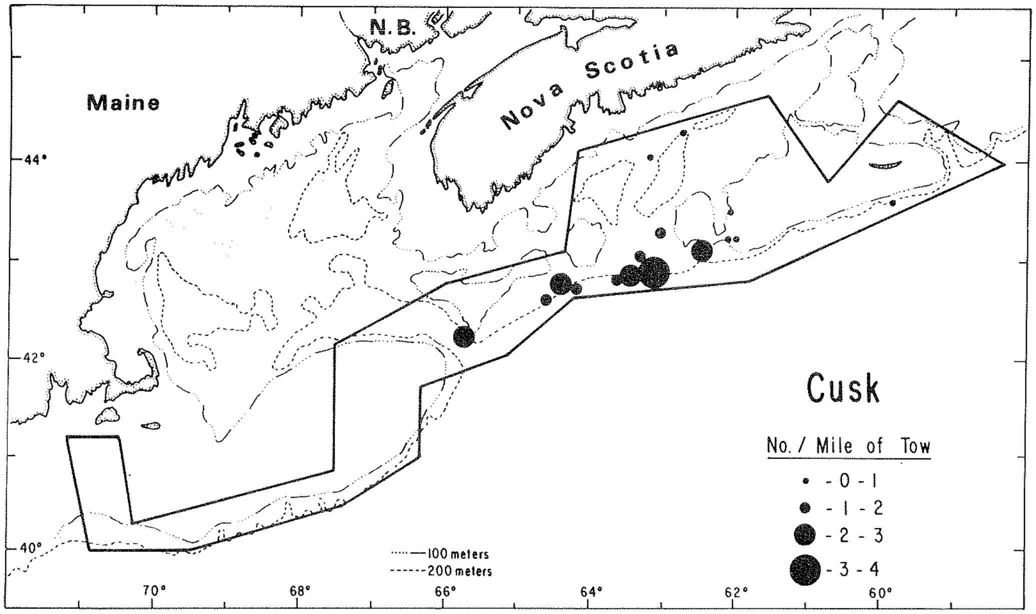


Fig. 10. Chart of the sample area showing the distribution of cusk.

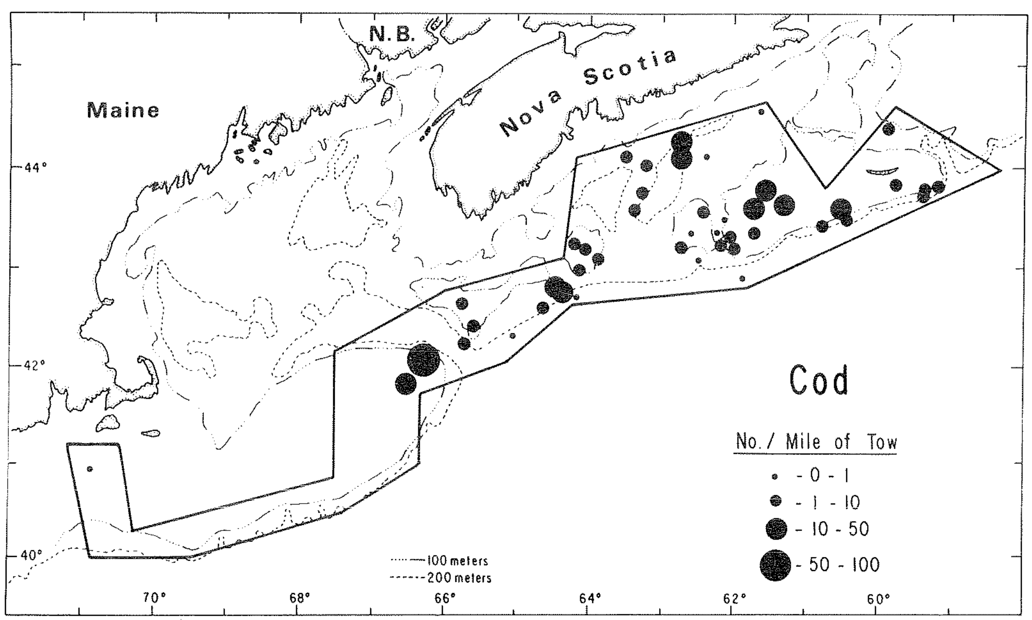


Fig. 11. Chart of the sample area showing the distribution of cod.

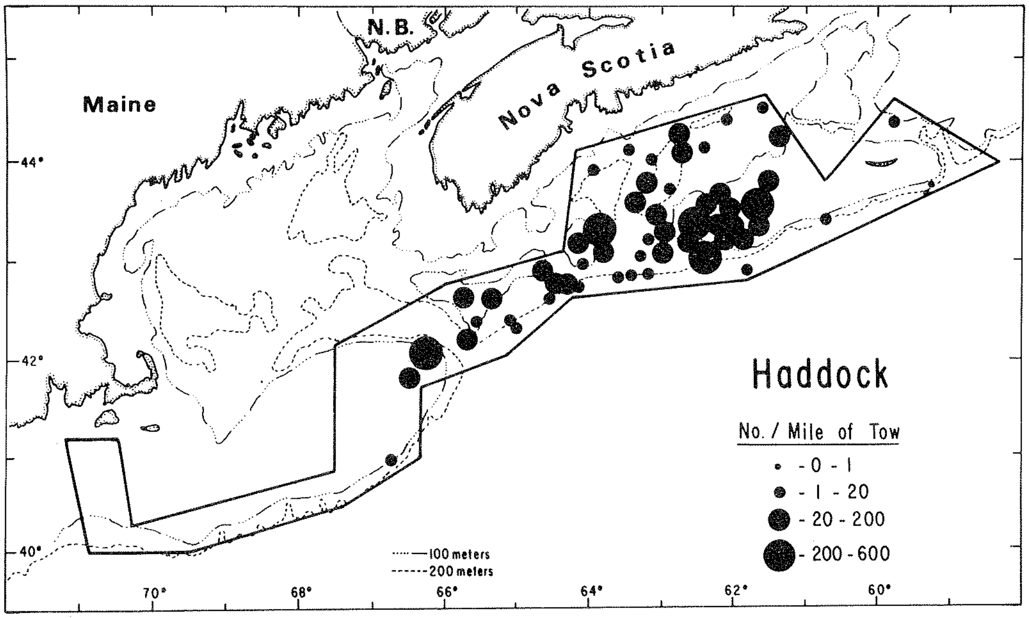


Fig. 12. Chart of the sample area showing the distribution of haddock.

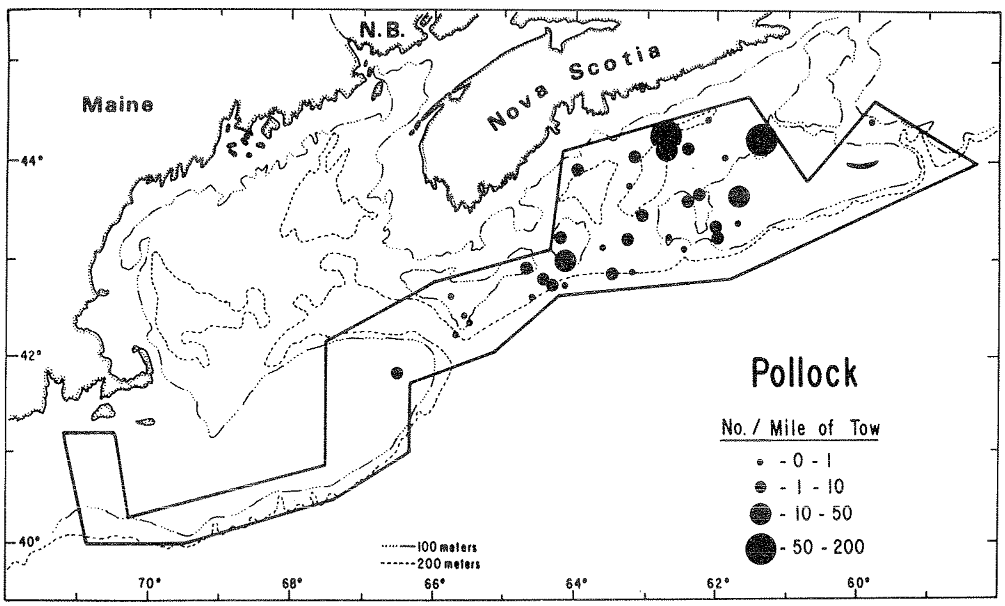


Fig. 13. Chart of the sample area showing the distribution of pollock.

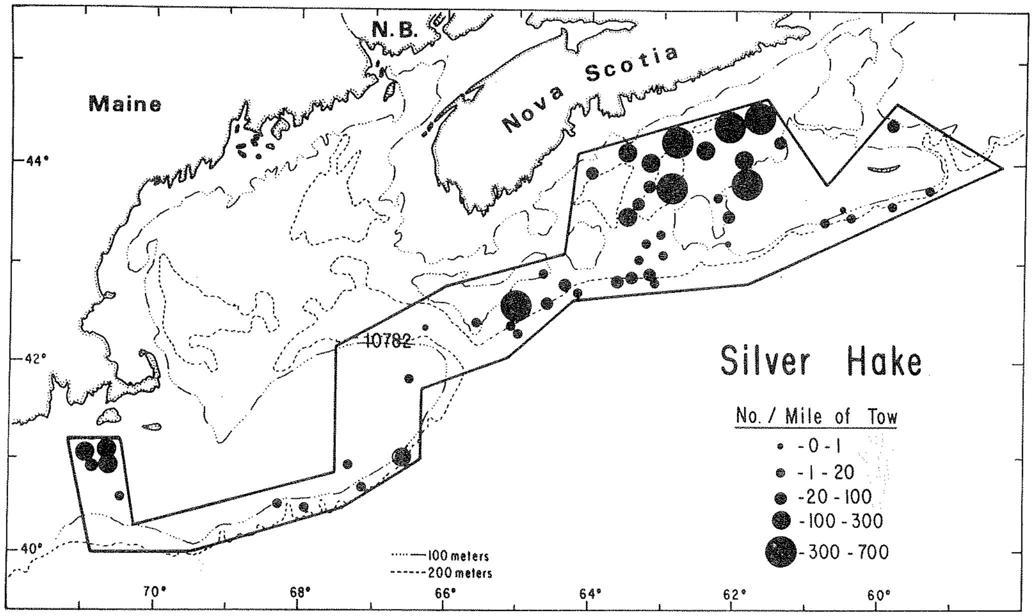


Fig. 14. Chart of sample area showing the distribution of silver hake.

