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Changes in the Distribution and Biological Characteristics in the Scotian Shelf Population of *Illex illecebrosus* Over the 1980-1983 Period

by

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SPECIAL SESSION ON SQUIDS

Introduction

Scotian Shelf bottom trawl surveys conducted during four periods each year (late spring, summer, late summer, and fall) from 1980 to 1983, will be used to describe changes in squid (Illex illecebrosus) distribution, abundance and biology within and between those years.

Rowell and Young (1984) reported results from the summer and fall groundfish surveys conducted by the Fisheries Research Branch, Department of Fisheries and Oceans for the years 1970 to 1983. Dupouy (1981); Dupouy and Minet (1982); Dupouy and Derible (1983); and Poulard et al. (1984) reported results from late summer bottom trawl surveys conducted between 1980 and 1983 by the Institut Française De Recherche Pour L'Exploitation De La Mer, St. Pierre et Miquelon (IFREMER). Amaratunga and Budden (1981) reported results from a late spring 1981 bottom trawl survey. Other late spring survey results have been previously unreported.

Distributional patterns based on squid density are examined in relation to an environmental data set of long-term bottom temperatures derived from the MEDS 'Nansen' file by Trites and Drinkwater (unpublished data).

Methods

Table 1 gives information on the specific cruises from which data has been used in present analysis, such as dates of survey, vessels, and gear. Four cruise periods (late spring, summer, late summer, and fall) for the period 1980 to 1983 are covered. The survey techniques are standard within each period but some differences between periods are worthy of mention. The late spring cruise in 1980, encompassed the entire Scotian Shelf, but has since been conducted only along the Shelf-edge. The Scotian Shelf summer and fall groundfish surveys, recently described by Rowell and Young (1984), are conducted throughout the Scotian Shelf and Bay of Fundy area. The late summer surveys, conducted largely by IFREMER are concentrated on a group of eighteen of the groundfish survey strata which equate roughly to the Shelf-edge area, those Shelf areas with depths of 50 to 200 fathoms between the Northeast Channel (66°W) and Emerald Basin (61°W), as well as the Gully and Stratum 57 north of Sable Island.

Data from all four periods are used in examining seasonal and annual catch rate patterns as well as length frequency patterns. Since no maturation data is available for the fall period, only three seasons are analyzed. Data from the summer, late summer, and fall periods are used in the examination of seasonal and annual biomass patterns for a subset of data from 18 consistently surveyed strata. The summer and fall periods alone are considered in the discussion of distributional changes in squid density in relation to mean bottom temperatures.

Deviations ($\pm$ 1 std. dev. from the mean) between long-term normal bottom temperature values and those observed in the summer and fall surveys were initially examined, but did not correlate with observed patterns of squid density. We then decided to examine squid density using the apparent squid preference for bottom temperatures in excess of 6°C (Poulard et al. 1984) as a basis for categorizing bottom temperatures. This provided a somewhat better correlation.

Squid maturation indices used are as described in Amaratunga and Durward (1978) and Durward et al. (1978) for males and females, respectively.

Results and Discussion

Geographic Distribution

Seasonal and annual catch rate patterns

Catch rate patterns for the four seasonal survey periods from 1980-1983 are presented in Figure 1. The high variability in catch rate patterns reported by Rowell and Young (1984) for the July 1970-1983 groundfish survey series is also seen seasonally and interannually for the periods reported here. Below, we summarize the patterns by month and relate observed changes between years.

June

In early season, the squid population appears to have been restricted largely to the Shelf-edge. Largest concentrations appeared in the area of 61°-63°W. This was particularly true in periods of low biomass (June 1980 and June 1983). When higher early season biomass was seen, as in 1981 and 1982, the squid concentrations were more dispersed, extending along the Shelf-edge from Browns Bank (66°W) to Banquereau (58°W). With the exception of 1981, catch rates east of 61°W were low. In 1980 and 1983, there were virtually no catches east of 61°W.

July

In all years but 1983, the population in July had dispersed shoreward over a wide area of the Scotian Shelf. With the exception of 1981, the population appears to have broken up into a number of apparently discrete concentrations. In most years there was also an extension of concentrations along the Shelf-edge to the east of 61°W, and in some years, such as 1980 and 1982, along the Laurentian Channel and areas off eastern Cape Breton. In only two of the four years (1980 and 1981) was there a movement of squid into the Bay of Fundy or its approaches.

September

Sampling during this period was less complete, with no coverage of the Bay of Fundy and only limited coverage for those areas shoreward of the Shelf-edge from approximately 62°W and eastward. During this period, squid concentrations appeared along the Shelf-edge and extended shoreward, with the main shoreward extension primarily between 62°-65°W. Eastward of 61°W squid concentrations appeared scarce, with the exception of the Shelf-edge and Gully in some years (1980, 1981). In years of lower abundance, such as 1982 and 1983, they were virtually absent from areas to the east of 60°W. In 1980, the pattern of distribution which showed discrete concentrations in July, showed a much more contiguous pattern in September. In 1980, and to a greater extent in 1981, after July there was a westward extension of squid concentration along the Shelf-edge to the Northeast Channel. In 1983, there were only two areas of high squid concentration in July; along the Shelf-edge at 62°W and in the Gully at 60°W. Whereas in September, high concentrations were found all along the Shelf-edge from 60-66°W and a small concentration was found inshore above the LaHave and Emerald Basins. Due to a data entry error, 13 stations, having catches of up to 25 kg/30 min. tow in the area around Emerald Basin are not shown in Figure 1.

October

By late season, squid concentrations appeared more discrete and were much more widely dispersed than earlier in the year. Catch rates were much reduced over the entire area of distribution. In all four years, squid were found in the Bay of Fundy, its approaches, and the most western areas of the Scotian Shelf (except for 1983). With the exception of 1980, concentrations over the inner shelf areas east of 62°W were virtually absent. It should noted, that the annual groundfish surveys (July, October) have the best overall coverage of the Scotian Shelf, but they do not sampled shoreward of the 50 fm isobath. Even along the Shelf-edge, the fall distribution appeared more fragmented than in July and September.

Seasonal and annual biomass patterns

Biomass levels, within the 18 strata which had been consistently surveyed throughout three of the four survey periods (July, September, October) in all four years, are presented in Figure 2. As with the previous section, biomass patterns are summarized by survey month and the seasonal and interannual changes are discussed.

July

In early season, there was one stratum out of the eighteen in each of the years where the greatest biomass appeared. The stratum varied between years, but at a maximum, the biomass within the "high" stratum was an order of magnitude greater than in the next lower stratum. The "high" stratum was different in each year. High strata in July were always to the west of 61°W.

September

In mid-season, there were generally a number of high biomass strata in the two years of highest overall biomass (1980 and 1981). In the lowest biomass year, 1982, there was a flatter distribution with no "high" strata, while in 1983 the pattern of one "high" stratum seen in July prevailed through September. Although the number of strata having moderate to high levels of biomass increases substantially by September, it was only in the year of highest overall biomass that high biomass was seen in strata to the east of 61°W.

October

By late-season, biomass levels in all strata were low and the distribution among strata was wide, although less than in mid-season. Again, the marked lack of any significant biomass to the east of 61°W was seen.

Distributional changes in density of squid in relation to bottom temperatures

Density patterns, in number of squid per square nautical mile, for strata surveyed during the summer (July) and fall (October) from 1980-1983, are presented in Figure 3.0-3.3 along with mean bottom temperatures by stratum for the same periods. Bottom temperatures have been classed based on evidence for preferred temperature regimes for squid as indicated in previous studies (Dupouy 1981; Dupouy and Minet 1982; Dupouy and Derible 1983; and Poulard et al. 1984): areas with mean bottom temperatures being classed from least to most preferred at <6°C, 6°-8°C, and >8°C.

The seasonal and interannual patterns of distribution and temperature are described below.

1980

In summer 1980, highest bottom temperatures were in the Bay of Fundy, over virtually the entire Shelf area between LaHave Basin (64°W) and 62°W, including an extension along the Shelf-edge between 59°-66°W. All larger strata west of 62°W, with the exception of Stratum 76, had temperatures > 6°C. No significant squid concentrations were found in the highest temperature areas. Greatest concentrations were in the western Shelf areas between 64°W and 67°W, with temperatures ranging from 5.7°-7.1°C.

In fall 1980, highest temperatures were seen over essentially the same central area of the Shelf near LaHave (Stratum 71) and Emerald (Stratum 61) Basins, and had increased in the western Shelf area around Browns Bank (Stratum 80). No data were available for the Bay of Fundy and its approaches. Higher temperatures were also seen in the area between Cape Breton and the Laurentian Channel edge (St. Annes Bank, Stratum 42) as well as the Gully (Stratum 52), Middle Bank (Stratum 58), and the eastern part of Banquereau Bank (Strata 47). Low temperatures were present throughout the Shelf area north of Banquereau Bank (Strata 43, 44, 45). Highest squid densities in September 1980 were in the entrance to the Bay of Fundy (Stratum 93) and, surprisingly, in the cold (2.0°C) area of the Shelf north of Banquereau Bank (Stratum 44). Less dense aggregations were seen in the central Shelf area around LaHave and Emerald Basins. The western area of the Shelf from 64°W to 67°W, which in the summer had the highest density, had by fall a low density of squid, despite continued high temperatures (6.9°-10.1°C).

1981

In summer 1981, the distribution of highest temperatures was somewhat similar to that in 1980, except that the area of warmest temperatures in the Bay of Fundy and approaches was restricted to the strata bordering the Nova Scotia coast (Strata 90 and 95), and warmer water also extended over Sable

Island Bank (Stratum 55) and along the Banquereau Shelf-edge (Strata 49, 50, 51) to the Laurentian Channel. Areas of intermediate temperature bottom water were also more extensive than in 1980, extending above Sable Island and covering all of the strata to the west.

Highest squid densities were seen in the 10.1°C water of the Bay of Fundy (Stratum 95), and in the 8.8°C and 5.4°C water of Strata 62 and 59 respectively. Major, but less dense concentrations were seen primarily in the nearshore Strata (60, 70) north of LaHave and Emerald Basins, where water temperatures were 9.0°C and 7.8°C respectively, and in Strata 65 where the bottom temperature was 9.5°C. Lower densities were encountered over virtually all the remaining Shelf areas, including the cooler areas north of Banquereau Bank (i.e. Stratum 44 at 2.9°C) as well as high temperature areas such as LaHave and Emerald Basins (Strata 71 and 61).

The fall 1981 pattern of bottom temperatures was very similar to that for summer, but the areas of higher and intermediate temperature had expanded. High temperatures were now seen in along the western Shelf-edge as far as Stratum 82, south of Browns Bank, as well as on Browns (Stratum 80). Stratum 48 on Banquereau Bank, which had a bottom temperature of 3.7°C in summer, by fall had a temperature of 8.7°C. Strata along the Shelf-edge east of 61°W were somewhat cooler than in summer, but still had high intermediate temperatures 7.0°-8.0°C. Intermediate temperatures prevailed over the rest of the Shelf area from Banquereau westward, except for the north eastern areas of the central Shelf above Banquereau and Middle Bank.

By fall 1981, squid densities were generally lower over all strata and the areas of high and intermediate concentrations were much reduced. Some interesting shifts in density were seen, in that those areas having the highest densities in summer (Strata 95, 62, 59) now had very low densities despite continued high bottom temperatures in Strata 95 and 62 (12.1° and 9.3°C respectively) and a slight increase in the cooler Stratum 59 (from 5.4°C in summer to 5.6°C in fall).

Highest squid densities were found on Sable Island Bank (Stratum 55) where bottom temperatures averaged 9.6°C. This again reflected a shift from summer, when, despite high temperatures (8.2°C), Stratum 55 had a relatively low density of squid. Squid were, by fall, either absent or in very low density over all of the Shelf area east of 62°W with the exception of Western and Sable Island Banks (Strata 64 and 55). They were also absent or in low density to the west of LaHave Basin (Stratum 71) with the exception of intermediate densities in Stratum 81 surrounding Browns Bank and Stratum 90 in the approaches to the Bay of Fundy.

1982

In summer 1982, highest temperatures (8.4°-10.0°C) were seen in the inner Bay of Fundy and along the nearshore areas of its approaches, in the area surrounding Browns Bank (Strata 81 and 82) and in LaHave Basin (Stratum 71). With the exception of Stratum 77, all larger strata west of 62°W had temperature > 6°C. To the east of 62°W all strata had temperatures < 6°C. Highest squid densities were in Stratum 81 surrounding Browns Bank and Stratum 84 in the Gulf of Maine, where mean bottom temperatures were 10.0°C and 7.6°C respectively. The Bay of Fundy and its approaches, the central area of the Shelf between the east end of Browns Bank (approx. 65°W) and the west end of Emerald Basin (approx. 63°W), and the Western, Sable Island, Middle and Banquereau Bank areas, as well as the inshore Cape Breton area, had very low densities. Low densities were apparent along the Laurentian Channel east of Cape Breton and along the Shelf-edge south of Sable Island Bank.

