NOAA Technical Memorandum NMFS-NE-186

Essential Fish Habitat Source Document:

Silver Hake, *Merluccius bilinearis*, Life History and Habitat Characteristics

Second Edition

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

August 2004

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Second Edition

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Editorial Notes on "Essential Fish Habitat Source Documents" Issued in the *NOAA Technical Memorandum NMFS-NE* Series

Editorial Production

For "Essential Fish Habitat Source Documents" issued in the *NOAA Technical Memorandum NMFS-NE* series, staff of the Northeast Fisheries Science Center's (NEFSC's) Ecosystems Processes Division largely assume 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 is performed by, and all credit for such production rightfully belongs to, the staff of the Ecosystems Processes Division.

Internet Availability and Information Updating

Each original issue of an "Essential Fish Habitat Source Document" is published both as a paper copy and as a Web posting. The Web posting, which is in "PDF" format, is available at: *http://www.nefsc.noaa.gov/nefsc/habitat/efh*.

Each issue is updated at least every five years. The updated edition will be published as a Web posting only; the replaced edition(s) will be maintained in an online archive for reference purposes.

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.* 1991a[a], b[b]), mollusks (*i.e.*, Turgeon *et al.* 1998[c]), and decapod crustaceans (*i.e.*, Williams *et al.* 1989[d]), and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals (*i.e.*, Rice 1998[e]). 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[f]; McEachran and Dunn 1998[g]).

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

[b]Robins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991b. World fishes important to North Americans. *Amer. Fish. Soc. Spec. Publ.* 21; 243 p.

[c]Turgeon, 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.

[d]Williams, 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.

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

[f]Cooper, J.A.; Chapleau, F. 1998. Monophyly and interrelationships of the family Pleuronectidae (Pleuronectiformes), with a revised classification. *Fish. Bull. (Washington, DC)* 96:686-726.

[g]McEachran, J.D.; Dunn, K.A. 1998. Phylogenetic analysis of skates, a morphologically conservative clade of elasmobranchs (Chondrichthyes: Rajidae). *Copeia* 1998(2):271-290.

PREFACE TO SECOND EDITION

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 NOAA Fisheries to assist the regional fishery management councils in the implementation of EFH in their respective fishery management plans.

NOAA Fisheries 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 a series EFH species reports (plus one consolidated methods report). The EFH species reports are a survey of the important literature as well as original analyses of fishery-independent data sets from NOAA Fisheries 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 understandably have begun to be referred to as the "EFH source documents."

NOAA Fisheries 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.

The initial series of EFH species source documents were published in 1999 in the *NOAA Technical Memorandum NMFS-NE* series. Updating and review of the EFH components of the councils' Fishery Management Plans is required at least every 5 years by the NOAA Fisheries Guidelines for meeting the Sustainable Fisheries Act/EFH Final Rule. The second editions of these species source documents were written to provide the updated information needed to meet these requirements. The second editions provide new information on life history, geographic distribution, and habitat requirements via recent literature, research, and fishery surveys, and incorporate updated and revised maps and graphs. This second edition of the silver hake EFH source document is based on the original by Wallace W. Morse, Donna L. Johnson, Peter L. Berrien, and Stuart J. Wilk, with a foreword by Jeffrey N. Cross (Morse *et al*. 1999).

Identifying and describing EFH are the first steps in the process of protecting, conserving, and enhancing essential habitats of the managed species. Ultimately, NOAA Fisheries, 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.

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INTRODUCTION

Silver hake, *Merluccius bilinearis* (Figure 1), are distributed on the continental shelf of the northwest Atlantic Ocean from the Gulf of St. Lawrence and the southern edge of the Grand Banks, Newfoundland, Canada (Leim and Scott 1966; Brodziak 2001) to Cape Fear, North Carolina (Karnella 1973) and perhaps as far south as South Carolina (Bolles and Begg 2000). Their presence in the deep waters off the Bahamas reported by Norman (1939) was probably a misidentification of *Merluccius albidus*, the offshore hake. In general, silver hake are abundant from Nova Scotia to New Jersey.

Silver hake are slender, fast swimming gadids with well-developed gill rakers and eyes, strong teeth, and pike-like jaws (Garrison and Link 2000). These demersal fish are often found in dense schools associated with specific hydrographic conditions, prey concentrations, and spawning requirements.

Silver hake are distributed from shallow waters to depths greater than 400 m (Dery 1988; Bolles and Begg 2000). Scotian Shelf silver hake prefer warm bottom water, which extends to depths > 120m on the shelf (Rikhter *et al*. 2001).

STOCK STRUCTURE

In U.S. waters, two stocks of silver hake have been tentatively identified based on morphometric differences. They are managed separately due to differences in exploitation patterns (Garrison and Link 2000). One stock ranges from the Gulf of Maine to northern Georges Bank, while the other stock ranges from southern Georges Bank to Cape Hatteras. Both can be found on Georges Bank during summer months (Brodziak 2001).

Numerous studies using a variety of methods, including morphometrics (Conover *et al*. 1961; Almeida 1987), growth patterns on otoliths (Nichy 1969), serological analyses (Konstantinov and Noskov 1969; Schenk 1981), seasonal distribution patterns (Anderson 1974; Almeida 1987), and growth (Helser 1996), indicate that fish in the Middle Atlantic Bight are distinct from fish in the Gulf of Maine. The line dividing these two stocks occurs somewhere between Nantucket Shoals and the northern edge of Georges Bank. A reevaluation of how the stocks are defined has arisen due to the need for an efficient means of determining levels of stock mixing for fishery assessment and management. Distributions of the two stocks vary seasonally and spatially, most likely in response to temperature and depth (Bolles and Begg 2000). Helser (1996) found that silver hake growth rates differed both between and within the two stocks, a finding that is inconsistent with the stock boundaries currently defined and confounds the delineation of the stocks and the degree to which they mix. Bolles and Begg (2000) report that some level of mixing does occur and is probably due to the wide migratory patterns of silver hake. The degree to which morphological differences between silver hake stocks are caused by environmental or genetic influences is not known.

Although there is uncertainty as to the how the stocks are defined, it has been proven that there are two stocks. Bolles and Begg (2000) confirmed in their study that two stocks exist by using whole otolith morphometrics and growth rates. Their study found the northern stock grew at a slower rate and had larger otoliths than the southern stock. Also, otoliths of the northern stock tended to be longer, wider, and greater in area and perimeter than similar-sized fish from the southern stock. This was probably due to the fact that the northern fish were older and had more time to accumulate otolith material. Although no statistical analyses were used to test her observations, Dery (1988) observed that silver hake otoliths from the northern stock were narrower and thicker in cross-section than those of the southern stock.

Calculating linear discriminate functions of otolith morphometric characteristics for 1-year old silver hake on a yearly basis, differentiated by sex, should provide a level of discrimination not yet seen for silver hake stocks in U.S. waters of the northwest Atlantic and may assist in estimating levels of stock mixing. Whole otolith morphometrics in combination with image processing and discriminant function analysis can provide successful identification of stocks that is essential for assessment and management purposes (Bolles and Begg 2000).

LIFE HISTORY

EGGS

The eggs are pelagic, 0.88-0.95 mm in diameter, drift with the prevailing currents, and hatch in about two days at 20°C.

LARVAE

Newly hatched larvae are pelagic and are about 2.6-3.5 mm long (Fahay 1974, Steves and Cowen 2000). Steves and Cowen (2000) estimate larval duration in the New York Bight at 34.5 days; the larvae are an important constituent of the summer ichthyoplankton. Jeffrey and Taggart (2000) estimate a pelagic existence at 3-5 months for the Scotian Shelf. Their study also provides evidence for larvae inhabiting the upper mixed layer of the Scotian Shelf. When hake reach 17-20 mm long, the larvae descend to the bottom as juveniles. Steves and

Cowen (2000) found larval growth to be slower prior to settlement, indicating that growth potential might be increased by settlement.

JUVENILES AND ADULTS

Steves *et al*. (2000) found that age-0 silver hake (average length 28 mm SL) settled on the outer shelf of the New York Bight mostly during summer and fall, where inferred growth rates were about 15 mm per month; Steves and Cowen (2000) suggest that silver hake experience higher abundance and growth rates when settlement on the shelf occurs in September rather than in October. Steves and Cowen (2000) also found a minimum size of 12.9 mm in samples collected by a beam trawl with a 4 mm mesh size, suggesting that silver hake settle to the bottom at smaller sizes and sooner than originally thought by Fahay (1974), who reported a minimum size of 17-20 mm in otter trawl collections that used a 6.4 mm mesh.

Juvenile and adult silver hake migrate to deeper waters of the continental shelf as water temperatures decline in the autumn and return to shallow waters in spring and summer to spawn. Major spawning areas include the coastal Gulf of Maine, southern and southeastern Georges Bank, and the southern New England area south of Martha's Vineyard. Vinnichenko *et al*. (2001) found that on the Scotian Shelf silver hake were distributed to depths of 150-250 m during spring, moving to depths of 100-150 m during the spawning season. In July, they migrated along the slope to 250 m. According to Rikhter *et al*. (2001), long term studies have shown that such life-cycle stages as over wintering and feeding occur in near bottom slope water. Older hake prefer the warmer waters of the shelf slope and deep-water shelf area.

Silver hake are relatively fast growing, reaching sexual maturity at 2-3 years (20-35 cm), and live a maximum of 14 years, although in recent years fish older than 6 years are rare (Brodziak 2001).

REPRODUCTION

Silver hake eggs and larvae have been collected in all months on the continental shelf in U.S. waters, although the onset of spawning varies regionally (Bigelow and Schroeder 1953; Marak and Colton 1961; Sauskan and Serebryakov 1968; Fahey 1974; Morse *et al*. 1987; Waldron 1988; Berrien and Sibunka 1999). Silver hake spawn over a wide range of temperatures and depths. Rikhter *et al*. (2001) found Scotian Shelf silver hake preferred warm, shallow waters (> 10ºC) at depths of 30-40 m for mass spawning.

Spawning begins in January along the shelf and slope in the Middle Atlantic Bight. During May, spawning proceeds north and east to Georges Bank. By June spawning spreads into the Gulf of Maine and continues to be centered on Georges Bank through summer. In October, spawning is centered in southern New England and by December is observed again along the shelf and slope in the Middle Atlantic Bight. Peak spawning occurs May to June in the southern stock and July to August in the northern stock (Brodziak 2001). Over the U.S. continental shelf, significant numbers of eggs are produced beginning in May. Numbers increase through August and decline rapidly during September and October (Berrien and Sibunka 1999).

According to Koeller *et al*. (1989), spawning on the Scotian Shelf occurs from July to October. Rikhter *et al*. (2001) found similar results; spawning begins by the end of June, approaches a peak in July-August, and finishes in September. They also found summer current patterns define spawning conditions for silver hake of the Scotian Shelf.

Female silver hake are asynchronous spawners that produce and release several batches of eggs during the spawning season (Sauskan and Serebryakov 1968). Up to 3 spawning events may occur within one season (Steves and Cowen 2000).

The primary spawning grounds most likely coincide with concentrations of ripe adults and newly spawned eggs. These grounds occur between Cape Cod, Massachusetts, and Montauk Point, New York (Fahay 1974), on the southern and southeastern slope of Georges Bank (Sauskan 1964) and the area north of Cape cod to Cape Ann, Massachusetts (Bigelow and Schroeder 1953).

AGE AND GROWTH

Studies of age and growth of silver hake in U.S. waters began with Schaefer (1960). Nichy (1969) aged juvenile fish and conducted an age validation study. In an investigation of the effect of stock size on growth of various age classes in the northern Georges Bank-Gulf of Maine stock, Ross and Almeida (1986) and Penntila *et al*. (1989) used von Bertalanffy growth functions to describe growth of the northern and southern stocks. Although Almeida (1978) found faster growth and greater size in the northern stock compared to the southern stock, Bolles and Begg (2000) reported slower growth for the northern stock. The authors also found northern fish to be older.

Helser (1996) made a detailed analysis of the growth of silver hake in four areas of the U.S. continental shelf during 1975-1980, 1982-1987, and 1988-1992. He found significant differences in growth between the Middle Atlantic and southern Georges Bank in all three periods, between northern Georges Bank and the Gulf of

Maine during 1975-1980 and 1982-1987 and between northern and southern Georges Bank during 1982-1987. Growth in the Gulf of Maine was slow on average, but the fish attained the large asymptotic length (k = 0.33, $L\infty$ = 47 cm) compared to the Middle Atlantic Bight (k = 0.51, $L\infty$ = 43 cm). Growth on Georges Bank was intermediate.

Growth analyses on silver hake were conducted based on National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center (NEFSC) survey size-at-age data for the spring and fall surveys. (Brodziak *et al*. 2001). Growth curves were computed for the early 1970s and 1990s to investigate time periods not covered in Helser's (1996) study. Results showed a substantial change in growth between the early 1970s and the 1990s for the northern and southern stock areas and combined stock area. During the early 1970s the average silver hake growth pattern conformed to a von Bertalanffy model, while during the 1990s the average growth pattern was nearly linear with age (Brodziak *et al*. 2001).

Females grow faster and live longer than males. According to Waldron (1992), the majority of the silver hake population after age 5 consists of females, suggesting that mortality on males was high due to cannibalism, predation, or other natural influences. Reported maximum lengths and ages are 34 cm and 6 years for males, and 60-64 cm and 12 years for females (Bigelow and Schroeder 1953; Nichy 1969). Dery (1988) reported maximum lengths and ages of 42 cm and 10 years for males, and 67 cm and 12 years for females. Interestingly, maximum lengths of silver hake collected during the NEFSC bottom trawl survey are 78 cm in spring and 76 cm in autumn. Table 1 lists mean lengths at age to indicate relative size-at-age for 1988-1992 for Gulf of Maine, Middle Atlantic, northern and southern Georges Bank.

Silver hake median length at maturity (i.e., 50% mature) has declined in recent years. Rikhter *et al*. (2001) report Scotian Shelf males reaching 50% maturity at 24 cm and females at 27 cm. Table 2 lists observations of silver hake age and length at maturity.

FOOD HABITS

Silver hake are an important predator species on the continental shelf of the Northwest Atlantic [Garrison and Link (2000); see also Tsou and Collie (2001a, b) for Georges Bank]. Their dominant biomass and high prey consumption affect population dynamics and contribute heavily to the regulation of this ecosystem (Bowman 1984; Garrison and Link 2000). These semi-pelagic predators are nocturnal feeders (Koeller *et al*. 1989) with a predictable diet consisting of fish (80.0%), crustaceans (10.2%), and squid (9.2%) (Bowman 1983). The diet of young silver hake consists of euphausiids, shrimp, amphipods, and decapods (Bowman 1984; Waldron 1992; Sigaev 1995; Steves and Cowen 2000). All silver hake are ravenous piscivores that feed on smaller hake and other schooling fishes such as young herring, mackerel, menhaden, alewives, sand lance, or silversides (Sigaev 1995; Link and Garrison 2002a) as well as crustaceans and squids (Schaefer 1960; Domanevsky and Nozdrin 1963; Dexter 1969; Edwards and Bowman 1979; Bowman 1984; Helser *et al*. 1995; Sigaev 1995; Garrison and Link 2000).

Variations in diet are dependent upon size, sex, season, migration, spawning, and age (Schaefer 1960; Domanevsky and Nozdrin 1963; Dexter 1969; Edwards and Bowman 1979; Bowman 1984; Helser *et al*.; 1995; Sigaev 1995; Garrison and Link 2000; Vinogradov 2000; Link and Garrison 2002a, b). Garrison and Link (2000) concluded that size has the most influence on diet. Silver hake larvae feed on planktonic organisms such as copepod larvae and younger copepodites. Scotian Shelf fish that are 10-40 cm feed mainly on euphausiids, which are an essential part of the hake diet and, according to Vinogradov (2000), important in determining the success of the individual life stages.

Migration results in seasonal and yearly variations in silver hake diet (Garrison and Link 2000). According to Waldron (1992), silver hake diet changes from fish in the spring and autumn to fish, crustaceans, and mollusks during the summer. Small fish 26-55 mm in length were observed to consume more food in October and November, while larger fish 86-115 mm experience increased food consumption by January (Vinogradov 2000). Vinnichenko *et al*. (2001) found feeding was most active during the summer on the Scotian Shelf, with euphausiids and Themisto being the dominant prey. Other prey items include shrimp, fishes, crabs, and squids. There is, however, no rapid shift in the diet of juveniles that can be associated with ontogenetic vertical migration or the critical life history change (Koeller *et al*. 1989).

Rikhter *et al*. (2001) observed increases in pelagic silver hake catches during zooplankton ascent at night and descent in the morning. This leads to the conclusion that diurnal vertical migrations of silver hake are related to diurnal vertical migrations of plankton.

Spawning also influences feeding behavior. Bowman (1984) found that silver hake stomachs contained a greater amount of food before and after spawning. During spawning, about nine times less food was present in hake stomachs compared to the stomachs of other fish. Furthermore, this study determined that depth affects the type and quantity of food consumed by silver hake. (i.e.; fish sampled at deeper depths have less food in their stomachs).

Bowman (1984) determined that male diets have the largest percentage of crustaceans, while female diets have the largest percentage of fish and squid. According to Waldron (1992), crustaceans constitute 48% of the total weight of all prey in the diet of male silver hake. Fish consumption was half that of crustaceans and consisted of mainly myctophids and other silver hake. Crustaceans ranked highest in frequency of occurrence in the diet of female silver hake; however, weight contribution was less for males. Fish prey represented 53% of the female silver hake diet. Females generally consumed twice the amount by weight of fish prey as males. Waldron believes the differences noted between the sexes in prey selection are associated with size. Because females are larger, hence faster, they are able to consume larger, highly mobile prey such as fish and squid. Males on the other hand tend to be smaller at age and therefore concentrate much of their feeding activity on crustaceans, which are abundant and easily obtained. After the age of 5, females constitute over 70% of the silver hake population, so it is expected that the diet of older silver hake will consist of larger prey.

Age-zero silver hake may compete with or prey upon the early life history stages of other commercially important species (Koeller *et al*. 1989; Waldron 1992). The availability of suitable foods is more critical during the juvenile stage than the larval stage and may affect yearclass strength (Koeller *et al*. 1989). Early juvenile stage survival is related to feeding conditions and water temperature, especially during the thermal minimum (Koeller *et al*. 1989; Sigaev 1995; Vinogradov 2000). Sigaev (1995) found silver hake migrated along the warm side of the “shelf/slope” in search of food and were observed to avoid colder areas.

Diet also differs between the northern and southern stocks. The northern stock primarily consumes euphausiids, Atlantic herring, silver hake, and other fish, while the southern stock consumes crangonid shrimp, squids, cephalopods, and sand lance (Garrison and Link 2000). *Illex* sp. and *Loligo* sp. of squid are found in the diet of silver hake that live in southern habitats (Garrison and Link 2000).

Cannibalism is common among silver hake (Koeller *et al*. 1989; Garrison and Link 2000; Tsou and Collie 2001a, b; Link and Garrison 2002a). Conspecific juveniles contribute more than 10% to the adult diet and more than 20% to the total diet (Garrison and Link 2000). According to Tsou and Collie (2001a), cannibalism accounted for more than 50% of predation rates on Georges Bank. Cannibalism is most common in adult silver hake (Garrison and Link 2002a), although it can occur at the early juvenile stage (Koeller *et al*. 1989, Vinogradov 2000). This interaction can be extremely intense, with the potential to limit production (Koeller *et al*. 1989) and regulate the species (Waldron 1992). According to Vinogradov (2000), cannibalism of pelagic young hake seems to increase in years with unfavorable food conditions. For example, when euphausiids are scarce from October to January, cannibalism is significant, contributing 100% to some individual’s diets.

Bowman (1984) studied samples collected from 8 NEFSC Marine Resources Monitoring, Assessment, and Prediction (MARMAP) bottom trawl surveys conducted by NMFS between March 1973 and November 1976. These surveys were concentrated in the Middle Atlantic, Southern New England, and Georges Bank. It was found that 80% of the diet by weight was fish, 10.2% crustaceans, and 9.2% squid. Euphausiids consisted mainly of *Meganyctiphanes norvegica* and *Euphausia.* Decapod groups included Crangonidae (*Crangon septemspinosa* and *Sclerocrangon boreas*), Pandalidae (*Dichelopandalus leptocerus* and *Pandulus borealis*), and Pasiphaedae (*Pasiphaea multidentata*), as well as other unidentifiable decapods which were mostly shrimp. Amphipods present in the stomachs of silver hake were mainly from the Ampeliscidae (*Ampelisca agaxxize, A. spinipes, A. vadorum*, and *Byblis serrata*), Oediceroti-dae (*Manoculodes edwardsi* and *M. intermedius*), and Hyperiidea families. Other crustacean groups included the Mysidacea, Cumacea, and Copepoda. Additional stomach contents that were identified include cephalopods (*Loligo pealei* and *Rossia*), Polychaeta, and miscellaneous organisms such as Echinodermata, and Chaetognatha. The study also found that silver hake measuring less than 20 cm fork length (FL) ate mostly crustaceans, while those that were greater than 20 cm FL ate mostly fish and squid. Silver hake 3-5 cm FL contained the largest percentage of smaller crustacean forms, such as amphipods and copepods. Fish 6-20 cm FL ate decapods, euphausiids, and mysids.

Bowman (1984) found Cephalopoda to be another important prey group of silver hake. Fish in Southern New England ate the largest quantities of squid, 13.7% by weight. Squid comprised 6.7% of the silver hake diet of Georges Bank and 4.3% of the diet for Middle Atlantic. The percentage of euphausiids and squid in the diet tends to increase at deeper bottom depths, while the percent weight of fish in the diet shows a corresponding decrease. The trend is that fish sampled at deeper depths will have less food on average in their stomachs. Availability of prey is probably one of the most important factors in determining what type and how much food silver hake eat.

Waldron (1992) conducted food studies on silver hake age groups 1-9 on the Scotian shelf between 1981-1986. The author found silver hake ages 1-3 primarily fed on invertebrates, while fish older than 3 were piscivorous. Fish comprise more than 50% of the adult silver hake diet. It is believed that this large fish consumption influences population dynamics and may be a limiting factor to the recovery of overexploited stocks (Garrison and Link 2000).

The most frequently occurring prey items were crustaceans, especially the euphausiid *Meganyctiphanes norvegica*. By weight, fish constituted 48% of the diet. Cannibalism was a significant constituent, accounting for 25%, while unidentifiable fish accounted for 15% of the diet

There was a greater consumption of fish and mollusks and a decrease in the presence of crustaceans in the diet of age group 3. Sea cucumbers (Holothuroidea) were present in the diet of this age group, indicating vertical migration. The diet of silver hake less than four years of age primarily consisted of invertebrates, with fish and larger prey entering the diet after age 4. Age group 4 also showed a decrease in crustaceans in the diet and an increase in fish and mollusk consumption. Cannibalism was observed in this age group. For age group 6, fish (especially silver hake) was the single major prey species of total prey consumed. *Illex illecebrosus* was the major invertebrate prey item. Fish dominated age groups 7-9, with crustaceans not as prevalent in the diet of age group 7 and rarely seen in ages 8 and up. It was determined that crustaceans, particularly *M. norvegica*, were an important component in the diet for all ages. Their relative contribution by weight was far greater in ages 1-3. Generally, silver hake ages 4 and older preferred fish and mollusks as prey.

Koeller *et al*. (1989) also conducted diet studies on the Scotian Shelf. In October 1980, studies found that calanoids were the dominant prey items in fish up to 40 mm. The diet of fish larger than 40 mm consisted of larger prey such as amphipods, mysids, euphausiids, and calanoids. Cannibalism was evident in fish as small as 22-25 mm, and comprised 25% of the diet by weight of fish greater than 46 mm. The authors also found evidence for changes in feeding associated with depth. In October of 1980, *Metridia lucens* and *Candacia armata* increased in importance as food items for fish caught in shallow depth zones. This indicated that silver hake were feeding near the bottom, thus they must be distributed near the bottom.

The NEFSC has conducted quantitative food-habits sampling in seasonal surveys from 1973 to the present. The 1973-2001 NEFSC food habits database for silver hake [Figure 2; see Link and Almeida (2000) for details] generally confirms previous studies. Several other studies, such as Garrison and Link (2000) and Tsou and Collie (2001a, b) use the same database, although the years differ. Garrison and Link (2000) found that small (< 20 cm) silver hake consumed large amounts of euphausiids, pandalids, and other shrimp species. The diet of medium sized (20-50 cm) silver hake consisted of fishes, squids, and shrimp taxa. The diet of large (> 50 cm) silver hake consisted of over 50% fish, including Atlantic herring, clupeids, Atlantic mackerel, and other scombrids. A higher proportion of cephalopods, sand lance, and amphipods are present in the diets of silver hake that occupy southern habitats (Southern Atlantic Bight, Mid- Atlantic Bight, Southern New England). Silver hake of northern regions (Gulf of Maine, Georges Bank, Scotian Shelf) prey more heavily on pelagic fishes, euphausiids, and pandalid shrimps. For example, euphausiids make up 25% of the diet for silver hake of the Gulf of Maine and 7.2% for the Middle Atlantic Bight. Atlantic herring comprise 0.2% of the Middle Atlantic Bight diet and 12.9% of the Georges Bank diet. Squids (*Loligo* sp. and cephalopods), sand lance, and butterfish accounted for 5-10% of silver hake diets in the Middle Atlantic Bight and Southern New England compared to less than 1% in the Gulf of Maine and Southwestern Nova Scotian Shelf regions. Sissenwine *et al*. (1984) and Link and Garrison (2002a) also confirm that silver hake is a major piscivore on Georges Bank, with an ontogenetic shift in diet towards increased piscivory (Link and Garrison 2002a).

Tsou and Collie (2001a) used the NMFS food-habits database to identify trophic relationships for silver hake on Georges Bank for years 1978-1992. Based on the NEFSC survey database, silver hake ate the largest prey and had the widest range of prey preference relative to its body weight. It was discovered that more fish were consumed in the autumn with herring being the major prey item during that season. Cannibalism was observed to be especially important to silver hake in the spring. [See also Tsou and Collie (2001b)]. This may be related to the smaller preferred habitat range during this season, as the distribution of the adults and juveniles overlap more during this time, providing a greater opportunity for cannibalism (J. Brodziak, NOAA/NMFS/NEFSC, Woods Hole Laboratory, Woods Hole, MA, pers. comm.).

PREDATORS AND SPECIES ASSOCIATIONS

Silver hake are an important prey for offshore, silver, white, red, and spotted hakes (e.g., Tsou and Collie 2001b). Demersal gadids, pelagic species, and squids also feed upon small hakes (Garrison and Link 2000; Link and Garrison 2002a, b). They are an important food item for fish 76-90 mm, but do not contribute to the diet of fish less than 57 mm (Koeller *et al*. 1989). Larger cod (> 30 cm) consume more silver hake than smaller cod, and silver hake are a large component of cod diet in northern areas (Link and Garrison 2002a, b). Tsou and Collie (2001a) showed that silver hake was the most important prey species in the Georges Bank fish community and was preyed upon by all predators, but especially by cod and other silver hake, which accounted for 20-50% and 30-80% of predation, respectively [see also Tsou and Collie (2001b)]. Silver hake is a significant prey item for elasmobranchs, in particular spiny dogfish, but also skates such as winter skate (Tsou and Collie 2001a; Link *et al*. 2002). Gannon *et al*. (1998) examined stomach contents of harbor porpoises and found that silver hake was a common prey item.

GEOGRAPHICAL DISTRIBUTION

The overall distribution of silver hake is from the Gulf of St. Lawrence to Cape Hatteras (Figure 3). The areas of highest abundance are the southern edge of the Grand Bank, the Scotian Shelf, the Gulf of Maine, Georges Bank, and the Middle Atlantic Bight off Long Island.

EGGS

Silver hake eggs were found throughout the area surveyed during the NEFSC MARMAP ichthyoplankton surveys (Figure 4). They were most abundant in the deeper parts of Georges Bank (> 60 m) and the shelf off southern New England. Eggs were captured in all months of the year. From January to March, eggs occurred in small numbers in the deep waters of the Middle Atlantic Bight. By April, the occurrence of eggs extended eastward along the southern edge of Georges Bank and the total number of eggs increased slightly. During May and June the catches of eggs extended into the shelf and into nearshore waters of the Middle Atlantic Bight and southern New England areas. Some eggs were captured in the western part of the Gulf of Maine. By July and August the center of abundance had shifted east onto Georges Bank with southern New England and the Gulf of Maine continuing to show some catches of eggs. In September and October the occurrences of eggs began to decline with centers of abundance still on Georges Bank and extending into southern New England. Few eggs were captured in November or December, but those that were occurred in deeper waters of the Middle Atlantic Bight.

LARVAE

The individual survey distributions of silver hake larvae from Cape Hatteras, North Carolina to Nova Scotia based on 50 ichthyoplankton surveys in the NEFSC MARMAP series (1977-1984), reveal considerable year-to-year differences in the temporal and spatial patterns of abundance. Centers of abundance in July-September occurred on Georges Bank and in southern New England in 1977, 1978, 1982, and 1983. In 1981 few larvae were found anywhere in the survey area. Only in 1979 and 1980 were significant numbers of larvae encountered in the Gulf of Maine (Morse *et al*. 1987).