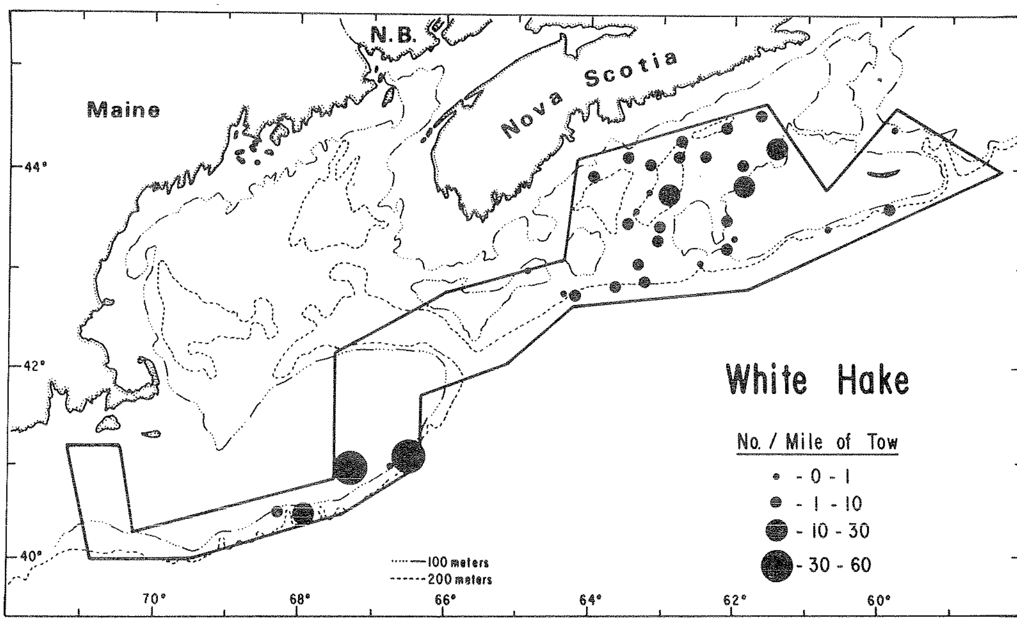


Fig. 15. Chart of sample area showing distribution of white hake.

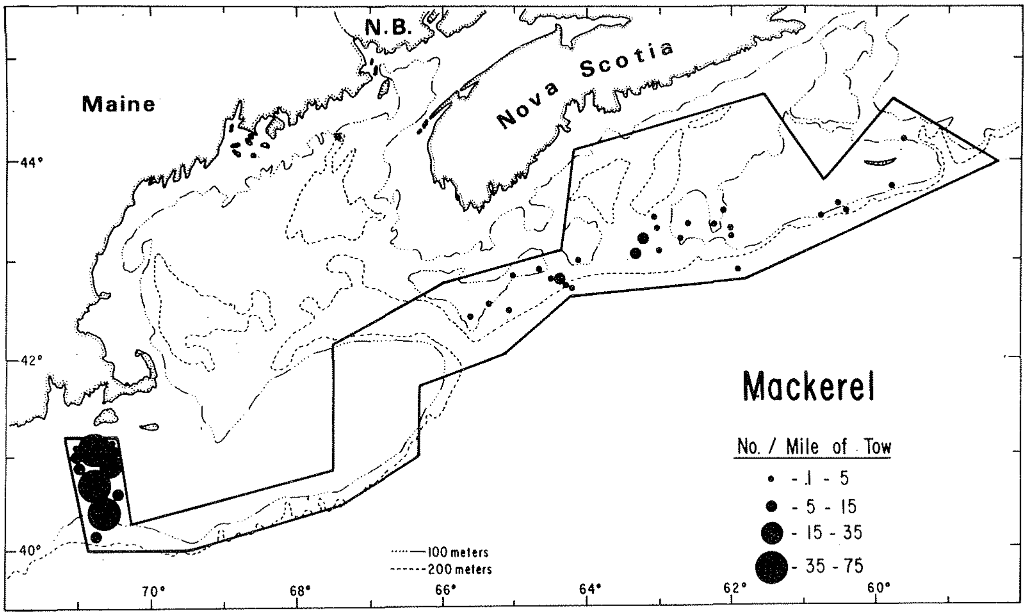


Fig. 16. Chart of sample area showing distribution of Atlantic mackerel.

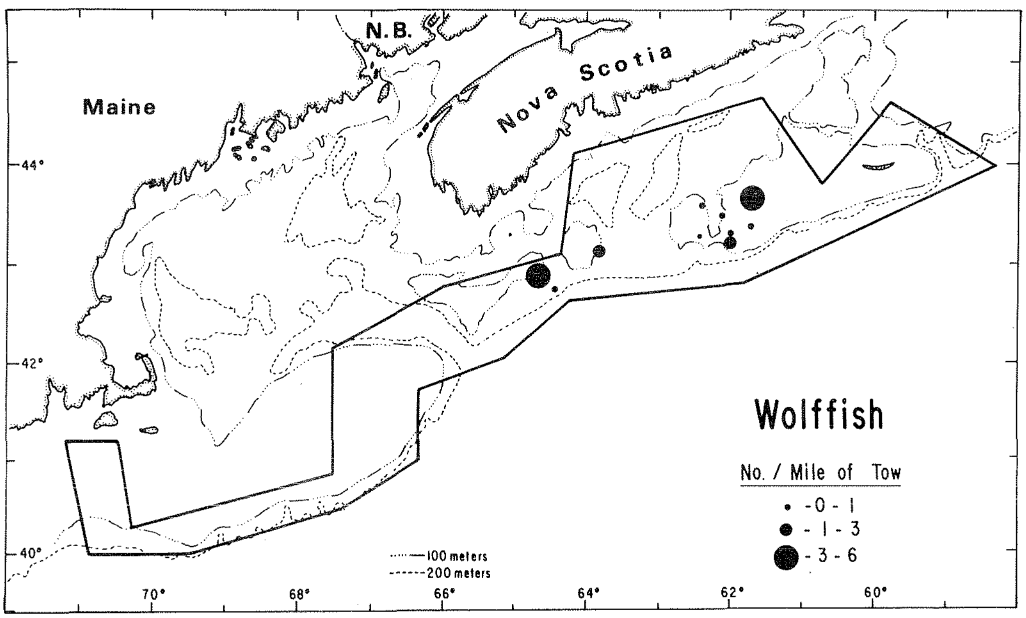


Fig. 17. Chart of sample area showing distribution of wolffish.

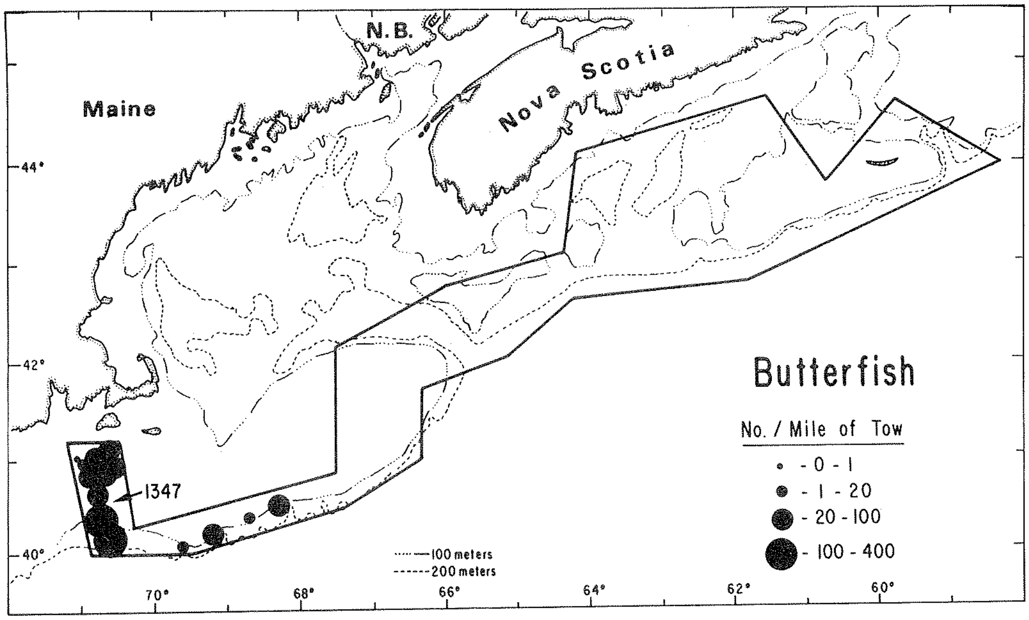


Fig. 18. Chart of sample area showing distribution of butterfish. The actual number of butterfish caught is indicated for one set in which the catch exceeded the designated categories.

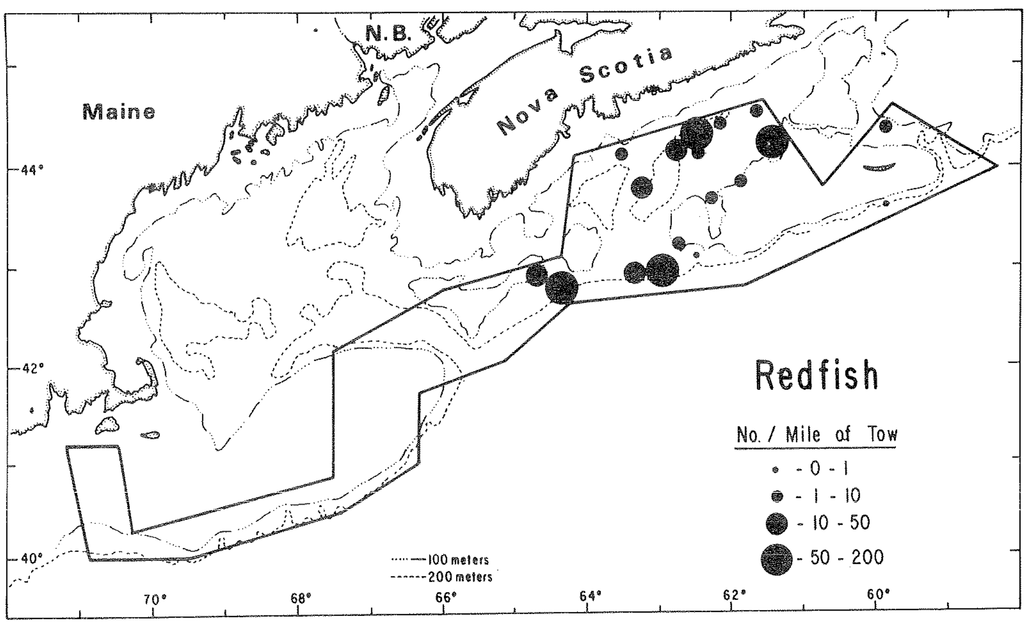


Fig. 19. Chart of sample area showing the distribution of redfish.

