NOAA Technical Memorandum NMFS-NE-130

Essential Fish Habitat Source Document:

Offshore Hake, *Merluccius albidus*, 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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NOAA Technical Memorandum NMFS-NE-130

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Offshore Hake, *Merluccius albidus*, 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

JEFFREY N. CROSS, CHIEF
ECOSYSTEMS PROCESSES DIVISION
NORTHEAST FISHERIES SCIENCE CENTER

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INTRODUCTION

Offshore hake, *Merluccius albidus*, (Figure 1) are distributed over the continental shelf and slope of the northwest Atlantic ocean (Figure 2) to the Caribbean and Gulf of Mexico (Bigelow and Schroeder 1955; Klein-MacPhee, in prep.). They are regularly caught along the outer edge of the Scotian Shelf (Markle *et al.* 1980), and constitute an important component in the Florida slope community, extending as far south as Cape Canaveral and Tortugas, FL (Ginsburg 1954; Helser 1997).

In contrast with the gadoid-like *Urophycis* species (red and white hake), species of the genus *Merluccius* are considered "true hakes" and have distinct morphological characteristics that separate them from *Urophycis* spp. (Helser 1997). Offshore hake closely resembles its sympatric species, silver hake, *Merluccius bilinearis,* and the two species are distinguishable only by differences in the number of gill rakers and lateral line scales (Ginsburg 1954; Markle 1982; Cohen *et al.* 1990). Because of the physical similarities, and since their distributions often overlap, offshore hake probably comprised a portion of the large catches of silver hake in the 1960's and 1970's and in fact, have been primarily collected as bycatch in the silver hake fishery (Helser 1997). However, more recent landings data, where the two species have been distinguished from one another, indicate that offshore hake may have constituted a very small proportion of the catch, e.g., < 0.1% in 1992 (Helser 1997).

Offshore hake has recently been added to the New England Fisheries Management Council (NEFMC) Multispecies Fishery Management Plan. Although the biology and population dynamics of this species have not been thoroughly investigated, particularly in U.S. waters, this Essential Fish Habitat (EFH) source document summarizes the information on the life history and habitat characteristics that is currently available.

LIFE HISTORY

EGGS

Offshore hake eggs are buoyant, spherical and transparent, possessing a single oil globule, 0.29-0.36 mm in diameter (Fahay 1983). There is considerable variation in the size of offshore hake eggs: 1.05-1.15 mm (Fahay 1983), 0.99-1.18 mm (Marak 1967) and 1.04-1.24 mm (Markle and Frost 1985) in diameter. Although possible, misidentification of offshore hake eggs with those of silver hake (since the distribution and spawning times of the two species may overlap) is improbable. Silver hake eggs tend to be much smaller, ranging in diameter from 0.88-0.95 mm (Kuntz and Radcliffe 1917; Fahay 1983) and 0.82-1.00 mm (Markle and Frost 1985), with an oil globule ranging in diameter from 0.19-0.23 mm (Kuntz and Radcliffe 1917) to 0.29-0.36 mm (Fahay 1983).

LARVAE

Hatching occurs after 6-8 days at 8.9-10.6^{o}C, at a length of 3-3.8 mm TL (Marak 1967). The larval body has four distinct concentrations of pigment: dorsal to the yolk sac; over the vent; at the midpoint of the trunk; and two-thirds the distance to the tail (Marak 1967). Pelvic buds appear at 5 mm TL and transformation (to juvenile stage) occurs at 20 mm TL (Fahay 1983). The instantaneous growth rate (G_w) of offshore hake larvae was calculated to be 0.219 at a mean surface temperature of 16.4^{o}C (Morse 1989). This calculation was based on a minimum length (L_n) of 3 mm TL and a maximum length (L_m) of 10 mm TL over a time (t) of 22.8 days. The estimated length-dependent mortality (Z_l) was 0.616 and the daily mortality rate (Z_t) was 0.189.

JUVENILES AND ADULTS

No age and growth data currently exist for offshore hake from U.S. waters. However, Helser (1997) used data from the Canadian Department of Fisheries and Oceans (DFO) Scotian Shelf offshore hake surveys to establish weight-length relationships and growth parameters, and compare them with those for silver hake. This preliminary analyses suggests that allometric growth between length and weight is the same for the two species, and there is some indication, although based on a limited number of offshore hake samples, that within species, allometric growth is different between the sexes.

As reported in Klein-MacPhee (in prep.), fish from the Gulf of Mexico showed rapid growth until age 3, at which time growth slowed, with females growing faster than males and apparently reaching greater age (Rohr and Gutherz 1977). Cohen *et al.* (1990), as cited in Klein-MacPhee (in prep.), indicate that the largest male recorded was 40 cm TL and the largest female was 70 cm TL. Size composition in the Northeast Fisheries Science Center (NEFSC) spring bottom trawl surveys (see Geographical Distribution) indicates that silver and offshore hake ranged from 8-60 cm TL with modes at 14-16 cm TL and 28-30 cm TL.

For the purpose of this report, juvenile offshore hake are defined as individuals < 30 cm TL and adults as individuals ≥ 30 cm TL (see Reproduction).

REPRODUCTION

There is little information available on the reproductive biology of offshore hake. Spawning appears to occur over a protracted period or even continually throughout the year from the Scotian Shelf through the Middle Atlantic Bight. For example, in New England, Cohen *et al.* (1990) indicates that spawning occurs from April to July at depths ranging from 330-550 m. Eggs and larvae have also been collected off of Massachusetts from April through July (Marak 1967). Smith *et al*. (1980) report that eggs and larvae were also present from April through June south of New England and in February and March south of Long Island, NY. Colton *et al.* (1979) indicated that while there was some uncertainty in the timing of offshore hake spawning in the Mid-Atlantic Bight, it appears to extend from June through September. This is supported by results from the New York Bight where Wilk *et al*. (1990) showed that while mean gonadosomatic indices (GSI) were highest in June and July, females in various stages of gonadal development were collected from spring through late fall. Eggs from offshore hake have been collected year-round on the Scotian Shelf (Markle and Frost 1985), and in U.S. waters by the NEFSC Marine Resources Monitoring, Assessment and Prediction (MARMAP) surveys (see Habitat Characteristics and Geographic Distribution). Fecundity is estimated at 340,000 eggs per female (Klein-MacPhee, in prep.).

Helser (1997) extrapolated Canadian Scotian Shelf data to estimate maturity for offshore hake in U.S. waters. Similar to silver hake, males matured at smaller sizes than females. The length at 50% maturation (L_{50}) was 26.5 cm TL for males and 30.1 cm TL for females. Females begin to mature at 25-28 cm TL. Wilk *et al*. (1990) found ripe females as small as 23 cm TL. Helser (1997) concluded that this variation might be due to regional environmental differences. Since there are no maturity data available for this species from NEFSC trawl surveys, adults are defined as individuals ≥ 30 cm TL for the purposes of this report.

FOOD HABITS

Offshore hake feed on fish and invertebrates. Juveniles feed on small fish, shrimps and other crustaceans, while adults feed primarily on fish, including lantern fishes, sardines, anchovies, juvenile conspecifics, and, to a lesser extent, on crustaceans, slender snipe eels (*Nemichthys scolopaceus*), and squids (Bigelow and Schroeder 1955; Langton and Bowman 1980; Cohen *et al.* 1990). Euphausiid prey have been identified as *Meganyctiphanes* sp. and *Thysanoessa* sp.; decapod prey includes pandalid shrimp, *Pandalus* sp. and *Dichelopandalus* sp., and pelagic shrimp, *Pasiphaea* sp. (Klein-MacPhee, in prep.).

Although based on a very small sample, the 1973-1990 NEFSC bottom trawl survey data on food habits support this range of prey type for two size classes of offshore hake: 11-30 cm TL, which roughly corresponds to juveniles, and 31-60 cm TL, which roughly corresponds to adults (Figure 3).

PREDATION

Small juveniles are prey for goosefish, *Lophius americanus*, and are also consumed by larger conspecifics and presumably by other fishes.

MIGRATION

There is no information available on migrations by offshore hake. Based on NEFSC bottom trawl survey data (see Geographical Distribution), this species remains at constant depths (primarily along the 200 m contour) during spring and fall. This is consistent with other published information indicating that this species is found at depths ranging from 80-1,170 m, with the highest abundance at 160-640 m (Klein-MacPhee, in prep.). It is also conjectured that adults migrate vertically in the water column at night (Bigelow and Schroeder 1955), although no data exist to support this.

STOCK STRUCTURE

Fish stocks are generally defined as having fixed spawning grounds, definite spawning seasons, and consistent migratory or movement patterns. Klein-MacPhee (in prep.) notes that there appear to be several stocks of offshore hake, with one population in the northern Gulf of Mexico that has diverged from both the southern Gulf population and the northern Atlantic population. Available data do not indicate separation in spawning grounds, spawning season, or migration patterns. Thus, offshore hake in the Georges Bank-New England-Middle Atlantic Bight region are considered a single stock.