In fall 1982, highest temperatures were again seen in the Bay of Fundy and its approaches (8.3°-11.7°C). Emerald Basin (Stratum 61), Sable Island Bank (Stratum 55) and Middle Bank (Stratum 58) also had high (>8°C) temperatures. Areas of intermediate temperature (>6°C) were general west of 62°W, with the exception in the larger strata, of Strata 60, 62 and 76. The area immediately north of Sable Island (Stratum 66) as well as the Shelf-edge south of Sable Island and Western Bank, and nearshore Cape Breton (Stratum 42) all had temperatures > 6°C. Squid distribution during the fall period showed no consistent relationship to temperature, with moderate squid densities seen in 4.6°C water in Stratum 60 north of Emerald Basin, as well as in 11.3°C water in the Bay of Fundy (Stratum 92). Very low densities were also seen over Middle Bank (Stratum 58) where the mean bottom temperature was 11.8°C. Densities overall were generally lower, and a shift had occurred in that areas such as Strata 81 and 84, which had high densities in summer, now had low densities despite continuance of bottom temperatures well above the minimum preferred level (7.6° and 7.4°C respectively). Overall, squid distribution on the Shelf was by fall contracted, being largely restricted to the Bay of Fundy approaches and the Shelf area between 62° and 66°W. In contrast to the fall of 1980, there were no concentrations along the Shelf-edge.

1983

In summer 1983, the areas of highest and intermediate temperatures were somewhat similar to those of 1982. The most significant difference was the extension of intermediate temperatures eastward along the Shelf-edge as far as Stratum 49 south of Banquereau Bank and over Sable Island Bank (Stratum 55).

Highest squid densities were not found in the high temperature strata, but in the intermediate temperature (6.6°C-6.8°C) strata south of Emerald Basin and along the intermediate depth area of the Shelf-edge south of Western and Sable Island Banks (Strata 65 and 54), as well as the low temperature areas of the Gully (Strata 52 and 57), where bottom temperatures were 4.0°-4.8°C. Intermediate densities were also seen in temperatures of 6.9°-8.8°C in the strata around Browns Bank (Strata 81 and 82).

In fall 1983, highest temperatures were seen in Stratum 65 south of Emerald Basin (8.5°C), along virtually the entire Shelf-edge west of 61°W (9.0°-9.6°C), and from the area around Browns Bank into the Gulf of Maine and Bay of Fundy (8.3°-11.2°C). Intermediate temperatures were seen over the remaining Shelf-edge, most larger strata of the inner Shelf areas west of 59°W, and south of Middle Bank (Stratum 58); exceptions being Strata 61, 64 and 76.

Squid densities remained highest, with the exception of the Gully area (Strata 52 and 57), in essentially the same areas where they had been high in summer. Squid were virtually absent from the remainder of the Shelf.

The distribution, as determined by density per stratum (Fig. 3.0-3.3), closely agreed with that determined by catch rate (Fig. 1). As might be expected, differences were generally related to the expansive effect of using fixed strata vs. the interpretive approach necessary in examining catch rate patterns.

Distribution of small squid in late summer

Secondary and tertiary cohorts of small squid are regularly seen over the Scotian Shelf during late summer. The size range of these squid varies considerably from year to year. Mesnil (1976) reported small squid ranging from 70-150 mm mantle length (ML) in the 1973 population and Dupouy and Minet (1982) reported squid ranging from 50-110 mm ML in 1981. In the period considered in this paper, distinct cohorts of squid were most clearly seen in the late summer (September) length frequency data (Fig. 4). Below we examine areal as well as depth distribution patterns for small squid, using 130 mm ML as the delimiting size.

Figures 5A-D show the areal distribution patterns for the years 1980-1983 respectively. It should be noted that the areal distribution of the September survey was limited, with no coverage of the northwestern Shelf, Bay of Fundy, or the central area of the Shelf east of approximately 60°W.

In 1980, small squid were very scarce, with only 4 stations resulting in catches of a few animals (<25) and one exceeding 50 animals. All small squid were captured between 62°W and 65°W along the Shelf-edge and shoreward as far as Emerald and LaHave Banks. During this period, larger squid were much more widely distributed along the Shelf-edge, Laurentian Channel, and over the central and shoreward areas of the Shelf (Fig. 1).

In 1981, small squid were encountered in greater numbers over a wider area of the Shelf, from approximately 59°W-66°W. Catches were made in the near shore strata over the central area of the Shelf and along the Shelf-edge, with greatest catches on the Shelf-edge south of Western Bank (approx. 62°W). This distributional pattern was close to that seen for larger squid, except in the Shelf-edge area south of Browns Bank (66°W) where no small squid were encountered and catches of larger squid were consistently made (Fig. 1).

In 1982, the year with the highest catches, small squid were present throughout the central Shelf area between 62°-66°W, with largest catches south of LaHave Basin (64°30W) and Emerald Bank (62°W). The distribution appears to have been the same as that for larger squid (Fig. 1).

In 1983, the pattern of distribution was very similar to that of 1982, with the exception that there were no areas of high catch. Again, the distribution was the same as for large squid.

As a general pattern, it appears the distribution of small squid may generally be limited to the more western and central areas of the Shelf and Shelf-edge. The virtual lack of catches along the Shelf-edge east of approximately 62°W and from the Gully and Laurentian Channel areas support this. In some years, such as 1980 and 1981, the differences in distribution between small and large squid appear to be greater than in others. It is also noteworthy that highest catches of small squid were made only on the outer area of the Shelf and Shelf-edge and the tows capturing small squid did not capture many large squid. With one exception, small squid were not found in tows where more than 75 kg of squid were caught. This suggests size related schooling and (or) differences in habitat preference between large and small squid. Interestingly, despite the areas of highest individual captures being on the outer Shelf and Shelf-edge, squid smaller than 130 mm ML were most abundant at the shallowest stations.

Figure 6 presents the bathymetric distribution of small squid versus total catch for the late summer survey in each year. Small squid were found between 75-349 m, but in all years more than 50% were captured at depths of 175 m or less. The closer agreement in 1982 and 1983, between depth of small squid capture and total catch, appears to support the conclusion reached above; that the distribution of small and large squid was much more similar in those years.

Patterns of Length Frequencies and Maturities

Length frequencies

Figure 4 presents length frequency histograms for the four periods and years under consideration. Data on males and females are presented separately for late spring (June) and late summer (September) and with sexes combined for summer (July) and fall (October). Although the vessels and bottom trawls used varied among some of the surveys, the data did not suggest that this had any great impact on the sizes of squid caught. We therefore believe the length frequency patterns are not greatly biased.

Although there is a general annual trend of increasing size, with modal mantle lengths (ML) ranging between 110-170 mm in the late spring and 190-230 mm in late summer, the patternr becomes less clear by fall (October). This is likely the combined result of large numbers of small squid influencing the relative frequencies and the impact of fishing removals, natural mortality and emigration. The largest squid in late spring have mantle lengths of approximately 200 mm and by fall of 290-300 mm It has long been well documented that, throughout the entire on-Shelf period, female Illex have greater modal lengths than male (Squires 1957 and 1967; Mercer and Paulmier 1973).

The use of combined male and female length data for the fall (October) period may account for the right skew in the length-frequency distributions.

In two of the four years (1980 and 1981), the disparity between male and female lengths increased markedly by late summer, while in 1983 such an increase is not apparent. The late summer population in 1982 shows no separation in modal lengths for males and females. As will be seen later in the maturity data (Table 2), in 1980 and 1981, both males and females were relatively well advanced in maturity stages by late summer. In late summer 1982, both males and females were less advanced, having similar maturity stage frequencies to those normally seen in late spring. Late summer 1983 was peculiar in that males again exhibited a slow maturation, whereas females had maturity stage frequencies equivalent to those seen in 1980. Since advances in maturities are generally correlated with increasing size, the relatively higher frequencies of more advanced males and females seen in 1980 and 1981 are probably related to the greater modal lengths.

In 1980, squid were considerably larger during the late spring and fall periods than in any other year. In summer, the 1980 modal length was greater than that for 1983 and intermediate to those of 1981 and 1982. By late summer, the 1980 modal lengths were similar to those of 1981, both being considerably larger than those for 1982 and 1983. The 1980 fall length frequency did not show the same degree of right skewness as seen in subsequent years. This may reflect a lower combined impact of fishing removals, natural mortalities, and emigration from the Shelf in October 1980 relative to other years. However, emigration would appear to be the factor most likely reflected in the observed variability. While the extreme right skewness observed in fall 1981 may be in part attributed to the impact of the second cohort, this was not a factor in 1983, since no second cohort was apparent.

In both 1981 and 1982, there were large numbers of small squid on the shelf in late summer. In 1981 there were two modal groups of smaller squid, one between 50-90 mm ML and another less distinct one between 120-170 mm ML. By the time the fall survey, approximately one month later, these two modes of smaller squid are seen between 60-120 mm ML and 150-190 mm ML respectively. In 1982, the length frequency distribution is much flatter, but one relatively distinct modal group of small squid is seen between 70-120 mm ML along with another less distinct one at 130-155 mm ML. By the time of the fall survey these modal groups are no longer distinguishable. In 1980, there were very few small squid evident in late summer, but by fall squid as small as 120 mm ML were found. In 1983, considerable numbers of small squid were evident in late summer, but no modal groups could be distinguished. However, by fall a very distinct modal group of small squid of 120-190 mm ML was apparent.

Maturation

Data on squid maturation were available for the June-September period (Table 2 and Fig. 7). As with the annual progression in mantle lengths, a pattern of progressive maturation is seen between late spring and late summer for both males and females. It is interesting that in the late spring to summer period there was little or no apparent change, with both males and females largely in Stages I and II. Over the same period, mantle lengths showed no progression either, probably in part as a result of the continuing immigration of smaller squid to the Shelf area. By late summer, the progression in maturities is clear, although highly variable between years and between sexes. In 1980 and 1981, mantle lengths increased substantially between summer and late summer and both male and female maturities have also progressed, with a decline in frequencies of Stage I, and a marked increase in frequencies of Stages II and III. In contrast, the late summer frequencies for 1982 are essentially the same as seen in late spring of the previous two years. The 1982 pattern is likely a reflection of the lower maturities among the large number of small squid seen in the late summer population. In 1983, the maturation process for both males and females appears to have been delayed, particularly for males which, in late summer, remained largely in Stage I. These maturities also appear to reflect the smaller size of squid found on the Shelf in late summer 1983. Modal lengths in September 1983 are only slightly greater than those seen in July 1980 and 1981.

Summary

General Patterns of Bottom Temperatures

Summer (July)

In all years, the western half of the Shelf had mean bottom temperatures >6°C, and the northeastern Shelf areas north of Sable Island and the Gully had temperatures generally several degrees cooler. In two of the four years there were extensions of warmer water (>6°C) in the Western and (or) Sable Island Bank areas, and in some years warm water extended into the Gully and northeastward along the Shelf-edge as far as the Laurentian Channel. Highest temperatures (>8°C) were generally seen in the area of the LaHave and Emerald Basins and in the Bay of Fundy and approaches. Areas along the Shelf-edge and near Browns Bank also had high temperatures in some years.

Fall (October)

By fall, in most years, the area of warmer temperatures extended beyond the area covered in summer, eastward over the Shelf to the strata surrounding Sable Island. Low temperatures ($<6°C$) continued to prevail over the northeastern Shelf areas north of Sable Island, with exceptions in some years when Middle Bank, the Gully, areas of Banquereau Bank and St. Anns Bank had warmer bottom water. Highest temperatures($>8°C$) were generally found in the same general areas as in summer, but covering a larger area of bottom. High bottom temperatures were found more frequently than in summer along the Shelf-edge, particularly in the western half of the Shelf, and in the area near, or over, Browns Bank.

General Patterns of Squid Distribution

Spring (June)

Greatest squid concentrations were most consistently seen along the Shelf-edge between Emerald and LaHave Basins (61°-62°W). In some years the distribution extended along the entire Shelf-edge to the limits of the area surveyed(57°-66°W).

Summer (July)

Greatest concentrations of squid were generally seen in the Western Shelf area around Browns Bank, and in the areas to the south, as well as those bordering, the east side of Emerald Basin. These were areas of intermediate (6°-8°C) and high ($>8°C$) bottom temperatures. Moderate to high concentrations were regularly seen in the cool water areas ($<6°C$) of the inner Shelf northward of Sable Island and, in years of intermediate temperatures (6°-8°C), along the Shelf-edge and Gully. Despite high temperatures in the Bay of Fundy and approaches, squid were generally very low in abundance during summer.

Late Summer (September)

Greatest squid concentrations were found along the Shelf-edge, between Western Bank and the Northeast Channel (61°-67°W), and extending shoreward between 62°-65°W. September was the period of highest biomass levels and generally had many more strata in the area indicated above. Eastward of 61°W, squid generally are low in abundance. It should be noted that sampling in September did not cover the Bay of Fundy or most of the middle and nearshore strata east of 61°W, the first consistently having high densities and the second occasional high densities in October.