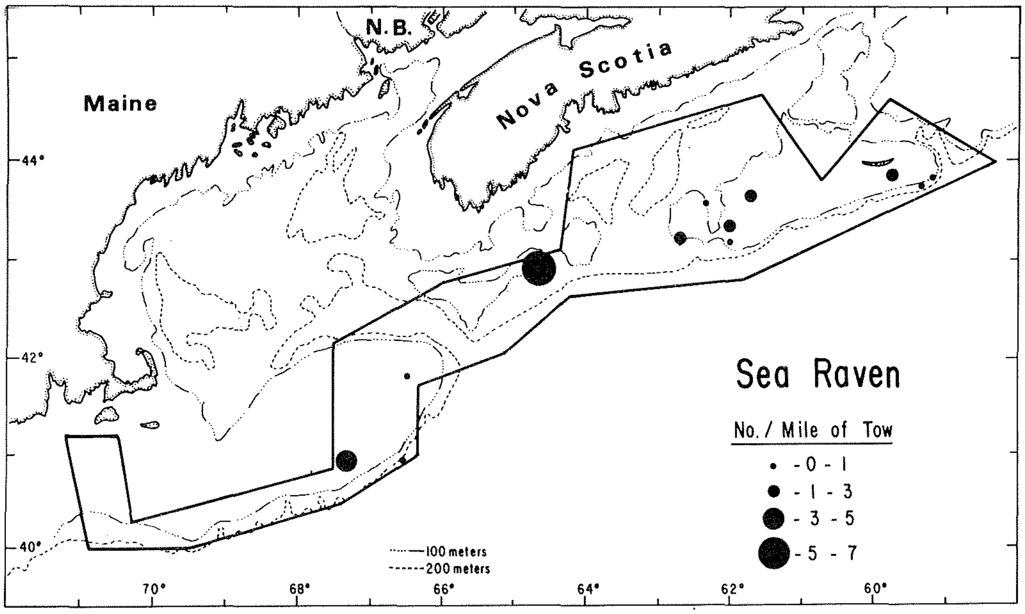


Fig. 20. Chart of sample area showing the distribution of sea raven.

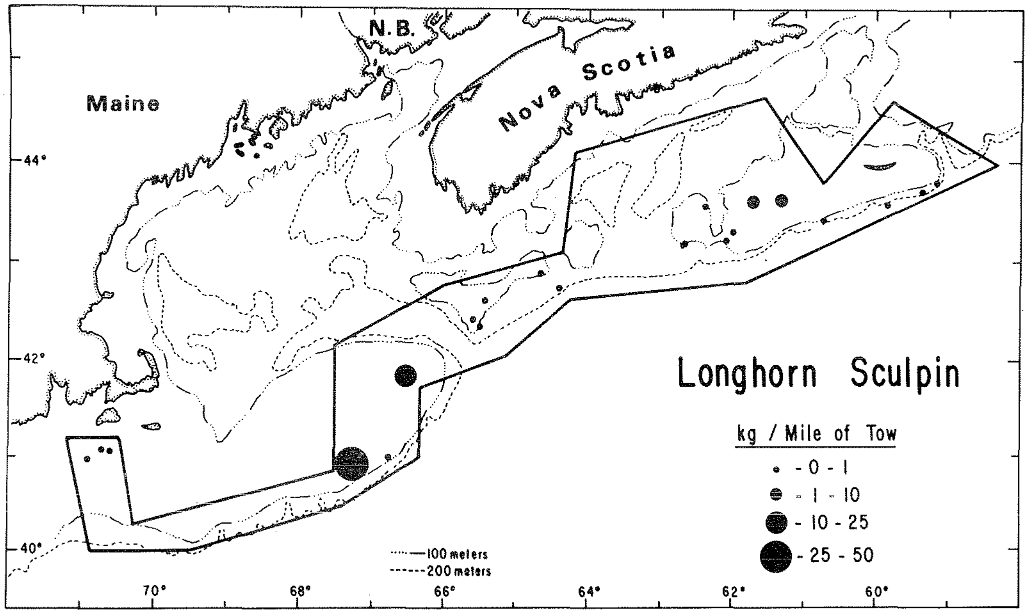


Fig. 21. Chart of sample area showing distribution of longhorn sculpin.

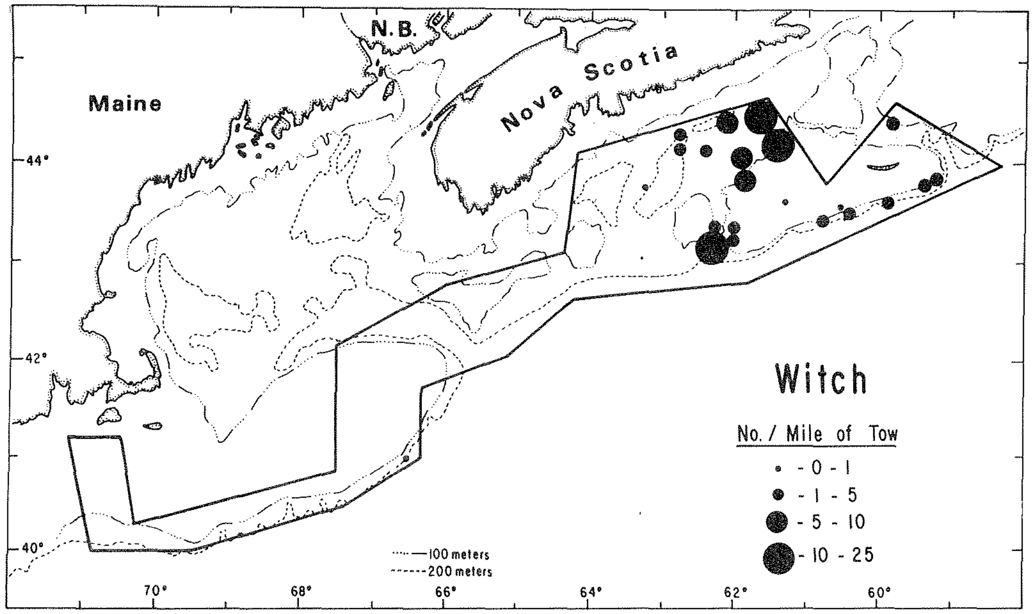


Fig. 22. Chart of sample area showing distribution of witch.

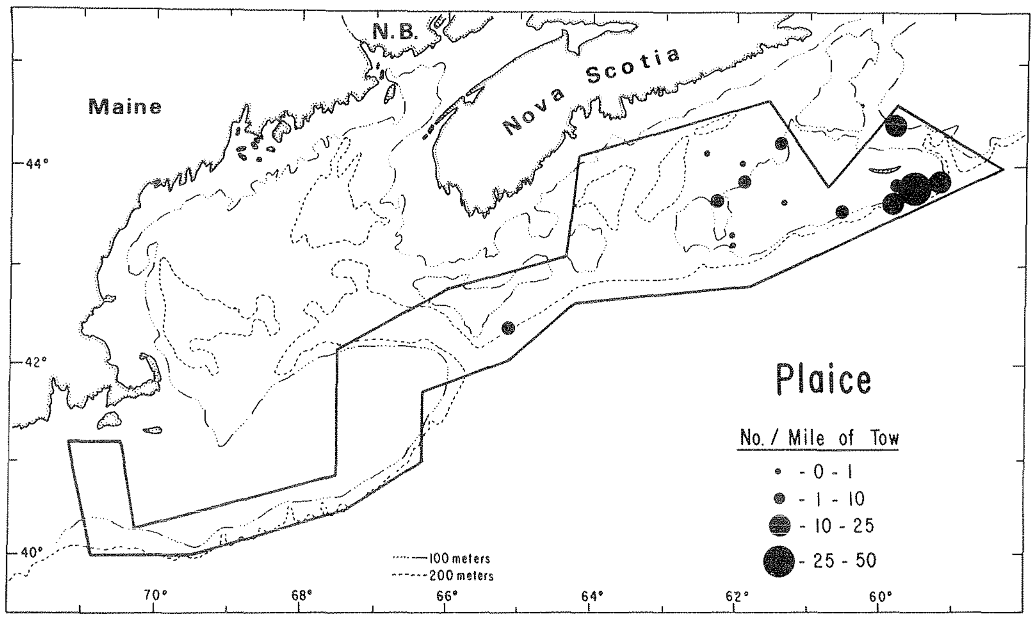


Fig. 23. Chart of sample area showing distribution of American plaice.

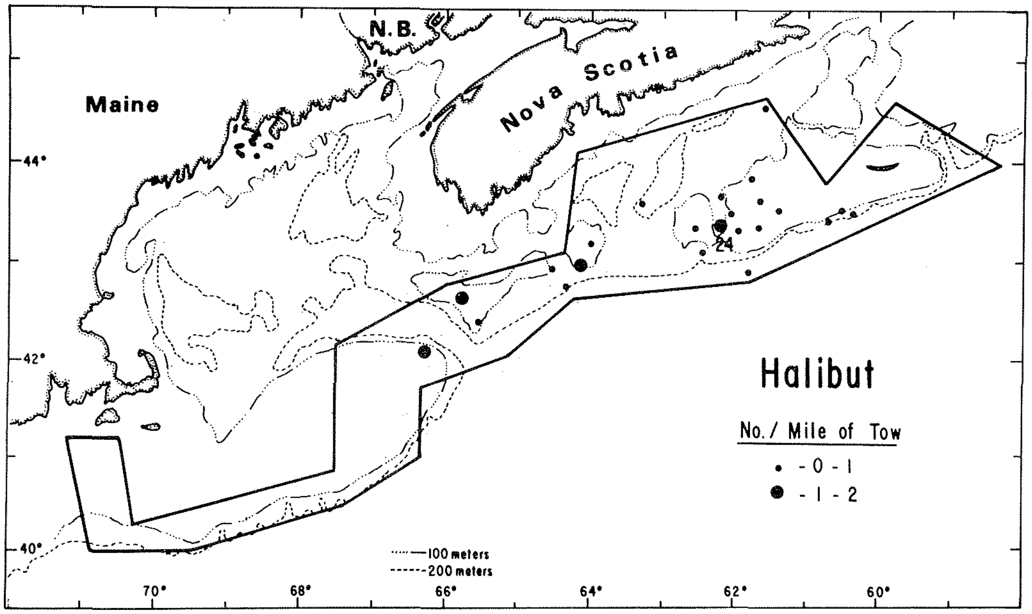


Fig. 24. Chart of sample area showing distribution of halibut. The actual number of halibut caught is indicated for one set in which the catch exceeded the designated categories.