HABITAT CHARACTERISTICS

A summary of environmental and habitat characteristics for offshore hake is presented in Table 1 based on a review of the literature and analyses of unpublished data.

EGGS

Data from the NEFSC MARMAP ichthyoplankton survey were used to determine the relationship between offshore hake egg abundance and temperature and depth (Figure 4) [see Reid *et al.* (1999) for methodology]. Although depth and temperature distribution varied seasonally, eggs were collected exclusively in waters of the outer continental shelf, and the presence of eggs in collections during every month supports the premise of protracted or continual spawning in this species (see

Geographical Distribution).

Offshore hake eggs were collected at temperatures ranging from 8-20^{o}C (Figure 4). From January through May, most eggs were collected at temperatures ranging from 9-13^{o}C. As water temperatures rose during the summer, the distribution shifted from June through August to slightly warmer temperatures ranging from 10-15^{o}C. By September, most eggs were found at even higher temperatures ranging from 14-19^{o}C. Beginning in October, however, the fall-winter pattern was evident with eggs distributed at increasingly colder temperatures until by December most eggs were collected at 10^{o}C.

Although offshore hake eggs were collected at depths ranging from 30-1250 m, there also appeared to be seasonal variation in depth distribution (Figure 4). From January through May, most eggs were collected at depths of 110-270 m while from June through August, eggs tended to be less dispersed and, with some exceptions, tended to be more concentrated at depths of 110-130 m. From September through November, eggs were again distributed more widely throughout the water column (130-250 m) while by December eggs were more concentrated at depths from 130-150 m. A small percentage of eggs were occasionally collected in deeper water (450-1250 m).

LARVAE

The NEFSC MARMAP data were also used to examine the relationships between catch of offshore hake larvae (< 21 mm) and water temperature and bottom depth (Figure 5) [see Reid *et al.* (1999) for methodology]. Similar to eggs, larvae were collected during every month in the waters of the outer continental shelf at temperatures ranging from 5-19^{o}C (see below). From March to May, most larvae were collected at temperatures ranging from 5-13^{o}C and as water temperatures warmed in summer, most were distributed at 11-15^{o}C from June through August. From September through November, larvae were primarily found at temperatures of 10-18^{o}C while during the winter months of December through February they were found at 11-14^{o}C (Figure 5).

Similar to the distribution of eggs, larvae were also collected at depths ranging from 30-1250 m (Figure 5). Although a few isolated individuals were occasionally collected at depths > 1000 m, the majority of offshore hake larvae were concentrated at depths ranging from 70-130 m, with little evidence of significant seasonal changes (Figure 5).

In an analysis of catch ability of fish larvae from the ichthyoplankton surveys, Morse (1989) noted that approximately 50% of all offshore hake larvae (2-10 mm TL) were caught at twilight and only 20% during the day. He conjectures that since most larvae are found along the shelf break at > 200 m (Morse *et al*. 1987) and given that the maximum depth sampled by the net was 200 m, this pattern may reflect vertical migration into the sampling area during twilight as well as visually-cued net avoidance. However, if, as indicated above, larvae are distributed at depths ranging from 70-300 m, vertical migration may not be as important a factor influencing the high catches recorded at twilight.

JUVENILES

Data from the NEFSC bottom trawl survey were analyzed to describe the relationship between bottom temperature and depth of juvenile offshore hake (< 30 cm TL) (Figure 6) [see Reid *et al.* (1999) for methodology]. Distributed along the continental slope throughout the year (see Geographic Distribution), juvenile offshore hake were collected at temperatures ranging from 1-13^{o}C, with abundance highest at 4-12^{o}C in spring and 7-12^{o}C in fall, when most of the surveys were conducted. In winter catches were highest at 11-12^{o}C, while in summer juveniles were distributed across a range of temperatures (1-12^{o}C) (Figure 6).

Catches of juveniles were made at depths ranging from 70-440 m (Figure 6). In autumn and spring juveniles were concentrated primarily from 170-340 m; in winter from 220-280 m and in summer distribution was less concentrated with juveniles collected at depths ranging from 70-350 m.

ADULTS

Data from NEFSC bottom trawl surveys were also used to describe the distribution of adult offshore hake relative to bottom temperature and depth (Figure 7). As with juveniles, adults were found throughout the year along the continental slope, and were collected at temperatures ranging from 3-14^{o}C. Spring and autumn distribution temperatures were similar, with most adults collected at 6-12^{o}C. In winter and summer, fish were also relatively uniformly distributed, from 6-12^{o}C in winter and from 5-9^{o}C in summer.

Adults were found at depths ranging from 60-460 m (Figure 7), also relatively similar to juveniles. In spring and autumn, most fish were collected at depths ranging from 150-380 m. In summer they were also relatively uniformly distributed at depths of 150-350 m, while in winter over two-thirds were concentrated at depths of 220-300 m.

These results are in agreement with Klein-MacPhee (in prep.) who notes that adults are found at depths ranging from 80-1,170 m and that the greatest abundance occurs at 160-640 m. Klein-MacPhee (in prep.) adds that adults are probably found on or near the bottom and may make diel vertical migrations. In the Gulf of Mexico, offshore hake apparently congregate by size and sex. Juveniles, young adult females and adult males at depths less than 550 m, and larger, mature females on the lower continental slope (Klein-MacPhee, in prep.). Feeding occurs near the bottom during the day and night (Rohr and Gutherz 1977).

A species association study using cluster analysis of NEFSC spring and fall bottom trawl survey catches (Colvocoresses and Musick 1984) found that offshore hake commonly co-occurred with three upper slope species: white hake, *Urophycis tenuis*, blackbelly rosefish, *Helicolenus dactylopterus*, and shortnose greeneye, *Chlorophthalmus agassizi*. Offshore hake were also associated, although to a lesser extent, with a group of bottom dwelling species including goosefish, *Lophius americanus*, witch flounder, *Glyptocephalus cynoglossus*, spotted hake, *Urophycis regia*, armored searobin, *Peristedion miniatum*, and fawn cusk-eel, *Lepophidium profundorum*.

GEOGRAPHICAL DISTRIBUTION

Offshore hake are distributed from the northwest Atlantic Ocean, including the Scotian Shelf and southeastern slope of Georges Bank, along the coast of Florida, and into the Gulf of Mexico to the coast of French Guiana (Klein-MacPhee, in prep.). However, relatively little is known about the overall distribution of this species based on research trawl surveys since they tend to be restricted to the continental shelf; the maximum depth of the NEFSC bottom trawl surveys is 370 m. Thus, very little is known about the offshore component of the species.

Offshore hake have been collected frequently in Canadian DFO bottom trawl surveys as far north as the Laurentian Trench. Juveniles and adults are not often taken in the NEFSC trawl surveys, although small numbers have been caught in the surveys in several deep basins in the Gulf of Maine. The overall distribution of offshore hake on the northwest Atlantic continental shelf during 1975-1994 was from the southern edge of the Grand Bank to Cape Hatteras, NC (Figure 2).

EGGS

Offshore hake eggs were collected as part of the NEFSC MARMAP ichthyoplankton surveys from 1978-1987 (Figure 8) [see Reid *et al*. (1999) for methodology]. They were most abundant along the continental shelf from east of Georges Bank to the Middle Atlantic Bight just south of Delaware Bay and infrequently off Cape Hatteras. Egg densities exceeded 10 per 10 m^2 during the first four years of the survey, but declined to less than 5 per 10 m^2 during the final five years, with the exception of 1984 (Berrien and Sibunka 1999). Eggs were collected in every month of the year, although the catch varied seasonally.

In January and February, eggs were sparsely distributed with small numbers collected from off Bank to Delaware Bay and Cape Hatteras (Figure 8). From March through June, eggs were collected in larger numbers as density increased along the outer margin of the continental shelf with abundance highest from east of Georges Bank to off the Hudson Canyon, although small numbers were collected from south of Delaware Bay to as far north as the Northeast Channel. From July through September, the numbers of eggs dropped sharply and were irregularly distributed from southeast of Georges Bank to Delaware Bay. Abundance rose again in October with a distribution similar to that in April, ranging from the Northeast Channel to the Mid-Atlantic Bight off the Hudson Canyon. Abundance decreased again during November and December with a distribution generally similar to that in January and February.

Markle and Frost (1985) indicate that planktonic eggs of offshore hake occur on the Scotian Shelf throughout the year. This is in contrast with the eggs of silver hake, which occurred only from May through November. Analysis of NEFSC MARMAP silver hake egg data indicates that while there is some spatial and temporal overlap, silver hake eggs are often found more widely distributed in inshore waters, particularly from May through October.

LARVAE

Offshore hake larvae were collected as part of the NEFSC MARMAP ichthyoplankton surveys from 1977-1987 (Figure 9) [see Reid *et al*. (1999) for methodology]. The seasonal distribution of larvae is similar to that of eggs. They were most abundant along the continental slope from Georges Bank to the Middle Atlantic Bight off the Delmarva peninsula. Offshore hake larvae were collected in every month of the year, although the catch varied seasonally.