Fall (October)

In fall, densities were generally lower and area of distribution more restricted than in summer. Moderate concentrations were most consistently seen in the areas surrounding Emerald Basin and in the area of Browns Bank where intermediate (6°-8°C) temperatures prevailed. There were generally no significant concentrations over the entire eastern half of the Shelf, or in the Bay of Fundy and approaches; although high concentrations did occasionally occur in both areas. In 1980, high concentrations were seen in the high temperature (>8°C) Bay of Fundy, but also in the very low (2.0°C) bottom temperatures of Stratum 44 in the northeast. It is interesting to note that in most years, the geographic areas of highest squid concentrations change considerably from summer to fall.

Bottom temperture vs. distribution

While there does appear to be a general tendency for Illex to concentrate in areas having warmer bottom temperatures, the relationship is far from clear and is obviously mediated by other factors. One may hypothesize that predators and prey interactions, as well as intraspecific competition are the mediators most likely to over-ride any temperature preference.

Small squid vs. larger squid distribution

In late summer (September), squid less than 130 mm ML in size were generally limited to the western half of the Shelf in areas where warmer temperatures persisted from July through October. Although the general areal distribution of small squid was similar to that of larger squid, there do appear to have been differences when the catch rates and patterns are examined on a finer scale. These suggest both areal and bathymetric differences; small squid not generally being captured along with significant catches of large squid, and small squid being more frequently encountered at shallower mean depths.

Biological Characteristics

A pattern of increasing squid length and maturation is regularly seen. Maturation, is accelerated, but certainly not complete, by late summer and length increases more continuously through the four periods. In 1980 and 1981, both length and maturation were more advanced by comparison to 1982 and 1983. Smaller squid were seen regularly by late summer but in some years (1981 and 1982) with increased frequency. In these years, secondary and tertiary cohorts were observed.

Conclusions

- The pattern of mean bottom temperatures over the Scotian Shelf shows a very regular pattern, with temperatures $\geq$6°C over the western half of the Shelf (west of approx. 62°W) and generally cooler temperatures to the northeast and over Banquereau Bank.
- The area of Shelf and Shelf-edge having temperatures $\geq$ 6°W is generally larger later in the year and often extends to limited areas of the northeastern Shelf and Banquereau Bank.
- Highest concentrations of squid are most consistently seen in the western Shelf area around Browns Bank and those areas to the south of and bordering the east side of Emerald Basin in areas of intermediate (6°-8°C) and high (>8°C) bottom temperatures. In most years, there is one stratum, during any particular season, with much higher density than all others.
- Temperatures >6°C, while apparently preferred, are not limiting; highest concentrations being regularly seen in areas of much cooler bottom temperatures.
- Secondary and tertiary cohorts of smaller squid are regularly seen on the western half of the Scotian Shelf in September and October. These small squid appear relatively more abundant in years when squid biomass is low.
- Although small squid have the same general areal distribution, they appear to have fine scale differences in this distribution as well as bathymetric differences.

- Maturation patterns for both males and females vary widely from year to year, particularly in late summer. This variation appears related to the length frequency pattern within the population.

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Table 1. Summary of survey data, vessels and sampling gear.

Year	Period	Vessel	Affiliation	Dates	Trawl Type
1980	Late spring	M.V. Brandal	DFO/I&MP	June 5-July 3	Western II A
	Summer	R.V. Cameron	DFO/FRB	July 7-27	Yankee 36
	Late Summer	R.V. Lady Hammond	DFO/IMP	Aug. 19-24	Western II A
		R.V. La Perle	IFREMER	Sept. 4-24	Lofoten
	Fall	R.V. Lady Hammond	DFO/FRB	Oct. 11-Nov. 8	Western II A
1981	Late spring	R.V. Lady Hammond	DFO/I&MP	June 1-11	Western II A
	Summer	R.V. Cameron	DFO/FRB	July 4-25	Yankee 36
	Late summer	R.V. Thalassa	IFEMER	Aug. 28-Sept. 23	Lofoten
	Fall	R.V. Lady Hammond	DFO/FRB	Sept. 28-Oct. 22	
1982	Late spring	R.V. Lady Hammond	DFR/I&MP	June 1-10	Western II A
	Summer	R.V. Lady Hammond	DFO/I&MP	July 10-30	Western II A
	Late summer	R.V. Cryos	IFREMER	Aug. 19-Sept. 18	Lofoten
	Fall	R.V. Lady Hammond	DFO/FRB	Sept. 28-Oct. 24	Western II A
1983	Late spring	R.T.M. Gizhiga	USSR/Atlant NIRO	June 1-11	Soviet Hake
	Summer	R.V. Needler	DFO/FRB	July 5-28	Western II A
	Late summer	R.V. Needler	DFO/I&MP	Sept. 12-29	Western II A
		R.V. Cryos	IFREMER	Aug. 31-Oct. 2	Lofoten
	Fall	R.V. Needler	DFO/FRB	Oct. 4-27	Western II A

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Table 2. Frequencies of maturation stages for males and females from three cruise periods between 1980 and 1983.

	Month	June					July					September				
	Maturity Stage	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
1980	Male	.82	.18	-	-		.90	.10	-	-		.43	.45	.12	-	
	Female	.85	.10	.04	-	-	.84	.14	.02	-	-	.10	.61	.29	-	-
1981	Male	.70	.30	-	-		-	-	-	-		.45	.33	.22	-	
	Female	.79	.20	.04	-	-	-	-	-	-	-	.08	.62	.30	-	-
1982	Male	1.0	-	-	-		.99	.01	-	-		.90	.09	.01	-	
	Female	.94	.05	.01	-	-	.78	.21	.01	-	-	.52	.43	.05	-	-
1983	Male	-	-	-	-		.75	.23	.02	-		.75	.23	.02	-	
	Female	-	-	-	-		.91	.06	.02	.01		.08	.87	.05	-	-

N.B. no maturity data available from summer 1981 and late spring 1983 programs.

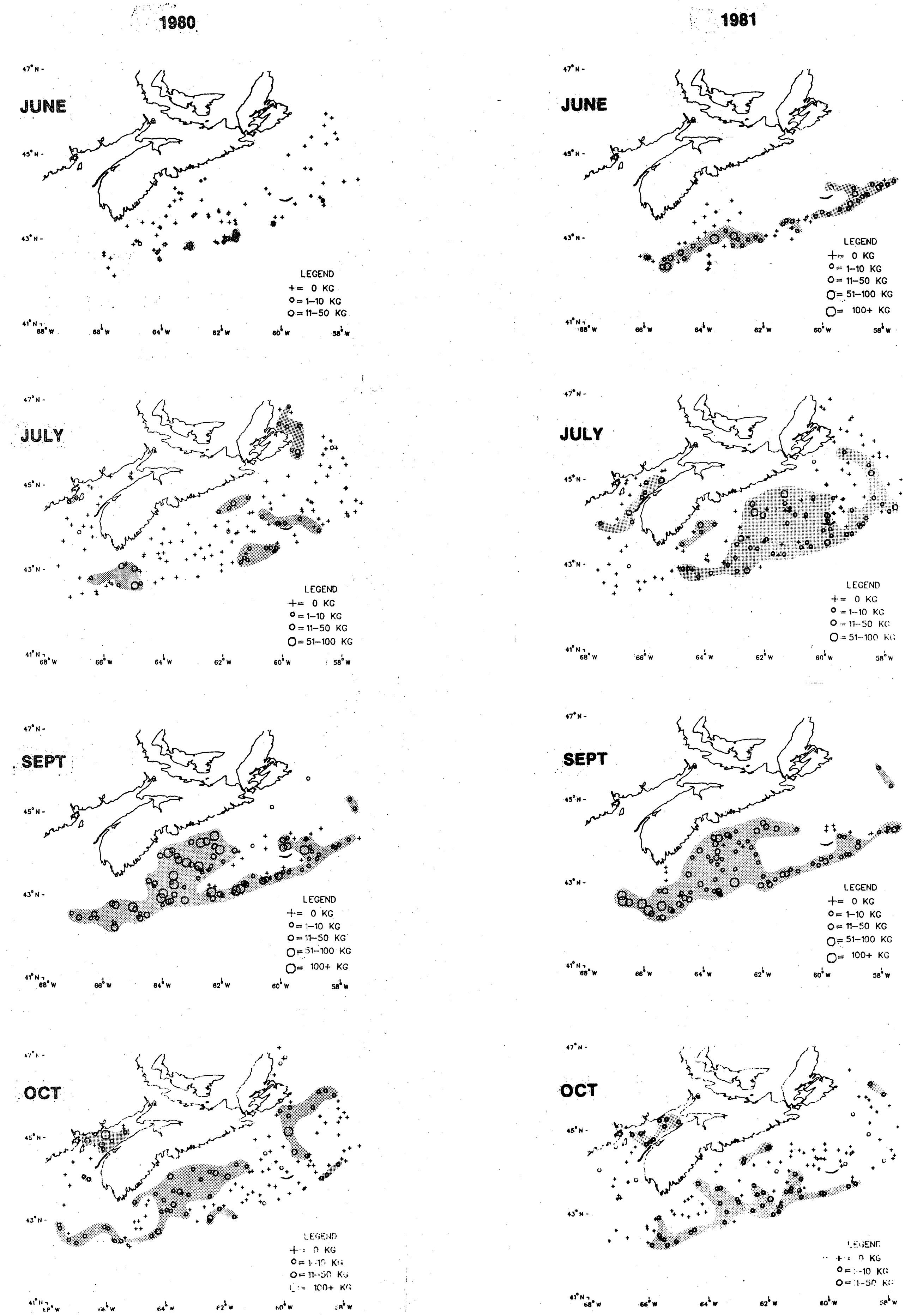


Fig. 1. Distribution of squid (Illex illecebrosus) catches (kg/tow) on the Scotian Shelf during four periods in 1980-1983. Areas of apparent concentrations are shaded.

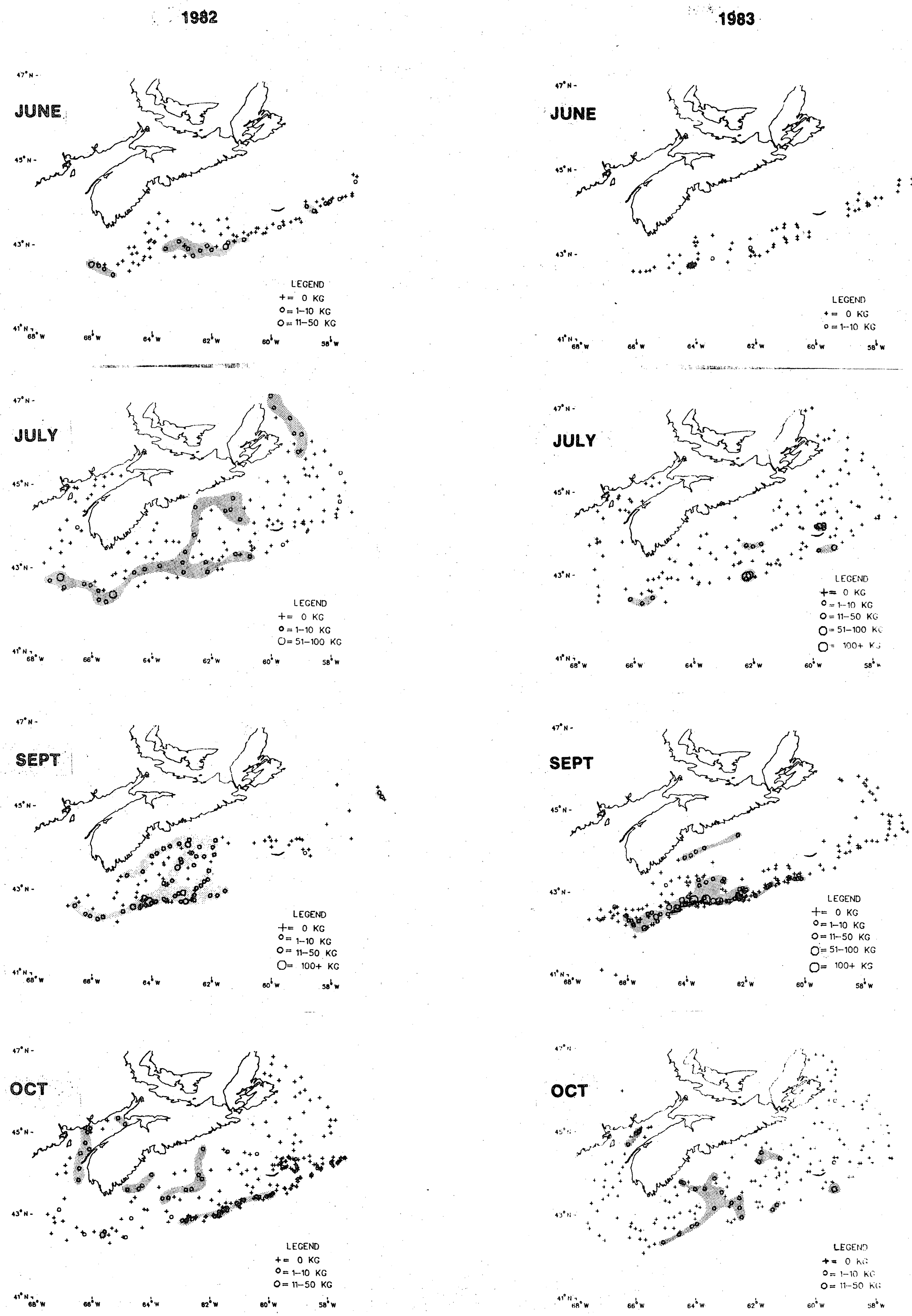


Fig. 1. (continued)

