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Management Units and the Squid Resources of the Gulf of Maine,
Illex illecebrosus and Loligo pealei

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ABSTRACT

The short finned (Illex illecebrosus) and long-finned (Loligo pealei) squids are the only cephalopods fished and managed in the Gulf of Maine. In U.S. waters, both species are managed on an April 1 to March 31 fishing year with additional areal restrictions for foreign vessels. In Canadian waters, where its area of occurrence is limited and abundance generally very low, there is currently no management of long-finned squid, although the mechanism for such exists. The short-finned squid is managed on a July 1 to November 15 fishing year and fishing limited to the area seaward of the Small Mesh Gear Line.

The areal distribution of the two species differs considerably, with the short-finned squid being found further north and the main area of overlap occurring south of Cape Cod.

The biology and ecology of the two species also differs, the short-finned squid being primarily a winter spawner undergoing long migrations and the long-finned squid being a summer spawner with apparently very limited migrations. Although strong evidence is lacking, it appears that both species represent single stocks.

Since both the main Canadian and U.S. fisheries areas are well removed from the vicinity of the ICJ line, there appears to be no significant difference in benefit to management in the use of either the ICJ line or the existing NAFO lines.

Areas recommended for continued or future research include systematics and early life history studies as well as tagging and electrophoretic studies aimed at stock discrimination.

RESUME

Les calmars à courtes nageoires (Illex illecebrosus) et les calmars du nord-ouest Atlantique (Loligo pealei) sont les seuls mollusques céphalopodes pêchés et aménagés dans le golfe du Maine. Dans les eaux américaines, les deux espèces sont aménagées pendant une année halieutique qui va du 1^{er} avril au 31 mars; les navires battant pavillon étranger font toutefois l'objet de restrictions régionales supplémentaires. Dans les eaux canadiennes, où la zone d'occurrence du calmar du nord-ouest Atlantique est limitée et son abondance généralement très faible, l'aménagement de cette espèce n'est pas pratiqué actuellement, bien que les mécanismes voulus soient déjà en place. Les calmars à courte nageoire est aménagé au cours d'une année halieutique qui va du 1^{er} juillet au 15 novembre et la pêche est limitée à la zone hauturière de la Ligne pour engins de pêche à petites mailles.

La répartition géographique des deux espèces diffère considérablement, le calmar à courte nageoire se tenant plus au nord et la principale zone de chevauchement se situant au sud du cap Cod.

La biologie et l'écologie des deux espèces sont aussi très différentes : le calmer à courte nageoire est avant tout un reproducteur d'hiver qui entreprend de longues migrations, tandis que le calmar du nord-ouest Atlantique est un reproducteur d'été dont les migrations semblent très limitées. Même s'il n'existe pas encore de preuve formelle, il semble bien que ces espèces représentent toutes deux des stocks uniques.

Comme les principales zones de pêche du Canada et des Etats-Unis sont toutes deux bien éloignées du voisinage de la ligne de la CIJ, il ne semble y avoir aucune différence significative du point de vue des avantages d'aménagement entre l'utilisation de la ligne de la CIJ ou des lignes existantes de l'OPANO.

Les domaines recommandés pour poursuivre ou entreprendre des recherches sont notamment ceux de la systématique et de l'histoire du stade biologique précoce, de même que l'étiquetage et les études en électrophorèse qui sont orientées vers la discrimination des stocks.

HISTORY OF MANAGEMENT AREA DEFINITION

There are two management regimes in effect within the Gulf of Maine, that developed for U.S. waters by the NMFS in concert with the Mid-Atlantic, New England, and South Atlantic Fishery Management Councils and that developed for Canadian waters by Fisheries and Oceans in concert with the Northwest Atlantic Fisheries Organization (NAFO). Both regimes have evolved since extension of jurisdiction by both the U.S. and Canada in 1977. Prior to this, management and regulation of the Northwest Atlantic fishery resources were carried out under the International Commission for the Northwest Atlantic Fisheries (ICNAF), established in 1950. Management of squid resources was initiated by ICNAF in 1974. Lange and Sissenwine (1983) provide a concise summary of the evolution of management regimes in both U.S. and Canadian waters.

Since 1974, both the short-finned (Illex illecebrosus) and long-finned (Loligo pealei) squid have been managed as single stocks throughout their ranges.

In U.S. waters, both the short and long-finned squid stocks are currently managed on an April 1-March 31 fishing year (Lange, MS 1984a and b). Areal restrictions in both fisheries appear limited to foreign fishing. Foreign fishing has since 1977 been restricted to 5 windows (Fig. 1) of which only window #5 falls within the area currently under consideration (NAFO Divisions 4X, 5Y, and Subdivision 5Ze).

In Canadian waters, there is currently no management of long-finned squid, although the mechanism for such exists under NAFO. This is a consequence of the distribution pattern of L. pealei and its generally very low abundance in Division 4X. The short-finned squid I. illecebrosus is managed on a July 1-November 15 fishing year. Prior to 1979 there were no areal restrictions on the squid fishery. Areal restrictions on the 4X squid fishery were subsequently imposed, limiting the fishery for squid to the area seaward of the Small Mesh Gear Line (SMGL).

BIOLOGICAL BASIS FOR DEFINITION OF UNIT STOCKS

1. Illex illecebrosus

a) Biological and oceanographic features

Rowell et al. (1985a) provide a detailed summary of the biological features of I. illecebrosus and of the oceanographic features which appear to influence its early life history and distribution. What follows is a condensation of their summary.

The short-finned squid is seasonally distributed from the Gulf of Mexico to the Labrador seas (Clarke, 1966; Lu, 1973; Roper and Lu, 1979). Adults are found in greatest concentration in the central area of the range, i.e. Georges Bank, Scotian Shelf, and inshore Newfoundland waters (Squires, 1957; Mercer, MS 1973; Lange, MS 1980; Amaratunga, MS 1981; Dawe and Drew, 1981; Lange and Sissenwine, 1983). Although catches of I. illecebrosus have been

recorded from the surface to depths of 1,000 m (Rathjen, 1981) the bulk of the population appears to be concentrated over shallower areas of the Continental Shelf where bottom temperatures are in the range of 6°-12°C (Dupouy, MS 1981; Poulard et al., MS 1984). Rowell et al. (1985b) describe both seasonal and interannual distributional changes of I. illecebrosus on the Scotian Shelf and suggest that although adult squid appear to prefer areas having bottom temperatures greater than 6°C, temperature itself is not limiting. Squid migrate on the Shelf areas in spring and early summer with highest concentrations initially found along the Shelf-edge. Throughout the summer and fall, the rapidly growing squid spread shoreward over the Shelf. Rowell et al. (1985b) describe the pattern for the Scotian Shelf as a whole, while Figures 2 and 3 taken from Almeida et al. (MS 1984) illustrate the same pattern between Cape Hatteras and the Gulf of Maine.