The cumulative distribution and abundance of silver hake larvae from all NEFSC MARMAP surveys is shown in Figure 5. The overall pattern of distribution is similar to the distribution of eggs, wherein the center of abundance is on Georges Bank and a secondary center is in the southern New England area. Few larvae were captured from January through March and none in April, but those that were captured occurred in the Middle Atlantic Bight (Figure 5). The low catches reflect the relatively low egg production of silver hake during the early months of the year. During May and June, larvae were abundant in depths from 60-130 m from off Virginia to the southwestern part of Georges Bank. The peak months of larval abundance were July-September and the centers of abundance were in southern New England and on Georges Bank. Distribution of larvae during October to December had shifted to the west from Georges Bank to southern New England and the Middle Atlantic Bight, and abundance had dropped following the decrease in egg production during the late autumn and early winter. Table 3 lists the published reports of the nearshore and estuarine occurrences of silver hake eggs and larvae south of Cape Cod.

JUVENILES

NEFSC bottom trawl surveys [see Reid *et al*. (1999) for details] captured juvenile ($\leq$ 22 cm TL) silver hake year-round and show some of the seasonal on-shore/offshore movements mentioned above. (Figure 6; note that winter and summer distributions are presented as presence/absence data, precluding a discussion of abundances.) In winter, juveniles were found across the shelf in the Middle Atlantic Bight and southern New England areas, along the southern and northern edges of Georges Bank, and scattered throughout the Gulf of Maine. In spring, they were found throughout the survey area, but tended to avoid the shallowest part of Georges Bank. Concentrations occurred in relatively shallow waters in southern New England and in most of the southern and western parts of the Gulf of Maine. In summer, juveniles were found across the shelf in the Middle Atlantic Bight and southern New England areas and along the southern and northern edges of Georges Bank, with concentrations in the Gulf of Maine. By autumn, the distribution of juveniles again covered the shelf. Concentrations occurred in nearshore waters off New Jersey and Long Island, south of Rhode Island, on Georges Bank, and along the coast of Massachusetts and Maine.

Silver hake juveniles (22 cm TL) were caught throughout the Massachusetts trawl survey area [see Reid *et al*. (1999) for details] in spring and autumn, with concentrations off Cape Ann, in Cape Cod Bay, and south of Martha's Vineyard. Light catches were made in Vineyard Sound and Buzzards Bay (Figure 7).

Juvenile silver hake were captured throughout Narragansett Bay in all seasons with the highest average catches of juveniles (~3 hake/tow) occurring in summer (Table 4; Figure 8). In general, low numbers of hake occurred throughout the Bay, with the highest average catches occurring at the ocean station 1. Seasonal length frequencies indicate that juveniles and adults occurred in similar proportions during all seasons except summer, when juveniles dominated the catches.

The distributions and abundances of both juveniles and adults in Long Island Sound (Figures 9-11) as described by Gottschall *et al*. (2000) will be discussed in the Habitat Characteristics section. Silver hake sampled in the survey ranged from 8-38 cm (Figure 10) and were commonly observed in all months, ranging from 27.6% occurrence in September to 72.2% in June (Figure 11D). Abundance peaked in June, dropped in August and September, and increased again in October and November (Figure 11A).

Surveys of the Hudson-Raritan estuary show that juvenile silver hake were found throughout most of the area but were concentrated near the ocean (Figure 12). The highest catches occurred in autumn (Oct.-Dec.). No juveniles were captured in summer (July-Aug.).

The 1988-1999 Virginia Institute of Marine Science (VIMS) trawl surveys of Chesapeake Bay shows that silver hake abundance increases as spring progress, peaking in April and May (Figure 13 [both juveniles and adults]; Geer [2002]). Catches were concentrated in the Bay proper in the deeper waters of the channels (Figure 14; Geer [2002]).

ADULTS

NEFSC bottom trawl surveys [Figure 15; see Reid *et al*. (1999) for details] captured adult (> 22 cm TL) silver hake year round and show some of the seasonal onshore/offshore movements above. (Note that winter and summer distributions are presented as presence/absence data, precluding a discussion of abundances.) In winter, adults were distributed across the shelf in the northern Middle Atlantic Bight and southern New England areas, along the southern and northern edges of Georges Bank, and scattered throughout the Gulf of Maine. In spring they were found throughout the survey area, but tended to avoid the shallowest parts of the Middle Atlantic Bight and Georges Bank. Concentrations occurred in relatively deep waters of the Middle Atlantic, southern New England, along the southern and northern edges of Georges Bank, and in the western part of the Gulf of Maine. In summer, adults were found across the shelf in the Middle Atlantic Bight and southern New England areas and along the southern and northern edges of Georges Bank. By autumn, the distribution of adults again covered the shelf except for the southwestern part of the Middle Atlantic Bight and in the center of Georges Bank. Concentrations occurred south of Rhode Island, on the northern edge of Georges Bank, and most of the Gulf of Maine.

Silver hake adults (> 22 cm TL) were caught throughout the Massachusetts trawl survey area [Figure 16; see Reid *et al*. (1999) for details] in spring and autumn, with concentrations off Cape Ann and in Cape Cod Bay. In spring, there were concentrations south of Martha's Vineyard and light catches made in Vineyard Sound and Buzzards Bay. In autumn, light catches were made south of Martha's Vineyard.

Results of the Rhode Island trawl survey showed that, in general, low numbers of hake occurred throughout Narragansett Bay and the highest average catches were at the ocean station 1 (Figure 8). Adult hakes occurred throughout the bay in small numbers in all seasons. Seasonal length frequencies indicate that juveniles and adults occurred in similar proportions during all seasons except summer, when juveniles dominated the catches.

The distribution and abundance of both adults and juveniles in Long Island Sound were discussed previously (Figures 9-11; Gottschall *et al*. [2000]).

The Hudson-Raritan estuary trawl survey caught a total of just one adult silver hake in January 1995.

The seasonal distribution and abundance of both adults and juveniles in Chesapeake Bay were discussed previously (Figures 13 and 14).

Jury *et al*. (1994) compiled summaries of the occurrence and relative abundance of eggs, larvae, juveniles and adults in estuaries north of Cape Cod. Stone *et al*. (1994) compiled similar data for Cape Cod to Cape Hatteras (Table 5).

MIGRATION

Silver hake migration is triggered by seasonal changes in water temperature. In the spring they begin to move towards shallow and warmer water, where spawning occurs during late spring and early summer (Brodziak 2001; Northeast Fisheries Science Center 2002). They return to deeper water in autumn. During winter, fish in the northern stock move to deep basins of the Gulf of Maine, while fish in the southern stock move to outer continental shelf and slope waters (Brodziak 2001). During the spring and summer, silver hake move into nearshore waters in the Gulf of Maine, to the northern edge of Georges Bank, and northward in the Middle Atlantic Bight. By autumn, they return again to the deeper basins in the Gulf and along the continental slope. Juveniles follow distribution and movement patterns similar to adult silver hake; however centers of abundance for juveniles occur in shallower waters such as inshore along the Middle Atlantic and on the shoals of Georges Bank.

Older or larger fish were found to migrate into broader areas of the shelf, suggesting that nursery habitats are less restrictive than settlement areas. This may be explained by two non-exclusive mechanisms: inshore migration of juveniles, and increased mortality offshore (Steves and Cowen 2000). However, also note that there is some suggestion that there have been changes in the spatial distribution of silver hake by stock area, as is discussed in Brodziak *et al*. (2001).

The Koeller *et al.* (1989) study supports earlier trawl data that discovered the existence of diel and ontogenetic migratory behavior of larvae and juveniles. This study also found that shortly after metamorphosis, silver hake begin a strong diel vertical migration during which they are near or on the bottom by day and throughout the water column at night. Bowman and Bowman (1980) also found this to be true in adults. As stated in the diet section, Sigaev (1995) observed aggregations of silver hake migrated along the warm side of the "shelf/slope" hydrological front in search of food and Rikhter *et al*. (2001) found that diurnal vertical migrations of silver hake are related to diurnal vertical migrations of plankton.

HABITAT CHARACTERISTICS

EGGS

Data from the NEFSC MARMAP ichthyoplankton survey was used to determine the relationships between bottom depth and water temperature in the upper 15 m and silver hake egg abundance (Figure 17). Eggs occurred in relatively deeper water than the stations sampled. The bottom depths where eggs were captured ranged from 10-1250 m, however most eggs were collected between 50-150 m. A shift to shallower shelf waters during late spring is evident (Figure 17); the average depth of egg occurrences declined from about 100 m in spring to about 60 m in summer.

The percent frequencies of stations sampled show an expected annual cycle in water temperatures (Figure 17). The occurrences of eggs show a similar cycle. During March and April when temperatures are coldest, silver hake eggs were found at 5-12°C, the coldest temperatures of the year. As the water warmed in the spring, the occurrences of eggs shifted to warmer waters until summer, when eggs were found mostly between 13 and 20°C. During autumn the waters began to cool and egg occurrences shifted to cooler temperatures of 10-15°C. Peak abundance of eggs occurred from June to September when temperatures were 11-17°C. The large bar in June at 21°C reflects an unusually large catch of eggs (18,908 eggs/10m^2).

The results from the NEFSC MARMAP survey support published observations of depth and temperature occurrences of silver hake eggs (Bigelow and Schroeder 1953; Fahay 1974; Waldron 1988).

In the Middle Atlantic Bight, newly spawned eggs were collected at surface water temperatures between 13°C and 22°C (Fahey 1974). In the Gulf of Maine, Bigelow and Schroeder (1953) reported that spawning temperatures ranged from 5°C to 13°C.

LARVAE

The relationships of bottom depth and water temperature to the abundance of silver hake larvae from the NEFSC MARMAP survey are shown in Figure 18. Larvae occurred in shallower water than eggs and in relatively deeper water than the overall depths of stations sampled. The bottom depths where larvae were captured ranged from 10-1250 m, however most occurred between 50-130 m. The depths of larvae occurrence remained stable throughout most of the year, but a shift to slightly deeper waters occurred during May and June.

The occurrences of larvae in relation to water temperature showed that temperature preference varied in response to the annual warming and cooling cycle (Figure 18). During the months of February and March when temperatures are coldest, larvae were found in the coldest water of the year, with temperatures ranging from 5-12°C. As the water warmed in the spring, the occurrences of larvae shifted to warmer waters until summer when they were found mostly between 10-16°C. During autumn, the waters began to cool, but larvae remained in warmer waters 10-16°C. Peak abundance of larvae occurred from July to October. During these months most larvae were found in temperatures of 11-16°C.

JUVENILES

Silver hake juveniles and adults are found over wide temperature and depth ranges in U.S. continental shelf waters (Table 6). The spring and fall distributions of juvenile silver hake relative to bottom water temperature, depth, and salinity based on 1963-2002 NEFSC bottom trawl surveys from the Gulf of Maine to Cape Hatteras are shown in Figure 19. In spring, they were found in waters between 2-16ºC, with the majority at about 4-8ºC. During that season they were found over a depth range of 1-400 m. Juveniles were found at salinities between 30-36 ppt, with most between 33-34 ppt. During autumn, juvenile silver hake were found over a temperature range of 4-21°C, with most caught roughly between 6-13°C. During this time, they were found over depths ranging from 1-400 m. They were found at salinities ranging from about 32-36 ppt, with the majority between 33-34 ppt.

The spring and autumn distributions of juvenile silver hake in Massachusetts coastal waters relative to bottom water temperature and depth based on 1978-2002

Massachusetts inshore trawl surveys are shown in Figure 20. During the spring, juveniles were found in waters ranging from 1-13°C with the majority spread between 4-6ºC. Their depth range was from 11-85 m, with the majority between 41-60 m. In the autumn they were found in temperatures ranging from 4-18ºC, with most spread between 6-10ºC. Juveniles were found over a depth range of 11-85 m, with the highest percentages found between 41-60 m.

The seasonal distributions of juvenile silver hake relative to bottom water temperature and depth based on 1990-1996 Rhode Island Narragansett Bay trawl surveys are shown in Figure 21. In the winter they were found at temperatures ranging from 3-8ºC, with most at about 7ºC. In the spring they were found in waters ranging from approximately 2-14ºC, with the majority spread between 6-12ºC. During the summer, juveniles where found at temperatures ranging from 10-18ºC, with most at about 10ºC. In the autumn they were found in waters ranging from 7-21ºC, with a large percentage at 17ºC. Juvenile silver hake were found at depths ranging from approximately 20-120 ft in winter, spring, and summer, with the majority found at about 100 ft. During the autumn they were found at depths ranging between 30-80 ft, with most found at 30 ft.

The distributions and abundances of both juvenile and adult silver hake in Long Island Sound from April to November 1984-1994, based on the Connecticut Fisheries Division bottom trawl surveys, are shown in Figures 9-11. The following description of their distributions relative to depth and bottom type is taken verbatim from Gottschall *et al*. (2000).

Silver hake were primarily distributed in the Central and Western Basins (Figure 9). Generally, silver hake abundance was highest over mud bottom with abundance over transitional and sand bottoms ranking second and third respectively (Figure 11B), and abundance tended to increase with depth (Figure 11C). This pattern became more evident through spring as abundance increased, and was very pronounced in summer. During July, a month of high abundance, they were concentrated in depths > 27 m over mud bottom in the two basins. Eight of the nine largest samples observed in July occurred over mud bottom, and seven occurred in depths > 27 m (the other two were between 18-27 m). Although abundance was low in autumn, the distribution of silver hake was similar to summer. In November, when abundance increased again, silver hake were distributed in all depths, although primarily in the northern half of the Central Basin (Gottschall *et al*. 2000).

The distributions of juvenile silver hake relative to bottom water temperature, dissolved oxygen, depth, and salinity based on 1992-1997 NEFSC Hudson-Raritan estuary trawl surveys are shown in Figure 22. Juveniles were found in waters ranging from 1-23ºC, with the majority found at 5ºC and between 20-21ºC. They were found in dissolved oxygen levels of 4-12 mg/L, with most spread between 10-11 mg/L. They were found over a depth range of 15-75 ft, with the highest percentages found between 40-45 ft. Juveniles were found in salinities ranging from 15-33 ppt, with the majority found at 28 ppt.

The hydrographic preferences of both juvenile and adult silver hake in Chesapeake Bay from the 1988-1999 VIMS trawl surveys are shown in Figure 23 (all years and months combined). Geer (2002) states that catches are concentrated in the Bay proper in the deeper waters of the channels at depths > 10 m, and prefer high salinity with nearly 95% of the catch in waters > 24 ppt. Temperature observations indicate a preference for waters < 14ºC.

Auster *et al*. (1997) found that silver hake (1.5-5 cm) in the Middle Atlantic Bight were more abundant on silt-sand bottoms containing amphipod tubes at depths of 55 m. Steves and Cowen (2000) found amphipod tube mats to be associated with 0-group silver hake within the New York Bight. Steves and Cowen (2000) also suggest that early settlement patterns of silver hake are cued to a narrow interaction of temperature and depth, with a subsequent broadening of habitat preference as juveniles grow and local physical regimes shift. Steves *et al*. (2000) found that age-0 silver hake showed some movement in depth between their settlement and nursery areas within the outer shelf of the New York Bight; also, settlement did not peak until bottom temperature was > 9°C.

Auster *et al*. (2003) studied the small scale spatial distributions of both juvenile and adult silver hake within sand wave habitats and the diel patterns of habitat use on the southern side of Georges Bank and on Stellwagon Bank. Silver hake were not randomly distributed within sand wave habitats; there was a positive relationship between fish length and sand wave period. However, other factors, such as currents and available prey, may also influence their distribution in these habitats. Fish were in direct contact with these sand wave habitats with greater frequency during the day, and fish were observed in social or co-operative foraging (polarized groups of fish swimming in linear formation) during the day and at dusk. At one site in the Mid-Atlantic Bight, silver hake (12.6-27.6 cm) were found on flat sand, sand-wave crests, shell and biogenic depressions, but most often on flat sand (Auster *et al*. 1991). Silver hake were associated with particular microhabitats (e.g., sand-wave crests, biogenic depressions) at the 55 m site during the day but were randomly distributed during the night; this may be attributed to diel differences in feeding behavior (Auster *et al*. 1995). At the larger, regional scale within the New York Bight, juveniles showed high variability in abundance between stations in a study by Sullivan *et al*. (2000).

ADULTS

The spring and fall distributions of adult silver hake relative to bottom water temperature, depth, and salinity based on 1963-2002 NEFSC bottom trawl surveys from the Gulf of Maine to Cape Hatteras are shown in Figure 24. In the spring, adult silver hake were found over a temperature range of 2-15°C, with the majority found between 6-12°C. They were found in depths ranging from 11-500 m. Adults were found in salinities ranging from 32-36 ppt with most spread between 33-35 ppt. During the autumn, adults were found over a temperature range of 4-17°C, with greatest percentages between about 7-10°C. In this season, they were found over a depth range of 21-400 m. They were found at a salinity range of between 32-36 ppt, with most between 33-35 ppt.

The spring and autumn distributions of adults in Massachusetts coastal waters relative to bottom water temperature and depth are shown in Figure 25. In the spring, adults were found over a temperature range of 1-13 °C, with a large percentage spread between 4-6ºC. They were found in depths ranging from 11-85 m, the majority found between 31-60 m. During the autumn, adults were found in waters ranging from 4-14ºC, with most found between 6-10ºC. They were found over a depth range of 21-85 m, with a large percentage between 41-60 m.

Overall, it was found that silver hake tend toward warmer water in the spring. In both spring and autumn, temperatures lie will within the preferred temperature range published for this species (Northeast Fisheries Science Center 2002).

The seasonal distributions of adult silver hake relative to bottom water temperature and depth based on 1990-1996 Rhode Island Narragansett Bay trawl surveys are shown in Figure 26. In the winter they were found in waters ranging from 5-10ºC, with a large percentage found at 7ºC. In the spring adults were found in temperatures ranging from 7-14ºC, with the majority found at 14ºC. In the summer they were found at temperatures ranging from 11-16ºC, with about 80% found at 16ºC. In the autumn they were found in waters ranging from 11-20ºC, with the majority spread between 11-15ºC. Adult silver hake were found at depths ranging from approximately 30-120 ft in the winter, spring and autumn, with the largest percentages found between 80-100 ft. In the summer, they were found at depths ranging from 70-100 ft, with about 70% found at 100 ft.

The distributions and abundances of both juvenile and adult silver hake in Long Island Sound relative to depth and bottom type were discussed previously (Figures 9-11; Gottschall *et al*. [2000]).

The hydrographic preferences of both juvenile and adult silver hake in Chesapeake Bay from the 1988-1999 VIMS trawl surveys were discussed previously (Figure 23).

Scott (1982) reported that silver hake on the Scotian Shelf were mostly found at salinities between 33 and 34 ppt, but were captured in salinities ranging from 31-34 ppt. In a large-scale analysis of research bottom trawl surveys on the Scotian Shelf, Scott (1982) found silver hake occurred on all bottom types from gravel to fine silt and clay, but were mainly associated with silts and clays. The areal trends in bottom type on the Scotian Shelf shows coarse sand and gravel is associated with shallow water and finer grain deposits are associated with deeper water. It was also found that the proportion of gravel increases from east to west. Thus, the areal trends in grains size and bottom water temperatures, as well as prey distributions, confound our ability to determine which factors contribute to distribution pattern of silver hake on the Scotian Shelf.

For small scale spatial distributions of both juvenile and adult silver hake within sand wave habitats and the diel patterns of habitat use on Georges Bank, Stellwagon Bank, and the Mid-Atlantic Bight, see the discussion of the Auster *et al*. (1991, 1995, 2003) studies in the juvenile Habitat Characteristics section, above.

Helser and Almeida (1997) performed a detailed analysis of the possible effects of stock abundance, growth, spring water temperatures, and depths on the proportion of silver hake that are mature at age 2 and 3. Population abundance accounted for most of the variation in sexual maturity. Growth in the southern stock accounted for some additional variation. Both catch-weighted water temperature and catch-weighted bottom depth had no statistically significant effect on the proportion mature at age 2 or 3 for the northern stock, or at age 2 for the southern stock. A slight effect was found for the proportion mature at age 3 for the southern stock.

Steves and Cowen (2000) found through age-at-length studies that silver hake growth and abundance is higher in cooler waters of the outer shelf of the New York Bight, possibly due to an interaction between temperature and food availability.

As stated in the food habits section, Bowman (1984) determined that depth affects the type and quantity of food consumed by silver hake (i.e., fish sampled at deeper depths have less food in their stomachs.)

STATUS OF THE STOCKS

Long-term trends in NEFSC fall survey data indicate that the northern stock of silver hake is at a relatively high biomass level, while the southern stock is currently at a relatively low biomass level (New England Fishery Management Council 2003). Figure 27 illustrates trends in the autumn survey biomass index for both stocks. Over time, the biomass index for southern silver hake gradually decreased to levels indicating that the stock was in an overfished condition in the 1990s. The trend has recently reversed, and the 1999-2001 survey average increased above the biomass threshold. The 2001 autumn survey point for southern silver hake was the highest since the mid-1980s, although during 2002, the stock was below its biomass target (-22%), but above its threshold level (+55%) (New England Fishery Management Council 2002, 2003). Both northern and southern stocks of silver hake are not considered to be overfished; however, while the northern stock is considered to be rebuilt, the southern stock has not yet completely rebuilt to its target level after being in an overfished condition during 1998-2000 (New England Fishery Management Council 2003). According to Garrison and Link (2000), silver hake have sustained considerable exploitation in directed fisheries and as incidental catch in otter-trawl fisheries for other groundfish over the last four decades. Foreign exploitation of the southern stock as bycatch in the squid fishery continued until 1987 (Brodziak 2001).

Periods of high (1989-1993) and low abundance (1967-1971) were analyzed for the distribution and relative abundance of juveniles and adults in autumn (Figure 28). The overall distribution of juveniles and adults appears about the same regardless of stock size. The relative abundance is quite different between the two time periods. Much higher catches of juveniles and adults occurred on Georges Bank and particularly in the Gulf of Maine during the period of high abundance.

RESEARCH NEEDS

- Questions remain about the definition of silver hake stocks. Research is needed to define the biological basis of the two (or more) stocks. Seasonal distributions indicate considerable movement of fish across the current stock boundary line on Georges Bank, which raises the question of the degree of intermixing between the stocks. What is currently known is based on results from the late 1970s and early 1980s.
- There is evidence of temporal changes in growth for both stocks (Brodziak *et al*. 2001). The observed temporal differences in growth warrant further investigation.
- The habitat parameters used in this report are location, depth, temperature, and, for Long Island Sound, salinity. A critical parameter is bottom type, which needs to be included in future habitat considerations.
- Little is known about the effects of prey on the distribution of silver hake. Additional food habits analysis is needed to determine the possible relationships between predators and prey and distribution abundance for predicting and managing stock recovery. Analyses of stomach content[s] should be performed on board at each trawling station during surveys. These analyses should include length-frequency measurements and a stomach content index to determine the prevalence of small zooplankton, large zooplankton, and other prey species such as fish.
- There are indications that fine scale (less than shelf wide) habitat characteristics may be important at various times in the life of silver hake. Examples are food and predator abundance during the larval stage, fine-scale bottom structure for small juveniles, and the contribution of estuaries to the success of year classes.
- The settlement needs of silver hake need to be better defined. A change from a completely pelagic existence to one partially demersal may be considered settlement.
- Silver hake fecundity has not been sufficiently researched. The data presently available only allows for a general observation that a high fecundity is typical of this species, similar to other gadoids.

ACKNOWLEDGEMENTS

The authors wish to thank Jason Link of the NEFSC Woods Hole for providing the NEFSC food habits graphs. Barry Shafer and John McCarthy created the NEFSC maps and bar charts. Jon Brodziak of the NEFSC Woods Hole provided reviews and comments.

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Table 1. Mean length (cm) at age (years) in silver hake, *Merluccius bilinearis,* for Gulf of Maine (GM), Middle Atlantic (MA), northern Georges Bank (NGB), and southern Georges Bank (SGB) from samples collected during 1988-1992; based on Helser (1996).

	Area			
Age	**GM**	**MA**	**NGB**	**SGB**
1	12.3	9.1	12.1	11.7
2	22.0	21.2	22.1	21.4
3	28.8	28.7	28.8	27.8
4	33.6	33.5	33.3	31.9
5	37.0	36.4	36.3	34.6
6	39.3	38.2	38.3	36.4
7	41.0	39.4	39.7	37.5
8	42.1	40.1	40.6	38.3
9	43.0	40.5	41.2	38.8
10	43.5	40.8	41.6	39.1
11	43.9	41.0	41.9	39.3
12	44.2	41.1	42.1	39.4

Table 2. Observations of silver hake, *Merluccius bilinearis,* age and length at maturity.

Author	Years	Area	Age (years)	Length (cm)
Bigelow and Schroeder (1953)	1950s	Gulf of Maine	~ 2	
Sauskan (1964)	1962-1964	Georges Bank	2-3	29-33
Morse (1979)	1977	US Shelf		24-26
Beacham (1983)	1960s-1970s	Scotian Shelf	1-2	31 females 1960s; 26 females 1970s
O'Brien *et al.* (1993)	1985-1989	US Shelf	1.6-1.7	22.3-22.7 males 23.1-23.2 females
Helser and Almeida (1997)	1973-1990	US Shelf	2 - 20% mature in 1973 2 - 80% mature in 1990	
Bolles and Begg (2000)	1990	Gulf of Maine-Northern Georges Bank	2	16-24 males 17-28 females
		Southern Georges Bank-Middle Atlantic Bight	2	17-26 males 18-22 females
Brodziak (2001)	1999	Gulf of Maine-Northern Georges Bank	1.7 - A_{50}	22.3 males - L_{50} 23.1 females - L_{50}
		Southern Georges Bank-Middle Atlantic Bight	1.6 - A_{50}	22.7 males - L_{50} 23.2 females - L_{50}
Rikhter *et al*. (2001)	1960s-1997	Scotian Shelf	~ 2 - A_{50}	24 males - L_{50} 27 females - L_{50}

Table 3. Published reports of the nearshore and estuarine occurrences of silver hake, *Merluccius bilinearis,* eggs and larvae from the area south of Cape Cod.

Study	Area and Dates	Eggs	Larvae
Herman (1963)	Narragansett Bay March 1957 - March 1958, weekly sampling	6 eggs July - October. Temperatures 14.8–21.4°C	33 larvae July - October Temperatures 12.0-22.4°C
Bourne and Govoni (1988)	Narragansett Bay, RI June 1972 - August 1973	Listed as present in low numbers	Listed as present in low numbers
Perlmutter (1939)	Salt waters of Long Island, NY 1938	Small numbers off Montauk Point in June & July	37 Larvae (2.6-6.0 mm) from June to September, most in June in Block Island Sound
Merriman and Sclar (1952)	Block Island Sound, RI 1943 – 1946	None	16 larvae (4.0-9.0 mm) July and November
Wheatland (1956)	Long Island Sound March 1952 - March 1954	None	None
Richards (1959)	Long Island Sound 1954 – 1955	None	None
Monteleone (1992)	Great South Bay, NY April 1985 - December 1986	None	None
Dovel (1981)	Hudson River March - December 1972	None	None
Virginia Institute of Marine Science Fisheries Laboratory (1961)	Lower Chesapeake Bay and nearshore ocean December 1959 - December 1960	None	31 larvae (4-21 mm) caught only in the ocean. December - April, June

Table 4. Average number of silver hake, *Merluccius bilinearis,* in Narragansett Bay, per tow by season. From the Rhode Island Division of Fish and Wildlife bottom trawl surveys of Narragansett Bay, 1990 - 1996.

Species	**Juveniles**				**Adults**			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Silver Hake	2.353	0.286	3.031	1.425	1.495	0.449	0.179	0.187

Table 5. Summary of the distribution and abundance of silver hake, *Merluccius bilinearis,* in North Atlantic and Mid-Atlantic estuaries based on Jury *et al.* (1994) and Stone *et al.* (1994).

	Adults			Sp Adults			Juveniles			Larvae			Eggs		
Estuary	T	M	S	T	M	S	T	M	S	T	M	S	T	M	S
Passamaquoddy Bay		**c**	**a**			r		**c**	**a**	*	*	r	*	*	r
Englishman/Machias Bays		c	a			r		c	a	*	*	r	*	*	r
Narragaugus Bay		c	a			r		c	a	*	*	r	*	*	r
Blue Hill Bay		c	a			r		c	a	*	*	r	*	*	r
Penobscot Bay		**c**	**a**			**r**		**c**	**a**	*	*	**r**	*	*	**r**
Muscongus Bay		**c**	**c**			**r**		**c**	**c**	*	*	**r**	*	*	**r**
Damariscotta Bay		**c**	**c**			**r**		**c**	**c**	*	*	**r**	*	*	**r**
Sheepscot Bay		**c**	**a**			**r**		**c**	**c**	*	*	**r**	*	*	**r**
Kennebec/Androscoggin Rivers		**c**	**c**			n		**c**	**c**	*	*	n	*	*	n
Casco Bay		c	c			r		c	c	*	r	c		r	c
Saco Bay		c	c			r		c	c		r	r		r	r
Wells Harbor	nz		r	nz	*		nz		r	nz		r	nz		r
Great Bay			R						r			**r**			**r**
Merrimack River		r	nz			nz		r	nz		r	nz		**R**	nz
Massachusetts Bay	nz	nz	**c**	nz	nz	**c**	nz	nz	**c**	nz	nz	**c**	nz	nz	**c**
Boston Harbor	nz	c	c	nz			nz	c	c	nz	r	c	nz	r	c
Cape Cod Bay	nz	c	c	nz		c	nz	c	c	nz	r	c	nz	r	c
Waquoit Bay	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Buzzards Bay	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Narragansett Bay	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Connecticut River	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Gardiners Bay	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Long Island Sound	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Great South Bay	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Hudson River/Raritan Bay	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Barnegat Bay	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
New Jersey Inland Bays	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Delaware Bay	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Delaware Inland Bays	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Chincoteague Bay	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Chesapeake Bay mainstream	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Chester River	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Choptank River	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Patuxent River	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Potomac River	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Tangier/Pocomoke Sounds	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Rappahannock River	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
York River	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
James River	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n

Relative Abundance
h = Highly abundant, a = abundant,
c = common, r = rare, blank = not present,
n = no data presented, * = no data available,
nz = particular zone not present

Data Reliability for Life Stages
Highly Certain = Bold and Underlined Text
Moderately Certain = Bold Text
Reasonable Inference = Normal Text

Tidal Zones
T = Tidal Fresh 0.0-0.5 ppt
M= Mixing Zone 0.5-25 ppt
S = Seawater Zone > 25 ppt

Table 6. Published observations about silver hake, *Merluccius bilinearis*: bottom water temperature, depth distributions, and preferences.

