NOAA Technical Memorandum NMFS-NE-133

Essential Fish Habitat Source Document:

Red Hake, *Urophycis chuss*, Life History and Habitat Characteristics

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

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Essential Fish Habitat Source Document:

Red Hake, *Urophycis chuss*, Life History and Habitat Characteristics

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

Editorial Production

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

Special Acknowledgments

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

Internet Availability

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

Information Updating

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

Species Names

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

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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. 1991. Common and scientific names of fishes from the United States and Canada. 5th ed. *Amer. Fish. Soc. Spec. Publ.* 20; 183 p.

[b]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.

[c]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.

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

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

FOREWORD

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

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

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

NMFS Strategic Plan for Fisheries Research (February 1998)

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

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

The Northeast Fisheries Science Center compiled the available information on the distribution, abundance, and habitat requirements for each of the species managed by the New England and Mid-Atlantic Fishery Management Councils. That information is presented in this series of 30 EFH species reports (plus one consolidated methods report). The EFH species reports comprise a survey of the important literature as well as original analyses of fishery-independent data sets from NMFS and several coastal states. The species reports are also the source for the current EFH designations by the New England and Mid-Atlantic Fishery Management Councils, and have understandably begun to be referred to as the "EFH source documents."

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

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

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

JAMES J. HOWARD MARINE SCIENCES LABORATORY
HIGHLANDS, NEW JERSEY
SEPTEMBER 1999

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ECOSYSTEMS PROCESSES DIVISION
NORTHEAST FISHERIES SCIENCE CENTER

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INTRODUCTION

Red hake (*Urophycis chuss*; Walbaum 1792; Figure 1) is a demersal fish that occurs from North Carolina to Southern Newfoundland and is most abundant between Georges Bank and New Jersey (Sosebee 1998). Although rarely found in the Gulf of St. Lawrence, it is sometimes caught on the southern Grand Banks (Scott and Scott 1988). In U.S. waters the species is managed under the Northeast Multispecies Fishery Management Plan (NEFMC 1993).

This document provides information on the life history and habitat characteristics of red hake inhabiting the Gulf of Maine, Georges Bank, and the Middle Atlantic Bight.

LIFE HISTORY

Red hake are relatively short-lived, reaching a maximum age of 14 years and a maximum size of 63 cm TL for females (Dery 1988), but few are collected that are over 8 years old and more than 50 cm in length. Their growth rate is initially rapid but declines at maturity; the species does not reach the large size of its congener the white hake (*U. tenuis*).

Red hake make seasonal migrations to follow preferred temperature ranges. During warmer months, they are most common in depths less than 100 m; during colder months, they are most common in depths greater than 100 m. Fritz (1965) reported that they range from 30 to 370 m and that they are most common in the fall between 50 and 210 m.

EGGS

Our understanding of the environmental associations of the eggs of this species is poor because the eggs of several species of *Urophycis* and *Phycis* hake co-occur north of Cape Hatteras and presently they are not readily separable to species in plankton collections (Berrien and Sibunka 1999) despite the discussion on their tentative identification in Bigelow and Schroeder (1953). Based on eggs taken from spawning red hake, the eggs are about 0.6-1.0 mm in diameter, buoyant, and float near the surface. Hatching occurs in 3-7 days at typical spawning temperatures (Able and Fahay 1998).

LARVAE

Red hake larvae are < 2.0 mm at hatching (Able and Fahay 1998). Larval red hake dominate the summer ichthyoplankton in the Middle Atlantic Bight and were most abundant at mid- and outer continental shelf stations (Comyns and Grant 1993). Few red hake larvae have been collected in the Gulf of Maine suggesting that spawning in the Middle Atlantic Bight produces the majority of recruits to the Gulf of Maine stock. Larval red hake have been collected in the upper water column from May through December (Collette and Klein-MacPhee, in prep.).

Accurate identification and separation of red and white hake larvae in the Gulf of Maine was problematic and records prior to Methven (1985) may be in error or include mixtures of two or more species (Collette and Klein-MacPhee, in prep.). To complicate things further, post-larval hake in the northern Gulf of Maine and Canadian waters have morphometric characteristics (e.g., scale count and otolith shape) that appear intermediate between red hake and white hake (Bigelow and Schroeder 1953; Dery 1988). Although egg identification is problematic in collections, red hake larvae can be identified because of artificial spawning and rearing studies (Miller and Marak 1959). The larvae were not confidently identified in Northeast Fishery Science Center (NEFSC) Marine Resources Monitoring, Assessment and Prediction (MARMAP) surveys until 1982 (Reid *et al.* 1999).

JUVENILES

Recently metamorphosed juveniles remain pelagic until they reach 25-30 mm TL in about two months (Methven 1985). They gradually descend to the bottom at a size of about 35-40 mm TL (Fahay 1983; Able and Fahay 1998). Pelagic juvenile red hake gather around floating debris, under patches of sargassum, and occasionally within the tentacles of jellyfish (Wicklund 1966).

Demersal settlement generally occurs between September and December with peaks in October-November (Collette and Klein-MacPhee, in prep.). Laboratory studies suggest that a strong thermocline in the water column can inhibit benthic settlement when cold water below the thermocline requires descending juveniles to hesitate and acclimate to cooler bottom temperatures. Delayed descent to the bottom may expose juveniles to greater risk of predation within the thermocline while they acclimate. Red hake undergo additional changes in body shape and color upon reaching their benthic habitat (Steiner and Olla 1985).

Shelter is a critical habitat requirement for red hake (Steiner *et al.* 1982). Newly settled juveniles occur in depressions on the open seabed (Able and Fahay 1998). Older juveniles commonly associate with shelter or structure, often with living sea scallops (*Placopecten magellanicus*) where they can be found under the scallops on the sediment or within their open mantle cavity (Steiner *et al.* 1982; Garman 1983; Able and Fahay 1998). Juveniles maintain this association until they are about 10-13 cm TL. Small scallops tend to shelter small juvenile red hake and larger scallops shelter a wider range of sizes. Juveniles also use Atlantic surf clam (*Spisula solidissima*) shells, seabed depressions made by larger fish or decapod crustaceans, moon snail egg case collars, anemone and polychaete tubes (Wicklund 1966; Ogren *et al.* 1968; Stanley 1971; Shepard *et al.* 1986), submerged man-made objects, debris, and artificial reefs (Eklund 1988). Larger juveniles remain near scallop beds and other structures in coastal areas and embayments; later they join older fish in an offshore migration in the Middle Atlantic Bight. By the end of the first summer, red hake juveniles are about 10 cm TL. There is little growth over the winter and at the end of 12 months they are about 15-17 cm TL (Able and Fahay 1998). They occur in larger estuaries, including the Chesapeake Bay main stem, Delaware Bay, and Hudson-Raritan estuary, during cooler seasons, and along coastal New England into Canadian waters from spring to fall (Jury *et al.* 1994; Stone *et al.* 1994; Wilk *et al*. 1998).

ADULTS

Adult red hake are common on soft sediments and much less common on gravel or hard bottoms. They are not confined to the bottom and can be found in the water column (Collette and Klein-MacPhee, in prep.; Gottschall *et al.*, in review). Adults are usually found in depressions in softer sediments or shell beds and not on open sandy bottom. They create the depressions or use existing depressions (Auster *et al.* 1991). Adults also inhabit inshore artificial reefs off New York during the summer (Ogren *et al*. 1968), and Eklund (1988) reported that they were most abundant on natural and artificial reefs off Delaware-Virginia during April-May.

REPRODUCTION

Major spawning areas occur on the southwest part of Georges Bank and on the continental shelf off southern New England and eastern Long Island; however, a nearly ripe female was collected during April in Chesapeake Bay (Hildebrand and Schroeder 1928). Spawning adults and eggs are also common in the marine parts of most coastal bays between Narragansett Bay, Rhode Island, and Massachusetts Bay, but rarely in coastal areas to the south or north (Jury *et al.* 1994; Stone *et al.* 1994). Based on condition of the gonads, red hake spawning occurs at temperatures between 5-10^{o}C from April through November (Wilk *et al.* 1990). In the Gulf of Maine, spawning may not begin until June with a peak during July-August (Dery 1988; Scott and Scott 1988). Spawning red hake are most abundant in May-June in the New York Bight and on Georges Bank (Collette and Klein-MacPhee, in prep.). Eklund (1988) reported a peak in their gonadosomatic index (GSI) during May-July and the presence of ripe eggs in June-July off Delaware. Their fecundity is unknown.

Female red hake are generally larger and live longer than males (Dery 1988). O'Brien *et al.* (1993) reported that for the northern stock, 50% of females are mature at an age of 1.8 years and 26.9 cm TL, and 50 % of males are mature at 1.4 years and 22.2 cm TL. For the southern stock, size at 50% maturity is 25.1 cm TL for females and 23.8 cm TL for males; both sexes reach maturity at 1.7-1.8 years. Size and age at maturity may increase near the southern limits of the range.

FOOD HABITS

Larvae prey mainly on copepods and other micro-crustaceans, and are sometimes found under floating eelgrass or algae looking for prey.

Juvenile red hake leave shelter at night and commonly prey on small benthic and pelagic crustaceans, including larval and small decapod shrimp and crabs, mysids, euphausiids, and amphipods (Steiner *et al.* 1982; Garman 1983; Bowman *et al.* 1987) (Figure 2). In the Hudson-Raritan estuary, *Crangon* shrimp, the mysid *Neomysis americana* and other small epibenthic crustaceans are the dominant prey (Steimle *et al*., in prep.). Night feeding is possible because their pelvic fins and chin barbels are chemo-sensitive to presence of prey (Pearson *et al.* 1980). Amphipods, small decapods (e.g., *Crangon* shrimp), and polychaetes are important prey in the Middle Atlantic Bight, but dominant prey can change seasonally and include copepods and chaetognaths (Bowman 1981; Luczkovich and Olla 1983; Sedberry 1983; Bowman *et al.* 1987). In the laboratory, red hake feed day and night and can eat up to 7.4 % of their body weight per day; feeding rates in the wild may be higher (Luczkovich and Olla 1983; Collette and Klein-MacPhee, in prep.).

Adult red hake, like juveniles, prey upon crustaceans, but also consume a variety of demersal and pelagic fish and squid (Langton and Bowman 1980; Bowman and Michaels 1984; Vinogradov 1984; Steimle 1985) (Figure 2). Rachlin and Warkentine (1988) showed that the diet of red hake overlaps the diet of the two other *Urophycis* spp. in the New York Bight.

PREDATION

Red hake (presumably mostly juveniles) are eaten by larger predators such as striped bass (*Morone saxatilus*), spiny dogfish (*Squalus acanthias*), goosefish (*Lophius americanus*), white hake (*Urophycis tenuis*), silver hake (*Merluccius bilinearis*), sea raven (*Hemitripterus americanus*), harbor porpoise (*Phocoena phocoena*) and other predators (Schaefer 1960; Bowman *et al*. 1984;

Gannon *et al.* 1997). Adult red hake are also cannibalistic on their young.

Despres-Patanjo *et al.* (1982) reported that red hake were found with fin rot and skin ulcers, but at a relatively low incidence (about 1%). These diseases are often associated with degraded environmental conditions.

MIGRATION

Red hake make extensive seasonal, depth- and temperature-related migrations. They are most common in depths < 100 m during warmer months and in depths > 100 m during colder months.

Red hake are summer migrants into coastal waters and estuaries of the Gulf of Maine and southern New England where they commonly occur in coastal bays and estuaries < 10 m deep (Tyler 1971; Jury *et al.* 1994; Stone *et al.* 1994). Juveniles commonly occur in some coastal bays south to the main stem of the Chesapeake Bay in the winter-spring, but less so in the summer (Hildebrand and Schroeder 1928; Stone *et al.* 1994; Murdy *et al.* 1997). Red hake migrate into deeper waters (to 980 m) during the winter in the Gulf of Maine, the outer continental shelf south of Georges Bank (Bigelow and Schroeder 1953; Murawski and Finn 1988), and into the submerged Hudson Shelf Valley south of Long Island.

In the Gulf of Maine, red hake move inshore in the autumn and winter as the coastal waters cool; if temperatures drop too low, red hake will move offshore. They move into Passamaquoddy Bay, Canada, in the summer and leave in the autumn, possibly because temperatures remain cooler in the summer and become too cold in the winter (Bigelow and Schroeder 1953).

In the Middle Atlantic Bight, red hake occur most frequently in coastal waters in the spring and fall; they move offshore to avoid the warm summer temperatures (Bigelow and Schroeder 1953), although juveniles are found in deep holes and channels in coastal bays during the summer. In the winter, most of the population moves offshore, but the degree of movement probably depends on the severity of the winter. Winter migrants return inshore the following spring (Able and Fahay 1998).

STOCK STRUCTURE

Red hake are managed as two U.S. stocks: a northern stock, from the Gulf of Maine to northern Georges Bank and a southern stock, from southern Georges Bank into the Middle Atlantic Bight. The stocks are divided along the central east-west axis of Georges Bank (Sosebee 1998).

HABITAT CHARACTERISTICS

The hydrographic and physical characteristics of the habitat associated with the occurrence of red hake are presented in Table 1.

EGGS

The pelagic eggs of red hake are not separated from eggs of similar species in field collections, thus the characteristics of the habitat in which red hake eggs are commonly found are poorly known. Spawning occurs in the summer on the continental shelf in the Middle Atlantic Bight and is concentrated off southern New England (Able and Fahay 1998).

LARVAE

Red hake larvae were collected on the middle to outer continental shelf of the Middle Atlantic Bight at temperatures between 8 and 23^{o}C (most were collected between 11-19^{o}C) within water depths between 10 and 200 m, with a few deeper occurrences (Figure 3). Few larvae were collected in the Gulf of Maine.

JUVENILES

Bigelow and Schroeder (1953) report that the "youngest fry" were observed swimming at the surface in the west-central Gulf of Maine during the summer at a temperature of about 20^{o}C. In the bays and estuaries south of Cape Cod during the summer, juveniles (< 24 cm TL) usually avoid shallow waters that are warmer than about 22^{o}C, but they do inhabit deeper bays such as Narragansett Bay, Rhode Island (Figure 4). North of Cape Cod where waters are cooler, juveniles can remain inshore throughout the summer; they were abundant in spring (May) and in early autumn (September) (Figure 5).

