



NOAA Technical Memorandum NMFS-NE-146

Essential Fish Habitat Source Document:
Longfin Inshore Squid, *Loligo pealeii*,
Life History and Habitat Characteristics

**U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts**

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Essential Fish Habitat Source Document:

Longfin Inshore Squid, *Loligo pealeii*, Life History and Habitat Characteristics

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Editorial Notes on Issues 122-152 in the NOAA Technical Memorandum NMFS-NE Series

Editorial Production

For Issues 122-152, staff of the Northeast Fisheries Science Center's (NEFSC's) Ecosystems Processes Division have largely assumed the role of staff of the NEFSC's Editorial Office for technical and copy editing, type composition, and page layout. Other than the four covers (inside and outside, front and back) and first two preliminary pages, all preprinting editorial production has been performed by, and all credit for such production rightfully belongs to, the authors and acknowledgees of each issue, as well as those noted below in "Special Acknowledgments."

Special Acknowledgments

David B. Packer, Sara J. Griesbach, and Luca M. Cargnelli coordinated virtually all aspects of the preprinting editorial production, as well as performed virtually all technical and copy editing, type composition, and page layout, of Issues 122-152. Rande R. Cross, Claire L. Steimle, and Judy D. Berrien conducted the literature searching, citation checking, and bibliographic styling for Issues 122-152. Joseph J. Vitaliano produced all of the food habits figures in Issues 122-152.

Internet Availability

Issues 122-152 are being copublished, *i.e.*, both as paper copies and as web postings. All web postings are, or will soon be, available at: www.nefsc.nmfs.gov/nefsc/habitat/efh. Also, all web postings will be in "PDF" format.

Information Updating

By federal regulation, all information specific to Issues 122-152 must be updated at least every five years. All official updates will appear in the web postings. Paper copies will be reissued only when and if new information associated with Issues 122-152 is significant enough to warrant a reprinting of a given issue. All updated and/or reprinted issues will retain the original issue number, but bear a "Revised (Month Year)" label.

Species Names

The NMFS Northeast Region's policy on the use of species names in all technical communications is generally to follow the American Fisheries Society's lists of scientific and common names for fishes (*i.e.*, Robins *et al.* 1991^a), mollusks (*i.e.*, Turgeon *et al.* 1998^b), and decapod crustaceans (*i.e.*, Williams *et al.* 1989^c), and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals (*i.e.*, Rice 1998^d). Exceptions to this policy occur when there are subsequent compelling revisions in the classifications of species, resulting in changes in the names of species (*e.g.*, Cooper and Chapleau 1998^e).

^aRobins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991. Common and scientific names of fishes from the United States and Canada. 5th ed. *Amer. Fish. Soc. Spec. Publ.* 20; 183 p.

^bTurgeon, D.D. (chair); Quinn, J.F., Jr.; Bogan, A.E.; Coan, E.V.; Hochberg, F.G.; Lyons, W.G.; Mikkelsen, P.M.; Neves, R.J.; Roper, C.F.E.; Rosenberg, G.; Roth, B.; Scheltema, A.; Thompson, F.G.; Vecchione, M.; Williams, J.D. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. 2nd ed. *Amer. Fish. Soc. Spec. Publ.* 26; 526 p.

^cWilliams, A.B. (chair); Abele, L.G.; Felder, D.L.; Hobbs, H.H., Jr.; Manning, R.B.; McLaughlin, P.A.; Pérez Farfante, I. 1989. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. *Amer. Fish. Soc. Spec. Publ.* 17; 77 p.

^dRice, D.W. 1998. Marine mammals of the world: systematics and distribution. *Soc. Mar. Mammal. Spec. Publ.* 4; 231 p.

^eCooper, J.A.; Chapleau, F. 1998. Monophyly and interrelationships of the family Pleuronectidae (Pleuronectiformes), with a revised classification. *Fish. Bull. (U.S.)* 96:686-726.

FOREWORD

One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats.

Magnuson-Stevens Fishery Conservation and Management Act (October 11, 1996)

The long-term viability of living marine resources depends on protection of their habitat.

NMFS Strategic Plan for Fisheries Research (February 1998)

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), which was reauthorized and amended by the Sustainable Fisheries Act (1996), requires the eight regional fishery management councils to describe and identify essential fish habitat (EFH) in their respective regions, to specify actions to conserve and enhance that EFH, and to minimize the adverse effects of fishing on EFH. Congress defined EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.” The MSFCMA requires NMFS to assist the regional fishery management councils in the implementation of EFH in their respective fishery management plans.

NMFS has taken a broad view of habitat as the area used by fish throughout their life cycle. Fish use habitat for spawning, feeding, nursery, migration, and shelter, but most habitats provide only a subset of these functions. Fish may change habitats with changes in life history stage, seasonal and geographic distributions, abundance, and interactions with other species. The type of habitat, as well as its attributes and functions, are important for sustaining the production of managed species.

The Northeast Fisheries Science Center compiled the available information on the distribution, abundance, and habitat requirements for each of the species managed by the New England and Mid-Atlantic Fishery Management Councils. That information is presented in this series of 30 EFH species reports (plus one consolidated methods report). The EFH species reports comprise a survey of the important literature as well as original analyses of fishery-

independent data sets from NMFS and several coastal states. The species reports are also the source for the current EFH designations by the New England and Mid-Atlantic Fishery Management Councils, and have understandably begun to be referred to as the “EFH source documents.”

NMFS provided guidance to the regional fishery management councils for identifying and describing EFH of their managed species. Consistent with this guidance, the species reports present information on current and historic stock sizes, geographic range, and the period and location of major life history stages. The habitats of managed species are described by the physical, chemical, and biological components of the ecosystem where the species occur. Information on the habitat requirements is provided for each life history stage, and it includes, where available, habitat and environmental variables that control or limit distribution, abundance, growth, reproduction, mortality, and productivity.

Identifying and describing EFH are the first steps in the process of protecting, conserving, and enhancing essential habitats of the managed species. Ultimately, NMFS, the regional fishery management councils, fishing participants, Federal and state agencies, and other organizations will have to cooperate to achieve the habitat goals established by the MSFCMA.

A historical note: the EFH species reports effectively commence a series of reports published by the NMFS Sandy Hook (New Jersey) Laboratory (now formally known as the James J. Howard Marine Sciences Laboratory) from 1977 to 1982. These reports, which were formally labeled as *Sandy Hook Laboratory Technical Series Reports*, but informally known as “Sandy Hook Bluebooks,” summarized biological and fisheries data for 18 economically important species. The fact that the bluebooks continue to be used two decades after their publication persuaded us to make their successors – the 30 EFH source documents – available to the public through publication in the *NOAA Technical Memorandum NMFS-NE* series.

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SEPTEMBER 1999

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INTRODUCTION

The longfin inshore squid, *Loligo pealeii*, is a pelagic schooling species of the molluscan family Loliginidae (Figure 1). It is distributed in continental shelf and slope waters from Newfoundland to the Gulf of Venezuela; it occurs in commercial abundance from southern Georges Bank to Cape Hatteras. Exploitation of the species is currently managed by the Mid-Atlantic Fishery Management Council under the Atlantic Mackerel, Squid and Butterfish Fishery Management Plan (MAFMC 1996). Within the range of commercial exploitation, the population is considered to be a single stock unit. This Essential Fish Habitat Source Document provides information on the life history and habitat characteristics of longfin inshore squid inhabiting the Gulf of Maine, Georges Bank, and the Middle Atlantic Bight.

LIFE HISTORY

A brief synopsis of the life history characteristics of the longfin inshore squid is provided by Brodziak (1995) and Amendment #6 to the Fishery Management Plan for the Atlantic Mackerel, Squid and Butterfish Fisheries (MAFMC 1996). More detailed information is provided here.

EGGS AND LARVAE

The 1 mm x 1.6 mm eggs are encased in a gelatinous capsule as they pass through the female oviduct during mating. Each capsule contains 150-200 eggs (Arnold *et al.* 1974; Gosner 1978; MAFMC 1996) and is about 50-80 mm long and 1 cm in diameter (Gosner 1978; Lange 1982; MAFMC 1996). During spawning, the male cements bundles of spermatophores into the mantle cavity of the female; as the capsule of eggs passes out through the oviduct, the jelly is penetrated by the sperm (Black *et al.* 1987). The egg capsules are laid on the bottom in clusters 50-60 cm wide composed of hundreds of capsules (Gosner 1978; Griswold and Prezioso 1981). Each female lays 20-30 capsules (Lange 1982). The number of eggs spawned per female has been reported as 950-8,500 (Haefner 1959), 3,500-6,000 (Summers 1971), 2,500-15,900 (Vovk 1972b), and 3,000-6,000 (MAFMC 1996). Development time varies from 257 to 642 hrs depending on water temperature; 26.7 days to hatching at 12-18°C, 18.5 days at 15.5-21.3°C, and 10.7 days at 15.5-23.0°C (Summers 1971).

Little is known about the larval stages of the longfin inshore squid (MAFMC 1996) because they are not often found in the spawning areas. Larvae are pelagic in near surface waters (McMahon and Summers 1971) and are referred to as paralarvae (Young and Harman 1988).

Larvae 2-4 mm in length have been caught in the Gulf of Maine (Bigelow 1924).

JUVENILES AND SUBADULTS

There are two juvenile stages; 'juvenile' is the stage after the paralarval stage and before the subadult stage; 'subadult' is the stage before maturity when the morphological characteristics of adults are attained (Young and Harman 1988). The shift from inhabiting surface waters to a demersal lifestyle occurs at 45 mm (Vecchione 1981). Off Martha's Vineyard, the juvenile life stage lasts about 1 month; by November subadults migrate to the outer shelf areas where they remain until March (Summers 1968a, b). Subadults are thought to overwinter in deeper waters along the edge of the continental shelf (Black *et al.* 1987). Young-of-the-year (subadults) are found with adults in mid-summer trawls (Summers 1968a, b). Sexual maturity is first reached at 8-12 cm, although most mature individuals are > 10 cm (Macy 1980; Brodziak and Hendrickson 1999). The length at which 50% of individuals are sexually mature (L_{50}) is 16 cm (Brodziak 1995).

ADULTS

Historically, the lifespan of longfin inshore squid was believed to be 1-2 years (Summers 1971; Lange 1982). However, recent studies using statolith aging demonstrated exponential growth and a lifespan of less than 1 year (Brodziak and Macy 1996).

Longfin inshore squid reach sizes greater than 40-50 cm mantle length (ML), although most are less than 30 cm (Vecchione *et al.* 1989; Brodziak 1995). They are sexually dimorphic – males grow more rapidly and reach larger size at age than females (Brodziak 1995). Longfin inshore squid migrate offshore during late autumn and overwinter in warmer waters along the edge of the continental shelf; they return inshore during the spring and early summer (MAFMC 1996). Mature individuals enter inshore waters before immature ones (Macy 1982). Off Massachusetts, larger individuals migrate inshore in April-May while smaller individuals move inshore in the summer (Lange 1982). Longfin inshore squid form large schools based on size prior to feeding (Macy 1980) and make diurnal vertical migrations up into the water column at night (MAFMC 1996). This movement may be associated with the pursuit of food organisms such as euphausiids.

REPRODUCTION

Historically, longfin inshore squid were believed to

spawn from summer to early fall (Lange and Sissenwine 1980), although this varied among years and geographic areas. Brodziak and Macy (1996), however, recently reported that longfin inshore squid can spawn year round. Most eggs are spawned in May and hatching occurs in July (Summers 1971). Spawning has been reported from August to September in the Bay of Fundy (Stevenson 1934), from May to August in New England waters (Macy 1980; Summers 1971), and from late spring to early summer in the Middle Atlantic (Lange and Sissenwine 1983; Black *et al.* 1987). Mesnil (1977) reported that spawning on the Scotian Shelf and Georges Bank occurs during early spring and late summer.

Spawning has been reported in the Gulf of Maine in Cobequid Bay and Massachusetts Bay (Bigelow 1924), the Bay of Fundy (Stevenson 1934), Minas Basin (Cohen 1976), along the eastern coast of Nova Scotia in St. Margaret's and Terrence bays (Dawe *et al.* 1990), on Georges Bank (Mesnil 1977), and in the Middle Atlantic in Narragansett and Delaware bays (Haefner 1959; Griswold and Prezioso 1981).

FOOD HABITS

The diet of the longfin inshore squid changes with size; small immature individuals feed on planktonic organisms (Vovk 1972b; Tibbetts 1977) while larger individuals feed on crustaceans and small fish (Vinogradov and Noskov 1979). Cannibalism is observed in individuals larger than 5 cm (Whitacker 1978). Studies by Vovk and Khvichiya (1980) and Vovk (1985) showed that juveniles 4.1-6 cm long fed on euphausiids and arrow worms, while those 6.1-10 cm fed mostly on small crabs, but also on polychaetes and shrimp. Adults 12.1-16 cm long fed on fish (clupeids, myctophids) and squid larvae/juveniles, and those > 16 cm fed on fish and squid (Vovk and Khvichiya 1980; Vovk 1985). Fish species preyed on by longfin inshore squid include silver hake, mackerel, herring, menhaden (Langton and Bowman 1977), sand lance, bay anchovy, menhaden, weakfish, and silversides (Kier 1982). Maurer and Bowman (1985) demonstrated the following seasonal and inshore/offshore differences in diet: in offshore waters in the spring, the diet is composed of crustaceans (mainly euphausiids) and fish; in inshore waters in the fall, the diet is composed almost exclusively of fish; and in offshore waters in the fall, the diet is composed of fish and squid.