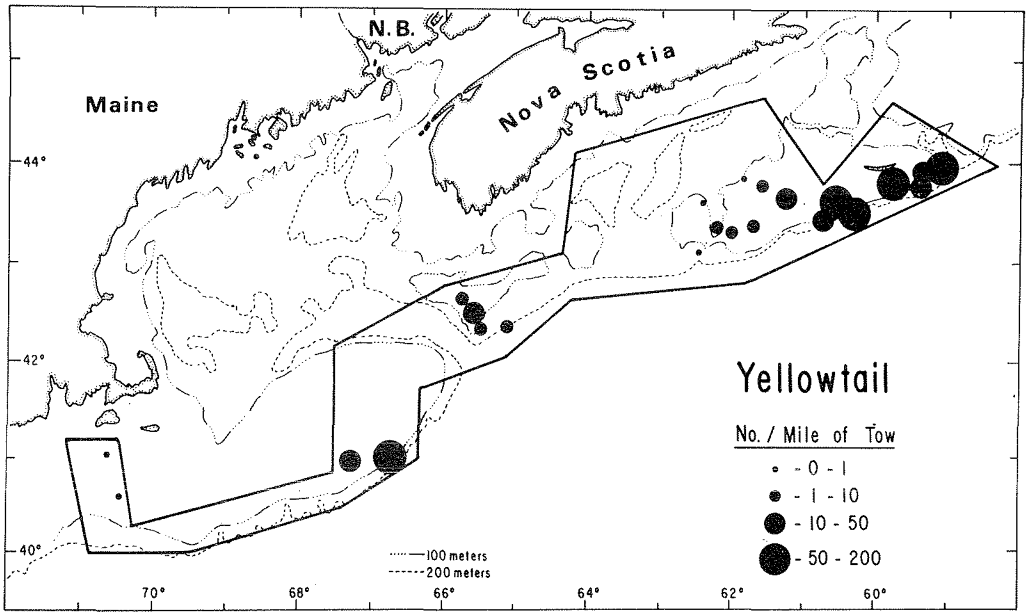


Fig. 25. Chart of sample area showing distribution of yellowtail.

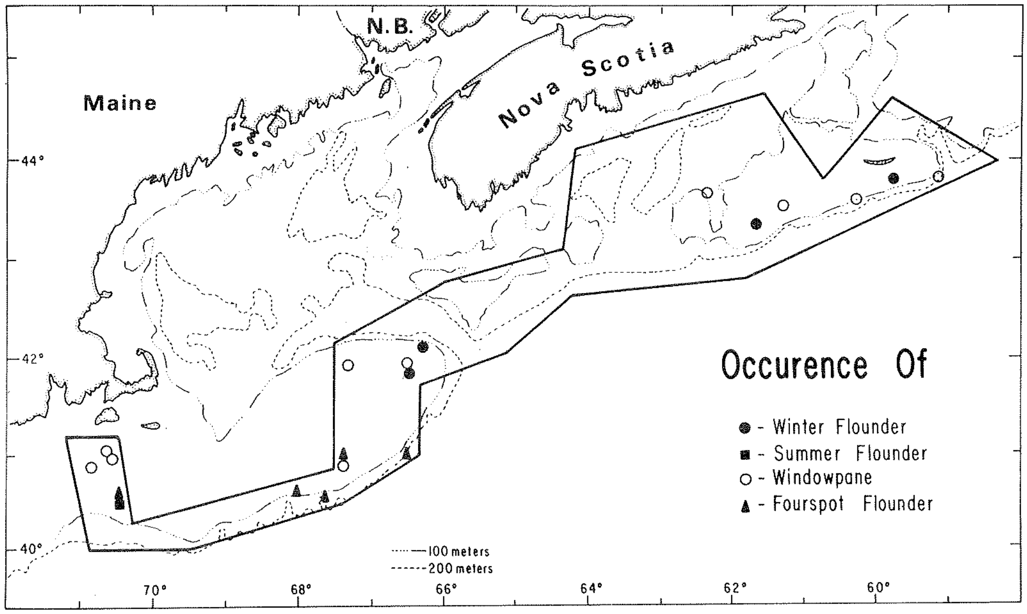


Fig. 26. Chart of sample area showing distribution of other flatfish which occurred irregularly.

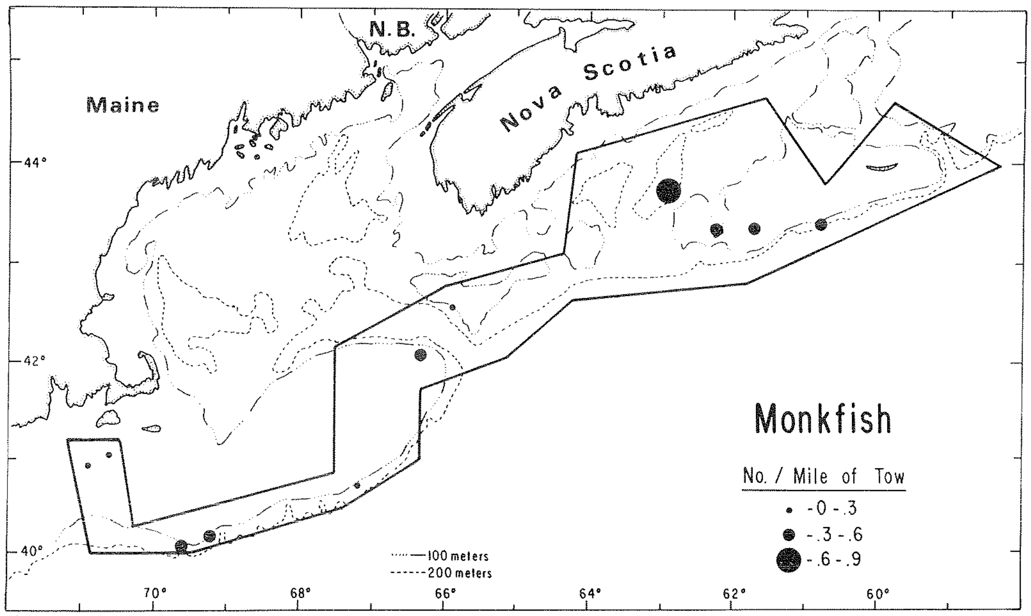


Fig. 27. Chart of sample area showing distribution of monkfish.

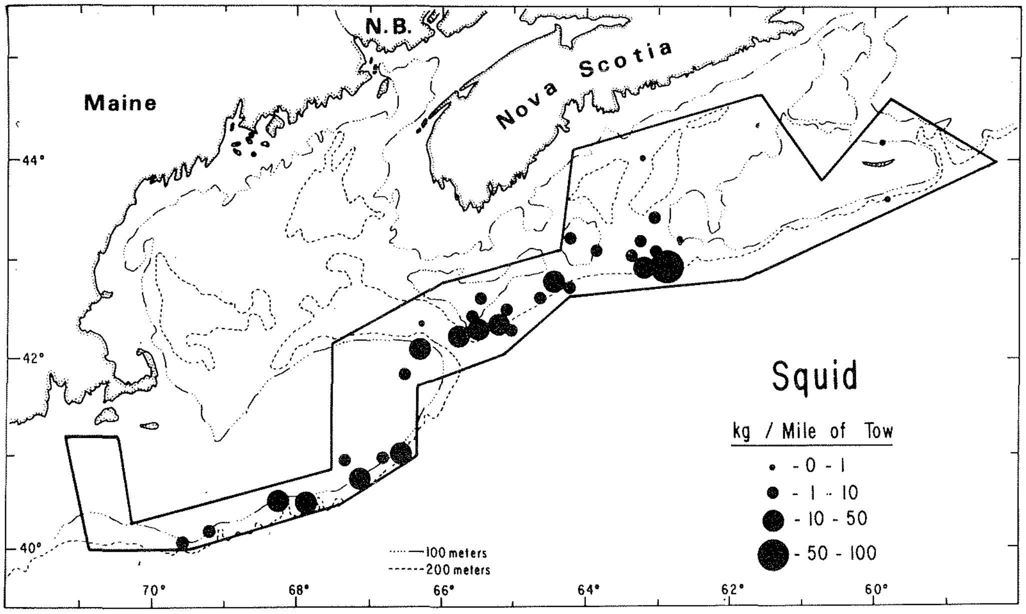


Fig. 28. Chart of sample area showing distribution of squid (Loligo and Illex).

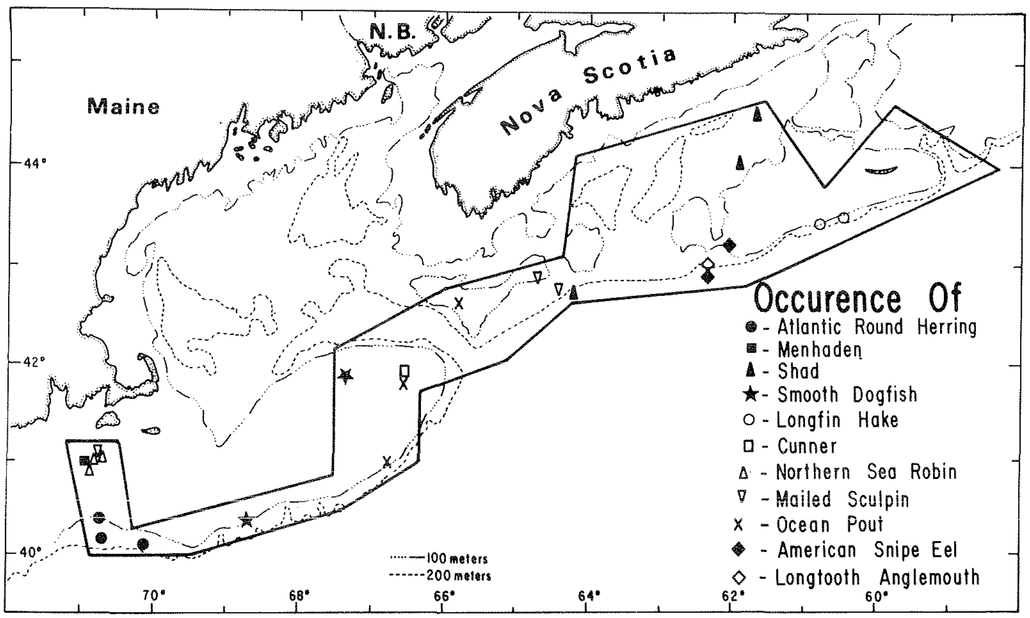


Fig. 29. Chart of sample area showing occurrence of other species in the catch.