I. illecebrosus have not yet been definitively aged, but concentric rings in the statoliths have been investigated and appear likely in future to provide a useful ageing structure (Lipinski, MS 1978; Hurley et al., MS 1979; Morris and Aldrich, 1985; Dawe et al., 1985). It is generally believed that the life span is approximately 1 year (Squires, 1957), but life cycles of 18-24 months have been proposed (Mesnil, 1977; Lange and Sissenwine, MS 1981). The bulk of the population, throughout the range, is believed to result from a protracted winter spawning. In Newfoundland waters length frequencies are generally unimodal, while on the Scotian Shelf secondary and tertiary modal groups of smaller squid are regularly seen in late summer and autumn (Squires, 1957, 1967; Amaratunga, MS 1980; Dupouy, MS 1981; Poulard et al., MS 1984; Rowell and Young, MS 1984; Rowell et al., 1985b). On Georges Bank and off the Mid-Atlantic area several modal groups are regularly seen (Mesnil, 1977; Lange, MS 1980; Lange and Sissenwine, MS 1981). While the winter-spawned population dominates, it is occasionally superceded by a cohort of later spring-spawned or summer-spawned squid. Lange and Sissenwine (MS 1981) have estimated that in some years this summer-spawned component may constitute up to 86% of the autumn population.

Adult squid leave the northern shelf areas in late autumn when the males are in an advanced stage of maturity. The females are less advanced at this time and this suggests that some time must elapse between their disappearance from the shelf areas and the occurrence of mating and spawning. Tagging studies (Amaratunga, MS 1981; Dawe et al., 1981) indicate a general southwestward movement from Newfoundland waters to and along the Scotian Shelf. One squid tagged in northeastern Newfoundland was reported captured in Maryland; apparently migrating a distance of 2,300 km in 107 days. Large catches of I. illecebrosus by the research vessel Anton Dohrn over the Blake Plateau in autumn 1979 (Rathjen, 1981) indicate that large concentrations of adult I. illecebrosus may occasionally be found well south of Cape Hatteras. Trites (1983) examined and modelled the environmental factors and oceanographic processes likely to influence spawning and the subsequent distribution of larval and juvenile I. illecebrosus in the western North Atlantic. Taking into consideration information on minimum temperature requirements for fertilization and embryonic development (O'Dor et al., 1982) he determined that the shelf-slope region southwest of Chesapeake Bay might be an appropriate area for spawning. The suggested restriction of possible spawning areas to this region was based on preliminary evidence of bottom

spawning in captivity and the generally held belief that I. illecebrosus was a bottom spawner. More recent evidence (O'Dor, 1983) has indicated that spawning is pelagic and that the egg-masses produced may, being almost neutrally buoyant, remain in the water column. The possibility that spawning could occur over a wide area along the warm Frontal Zone of the Gulf Stream therefore, exists. Evidence from larval/juvenile surveys along the Gulf Stream Frontal Zone between the Straits of Florida in the south and to the southeast of the Grand Bank in the north (Amaratunga, MS 1981; Amaratunga and Budden, MS 1982; Dawe et al., MS 1981, MS 1982; Froerman et al., MS 1981; Arkhipkin et al., MS 1983; Fedulov et al., MS 1984; Dawe and Beck, 1985; Hatanaka et al., 1985; Rowell et al., 1985a; Rowell and Trites, 1985; Trites and Rowell, MS 1985) indicates a northeastward transport of both larvae and juveniles by the Gulf Stream from a spawning area either near to or south of Cape Hatteras. Trites and Rowell (MS 1985) present evidence suggesting that a major spawning area occurs in the Gulf Stream Frontal Zone in the area of, or to the south of, Cape Canaveral.

Figure 4 serves to illustrate the complex pattern of oceanographic conditions found in the Gulf Stream system as well as a generalized life cycle for I. illecebrosus.

b) Stock definition

Dawe et al. (1984) examined the problem of stock discrimination in I. illecebrosus by reviewing size and maturity data, tagging data, distribution of larvae and juveniles and the incidence of parasites. While not conclusive, their review suggests a single stock. Romero and Amaratunga (MS 1981) found a low frequency of polymorphic enzymes in electrophoretic studies on Scotian Shelf squid. While not conclusively ruling out the possibility of more than one stock throughout the range, the results indicated little genetic variability among squid from the Scotian Shelf.

The pattern of the life cycle, as described above, and the great capacity for mixing of larvae and juveniles in the highly dynamic Gulf Stream system would likely militate against the development of more than one stock.

c) Spatial characteristics of the fishery

In U.S. waters, the fishery for I. illecebrosus takes place from roughly June through December while the squid are over the Continental Shelf. Traditionally, the fishery took place between Hundson Canyon and Corsair Canyon on Georges Bank, being prosecuted by the same vessels which operated in the winter fishery for L. pealei (Lange and Sissenwine, 1983). The U.S. catch had until recently consisted largely of by-catch, but since 1982 there has been a shift in which domestic catches have increased steadily and foreign catches declined. The decline in catch by foreign vessels has been continued since 1977. In recent years, the bulk of the fishery for I. illecebrosus has been in Subarea 6. The pattern of change in distribution of domestic U.S. catches is shown in Figure 5. As previously noted, the foreign fishery has since 1977 been restricted to the five "windows" of the U.S. Fisheries Management Plan.

In Canadian waters, domestic catches from Division 4X have been small and restricted to coastal areas. As in the U.S.A., there was a rapid expansion of the foreign fishery on the Scotian Shelf from the early 1970's through to 1979. This fishery was largely restricted to the area along the Shelf-edge and, from 1979, to the area seaward of the SMGL. Figure 6 indicates the very limited change in fishing pattern brought about by restriction of squid fishing by the SMG regulation.

Under the 1979 Draft Fisheries Agreement, Canada had primary management responsibility for that portion of the stock in Subareas 3 and 4 and the U.S.A. had a similar responsibility in Subareas 5 and 6. Pending delimitation of the boundary, neither country was to fish Illex in the boundary region (unless otherwise agreed). The stock in each countries fishery zone was to be limited to fishing by that countries' vessels.