The Northeast Fisheries Science Center (NEFSC) bottom trawl survey data on food habits [see Reid *et al.* (1999) for details] show a similar ontogenetic shift in the diet of longfin inshore squid (Figure 2). During 1973-1980, the diet of squid 1-10 cm was composed primarily of crustaceans (23%), while fish were the most important prey item in the diet of squid 11-40 cm. During 1981-1990, the diet of squid 1-10 cm was composed of 42% cephalopods (i.e., squid), 26% fish, and 21% crustaceans,

while the diet of squid 11-40 cm was dominated by fish (39%) and cephalopods (22%).

PREDATION

Juvenile and adult longfin inshore squid are preyed upon by many pelagic and demersal fish species, as well as marine mammals and diving birds (Lange and Sissenwine 1980; Vovk and Khvichiya 1980; Summers 1983). Marine mammal predators include longfin pilot whale, *Globicephala melas*, and common dolphin, *Delphinus delphis* (Waring *et al.* 1990; Overholtz and Waring 1991; Gannon *et al.* 1997). Fish predators include bluefish, sea bass, mackerel, cod, haddock, pollock, silver hake, red hake, sea raven, spiny dogfish, angel shark, goosefish, dogfish, and flounder (Maurer 1975; Langton and Bowman 1977; Gosner 1978; Lange 1980).

HABITAT CHARACTERISTICS

The terms pre-recruit and recruit are used here in the description of the habitat characteristics and geographical distributions. These terms refer to the exploited and unexploited portions of the stock. Longfin inshore squid are exploited at a minimum mantle length of 9 cm; thus, pre-recruits are ≤ 8 cm and recruits are ≥ 9 cm. Information on the habitat characteristics and preferences of the longfin inshore squid is summarized in Table 1.

EGGS AND LARVAE

Egg masses are commonly found attached to rocks and small boulders on sandy/muddy bottom and on aquatic vegetation, such as *Fucus* sp., *Ulva lactuca*, *Laminaria* sp. and *Porphyra* sp. (Arnold *et al.* 1974; Griswold and Prezioso, 1981; Summers 1983). The eggs are demersal, are generally laid in waters < 50 m deep (Bigelow 1924; Griswold and Prezioso 1981; Lange 1982), and are found at temperatures of 10-23°C (McMahon and Summers 1971) and salinities of 30-32 ppt (McMahon and Summers 1971).

The larvae are pelagic near the surface (McMahon and Summers 1971; McConathy *et al.* 1980) and occur at temperatures of 10-26°C and salinities of 31.5-34.0 ppt (Vecchione 1981). Surface waters are important to hatchlings and larvae move deeper as they grow older (Vecchione 1981).

JUVENILES

Juveniles inhabit the upper 10 m of the water column over water 50-150 m deep (Mercer 1969; Vovk and

Khvichiya 1980; Brodziak and Hendrickson 1999). They are found at surface water temperatures of 10-26°C (Vecchione 1981; Brodziak and Hendrickson 1999) and salinities of 31.5-34.0 ppt (Vecchione 1981).

Longfin inshore squid pre-recruits (≤ 8 cm ML) caught during NEFSC trawl surveys were taken at depths ranging from 0-210 m (Figure 4). However, depth of occurrence varied seasonally in accordance with known inshore-offshore migrations. Most pre-recruits were taken at 70-120 m and 8-12°C in winter, 20-130 m and 10-13°C in spring, 10 m and 13-18°C in summer, and 10-40 m and 11-17°C in winter.

Off Massachusetts, most pre-recruits were found in 10-15 m of water at temperatures of 10-13°C in spring and 15-20°C in autumn (Figure 6). In Narragansett Bay, pre-recruits were found at depths of 3-34 m (27 m in winter, 6-12 m in spring, 30-34 m in summer, and 30 m in autumn) and temperatures of 9-25°C (10°C in winter, 9-16°C in spring, 11-25°C with most at 19°C in summer, and 13-23°C with most at 20°C in autumn) (Figure 8). In the Hudson-Raritan estuary, most pre-recruits were found at temperatures of 16-20°C, depths of 30 and 45-50 ft (~9 and 14-15 m), salinities of 30 ppt, and dissolved oxygen levels of 7-8 mg/L (Figure 10).

ADULTS

Adult longfin inshore squid inhabit the continental shelf and upper continental slope to depths of 400 m (Vecchione *et al.* 1989), but depth varies seasonally. In spring they occur at depths of 110-200 m (Serchuk and Rathjen 1974; Lange and Sissenwine 1980), in summer and autumn they inhabit inshore waters as shallow as 6-28 m (Summers 1968a, b; Serchuk and Rathjen 1974; Gosner 1978; Howell and Simpson 1994), and in winter they inhabit offshore waters to depths of 365 m (Lange 1982). They are found on mud or sand/mud substrate (Howell and Simpson 1994), at surface temperatures ranging from 9-21°C, and bottom temperatures ranging from 8-16°C (Summers 1969; Lux *et al.* 1974; Serchuck and Rathjen 1974; Lange and Sissenwine 1980; Macy 1980; Brodziak and Hendrickson 1999).

Longfin inshore squid recruits (≥ 9 cm) caught during NEFSC trawl surveys were taken at depths ranging from 0-300 m. However, depth of occurrence varied seasonally in accordance with known inshore-offshore migrations. Most recruits were collected at 50-120 m and 7-12°C in winter, 100-150 m and 10-12°C in spring, 10-20 m and 11-16°C in summer, and 20-70 m and 10-14°C in fall (Figure 4).

Off Massachusetts, most recruits were collected at 10-15 m and 10-13°C in spring, and 10-30 m and 16-20°C in autumn (Figure 6). In Narragansett Bay, recruits were found at depths of 3-37 m. Seasonally, in winter they were found at 27-30 m, in spring and summer at 3-37 m with most at 30-34 m, and in autumn 27-30 m. They were

also found at temperatures of 7-26°C. Seasonally, in winter they were found at 7-10°C, in spring 9-16°C with most at 11°C, in summer 9-26°C with most at 17-21°C, and in autumn 11-23°C with most at 15°C (Figure 8). In the Hudson-Raritan estuary, most recruits were found at temperatures of 16-17°C, depths of 50 and 60 ft (15 and 18 m), salinities of 30 ppt, and dissolved oxygen levels of 7-8 mg/L (Figure 10).

GEOGRAPHICAL DISTRIBUTION

Longfin inshore squid occur from Newfoundland to the Gulf of Venezuela, however, the principal concentrations occur from Georges Bank to Cape Hatteras (Brodziak 1995). Longfin inshore squid are generally found at water temperatures of at least 9°C (Lange and Sissenwine 1980). The population makes seasonal migrations that appear to be related to bottom water temperatures; they move offshore during late autumn to overwinter along the edge of the continental shelf and return inshore during the spring and early summer (MAFMC 1996). During winter and early spring when inshore waters are coldest, the population concentrates along the outer edge of the continental shelf where waters are 9-13°C. The inshore movement to the shelf areas takes place when water temperatures are rising (Black *et al.* 1987) and begins in the south and proceeds north along the coast (MAFMC 1996). A northerly extension of the range has been noted in summer (Black *et al.* 1987).

EGGS AND LARVAE

The egg and larval stages of longfin inshore squid were not sampled by the NEFSC Marine Resources Monitoring, Assessment and Prediction program (MARMAP) offshore ichthyoplankton surveys.

PRE-RECRUITS

NEFSC Bottom Trawl Surveys

The NEFSC bottom trawl surveys [see Reid *et al.* (1999) for details] captured longfin inshore squid pre-recruits (≤ 8 cm ML) during all seasons (Figure 3). In winter, pre-recruits were captured from Cape Hatteras to Nantucket Shoals, although most were found south of Long Island. They were generally found offshore of the 55 m (30 f) depth contour, with highest concentrations in the vicinity of the 183 m (100 f) contour. They were distributed farther inshore in the southern part of the range, presumably due to warmer water temperatures. In the spring, the distribution extended farther to the south, with high concentrations south of Cape Hatteras, and

farther to the north, with catches on Georges Bank and the Scotian Shelf. Although the highest concentrations were still found near the 183 m contour, concentrations inshore of the 55 m contour were much higher than in winter, indicating that the spring inshore migration had commenced. In summer, the highest concentrations occurred nearshore; a number of extremely dense schools ($> 10,000$ squid/tow) were found nearshore from the Delmarva Peninsula to Buzzards Bay, Massachusetts. Very few were caught on Georges Bank and in the Gulf of Maine. In autumn, longfin inshore squid were distributed throughout the continental shelf from the shore to the 183 m contour, although the highest concentrations were found nearshore. This presumably indicates the beginning of the offshore migration.

Pre-recruits were caught at a wide range of temperatures (Figure 4). In winter, they were found at 5-13°C, although most were caught at 8-12°C. In spring, they were at 6-20°C, with most caught at 10-13°C. In summer, they were found at 7-26°C, but most were caught at 13-18°C, with the highest catch at 18°C. In autumn, temperatures ranged from 7-27°C, with most caught at 11-17°C.

Pre-recruits were caught at depths ranging from 0-210 m, although this varied seasonally and in accordance with inshore-offshore migrations (Figure 4). In winter, depths ranged from 20-200 m, but most were caught between 70-120 m. In spring, depths ranged from 10-210 m, although most were caught at 20-130 m, and the highest catch was at 40 m. In summer, depths were much less variable, ranging from 0-110 m, and 70% were found at 10 m. In autumn, depths ranged from 10-150 m, but most were caught at 10-40 m, with the highest catch at 20 m.

Massachusetts Inshore Trawl Survey

Pre-recruits were collected in greater abundance in autumn than in spring in waters off Massachusetts (Figure 5). In the spring, high concentrations occurred in Buzzards Bay and around Martha's Vineyard and Nantucket islands. Low numbers were found in and around Cape Cod Bay, and none were captured north of Cape Cod. In the autumn, high concentrations were found in Buzzards Bay, around Martha's Vineyard and Nantucket, throughout Cape Cod Bay, in Massachusetts Bay, and north and south of Cape Ann. The lower numbers of pre-recruits in inshore waters in the spring was most likely due to the survey occurring prior to the main part of the inshore migration.

Pre-recruits were found at warmer temperatures in autumn than in spring (Figure 6). In spring, most were found at 10-13°C while in autumn most were found at 15-20°C. There was little difference in depth distribution in spring and autumn, with most found at 10-15 m (Figure 6). However, pre-recruits inhabited a wider range of temperatures in autumn.

Rhode Island Trawl Survey

Longfin inshore squid pre-recruits (≤ 8 cm ML) were caught during all seasons in Narragansett Bay (Figure 7). Catches were low in winter, increased slightly in spring, and were highest during summer and autumn. This pattern corresponds to inshore migrations beginning in early spring. Pre-recruits were found at depths ranging from 10 to 110 feet (3 to 34 m) (Figure 8). In winter the few pre-recruits caught were taken at 90 feet (27 m), in summer and spring most were caught at 20-40 feet (6-12 m) and 100-110 feet (30-34 m), and in autumn most were caught at 100 feet (30 m). Pre-recruits were collected at temperatures ranging from 9-25°C. They were collected at temperatures of 10°C in winter, from 9-16°C in spring, from 11-25°C with most at 19°C in summer, and from 13-23°C with most at 20°C in autumn.

Hudson-Raritan Estuary Trawl Survey

Longfin inshore squid pre-recruits (≤ 8 cm ML) were captured in the Hudson-Raritan estuary during spring, summer, and fall (Figure 9). They were found almost exclusively in the eastern portion of the bay and were collected in the highest numbers in the summer and autumn. Pre-recruits were collected at temperatures ranging from 9-24°C, but most were taken at 16-20°C. They were also collected at depths of 15-75 ft (~5-23 m), with most at 45-50 ft (~14-15 m), and salinities of 20-33 ppt, with the highest catch at 30 ppt. They were found at dissolved oxygen levels of 5-10 mg/L, with most at 7-8 mg/L (Figure 10). Longfin inshore squid require oxygen concentrations greater than 4 mg/L (Howell and Simpson 1994).

RECRUITS

NEFSC Bottom Trawl Surveys

The NEFSC bottom trawl surveys [see Reid *et al.* (1999) for details] captured longfin inshore squid recruits (≥ 9 cm ML) during all seasons. Their seasonal distributions are identical to that of pre-recruits and illustrate the spring and summer inshore and the autumn offshore migrations (Figure 3).

Recruits were caught at a wide range of temperatures (Figure 4). In winter, they were found at 4-13°C, although most were at 7-12°C. In spring, they were found at 5-17°C, with $> 60\%$ found at 10-12°C. In summer, they were caught at 6-26°C, but most were at 11-16°C, with the highest catch at 16°C. In autumn, temperatures ranged from 7-27°C, with most at 10-14°C.

Recruits were caught at depths ranging from 0-300 m, although this varied seasonally and in accordance with

inshore-offshore migrations (Figure 4). In winter, depths ranged from 20-290 m, although most were caught between 50-120 m. In spring, depths ranged from 0-270 m, but most were caught at 100-150 m, and the highest catch was at 120 m. In summer, depths were less variable, ranging from 0-110 m, and > 80% were caught at 10-20 m. In autumn, depths ranged from 10-300 m, but most were caught between 20-70 m.

Massachusetts Inshore Trawl Survey

The distribution of longfin inshore squid recruits (≥ 9 cm) in waters off Massachusetts was almost identical to that of pre-recruits, although the overall number of recruits was much lower (Figure 5). Recruits were also found at similar temperatures and depths as pre-recruits (Figure 6). Most were found at 10-13°C and 10-15 m in spring and 16-20°C and 10-30 m in autumn.