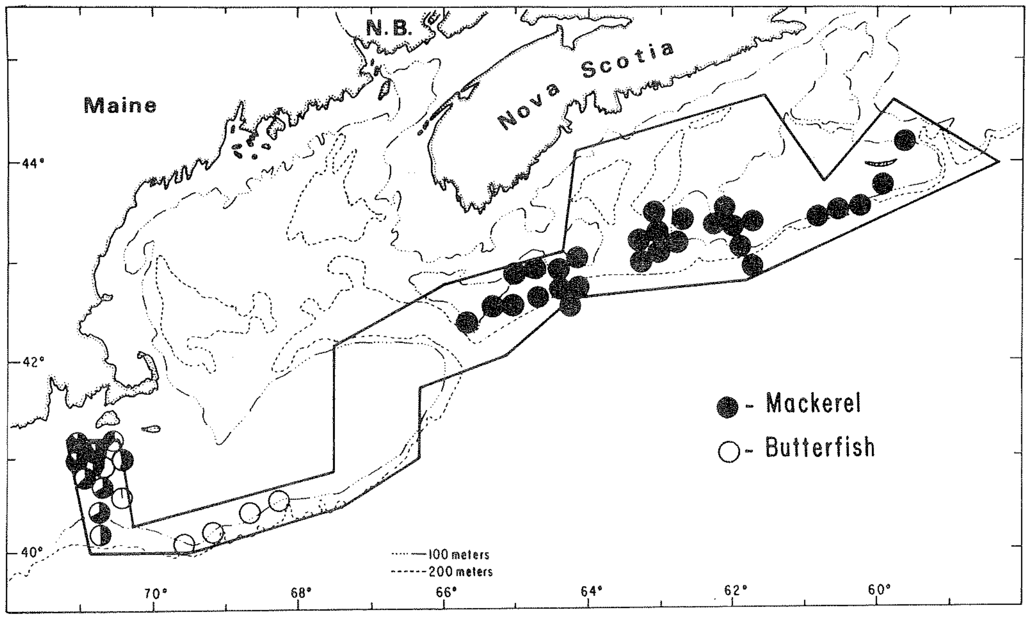


Fig. 30. Chart of the sample area showing the relative proportions of mackerel and butterfish in the catch.

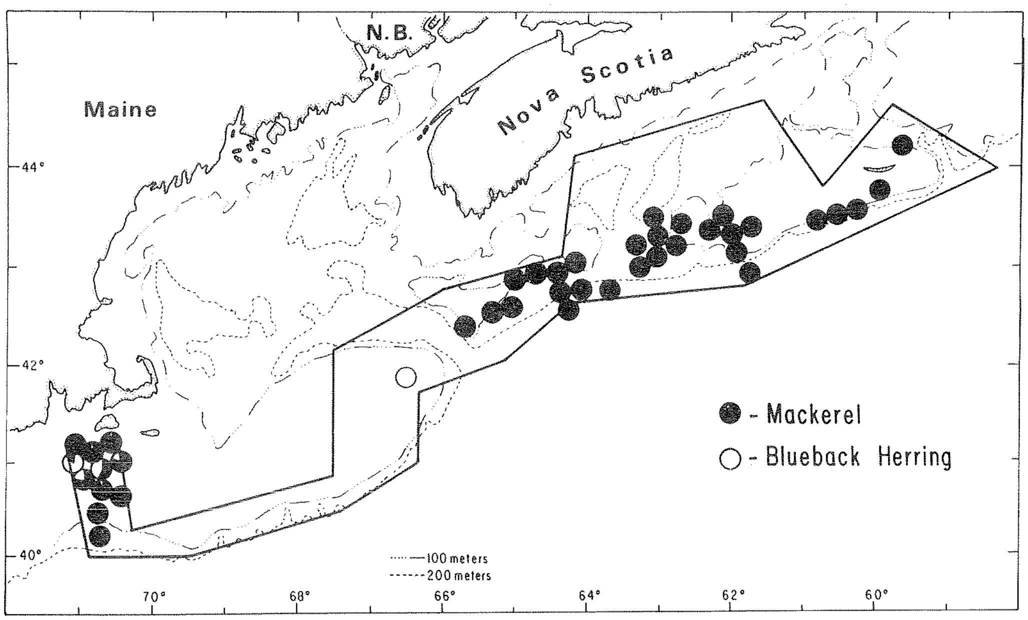


Fig. 31. Chart of the sample area showing the relative proportions of mackerel and blueback herring in the catch.

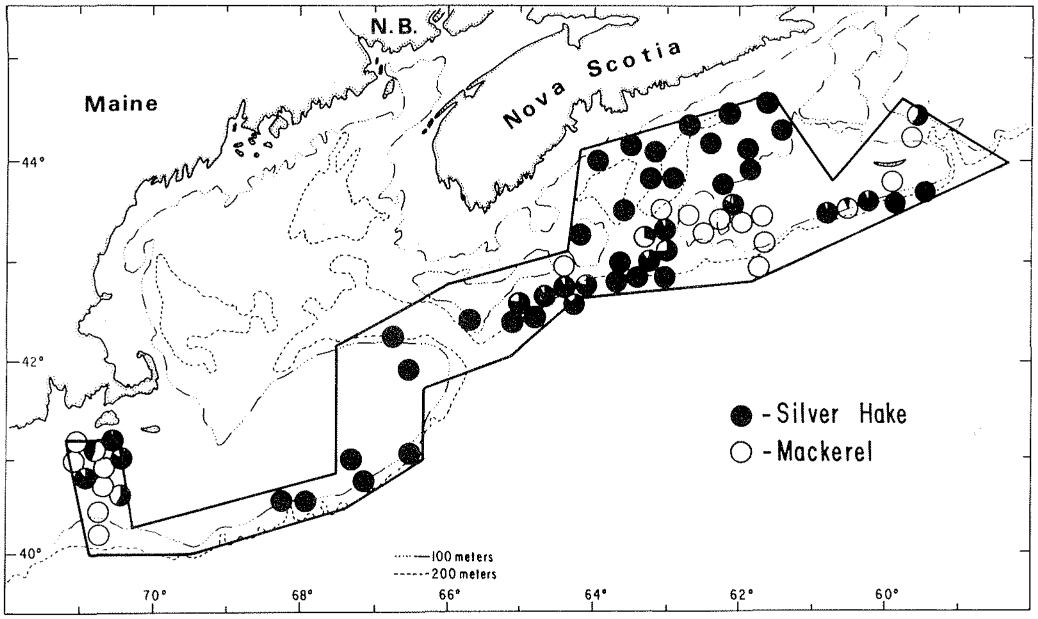


Fig. 32. Chart of the sample area showing the relative proportions of silver hake and mackerel in the catch.

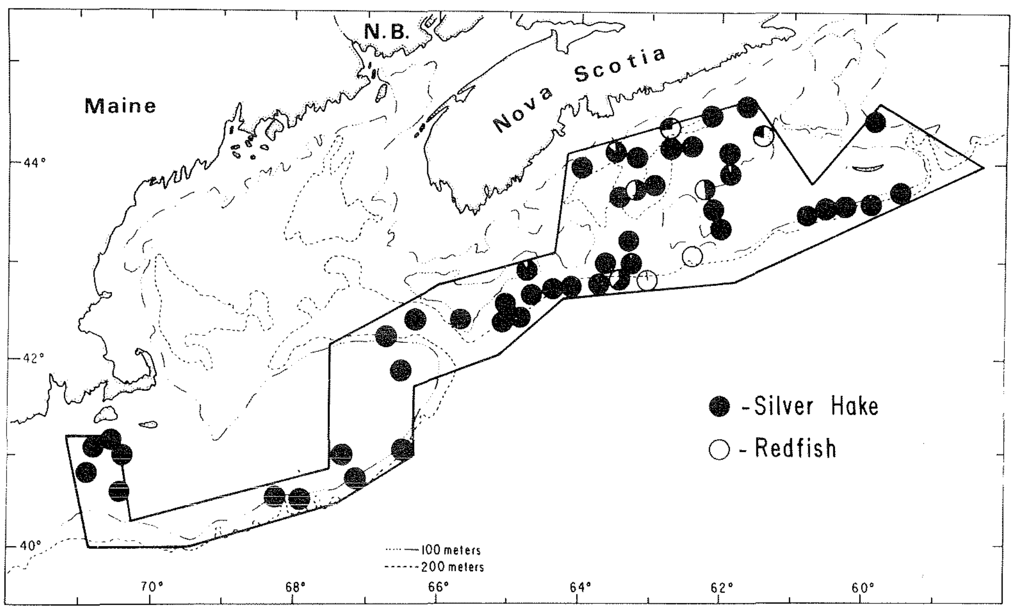


Fig. 33. Chart of the sample area showing the relative proportions of silver hake and redfish in the catch.

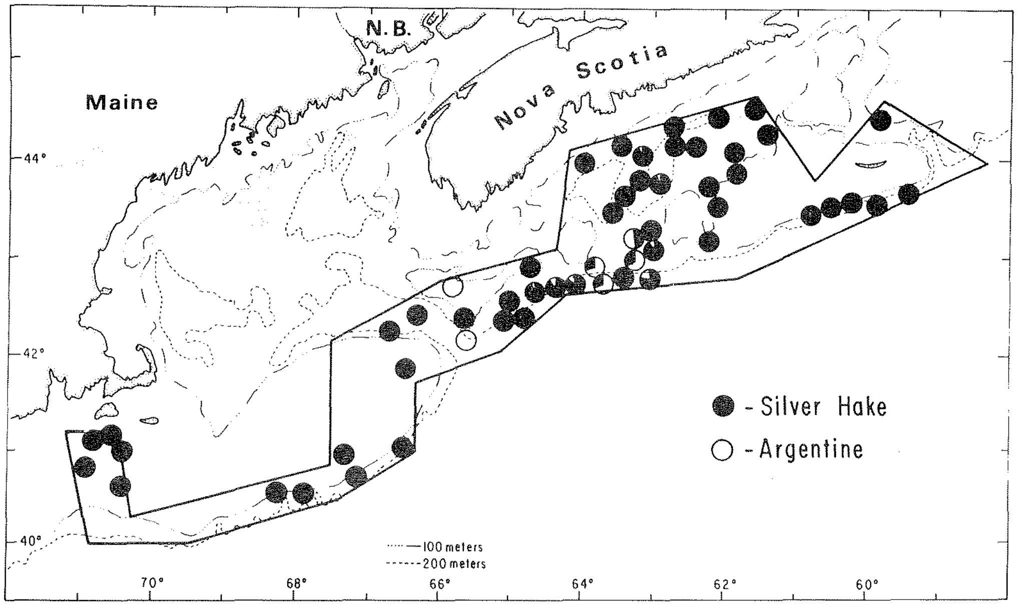


Fig. 34. Chart of the sample area showing the relative proportions of silver hake and argentine in the catch.