2. Loligo pealei

a) Biological and oceanographic features

Lange and Sissenwine (1980, 1983) provide summaries of the general biology and distribution of L. pealei. As can be seen from Figures 7 and 8 the long-finned squid is virtually absent from the Gulf of Maine area during winter and spring and present only in relatively low densities in autumn. Although distributed as far north as the Bay of Fundy (Stevenson, MS 1951; Summers, 1969) and southwestern areas of the Scotian Shelf, fishable concentrations are generally limited to the area between southern Georges Bank and Cape Hatteras (Tibbets, 1977). Unlike I. illecebrosus, the long-finned squid does not appear to undergo major migrations or have its life cycle influenced by major current systems such as the Gulf Stream. Migration over distances of as much as 200 km takes place annually between the overwintering area along the upper Continental Slope between western Georges Bank and Cape Hatteras and shallower areas of the shelf where spawning takes place in late spring and early summer (Summers, 1971).

As in the case of I. illecebrosus, L. pealei has not yet been aged. Summers (1971) estimated the life span at 14-24 months with some individuals surviving to about 36 months. The life cycle is poorly understood and may, as suggested by Mesnil (1977), involve two overlapping reproductive cycles which could account for the lengthy May through October spawning season and apparently variable age at spawning. Spawning peaks in May and to a lesser extent in October result in two distinct cohorts in most years (Lange, MS 1984a).

b) Stock definition

There have been no tagging experiments reported for L. pealei. Some electrophoretic studies have recently been conducted at the Marine Biological Laboratory, Woods Hole, on squid taken from inshore near Woods Hole and from offshore NMFS research cruises. Preliminary results have shown no apparent differences. For management purposes L. pealei has been treated as a single stock.

c) Spatial characteristics of the fishery

There is no fishery for L. pealei in Canadian waters (Division 4X) and historically there has been only a limited fishery in U.S. waters in Division 5Y and Subdivision 5Ze. It is unlikely that sufficient resource exists on the Canadian side of the ICJ Line to support a directed fishery. Under the 1979 Draft Fisheries Agreement, Canada was to have rights to 9% of the Loligo catch in Division 5Z and Subarea 6.

IMPLICATIONS FOR ESTABLISHMENT OF STATISTICAL AND MANAGEMENT BOUNDARIES

Although there is as yet no strong evidence that either I. illecebrosus or L. pealei represent single stocks, the limited evidence available suggests this to be the case.

Since L. pealei has only limited distribution and abundance on the Canadian side of the ICJ Line, there appears to be no significant benefit, in terms of management, of choosing one set of lines over another.

I. illecebrosus has a very wide distribution in both Canadian and U.S. waters and, in view of recent evidence that a single stock spawning off the southeastern U.S.A. may be the source of recruitment for all the fishing areas, it would be advantageous to coordinate management actions relative to this species. Since the period of rapid expansion of the Illex fisheries in the late 1960's and the 1970's there has been no significant fishery in the immediate area of the ICJ Line. The bulk of the fishery on the Canadian side has been generally confined to the outer Shelf-edge in Subdivision 4Xn and, since 1977, the foreign fishery on the U.S. side to the southern edge of Georges Bank in "window 5" (Subdivisions 5ZEo and 5ZEN) and "windows" further west. Since 1982, the domestic U.S. fishery, both U.S. landed and in joint ventures has increased rapidly, with the bulk of this fishery being in Subarea 5 and a small amount in Division 5Y. Since the greatest part of the fishery on both the Canadian and U.S. sides of the ICJ has taken place at some distance from the line, it would appear that either the existing NAFO lines or the ICJ line could be used with no significant benefit discernable for either.

RECOMMENDATIONS FOR FUTURE RESEARCH

Fundamental to clarifying the stock structure of I. illecebrosus in the Gulf of Maine, and throughout the species range, is the need to settle remaining taxonomic questions within the genus. This is particularly true of the early life stages which are widely distributed in the Gulf Stream Frontal Zone and the Slope Waters. Current research has focused on using these early life stages as a means of tracking back to the still unknown spawning areas. Off the southeastern U.S. the possibility exists for mixing of at least two and possibly three species. Until the taxonomic questions are settled, there will continue to be difficulties in evaluating larval/juvenile data from the more southern part of the range.

Although some electrophoretic studies have been conducted, the specimens used have been representative of only a relatively small part of the range such as the Scotian Shelf. Future studies should utilize specimens from the full range of the species, or at a minimum from the main fishing areas throughout the range.

Although tagging studies have been carried out, there has been only a limited amount of late-season offshore tagging. Unfortunately, while this has been attempted several times in recent years, population levels have been so low that jigging success was very poor and few tagged animals were released. The lack of significant commercial fisheries in the area south of Cape Hatteras also severely reduces the likelihood of tag recovery from the area in which spawning is believed to occur. Nonetheless, significant recoveries might be expected from the area of Cape Hatteras and immediately north of there should this, in fact, be on the migration route of maturing adults.

Current attempts to track the early life stages of Illex in the Gulf Stream Frontal Zone and during the shoreward migration through the Slope Waters would benefit from partitioning of survey areas and coordination of efforts to maximize usefulness of the data collected.