Very few larvae were collected from January to April; these were all taken along the continental slope off Long Island and New Jersey (Figure 9). Larvae were much more abundant from May through October, mainly along the continental slope from Long Island to the Delmarva peninsula, but also less frequently on Georges Bank and in the Gulf of Maine. Some larvae were found in relatively shallow, continental shelf waters off southern New England and in the Gulf of Maine in August and September. Larval abundance declined in November and December, with most larvae found on the continental slope immediately south of Georges Bank, and lower numbers found as far south as Delaware Bay and further inshore south of Cape Cod.

JUVENILES

Juvenile offshore hake (≤ 29 cm TL) were primarily taken by NEFSC bottom trawl surveys on the continental slope in the Middle Atlantic Bight (Figure 10). Juveniles were most abundant during the spring, when they were taken along the continental slope from Georges Bank to Cape Hatteras and along the slopes of several deep basins within the Gulf of Maine. A number of large catches (> 100 juveniles) were made in the Mid-Atlantic and within the Gulf of Maine. During autumn, much lower numbers were taken mainly along the continental slope from Georges Bank to Cape Hatteras. Summer and winter distributions are presented as presence and absence, precluding a discussion of abundance. During the summer and winter juveniles were taken along the continental slope in the Mid-Atlantic Bight, from south of Georges Bank to the Delmarva peninsula. During the spring, offshore hake ranged in size from 8-60 cm TL, with modes at 14-16 cm and 28-30 cm. Smaller juveniles, < 10 cm TL, were taken during autumn surveys.

ADULTS

The seasonal distribution of adult offshore hake (≥ 30 cm TL) from NEFSC bottom trawl surveys is similar to that of juveniles. Adults were most abundant during the spring; they were taken along the continental slope from Georges Bank to Cape Hatteras and in lower numbers within the Gulf of Maine (Figure 11). A number of large catches (> 100 adults) were made in the Mid-Atlantic off Long Island and New Jersey. During autumn, much lower numbers were taken primarily along the continental slope from Georges Bank to just north of Cape Hatteras. Summer and winter distributions are presented as presence and absence, precluding a discussion of abundance.

STATUS OF THE STOCKS

There is currently no directed fishery for offshore hake within the U.S. Exclusive Economic Zone (EEZ), and the stock has not been assessed. Offshore hake probably composed a portion of the large catches of silver hake in the 1960s and 1970s, and have been primarily collected as bycatch in the silver hake fishery (Helser 1997). However, more recent landings data, where the two species have been distinguished from one another, indicate that offshore hake may have constituted a very small proportion of the silver hake catch (Helser 1997).

RESEARCH NEEDS

Very little is known about the biology of offshore hake. In particular, the following areas require investigation:

(1) The stock structure of offshore hake within U.S. waters is unknown. Genetic, otolith fingerprinting, and/or tagging studies may be helpful to determining offshore hake stocks as fishery management units.

(2) Information on the location and timing of offshore hake spawning is needed. Currently, spawning is inferred from the distribution of eggs and larvae taken during research surveys.

(3) The results of trawl surveys conducted on the continental shelf (relatively low numbers taken primarily at the deepest extent of the surveys) suggest that a large proportion of the offshore hake population occurs off of the continental shelf, in waters not covered by research trawl surveys. More information on the offshore component of the population is needed to assess the overall distribution of this species.

(4) More information on the habitat requirements of the various life stages of offshore hake is needed. Currently, most information is limited to EFH levels 1 and 2, and no information on production by habitat type (i.e., EFH level 4) exists.

(5) Information on growth rates of all life stages of offshore hake is needed. Currently, growth rate information is available only for larvae (Morse 1989).

(6) Stock assessments of offshore hake are currently not being conducted. Proper assessment will require sampling of the component of the population off the continental shelf.

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Table 1. Life history and habitat characteristics of offshore hake, *Merluccius albidus*.

Life Stage	Location	Estuarine/ Ocean Use	Bottom Sediment	Bottom Temperature	Depth	Predators/ Prey	Major References
Eggs 1.05-1.15 mm diameter	Southern Georges Bank Middle Atlantic Bight	Planktonic	Not applicable	*(water column temp.)* Most abundant at 9-19°C Spring: 9-14°C Summer: 10-15°C Autumn: 11-19°C Winter: 9-13°C	Buoyant 110-750 m	Eaten by own and other species	Marak (1967) Fahay (1983) Markle and Frost (1985)
Larvae 3-20 mm	Gulf of Maine (spring and autumn) Southern Georges Bank Middle Atlantic Bight	Planktonic	Not applicable	*(water column temp.)* Most abundant at 5-18°C Spring: 6-14°C Summer: 11-15°C Autumn: 10-18°C Winter: 11-14°C	Water column 70-300 m	Eaten by adults of own and other species e.g., goosefish	Marak (1967) Fahay (1983) Markle and Frost (1985)
Juveniles < 30 cm TL	Gulf of Maine (spring) Southern Georges Bank Middle Atlantic Bight	Deeper continental shelf and slope	No information	Most abundant Spring: 4-12°C Autumn: 7-12°C	Most abundant 170-350 m	Eaten by adults of own and other species, e.g., goosefish. Prey on small fishes, small shrimps and other crustaceans	Cohen *et al.* (1990)
Adults ≥ 30 cm TL	Gulf of Maine (spring) Southern Georges Bank Middle Atlantic Bight	Deeper continental shelf and slope	No information	Most abundant Spring: 6-12°C Autumn: 6-12°C	Most abundant 150-380 m	Prey on small fishes including own species, shrimps, and other crustaceans	Cohen *et al.* (1990) Klein-MacPhee (in prep.)

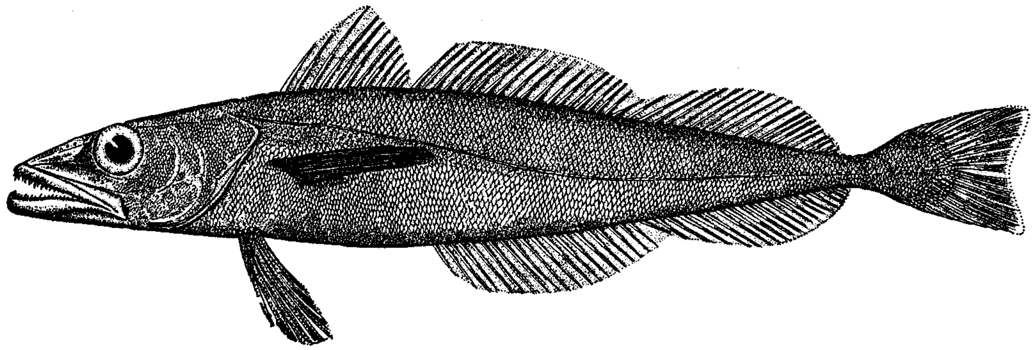


Figure 1. The offshore hake, *Merluccius albidus* (from a drawing by M.H. Carrington in Ginsberg 1954).

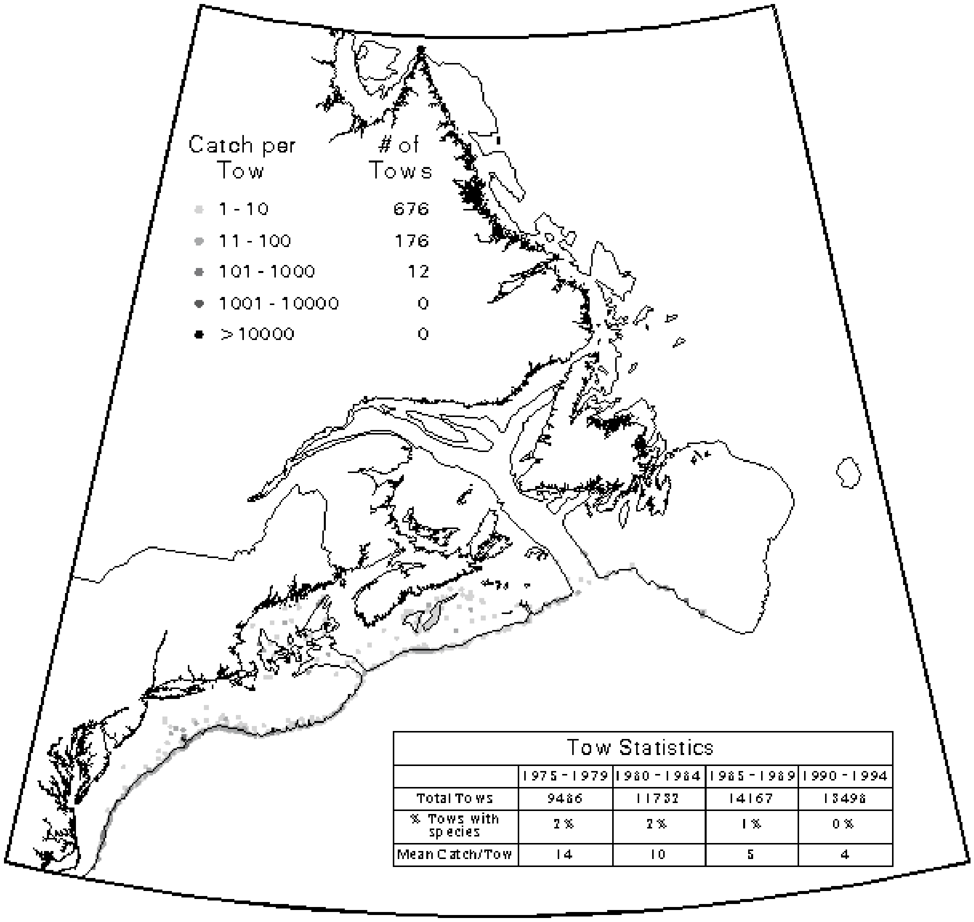


Figure 2. Distribution of offshore hake in the northwest Atlantic Ocean during 1975-1994. Data are from the U.S. NOAA/Canada DFO East Coast of North America Strategic Assessment Project (http://www-orca.nos.noaa.gov/projects/ecnasap/ecnasap_table1.html).