In the NEFSC bottom trawl survey, juvenile red hake were collected at a wide range of temperatures (2-20^{o}C) and depths (5 m to > 100 m), but they were most abundant at temperatures of 3-16^{o}C and at depths < 120 m; there were seasonal shifts in apparent preferences (Figure 6).

In the inshore waters off southern New England, juvenile red hake were collected at temperatures of 2-22^{o}C, in depths from 5 m to > 50 m, and at salinities of 24-32 ppt (Figures 4 and 5). In Long Island Sound, they were found mostly on mud substrates (Gottschall *et al.*, in review). Comparing red hake distribution in the Connecticut trawl survey to the sediment distribution in Reid *et al.* (1979) suggests that red hake prefer silty, fine sand sediments. In the Hudson-Raritan estuary, juveniles were collected at similar temperature and depth ranges as in southern New England when salinities were above about 22 ppt, but collection frequency declined above 28 ppt (Figure 7).

Age 0+ fish are sensitive to DO levels < 4.2 mg/L; in laboratory experiments, they left their bottom shelter and ascended into the water column, which increases their risk to predation (Bejda *et al.* 1987). This DO preference is reflected in their distribution in the Hudson-Raritan estuary (Figure 7). Older fish were less sensitive to low DO.

ADULTS

In general, adults are found at temperatures of 2-22^{o}C and at depths of about 5 m to > 300 m (Figures 5, 6, 8, and 9; Fritz 1965). In the Massachusetts, Rhode Island, and Long Island Sound surveys, adults were generally found in waters > 25 m deep, especially during the summer and fall (Figures 5 and 8). Adult red hake were usually found at a salinity range of 20-33 ppt in Long Island Sound and the Hudson-Raritan estuary (Figure 9). They appear to be sensitive to hypoxia; mortalities were noted during the 1976 anoxia episode off New Jersey (Azarovitz *et al.* 1979). In the Hudson-Raritan estuary they prefer DO concentrations > 6 mg/L (Figure 9). In Long Island Sound, they were found mostly on mud substrates (Gottschall *et al.,* in review). Even in deep water they have been observed using various types of shelter (Collette and Klein-MacPhee, in prep.).

GEOGRAPHICAL DISTRIBUTION

In the northwest Atlantic Ocean, red hake occur from Nova Scotia to Cape Hatteras, North Carolina. They are most abundant on Georges Bank, in the Gulf of Maine off Cape Cod, and in the northern Middle Atlantic Bight off Long Island (Figure 10).

EGGS

During cooler months (Dec-Apr), the undifferentiated *Urophycis-Phycis* hake spp. eggs were collected mostly at the edge of the continental shelf on southern Georges Bank and the Middle Atlantic Bight. During warmer months, hake eggs were collected across the entire shelf in this area. Relatively few hake eggs occur in the Gulf of Maine (Bigelow and Schroeder 1953; Berrien and Sibunka 1999). During the NEFSC MARMAP ichthyoplankton survey (1978-1987), *Urophycis-Phycis* spp. eggs were collected across the continental shelf in the Middle Atlantic Bight, on Georges Bank, and to a lesser degree in the Gulf of Maine (Figure 11).

LARVAE

In the NEFSC MARMAP ichthyoplankton survey (1982-1987), identified red hake larvae were collected on southern Georges Bank and on the mid- to outer continental shelf throughout the Middle Atlantic Bight (Figure 12); few larvae were collected in the Gulf of Maine. Larvae were collected most abundantly during surveys in the early fall, September-October. Red hake larvae dominate the summer ichthyoplankton in the Middle Atlantic Bight and were most abundant at middle and outer continental shelf stations (Comyns and Grant 1993). Few red hake larvae have been collected in the Gulf of Maine suggesting that spawning in the Middle Atlantic Bight supplies the majority of recruits to the Gulf of Maine stock.

Larvae have been also reported in the marine parts of several bays and estuaries in the Middle Atlantic Bight, including the Hudson-Raritan estuary, Narragansett Bay, Buzzards Bay, and in bays north of Cape Cod to about the Merrimack River, New Hampshire (Jury *et al.* 1994; Stone *et al.* 1994).

JUVENILES

In the NEFSC bottom trawl survey, juveniles were collected offshore primarily in the New York Bight, southern New England, and Georges Bank during the winter; in coastal waters of the Middle Atlantic Bight, and were widespread across the continental shelf east of Long Island, in the spring and summer; and off southern New England and on Georges Bank in the fall (Figure 13). Juveniles were common in the main stem of Chesapeake Bay (Hildebrand and Schroeder 1928), in the channels of the Hudson-Raritan estuary (Figure 14), in central Long Island Sound, especially in the spring (Figure 15), and in other southern and northern New England bays and estuaries (Figures 16 and 17). Red hake were rare or not reported in most other Middle Atlantic Bight bays and estuaries (Jury *et al.* 1994; Stone *et al.* 1994).

The distribution of juveniles varies with season. In the winter, juveniles were collected on the continental shelf from southern Georges Bank into the Middle Atlantic Bight. In spring-summer, they were collected mostly from coastal waters of the Middle Atlantic Bight to northern Georges Bank and into the Gulf of Maine. In summer-fall, there is an apparent return movement offshore; notable concentrations of juveniles occurred off southern New England and on Georges Bank (Figure 13). Juveniles were relatively common throughout the year in the Hudson-Raritan estuary and Narragansett Bay, and most abundant in Long Island Sound in the summer (Figures 14-16). Juvenile red hake were common south and north of Cape Cod in the spring, but in the fall they were common only north of the Cape (Figure 17).

ADULTS

Adult red hake (northern stock) were collected in the deeper basins of the Gulf of Maine and along the northern edge of Georges Bank in all seasons; they were also collected in inshore waters and on Georges Bank during the summer and autumn (Figure 13). In the Middle Atlantic Bight, adult red hake (southern stock) were collected most commonly offshore and along the deeper southern edge of Georges Bank during the winter and spring (Figure 13). They were also collected inshore near Martha's Vineyard, Massachusetts. In summer-fall, adult red hake were collected on Georges Bank, in coastal waters from ~10 m deep across the continental shelf to around 300 m; they were especially abundant off southern New England (Figure 13). They occur in larger estuaries, including the Chesapeake Bay main stem, Delaware Bay, and the Hudson-Raritan estuary, during cooler seasons, and along coastal New England into Canadian waters from spring to fall (Jury *et al.* 1994; Stone *et al.* 1994). They were abundant in Long Island Sound and Narragansett Bay (Figures 15 and 16), but not off southern Cape Cod in the fall (Figure 17) or in the Hudson-Raritan estuary during any season (Figure 14).

STATUS OF THE STOCKS

The NEFSC has monitored and assessed red hake as two stocks, northern and southern, separated by the central axis of Georges Bank. The bottom trawl survey abundance index for the northern stock was relatively low in the 1960s and early 1970s, increased until about 1990, and has since declined slightly (Figure 18). The southern stock index was relatively stable from the mid-1960s until the 1980s when it declined with a short period of increase about 1990-1991. The northern and southern stocks were considered under exploited until recently (Sosebee 1998). The red hake population is considered overfished because the abundance index is below the lowest quartile of the monitoring time series (National Marine Fisheries Service 1997), but only the southern stock (or overall stock) is currently considered overfished (Sosebee 1998).

RESEARCH NEEDS

- Red hake spawning grounds and the habitat characteristics of the grounds need to be identified.
- A cost-effective way to separate and identify the eggs of various *Urophycis* spp. is needed to better define what habitats support the eggs of each species (Fahay 1983).
- The use by and relative importance to juveniles of shelter habits other than scallop and clam shells needs to be determined.
- What are the effects of sea scallop dredging on juvenile red hake habitat (Steiner *et al.* 1982)?
- Is the degree of cannibalism associated with larval and/or juvenile red hake habitat quality or quantity (shelter availability) (Luczkovich 1982)?
- More information is needed about the construction of sediment depressions by adult red hake for shelter or ambush-feeding, the use of these depressions by other species, and the effects of trawling and scallop dredging on the use of these shelters.
- More information is needed about the occurrence and use of shallow coastal habitats in the Gulf of Maine by red hake larvae (K. Sosebee, NMFS, Northeast Fisheries Science Center, Woods Hole, MA, personal communication).
- Better estimates of the fecundity are needed for females from the northern and southern stocks.
- The occurrence of morphometric characteristics that are intermediate between red and white hake in the northern Gulf of Maine and Canada suggests further studies should be made on possible environmental or genetic causes.

ACKNOWLEDGMENTS

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Table 1. Summary of life history and habitat characteristics for red hake, *Urophycis chuss*. (NS = northern stock; SS = southern stock; MAB = Middle Atlantic Bight; NYB = New York Bight; SNE = southern New England; GB = Georges Bank; GOM = Gulf of Maine)

Life Stage	Time of Year	Size and Growth	Geographic Location	Habitat	Substrate
Spawning	**NS**: May-Nov.; peak Jul.-Aug.; **SS**: Apr.- Oct.; peak: May-June.	Mature at ~22-30 cm	Southwest GB to SNE; peak in SNE.	< 110 m, to coastal bays	Unknown
Eggs [a]	Dec.-Nov.; peak: June-July	0.6-1.0 mm	MAB, Dec.- Apr. off-shore; May-Oct. widespread.	Water column, inner shelf.	Buoyant in upper water column.
Larvae	**NS**: May-Dec.; peak: Sept.-Oct. **SS**: May -Nov.; peak Aug.-Sept.	Hatch at ~2.0 mm; after 2 months begin descent to bottom.	Mainly western GB, mid-shelf in SNE and NYB; few in GOM.	Coastal, < 200 m; pelagic followed by a benthic phase.	Newly settled larvae need shelter, including live sea scallops.
Juveniles	Throughout	Settle at 23-49 mm TL; can grow ~16 mm/month; reach 10 cm by end of first fall and 15-17 cm by 1 year.	Estuaries-outer shelf; **NS**: offshore in winter; inshore in summer; **SS**: inshore in spring-fall; offshore in summer and winter.	Mostly < 120 m to low tide line.	< 14 cm TL fish use shells or live scallops for shelter; > 14 cm use various sediment types and shelter.
Adults	Throughout	**NS**: females mature at 1.8 yrs and 27 cm TL; males at 1.4 yrs and 22 cm; **SS**: females mature at 25 cm TL and males at 24 cm.	Same as juveniles; center of abundance is in SNE.	5-300+ m; prefer 30-130 m	Sand-mud, and in holes and depressions.

[a] The eggs of this species are not reliably separated from other *Urophycis* or *Phycis* species in this area.

Table 1. cont'd.

Life Stage	Temperature	Salinity	Dissolved Oxygen	Prey	Predators	Notes
Spawning	10-12^{o}C					
Eggs [a]						Hatch in 3-7 days.
Larvae	8-23^{o}C; most abundant at 11-19^{o}C; acclimation to lower bottom temperatures needed in summer.			Copepods, micro-crustaceans; feeding is usually nocturnal.		Larvae and pelagic juveniles use floating or midwater objects for shelter.
Juveniles	2-22^{o}C, most abundant at 3-16^{o}C; avoid < 3^{o}C and > 22^{o}C.	Usually > 22 ppt; most abundant at 31-33 ppt.	Avoid < 4.2 ppm	Mainly crustaceans such as *Crangon*, but also amphipods and polychaetes.	Dogfish, striped bass, goosefish, white, red and silver hakes, and sea raven.	Primarily active at night; avoid hypoxic conditions; on- and offshore movements are temperature dependent.
Adults	2-22^{o}C; most abundant at 8-10^{o}C; avoid < 5^{o}C	> 20 ppt; most abundant at 33-34 ppt	Avoid < 3.0 ppm; most abundant > 6.0	Fish and crustaceans.	Probably striped bass, goosefish, and other larger fish.	Same as juveniles.

[a] The eggs of this species are not reliably separated from other *Urophycis* or *Phycis* species in this area.

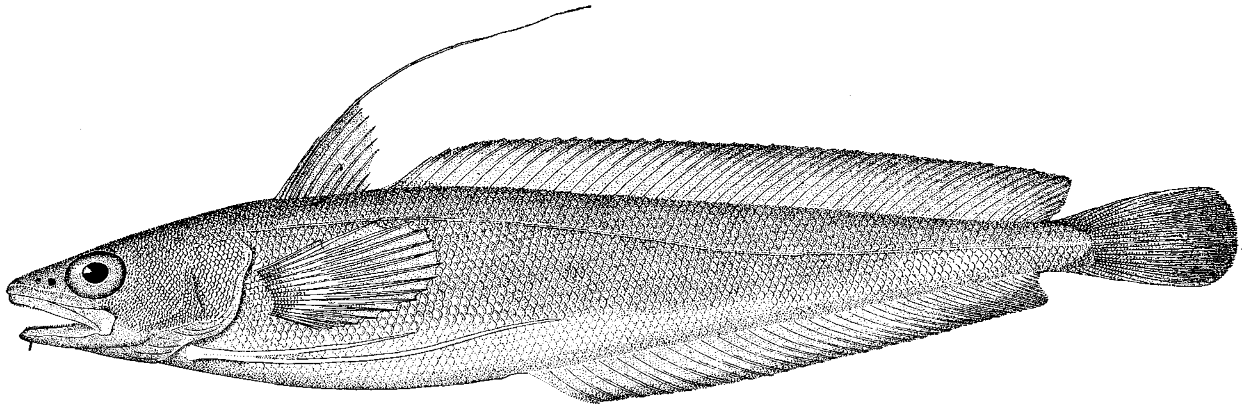


Figure 1. The red hake, *Urophycis chuss* (from Goode 1884).