Author	Area	Temperature (°C)		Depth (m)	
		Range	Preference	Range	Preference
Bigelow and Schroeder (1953)	Gulf of Maine	4-18	> 6	tide line - > 700	
Domanevsky and Nozdrin (1963)	Southeast Georges Bank		9-11		90-110
Sauskan (1964)	Georges Bank; 1962-1963	6-12	10-12: ripe adults, 6-10: post spawn		85-200 spring 40-110 summer
Fritz (1965)	Continental Shelf, NJ to Nova Scotia; Autumn, 1955-1961	3.9-19.4	6-12	30-410	70-210
Sarnits and Sauskan (1967)	Georges Bank 1964		7-8		140-230
Edwards (1965)	Southern New England		> 9		
Scott (1982)	Eastern Gulf of Maine	1-13	7-10	15 - > 200 fathoms	80-89 fathoms
Bowman (1984)	Northwest Atlantic 1973-1976			38-110	
Almeida (1987)	U.S Continental Shelf			Adults: inshore - 400	
Murawski and Finn (1988)	Georges Bank		Winter: 5.97 Spring: 8.45 Summer: 8.95 Autumn: 8.42		Winter: 208 Spring: 186 Summer: 97 Autumn: 163
Murawski (1993)	U.S. Continental Shelf		Spring: 6.76 Summer: 8.03 Autumn: 10.00		Spring: 186 Summer: 97 Autumn: 163
Sigaev (1995)	Scotian Shelf 1990	< 1-10.5	7-10.5		200
Helser and Almeida (1997)	U.S. Continental Shelf	5.5-10.5 most	> 8.0 southern Stock	50-150 most	> 80 southern Stock
Gottschall *et al*. (2000)	Long Island Sound			> 27 most	
Steves and Cowen (2000)	New York Bight Continental Shelf 1996-1997	0-25	8-10	0-200	60-100

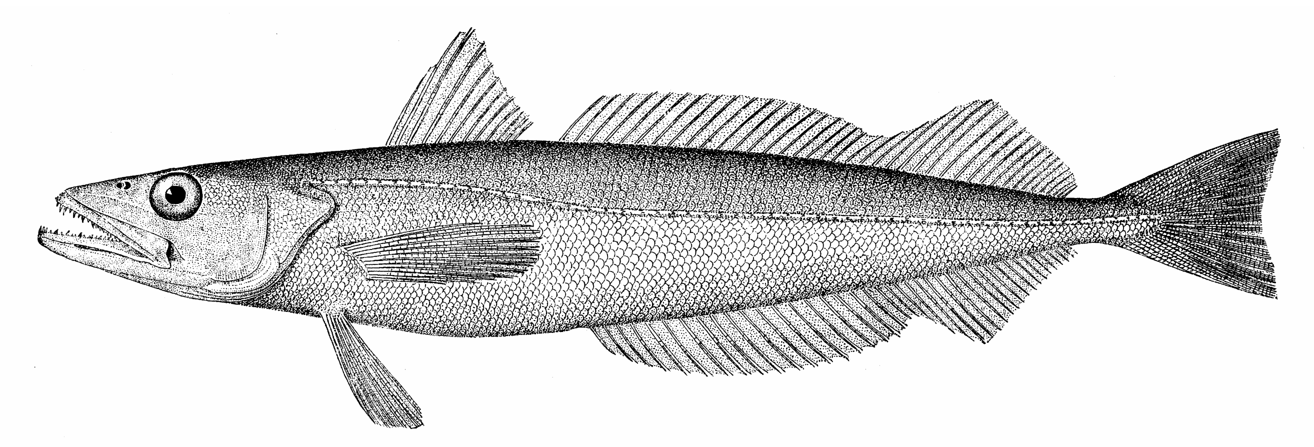


Figure 1. The silver hake, *Merluccius bilinearis* (Mitchell) (from Goode 1884).

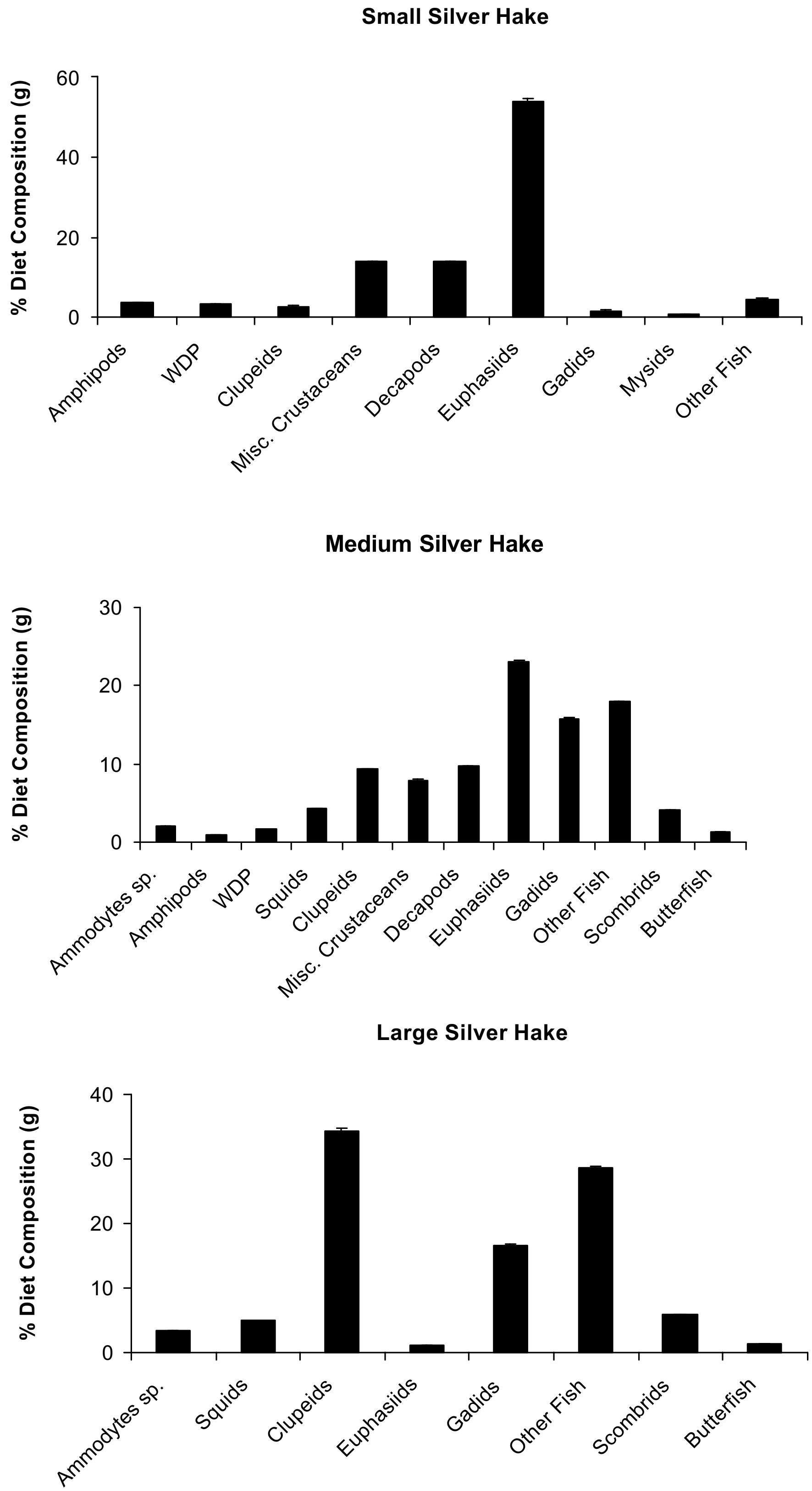
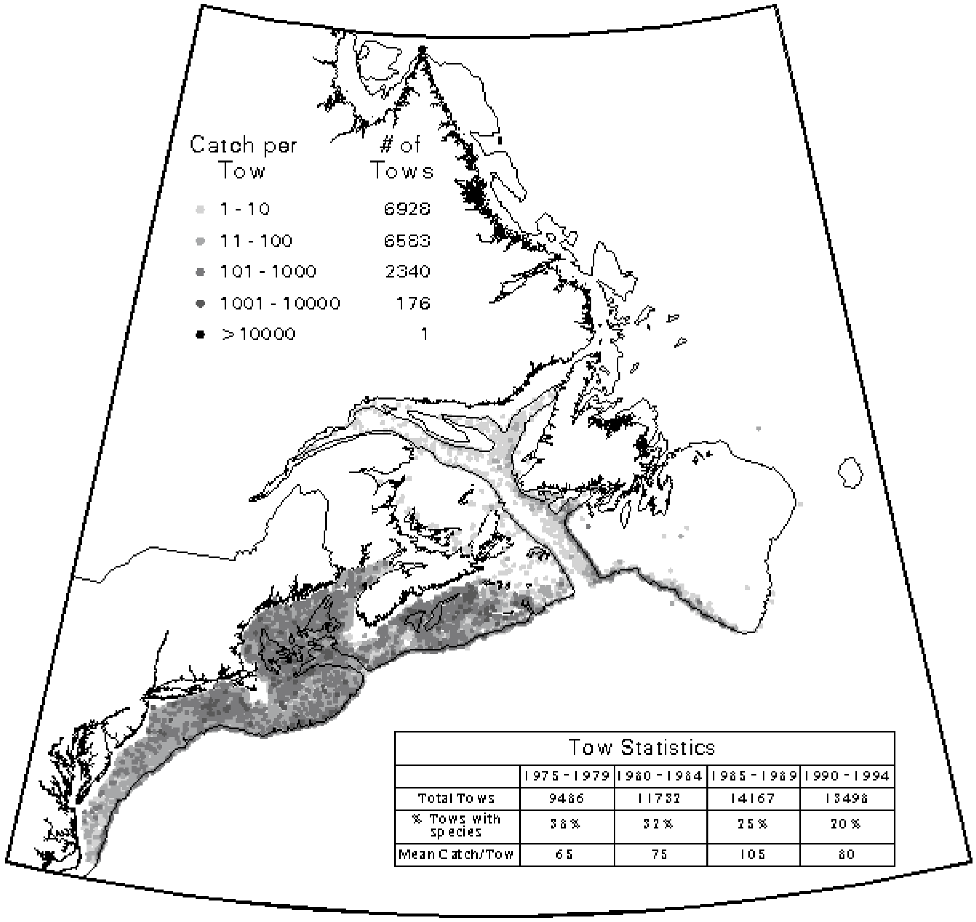


Figure 2. Percent of diet by weight of the major prey items in the diet of three size categories of silver hake collected during NEFSC bottom trawl surveys from 1973-2001 (all seasons). Size categories of silver hake are small: ≤ 20 cm; medium: > 20 cm and ≤ 40 cm; and large: > 40 cm. The category “WDP” refers to well-digested prey. For details on NEFSC diet analysis, see Link and Almeida (2000).



	1975 - 1979	1980 - 1984	1985 - 1989	1990 - 1994
Total Tows	9486	11732	14167	13498
% Tows with species	38 %	32 %	25 %	20 %
Mean Catch/Tow	65	75	105	80

Figure 3. Overall distribution of silver hake in the northwest Atlantic Ocean during 1975-1994. Data are from the U.S. NOAA/Canada DFO East Coast of North America Strategic Assessment Project (http://www-rca.nos.noaa.gov/projects/ecnasap/ecnasap_table1.html). Note that data for these plots came from trawl surveys, and the surveys did not use the same sampling gear. The Canadian and U.S. trawl surveys have catchabilities on the same order of magnitude, but they do differ enough to warrant cautious interpretation.

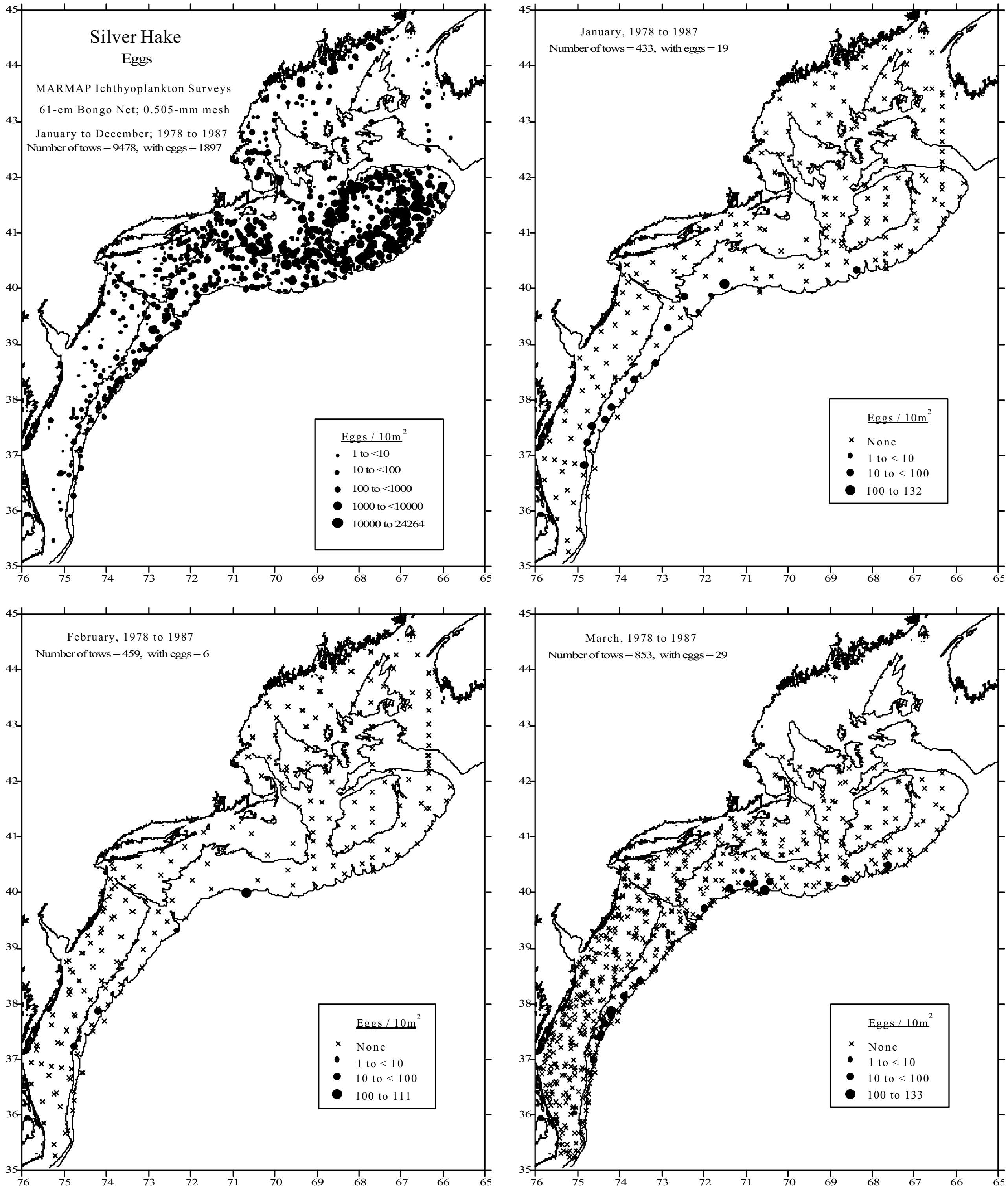


Figure 4. Distribution and abundance of silver hake eggs collected during NEFSC MARMAP ichthyoplankton surveys, January to December, 1978-1987 [see Reid *et al.* (1999) for details].

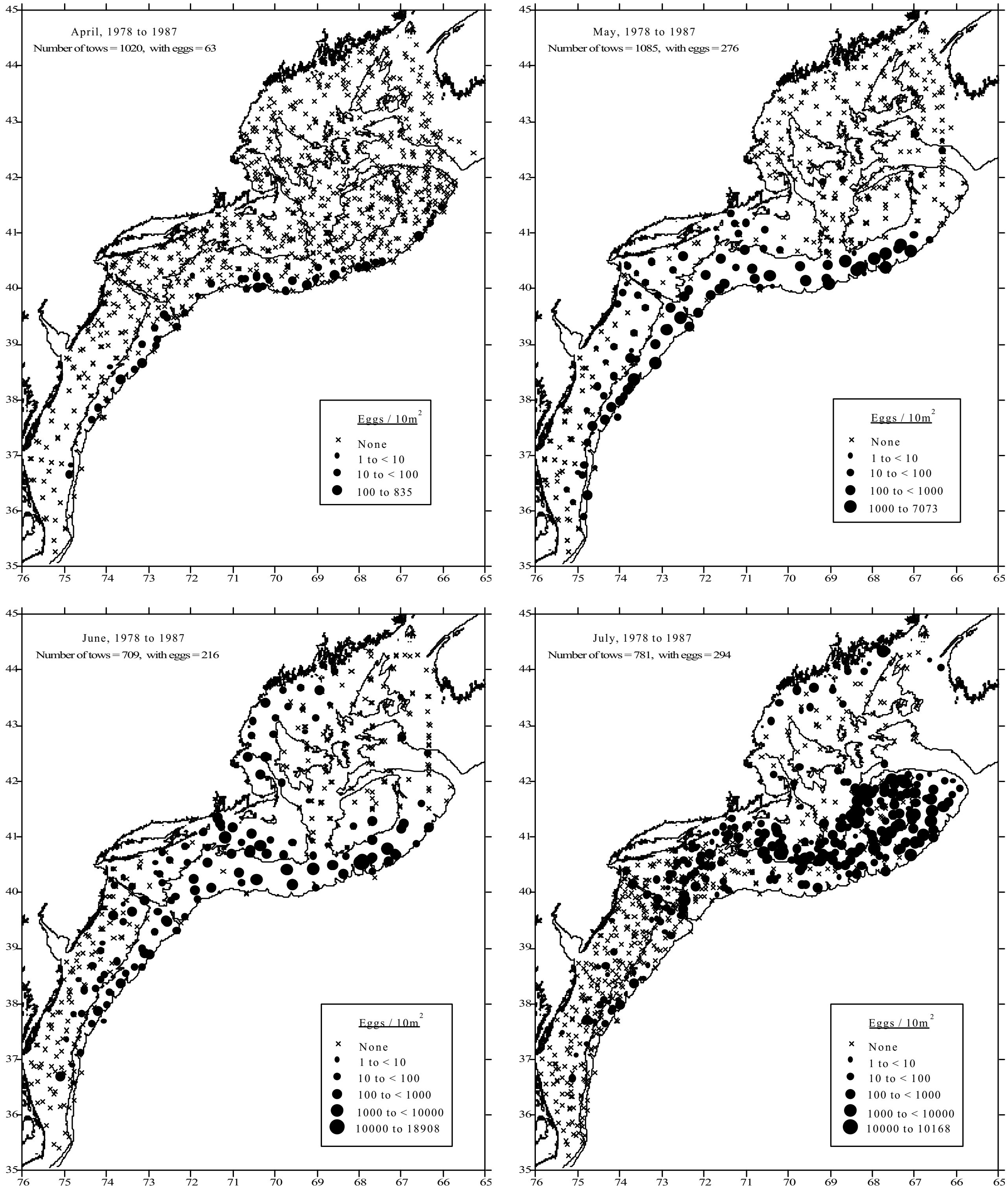


Figure 4. cont'd.

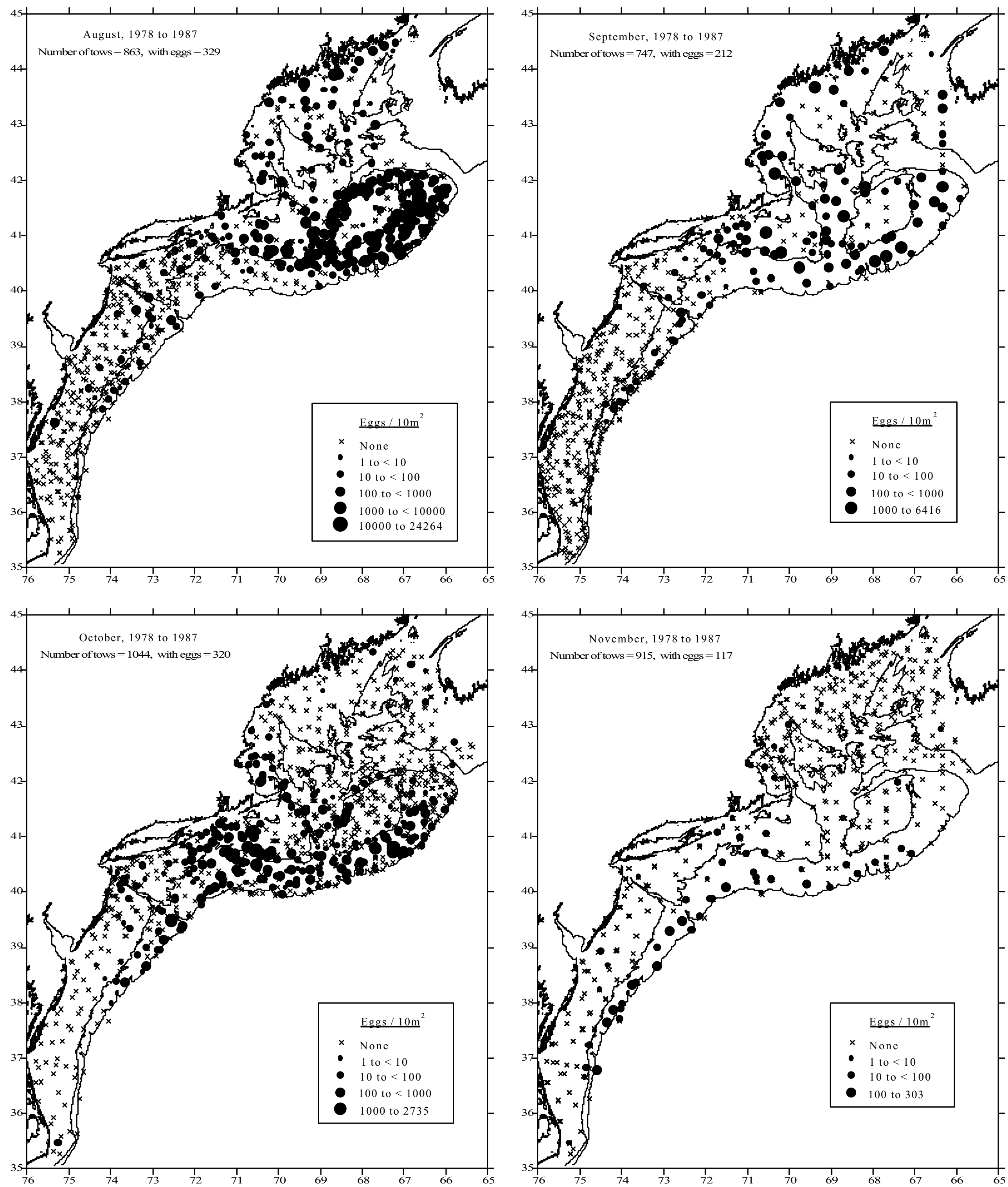


Figure 4. cont'd.

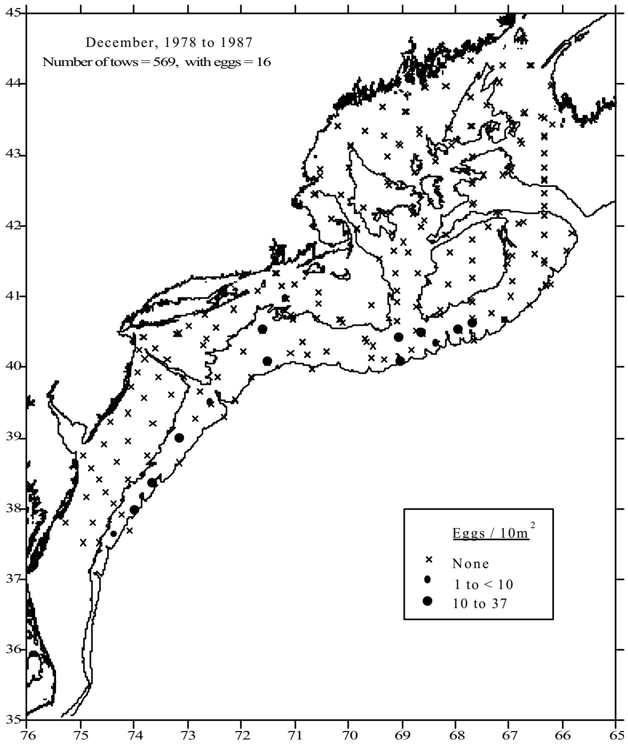


Figure 4. cont'd.

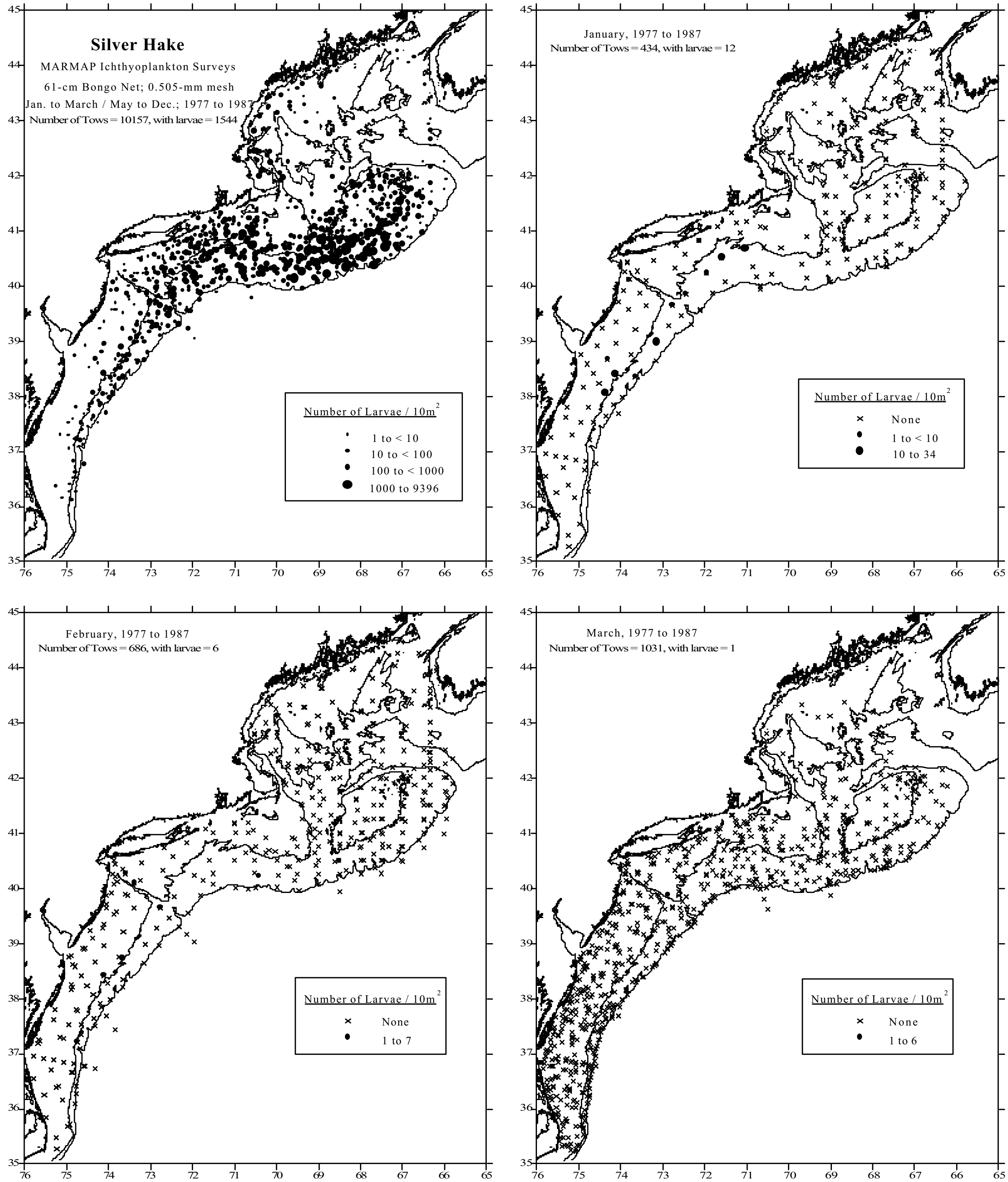


Figure 5. Distribution and abundance of silver hake larvae collected during NEFSC MARMAP ichthyoplankton surveys, 1977-1987 [see Reid *et al.* (1999) for details].