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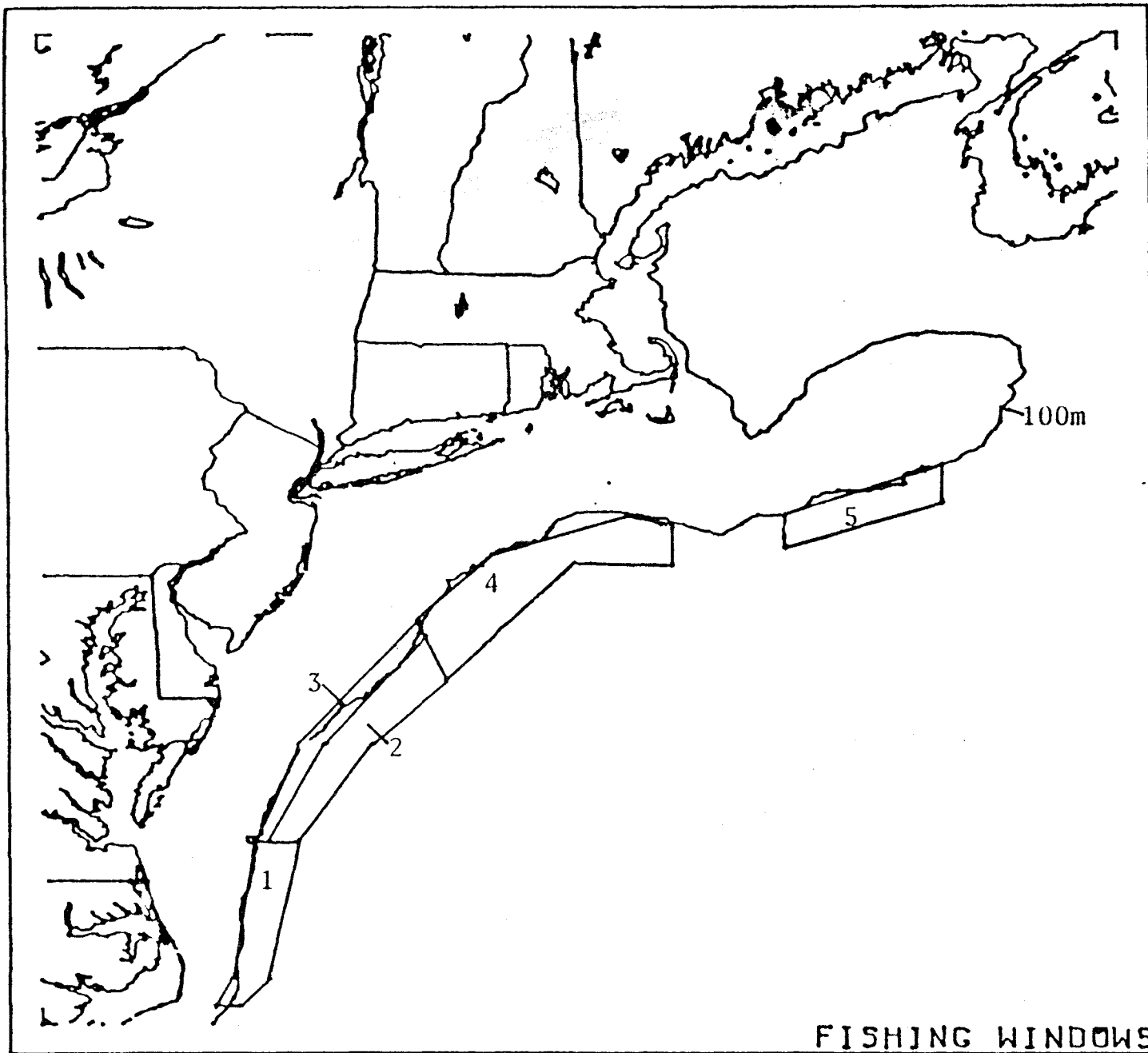


Figure 1. Areas of the Northwest Atlantic, off the USA, which are open to foreign fishing during authorized fishing seasons.
(From Lange, 1984a)

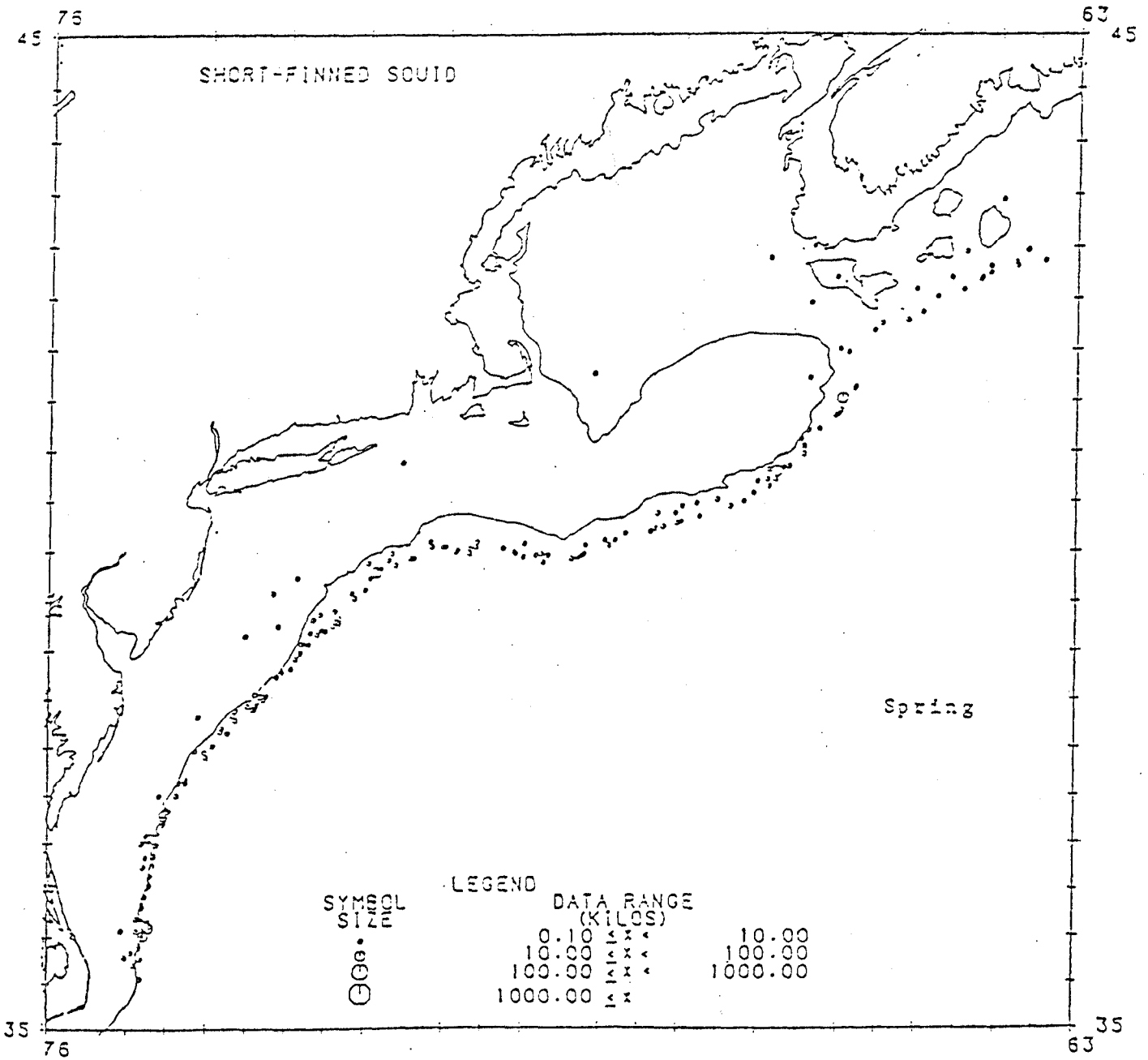


Figure 2 . Distribution of short-finned squid catches during 1964-1974, 1976 and 1978 spring surveys.