Rhode Island Trawl Survey

Longfin inshore squid recruits (≥ 9 cm) were caught during all seasons in Narragansett Bay (Figure 7). Catches were low in winter, increased somewhat in spring, and were highest during summer and autumn. This pattern corresponds to inshore migrations beginning in spring. Recruits were found at depths ranging from 10 to 120 feet (3-37 m) (Figure 8). In winter the few recruits caught were taken at 90-100 feet (27-30 m). In summer and spring they were taken at depths ranging from 10-120 feet (3-37 m), but most were caught at 100-110 feet (30-34 m). In autumn most were caught at 90-100 feet (27-30 m). Recruits were taken at temperatures ranging from 7-26°C (Figure 8). Seasonally they were collected at 7-10°C in winter, from 9-16°C with most at 11°C in spring, from 9-26°C with most at 17-21°C in summer, and from 11-23°C with most at 15°C in autumn.

Connecticut Trawl Survey

Longfin inshore squid were captured from throughout Long Island Sound in surveys conducted from 1992-1997 (Figure 11). A total of 70,930 were captured in all seasons, although they were much less abundant in winter and spring than in summer and autumn. The highest catches occurred in September-October; these were dominated by small squid ranging from about 2 to 12 cm (Gottschall *et al.*, in review). By November, abundance dropped dramatically, most likely due to the migration to offshore overwintering areas.

Squid taken in the surveys ranged from 2-40 cm ML. Recruits dominated the catches in winter and spring and pre-recruits were caught in high numbers in summer and fall (Figure 11). The largest squid were present in May

and June when 65% were adults; by September, most ranged from 4 to 9 cm, and only 1% were 16 cm or greater (Gottschall *et al.*, in review).

Hudson-Raritan Estuary Survey

Longfin inshore squid recruits (≥ 8 cm ML) were captured in the Hudson-Raritan estuary during spring, summer, and fall (Figure 9). They were found mostly in the eastern portion of the bay; the highest catches occurred in summer and autumn. Recruits were collected at temperatures ranging from 9-24°C, but most were at 16-17°C. They were also collected at depths of 15-75 ft (~5-23 m), with most at 50-60 ft (~15-18 m), and salinities of 20-33 ppt, with the highest catch at 30 ppt. They were found at dissolved oxygen levels of 5-10 mg/L, with most at 7-8 mg/L (Figure 10). Longfin inshore squid require oxygen concentrations greater than 4 mg/L (Howell and Simpson 1994).

STATUS OF THE STOCKS

The northwest Atlantic (Cape Hatteras to the Gulf of Maine) commercial landings of longfin inshore squid, *Loligo pealeii*, were 12,459 metric tons (mt) in 1996, a 33% decrease over the 1995 landings of 18,500 mt, and a 45% decrease from the 1994 landings of 22,500 mt (Figure 12; Northeast Fisheries Science Center 1996). Of the 1993 landings of 22,300 mt, 56% were caught in the Middle Atlantic Bight between Hudson Canyon and Baltimore Canyon and 50% were caught in the winter from January through March (Northeast Fisheries Science Center 1996).

Annual landings of *Loligo pealeii* from North Carolina to Maine by the distant water fleet were highest from 1972-1976 with a peak of 37,600 mt in 1973 (Lange 1982). Foreign fishing regulations were enforced in 1977 (MAFMC 1996); during the following three years, landings decreased to an average of 15,000 mt, then increased slightly in 1980-1984, but fell again to 15,000 mt in 1985-1987 (Northeast Fisheries Science Center 1996). Directed foreign fishing was eliminated in 1987 and commercial landings continued to fluctuate throughout the late 1980s and early 1990s. Annual domestic landings of *Loligo* averaged 17,800 mt in 1987-1992 (Brodziak 1995) and were taken primarily in the winter fishery in offshore waters of the New York Bight (Northeast Fisheries Science Center 1996).

Long-term data from the Northeast Fisheries Science Center fall and spring bottom trawl surveys indicate fluctuations in seasonal biomass as well. In the fall, 1973-1976, *Loligo pealeii* stock biomass averaged 62,000 mt (Northeast Fisheries Science Center 1996). The peak of 37,600 mt was landed in the commercial fisheries during this period. Stock biomass in the spring, 1972-1976, was

also above average with estimates of 22,000 mt. However, biomass decreased in the spring and fall, 1977-1982, to 10,000 and 33,000 mt, respectively, and during this time, commercial landings also declined (Northeast Fisheries Science Center 1996). During the next nine years, spring and fall biomass levels remained relatively above average with few periods of low abundance. Throughout 1992-1994, biomass decreased to considerably lower levels than during 1989-1991. Average biomass levels in 1992-1994 were 12,000 mt in spring and 45,000 mt in autumn; the spring 1994 level was almost a record low (Northeast Fisheries Science Center 1996). Stock biomass levels in the fall of 1992 and spring of 1993 were estimated to be 35-50% below the historical average even though the number of pre-recruits per tow was the highest ever in the fall of 1992 (Brodziak 1995). The *Loligo pealeii* stock in the northwest Atlantic from Cape Hatteras to the Gulf of Maine has a medium biomass level that is almost fully exploited (Northeast Fisheries Science Center 1996).

RESEARCH NEEDS

- There is little biological information on the egg and larval stages. There is a need for more information on the location of spawning beds and the movement of larvae.
- More information on growth rates and maturity are needed. For example, Brodziak and Macy (1996) demonstrated that growth rates are exponential, lifespans are less than one year, and spawning occurs throughout the year. More data from geographically and temporally diverse studies are needed to confirm these findings.
- The commercially exploited population from Cape Hatteras to Georges Bank is considered a single stock unit. More information is needed on stock structure, including gene flow and levels of genetic differentiation among geographic areas.

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REFERENCES CITED

- Arnold, J.M., W.C. Summers, D.L. Gilbert, R.S. Manalis, N.W. Daw, and R.J. Lasek. 1974. A guide to laboratory use of the squid, *Loligo pealei*. Marine Biological Laboratory, Woods Hole, MA. 74 p.
- Bigelow, H.B. 1924. Plankton of the offshore waters of the Gulf of Maine. Bull. U.S. Bur. Fish. 40(Part II): 1-509.
- Black, G.A.P., T.W. Rowell, and E.G. Dawe. 1987. Atlas of the biology and distribution of the squids *Illex illecebrosus* and *Loligo pealei* in the northwest Atlantic. Can. Spec. Pub. Fish. Aquat. Sci. 100. 62 p.
- Brodziak, J.T. 1995. Long-finned squid. In Conservation and Utilization Division, Northeast Fisheries Science Center eds. Status of the fishery resources off the northeastern United States for 1994. p. 112-113. NOAA Tech. Mem. NMFS-NE-108.
- Brodziak, J.K.T. and L.C. Hendrickson. 1999. An analysis of environmental effects on survey catches of squids *Loligo pealei* and *Illex illecebrosus* in the northwest Atlantic. Fish. Bull. (U.S.) 97: 9-24.
- Brodziak, J.K.T. and W.K. Macy, III. 1996. Growth of long-finned squid, *Loligo pealei*, in the northwest Atlantic. Fish. Bull. (U.S.) 94: 212-236.
- Cohen, A.C. 1976. The systematics and distribution of *Loligo* (Cephalopoda, Myopsida) in the western North Atlantic, with descriptions of two new species. Malacologia 15: 299-367.
- Dawe, E.G., J.C. Shears, N.E. Balch, and R.K. O'Dor. 1990. Occurrence, size, and sexual maturity of long-finned squid, *Loligo pealei*, at Nova Scotia and Newfoundland, Canada. Can. J. Fish. Aquat. Sci. 47: 1830-1835.
- Gannon, D.P., A.J. Read, J.E. Craddock, K.M. Frstrup, and J.R. Nicolas. 1997. Feeding ecology of long-finned pilot whales, *Glopioccephala melas*, in the western North Atlantic. Mar. Ecol. Prog. Ser. 148: 1-10.
- Goode, G.B. 1884. The fisheries and fishery industries of the United States. Section I: Natural history of useful aquatic animals. Govt. Print. Office, Washington, DC. Plates.
- Gosner, K.L. 1978. A field guide to the Atlantic seashore: Invertebrates and seaweeds of the Atlantic coast from the Bay of Fundy to Cape Hatteras. Houghton Mifflin Company, Boston, MA. 329 p.
- Gottschall, K., M.W. Johnson, and D.G. Simpson. In review. The distribution and size composition of finfish, American lobster, and long-finned squid in Long Island Sound, based on the Connecticut Fisheries Division bottom trawl survey, 1984-1994. NOAA Tech Rep.
- Griswold, C.A. and J. Prezioso. 1981. In-situ observations on reproductive behavior of the long-finned squid, *Loligo pealei*. Fish. Bull. (U.S.) 78: 945-947.
- Haefner, P.A., Jr. 1959. Morphometry and biology of *Loligo pealei* (LeSueur, 1821) and *Lolliguncula brevis* (Blainville, 1823) in Delaware Bay. M.S. thesis, Univ. of Delaware. Newark, DE. 61 p.
- Haefner, P.A., Jr. 1964. Morphometry of the common Atlantic squid, *Loligo pealei*, and the brief squid, *Lolliguncula brevis*, in Delaware Bay. Chesapeake

- Sci. 5: 138-144.
- Howell, P. and D. Simpson. 1994. Abundance of marine resources in relation to dissolved oxygen in Long Island Sound. *Estuaries* 17: 394-402.
- Kier, W.M. 1982. The functional morphology of the musculature of squid (Loliginidae). *Arms and tentacles*. *J. Morph.* 172: 179-192.
- Lange, A.M.T. 1980. The biology and population dynamics of the squids, *Loligo pealei* (LeSueur) and *Illex illecebrosus* (LeSueur), from the northwest Atlantic. M.S. thesis, Univ. of Washington. Seattle, WA. 178 p.
- Lange, A.M.T. 1982. Long-finned squid, *Loligo pealei*. In M.D. Grosslein and T.R. Azarovitz eds. *Fish distribution*. p.133-135. MESA New York Bight Atlas Monograph 15. N.Y. Sea Grant Institute, Albany, NY.
- Lange, A.M.T. and M.P. Sissenwine. 1980. Biological considerations relevant to the management of squid (*Loligo pealei* and *Illex illecebrosus*) of the northwest Atlantic. *Mar. Fish. Rev.* 42(7-8): 23-38.
- Lange, A.M.T. and M.P. Sissenwine. 1983. Squid resources of the northwest Atlantic. In J.F. Caddy ed. *Advances in assessment of the world cephalopod resources*. p. 21-54. FAO Fish. Tech. Pap. No. 231. Food and Agriculture Organization. Rome, Italy.
- Langton, R.W. and R.E. Bowman. 1977. An abridged account of predator-prey interactions for some northwest Atlantic species of fish and squid. U.S. Natl. Mar. Fish. Serv. Northeast Fish. Cent. Woods Hole Lab. Ref. Doc. 77-17.
- Lux, F.E., W.D. Handwork, and W.F. Rathjen. 1974. The potential for an offshore squid fishery in New England. *Mar. Fish. Rev.* 36(12): 24-27.
- Macy, W.K., III. 1980. The ecology of the common squid, *Loligo pealei* (LeSueur 1821), in Rhode Island waters. Ph.D. dissertation, Dalhousie Univ. Halifax, Nova Scotia.
- Macy, W.K., III. 1982. Development and application of an objective method for classifying long-finned squid, *Loligo pealei*, into sexual maturity stages. *Fish. Bull.* (U.S.) 80: 449-459.
- [MAFMC] Mid-Atlantic Fishery Management Council. 1996. Amendment #6 to the Fishery Management Plan and the final environmental impact statement for the Atlantic mackerel, squid, and butterfish fisheries. September 1996. MAFMC. [Dover, DE.]
- Maurer, R. 1975. A preliminary description of some important feeding relationships. *Int. Comm. Northwest Atl. Fish. (ICNAF) Res. Doc.* 75/IX/130.
- Maurer, R.O. and R.E. Bowman. 1985. Food consumption of squids (*Illex illecebrosus* and *Loligo pealei*) off the northeastern United States. *Northwest Atl. Fish. Organ. (NAFO) Sci. Coun. Stud.* 9: 117-124.
- McConathy, D.A., R.T. Hanlon, and R.F. Hixon. 1980. Chromatophore arrangements of hatchling loliginid squids (Cephalopoda, Myopsida). *Malacologia* 19: 279-288.
- McMahon, J.J. and W.C. Summers. 1971. Temperature effects on the developmental rate of squid (*Loligo pealei*) embryos. *Biol. Bull. (Woods Hole)* 141: 561-567.
- Mercer, M.C. 1969. A.T. Cameron Cruise 150, otter-trawl survey of the Mid-Atlantic Bight, August-September 1968. *Can. Fish. Res. Board Tech. Rep. No.* 122. 47 p.
- Mesnil, B. 1977. Growth and life cycle of squid, *Loligo pealei* and *Illex illecebrosus*, from the northwest Atlantic. *Int. Comm. Northwest Atl. Fish. (ICNAF) Sel. Pap. No.* 2: 55-69.
- Nesis, K.N. 1982. *Cephalopods of the world: Squids, cuttlefishes, octopuses, and allies*. T.F.H. Publications, Inc. Neptune City, NJ. 351 p.
- Northeast Fisheries Science Center. 1996. Report of the 21st Northeast Regional Stock Assessment Workshop (21st SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. *North-east Fish. Sci. Cent. Ref. Doc.* 96-05d. 200 p.
- Overholtz, W.J. and G.T. Waring. 1991. Diet composition of pilot whales, *Globicephala* sp. and common dolphins, *Delphinus delphis* in the Mid-Atlantic Bight during spring 1989. *Fish. Bull. (U.S.)* 89: 723-728.
- Rathjen, W.F. 1973. Northwest Atlantic squids. *Mar. Fish. Rev.* 35(12): 20-26.
- Reid, R., F. Almeida, and C. Zetlin. 1999. Essential fish habitat source document: Fishery independent surveys, data sources, and methods. NOAA Tech. Mem. NMFS-NE-122. 39 p.
- Serchuk, F.M. and W.F. Rathjen. 1974. Aspects of the distribution and abundance of the long-finned squid, *Loligo pealei*, between Cape Hatteras and Georges Bank. *Mar. Fish. Rev.* 36(1): 10-17.
- Sissenwine, M.P. and E.W. Bowman. 1978. An analysis of some factors affecting the catchability of fish by bottom trawls. *Int. Comm. Northwest Atl. Fish. (ICNAF) Res. Bull.* 13: 81-87.
- Stevenson, J.A. 1934. On the behavior of the long-finned squid *Loligo pealei* (LeSueur). *Can. Field Nat.* 48: 4-7.
- Summers, W.C. 1968a. The growth and size distribution of current year class *Loligo pealei*. *Biol. Bull. (Woods Hole)* 135: 366-377.
- Summers, W.C. 1968b. Winter distribution of *Loligo pealei* determined by exploratory trawling. *Biol. Bull. (Woods Hole)* 133: 489.
- Summers, W.C. 1969. Winter population of *Loligo pealei* in the Mid-Atlantic Bight. *Biol. Bull. (Woods Hole)* 137: 202-216.
- Summers, W.C. 1971. Age and growth of *Loligo pealei*, a population study of the common Atlantic coast squid. *Biol. Bull. (Woods Hole)* 141: 189-201.
- Summers, W.C. 1983. *Loligo pealei*. In P.R. Boyle ed. *Cephalopod life cycles, Vol. I: Species accounts*. p. 115-142. Academic Press, London, England.