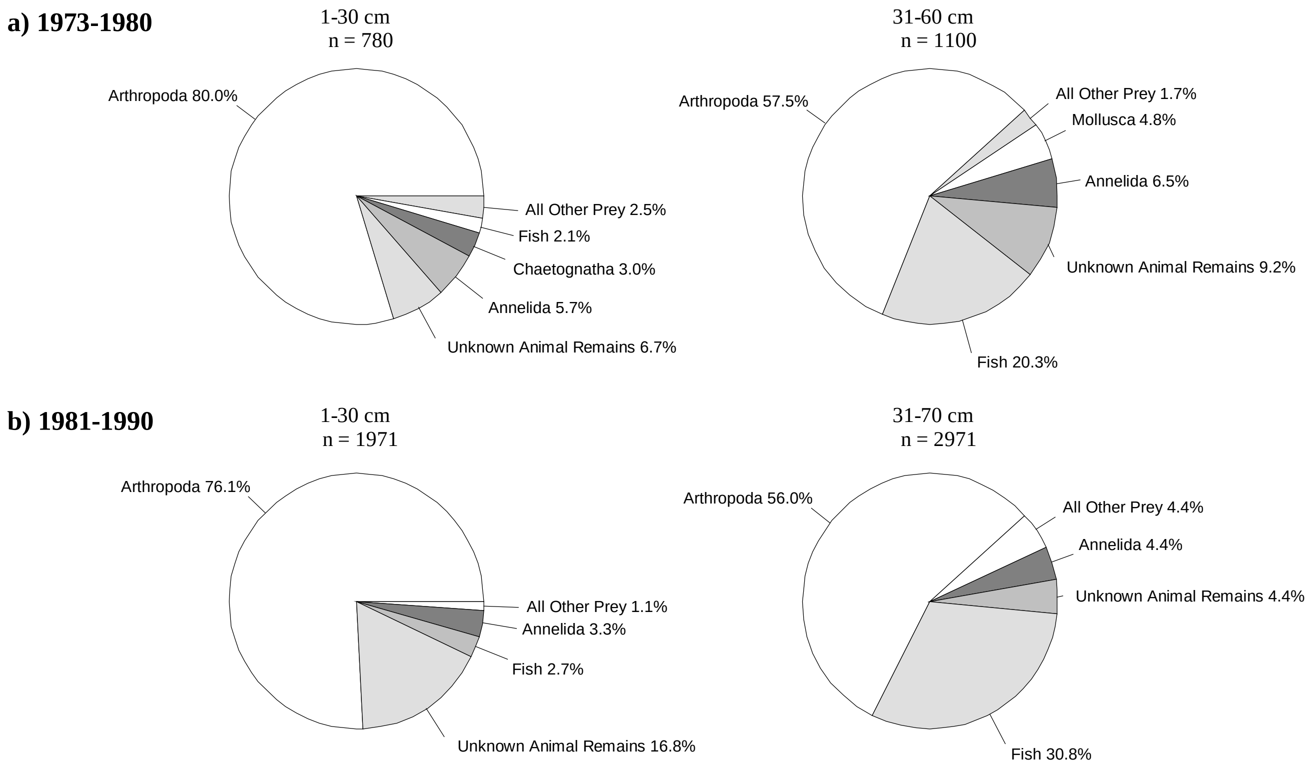


Figure 2. Abundance of the major prey items of red hake collected during NEFSC bottom trawl surveys from 1973-1980 and 1981-1990. Abundance in the 1973-1980 samples is defined by mean percent prey weights, and in the 1981-1990 samples as mean percent prey volume. The category “unknown animal remains” refers to unidentifiable animal matter. Methods for sampling, processing, and analysis of samples differed between the time periods [see Reid *et al.* (1999) for details]. The use of 30 cm as the segregation size between juveniles and adults differs from the actual size generally used (26 cm) and is an artifact of the diet database that summarized results in 10 cm length intervals.

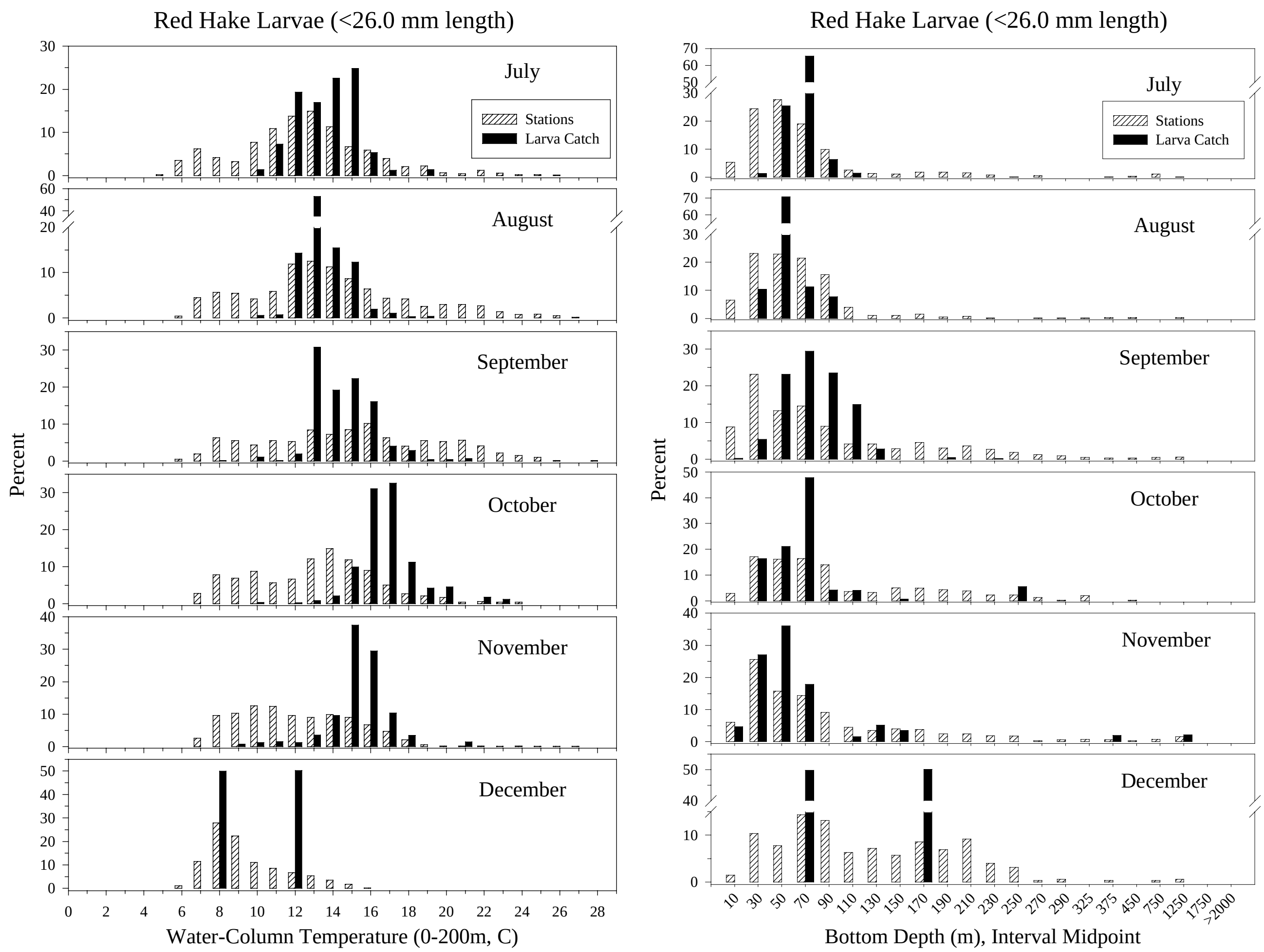


Figure 3. Abundance of red hake larvae relative to water column temperature (to a maximum of 200 m) and bottom depth from NEFSC MARMAP ichthyoplankton surveys (1982-1987) by month for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

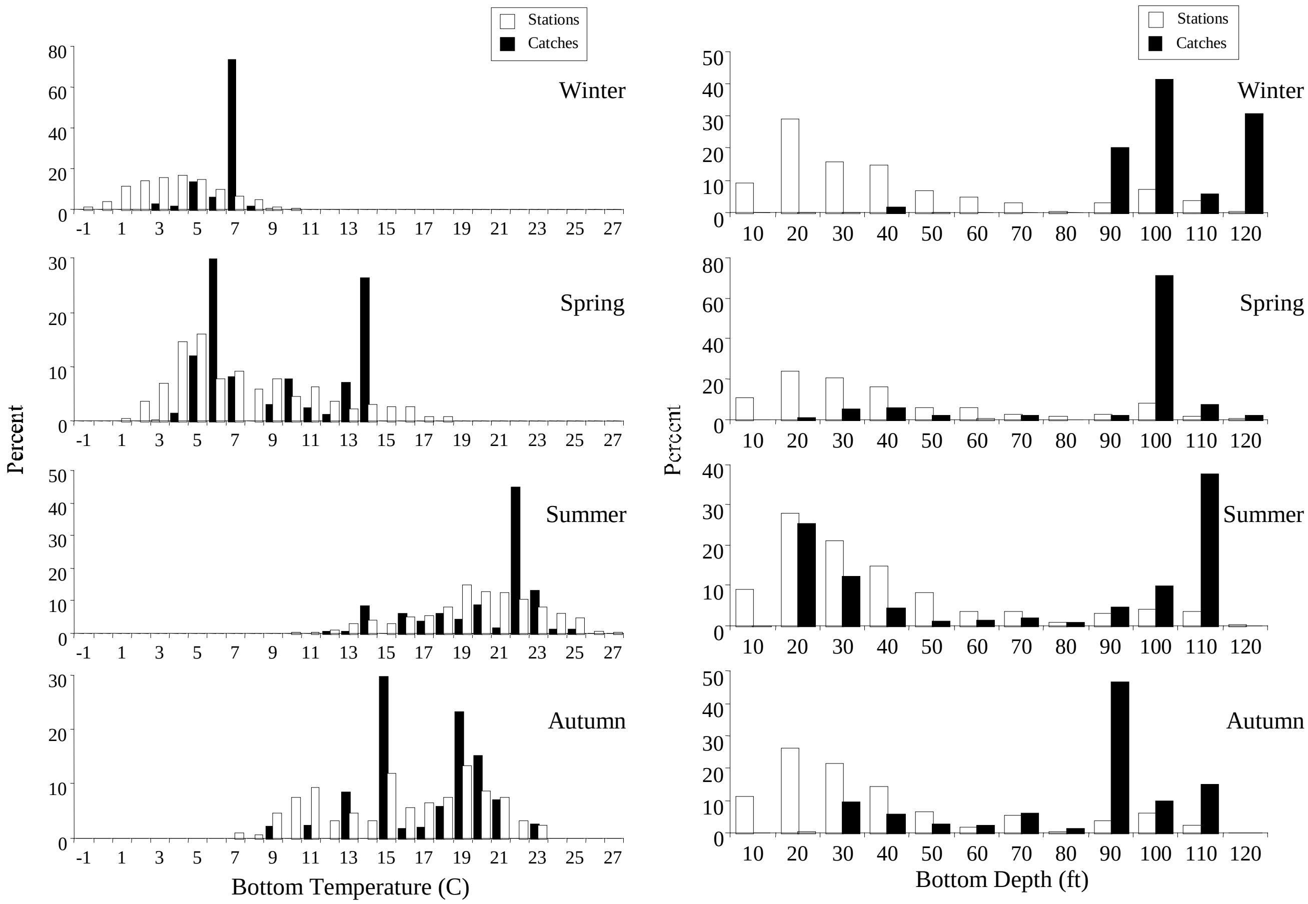


Figure 4. Seasonal abundance of juvenile red hake relative to mean bottom water temperature and bottom depth from Rhode Island Narragansett Bay trawl surveys, 1990-1996. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all catches.

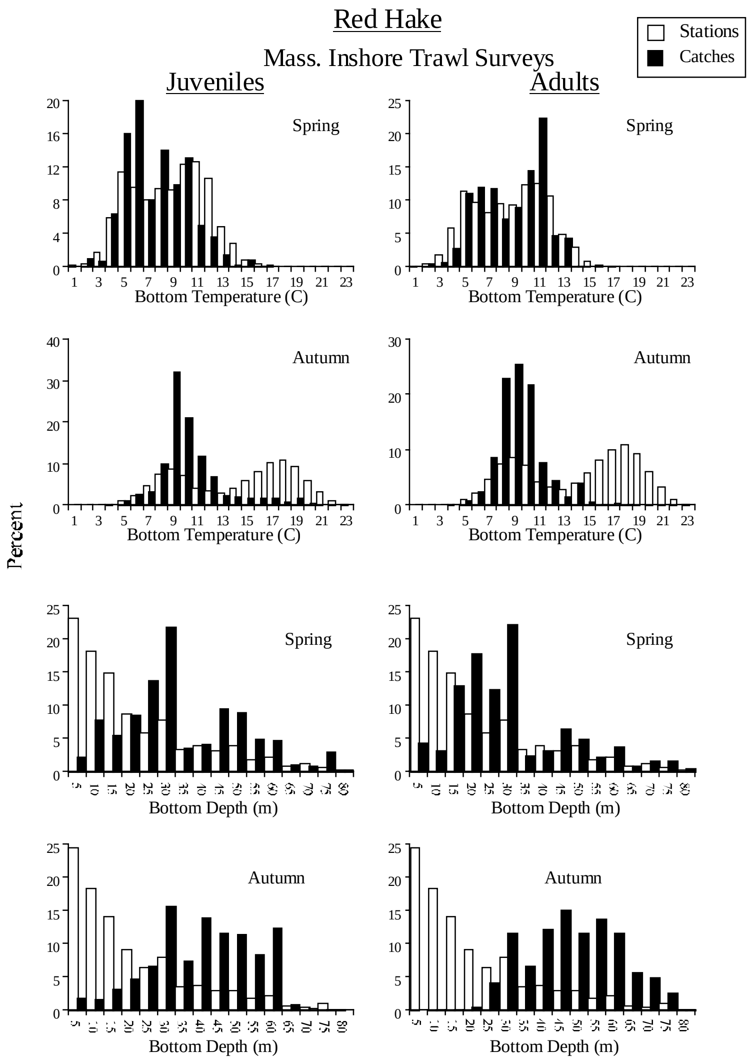


Figure 5. Abundance of juvenile and adult red hake relative to mean bottom water temperature and bottom depth from Massachusetts inshore bottom trawl surveys, spring and autumn 1978-1996. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all catches.