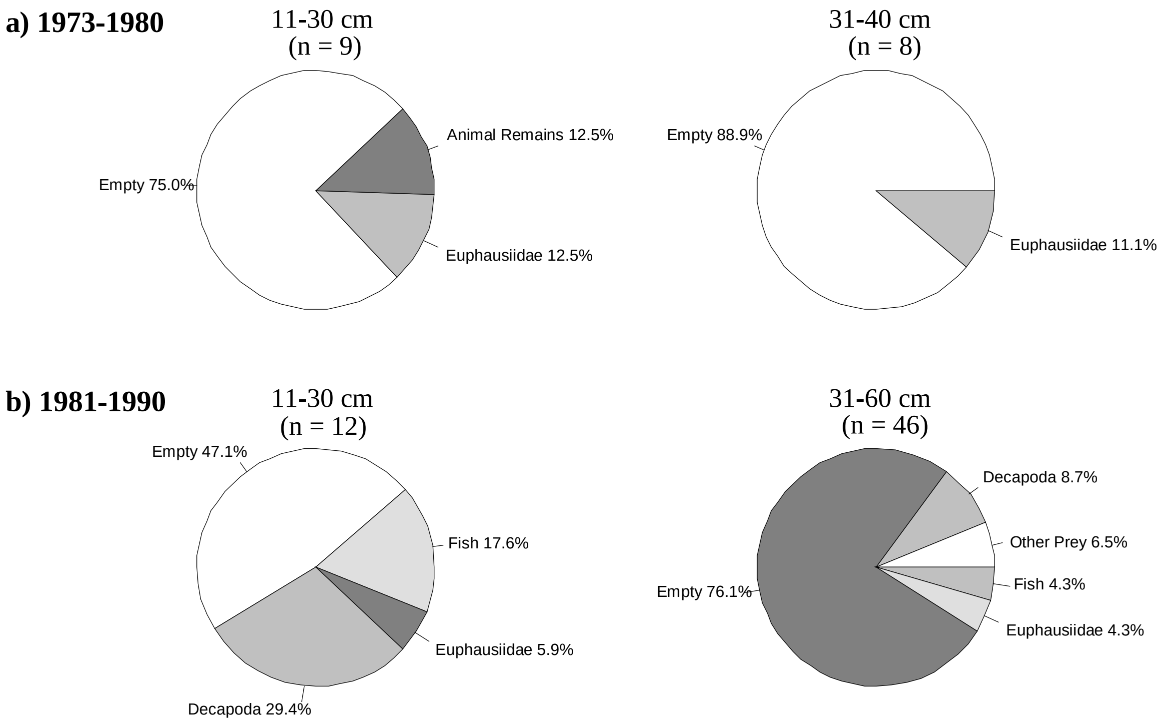


Figure 3. Abundance (percent occurrence) of the major prey items in the diet of offshore hake collected during NEFSC bottom trawl surveys from 1973-1980 and 1981-1990. The 11-30 cm size range corresponds, at least roughly, to juveniles, and the 31-60 cm size class corresponds to adults. The category "animal remains" refers to unidentifiable animal matter. Methods for sampling, processing, and analysis of samples differed between the time periods [see Reid *et al.* (1999) for details].

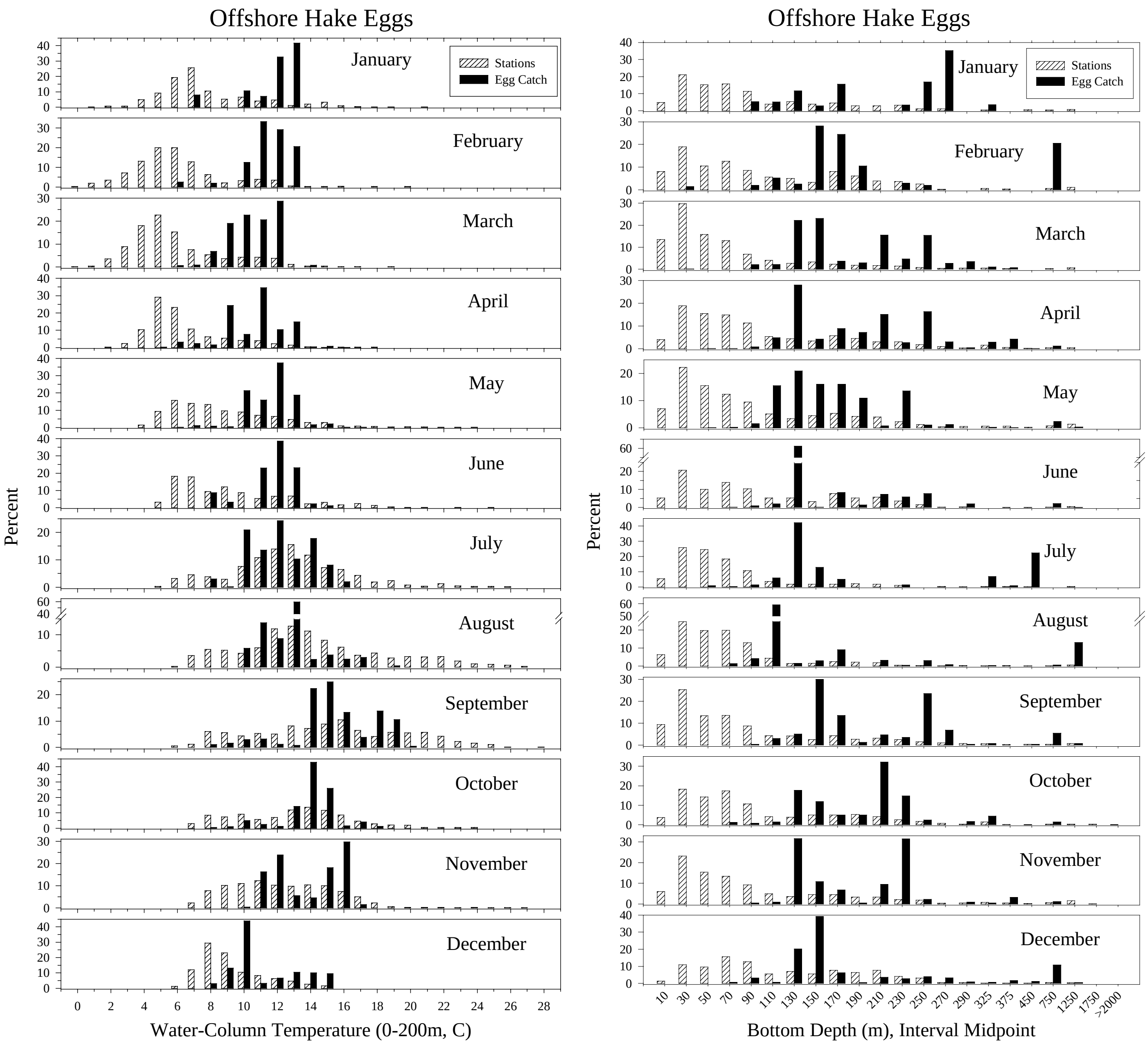


Figure 4. Abundance of offshore hake eggs relative to water column temperature (to a maximum of 200 m) and bottom depth from NEFSC MARMAP ichthyoplankton surveys (1978-1987) by month for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