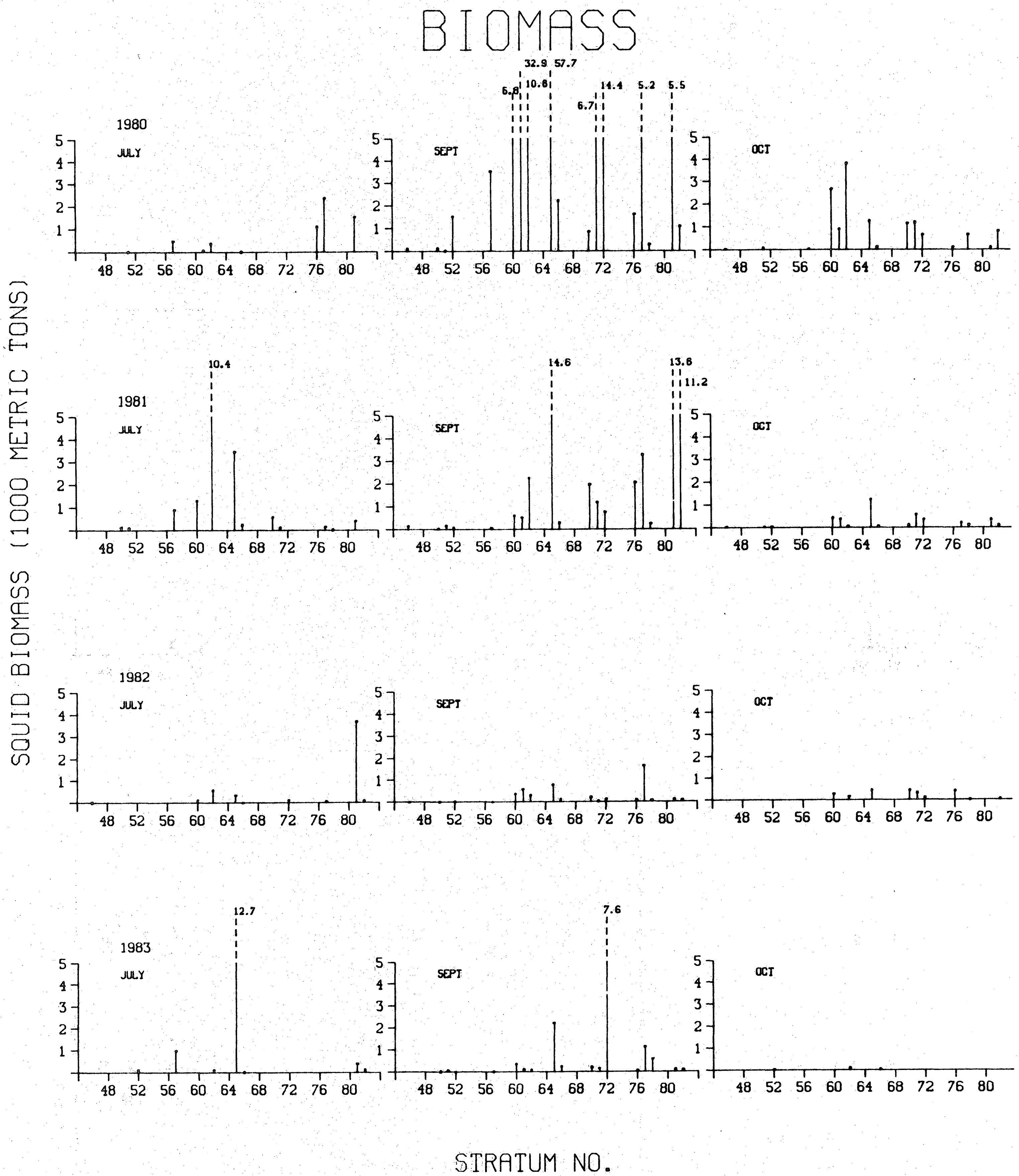


Fig. 2. Squid (Illex illecebrosus) biomass levels ($x10^3$ t) from the 18 groundfish strata during three periods in 1980-1983. Broken lines indicate levels off the scale (actual biomass given at the top of the bar).

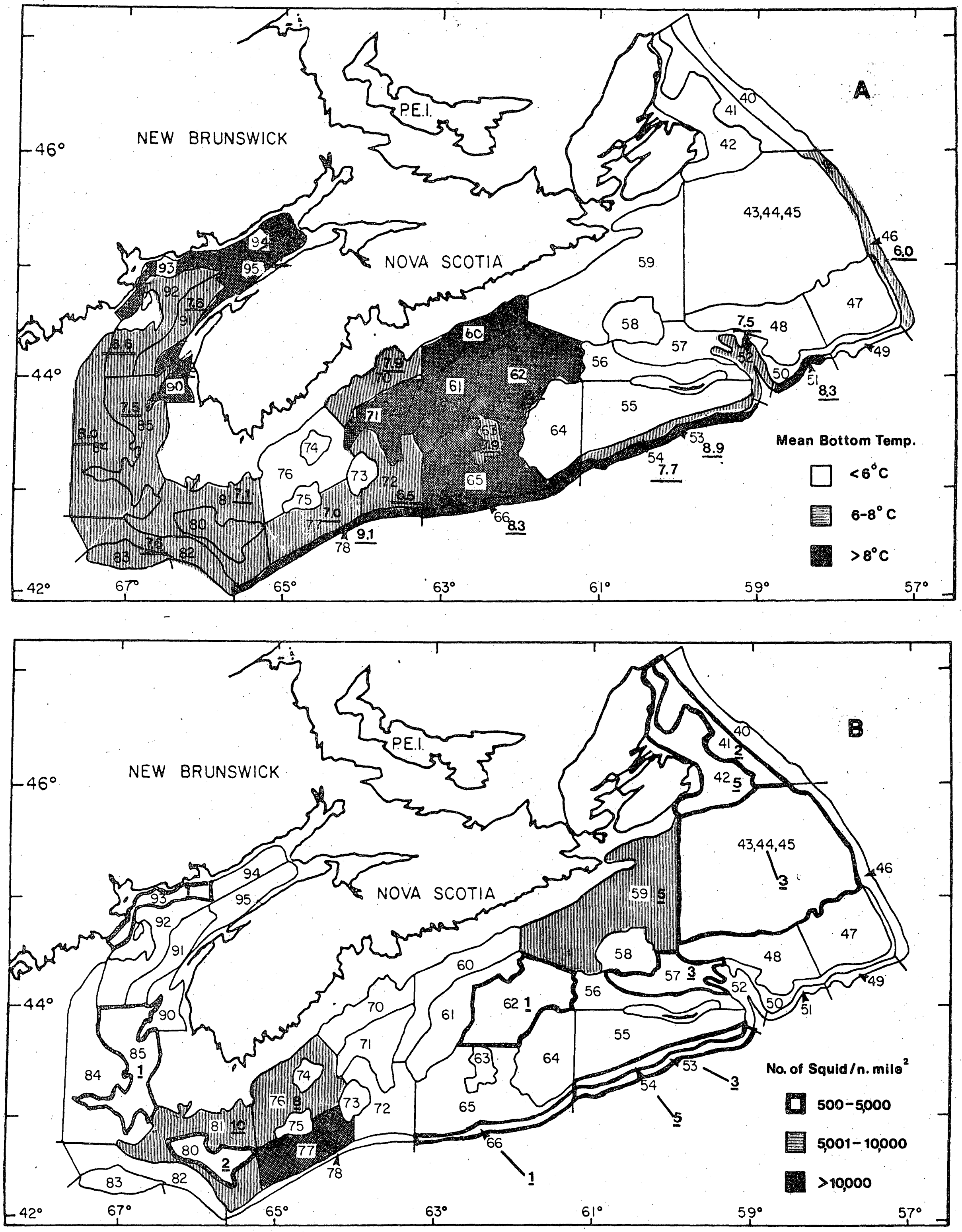
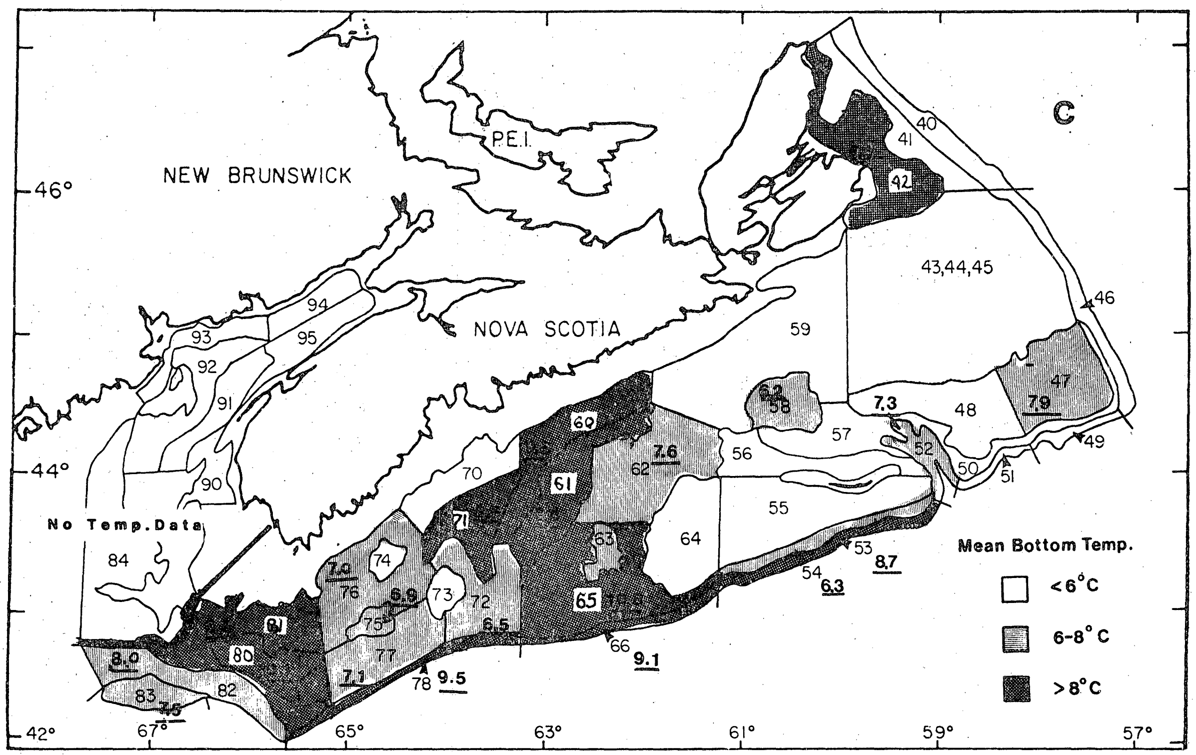


Fig. 3.0 (A, B) Bottom temperature and squid density patterns during July 1980.

A - Bottom temperature patterns with strata in ranges <6°C, 6°-8°C, and >8°C segregated. Mean bottom temperatures are shown underlined in each stratum with temperature >6°C.

B - Squid density by stratum in thousands per square nautical mile with strata in ranges <500, 500-5,000, 5,001-10,000, and >10,000 segregated. Numbers are shown underlined for those strata having more than 500 squid per square nautical mile.



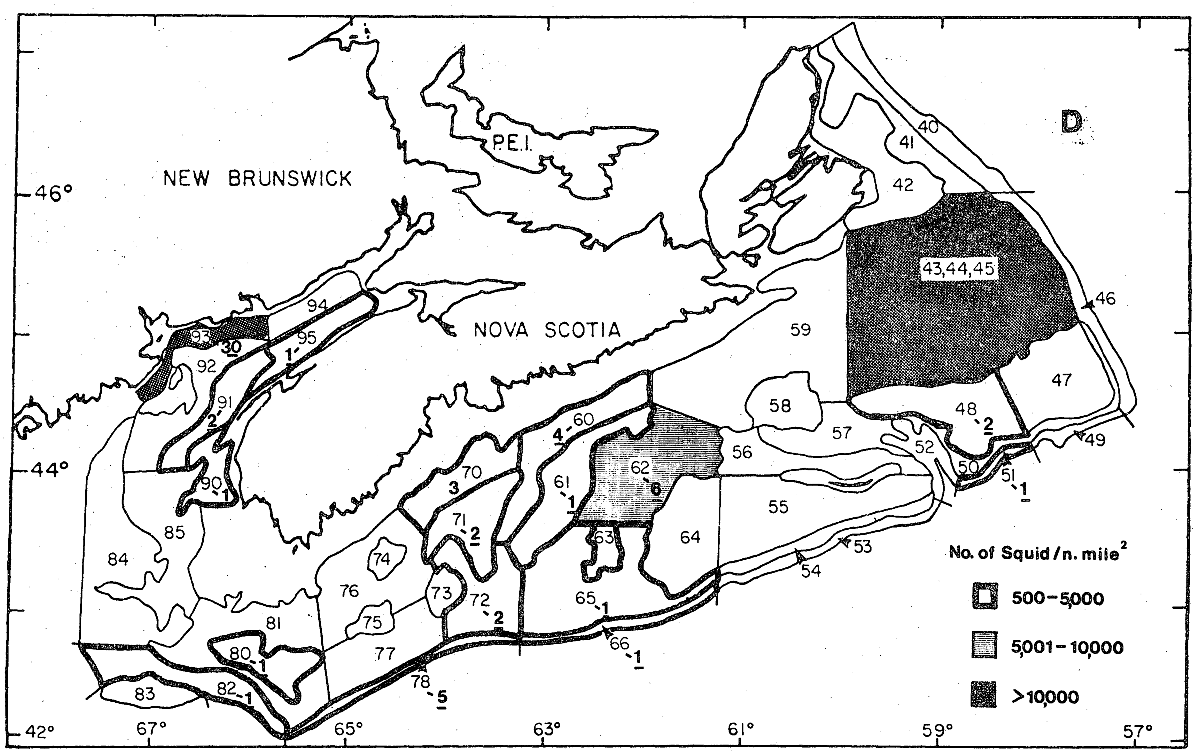


Fig. 3.0 (C, D) Bottom temperature and squid density patterns during October 1980.