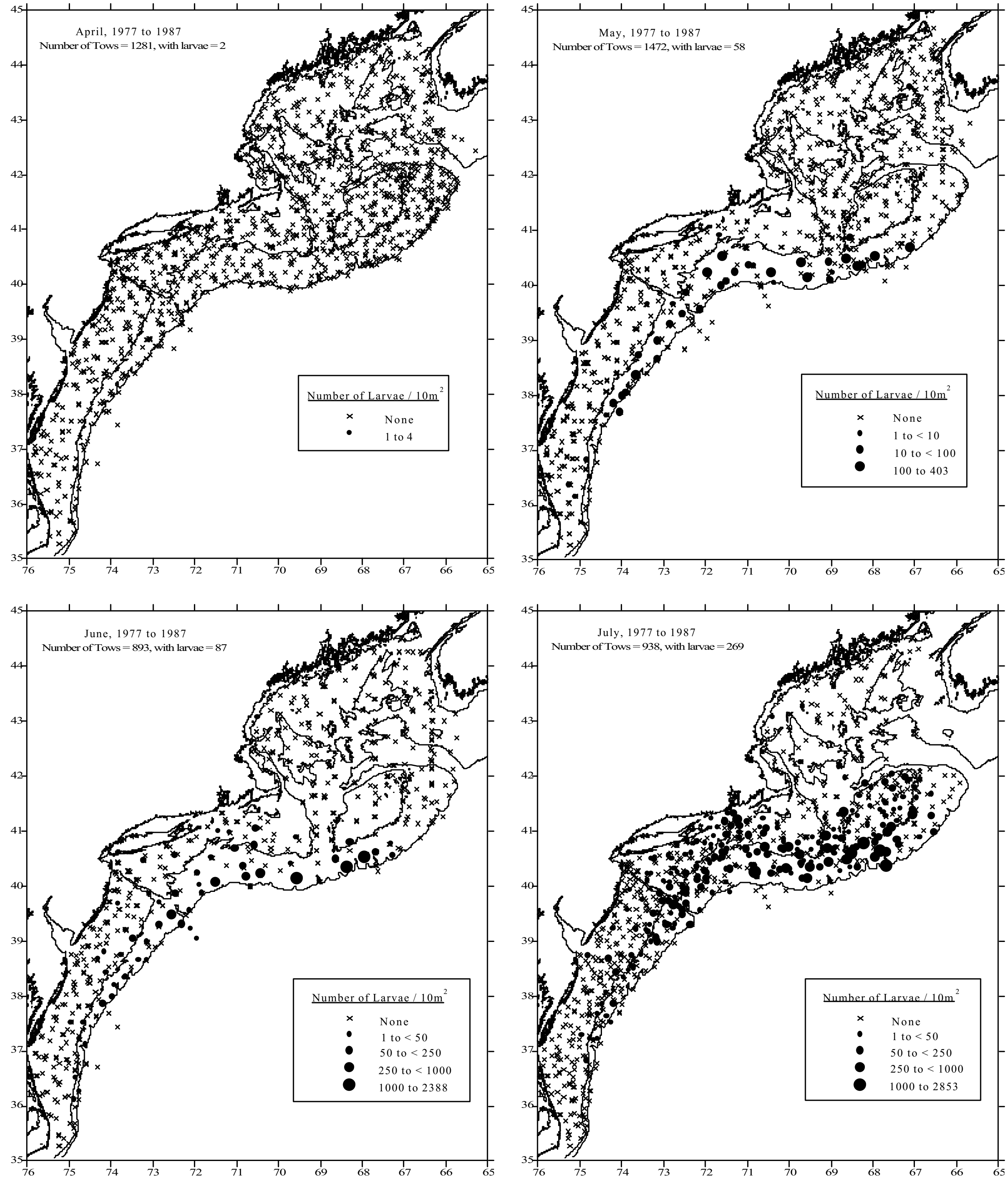


Figure 5. cont'd.

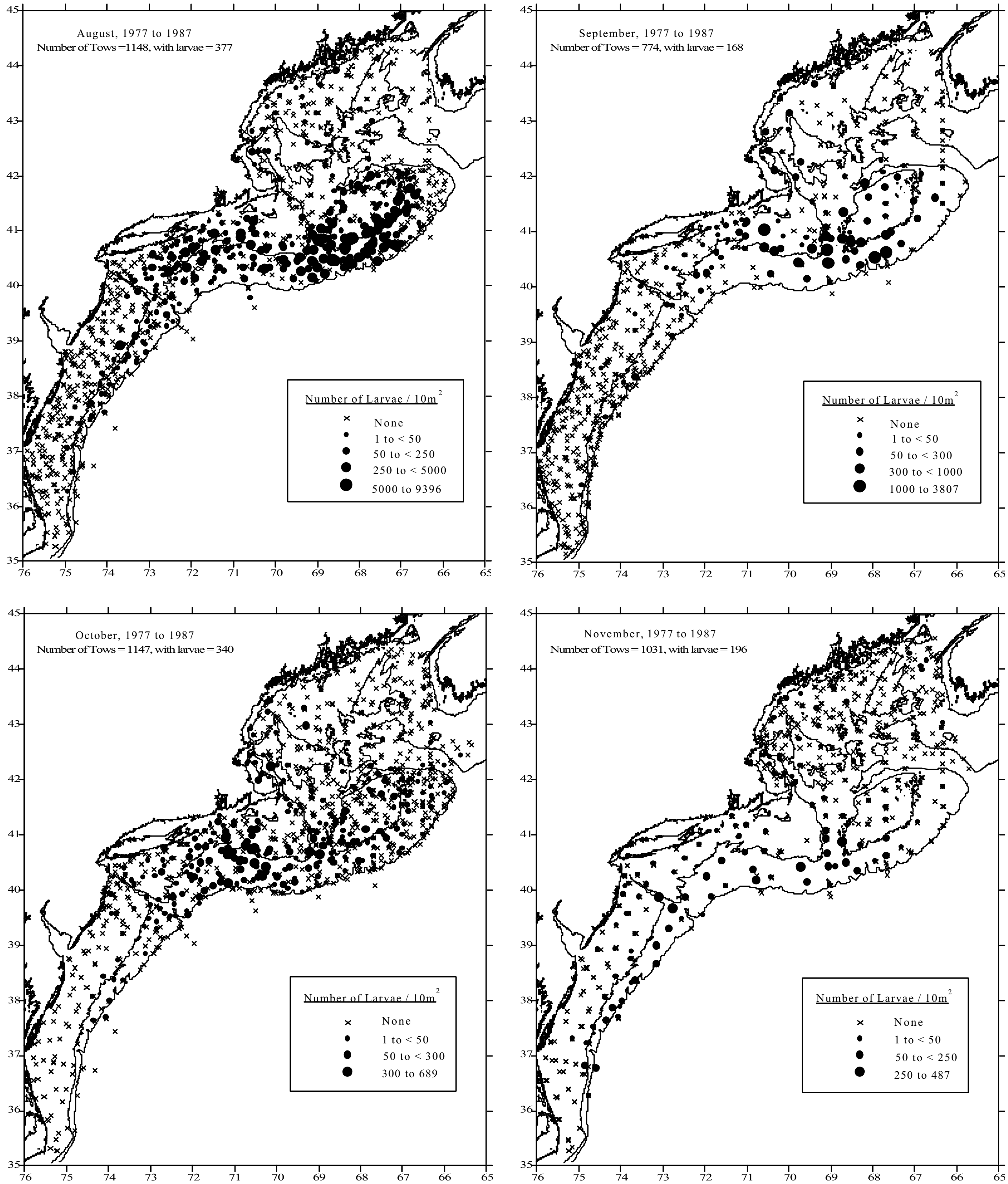
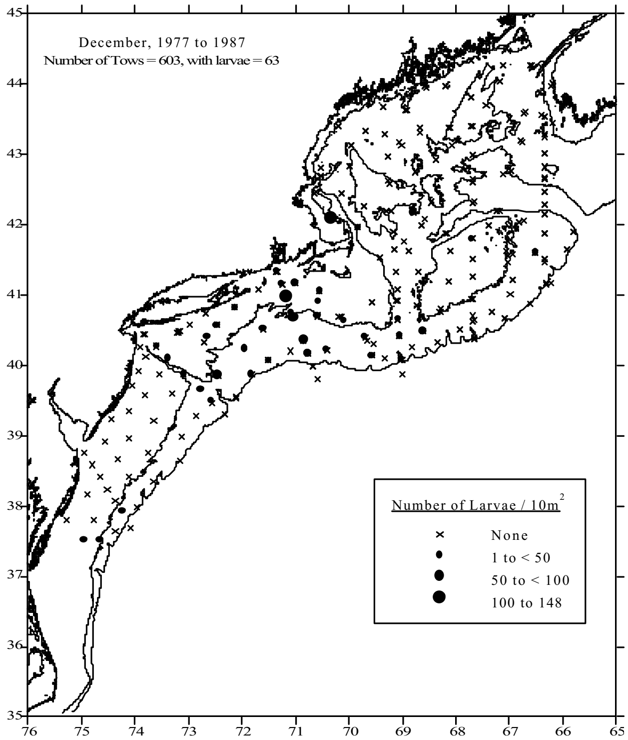


Figure 5. cont’d.



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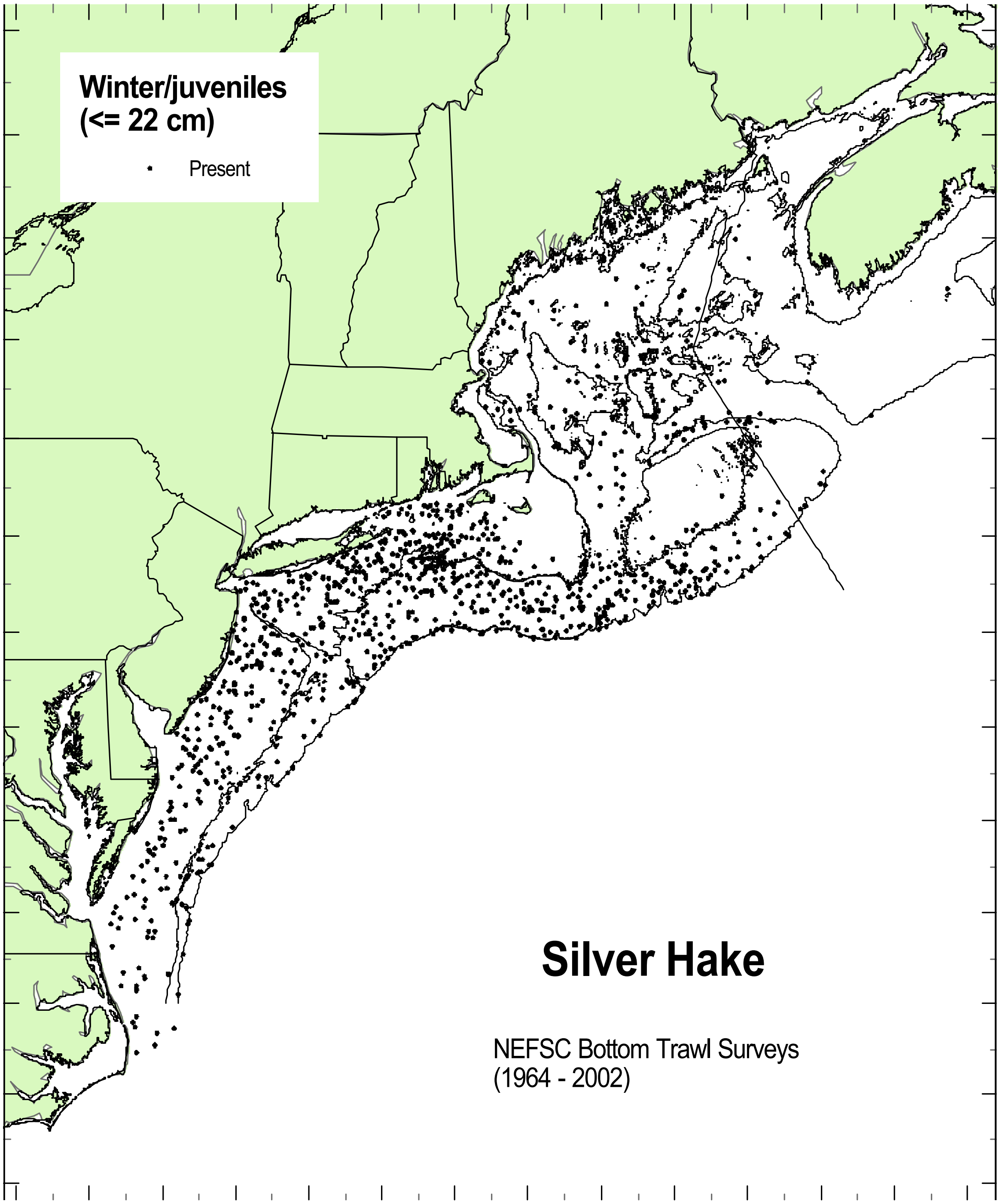
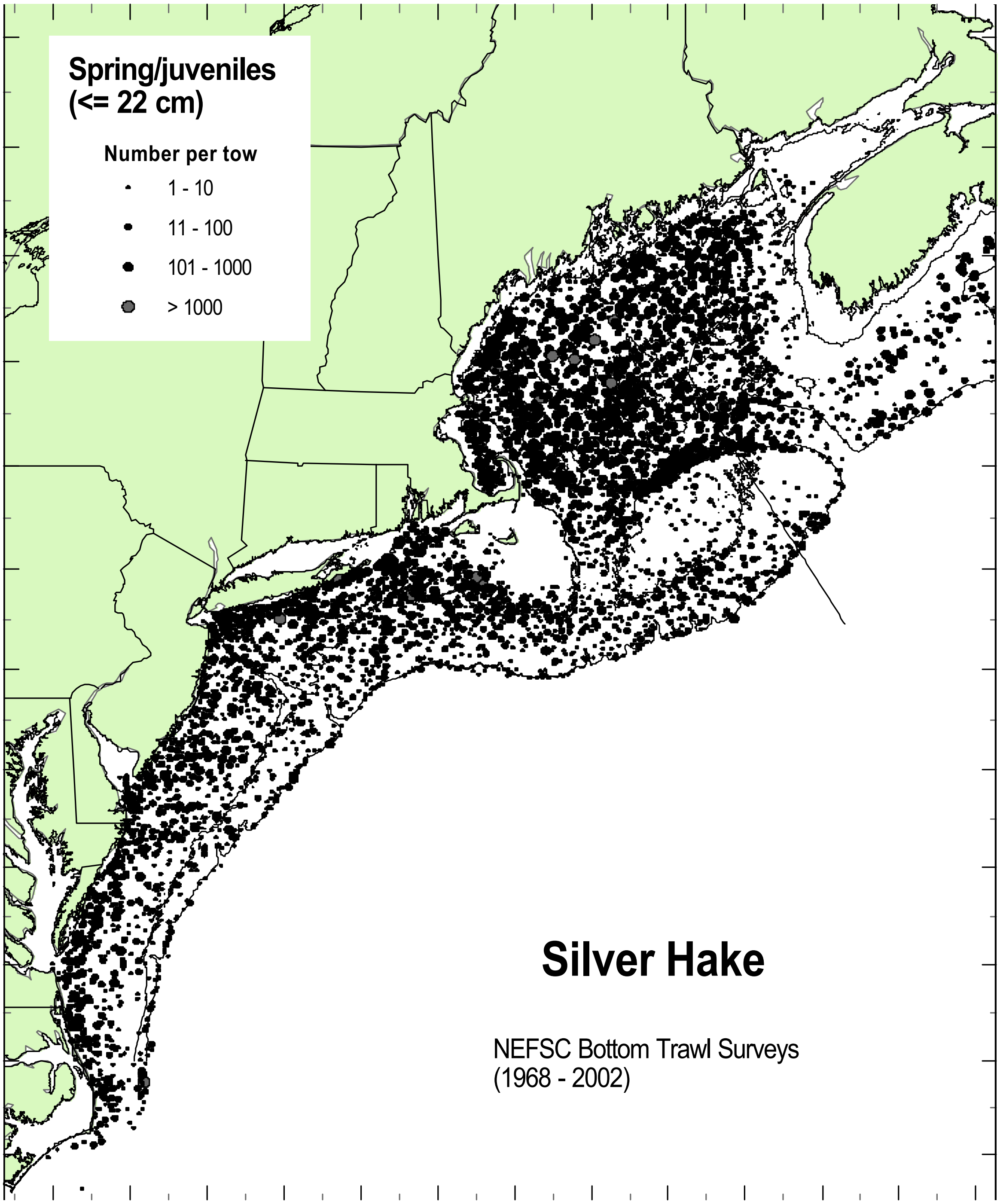


Figure 6. Seasonal distribution and abundance of juvenile silver hake collected during NEFSC bottom trawl surveys [1963-2002, all years combined; see Reid *et al.* (1999) for details]. Winter and summer distributions are presented as presence/absence data; survey stations where juveniles were not found are not shown.



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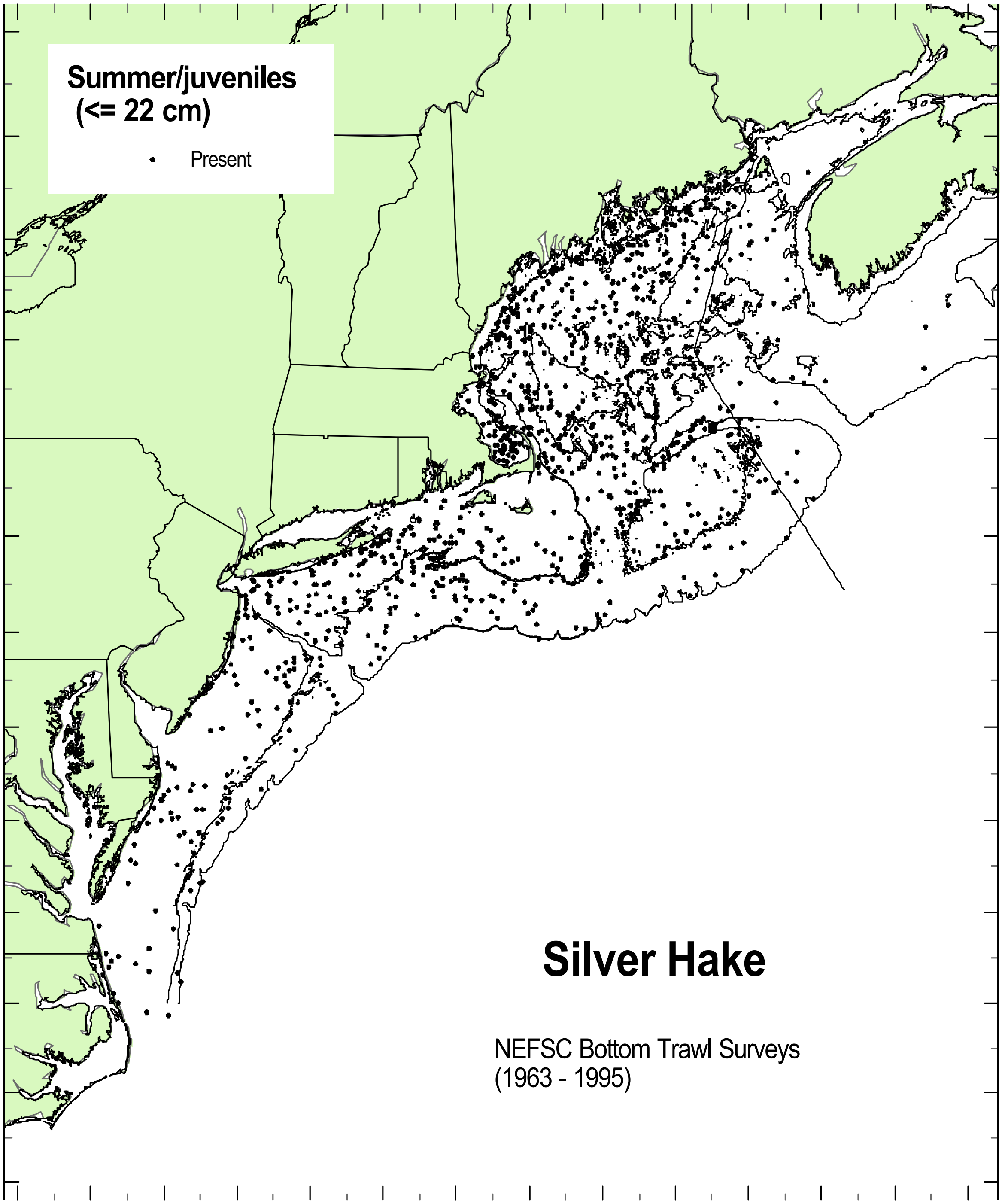

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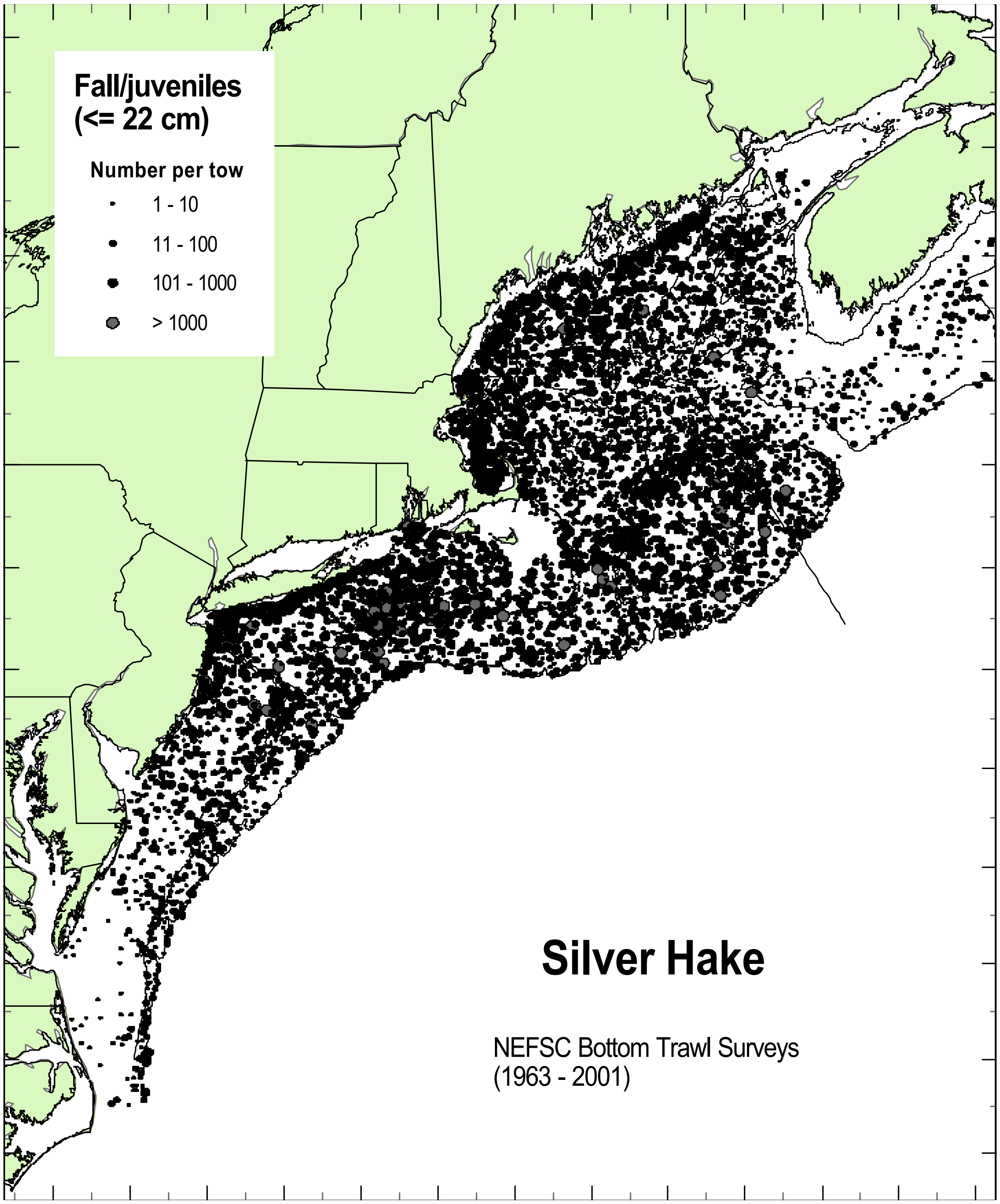


Figure 6. cont'd.

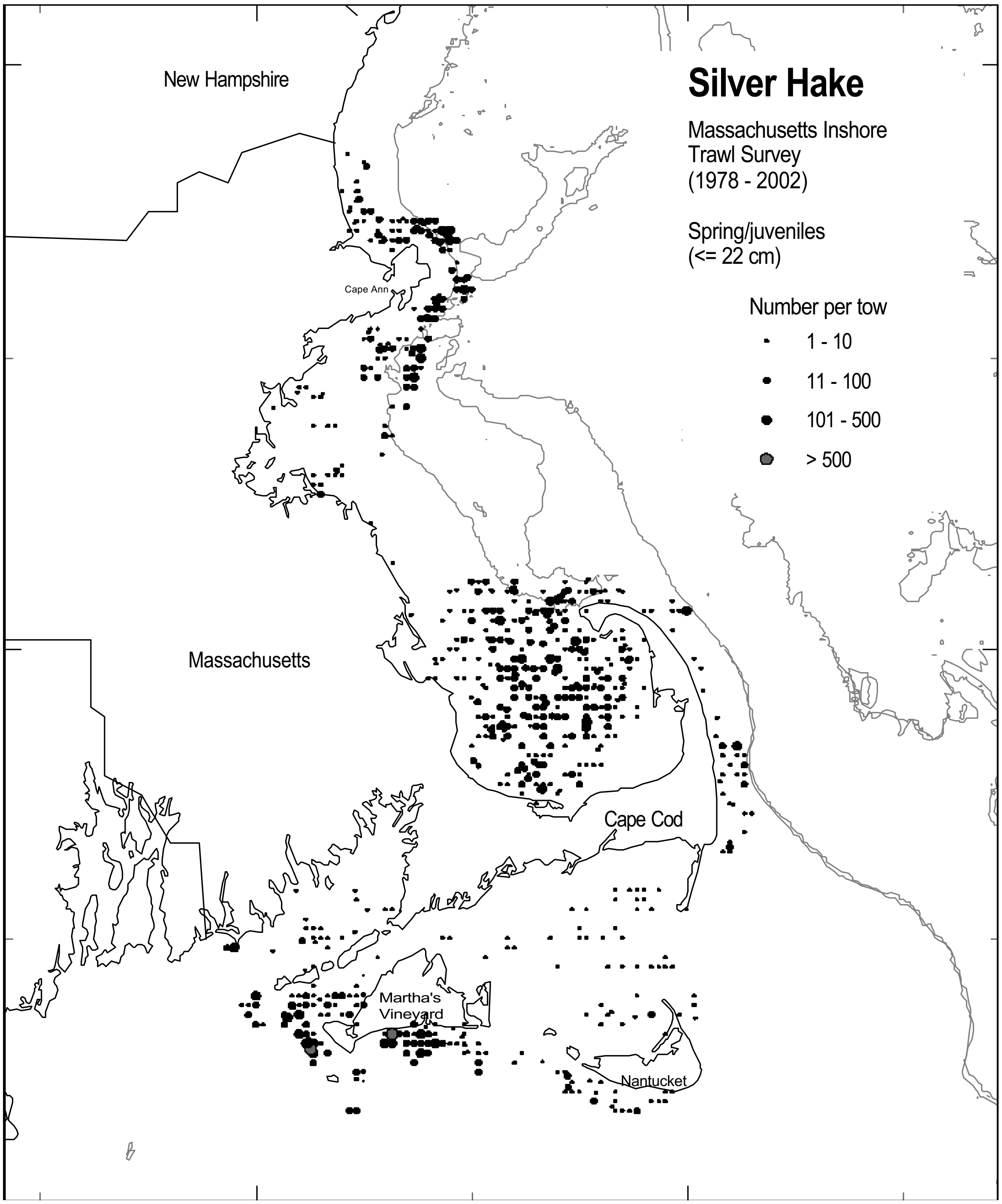


Figure 7. Distribution and abundance of juvenile silver hake in Massachusetts coastal waters collected during the spring and autumn Massachusetts inshore trawl surveys [1978-2002, all years combined; see Reid *et al.* (1999) for details].