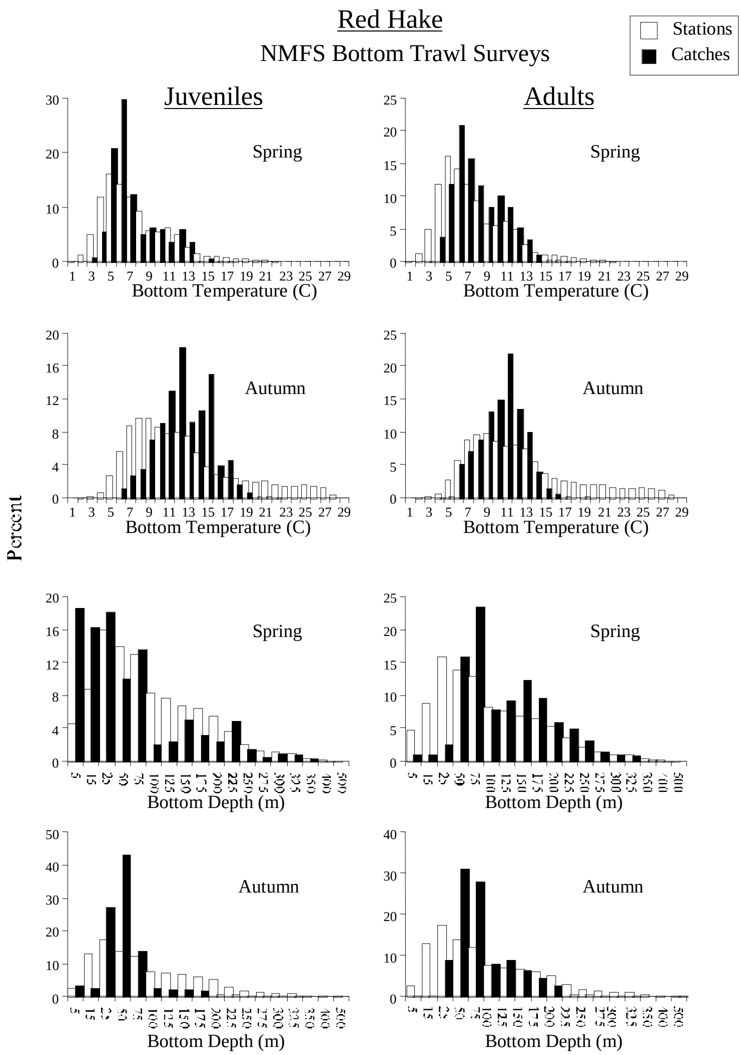


Figure 6. Abundance of juvenile and adult red hake relative to bottom water temperature and depth based on spring and fall NEFSC bottom trawl surveys (1963-1997, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

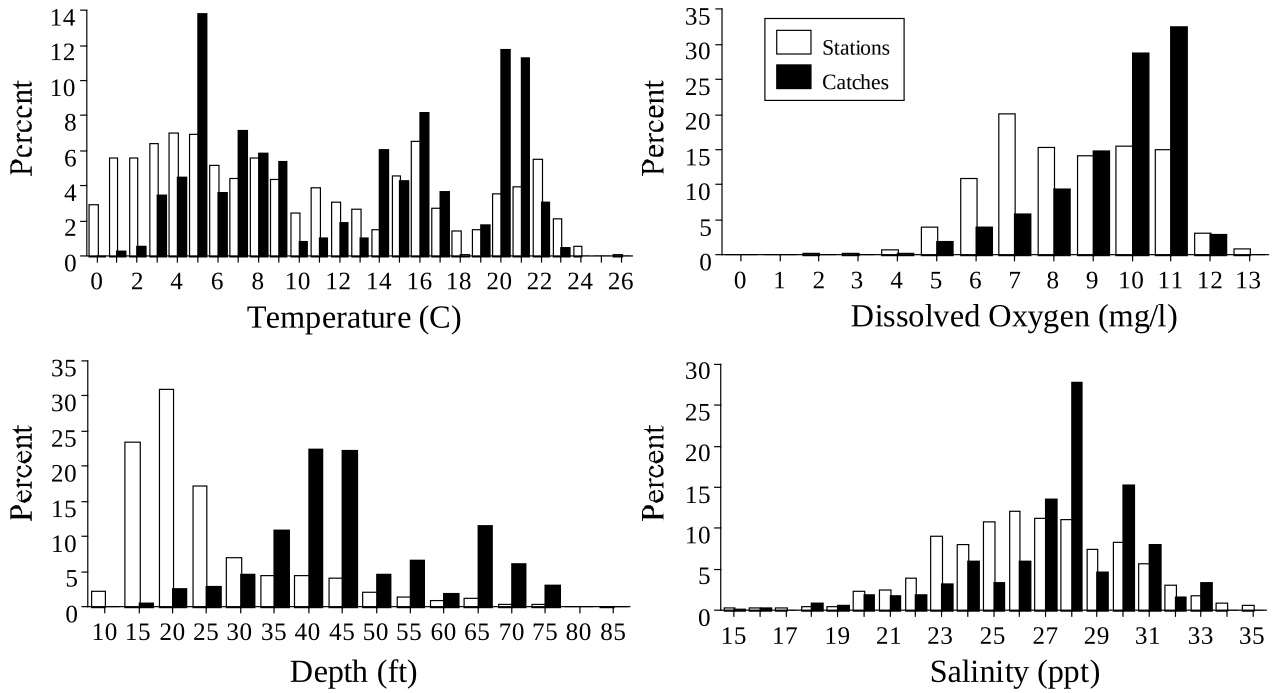


Figure 7. Abundance of juvenile (< 25 cm) red hake relative to mean bottom water temperature, dissolved oxygen, depth, and salinity from Hudson-Raritan estuary trawl surveys, January 1992-June 1997 (all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all catches.

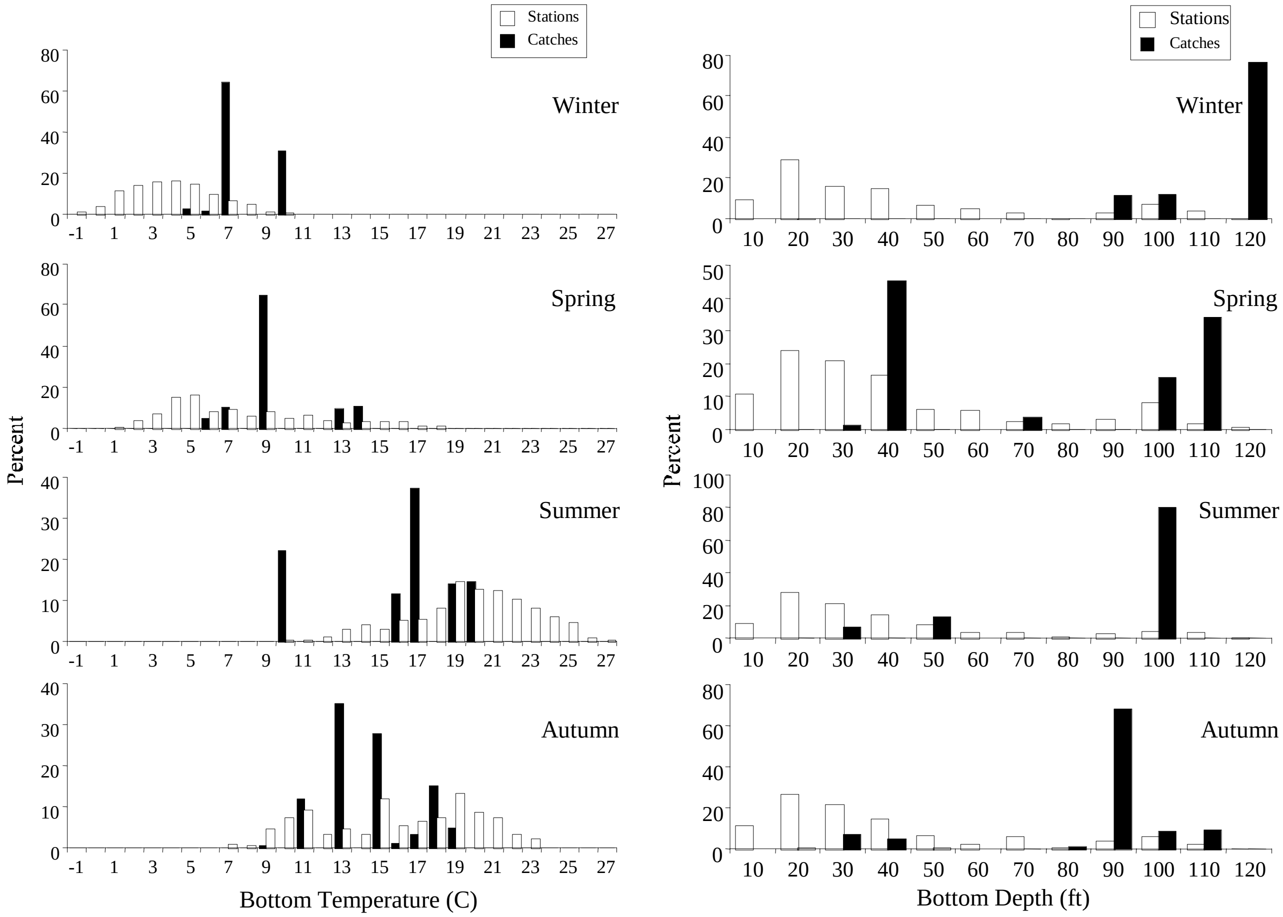


Figure 8. Seasonal abundance of adult red hake (≥ 26 cm) relative to mean bottom water temperature and bottom depth from Rhode Island Narragansett Bay trawl surveys, 1990-1996. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all catches.

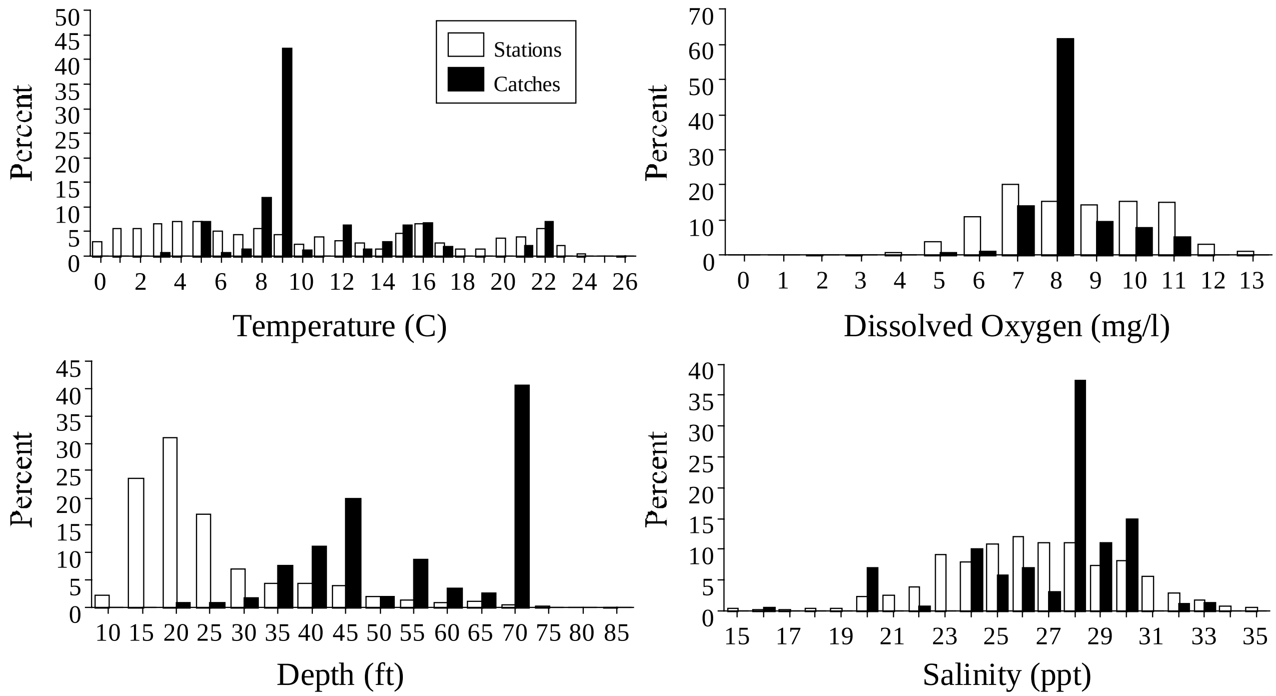
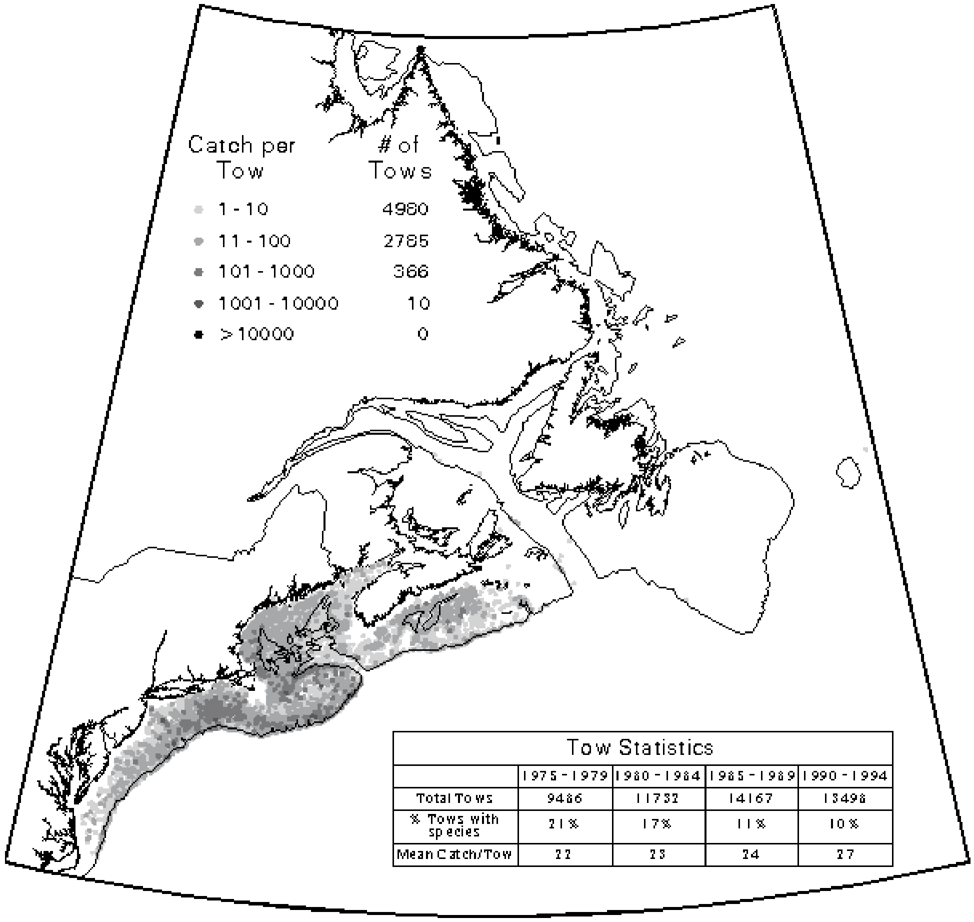


Figure 9. Abundance of adult (> 24 cm) red hake relative to mean bottom water temperature, dissolved oxygen, depth, and salinity from Hudson-Raritan estuary trawl surveys, January 1992-June 1997 (all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all catches.