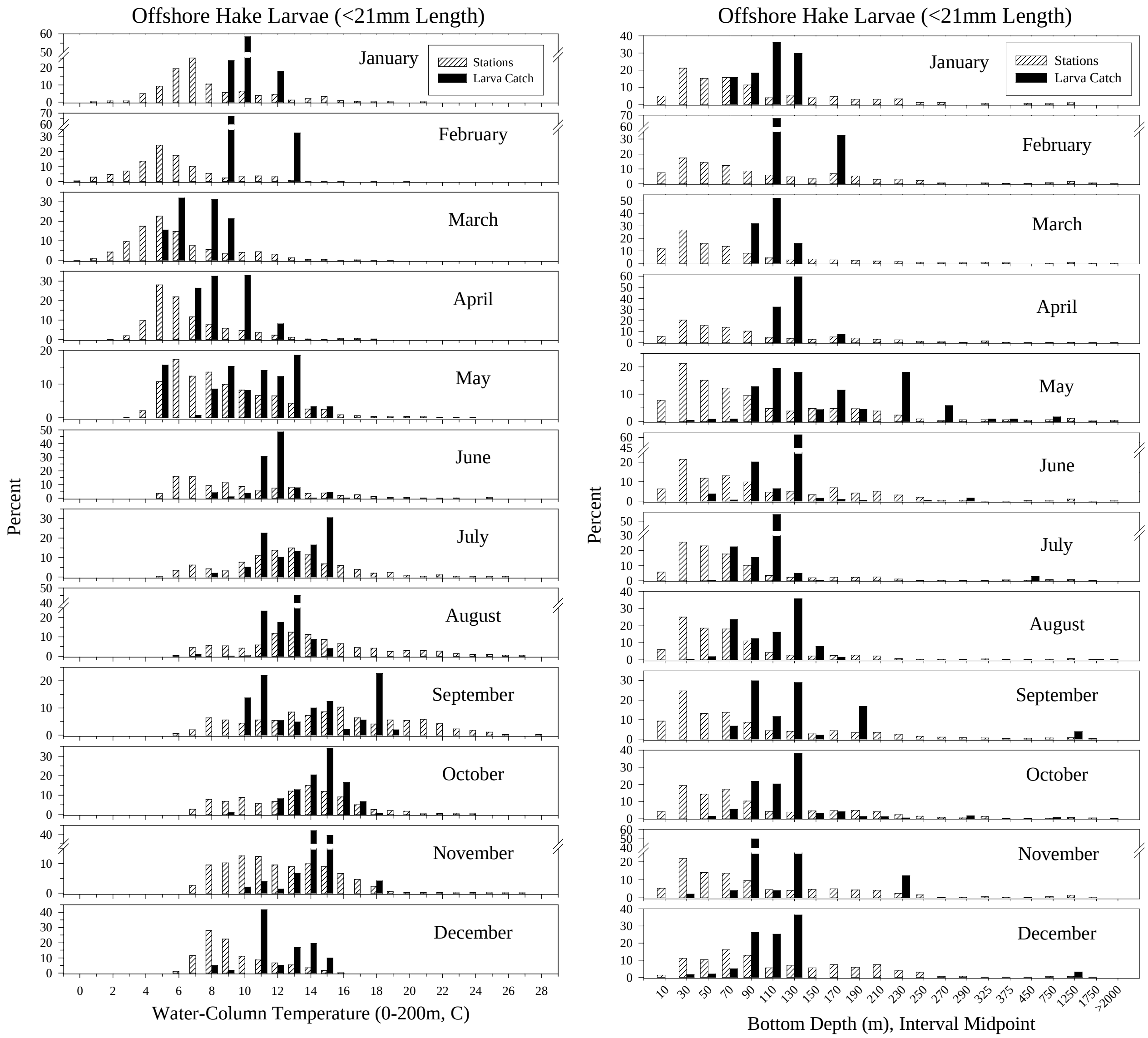


Figure 5. Abundance of offshore hake larvae (< 21 mm) relative to water column temperature (to a maximum of 200 m) and bottom depth from NEFSC MARMAP ichthyoplankton surveys (1977-1987) by month for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

Juveniles: total fish length ≤ 29 cm

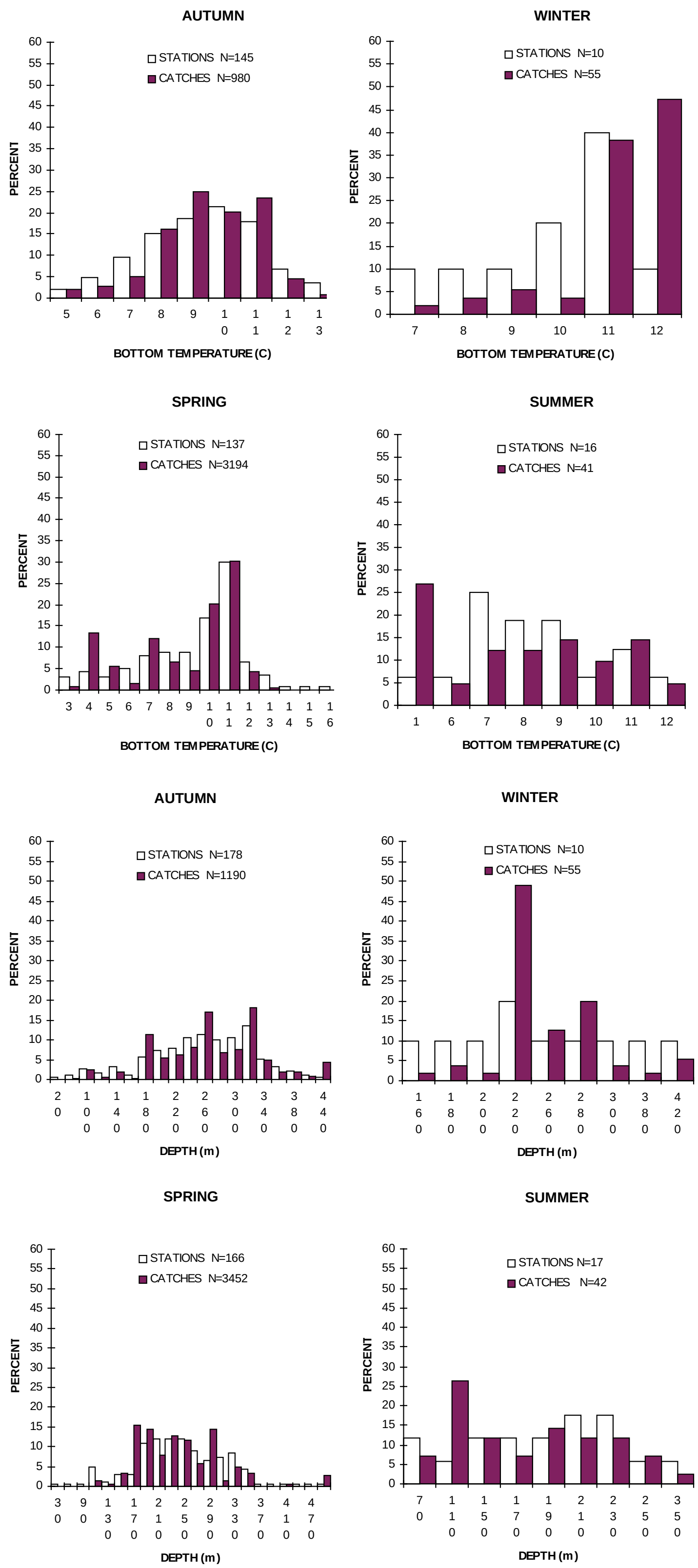


Figure 6. Abundance of juvenile offshore hake (≤ 29 cm) relative to bottom water temperature and depth based on NEFSC bottom trawl surveys (1963-1997) by season for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