- Tibbetts, A.M. 1977. Squid fisheries (*Loligo pealei* and *Illex illecebrosus*) off the northeastern coast of the United States of America, 1963-1974. Int. Comm. Northwest Atl. Fish. (ICNAF), Sel. Pap. 2: 85-109.
- Vecchione, M. 1981. Aspects of the early life history of *Loligo pealei* (Cephalopoda: Myopsida). J. Shellf. Res. 1: 171-180.
- Vecchione, M., C.F.E. Roper, and M.J. Sweeney. 1989. Marine flora and fauna of the eastern United States Mollusca: Cephalopoda. NOAA Tech. Rep. NMFS 73. 23 p.
- Vinogradov, V.I. and A.S. Noskov. 1979. Feeding of short-finned squid, *Illex illecebrosus*, and long-finned squid, *Loligo pealei*, off Nova Scotia and New England, 1974-75. Int. Comm. Northwest Atl. Fish. (ICNAF), Sel. Pap. 5: 31-36.
- Vovk, A.N. 1972a. Feeding habits of the North American squid, *Loligo pealei* (LeSueur). Trudy Atl. Nauchno-Issled. Inst. Rybn. Khoz. Okeanol., 42: 141-151. Can. Fish. Mar. Serv. Transl. Ser. 3304.
- Vovk, A.N. 1972b. Method of determining maturing stages in gonads of the squid *Loligo pealei*. Zool. Zh 51: 127-132. Can. Fish. Res. Transl. Ser. 2337.
- Vovk, A.N. 1983. Food relations of long-finned squid, *Loligo pealei* (LeSueur), in the northwest Atlantic and its position in the ecosystem. Northwest Atl. Fish. Organ. (NAFO) Sci. Council. Res. Doc. 83(IX/83). 20 p.
- Vovk, A.N. 1985. Feeding spectrum of longfin squid (*Loligo pealei*) in the northwest Atlantic and its position in the ecosystem. Northwest Atl. Fish. Org. (NAFO) Sci. Council. Stud. 8: 33-38.
- Vovk, A.N. and L.A. Khvichiya. 1980. On feeding of long-finned squid (*Loligo pealei*) juveniles in Subareas 5 and 6. Northwest Atl. Fish. Org. (NAFO) Sci. Council. Res. Doc. 80/VI/50. 9 p.
- Waring, G.T., P. Gerrior, P.M. Payne, B.L. Parry, and J.R. Nicolas. 1990. Incidental take of marine mammals in foreign fishery activities off the northeast United States, 1977-1988. Fish. Bull. (U.S.) 88: 347-360.
- Whitaker, J.D. 1978. A contribution to the biology of *Loligo pealei* and *Loligo plei* (Cephalopoda, Myopsida) off the southeastern coast of the United States. M.S. thesis, College of Charleston. Charleston, SC. 164 p.
- Young, R.E. and R.F. Harman. 1988. "Larva," "para-larva," and "subadult" in cephalopod terminology. Malacologia 29: 201-207.

Table 1. Summary of life history and habitat characteristics for longfin inshore squid, *Loligo pealeii*.

Life Stage	Size and Growth	Habitat	Substrate	Temperature	Salinity
Eggs ¹	Incubation time varies with temperature: 26.7 d at 12-18°C, 18.5 d at 15.5-21.3°C, and 10.7 d at 15.5-23.0°C.	Eggs generally in shallow waters, < 50 m.	Egg masses are commonly found on sandy/mud bottom; usually attached to rocks/boulders, pilings, or algae such as <i>Fucus</i> , <i>Ulva lactuca</i> , <i>Laminaria</i> and <i>Porphyra</i> sp.	Eggs found in waters 10-23°C; usually > 8°C. Optimal development at 12°C.	Found at 30-32 ppt.
Larvae ²	Paralarvae range in size from 1.4-15 mm ML (mantle length). Growth rates slower for winter-hatched animals than spring-hatched.	Found in coastal, surface waters in spring, summer and fall. Hatchlings found in surface waters day and night. Move deeper in water column as they grow larger.		Found at 10-26°C (at lower temperatures found at higher salinities).	Found at 31.5-34.0 ppt.
Juveniles ³	Size ranges from approx. 15 mm - 8 cm. At 6-8 cm sexual size dimorphism is evident, before offshore migrations occur. Growth rates of young-of-the-year are 12-38 mm/month.	Inhabit upper 10 m at depths of 50-100 m on continental shelf. Found in coastal inshore waters in spring/fall, offshore in winter. Migrate to surface at night. Ontogenetic descent: at 45 mm, chromatophores are concentrated on dorsal rather than ventral surface, indicating a change from inhabiting surface waters to demersal lifestyle.		Found at 10-26°C (at lower temperatures found at higher salinities). Juveniles prefer warmer bottom temperatures and shallower depths in fall than adults.	Found at 31.5-34.0 ppt.
Adults ⁴	Smallest size at maturity 8 cm ML; most are > 10 cm ML. Males grow faster than females and attain larger sizes; larger sizes at higher latitudes. Growth is rapid, faster in warm months (1.5-2.0 cm/month) than in cold months (0.4-0.6 cm/month). Life span is < 1 year. Maximum size and age are ~50 cm ML, 3 yrs.	Range from Newfoundland south to Cape Hatteras, on continental shelf and upper slope. Most abundant from Gulf of Maine to Hatteras. Mar-Oct: inshore, shallow waters up to 180 m. Winter: offshore deeper waters, up to 400 m on shelf edge. Most abundant at bottom during the day; move upwards at night. Generally found at greater depths and cooler bottom temperatures in the fall than juveniles.	Mud or sandy mud.	Found at surface temperatures ranging from 9-21°C and bottom temperatures ranging from 8-16°C.	

¹ Bigelow (1924), McMahon and Summers (1971), Arnold *et al.* (1974), Griswold and Prezioso (1981), Lange (1982), Summers (1983), Dawe *et al.* (1990)² McMahon and Summers (1971), McConathy *et al.* (1980), Vecchione (1981), Nesis (1982), Vovk (1983), Young and Hartman (1988)³ Summers (1968a, b), Mercer (1969), Macy (1980), Vovk and Khvichiya (1980), Vecchione (1981), Young and Hartman (1988), Brodziak and Henderson (1999)⁴ Haefner (1964), Summers (1968a, b, 1969, 1971, 1983), Rathjen (1973), Lux *et al.* (1974), Serchuk and Rathjen (1974), Cohen (1976), Mesnil (1977), Gosner (1978), Sissenwine and Bowman (1978), Lange (1980, 1982), Lange and Sissenwine (1980), Macy (1980), Nesis (1982), Vecchione *et al.* (1989), Dawe *et al.* (1990), Howell and Simpson (1994), Brodziak and Macy (1996), Brodziak and Henderson (1999)

Table 1. cont'd.

Life Stage	Prey	Predators	Spawning	Notes
<i>Eggs</i> ¹	N/A		Most eggs are spawned in May, hatching occurs in July. Fecundity ranges from 950-15,900 eggs per female.	Eggs are demersal. Enclosed in a gelatinous capsule containing up to 200 eggs. Each female lays 20-30 capsules. Laid in masses made up of hundreds of egg capsules from different females.
<i>Larvae</i> ²	Primary prey are copepods.			"Paralarvae" defined as stage after hatching when cephalopods are pelagic. Tentacles are non-functional at ≤ 15 mm.
<i>Juveniles</i> ³	Primary prey varies with size: < 4.0 cm: plankton, copepods; 4.1-6.0 cm: euphausiids, arrow worms; 6.1-10.0 cm: crabs, polychaetes, shrimp. Cannibalism observed in specimens larger than 5 cm ML (small <i>Illex illecebrosus</i> were found in 49 of 322 <i>Loligo</i> stomachs).	Many pelagic and demersal fish species as well as marine mammals and birds.		Changes in habitat as the squid grows are indicated by changes in the diet.
<i>Adults</i> ⁴	Fish prey includes silver hake, mackerel, herring, menhaden, sand lance, bay anchovy, menhaden, weakfish and silversides. Invertebrate prey include crustaceans (<i>Crangon</i> , <i>Palaemonetes</i> sp.) and squid. 15 cm adults can eat fish up to half their mantle length. At 16-25 cm, consume more fish and less crustaceans as growth increases; > 25 cm, more squid than fish eaten; and > 30 cm, almost exclusively squid.	Predators include many fishes (bluefish, sea bass, mackerel, cod, haddock, pollock, hakes, sea raven, goosefish, flounder, dogfish, angel sharks, skates), pilot whale (<i>Globicephala melas</i>) and common dolphin (<i>Delphinus delphis</i>), and diving birds.	Spawning occurs on Scotian Shelf, Georges Bank, Gulf of Maine and from Nantucket Shoals to Cape Hatteras in shallow waters, 10-90 m, from April-Nov (New England: May-Aug; Bay of Fundy: Aug-Sept). Georges Bank: two broods - early spring and late summer. Spring spawn: hatch in June, mature over winter. Summer spawn: hatch in fall, mature in 2nd winter. Mating occurs during inshore migration in spring. Mortality occurs after first spawning.	<i>Loligo</i> form schools according to size class prior to feeding. Oxygen requirement > 4 ml/l. Larger individuals migrate earlier (April-May) than smaller ones.

¹ Haefner (1959), Summers (1971), Vovk (1972b), Arnold *et al.* (1974), Gosner (1978), Griswold and Prezioso (1981), Lange (1982), Nesis (1982), Lange and Sissenwine (1983)

² Vecchione (1981), Vovk (1983), Young and Hartman (1988)

³ Vovk (1972b, 1985), Tibbetts (1977), Whitaker (1978), Vinogradov and Noskov (1979), Vovk and Khvichiya (1980), Vecchione (1981)

⁴ Stevenson (1934), Summers (1969, 1971), Vovk (1972a, 1985), Rathjen (1973), Maurer (1975), Cohen (1976), Langton and Bowman (1977), Mesnil (1977), Tibbetts (1977), Gosner (1978), Vinogradov and Noskov (1979), Lange (1980, 1982), Lange and Sissenwine (1980, 1983), Macy (1980), Griswold and Prezioso (1981), Kier (1982), Summers (1983), Maurer and Bowman (1985), Dawe *et al.* (1990), Waring *et al.* (1990), Overholtz and Waring (1991), Howell and Simpson (1994), Brodziak and Macy (1996), Gannon *et al.* (1997)

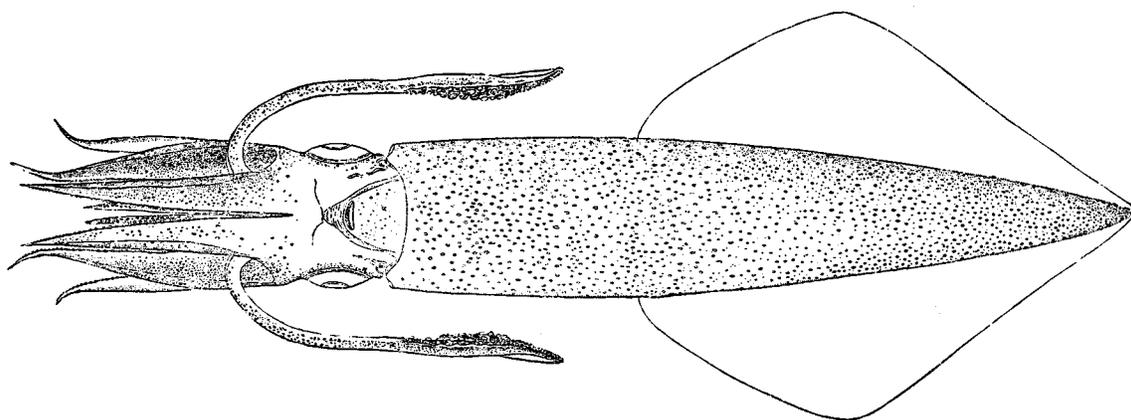


Figure 1. The longfin inshore squid, *Loligo pealeii* (from Goode 1884).