	1975 - 1979	1980 - 1984	1985 - 1989	1990 - 1994
Total Tows	9486	11732	14167	13498
% Tows with species	21%	17%	11%	10%
Mean Catch/Tow	22	23	24	27

Figure 10. Distribution and abundance of red hake from Newfoundland to Cape Hatteras during 1975-1994. Data are from the U.S. NOAA/Canada DFO East Coast of North America Strategic Assessment Project (http://www-orca.nos.noaa.gov/projects/ecnasap/ecnasap_table1.html).

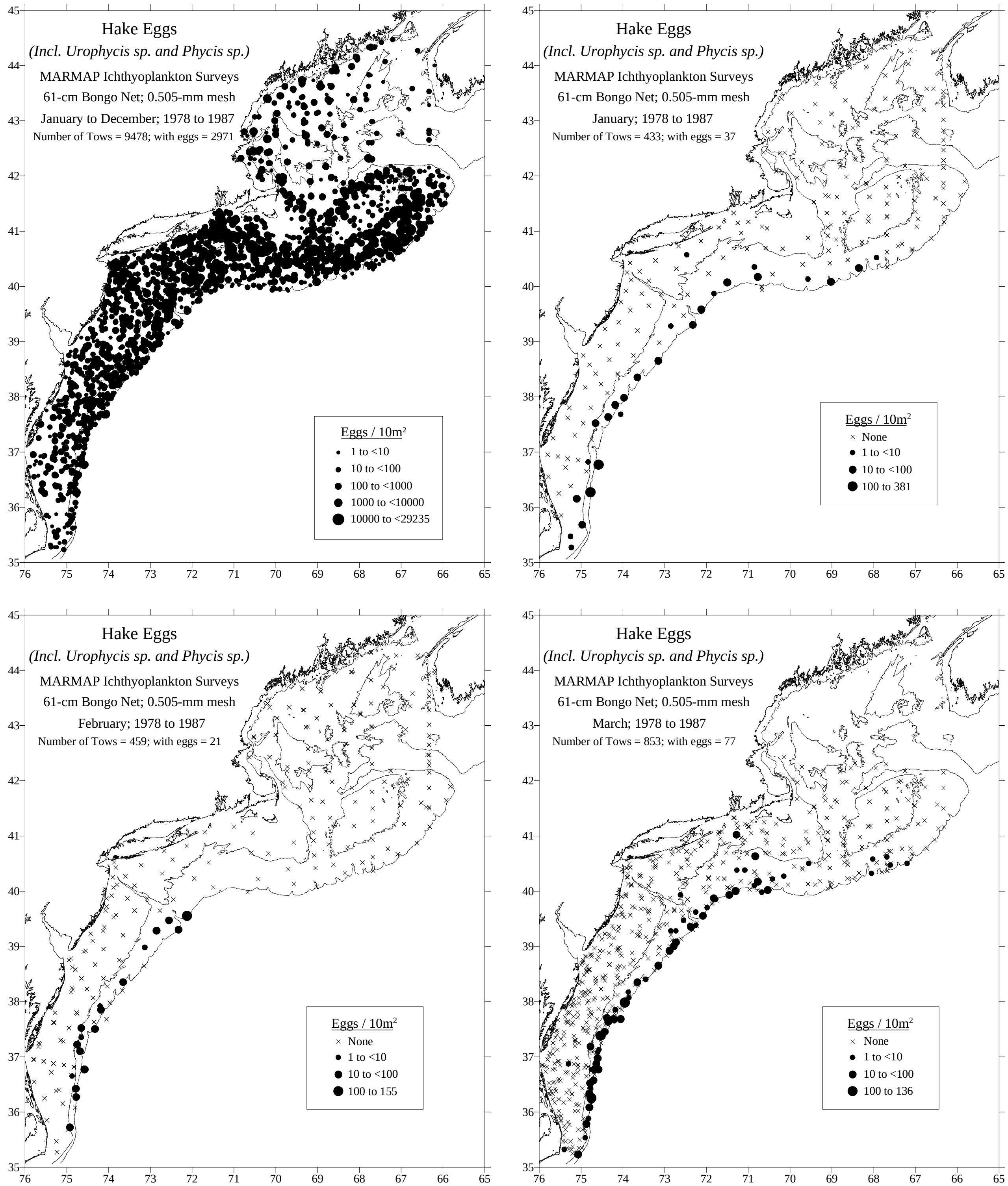


Figure 11. Distribution of hake (*Urophycis* and *Physcis* spp.) eggs collected during NEFSC MARMAP ichthyoplankton surveys from January to December, 1978-1987 [see Reid *et al.* (1999) for details].

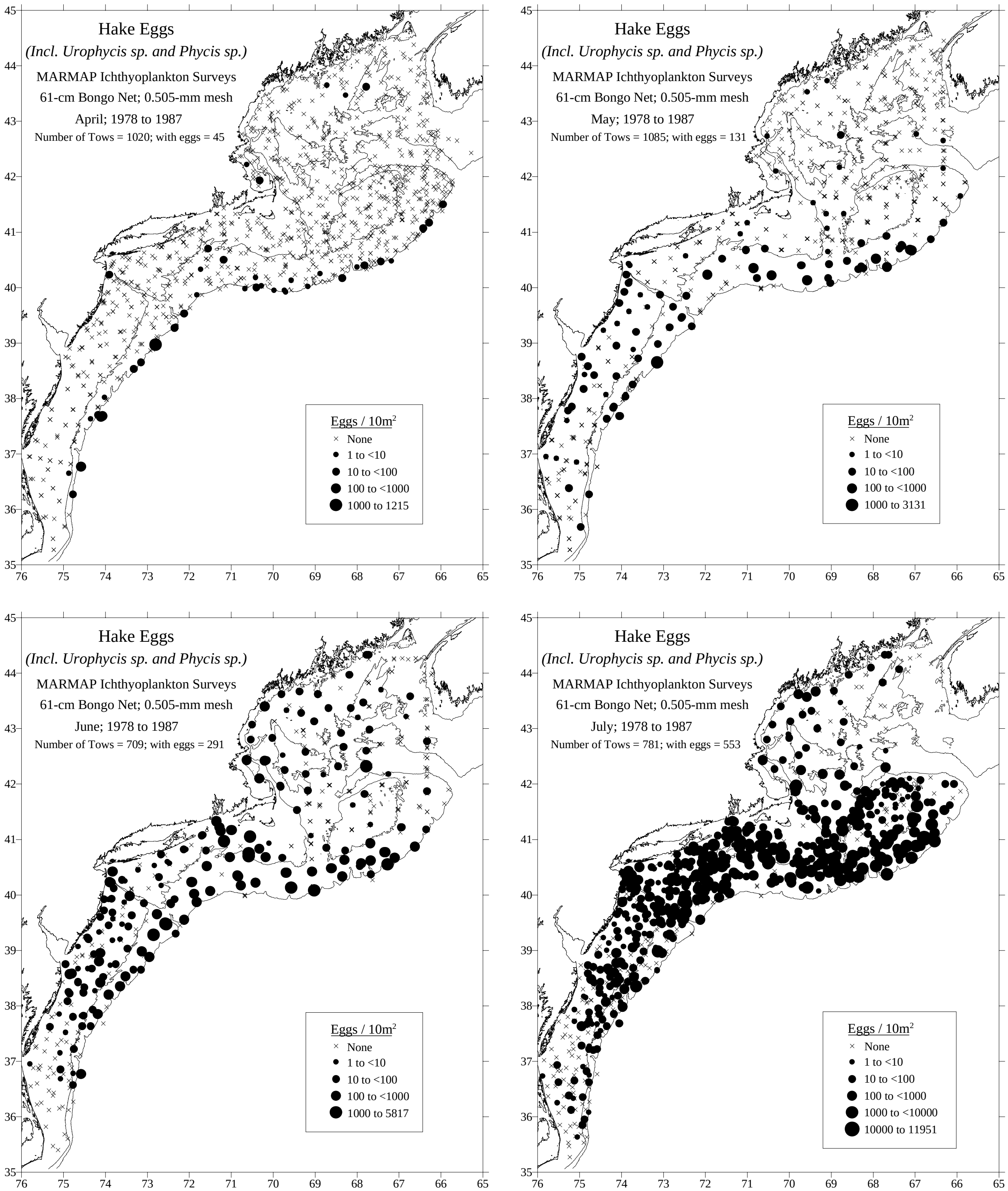


Figure 11. cont'd.

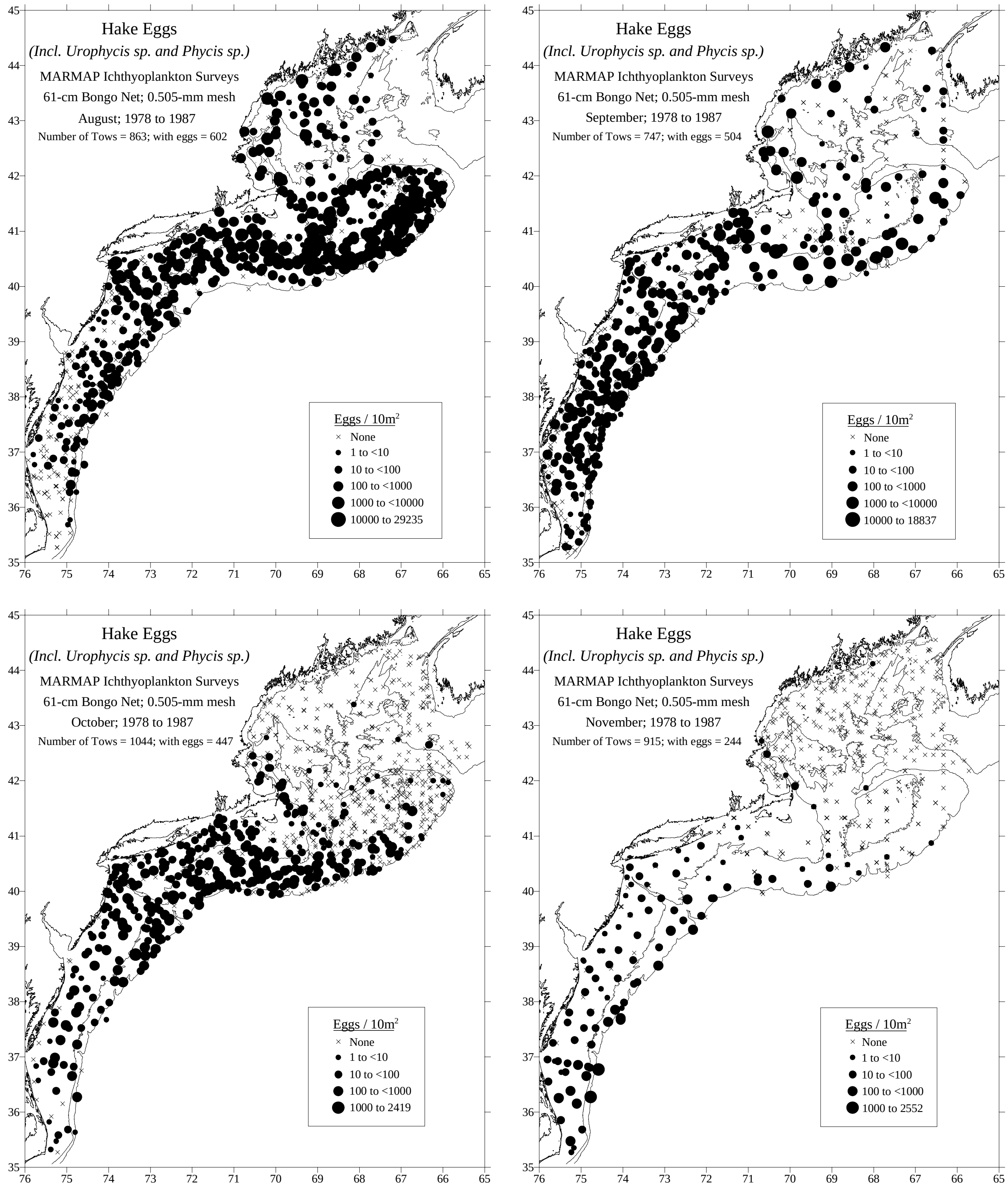


Figure 11. cont'd.

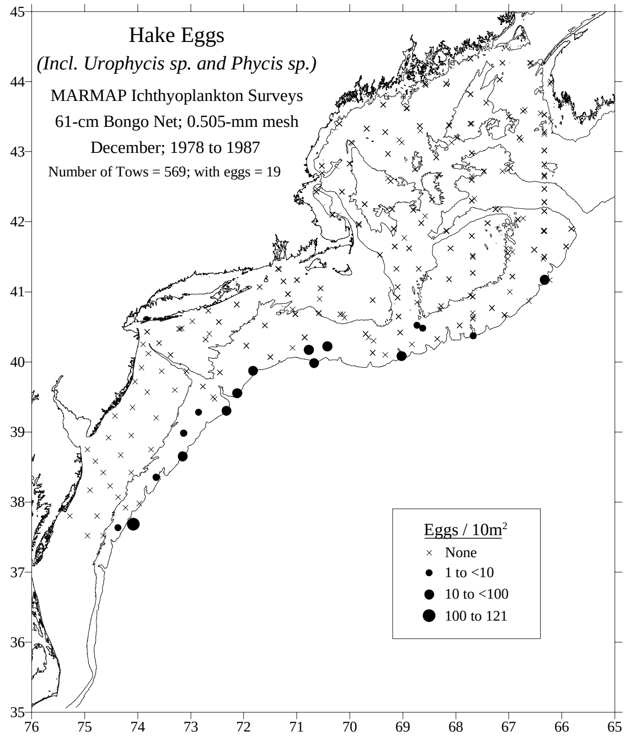


Figure 11. cont’d.