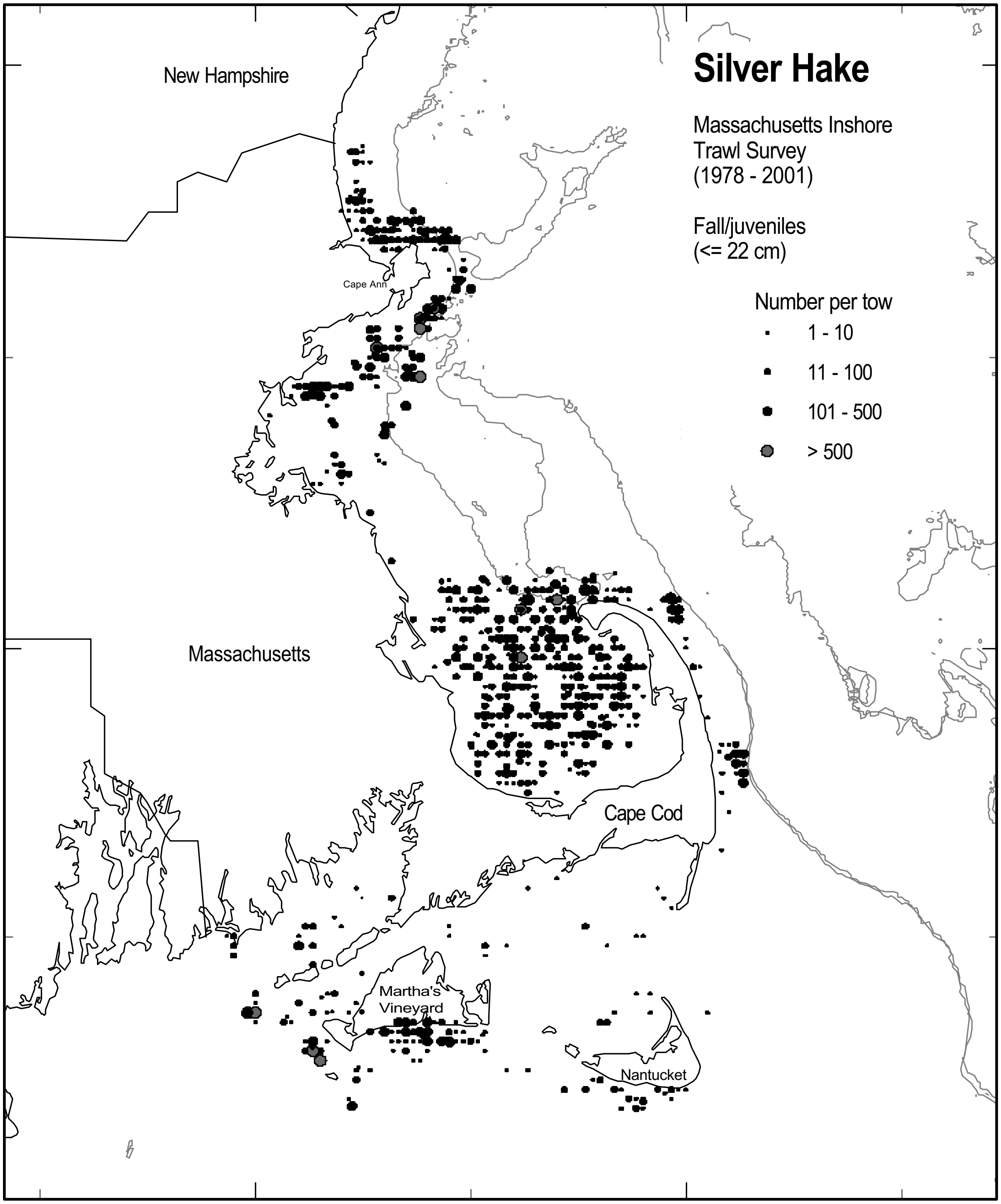


Figure 7. cont'd.

Silver Hake Juveniles (<23cm)

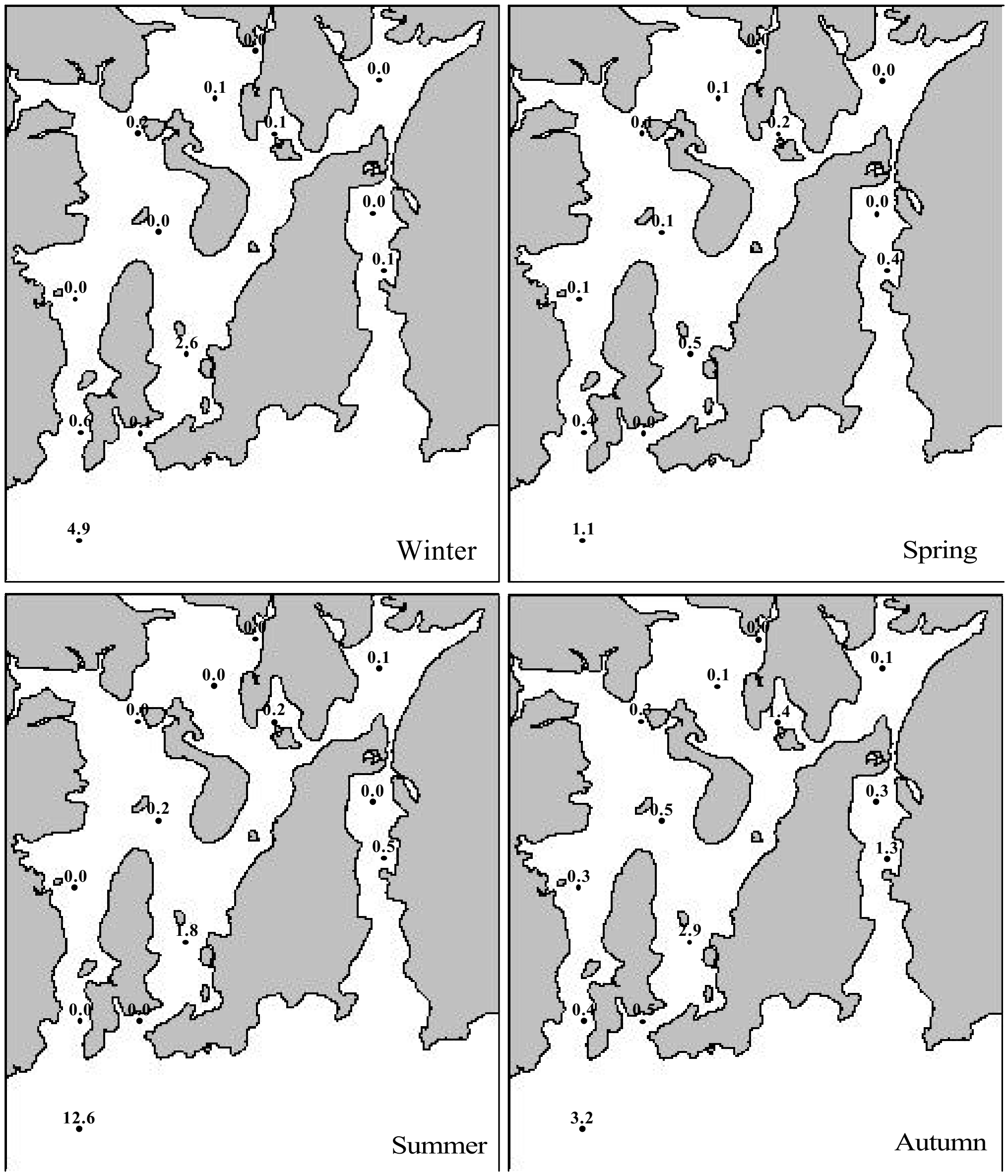
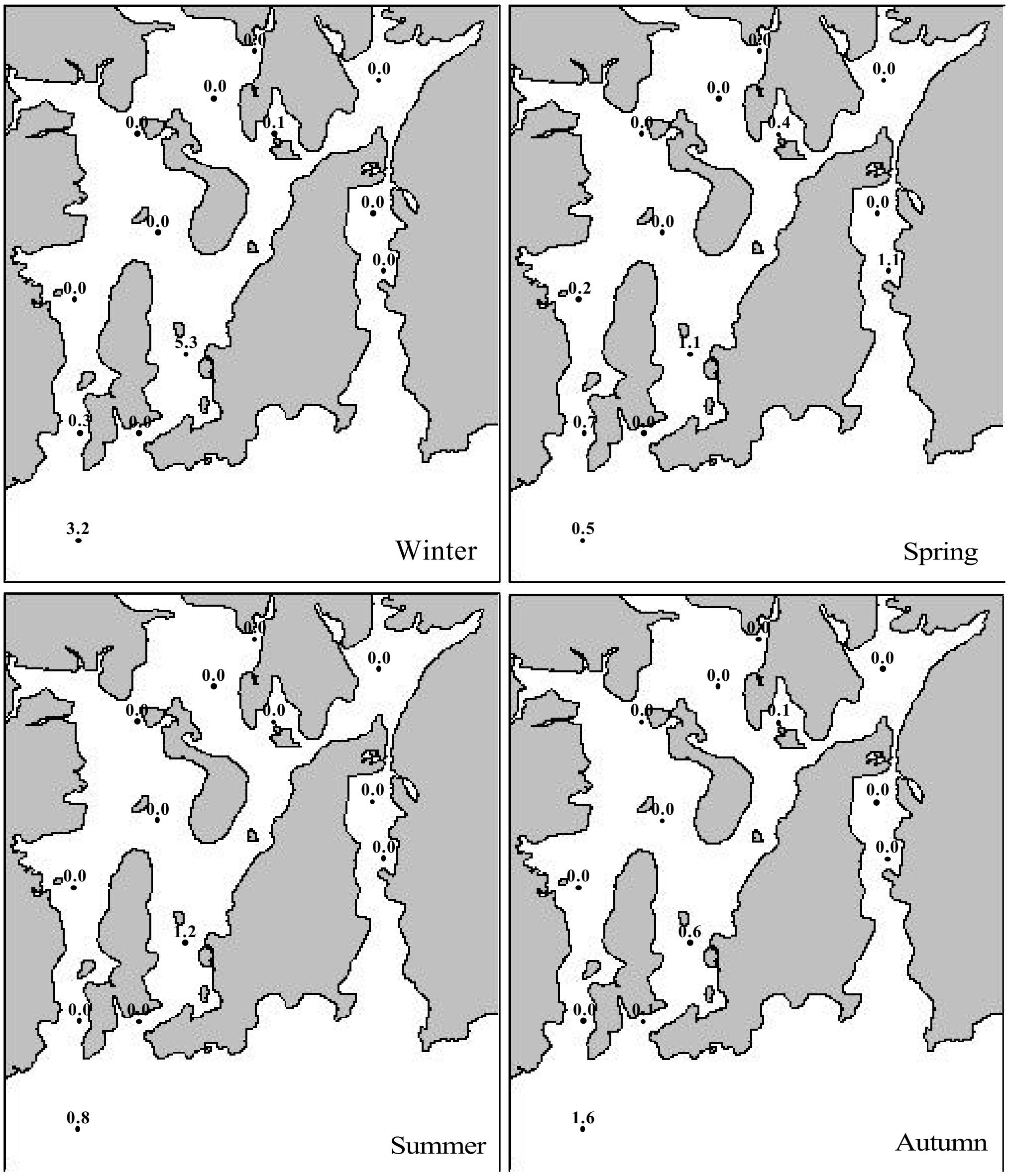


Figure 8. Distribution, abundance, and length frequencies of juvenile and adult silver hake collected during each season in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid *et al.* (1999) for details].

Silver Hake Adults (>=23cm)



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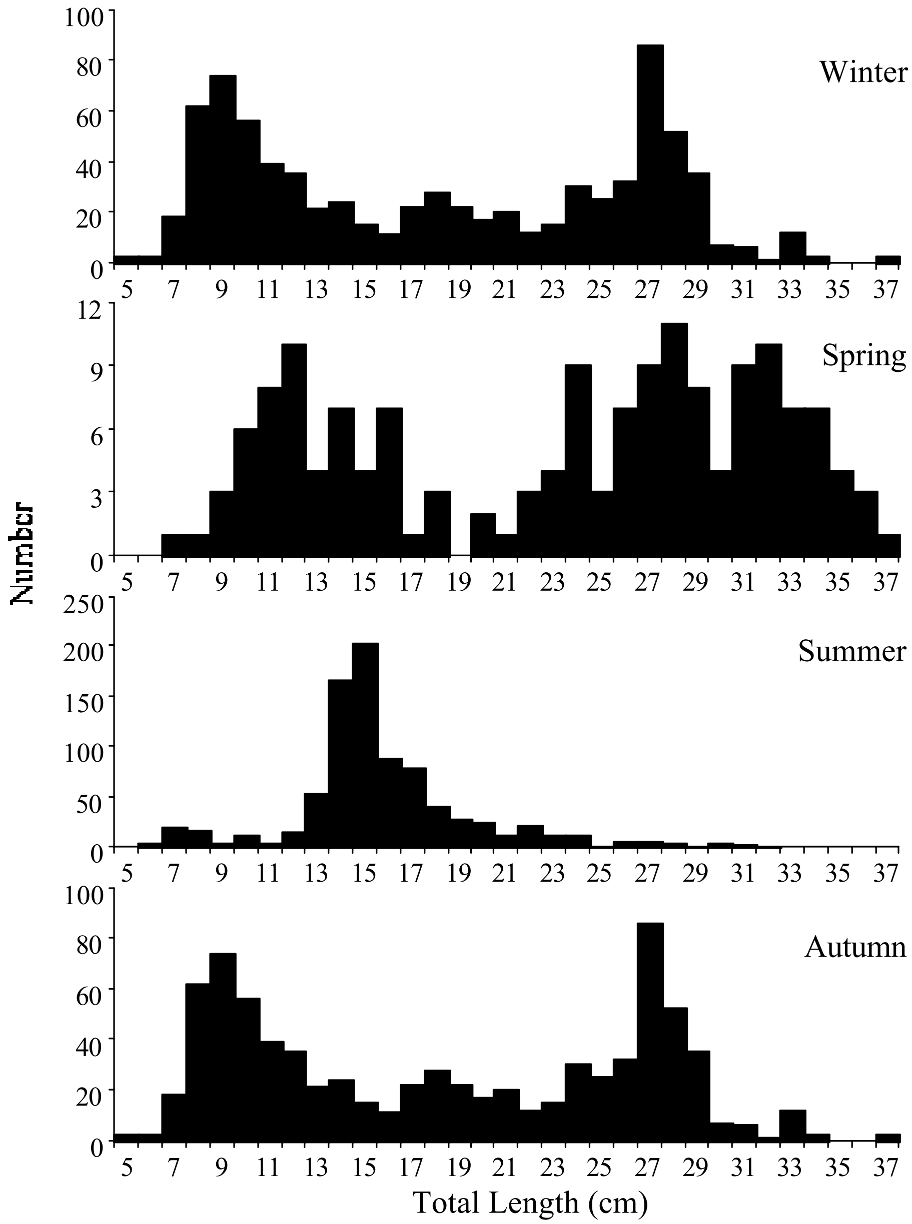

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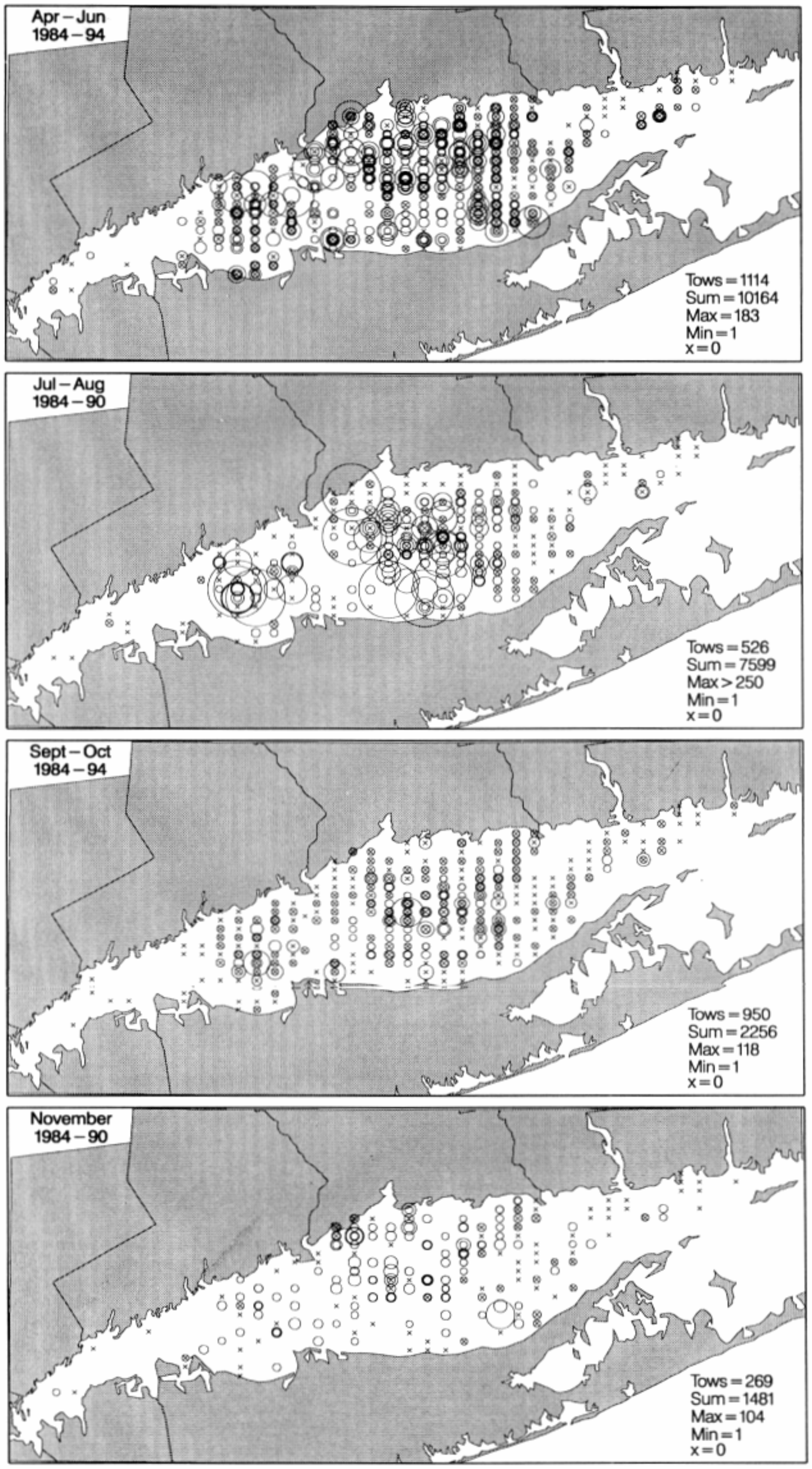


Figure 9. Distribution and abundance of juvenile and adult silver hake (8-38 cm TL) collected in Long Island Sound, based on the finfish surveys of the Connecticut Fisheries Division, 1984-1994 [from Gottschall *et al.* (2000)]. Circle diameter is proportional to the number of fish caught, and is scaled to the maximum catch (indicated by "max=" or "max>"). Collections were made with a 14 m otter trawl at about 40 stations chosen by stratified random design.

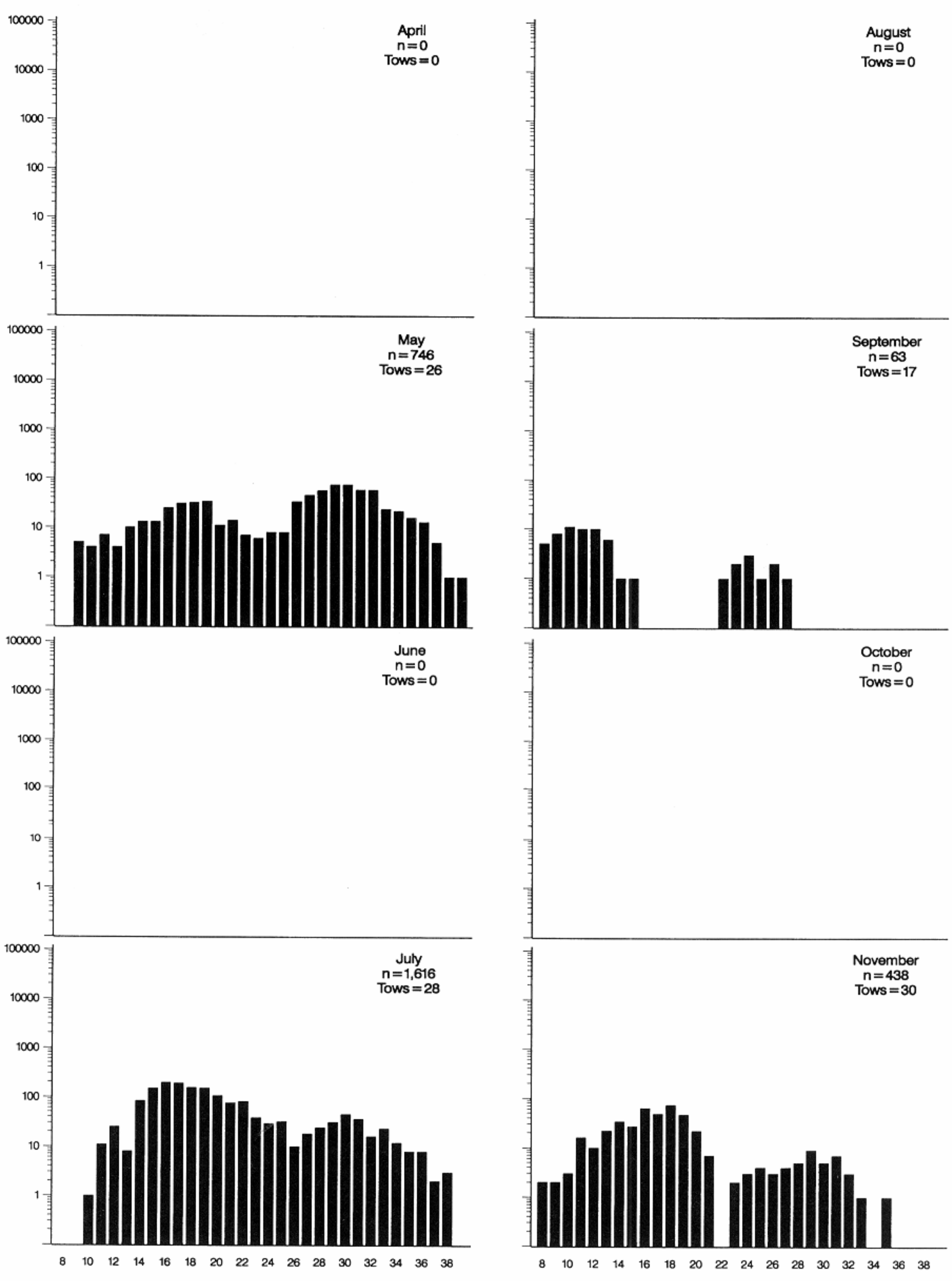


Figure 10. Monthly $\log_{10}$ length frequencies (cm) of juvenile and adult silver hake collected in Long Island Sound, based on 2,863 fish taken in 101 tows between 1989-1990. From Gottschall *et al*. (2000).

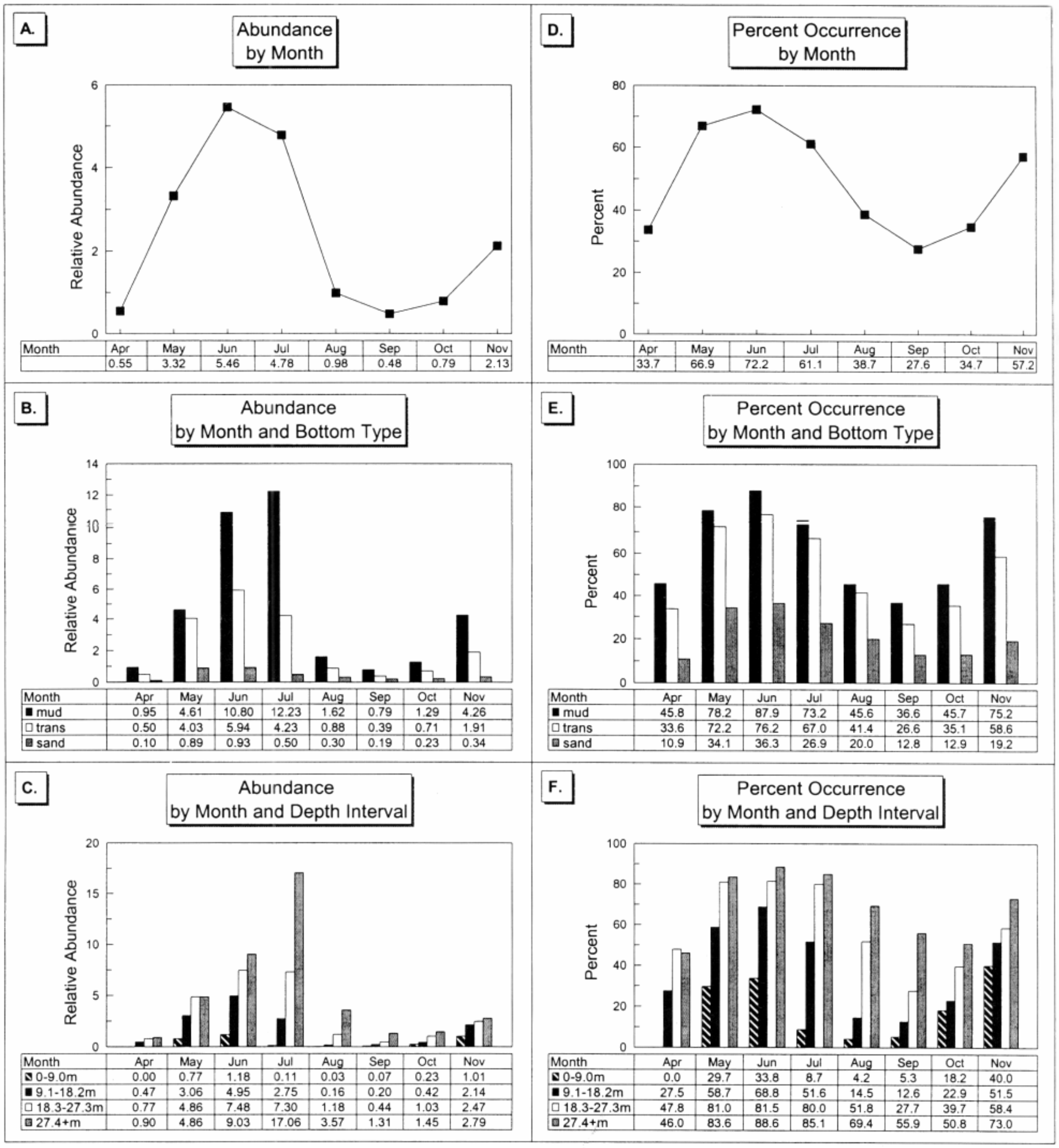


Figure 11. Relative abundance (geometric mean catch/tow) catch/tow and percent occurrence (proportion of samples in which at least one individual was observed) for juvenile and adult silver hake in Long Island Sound by month, month and bottom type, and month and depth interval. From Gottschall *et al.* (2000).

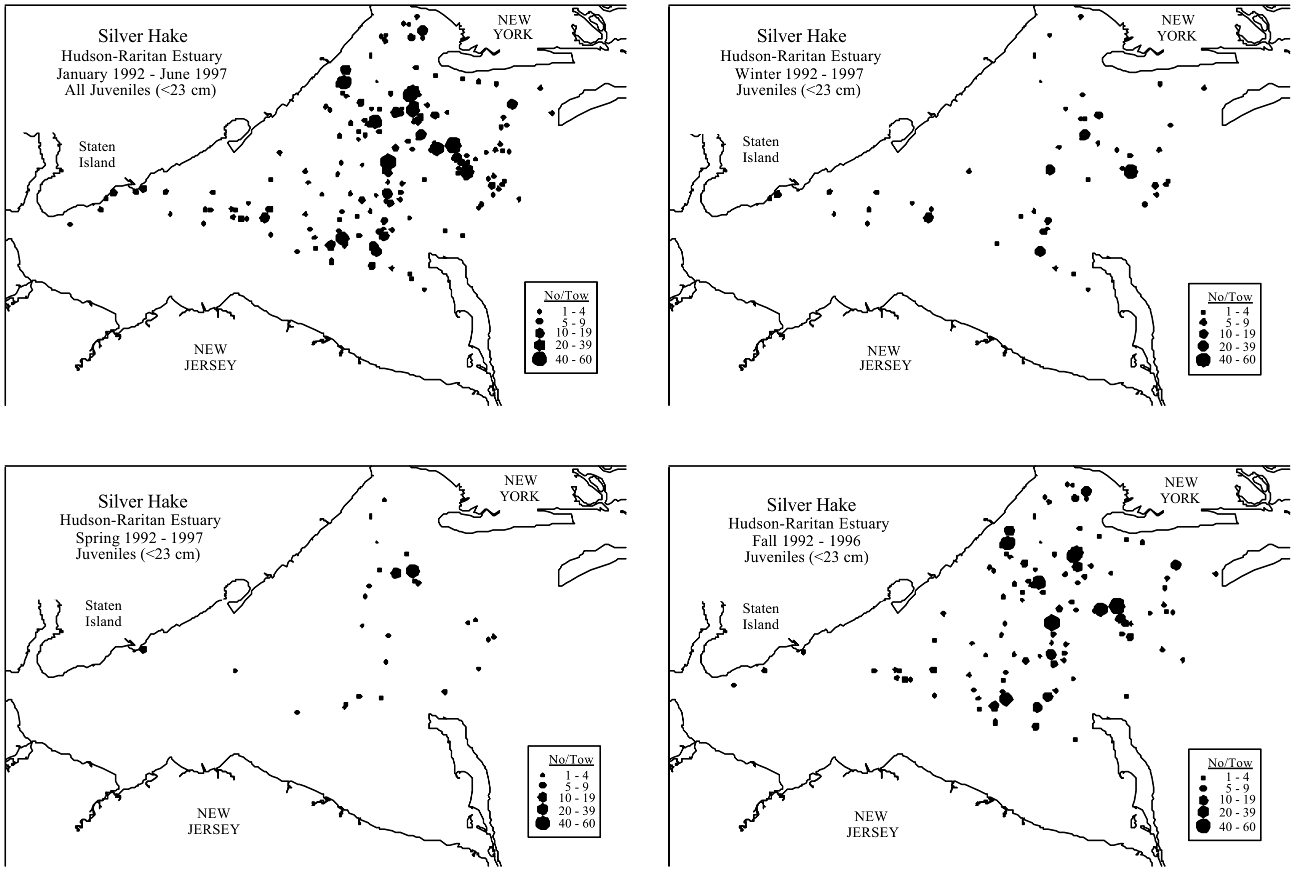


Figure 12. Distribution and abundance of juvenile silver hake collected in the Hudson-Raritan estuary from January 1992 - June 1997, based on Hudson-Raritan trawl surveys [see Reid *et al.* (1999) for details].