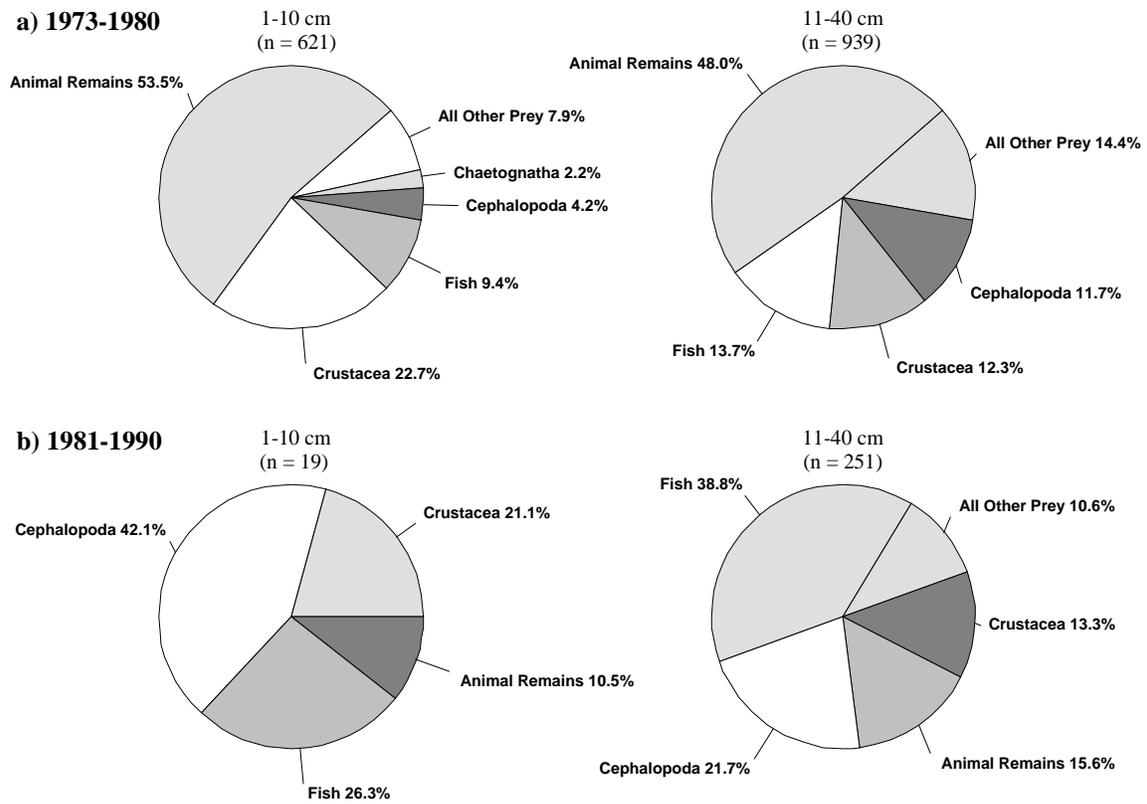


Figure 2. Abundance (percent occurrence) of the major prey items in the diet of longfin inshore squid collected during 1973-1980 and 1981-1990 NEFSC bottom trawl surveys. The 1-10 cm size range corresponds, at least roughly, to pre-recruits or juveniles, and the 11-30 cm size class corresponds to recruits or adults. The category “animal remains” refers to unidentifiable animal matter. Methods for sampling, processing, and analysis of samples differed between the time periods [see Reid *et al.* (1999) for details].

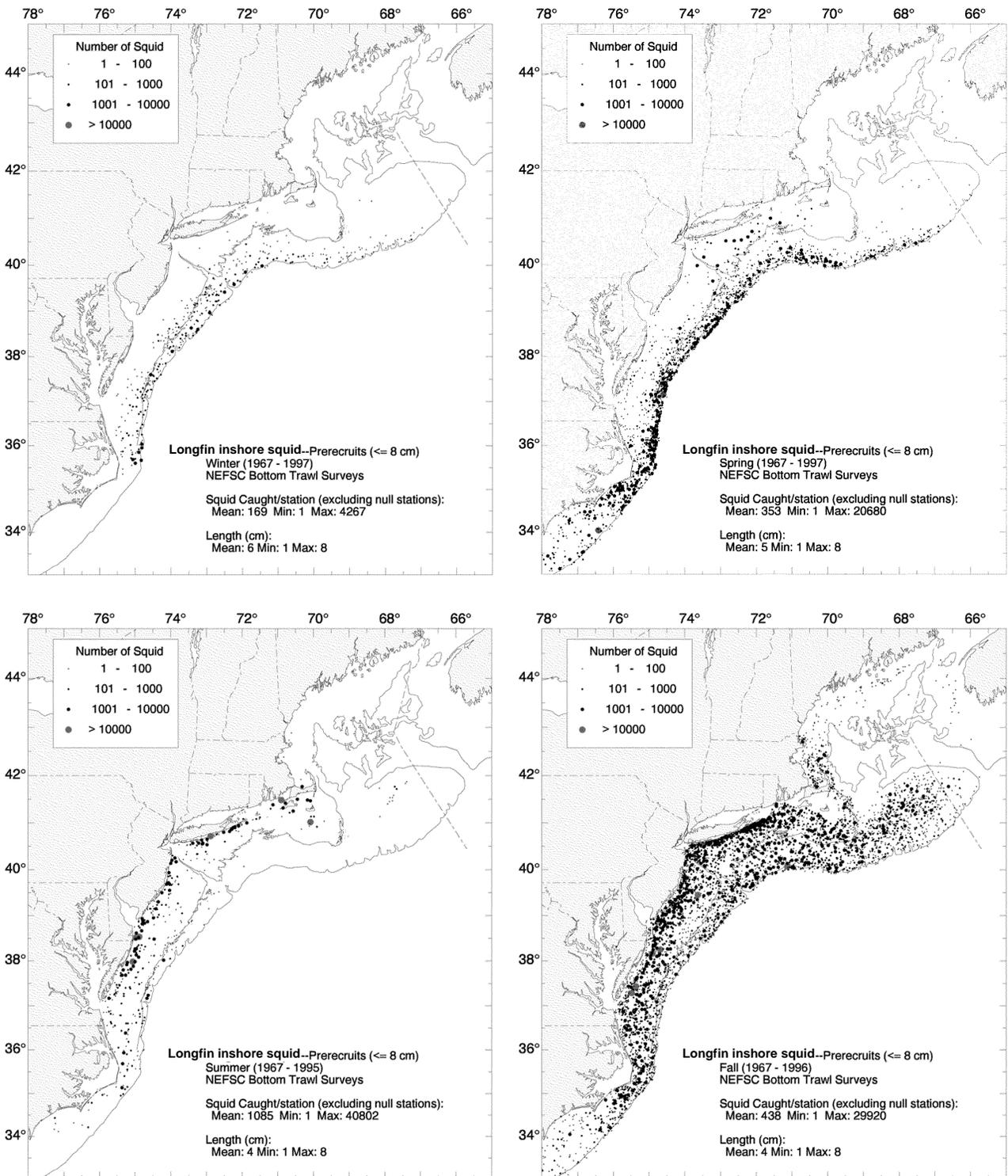


Figure 3. Distribution and abundance of longfin inshore squid pre-recruits (≤ 8 cm) and recruits (≥ 9 cm) collected during NEFSC bottom trawl surveys in winter (1967-1997), spring (1967-1997), summer (1967-1995) and autumn (1967-1996). Densities (number per tow) are represented by dot size [see Reid *et al.* (1999) for details].

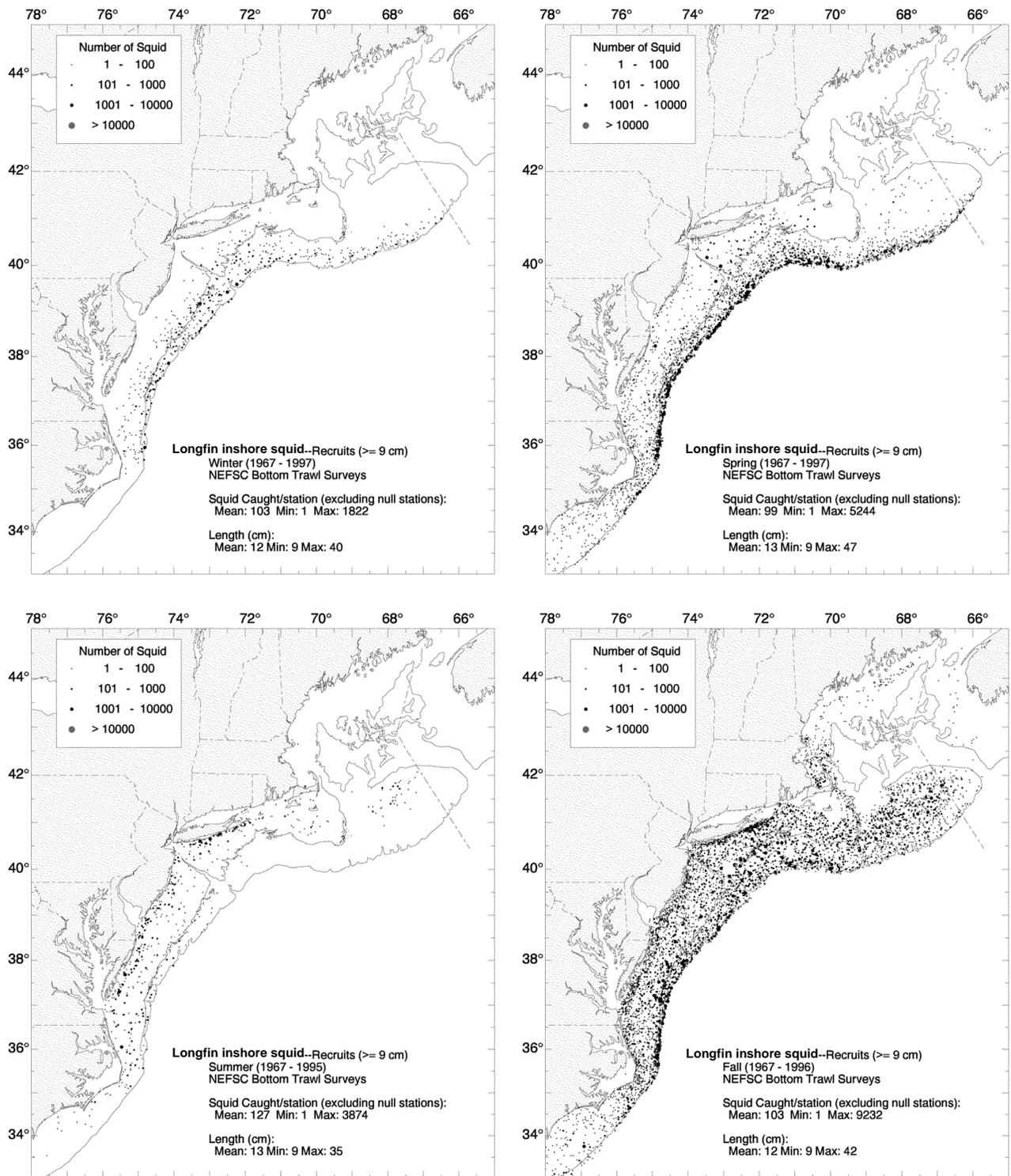


Figure 3. cont'd.