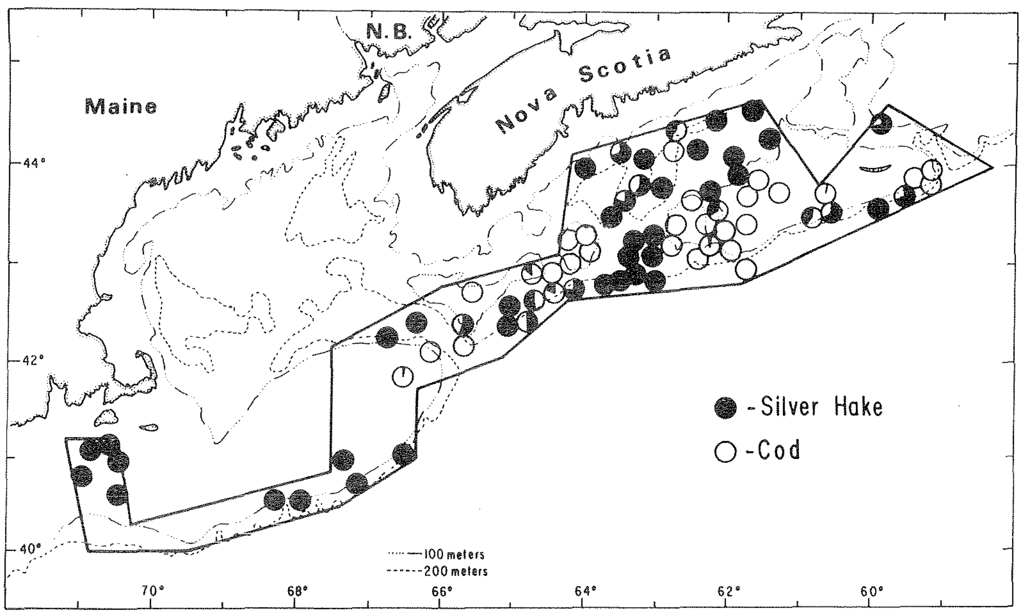


Fig. 35. Chart of the sample area showing the relative proportions of cod and silver hake in the catch.

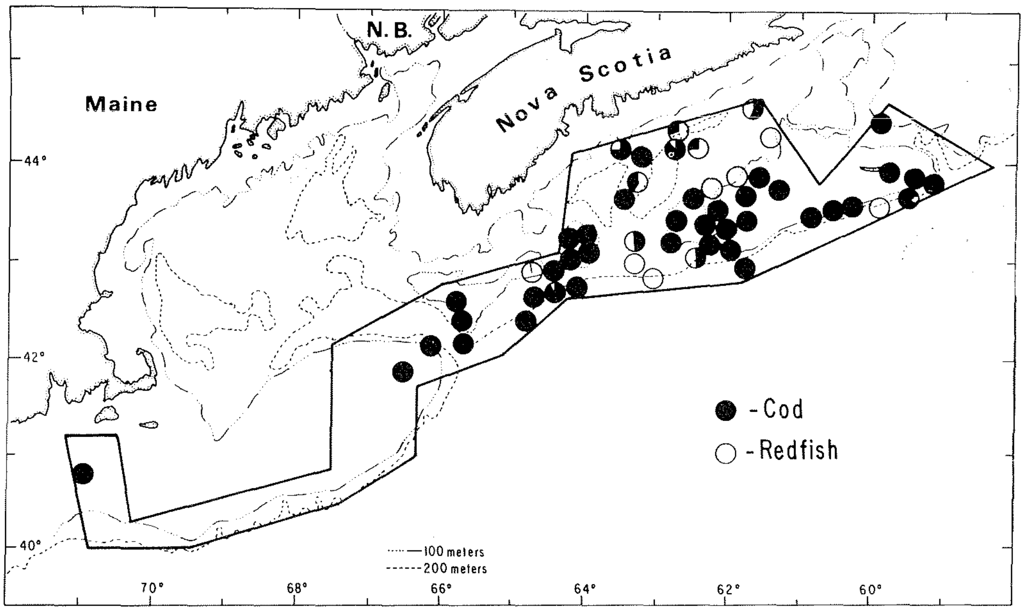


Fig. 36. Chart of the sample area showing the relative proportions of cod and redfish in the catch.

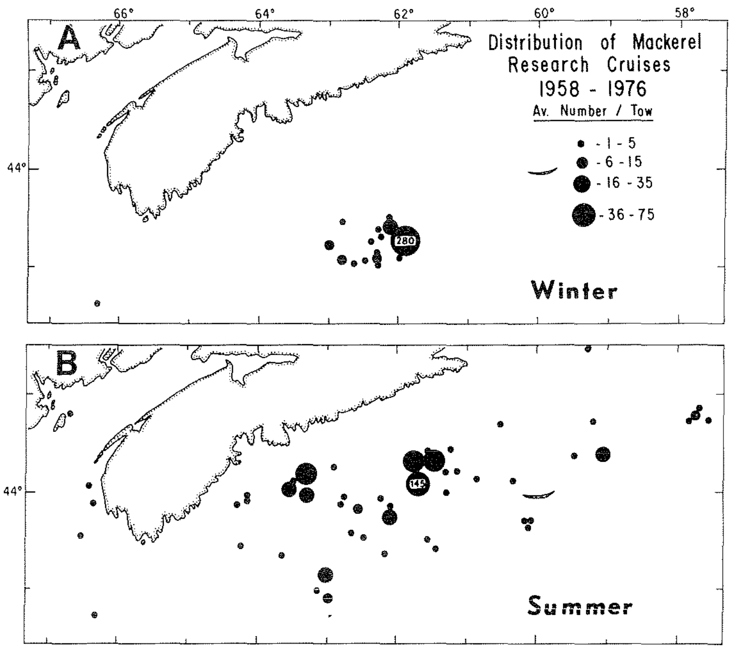


Fig. 37. Chart of the Scotian Shelf showing: (A) the winter distribution; and (B) the summer distribution of mackerel from past research cruises (1958-1976).

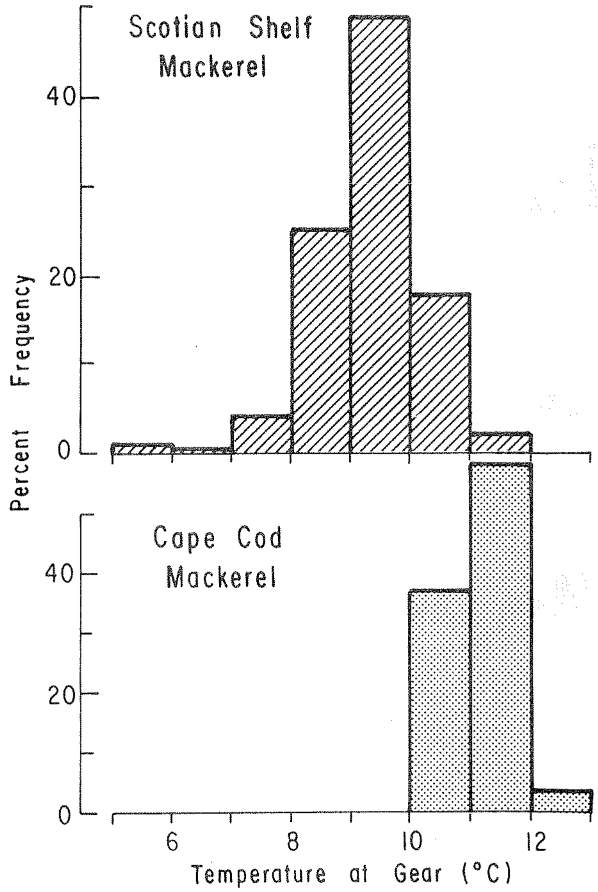


Fig. 38. Percent frequency of mackerel on the Scotian Shelf and Cape Cod showing temperature at which these animals were found.

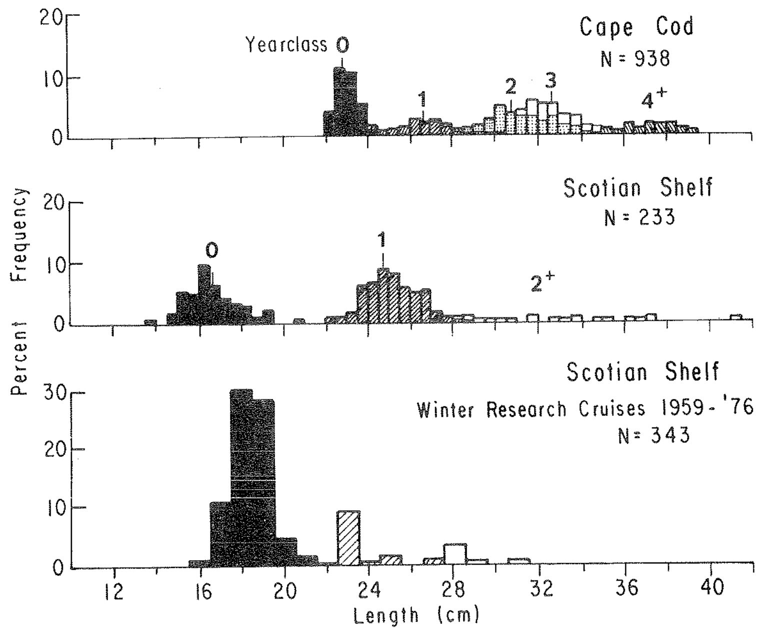


Fig. 39. Length-frequency histograms of mackerel from Cape Cod and the Scotian Shelf (present cruise and research cruises, 1959-76). The different age groups (yearclass) as derived from age-length keys shaded differently.

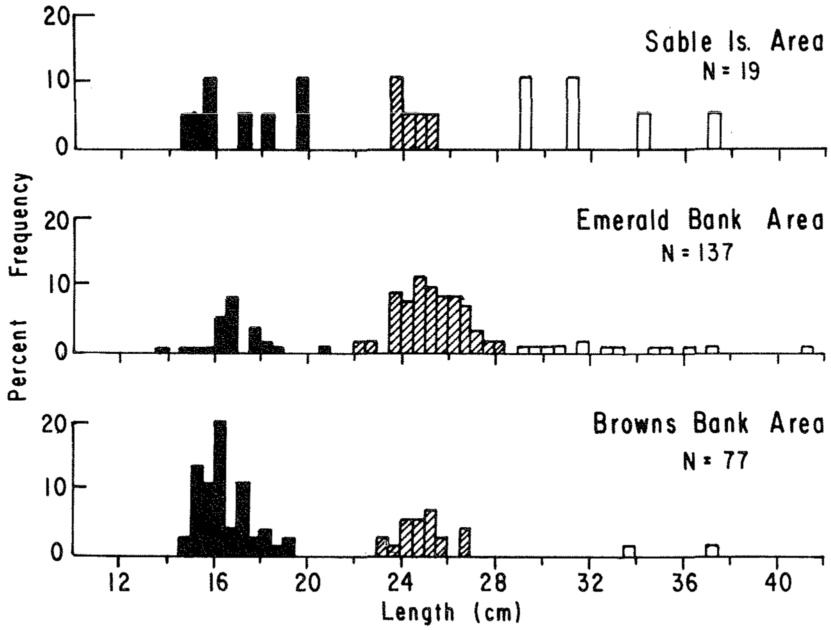


Fig. 40. Length-frequency histograms of mackerel from three areas of the Scotian Shelf. Black bars indicate age 0 animals, stippled bars represent age I animals, and white bars represent age II+ animals.