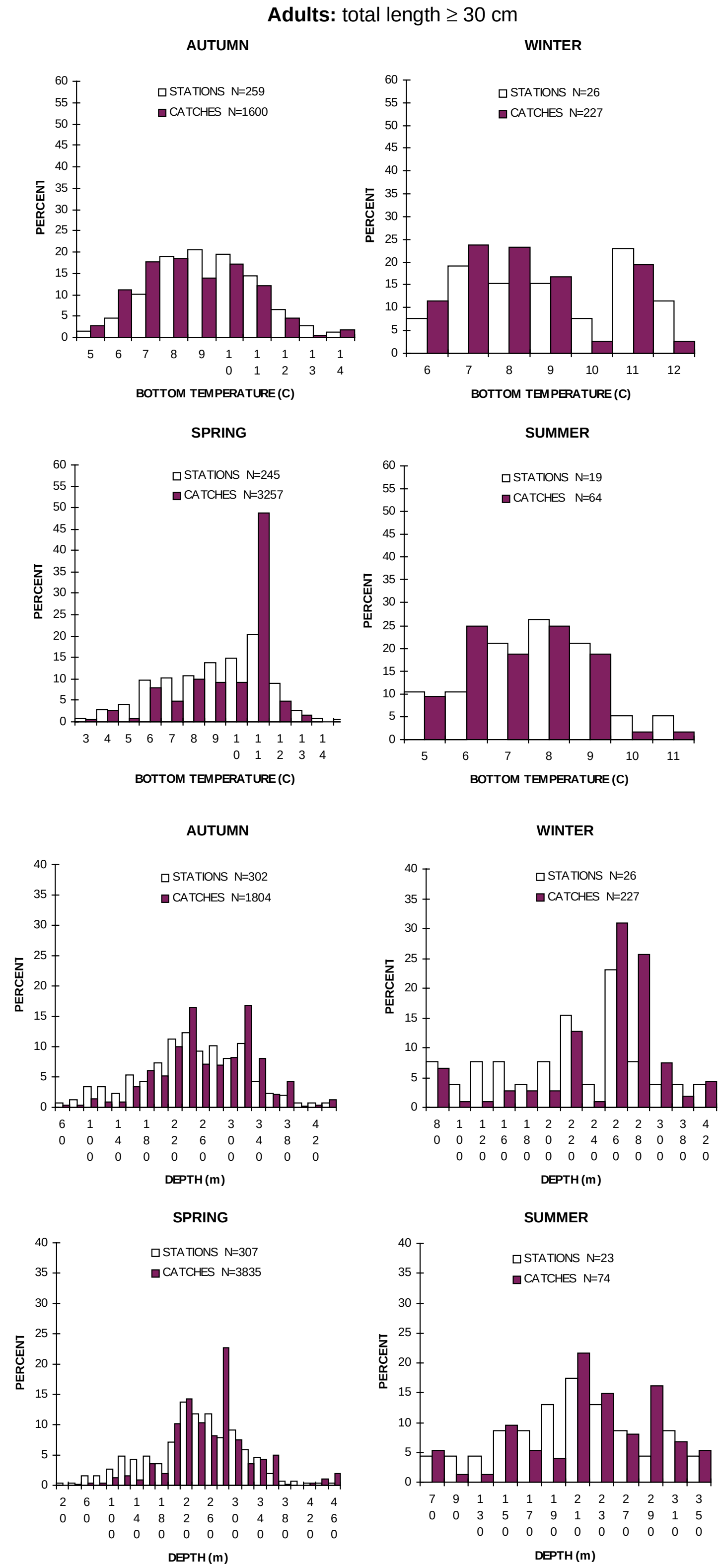


Figure 7. Abundance of adult offshore hake (≥ 30 cm) relative to bottom water temperature and depth based on NEFSC bottom trawl surveys (1963-1997) by season for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

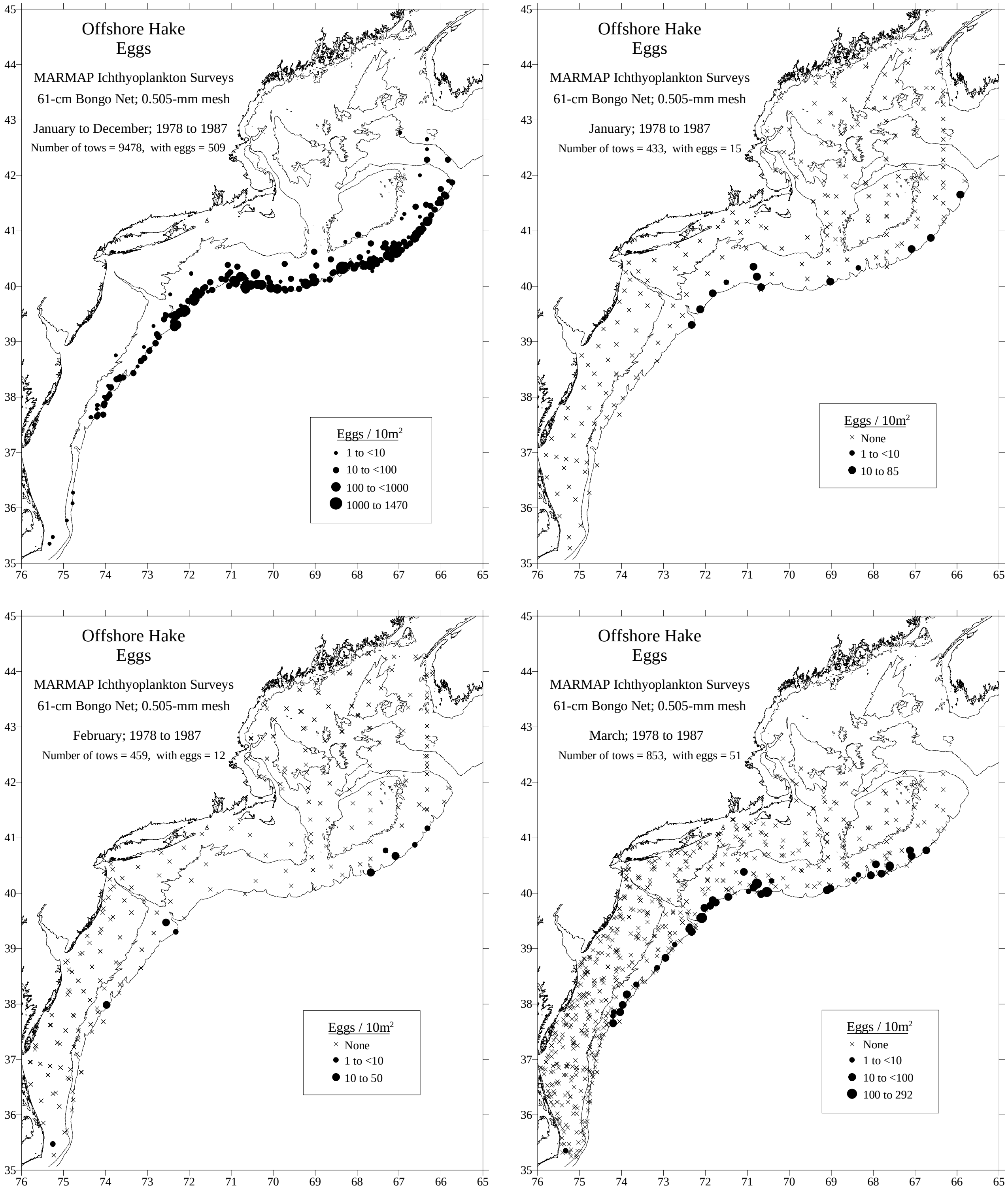
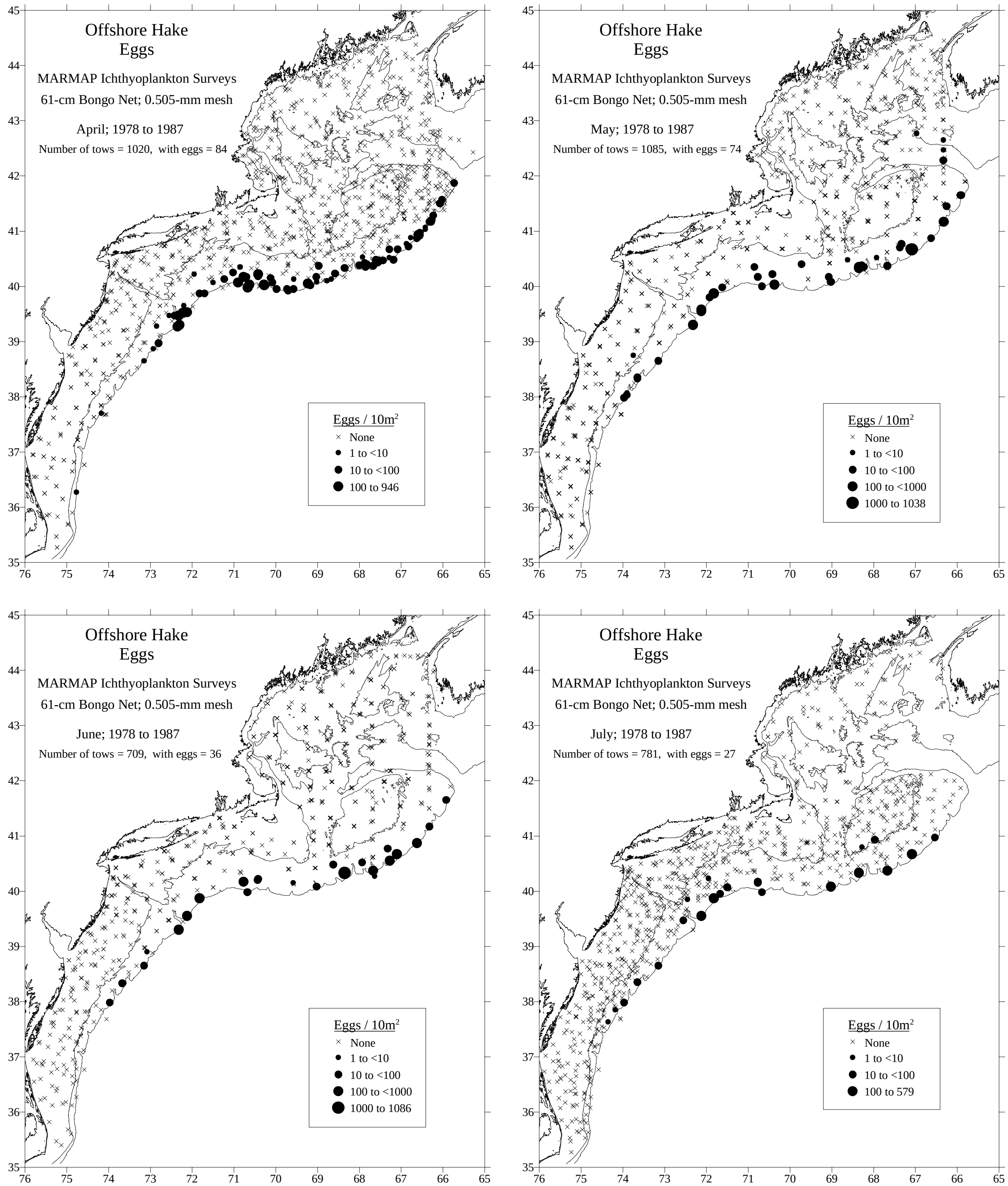


Figure 8. Distribution of offshore hake eggs based on NEFSC MARMAP ichthyoplankton surveys from January to December, 1978-1987 [see Reid *et al.* (1999) for details].