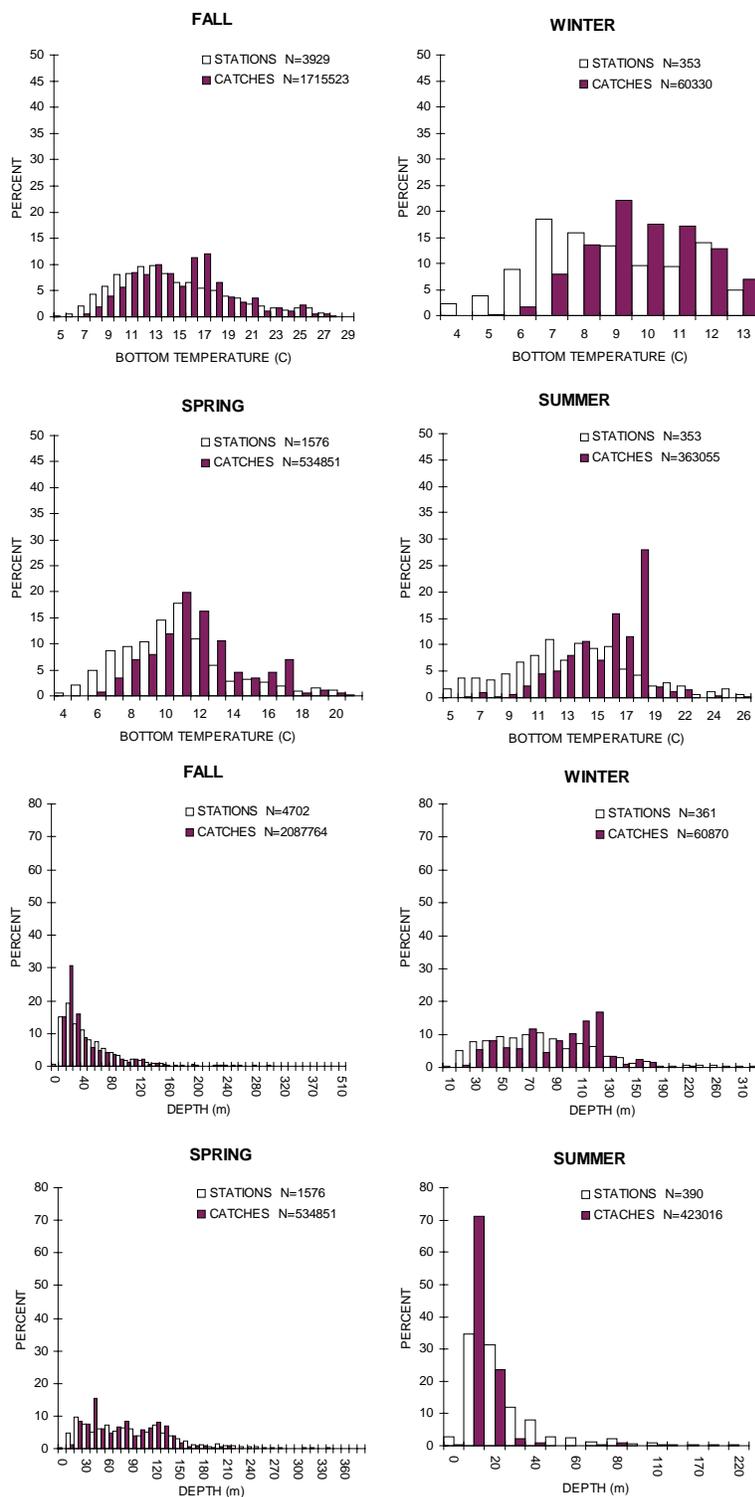
Pre-recruits: ≤ 8 cm ML

Figure 4. Seasonal abundance of longfin inshore squid pre-recruits (≤ 8 cm) and recruits (≥ 9 cm) relative to bottom water temperature and depth based on NEFSC bottom trawl surveys, all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/ 10 m^2).

Recruits: ≥ 9 cm ML

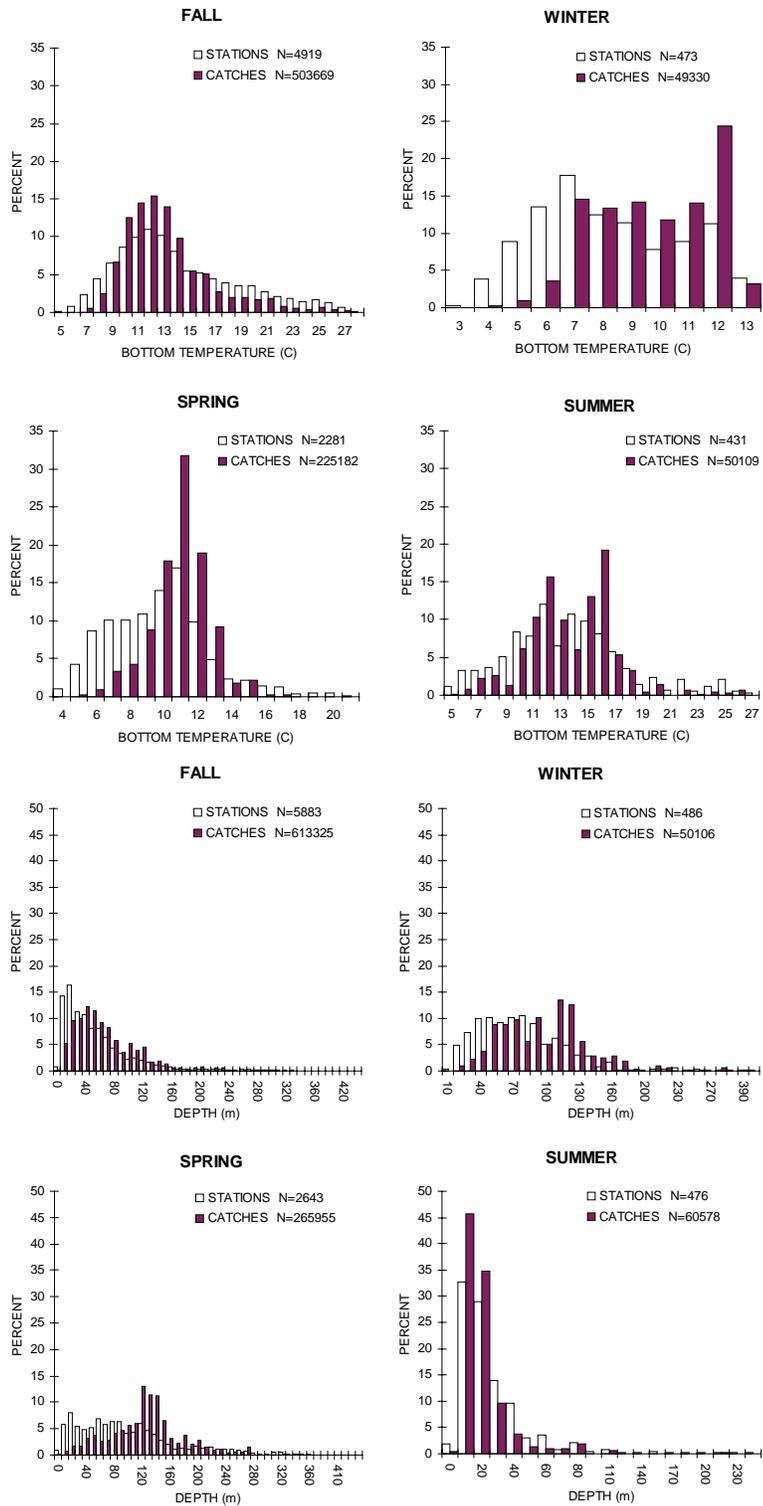


Figure 4. cont'd.

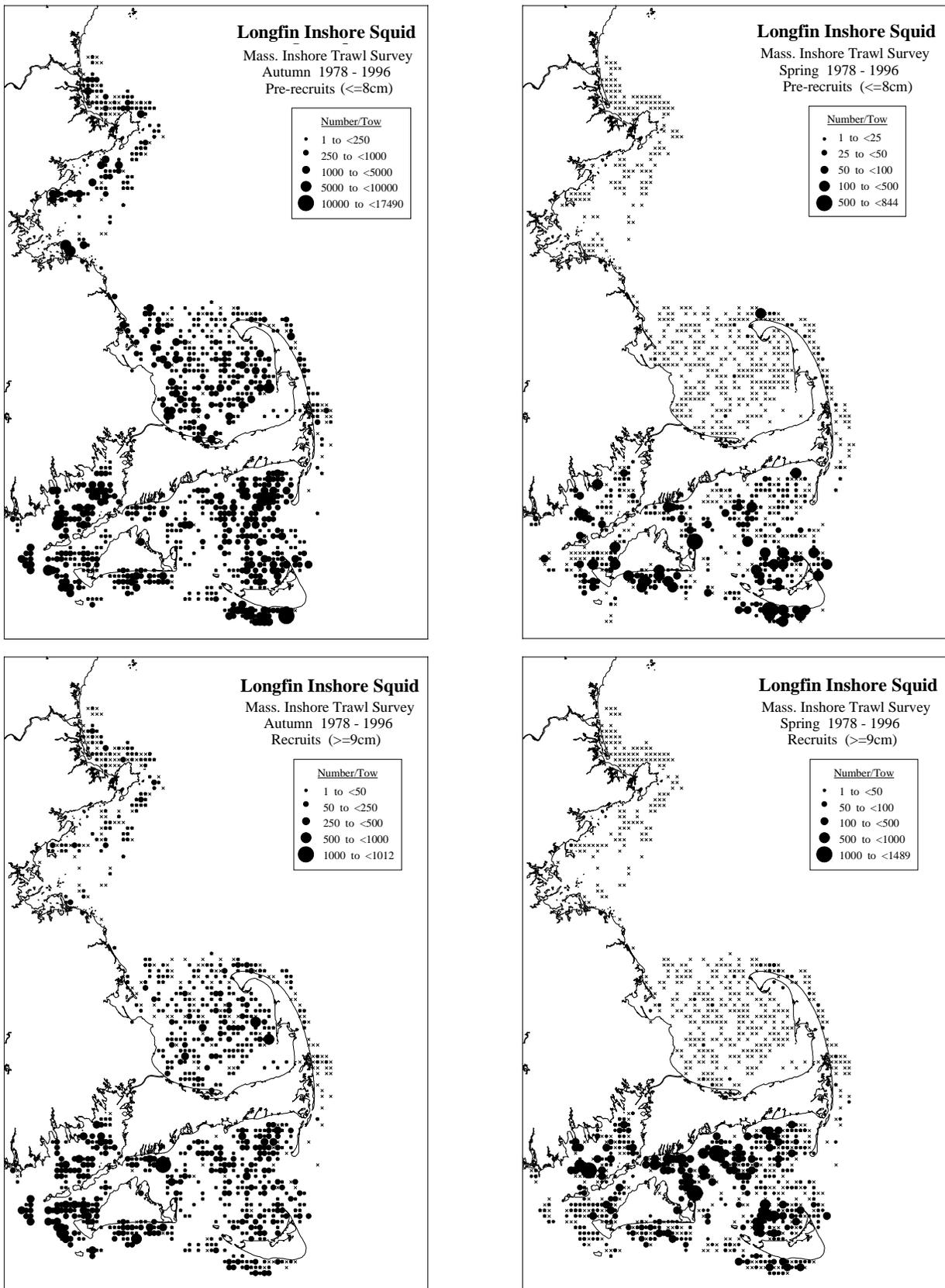


Figure 5. Distribution and abundance of longfin inshore squid pre-recruits (≤ 8 cm) and recruits (≥ 9 cm) in Massachusetts coastal waters during spring and autumn Massachusetts trawl surveys, 1978-1996 [see Reid *et al.* (1999) for details].

Longfin Inshore Squid Mass. Inshore Trawl Surveys

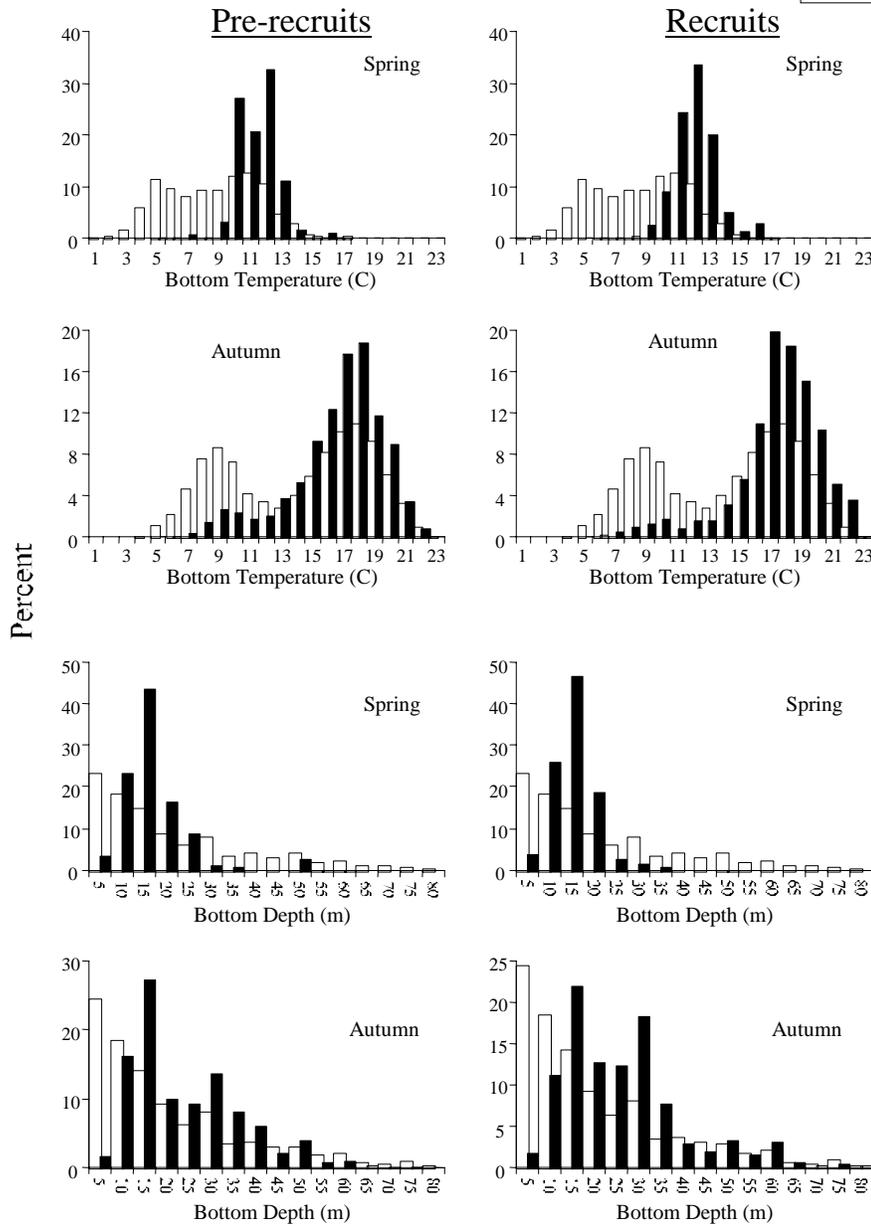
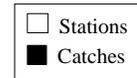


Figure 6. Abundance of longfin inshore squid pre-recruits and recruits relative to bottom water temperature and depth based on Massachusetts inshore bottom trawl surveys (spring and autumn 1978-1996, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m²).