(From Almeida et al., 1984)

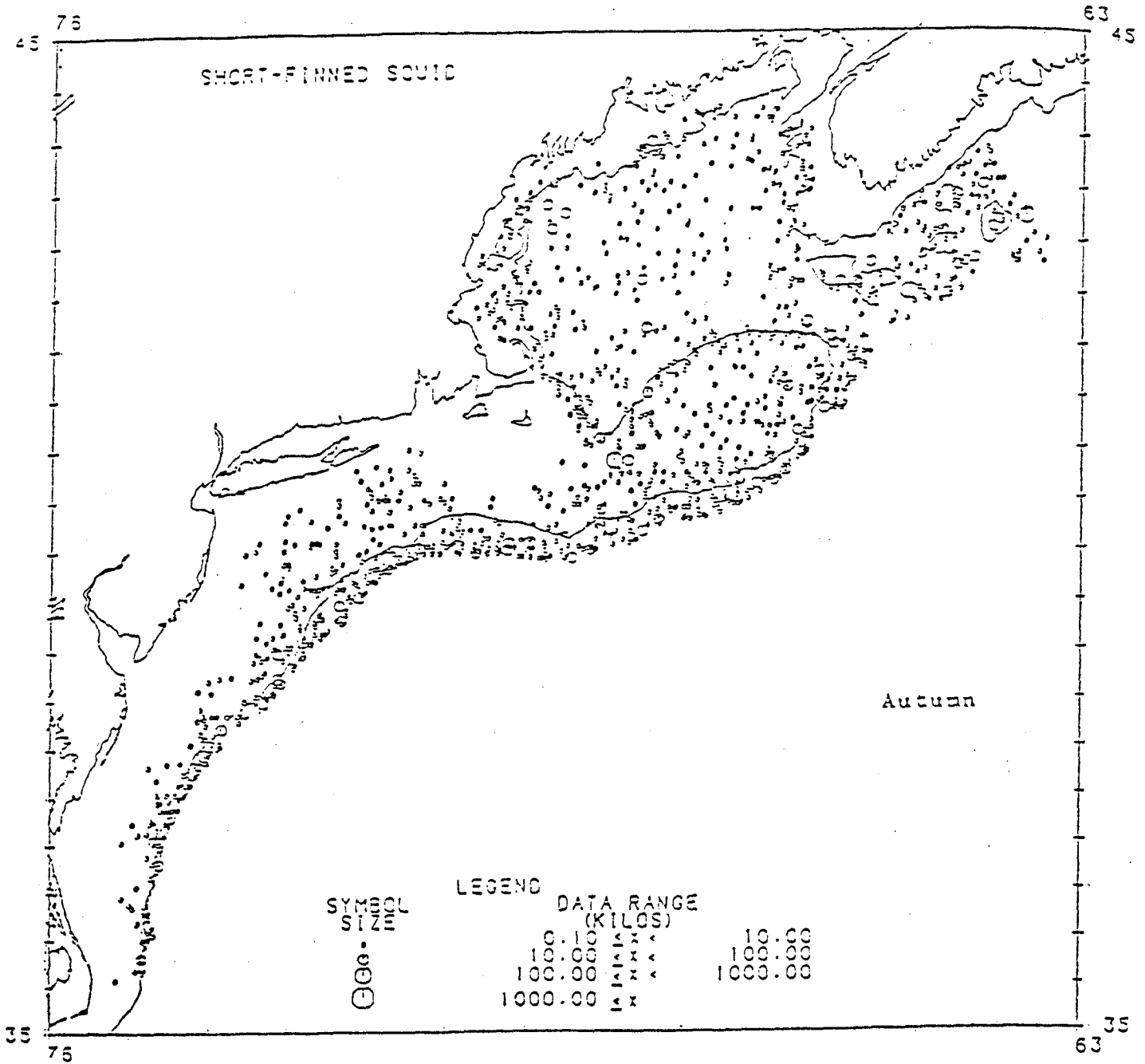


Figure 3 . Distribution of short-finned squid catches during 1965-1975 and 1977 autumn surveys.

(From Almeida et al., 1984)