C - Bottom temperature patterns with strata in ranges <6°C, 6°-8°C, and >8°C segregated. Mean bottom temperatures are shown underlined in each stratum with temperature >6°C.

D - Squid density by stratum in thousands per square nautical mile with strata in ranges <500, 500-5,000, 5,001-10,000, and >10,000 segregated. Numbers are shown underlined for those strata having more than 500 squid per square nautical mile.

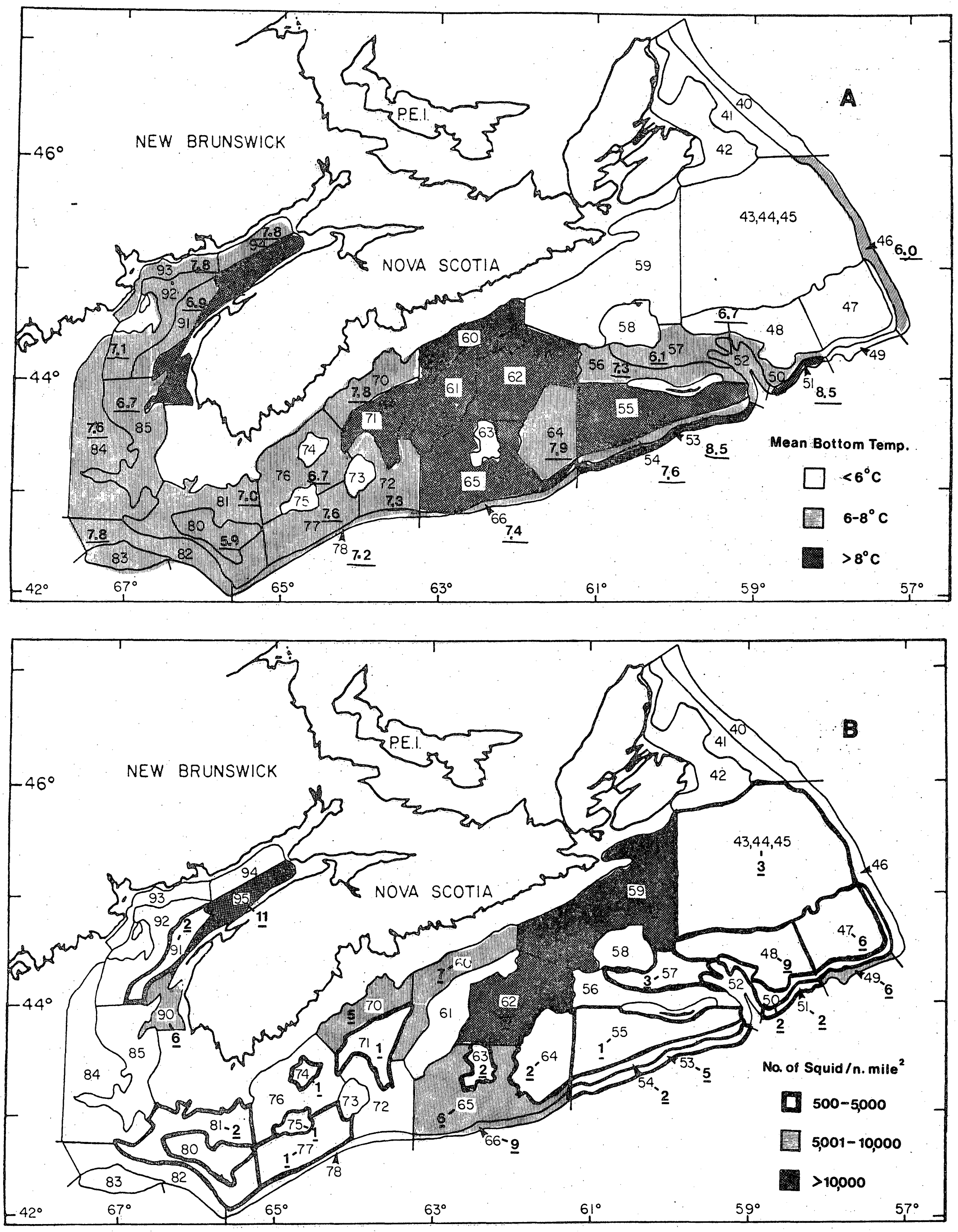


Fig. 3.1 (A, B) Bottom temperature and squid density patterns during July 1981.

A - Bottom temperature patterns with strata in ranges <6°C, 6°-8°C, and >8°C segregated. Mean bottom temperatures are shown underlined in each stratum with temperature >6°C.

B - Squid density by stratum in thousands per square nautical mile with strata in ranges <500, 500-5,000, 5,001-10,000, and >10,000 segregated. Numbers are shown underlined for those strata having more than 500 squid per square nautical mile.

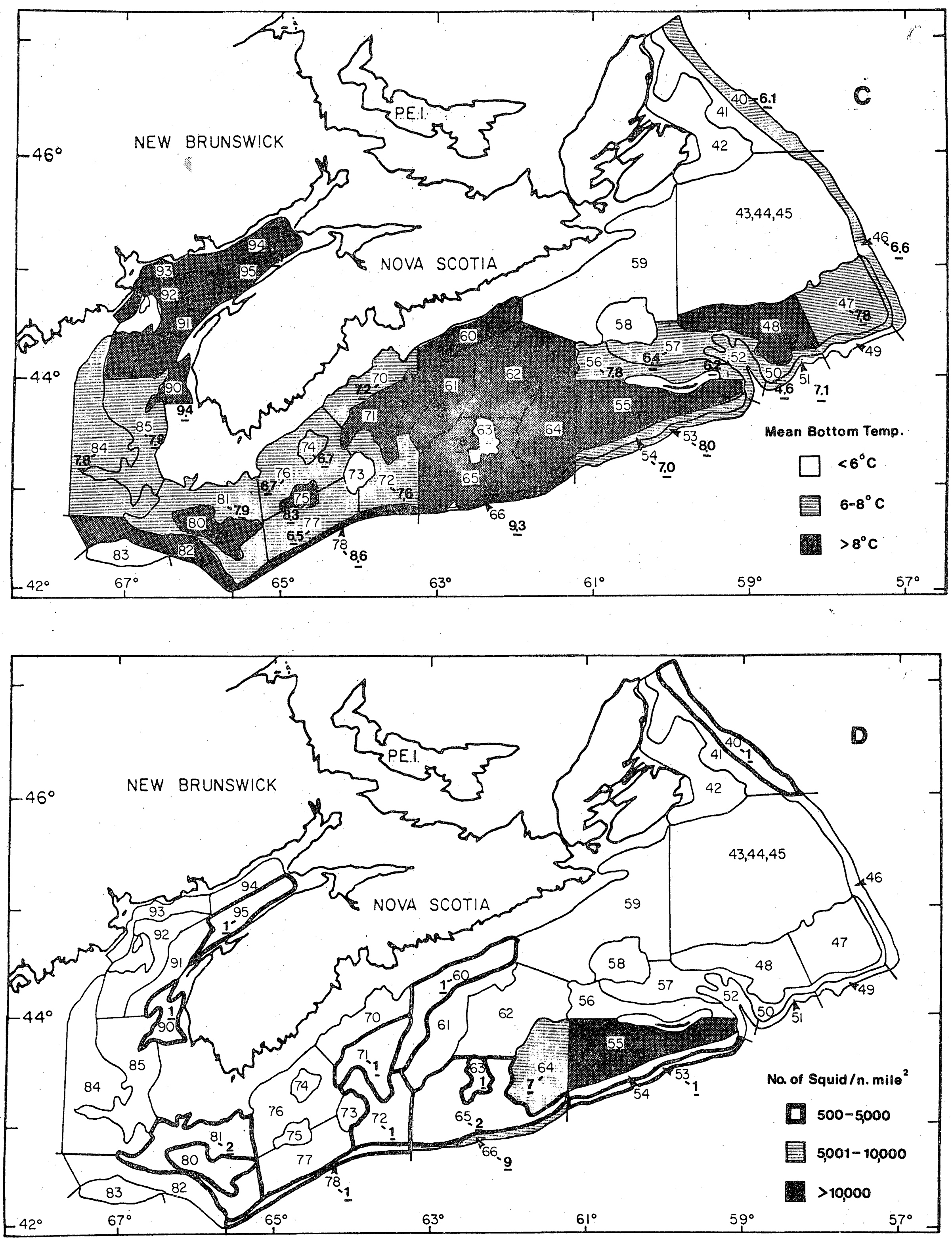


Fig. 3.1 (C, D) Bottom temperature and squid density patterns during October 1981.

C - Bottom temperature patterns with strata in ranges <6°C, 6°-8°C, and >8°C segregated. Mean bottom temperatures are shown underlined in each stratum with temperature >6°C.

D - Squid density by stratum in thousands per square nautical mile with strata in ranges <500, 500-5,000, 5,001-10,000, and >10,000 segregated. Numbers are shown underlined for those strata having more than 500 squid per square nautical mile.

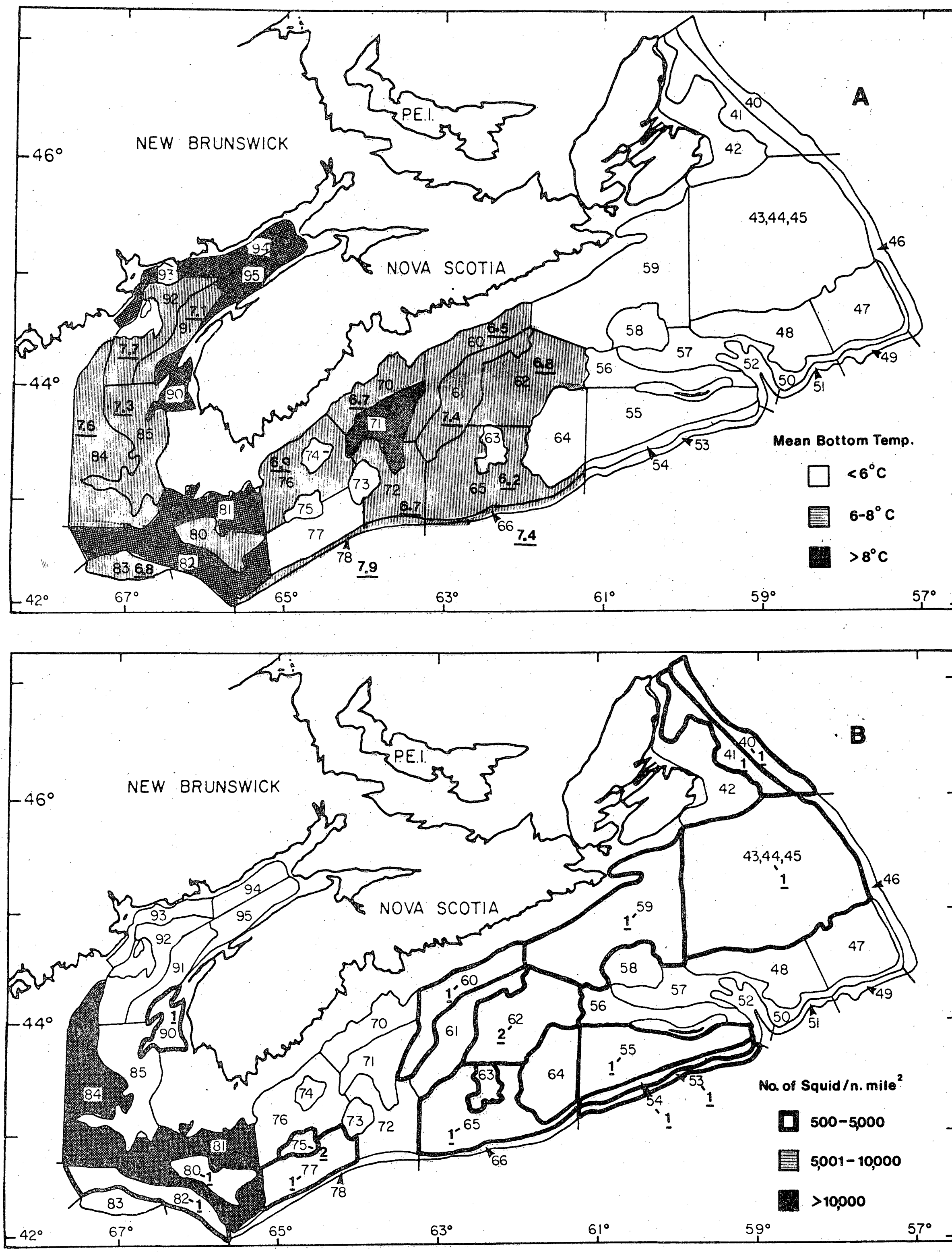


Fig. 3.2 (A, B) Bottom temperature and squid density patterns during July 1982.