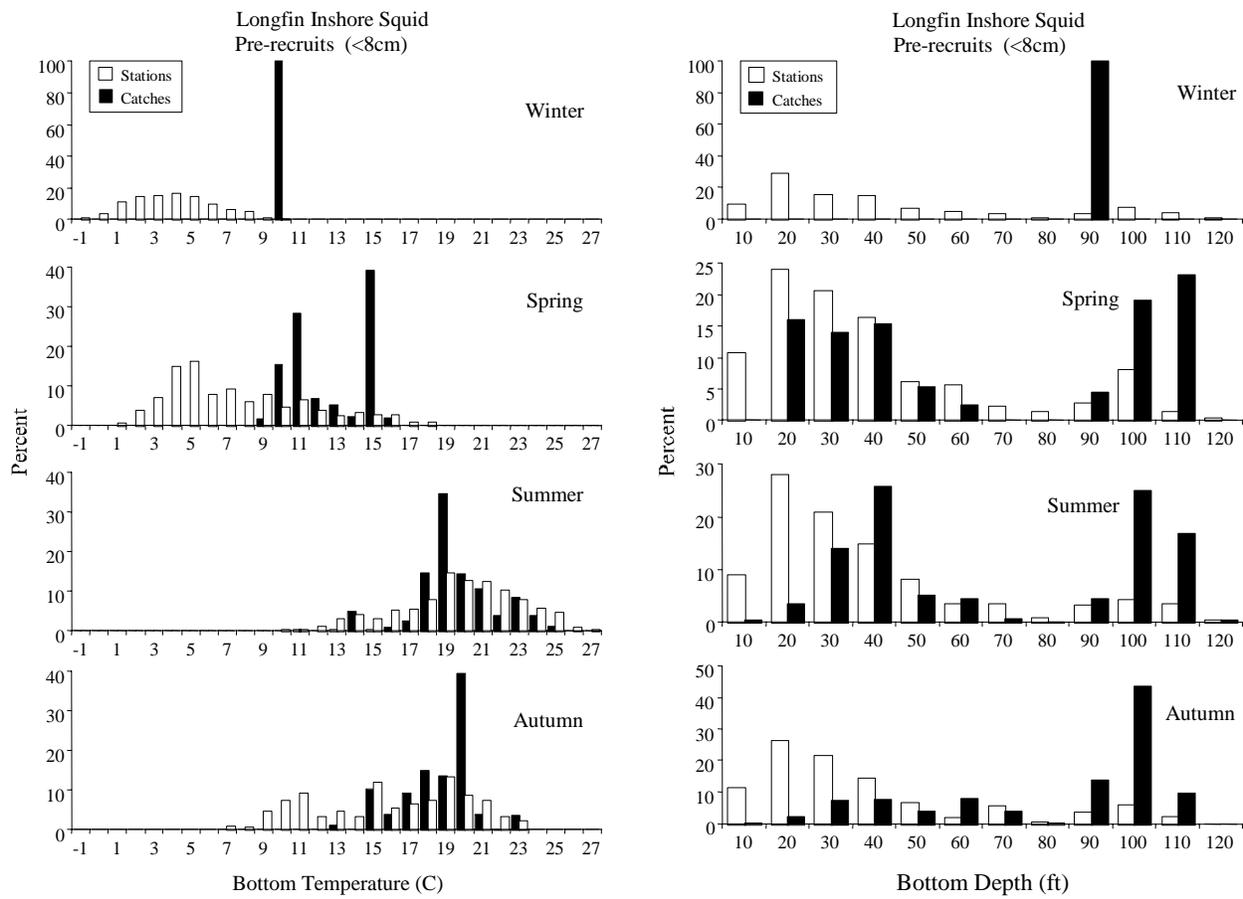


Figure 8. Seasonal abundance of longfin inshore squid pre-recruits (≤ 8 cm) and recruits (≥ 9 cm) relative to mean bottom water temperature and bottom depth from Rhode Island Narragansett Bay trawl surveys, 1990-1996. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all catches.

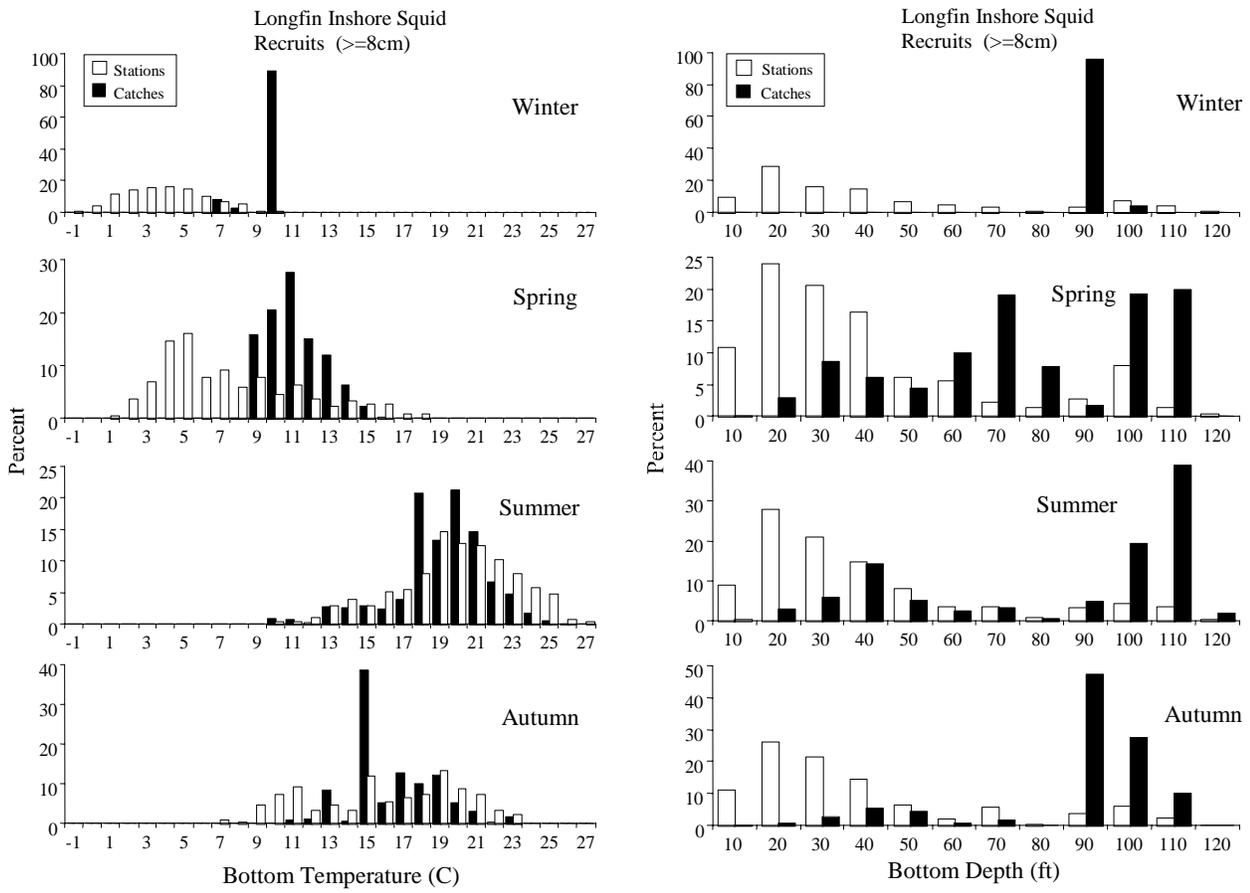


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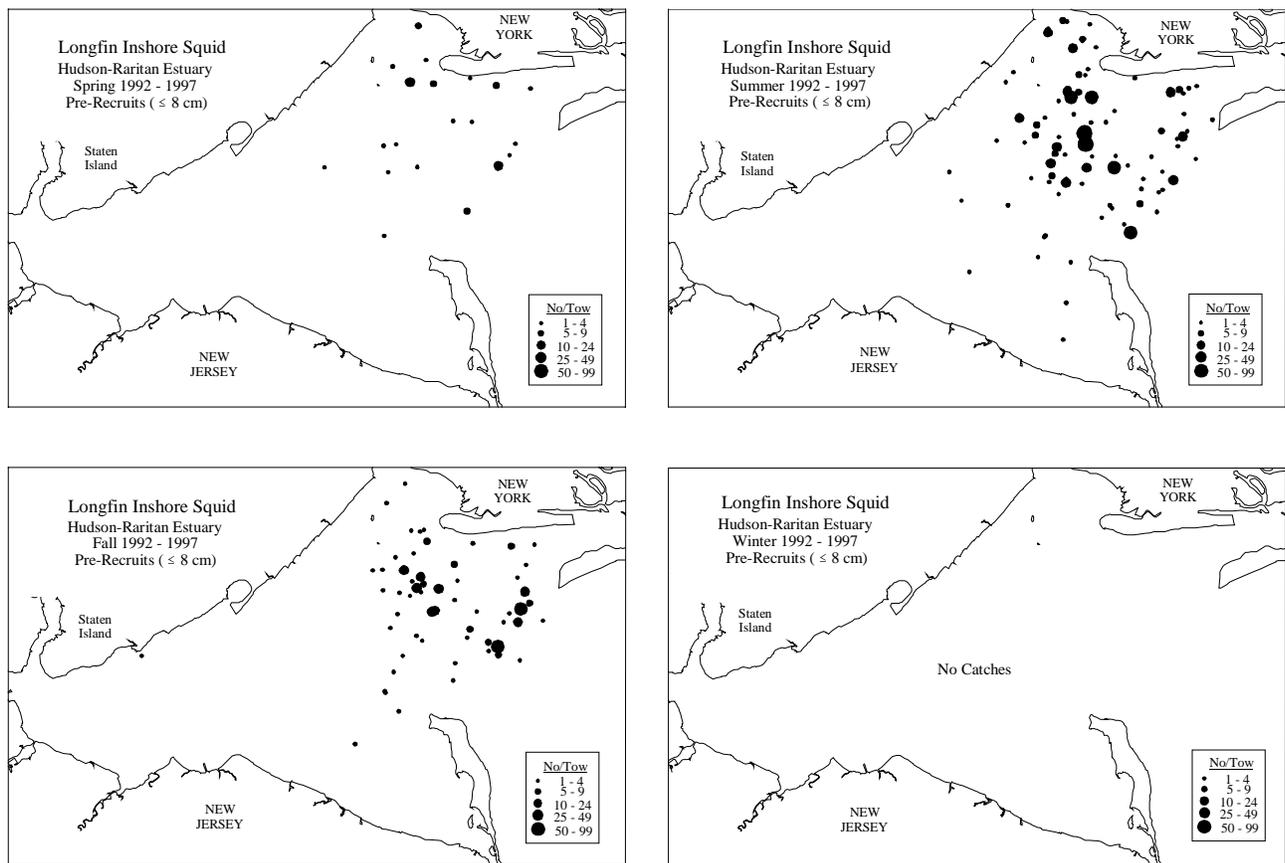


Figure 9. Seasonal distribution and abundance of longfin inshore squid pre-recruits (≤ 8 cm) and recruits (≥ 9 cm) collected in the Hudson-Raritan estuary during NEFSC Hudson-Raritan trawl surveys, 1992 – 1997 [see Reid *et al.* (1999) for details].