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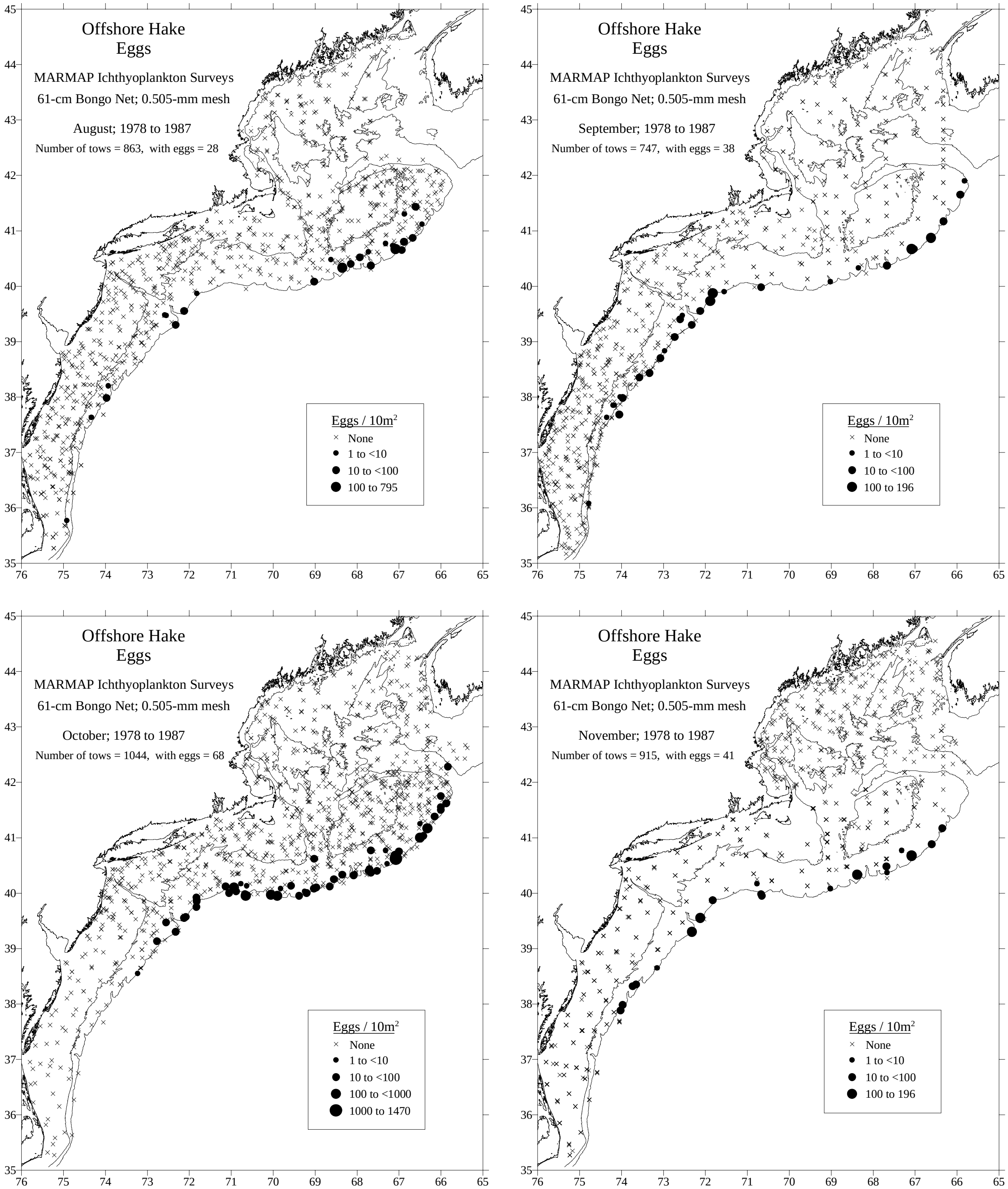

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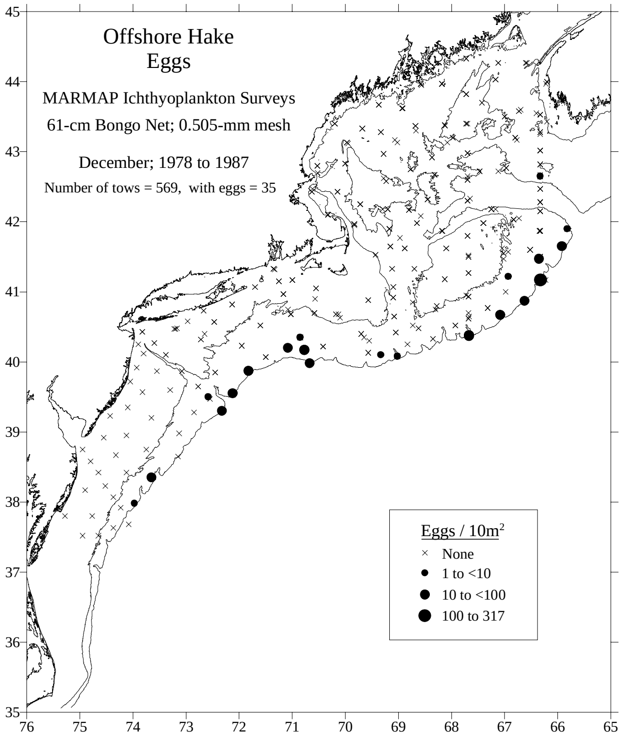