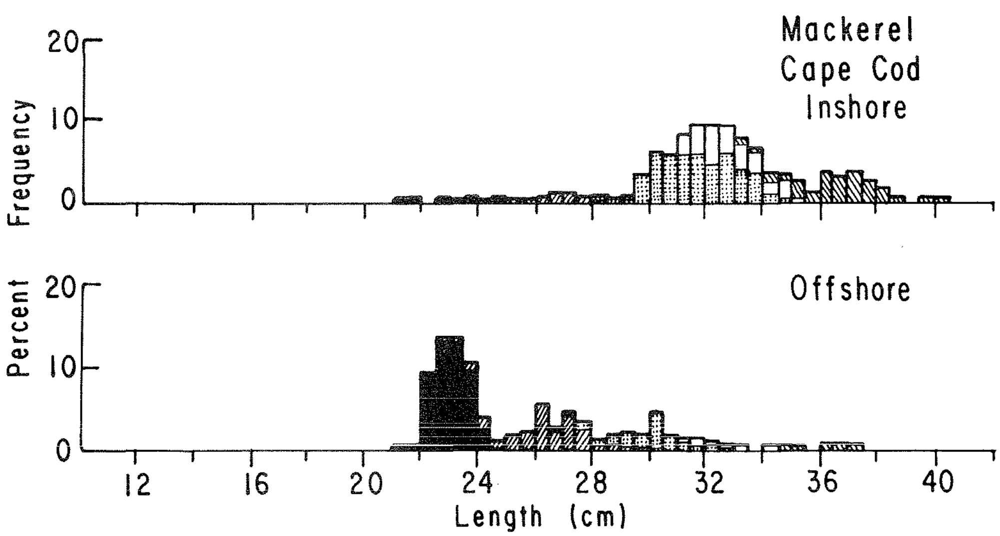


Fig. 41. Length-frequency histograms of mackerel from Cape Cod, inshore (upper diagram) and offshore (lower diagram).

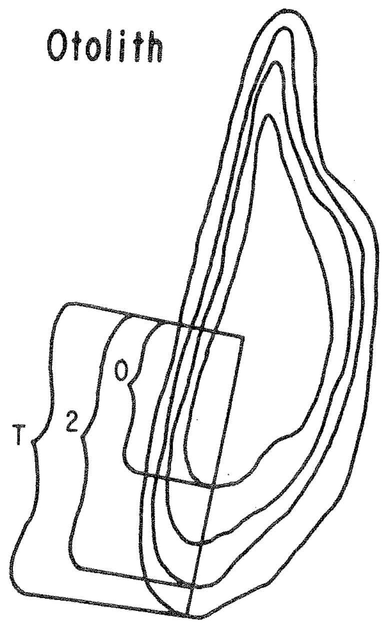


Fig. 42. Diagram of a mackerel otolith showing the various rings and measurements taken.

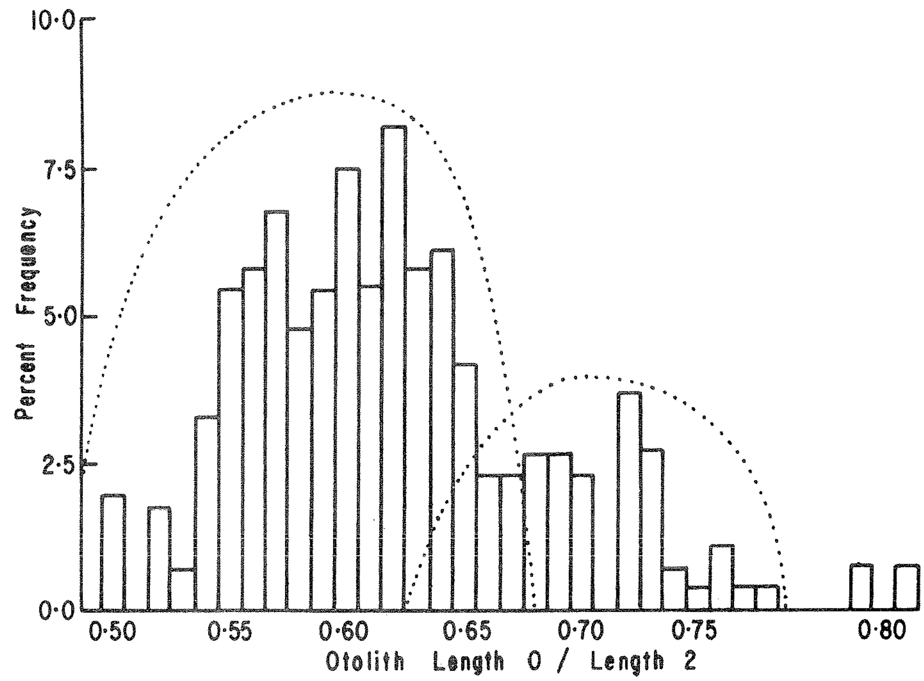


Fig. 43. Percent frequency of the otolith 0/2 length of mackerel. Dotted line represents the modes expected for the two population contingents, drawn by eye.

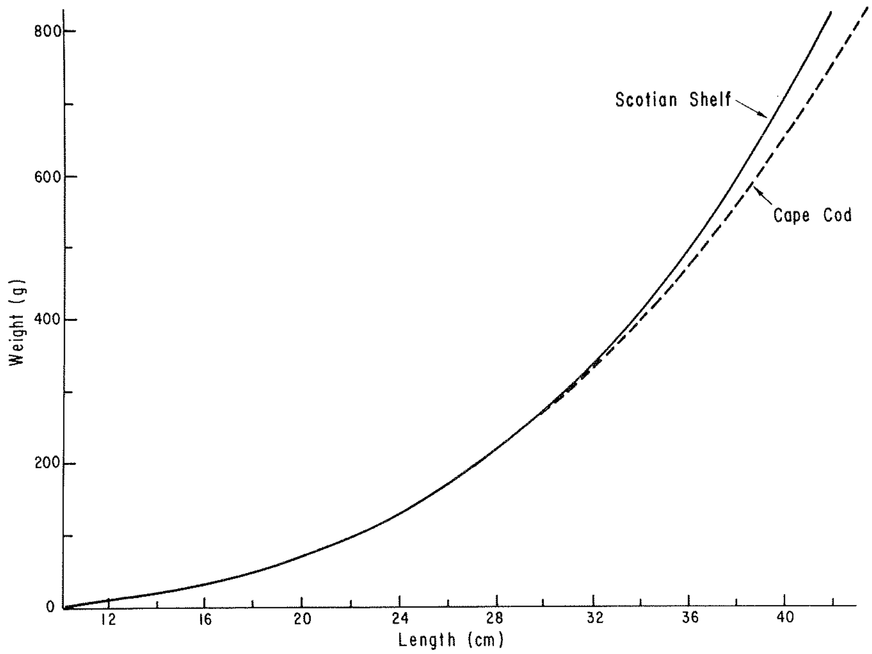


Fig. 44. The relationship between fork length and weight of mackerel.

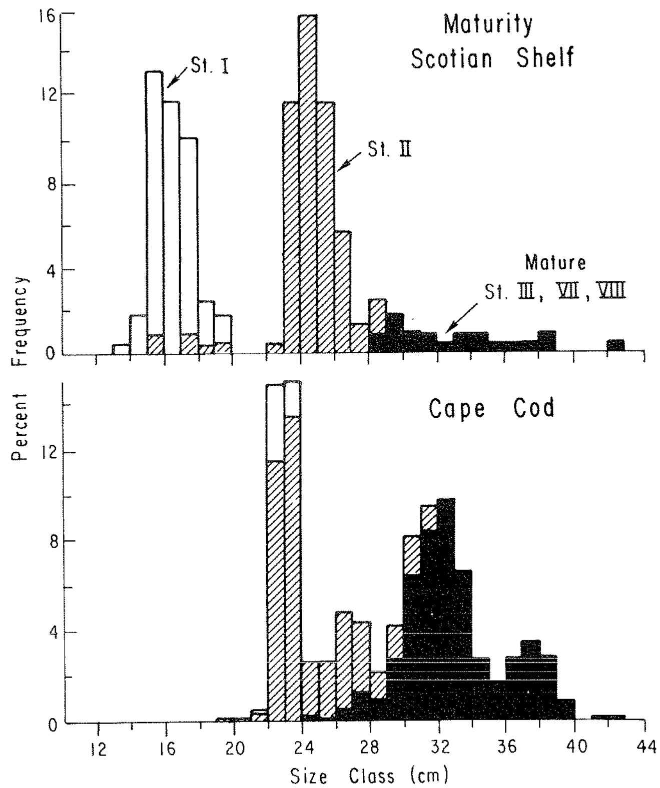


Fig. 45. Length frequencies showing gonad maturity for: Scotian Shelf mackerel (upper diagram) and Cape Cod mackerel (lower diagram). The different maturity groups by length are indicated (stage I - open, stage II - hatched, Stages III, VII, VIII - black.)

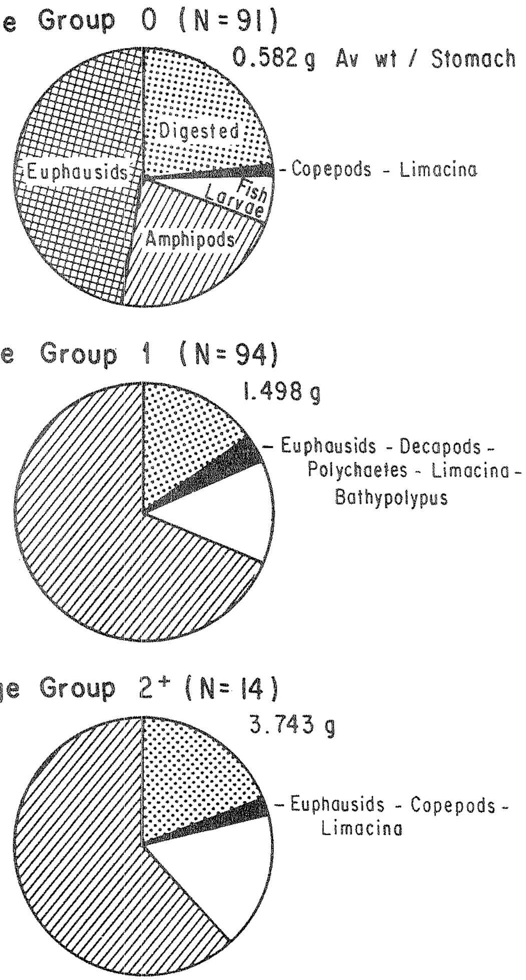


Fig. 46. The diet of Scotian Shelf mackerel showing the breakdown for year-classes.