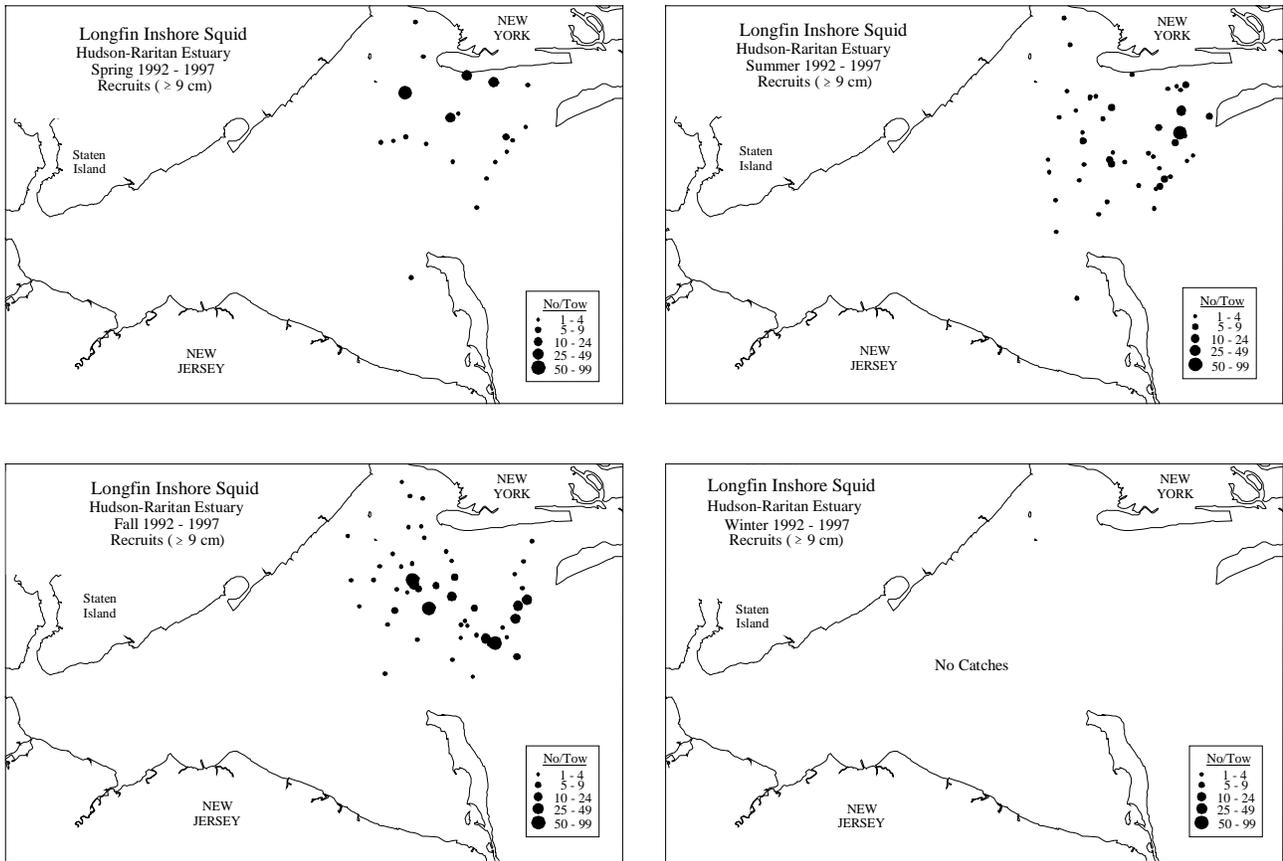


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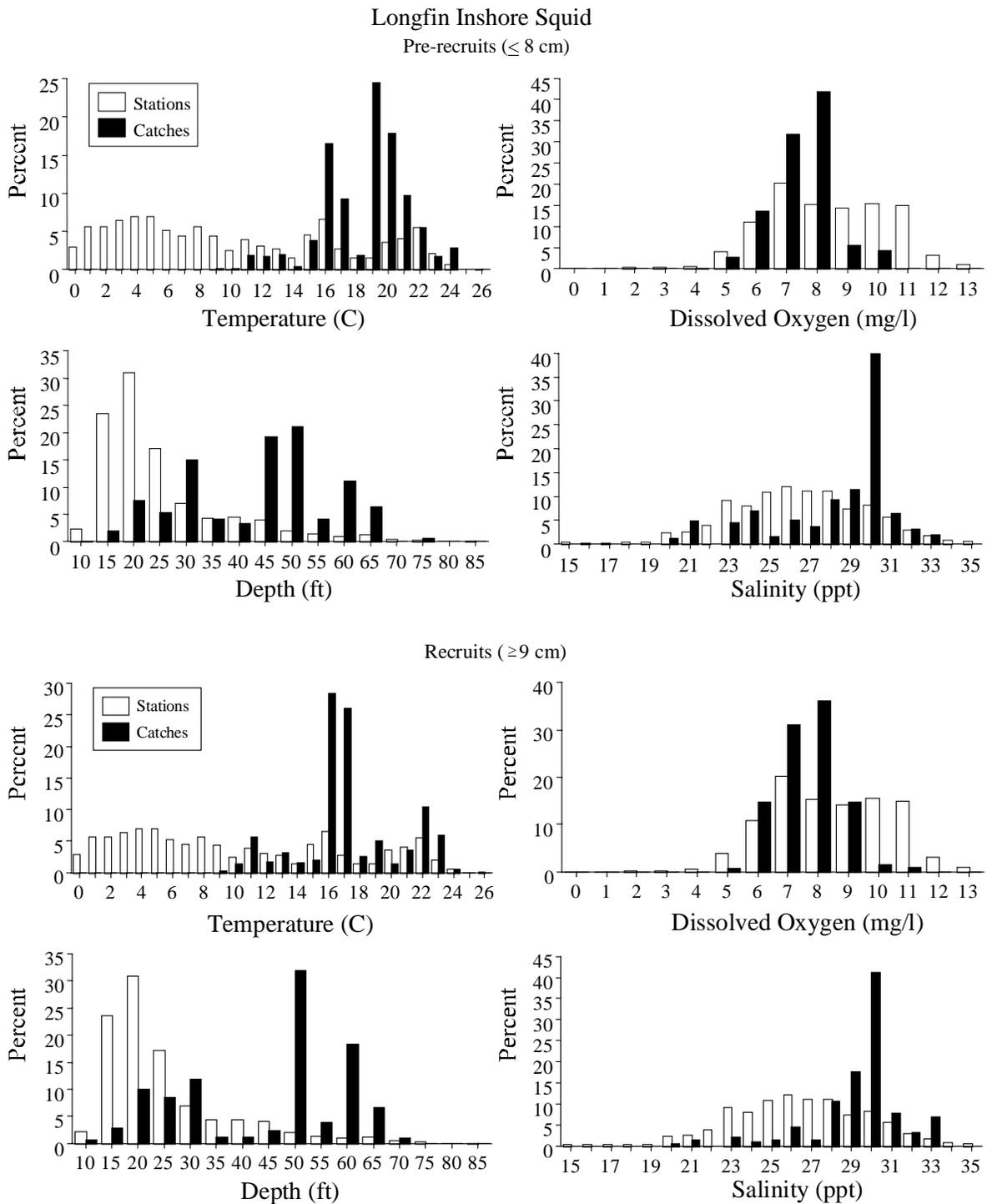


Figure 10. Abundance of longfin inshore squid pre-recruits (≤ 8 cm) and recruits (≥ 9 cm) relative to bottom water temperature, depth, dissolved oxygen, and salinity based on Hudson-Raritan estuary trawl surveys, 1992 – 1997, all seasons and years combined. Open bars represent the proportion of all stations surveyed, solid bars represent the proportion of the sum of all standardized catches.

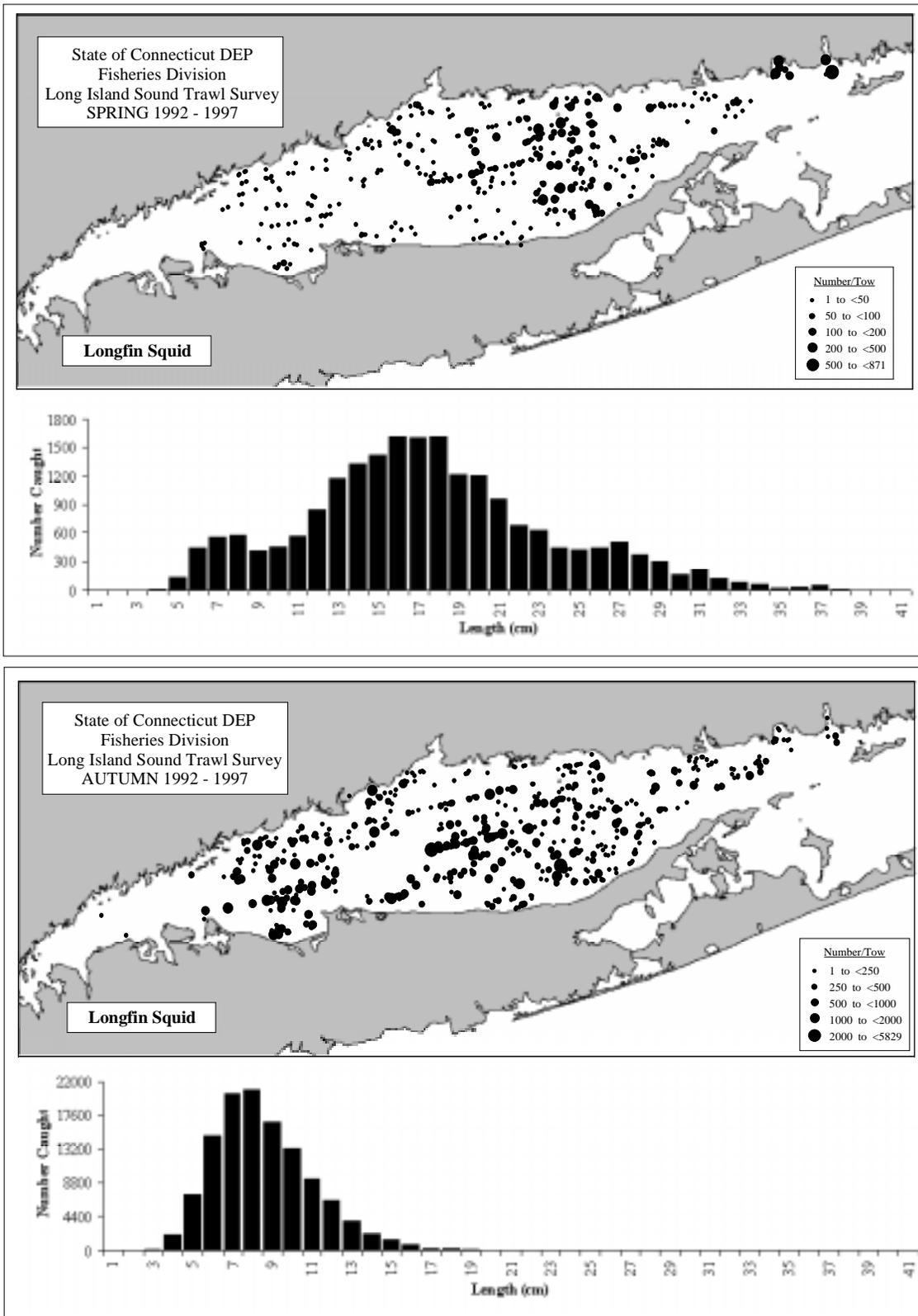


Figure 11. Distribution, abundance, and size frequency distribution of longfin inshore squid captured in Long Island Sound during spring and autumn Connecticut bottom trawl surveys, 1992-1997 [see Reid *et al.* (1999) for details].

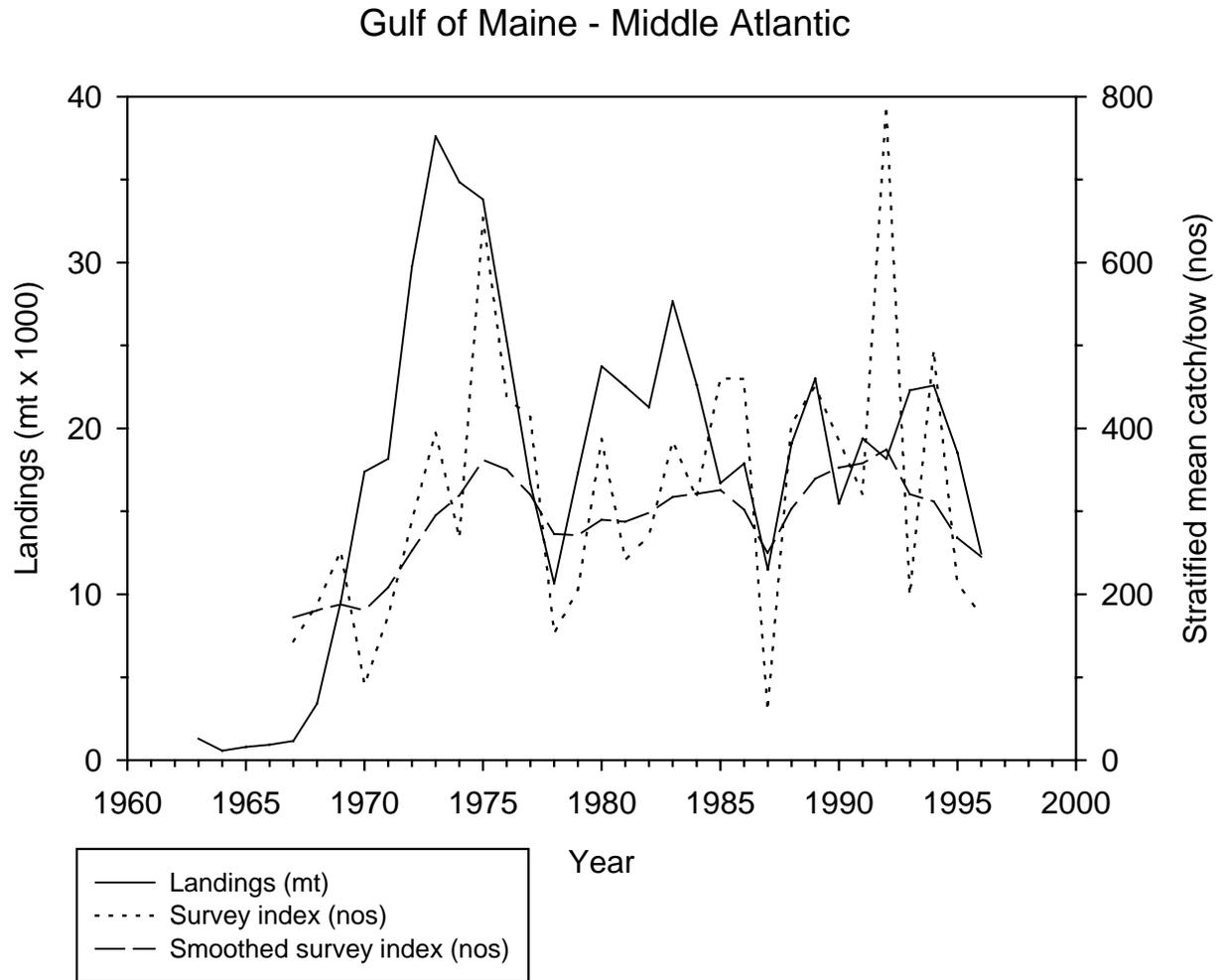


Figure 12. Commercial landings and population abundance indices (from the NEFSC bottom trawl surveys) for longfin inshore squid in the Gulf of Maine and Middle Atlantic Bight, 1963-1996.

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