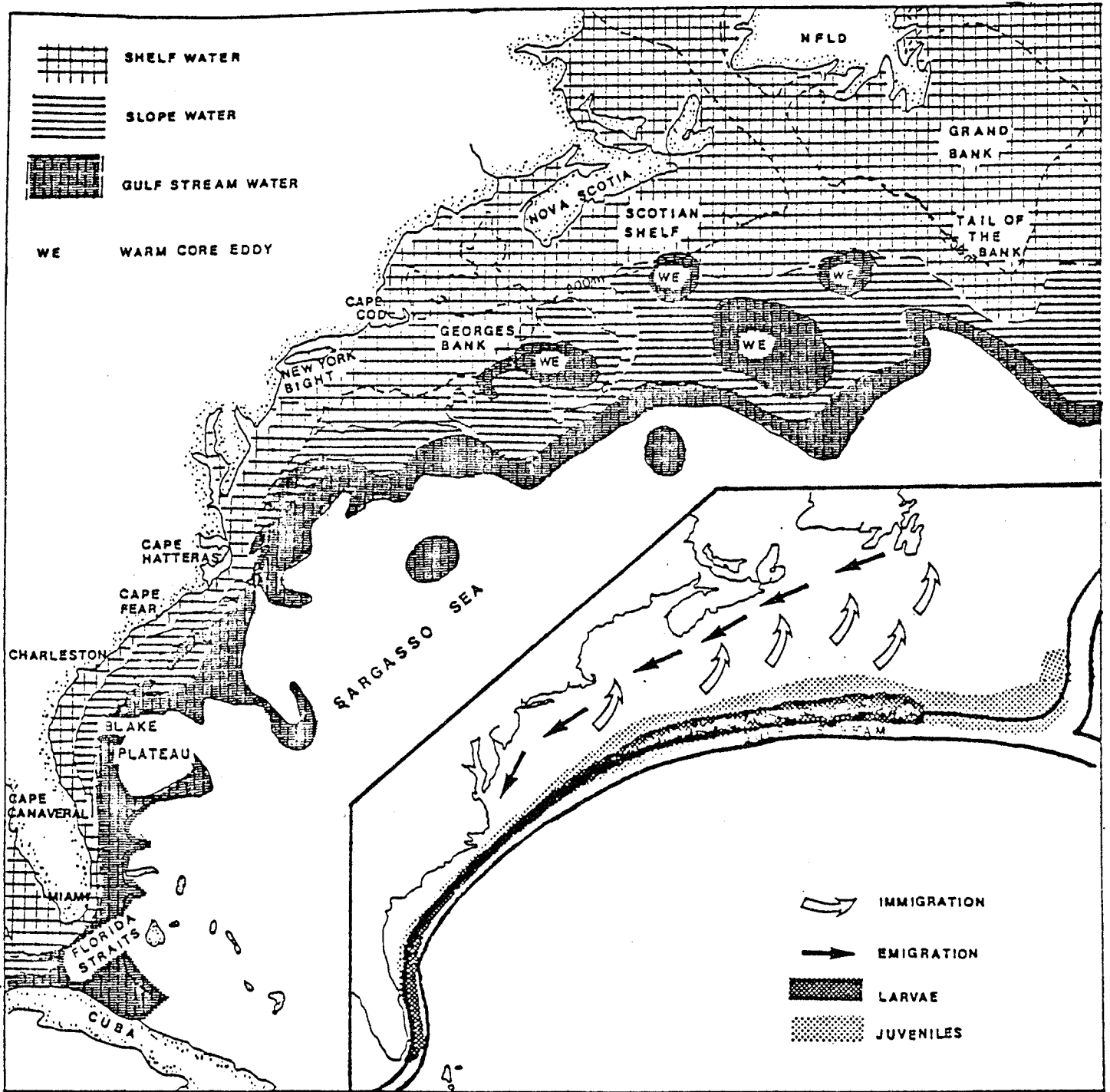


Figure 4. Map showing the Gulf Stream system off eastern North America, and major surface water-mass features for 4-5 January, 1985, (Extracted from United States National Weather Service NOAA/NESS satellite-derived oceanographic analysis maps). A schematic illustration of the general life-cycle of *Illex illecebrosus* in relation to the Gulf Stream is shown as an inset.

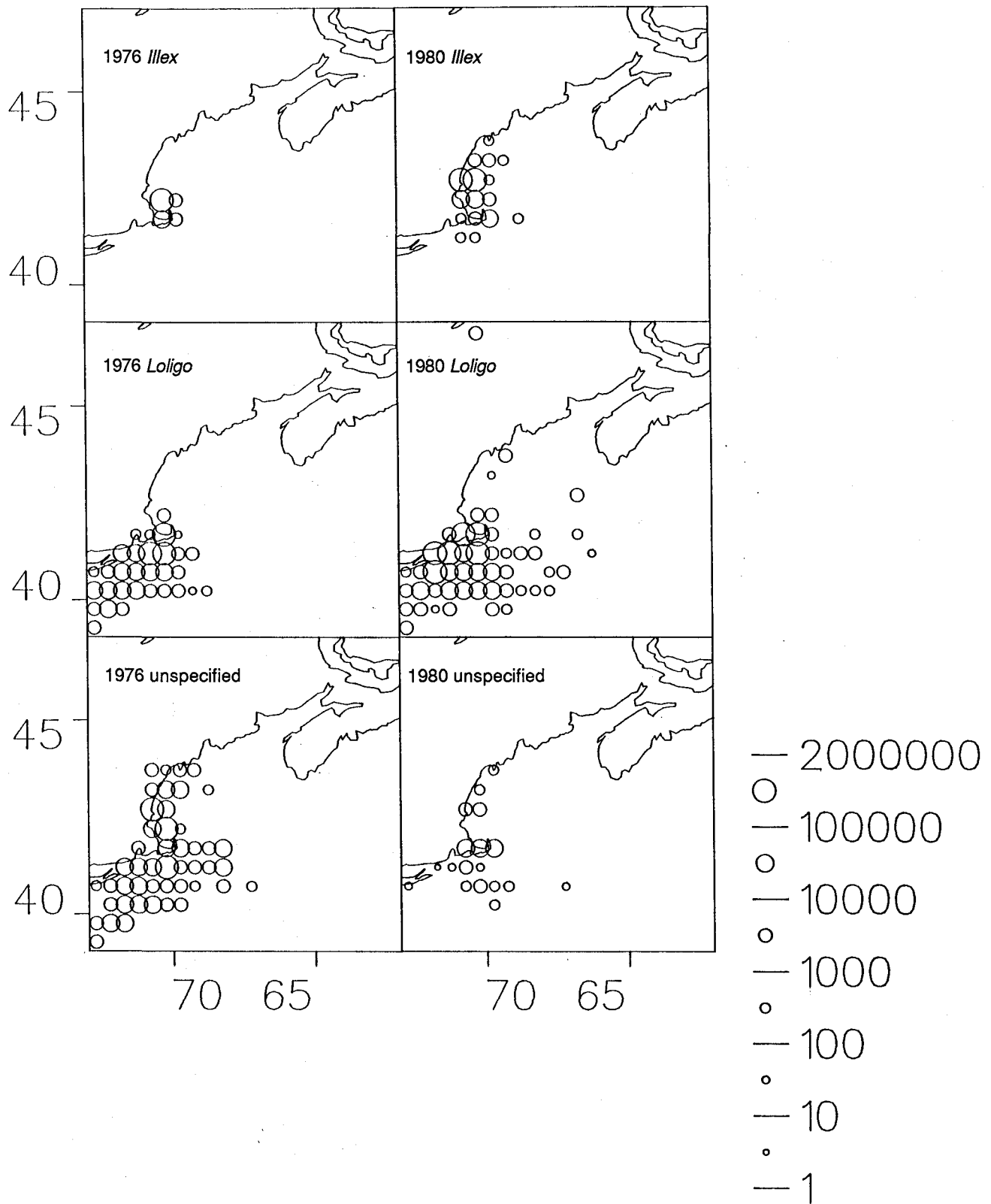
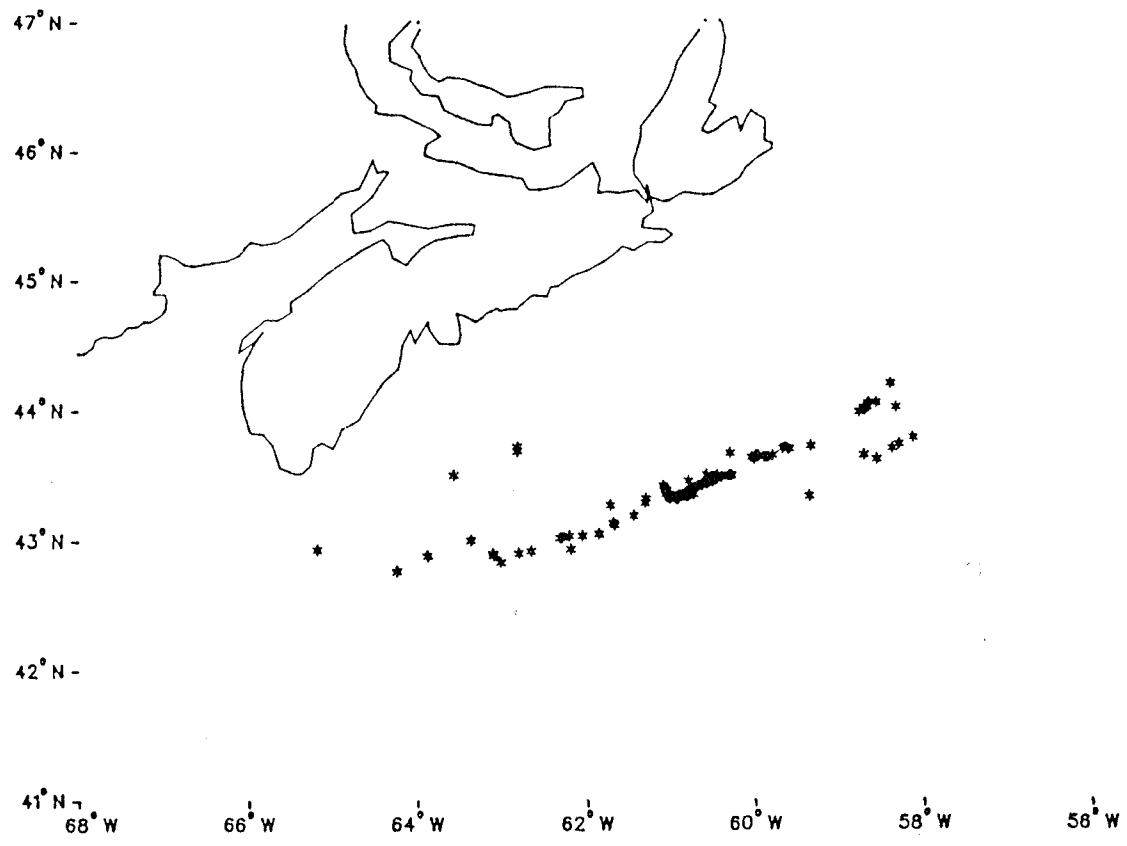