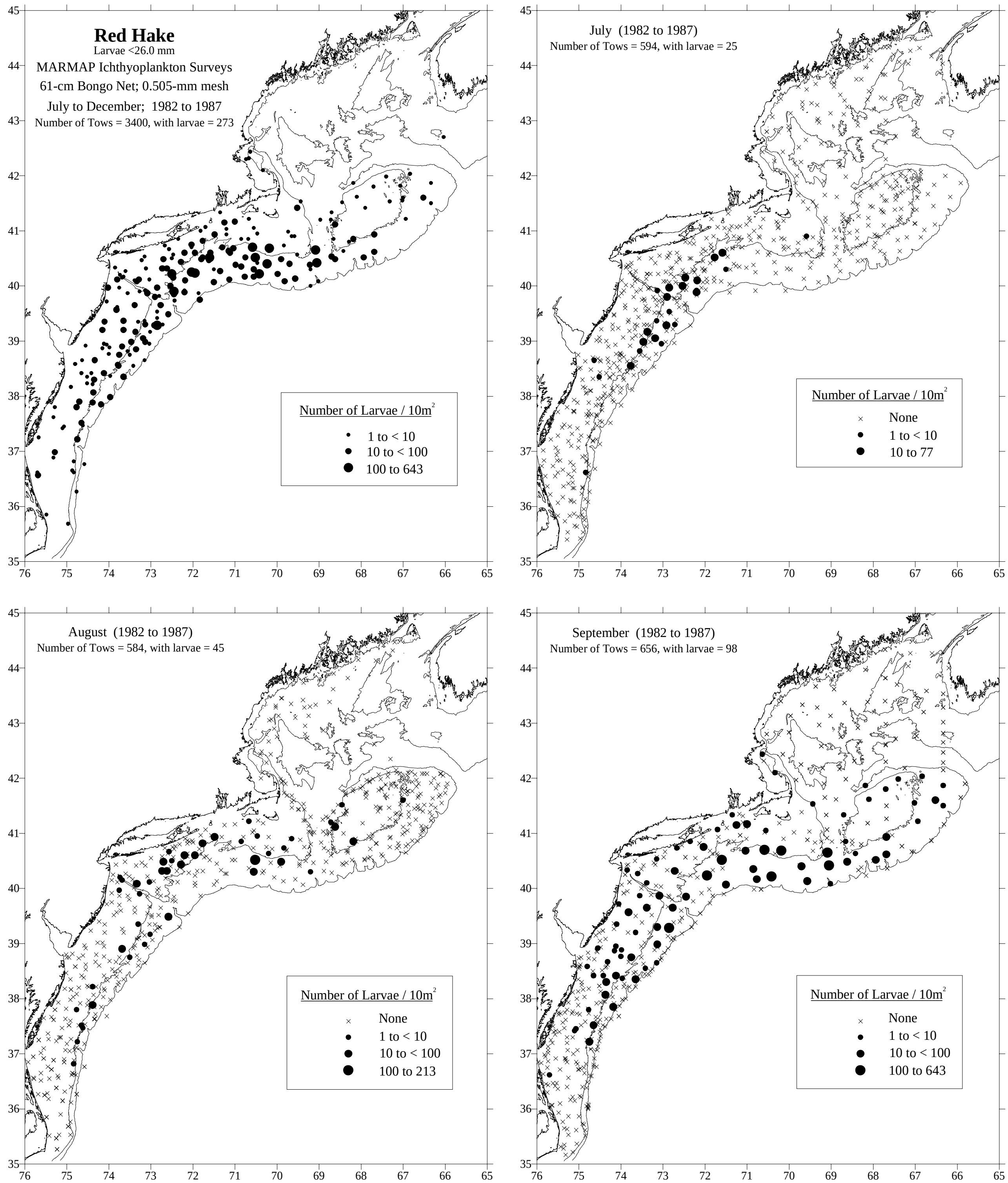


Figure 12. Distribution of red hake larvae collected during NEFSC MARMAP ichthyoplankton surveys, July through December 1982-1987 [see Reid *et al.* (1999) for details]. *Urophycis* larvae are difficult to identify to species, and misidentification was a problem until 1982. Due to the short period of reliable identifications, the distribution presented in this figure probably represents a minimum occurrence.

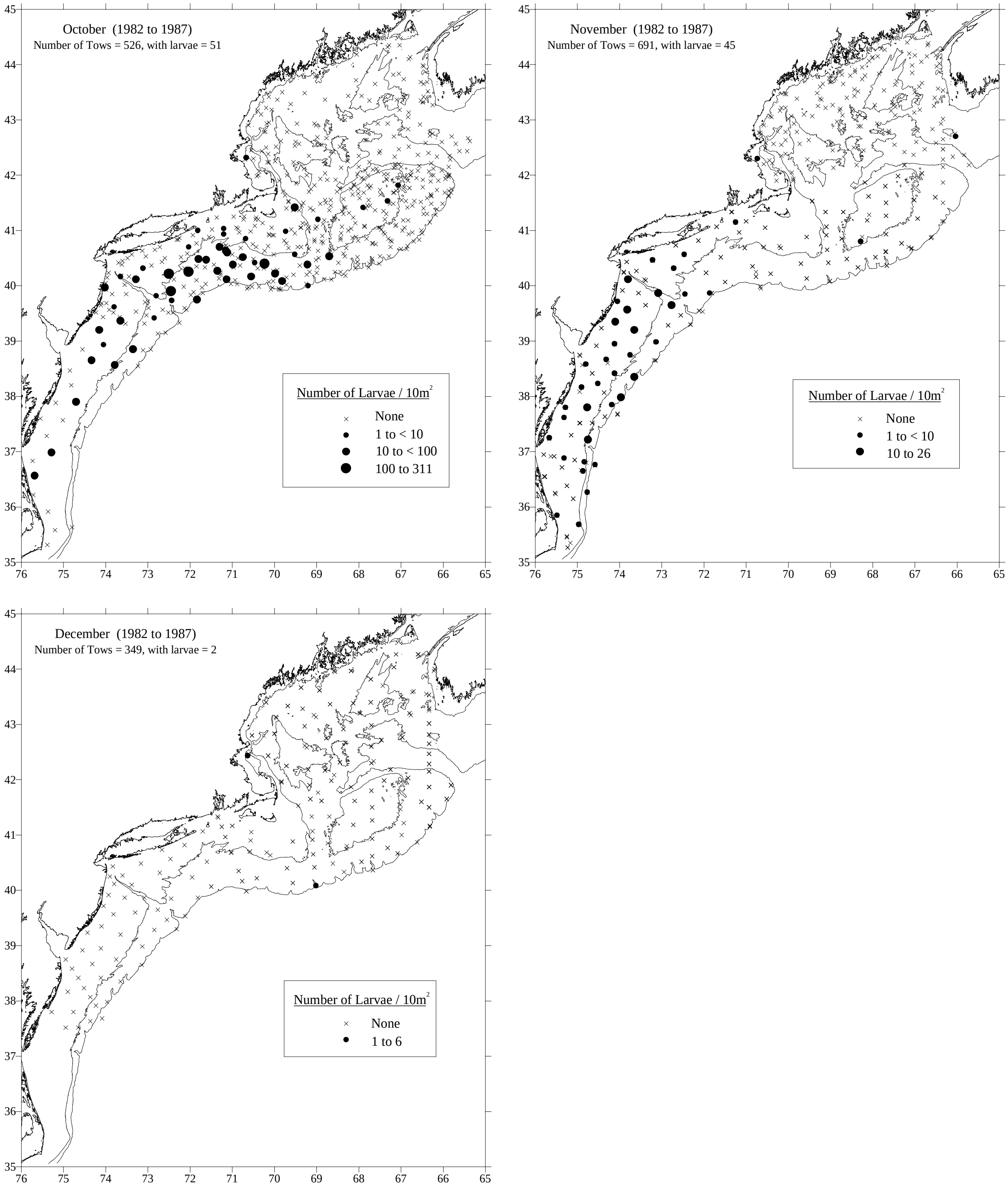


Figure 12. cont'd.

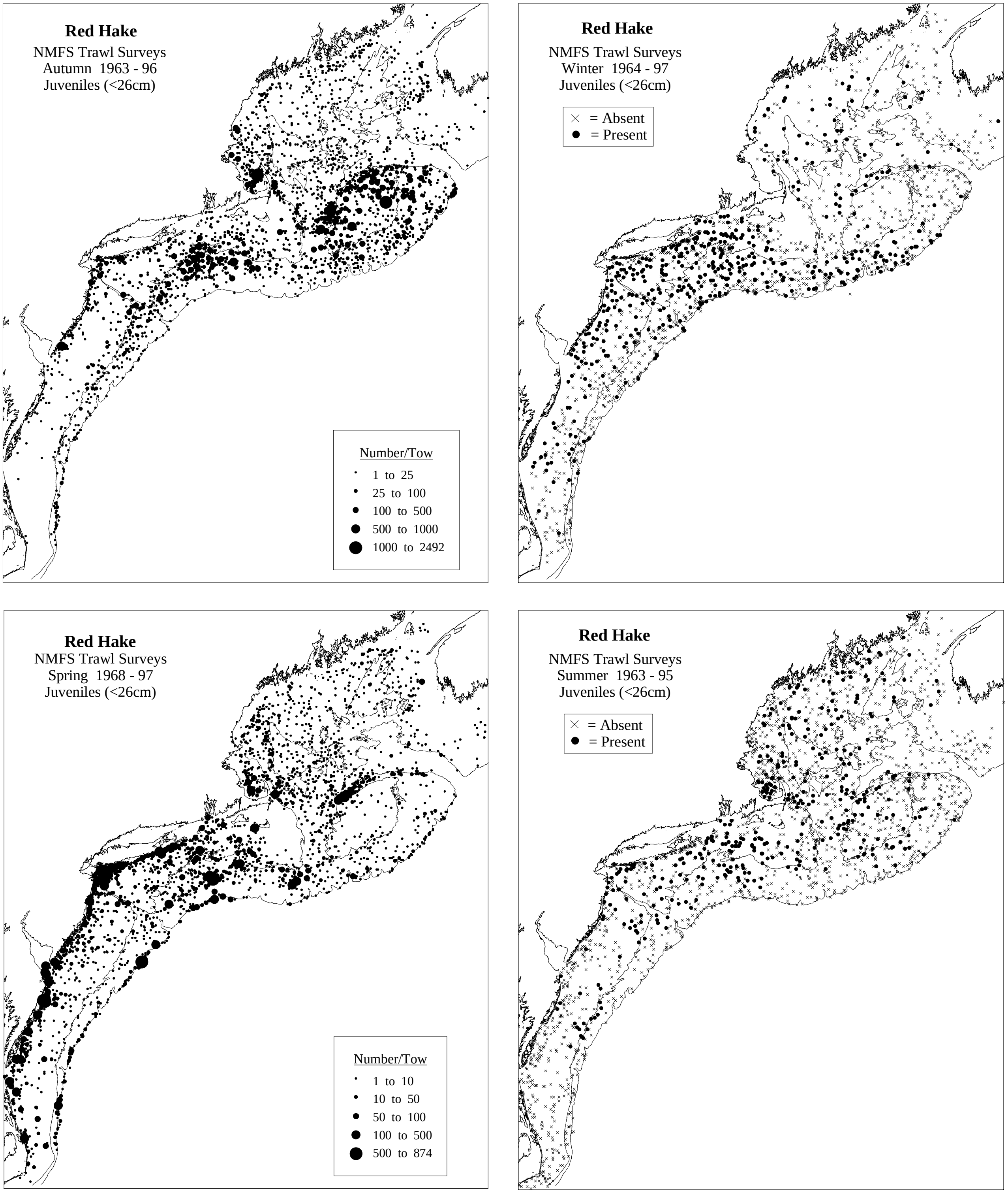


Figure 13. Distribution of juvenile (< 26 cm) and adult (≥ 26 cm) red hake collected during NEFSC bottom trawl surveys during all seasons, 1963-1997. Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].

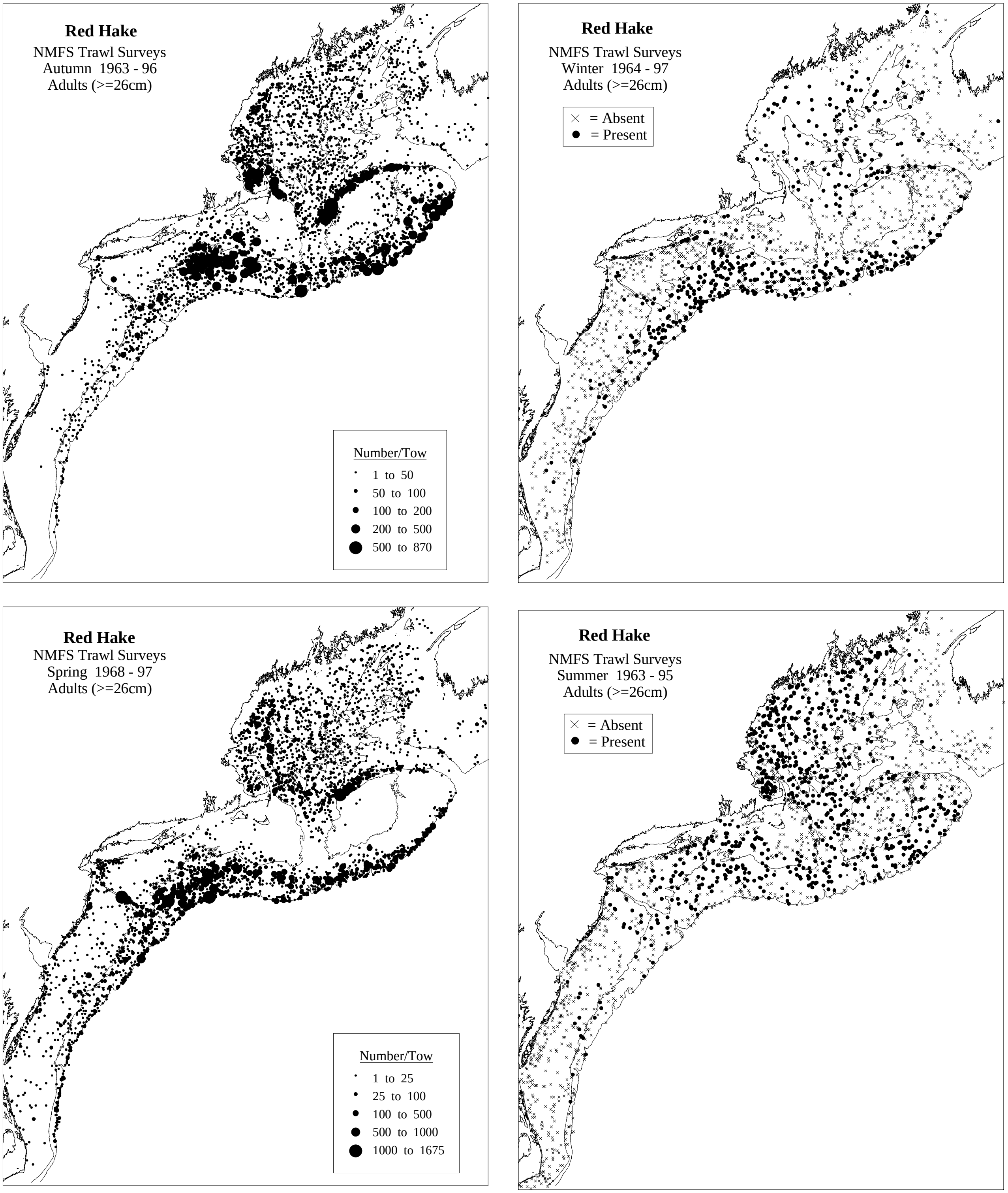


Figure 13. cont’d.