A - Bottom temperature patterns with strata in ranges <6°C, 6°-8°C, and >8°C segregated. Mean bottom temperatures are shown underlined in each stratum with temperature >6°C.

B - Squid density by stratum in thousands per square nautical mile with strata in ranges <500, 500-5,000, 5,001-10,000, and >10,000 segregated. Numbers are shown underlined for those strata having more than 500 squid per square nautical mile.

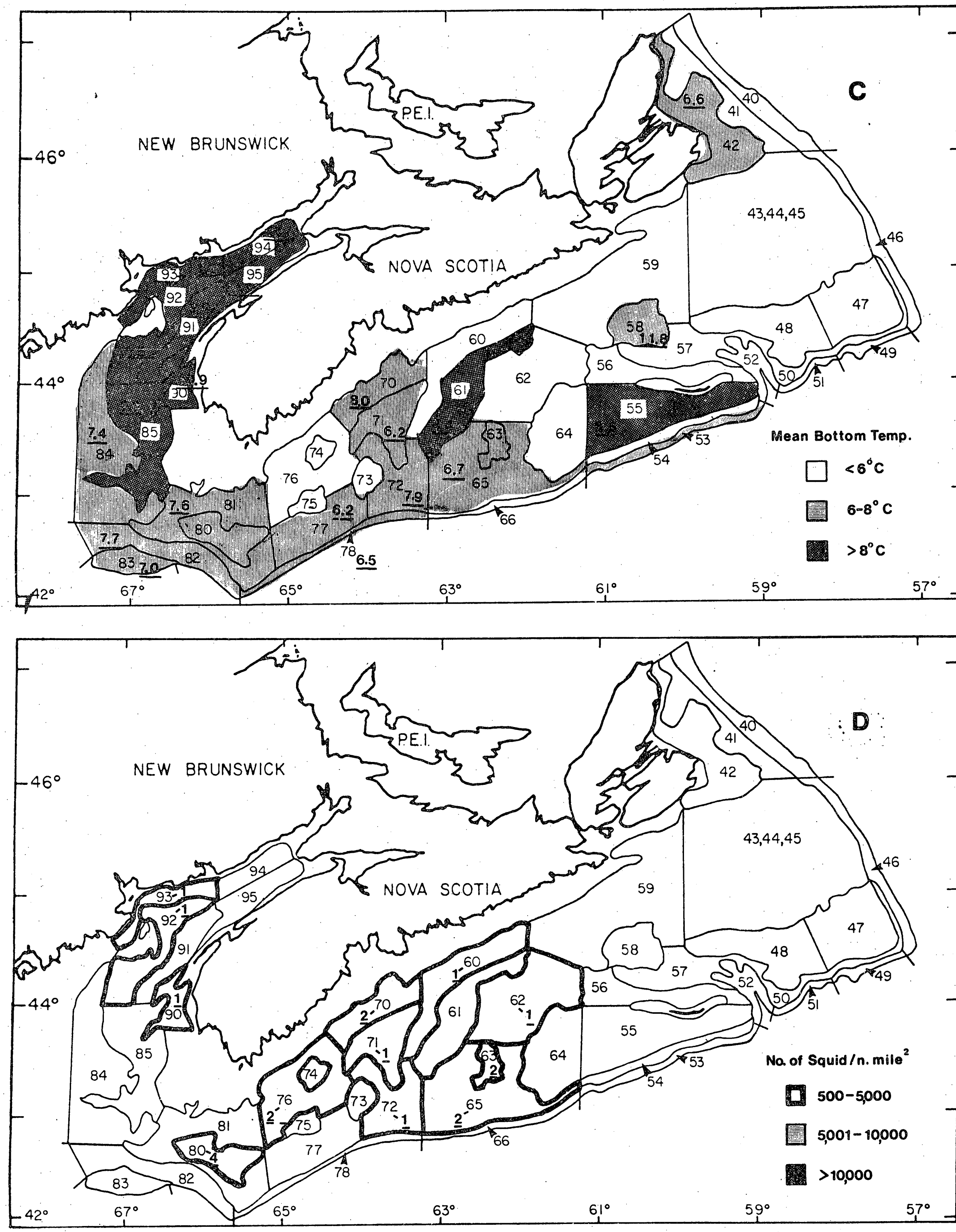


Fig. 3.2 (C, D) Bottom temperature and squid density patterns during October 1982.

C - Bottom temperature patterns with strata in ranges <6°C, 6°-8°C, and >8°C segregated. Mean bottom temperatures are shown underlined in each stratum with temperature >6°C.

D - Squid density by stratum in thousands per square nautical mile with strata in ranges <500, 500-5,000, 5,001-10,000, and >10,000 segregated. Numbers are shown underlined for those strata having more than 500 squid per square nautical mile.

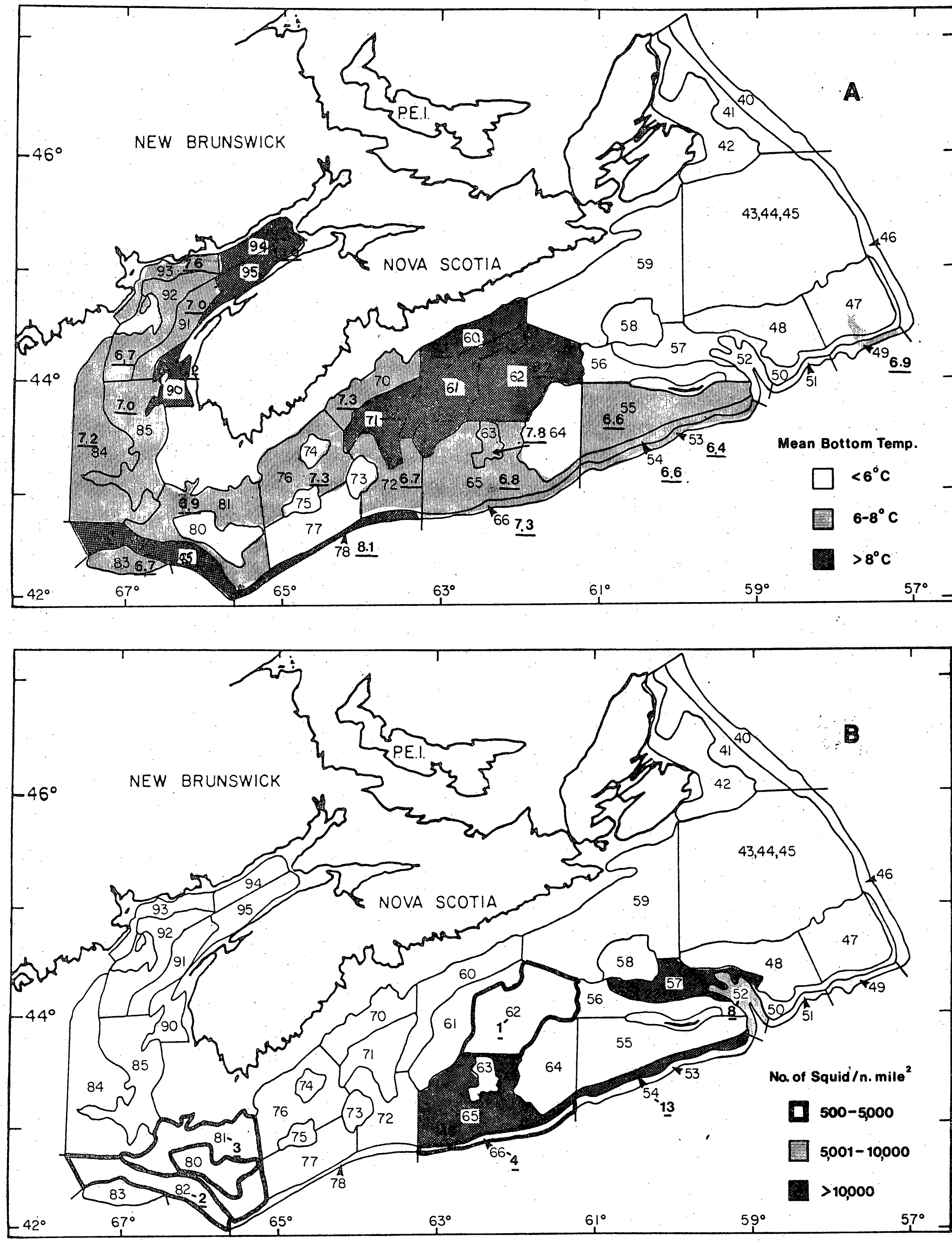


Fig. 3.3 (A, B) Bottom temperature and squid density patterns during July 1983.

A - Bottom temperature patterns with strata in ranges <6°C, 6°-8°C, and >8°C segregated. Mean bottom temperatures are shown underlined in each stratum with temperature >6°C.

B - Squid density by stratum in thousands per square nautical mile with strata in ranges <500, 500-5,000, 5,001-10,000, and >10,000 segregated. Numbers are shown underlined for those strata having more than 500 squid per square nautical mile..

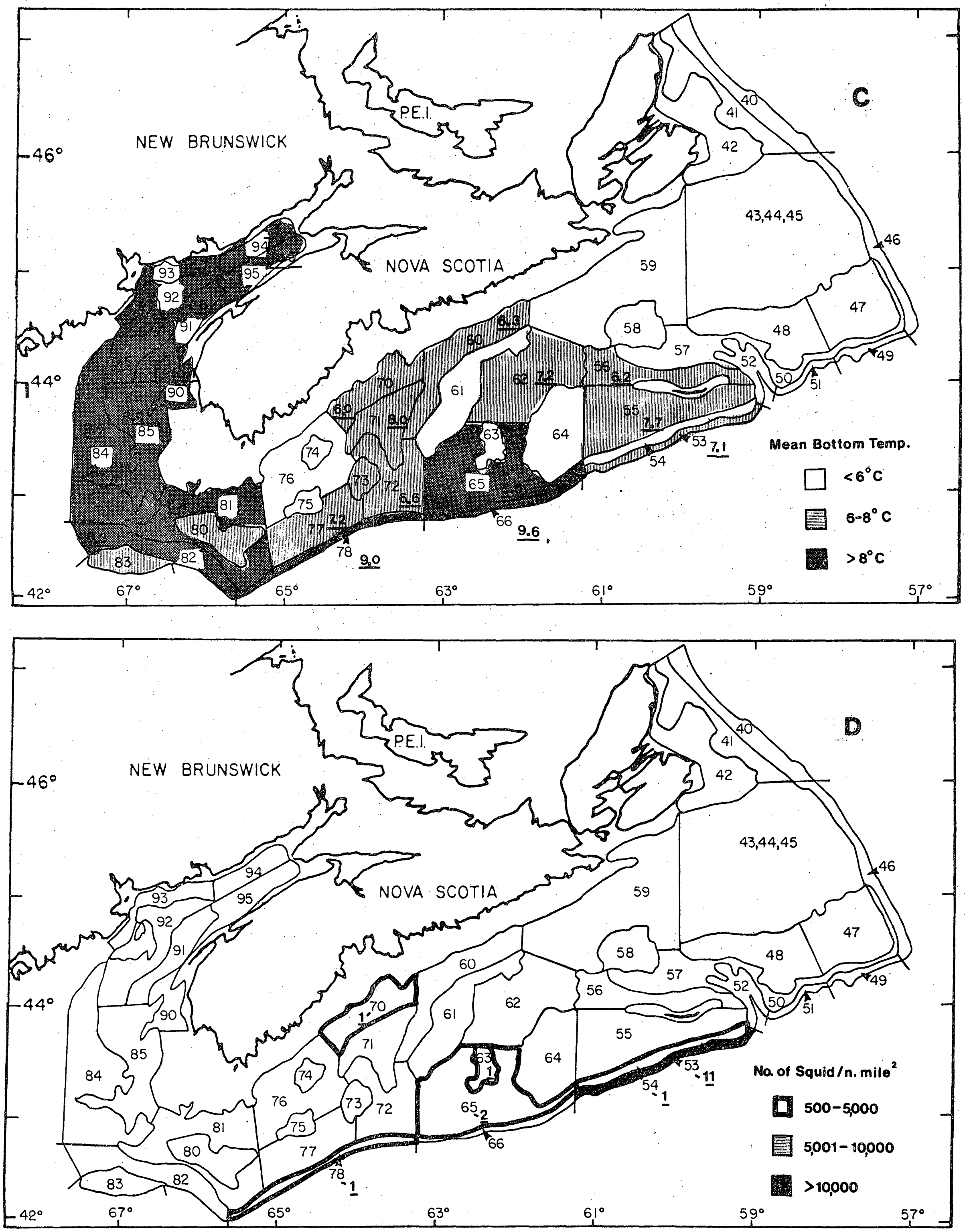


Fig. 3.3 (C, D) Bottom temperature and squid density patterns during October 1983.