Fig. 5. Distribution of domestic U.S. catches (Lbs. landed) of *I. illecebrosus*, *L. pealei*, and unspecified for 1976 and 1980.

OBS. SAMPLES - 1977



OBS. SAMPLES - 1980

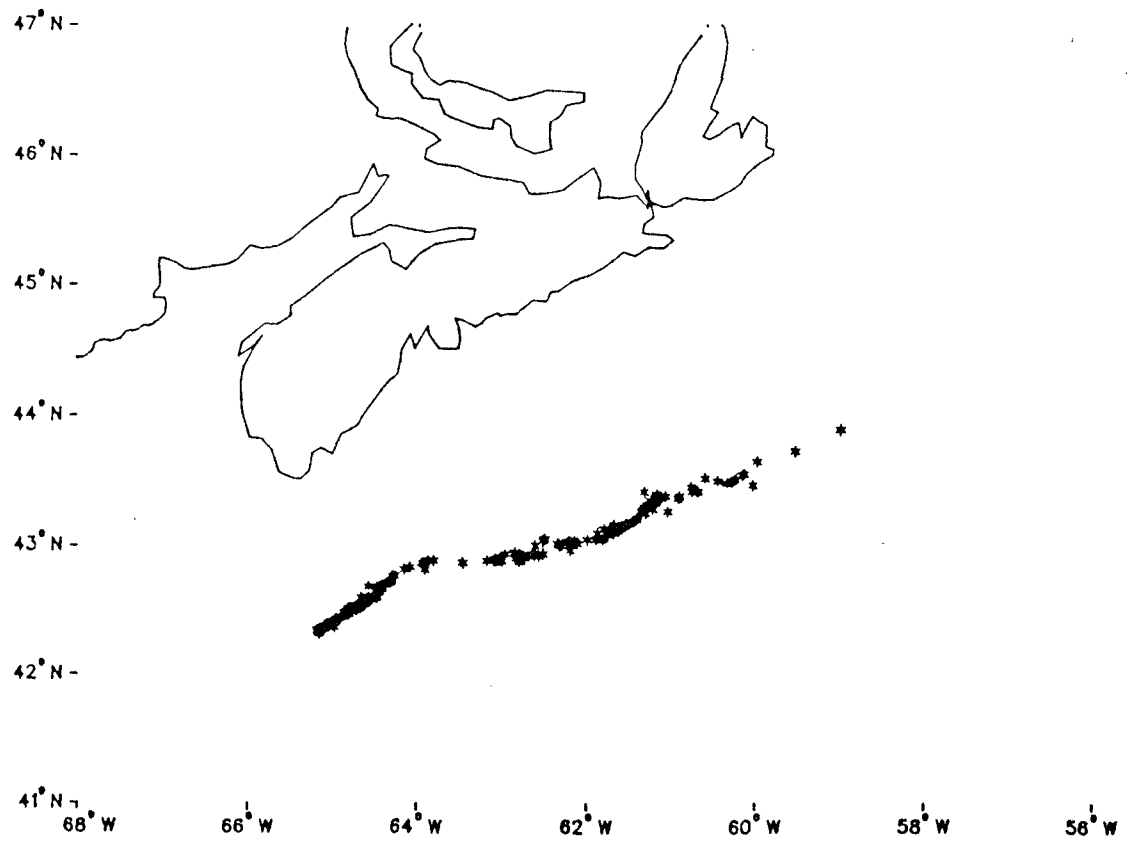


Figure 6. Fishing patterns prior to and after restriction of squid fishing to the area seaward of the SMGL.