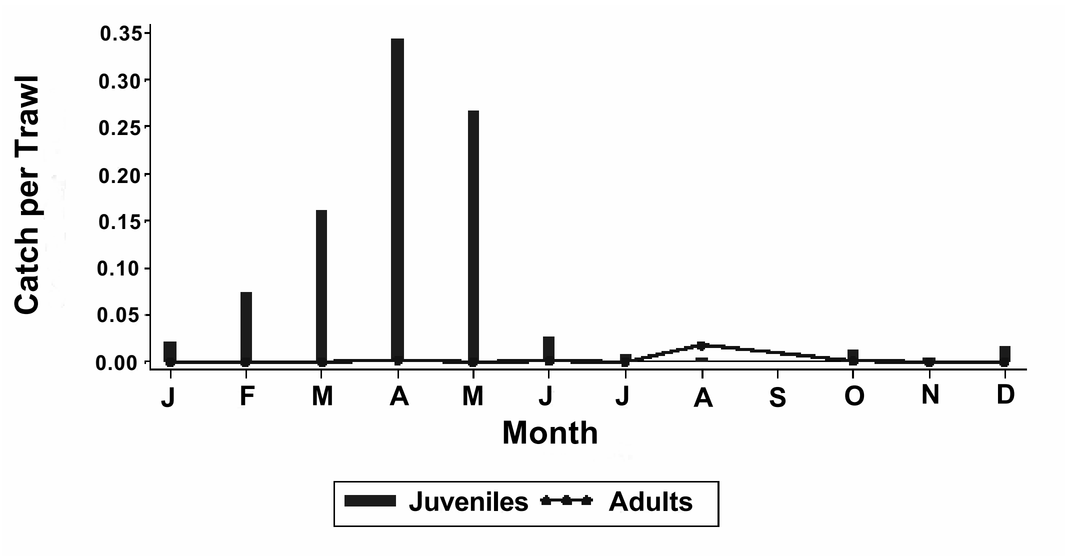


Figure 13. Catch per unit effort for total catch of juvenile and adult silver hake in Chesapeake Bay, from the Virginia Institute of Marine Science's (VIMS) trawl surveys, 1988-1999 (all years combined). Monthly surveys were conducted using a random stratified design of the main stem of the Bay using a 9.1 m semi-balloon otter trawl with 38 mm mesh and 6.4 mm cod end with a tow duration of five minutes. Adapted from Geer (2002).

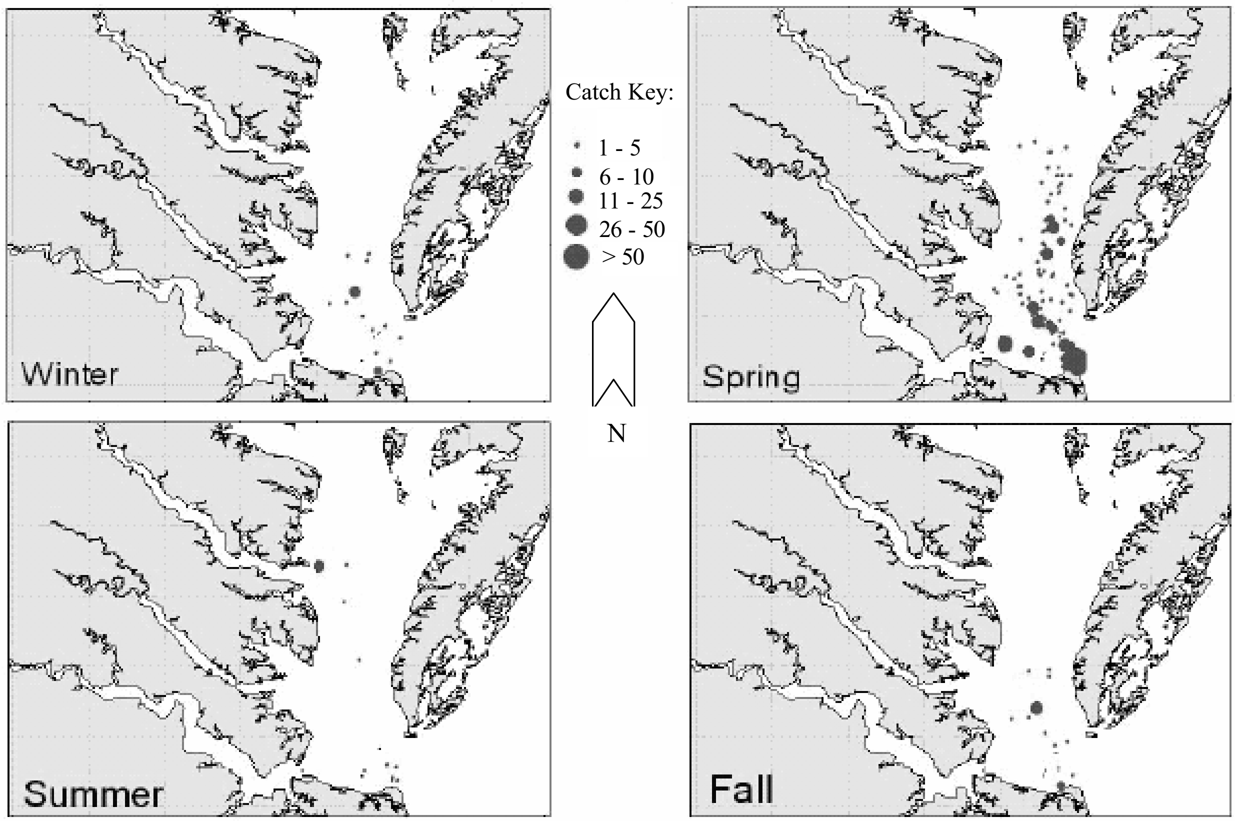


Figure 14. Seasonal distribution and abundance of silver hake in Chesapeake Bay, from the VIMS trawl surveys, 1988-1999 (all years combined). Adapted from Geer (2002).

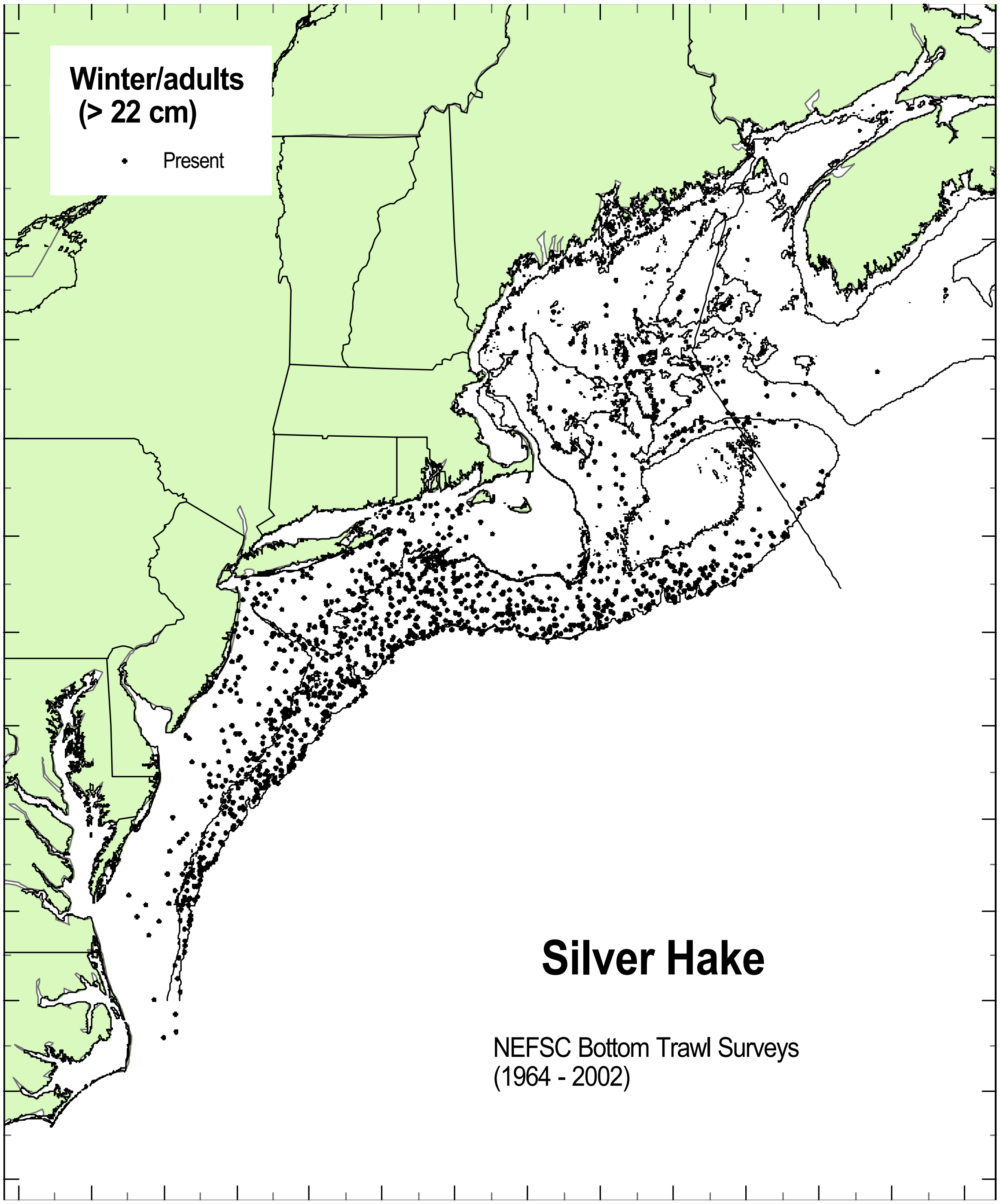


Figure 15. Seasonal distribution and abundance of adult silver hake collected during NEFSC bottom trawl surveys [1963-2002, all years combined; see Reid *et al*. (1999) for details]. Winter and summer distributions are presented as presence/absence data; survey stations where juveniles were not found are not shown.

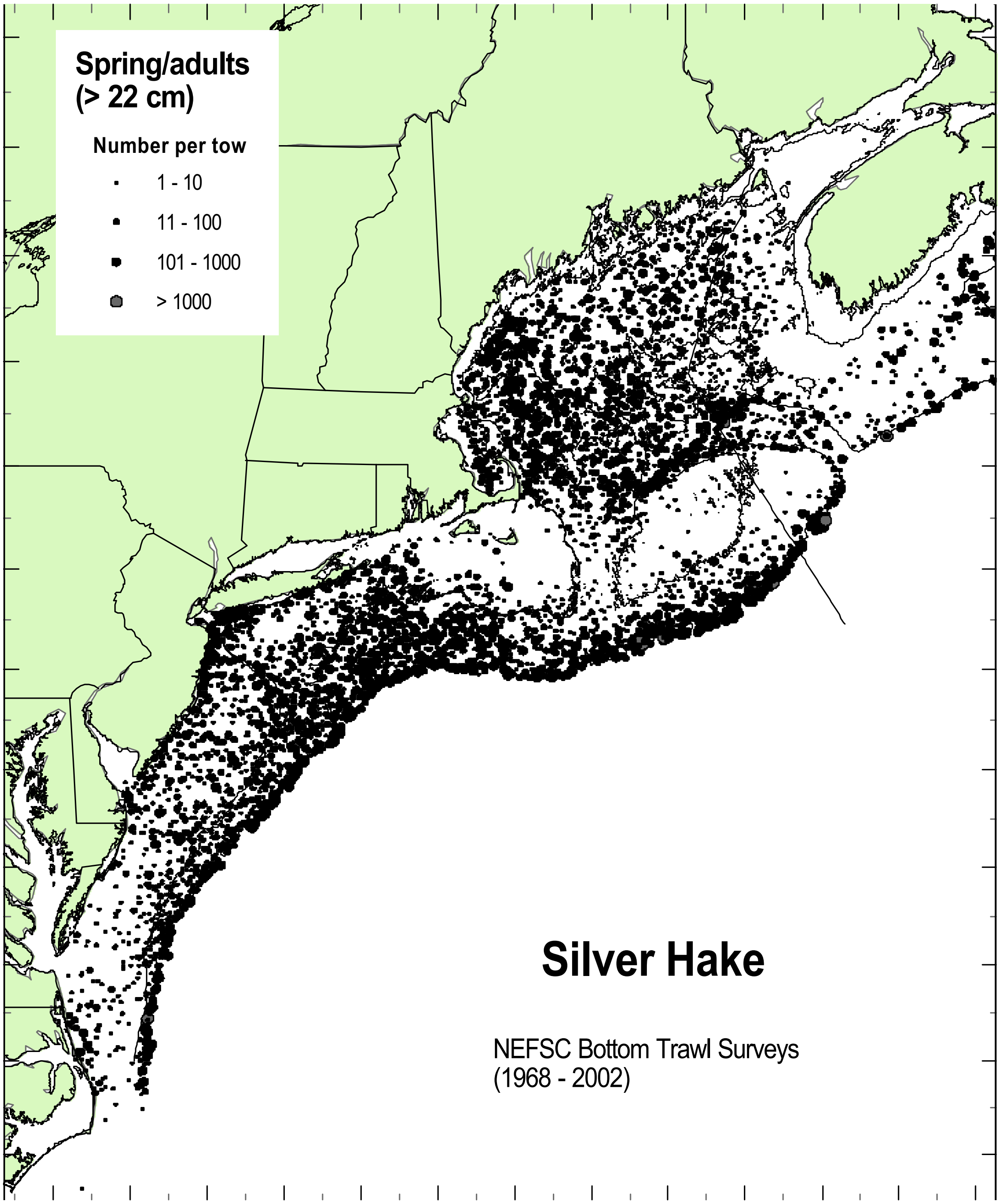


Figure 15. cont'd.

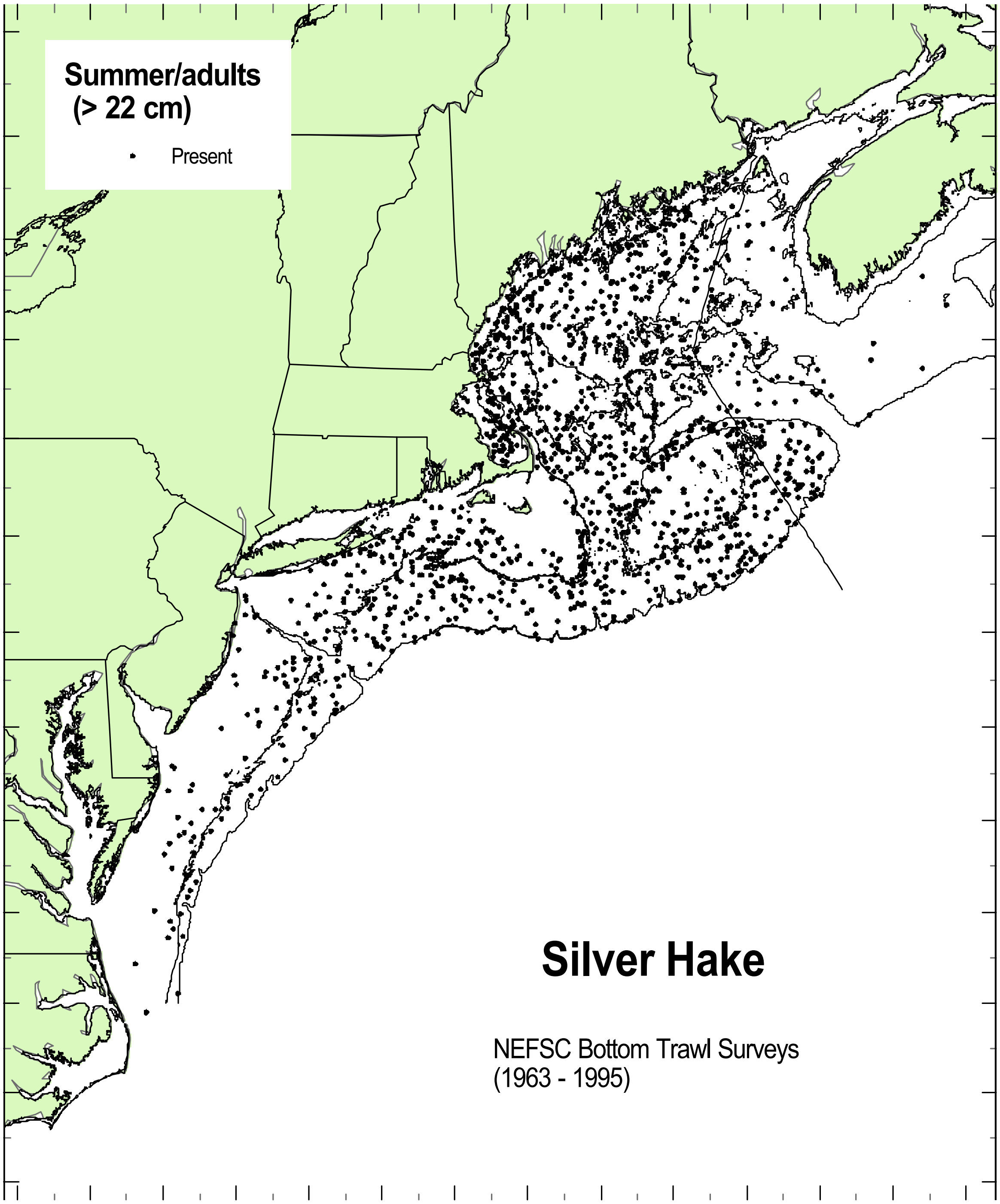


Figure 15. cont'd.

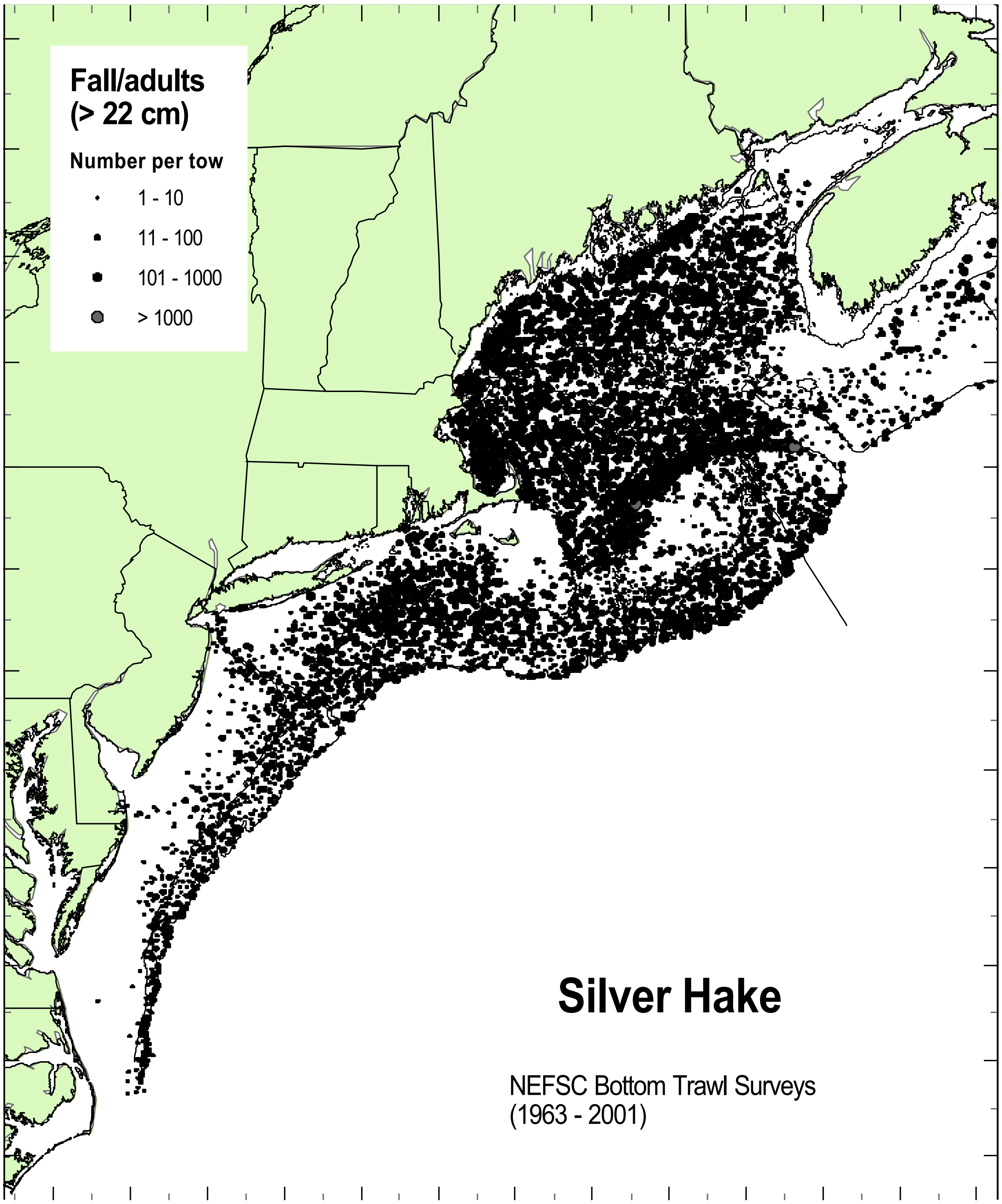


Figure 15. cont'd.

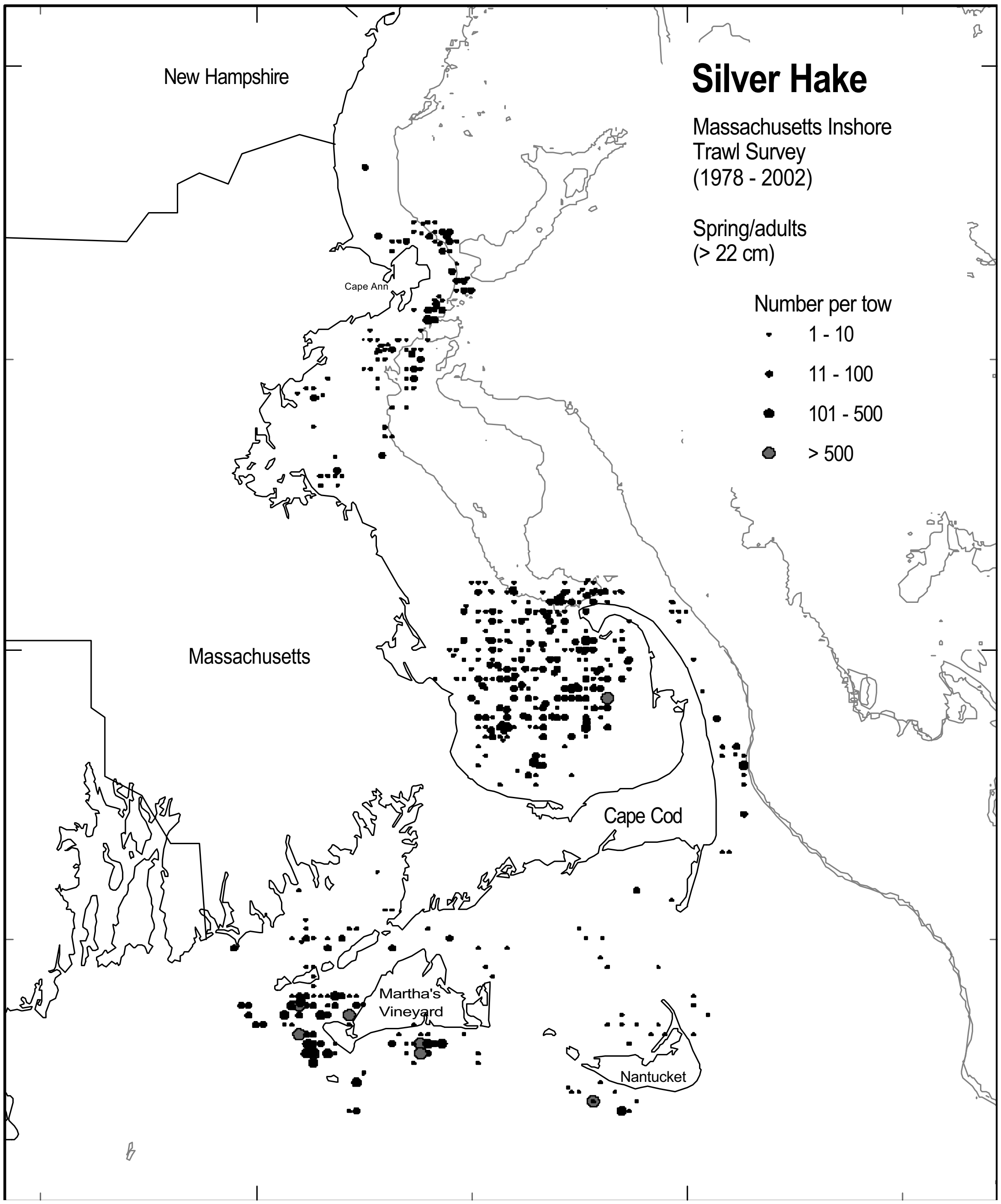


Figure 16. Distribution and abundance of adult silver hake in Massachusetts coastal waters collected during the spring and autumn Massachusetts inshore trawl surveys [1978-2002, all years combined; see Reid *et al.* (1999) for details].

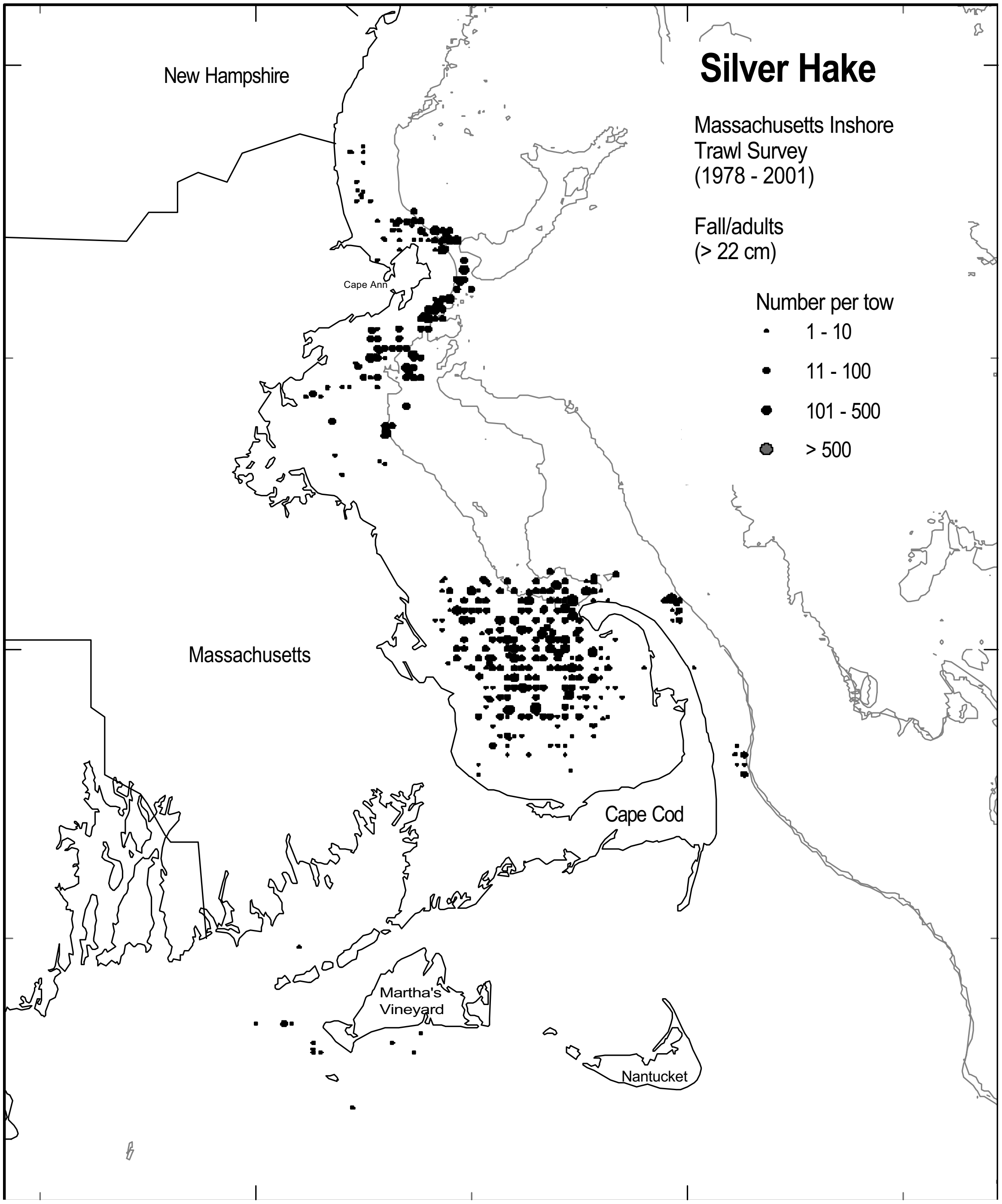


Figure 16. cont'd.