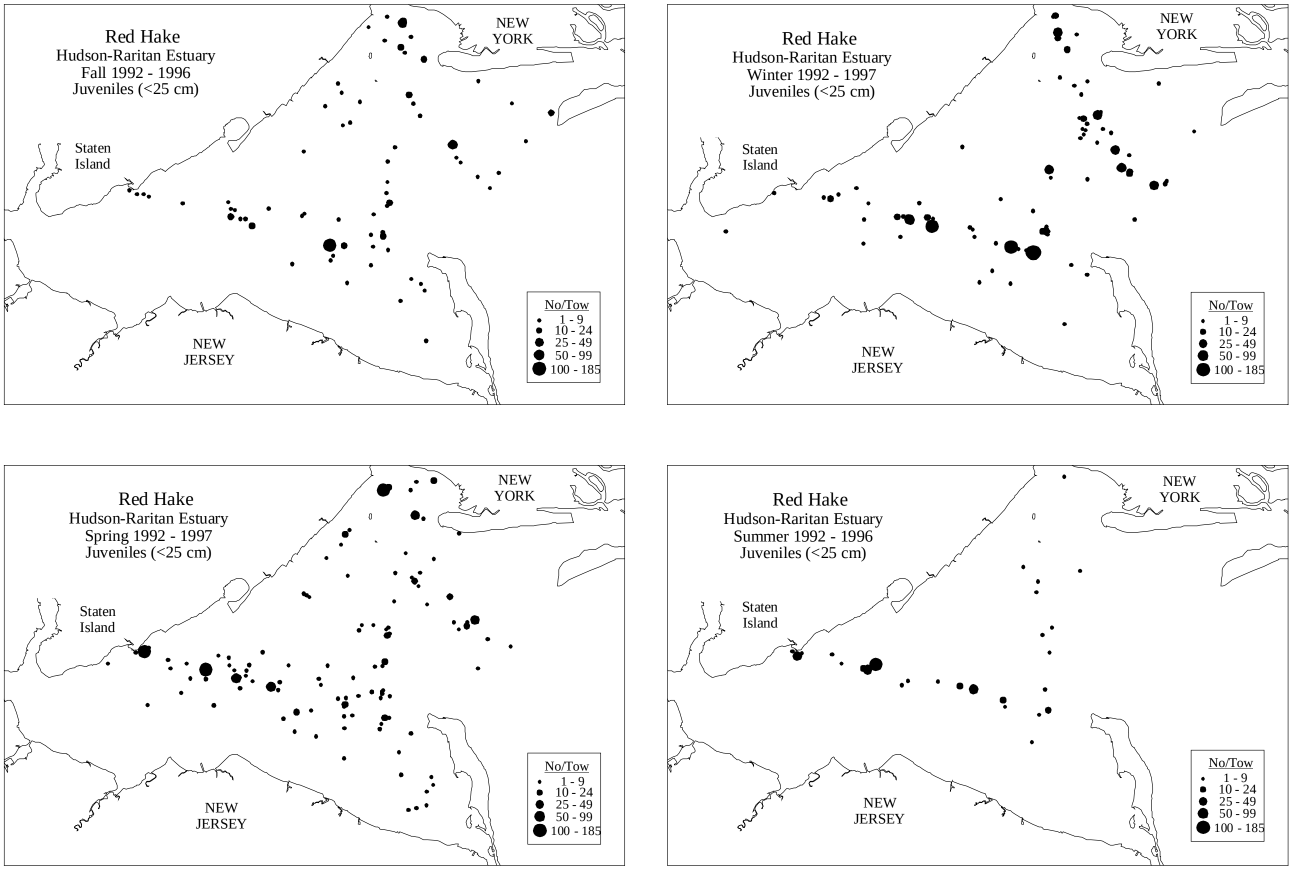


Figure 14. Distribution of juvenile (< 25 cm) and adult (> 24 cm) red hake collected in the Hudson-Raritan estuary, based on Hudson-Raritan trawl surveys during winter (January-March), spring (April and June), summer (July–August), and fall (October-December) from January 1992 to June 1997 [see Reid *et al.* (1999) for details].

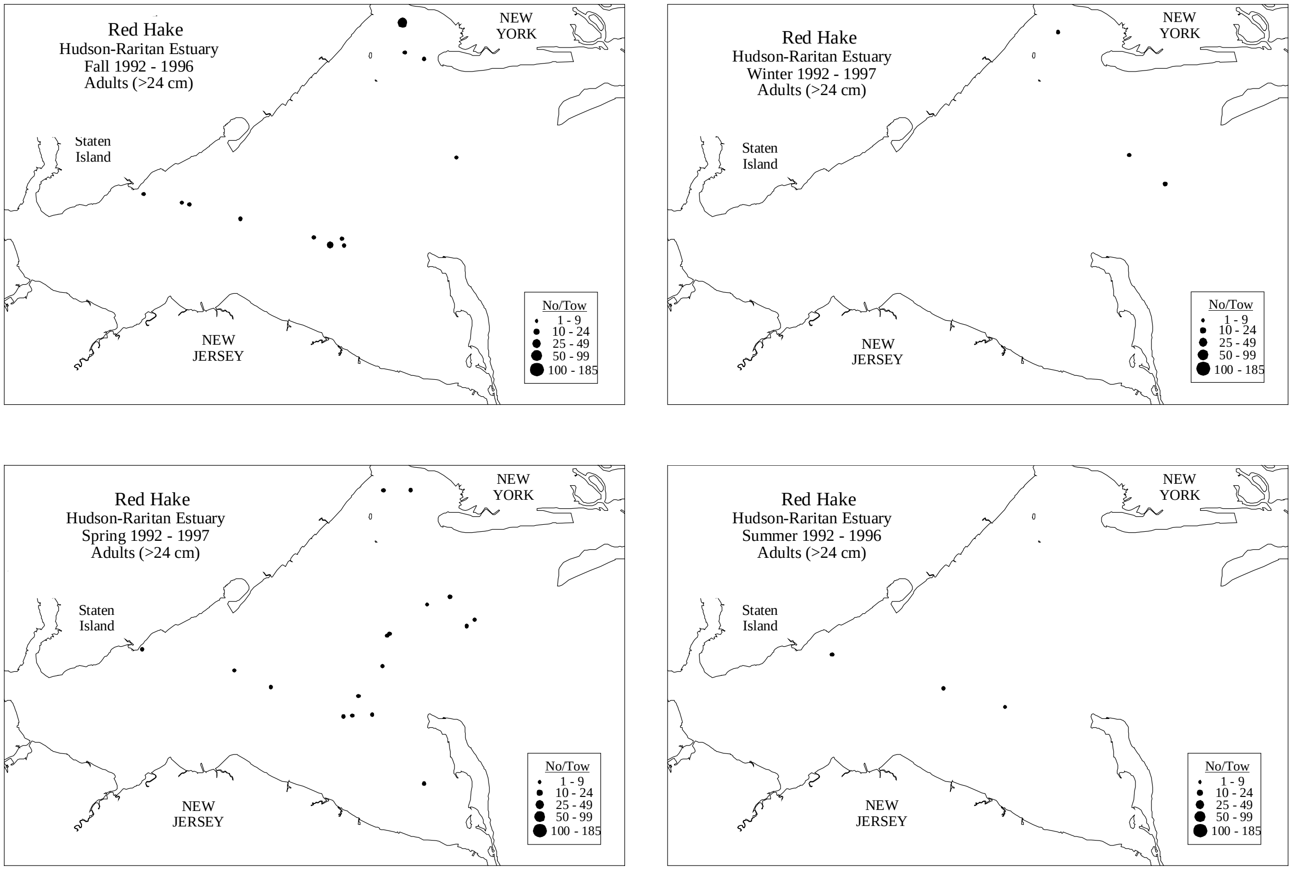


Figure 14. cont'd.

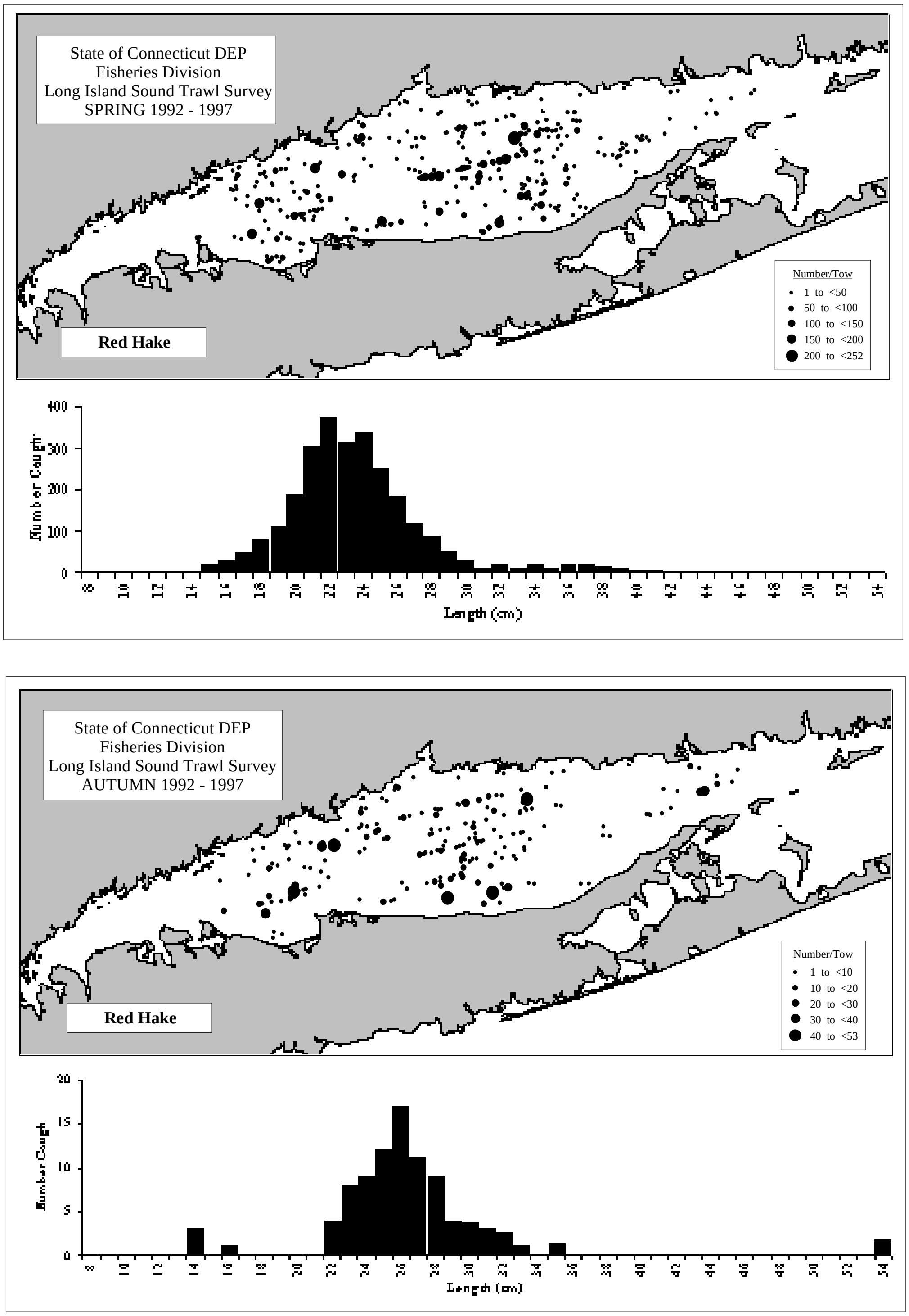


Figure 15. Abundance, distribution and size frequency distribution of red hake in Long Island Sound in spring and autumn, from the Connecticut bottom trawl surveys, 1992-1997 [see Reid *et al.* (1999) for details].