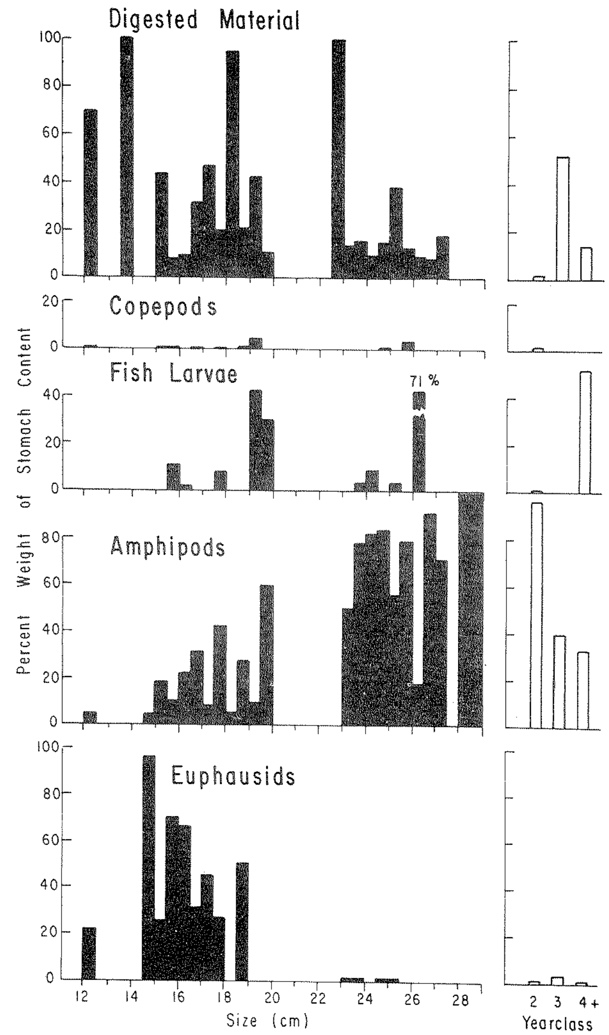


Fig. 47. Percent weight of food items in the stomachs of mackerel plotted against size-class of the fish.

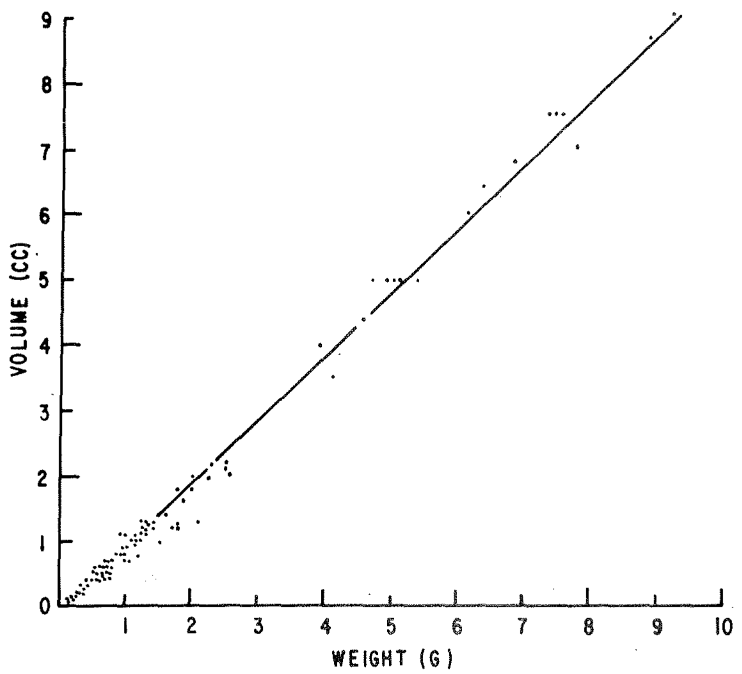


Fig. 48. The relationship between weight and volume of stomach content in mackerel.

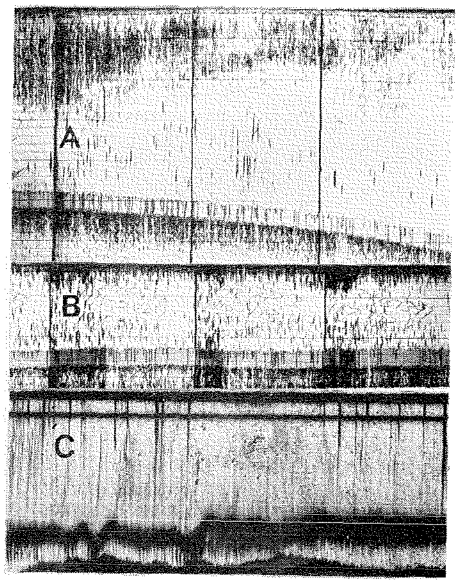


Fig. 49. Sonar traces showing mixed schools of: (A) mackerel with round herring and butterfish; (B) mackerel and blueback herring; and (C) mackerel and silver hake.

Table 1. Age-length key for mackerel caught on the Scotian Shelf, November-December, 1976

Size Class	0	1	2	3	4	5	6	7	Total
13	-	-	-	-	-	-	-	-	-
13.5	1	-	-	-	-	-	-	-	1
14	-	-	-	-	-	-	-	-	-
14.5	4	-	-	-	-	-	-	-	4
15	9	-	-	-	-	-	-	-	9
15.5	22	-	-	-	-	-	-	-	22
16	16	-	-	-	-	-	-	-	16
16.5	10	-	-	-	-	-	-	-	10
17	14	-	-	-	-	-	-	-	14
17.5	7	-	-	-	-	-	-	-	7
18	2	-	-	-	-	-	-	-	2
18.5	5	-	-	-	-	-	-	-	5
19	2	-	-	-	-	-	-	-	2
19.5	2	-	-	-	-	-	-	-	2
20	-	-	-	-	-	-	-	-	-
20.5	1	-	-	-	-	-	-	-	1
21	-	-	-	-	-	-	-	-	-
21.5	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-
22.5	-	1	-	-	-	-	-	-	1
23	-	13	-	-	-	-	-	-	13
23.5	-	15	-	-	-	-	-	-	15
24	-	18	-	-	-	-	-	-	18
24.5	-	18	-	-	-	-	-	-	18
25	-	16	-	-	-	-	-	-	16
25.5	-	10	-	-	-	-	-	-	10
26	-	7	-	-	-	-	-	-	7
26.5	-	7	-	-	-	-	-	-	7
27	-	4	-	-	-	-	-	-	4
27.5	-	-	-	-	-	-	-	-	-
28	-	2	1	-	-	-	-	-	3
28.5	-	1	1	-	-	-	-	-	2
29	-	1	1	-	-	-	-	-	2
29.5	-	-	2	-	-	-	-	-	2
30	-	-	-	1	-	-	-	-	1
30.5	-	-	-	1	-	-	-	-	1
31	-	-	-	-	-	-	-	-	-
31.5	-	-	1	1	-	-	-	-	2
32	-	-	-	1	-	-	-	-	1
32.5	-	-	-	-	-	-	-	-	-
33	-	-	-	1	1	-	-	-	2
33.5	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	3	-	-	3
34.5	-	-	-	-	-	-	-	-	-
35	-	-	-	-	-	-	-	-	-
35.5	-	-	-	-	-	-	1	-	1
36	-	-	-	-	-	-	-	-	-
36.5	-	-	-	-	-	-	-	-	1
Total	95	113	6	5	1	3	1	1	225
% Total	42.2	50.2	2.7	2.2	.4	1.3	0.4	0.4	

Table 2. Age-length key for mackerel caught in the Cape Cod area, November-December, 1976

Size Class	0	1	2	3	4	5	6	7	8	9	10+	Total
20.5	1	-	-	-	-	-	-	-	-	-	-	1
21	1	-	-	-	-	-	-	-	-	-	-	1
21.5	7	-	-	-	-	-	-	-	-	-	-	7
22	35	-	-	-	-	-	-	-	-	-	-	35
22.5	97	1	-	-	-	-	-	-	-	-	-	98
23	100	3	-	-	-	-	-	-	-	-	-	103
23.5	47	3	-	-	-	-	-	-	-	-	-	50
24	5	3	-	-	-	-	-	-	-	-	-	8
24.5	1	4	-	-	-	-	-	-	-	-	-	5
25	-	10	-	-	-	-	-	-	-	-	-	10
25.5	1	16	-	-	-	-	-	-	-	-	-	17
26	-	15	-	-	-	-	-	-	-	-	-	15
26.5	-	26	2	-	-	-	-	-	-	-	-	28
27	1	21	2	-	-	-	-	-	-	-	-	24
27.5	-	13	4	-	-	-	-	-	-	-	-	17
28	-	5	3	-	-	-	-	-	-	-	-	8
28.5	-	7	9	-	-	-	-	-	-	-	-	16
29	-	3	12	-	-	-	-	-	-	-	-	15
29.5	-	2	18	-	-	-	-	-	-	-	-	20
30	-	-	25	-	-	-	-	-	-	-	-	25
30.5	-	2	26	-	-	-	-	-	-	-	-	28
31	-	-	15	4	-	-	-	-	-	-	-	19
31.5	-	-	15	8	-	-	-	-	-	-	-	23
32	-	-	11	10	-	-	-	-	-	-	-	21
32.5	-	-	14	4	-	-	-	-	-	-	-	18
33	-	-	8	7	2	-	-	-	-	-	-	17
33.5	-	-	7	6	1	-	-	-	-	-	-	14
34	-	-	4	4	3	-	-	-	-	-	-	11
34.5	-	-	2	4	2	-	-	-	-	-	-	8
35	-	-	-	1	4	-	-	-	-	-	-	5
35.5	-	-	-	-	2	-	1	1	-	-	-	4
36	-	-	-	-	3	5	2	-	1	-	1	12
36.5	-	-	-	-	-	1	2	-	-	2	-	5
37	-	-	-	-	1	2	6	2	-	-	-	11
37.5	-	-	-	-	1	2	6	-	2	1	3	15
38	-	-	-	-	-	2	2	3	1	-	1	9
38.5	-	-	-	-	-	-	-	1	-	1	1	3
39	-	-	-	-	-	-	-	-	-	-	-	-
39.5	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-	-
40.5	-	-	-	-	-	-	-	-	-	-	3	3
Total	297	134	177	49	19	12	19	7	4	4	3	732
% Total	40.6	18.3	24.2	6.7	2.6	1.6	2.6	1.0	0.6	0.6	1.4	