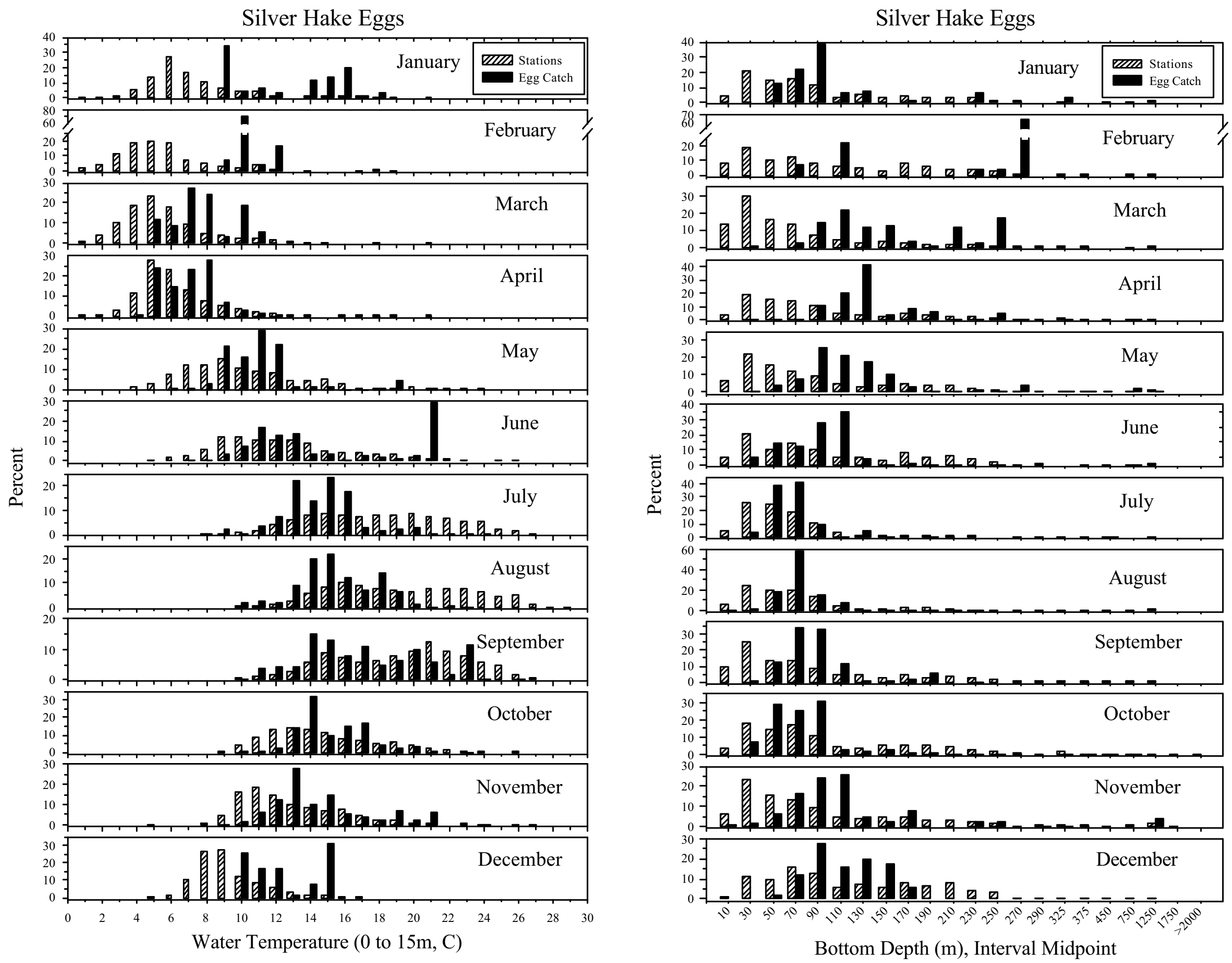


Figure 17. Abundance of silver hake eggs relative to water column temperature and bottom depth from NEFSC MARMAP ichthyoplankton surveys (1978-1987) by month for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

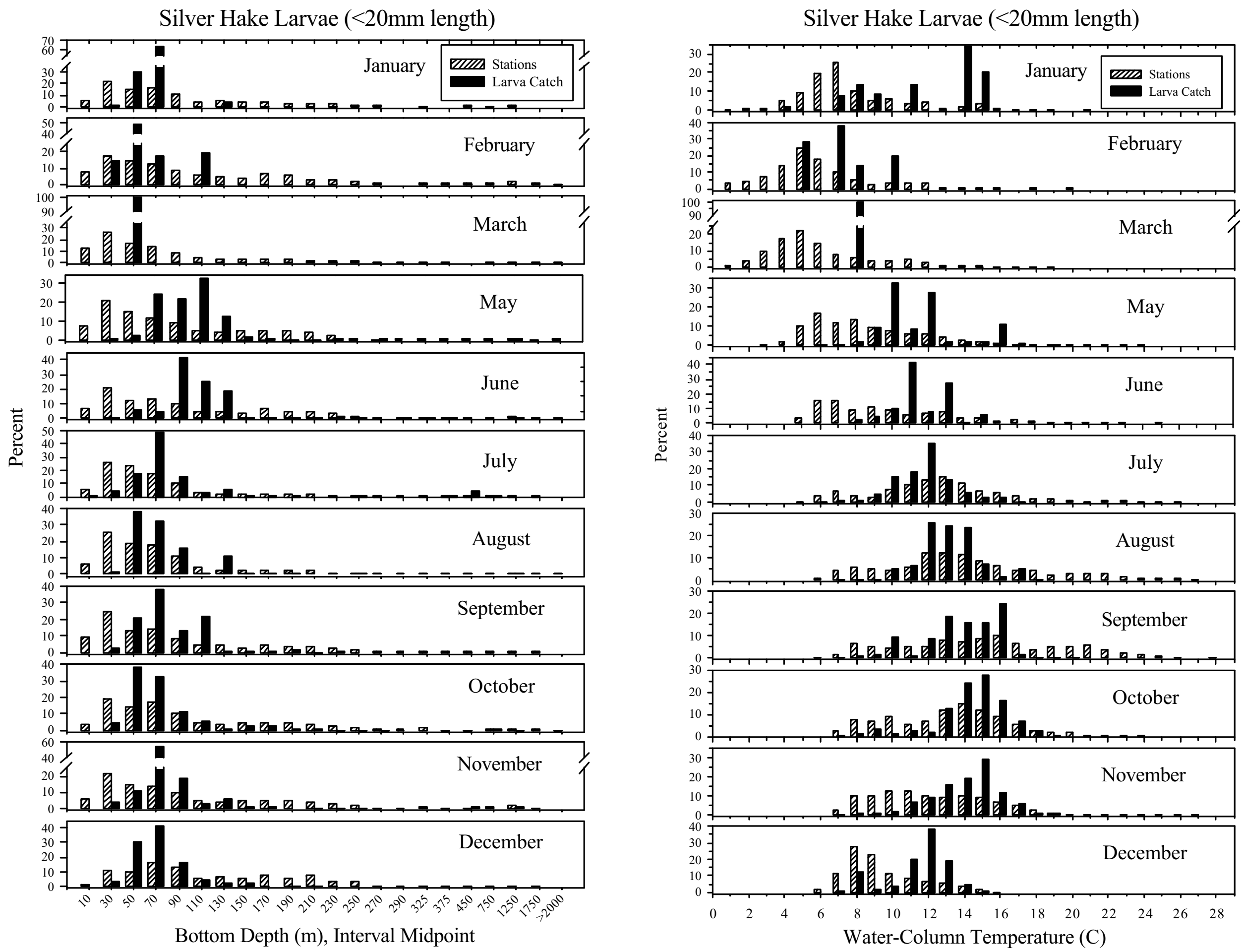


Figure 18. Abundance of silver hake larvae relative to water column temperature and bottom depth from NEFSC MARMAP ichthyoplankton surveys (1977-1987) by month for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

Silver Hake
NEFSC Bottom Trawl Survey
Spring/Juveniles

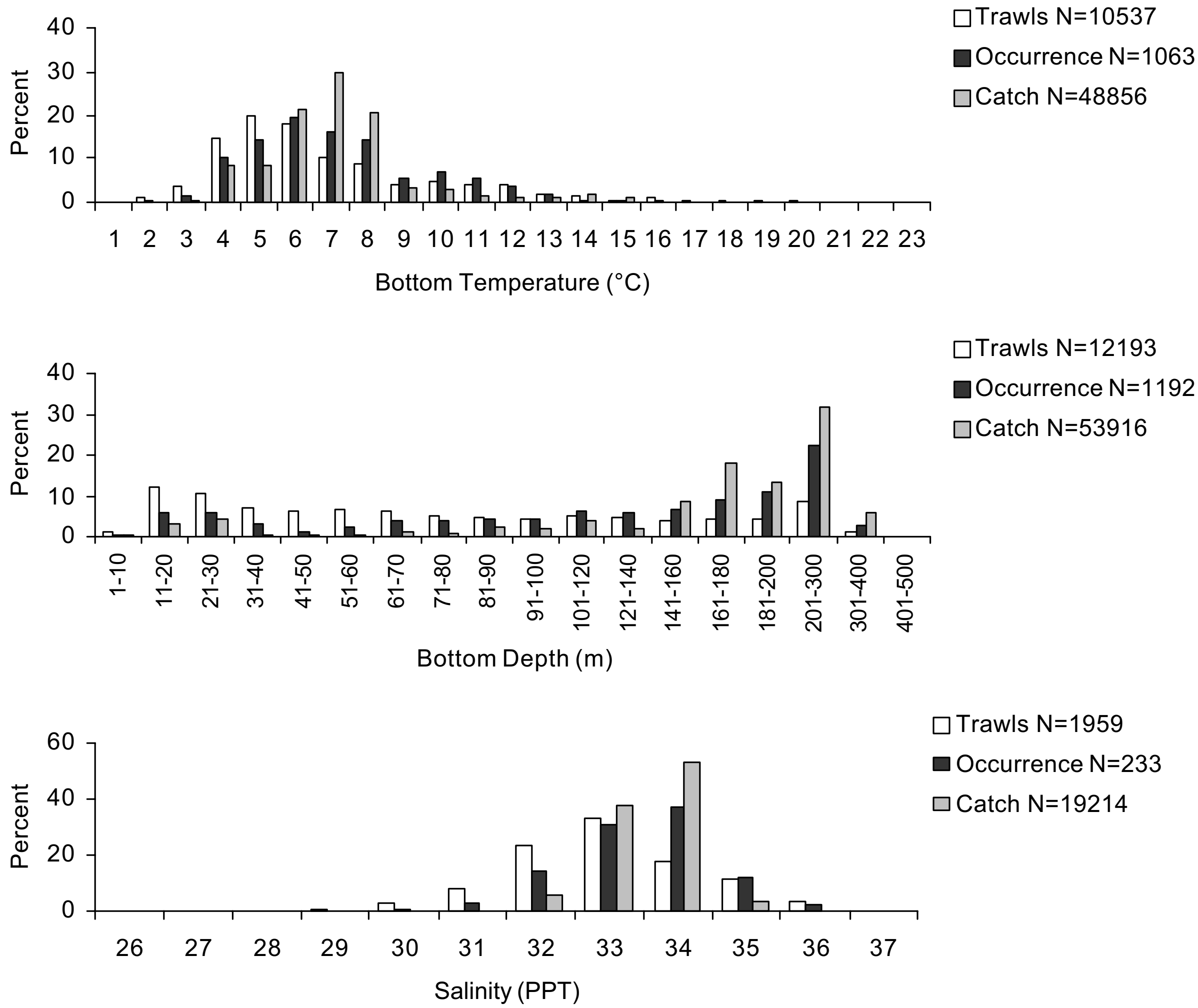


Figure 19. Spring and fall distributions of juvenile silver hake and trawls relative to bottom water temperature, depth, and salinity based on NEFSC bottom trawl surveys (1963-2002; all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which silver hake occurred, and gray bars represent, within each interval, the percentage of the total number of silver hake caught. Note that the bottom depth intervals change with depth (from 10 to 20 to 100 m) in the bottom depth bar chart.

Silver Hake
NEFSC Bottom Trawl Survey
Fall/Juveniles

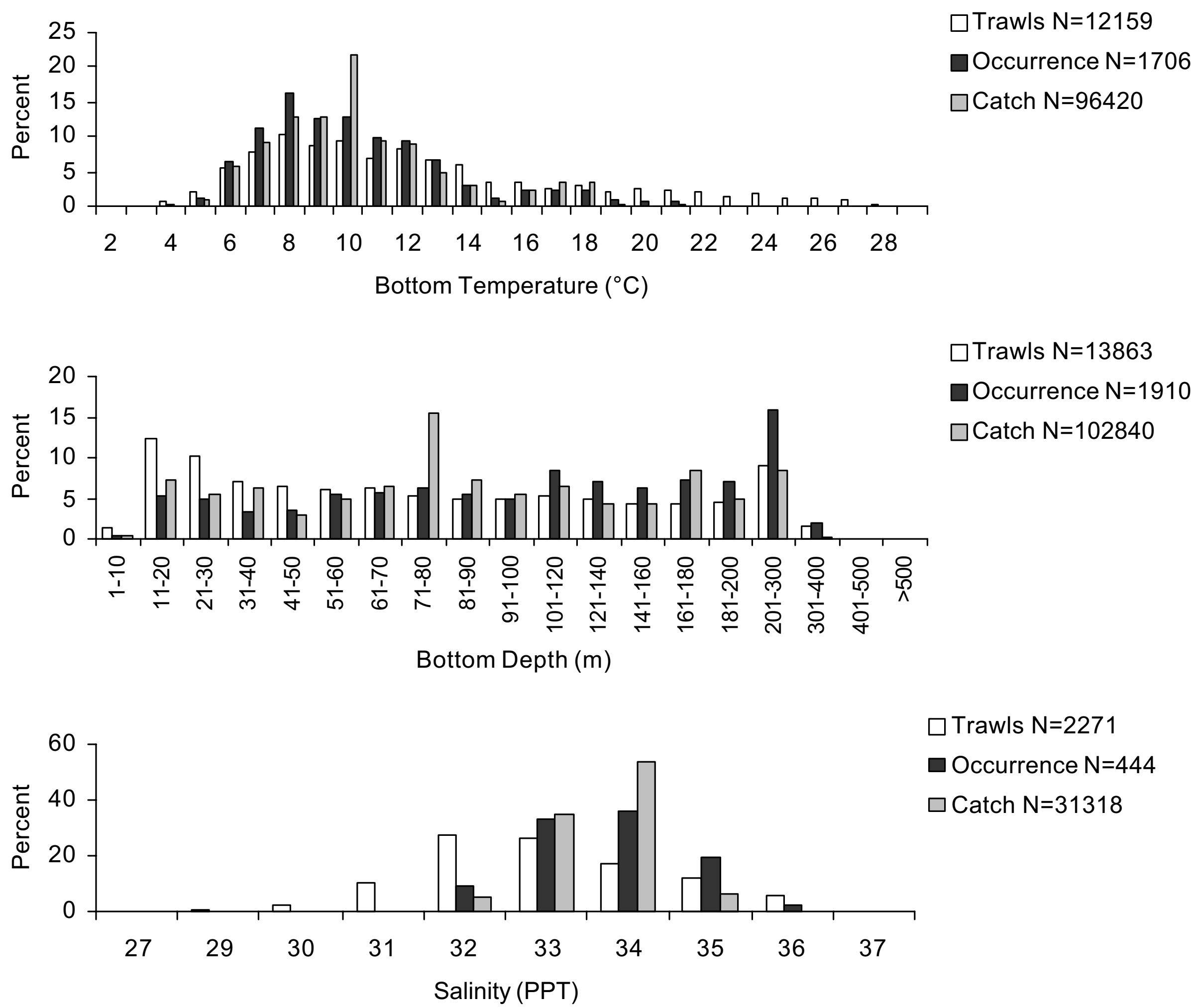


Figure 19. cont'd.

Silver Hake
Massachusetts Inshore Trawl Survey
Spring/Juveniles

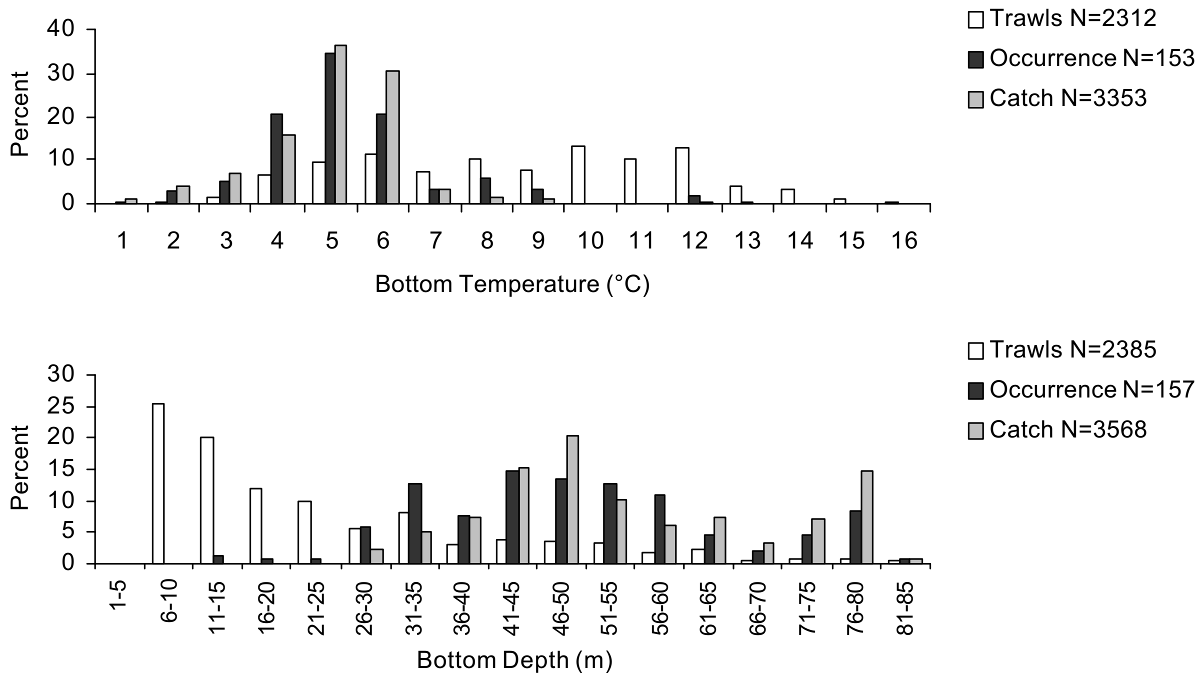


Figure 20. Spring and fall distributions of juvenile silver hake and trawls relative to bottom water temperature and depth based on Massachusetts inshore trawl surveys (1978-2002, all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which silver hake occurred, and gray bars represent, within each interval, the percentage of the total number of silver hake caught.

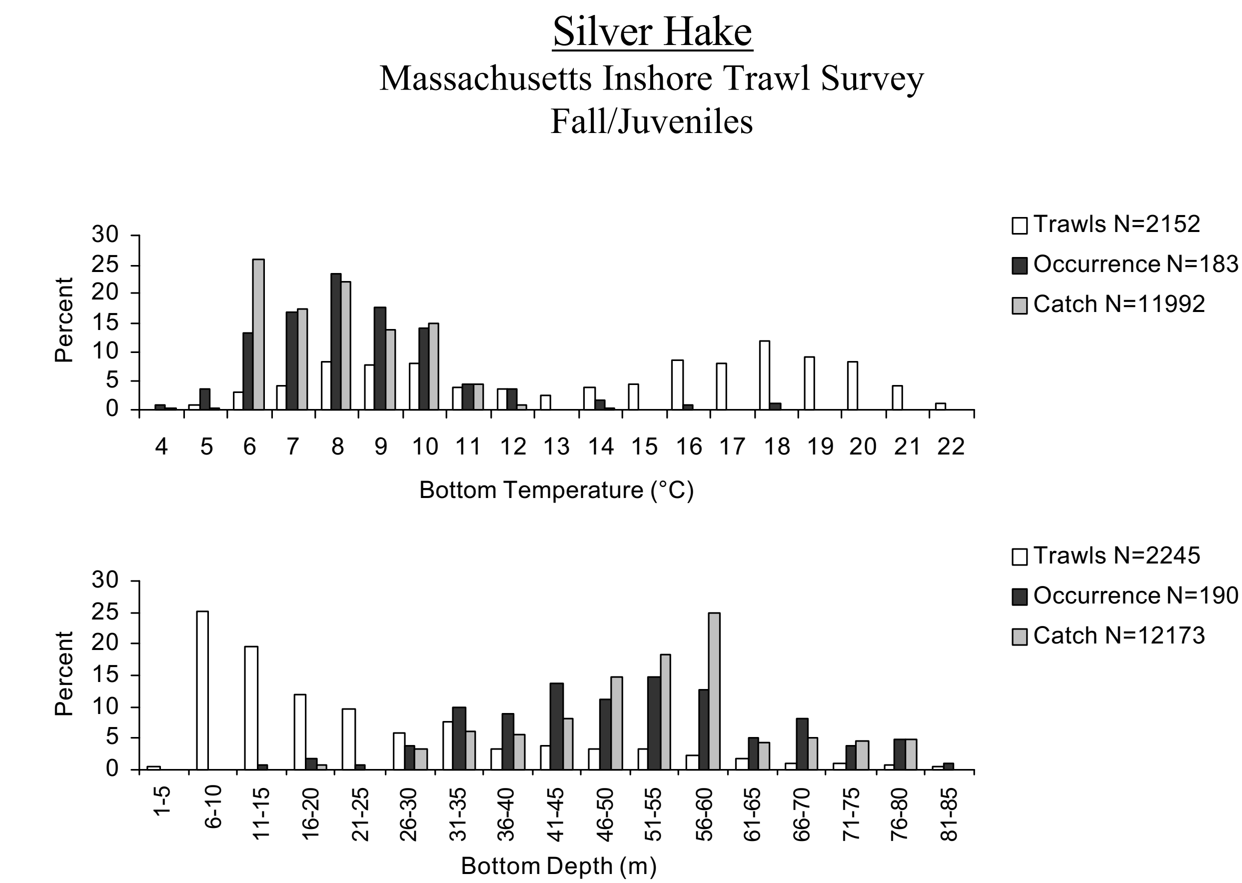


Figure 20. cont'd.

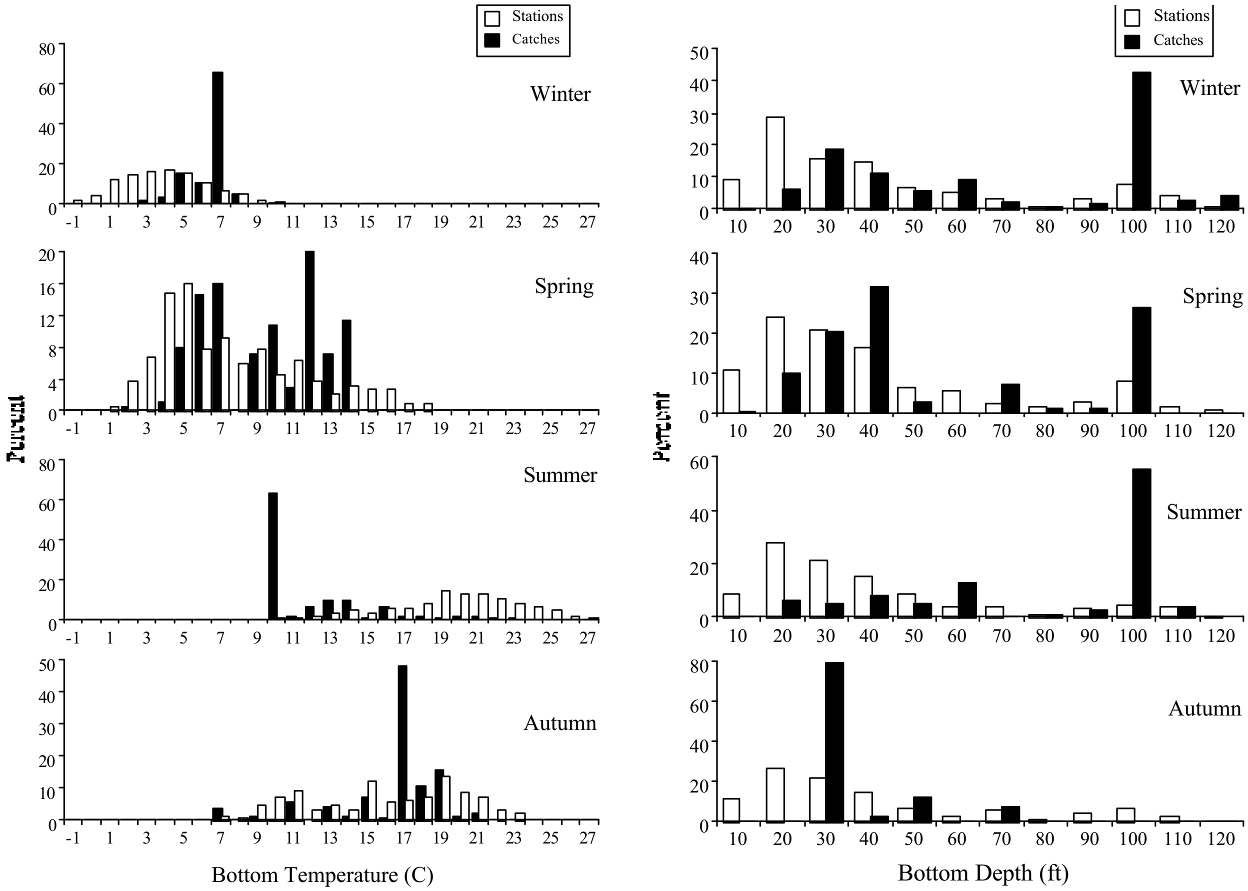


Figure 21. Seasonal distributions of juvenile silver hake and trawls relative to bottom water temperature and depth based on Rhode Island Narragansett Bay trawl surveys (1990-1996; all years combined). White bars give the distribution of all the trawls and black bars represent, within each interval, the percentage of the total number of silver hake caught.

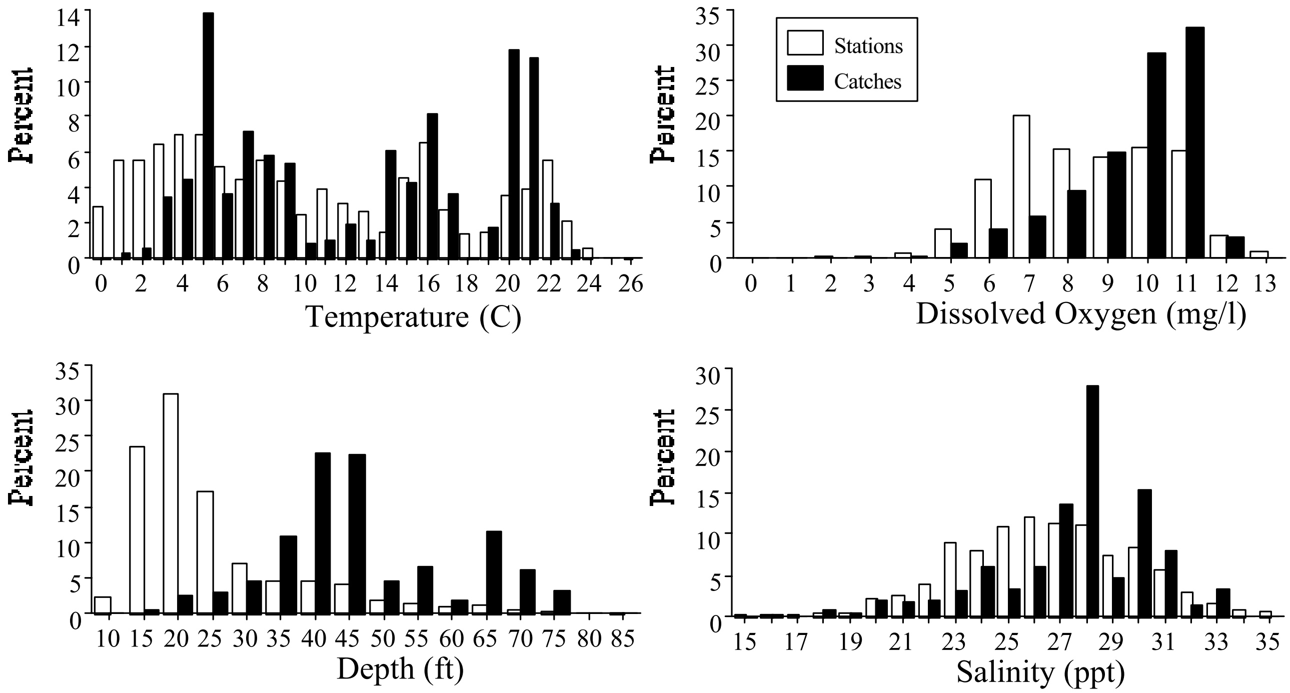


Figure 22. Distributions of juvenile silver hake and trawls relative to bottom water temperature, depth, salinity, and dissolved oxygen based on NEFSC Hudson-Raritan estuary trawl surveys (1992-1997; all years combined). White bars give the distribution of all the trawls and black bars represent, within each interval, the percentage of the total number of silver hake caught.