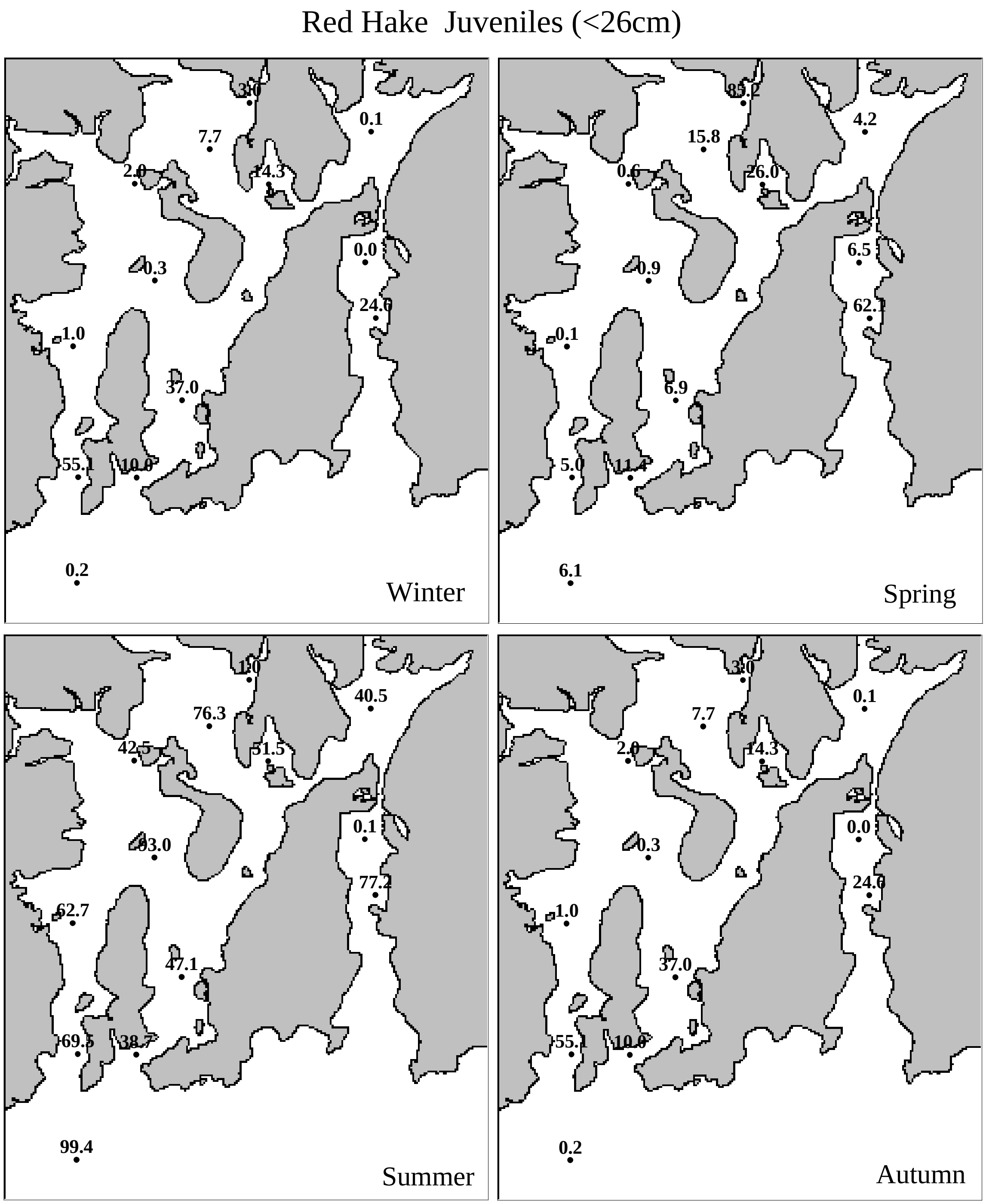


Figure 16. Seasonal distribution of juvenile (< 26 cm) and adult (≥ 26 cm) red hake collected in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid *et al.* (1999) for details].

Red Hake Adults (>=26cm)

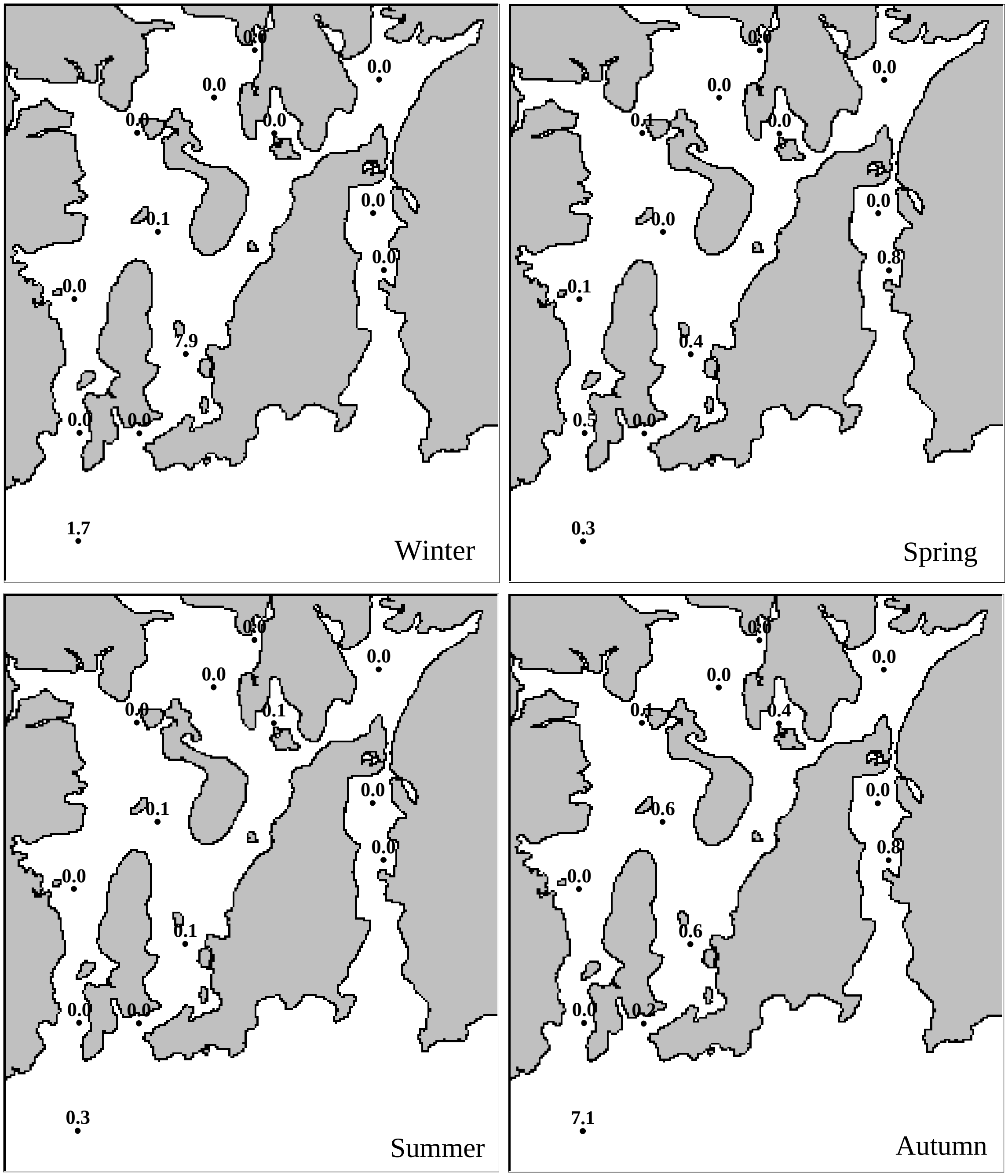


Figure 16. cont'd.

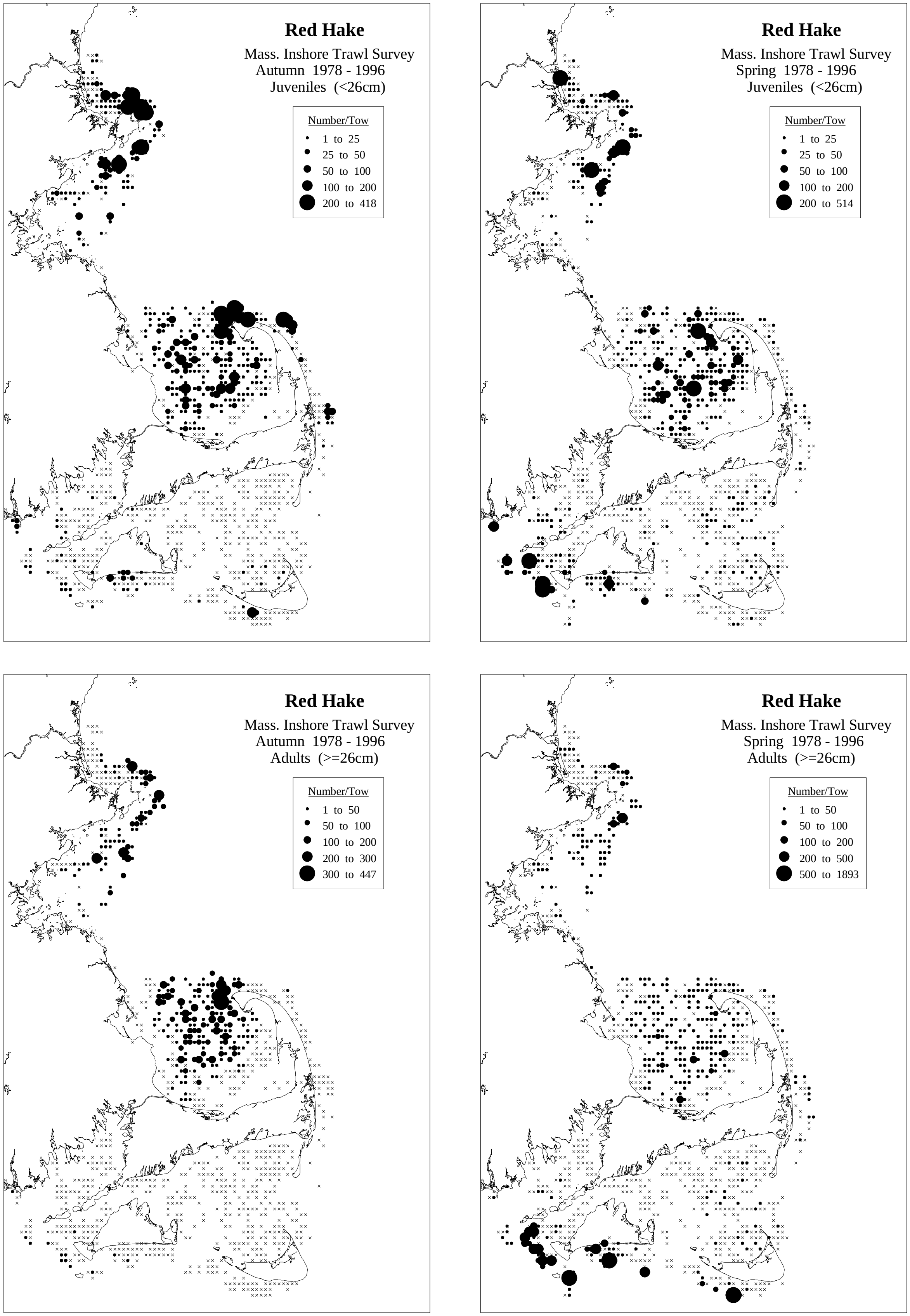


Figure 17. Distribution of juvenile (< 26 cm) and adult (≥ 26 cm) red hake in Massachusetts coastal waters during spring and autumn Massachusetts trawl surveys, 1978-1996 [see Reid *et al.* (1999) for details].

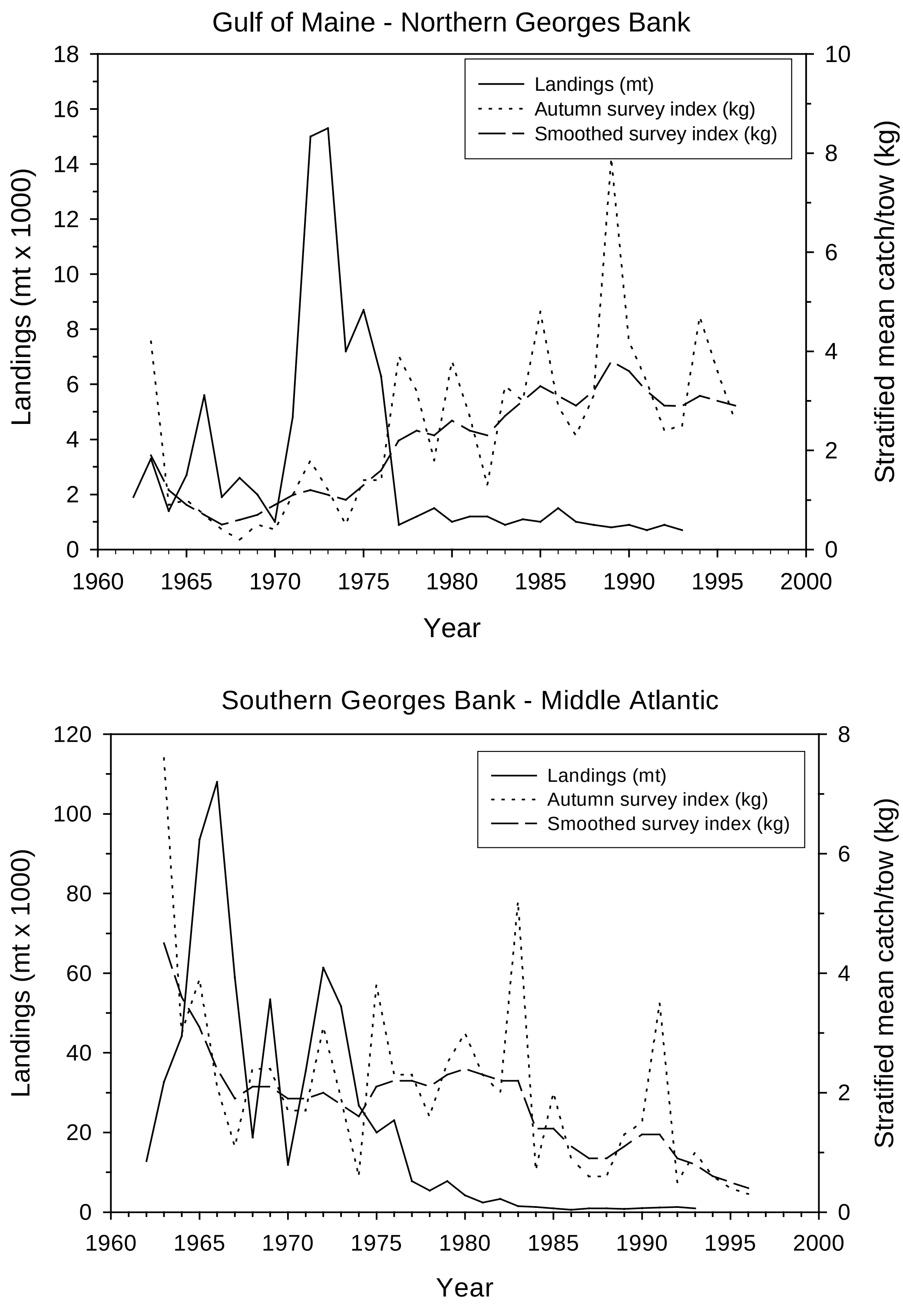


Figure 18. Commercial landings and abundance indices (from the NEFSC bottom trawl surveys) for northern and southern red hake populations.

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