C - Bottom temperature patterns with strata in ranges <6°C, 6°-8°C, and >8°C segregated. Mean bottom temperatures are shown underlined in each stratum with temperature >6°C.

D - Squid density by stratum in thousands per square nautical mile with strata in ranges <500, 500-5,000, 5,001-10,000, and >10,000 segregated. Numbers are shown underlined for those strata having more than 500 squid per square nautical mile.

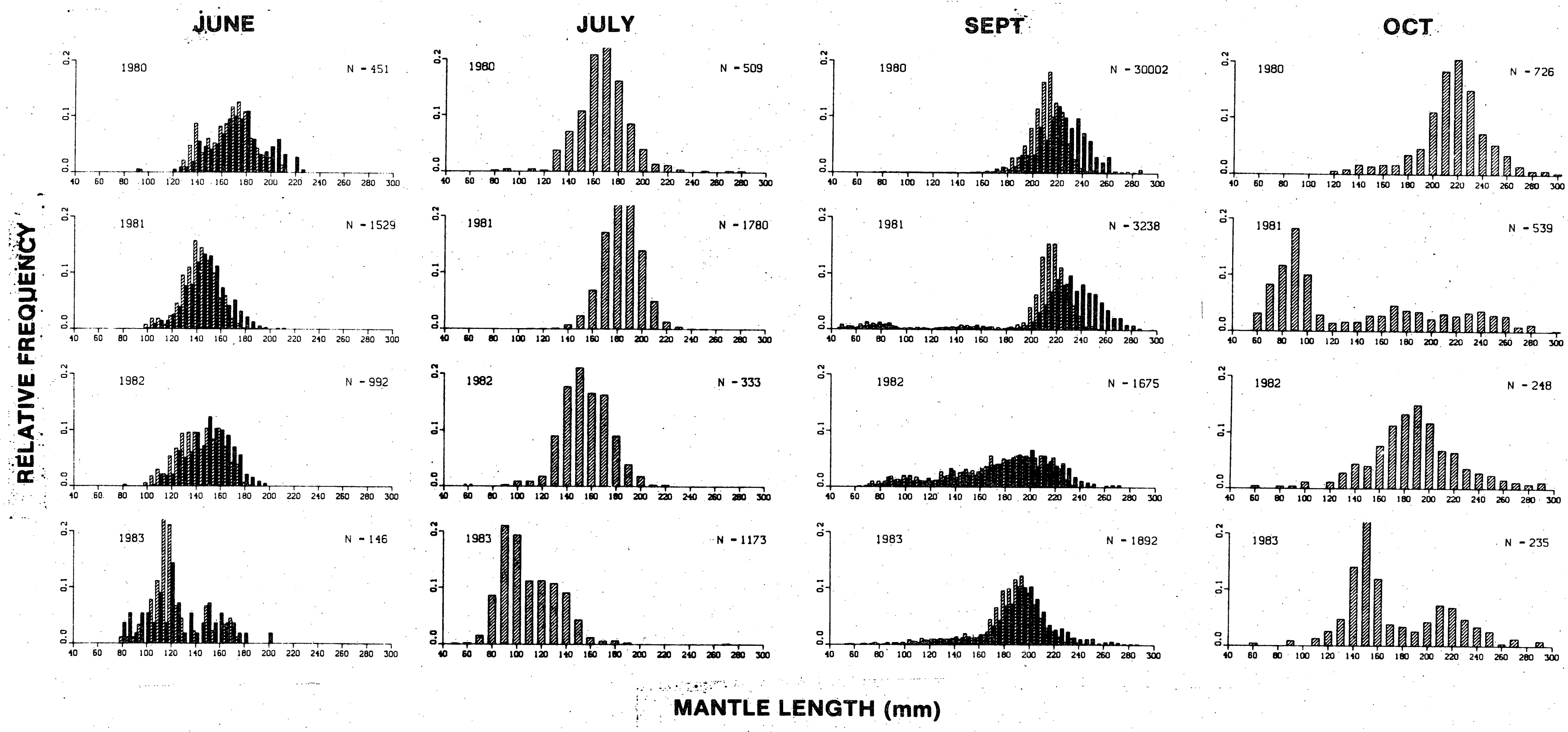


Fig. 4. Length frequency distribution of squid (<u>Illex illecebrosus</u>) on the Scotian Shelf during four periods in 1980-1983. Males (striped bar) and females (solid bar) are distinguished in the June and September periods.

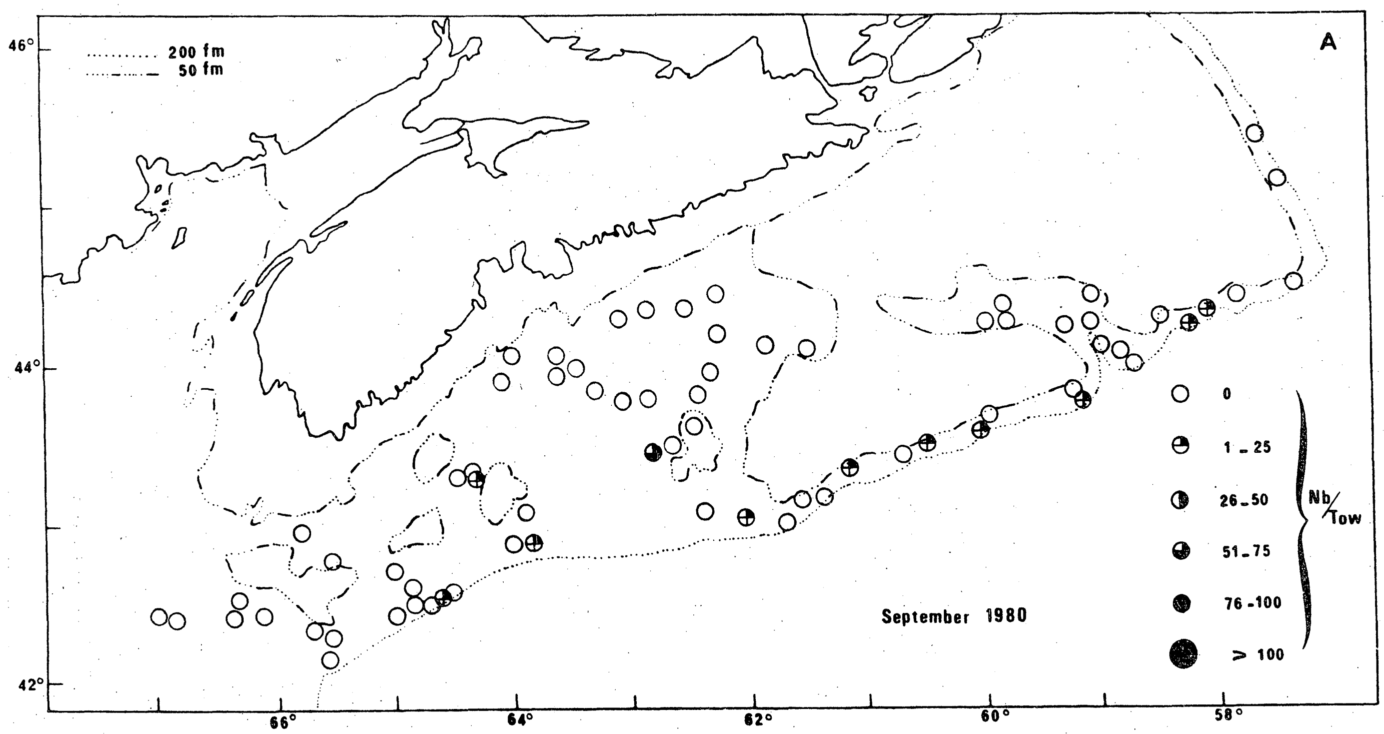


Fig. 5A. Geographic distribution of "small" (ML <13 cm) squid (Illex illecebrosus) from the R/V La Perle in late-summer 1980.

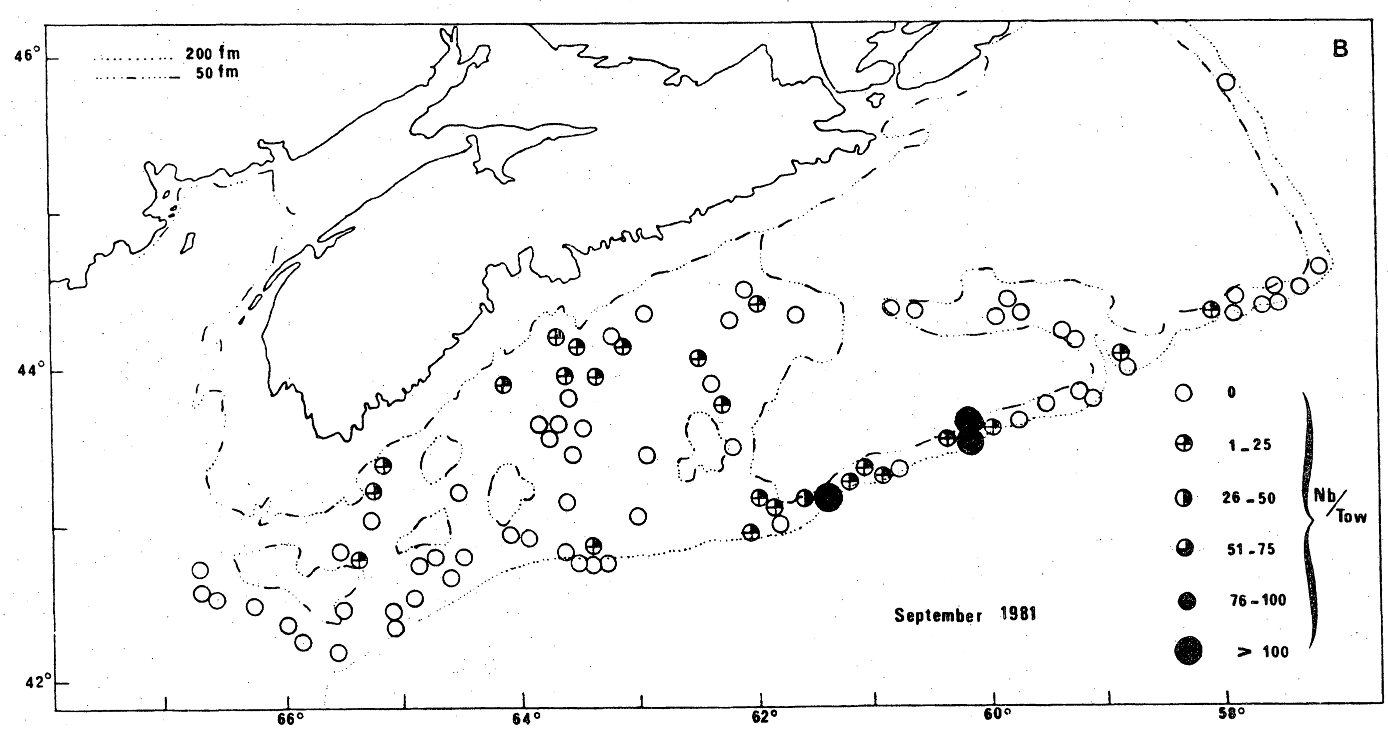


Fig. 5B. Geographic distribution of "small" (ML <13 cm) squid (Illex illecebrosus) from the R/V Thalassa in late-summer 1981.