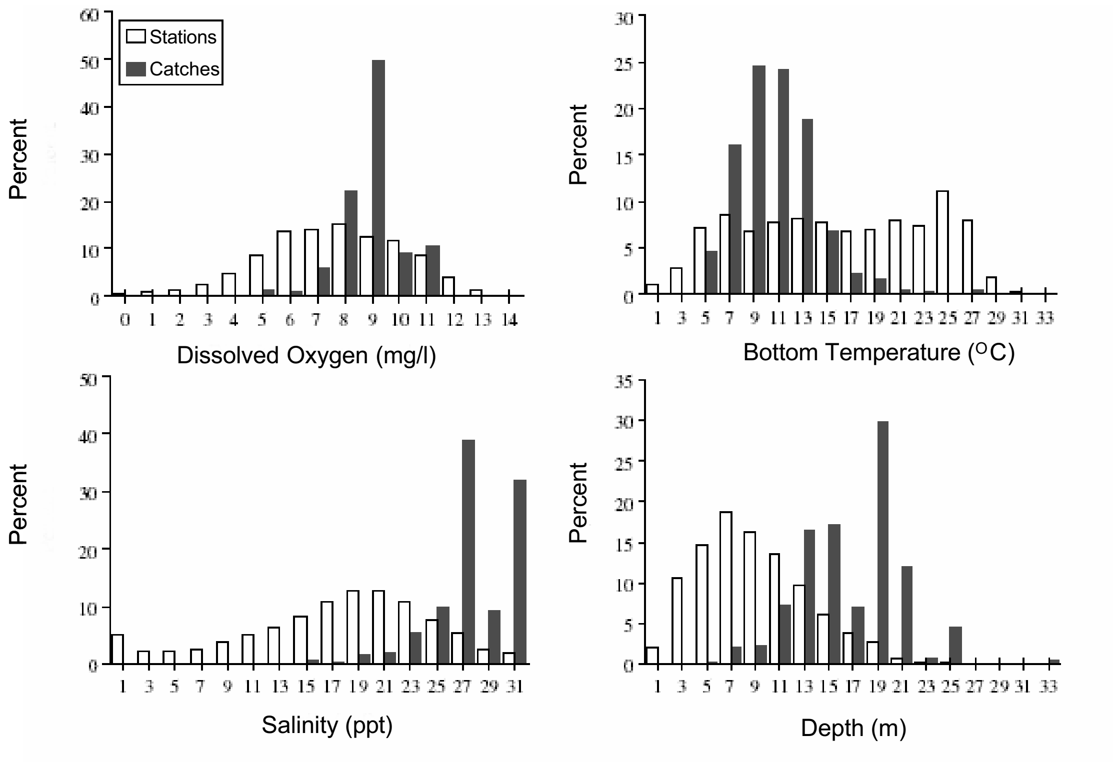


Figure 23. Hydrographic preferences for juvenile and adult silver hake in Chesapeake Bay, from the VIMS trawl surveys, 1988-1999 (all years combined). Adapted from Geer (2002).

Silver Hake

NEFSC Bottom Trawl Survey
Spring/Adults

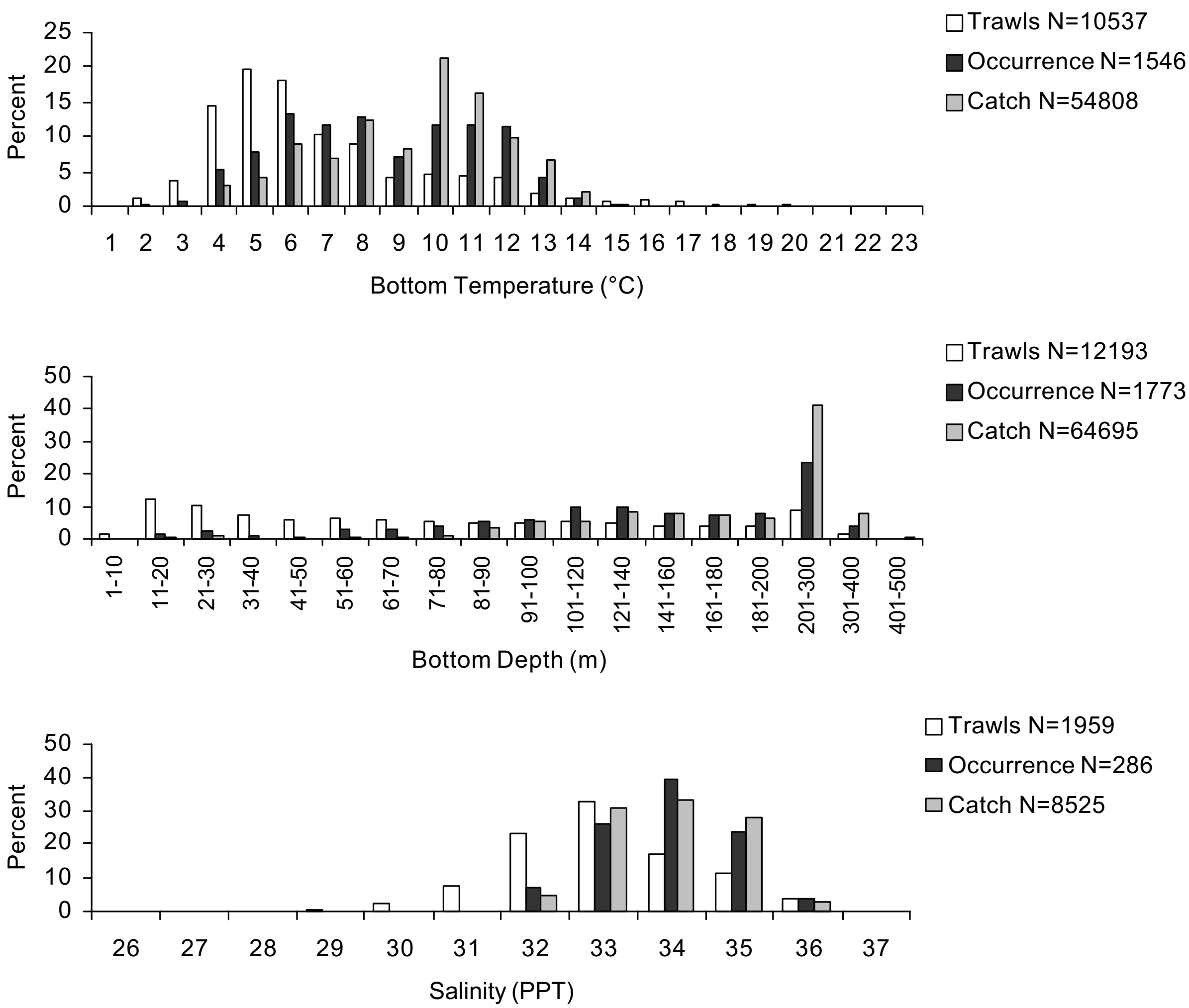


Figure 24. Spring and fall distributions of adult silver hake and trawls relative to bottom water temperature, depth, and salinity based on NEFSC bottom trawl surveys (1963-2002; all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which silver hake occurred, and gray bars represent, within each interval, the percentage of the total number of silver hake caught. Note that the bottom depth intervals change with depth (from 10 to 20 to 100 m) in the bottom depth bar chart.

Silver Hake
NEFSC Bottom Trawl Survey
Fall/Adults

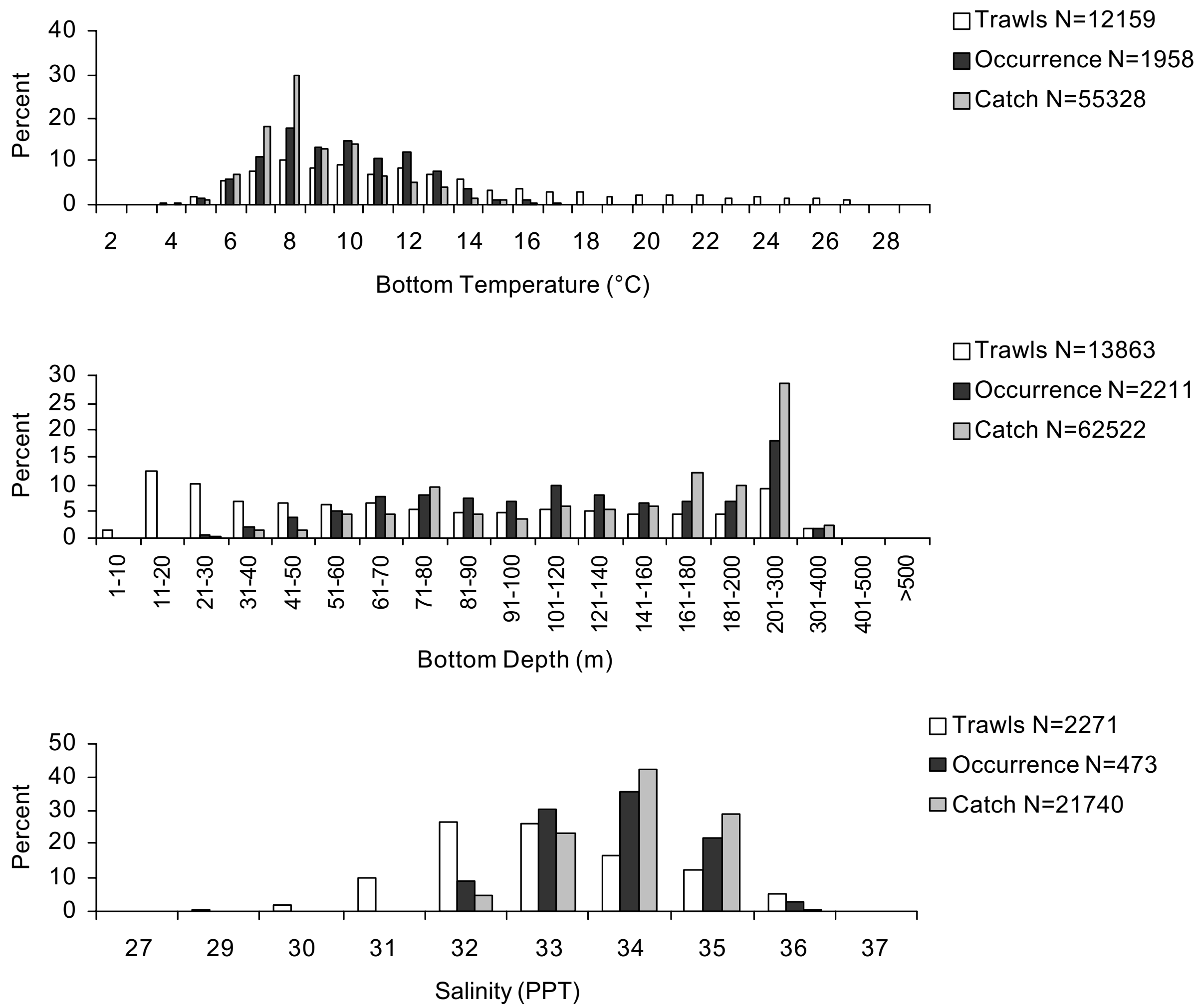


Figure 24. cont'd.

Silver Hake

Massachusetts Inshore Trawl Survey
Spring/Adults

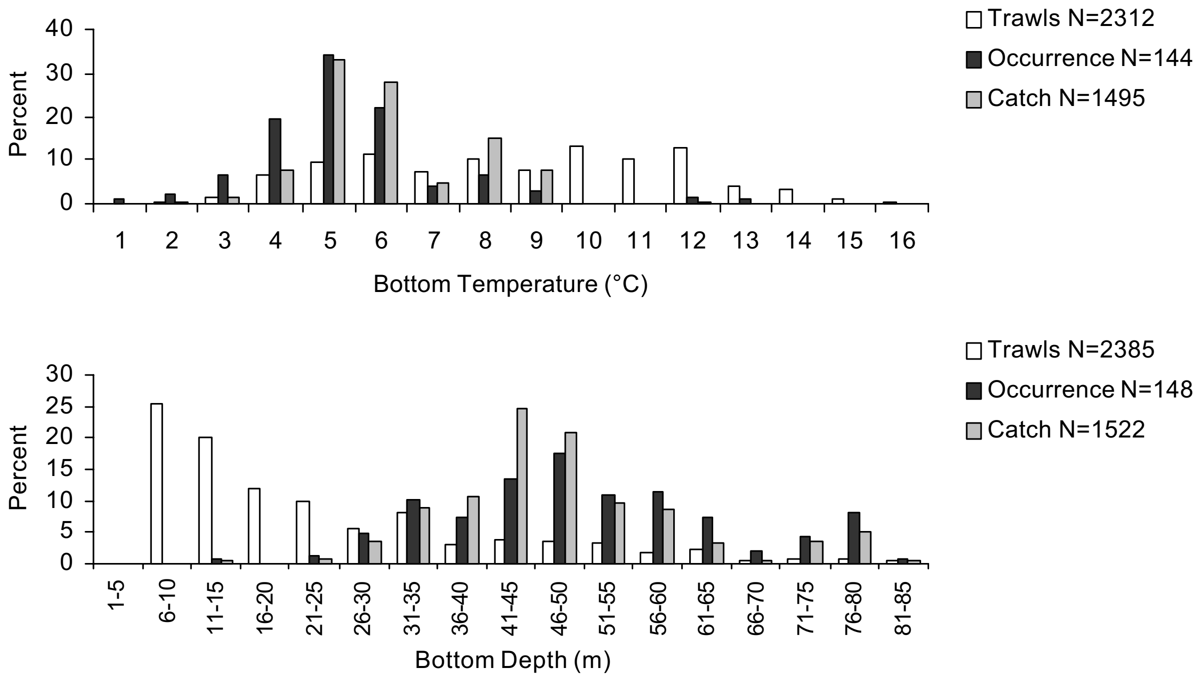
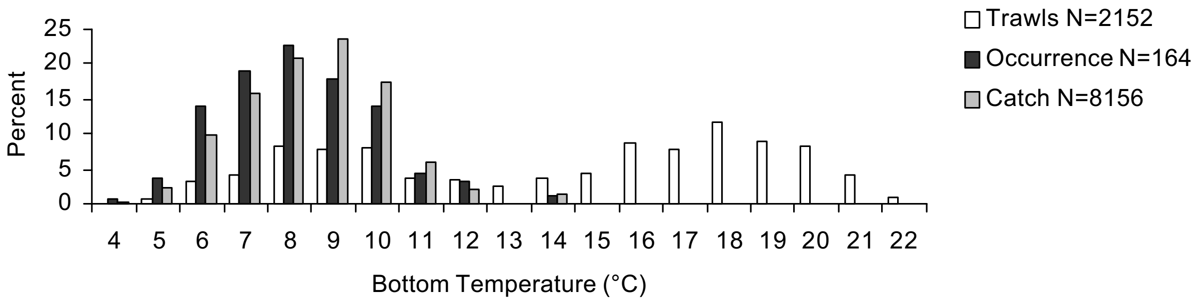


Figure 25. Spring and fall distributions of adult silver hake and trawls relative to bottom water temperature and depth based on Massachusetts inshore trawl surveys (1978-2002, all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which silver hake occurred, and gray bars represent, within each interval, the percentage of the total number of silver hake caught.

Silver Hake
Massachusetts Inshore Trawl Survey
Fall/Adults



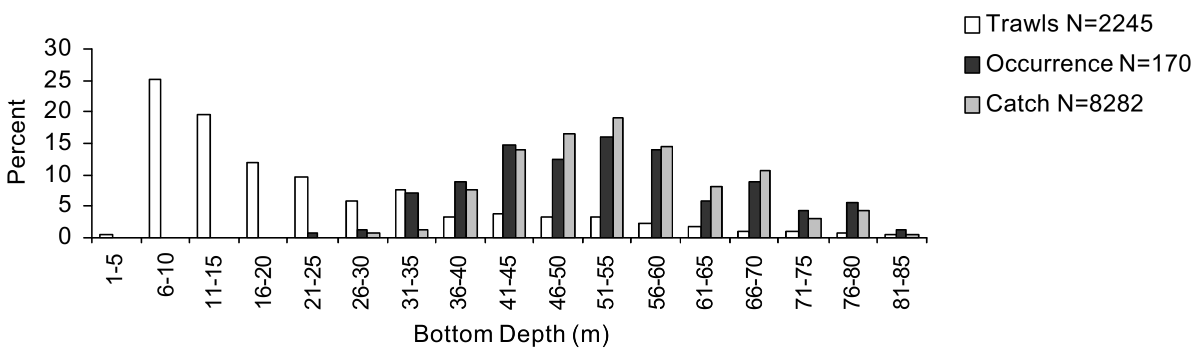


Figure 25. cont'd.

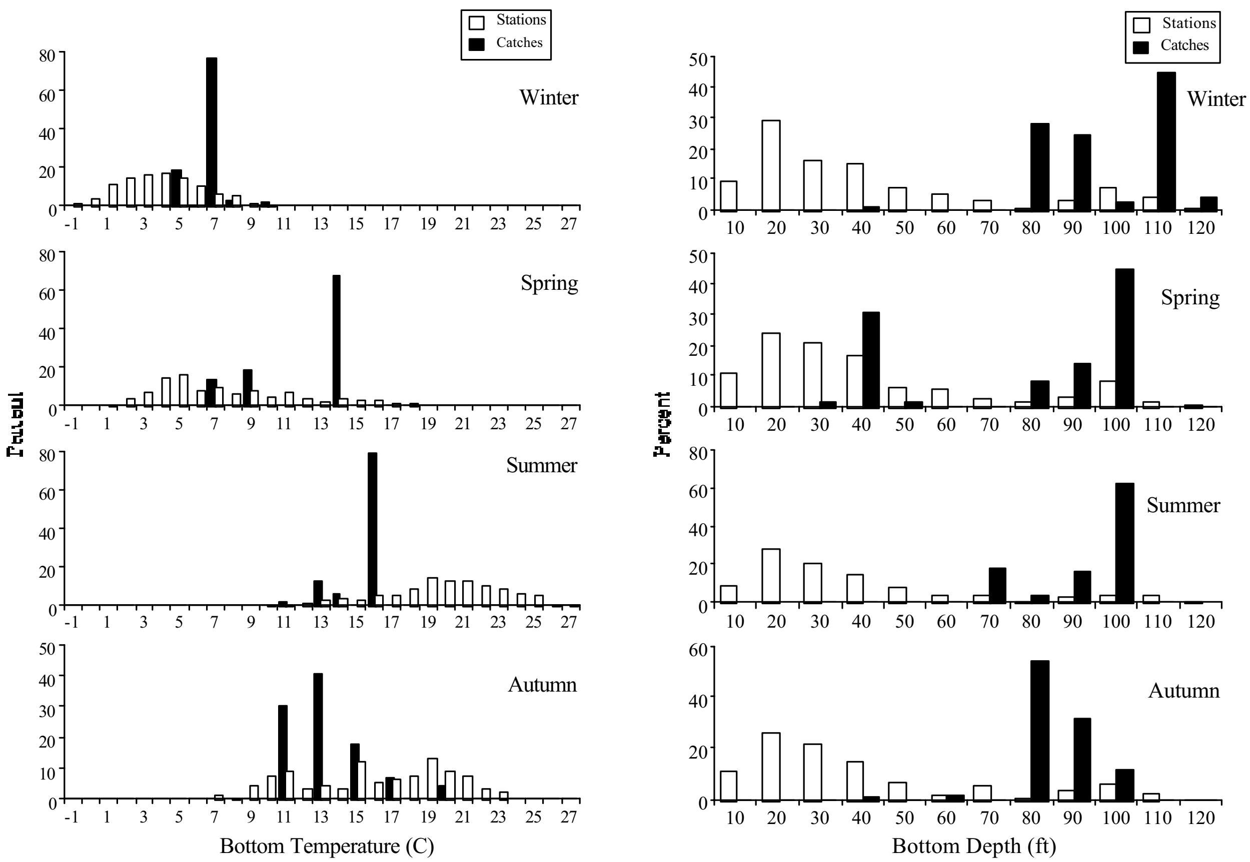
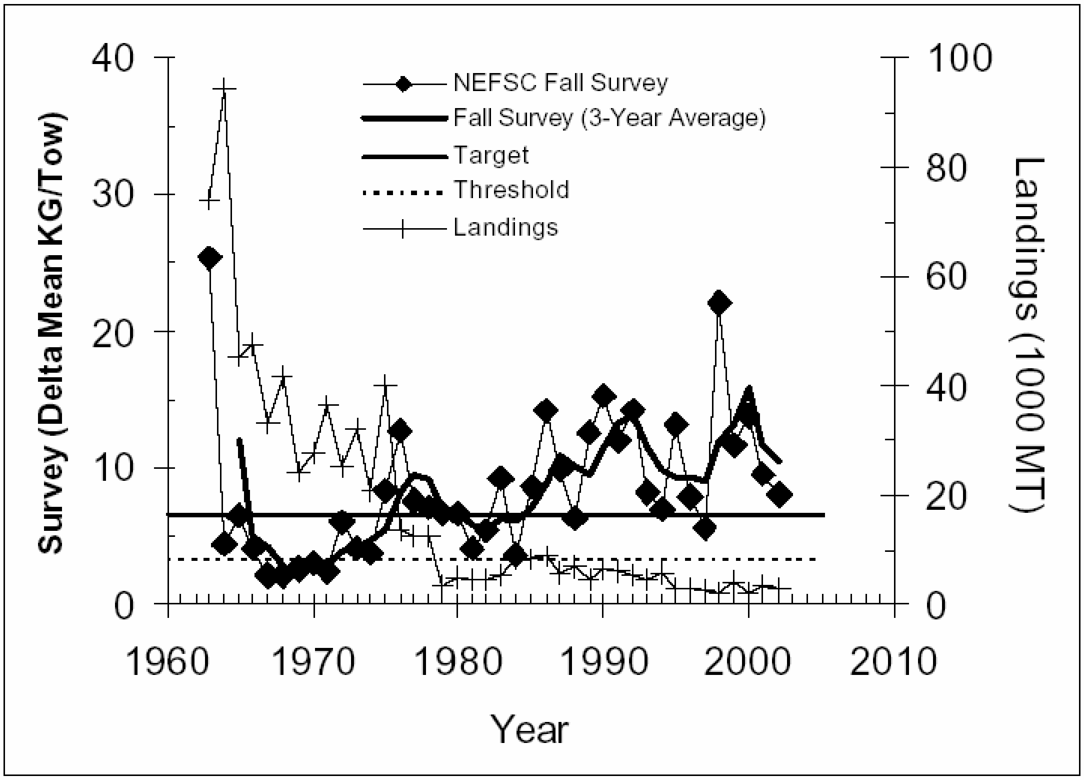


Figure 26. Seasonal distributions of adult silver hake and trawls relative to bottom water temperature and depth based on Rhode Island Narragansett Bay trawl surveys (1990-1996; all years combined). White bars give the distribution of all the trawls and black bars represent, within each interval, the percentage of the total number of silver hake caught.



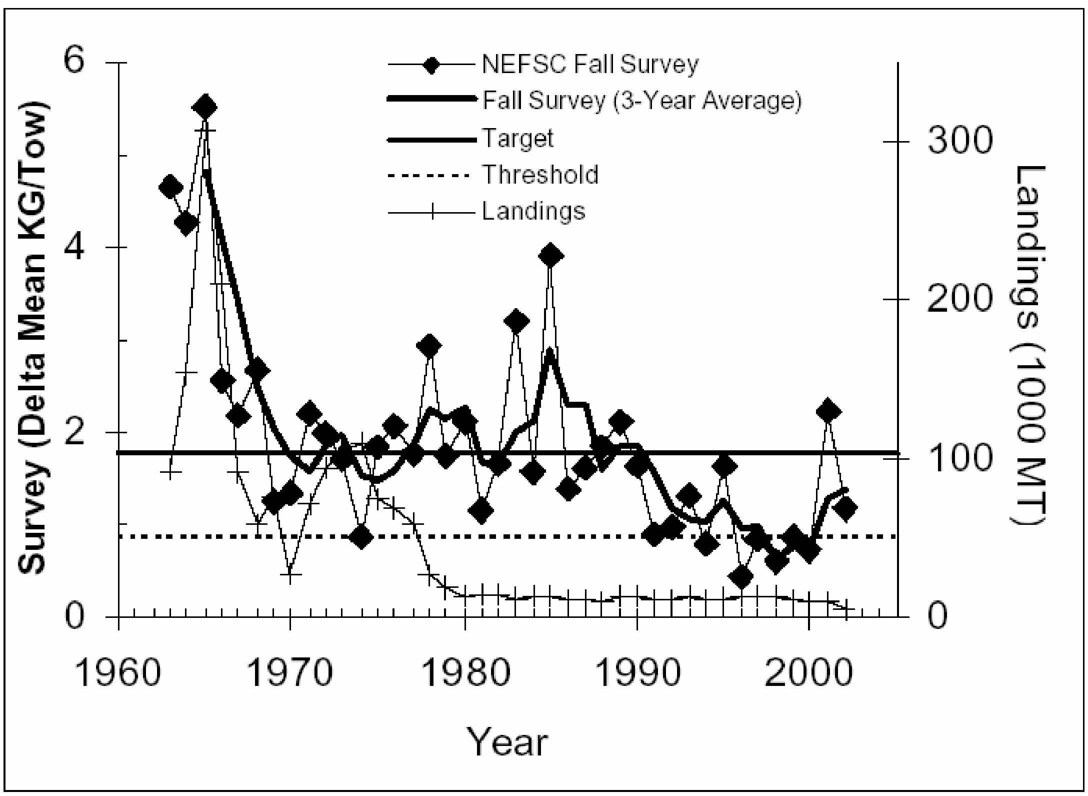


Figure 27. Trends in NEFSC fall survey data and landings for northern (top) and southern (bottom) stocks of silver hake, from New England Fishery Management Council (2003).

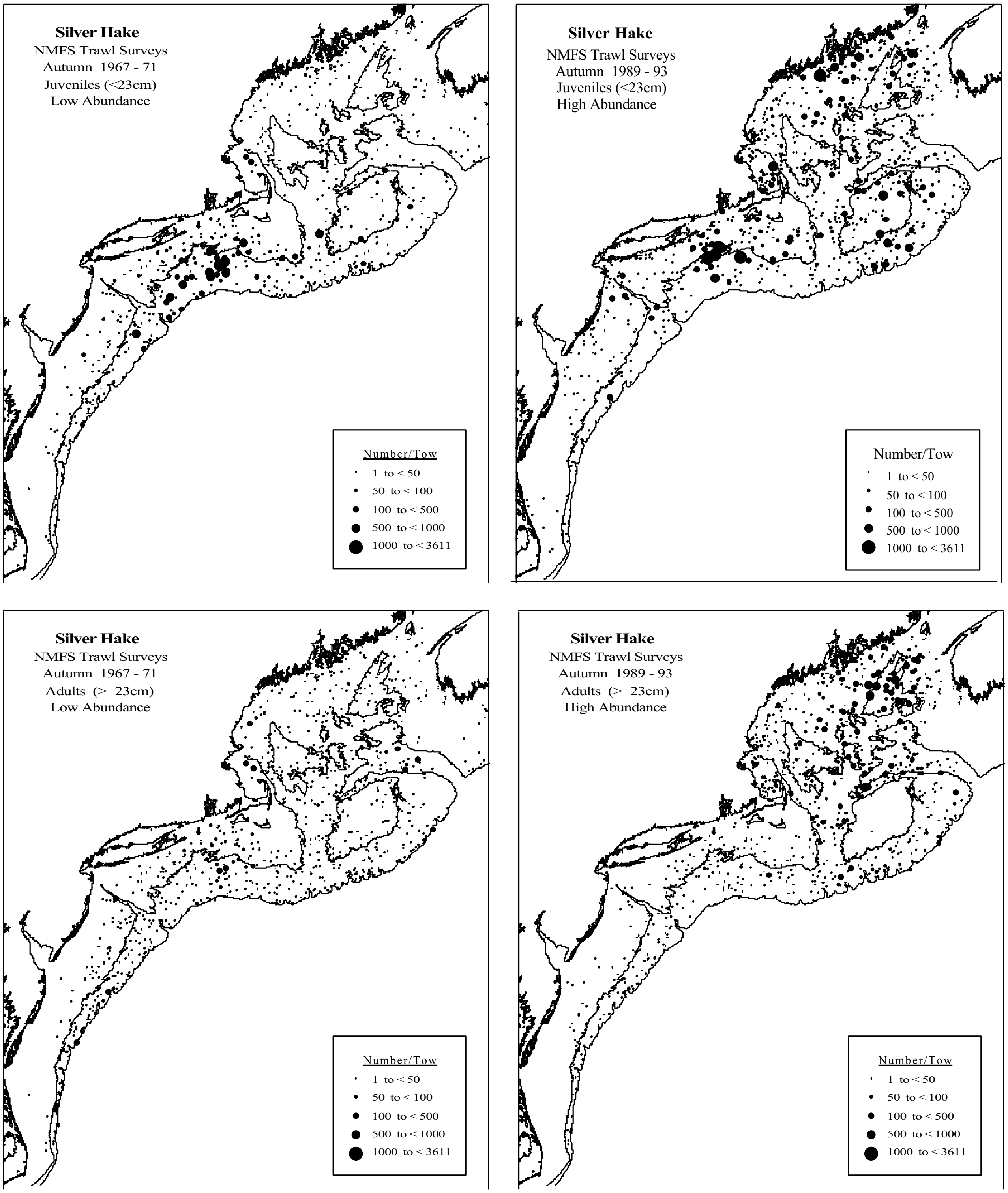


Figure 28. Distribution and abundance of juvenile and adult silver hake from NEFSC autumn bottom trawl surveys during a period of relatively low abundance (autumn 1967-1971) and a period of relatively high abundance (autumn 1989-1993).

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The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

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