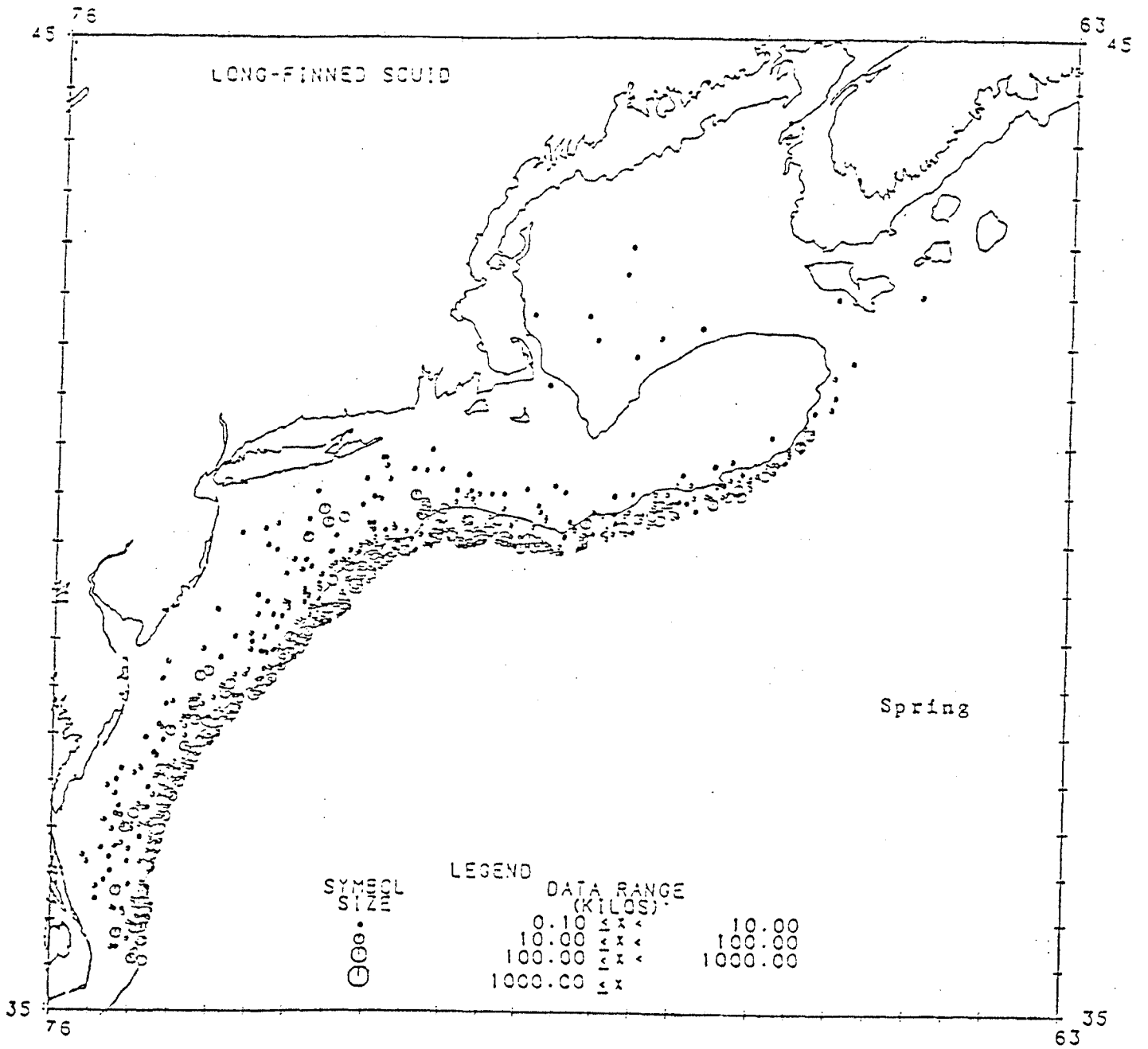


Figure 7. Distribution of long-finned squid catches during 1964-1974, 1976 and 1978 spring surveys.

(From Almeida et al., 1984)

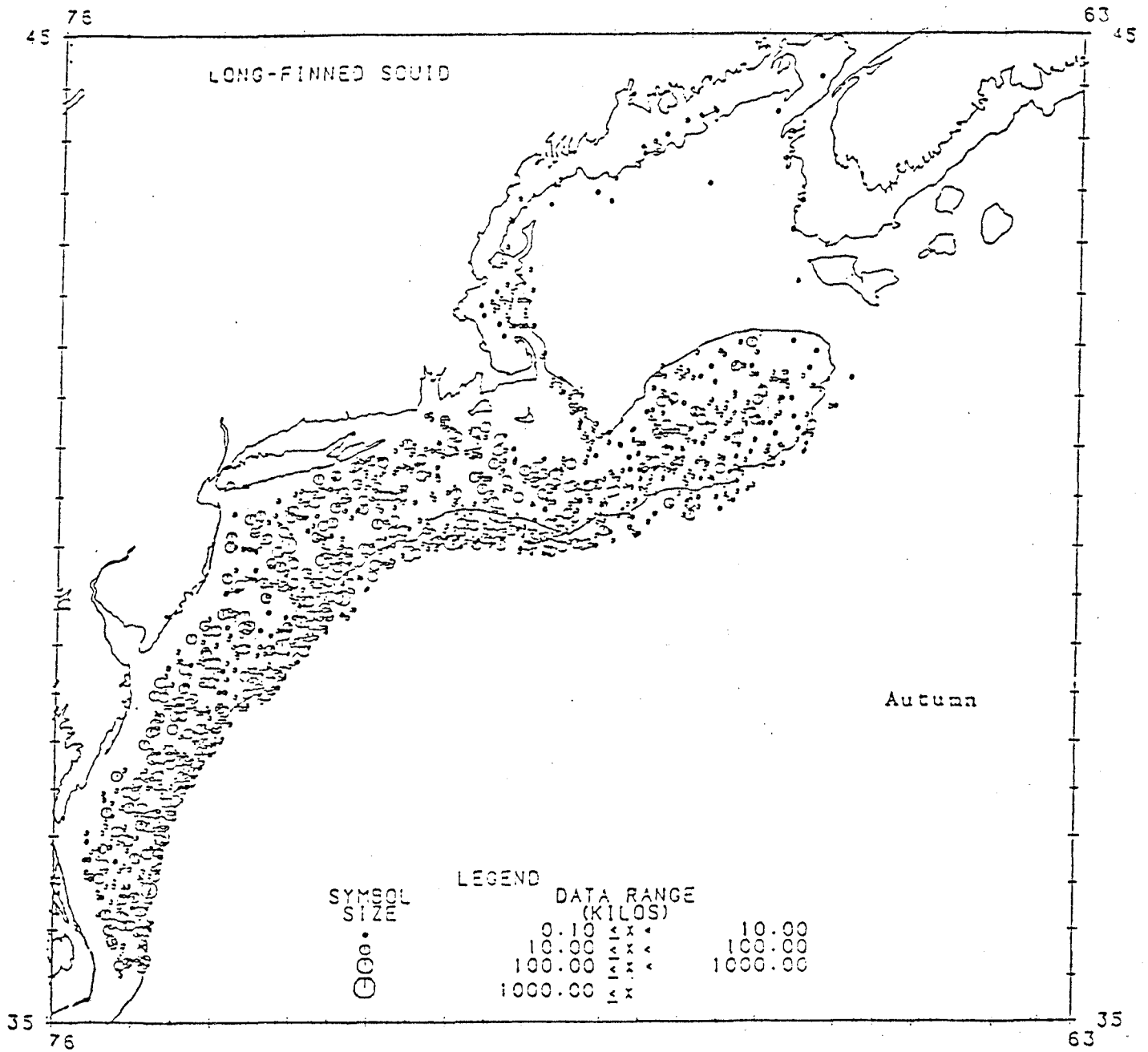


Figure 8 . Distribution of long-finned squid catches during 1965-1975 and 1977 autumn surveys.

(From Almeida et al., 1984)