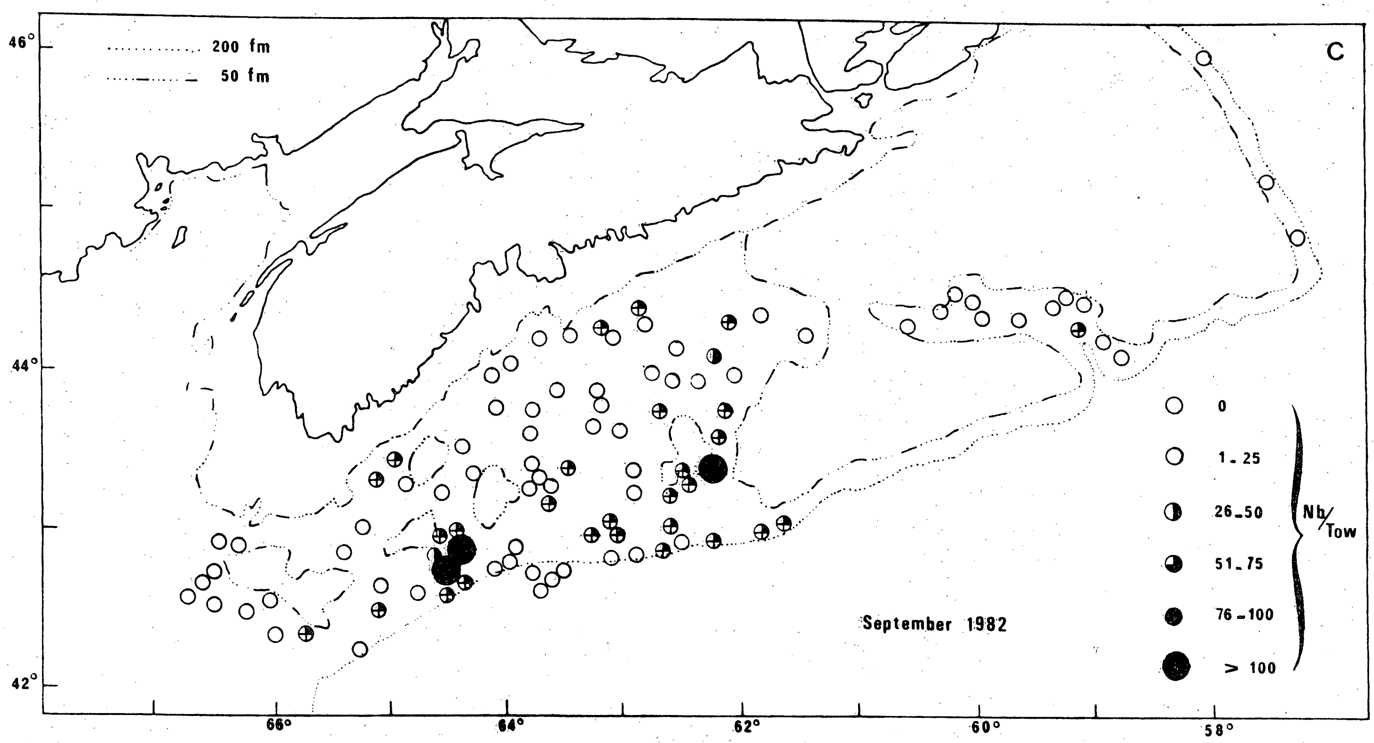


Fig. 5C. Geographic distribution of "small" (ML <13 cm) squid (Illex illecebrosus) from the R/V Cryos in late summer 1982.

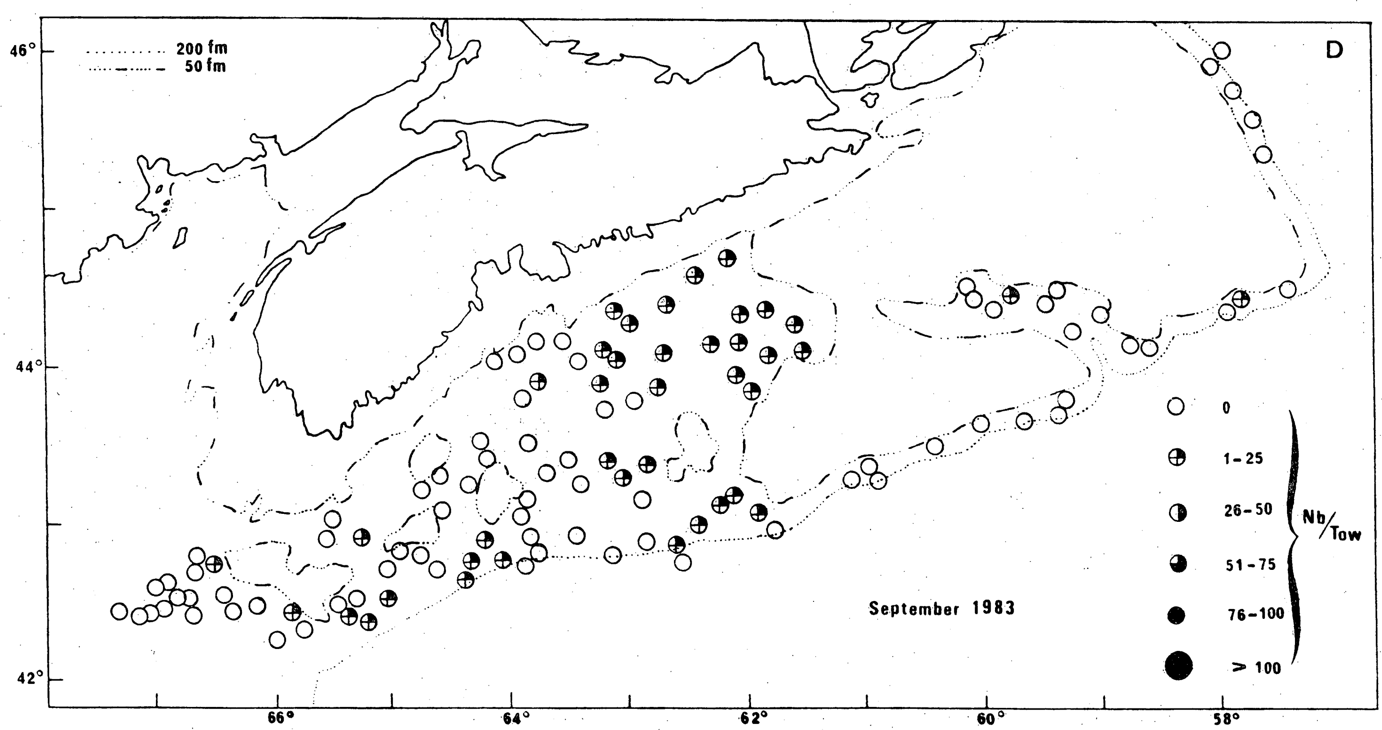


Fig. 5D. Geographic distribution of "small" (ML <13 cm) squid (Illex illecebrosus) from the R/V Cryos in late summer 1983.

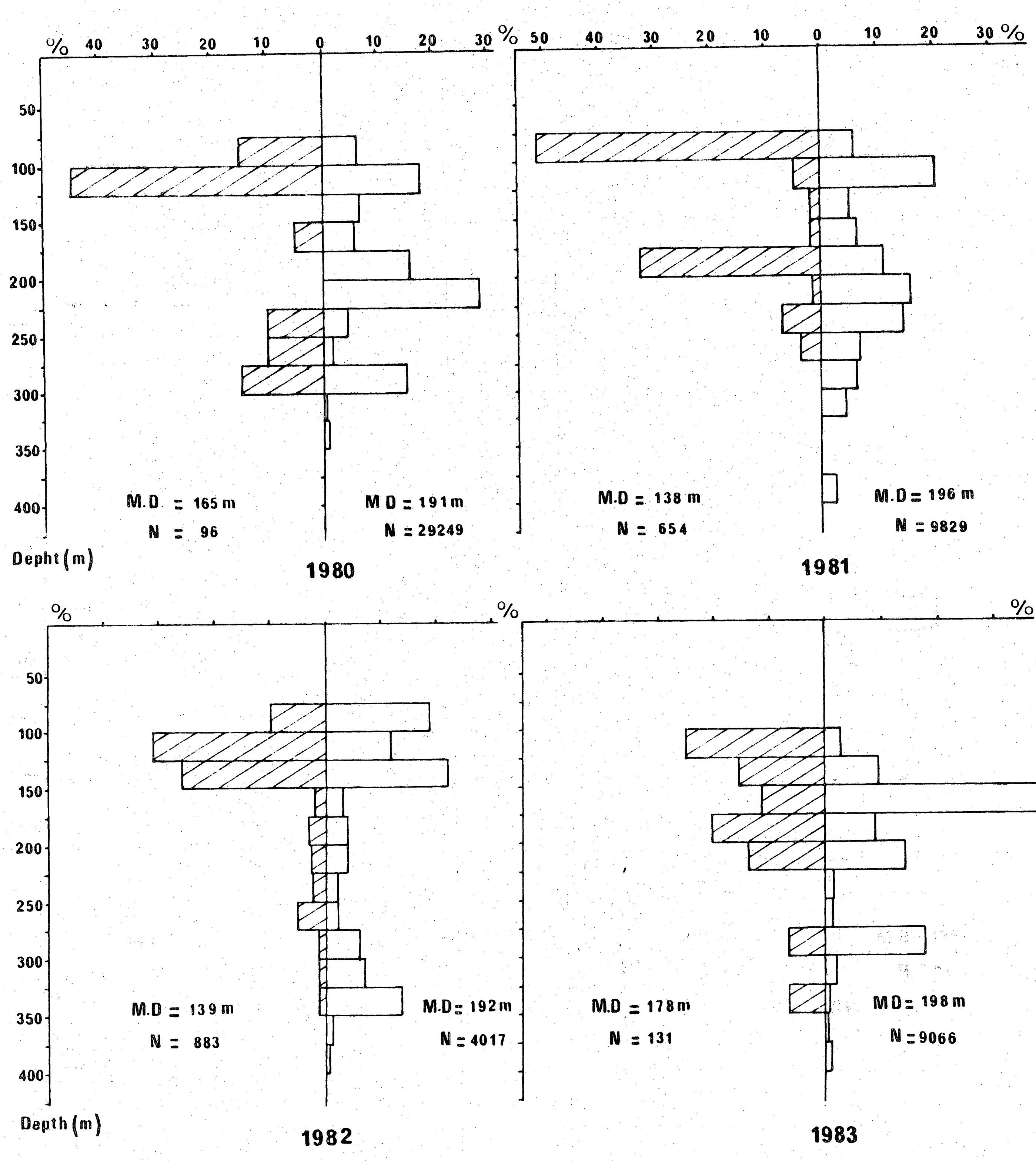


Fig. 6. Bathymetric distribution of "small" squid (ML <13 cm, hachured histograms) and of the whole squid catch in late summer from 1980 to 1983 (M. D. is mean depth and N is the number caught).

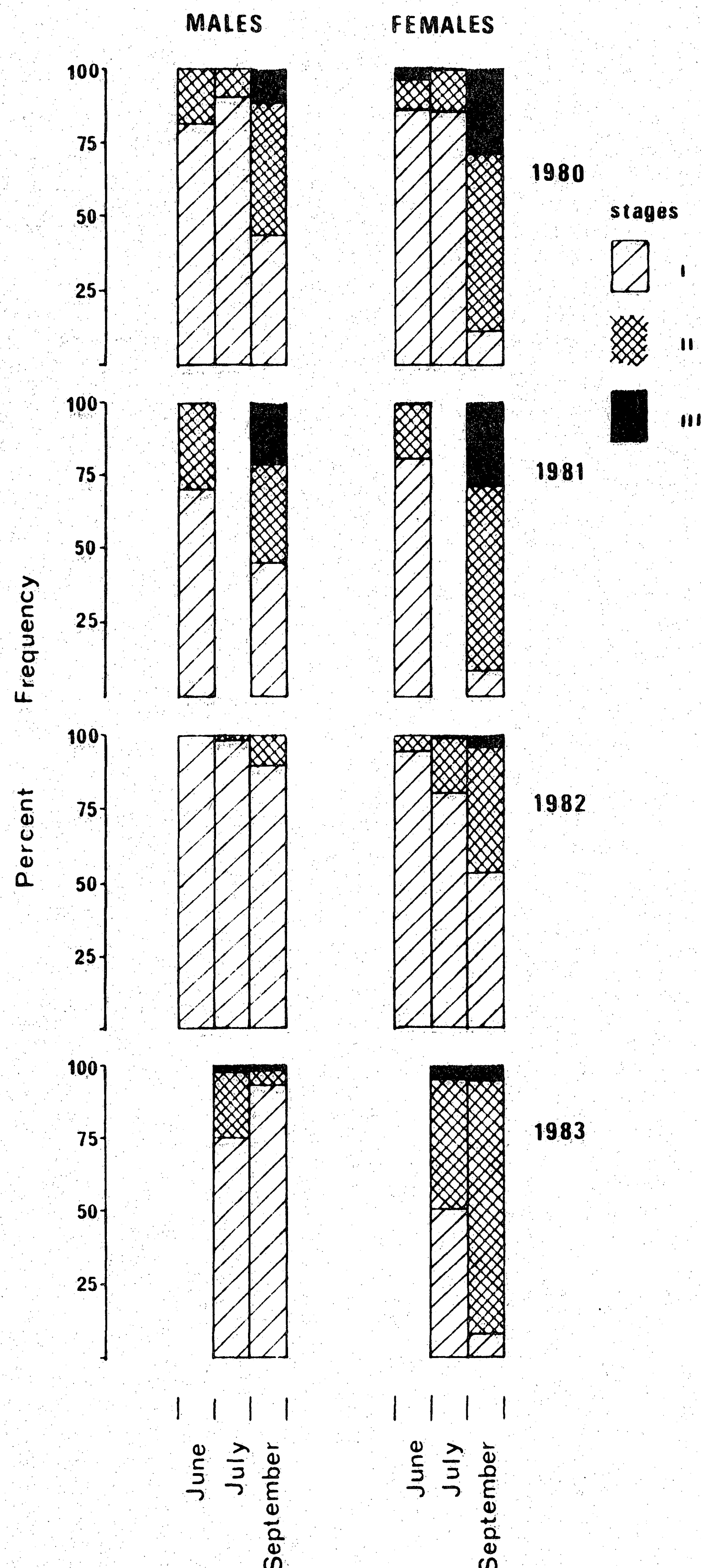


Fig. 7. Evolution of sexual maturity of squid from late spring to late summer, as shown by data collected from 1980 to 1983.