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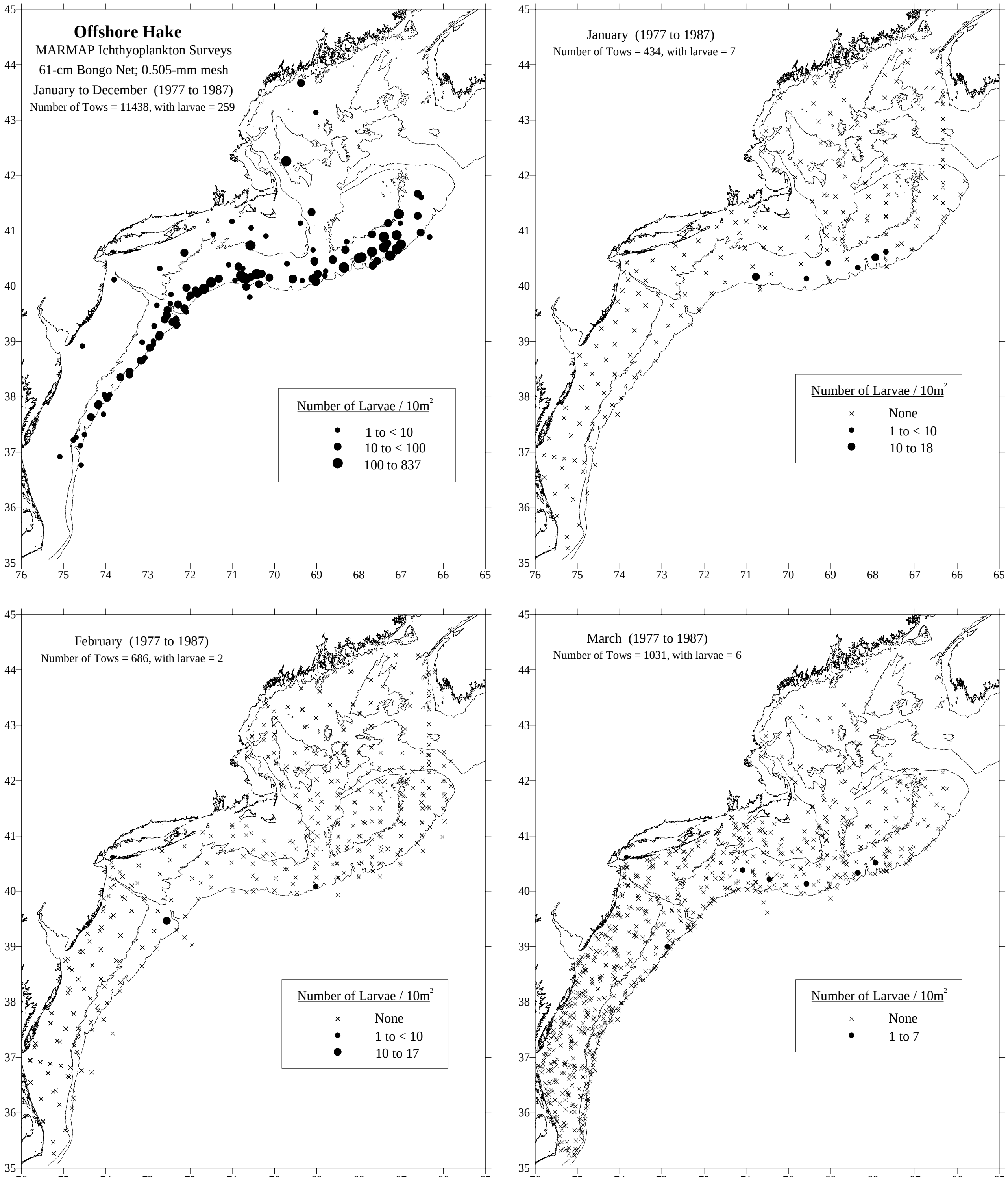
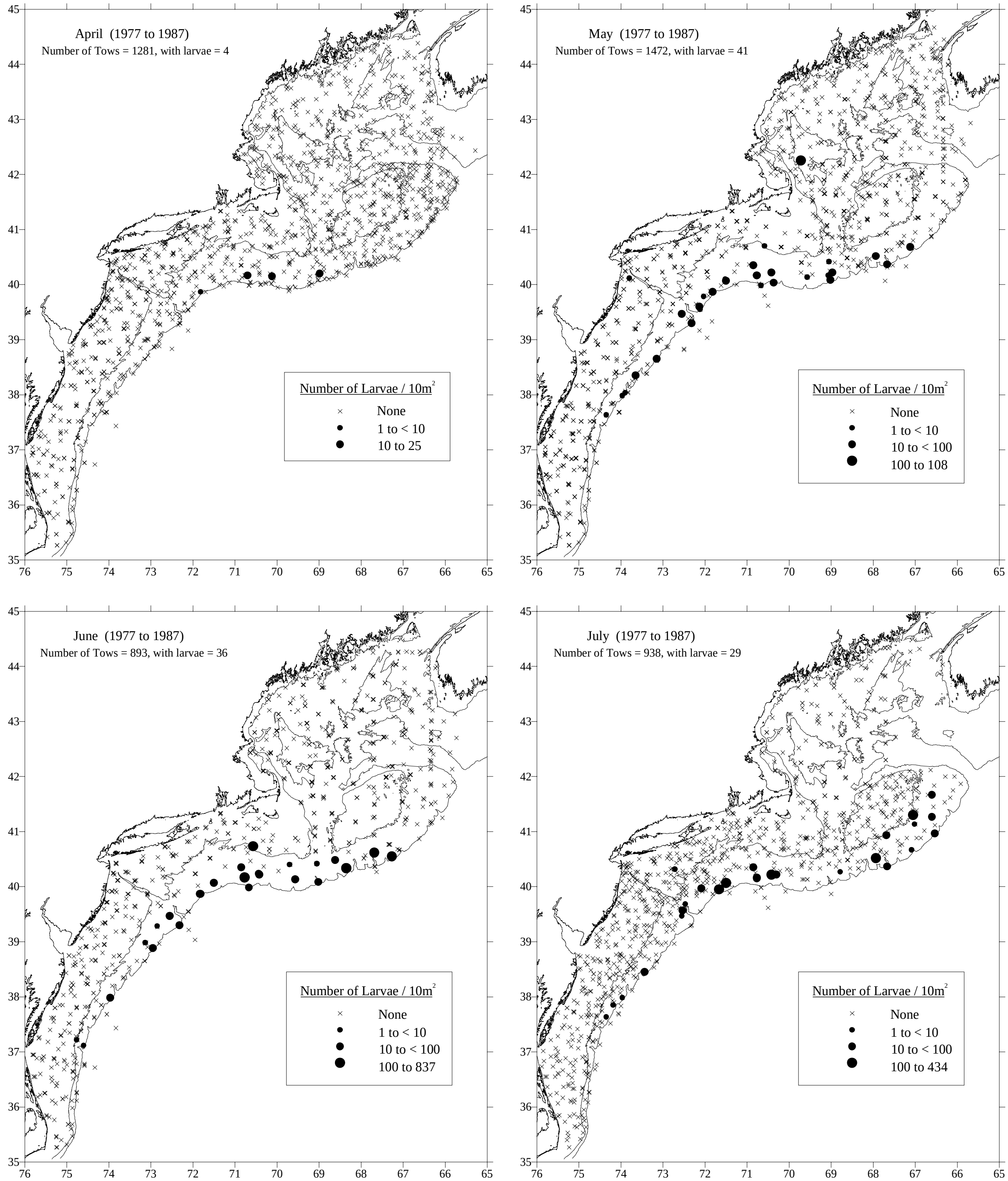


Figure 9. Distribution of offshore hake larvae (< 21 mm) based on NEFSC MARMAP ichthyoplankton surveys from January to December, 1977-1987 [see Reid *et al.* (1999) for details].



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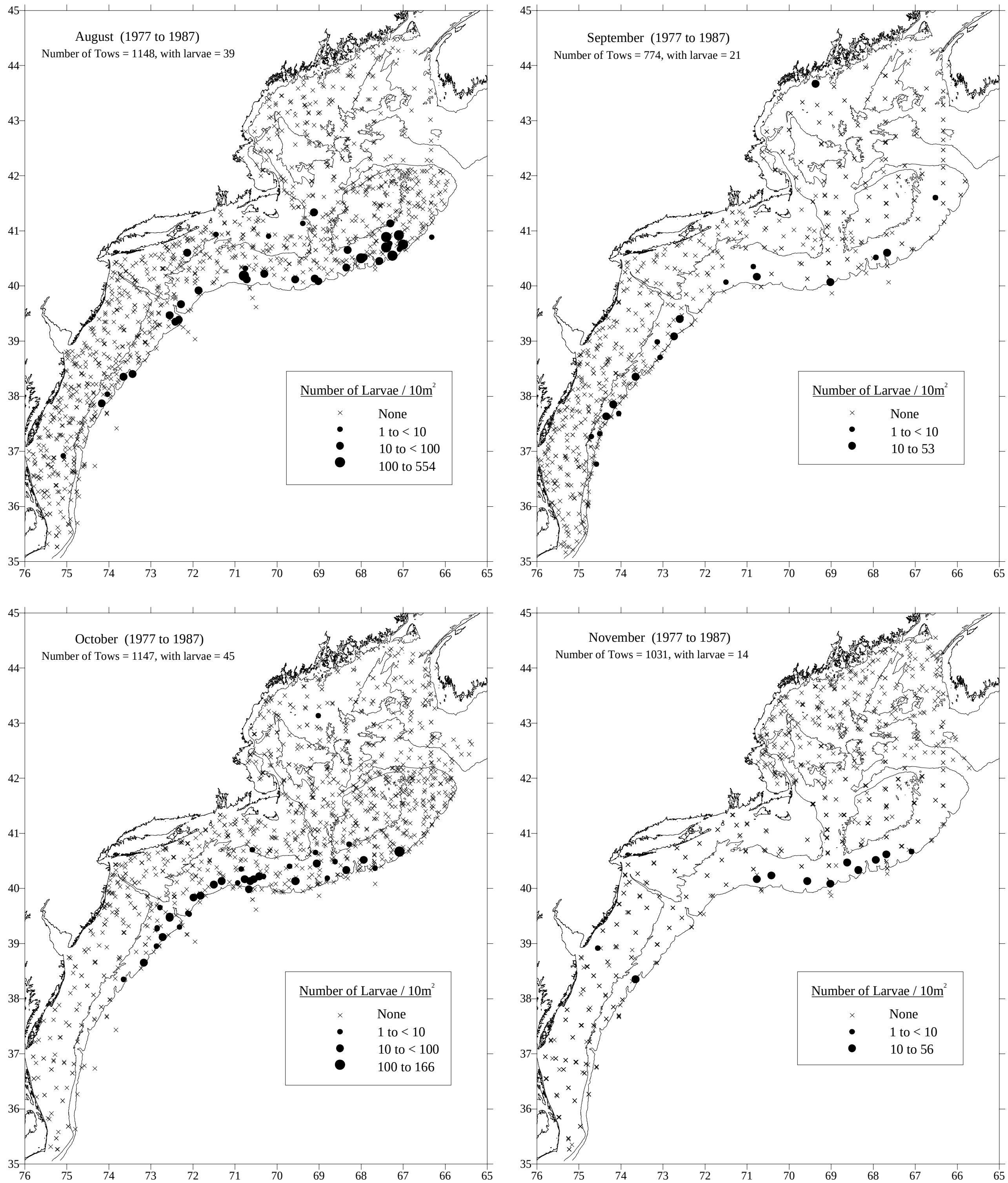

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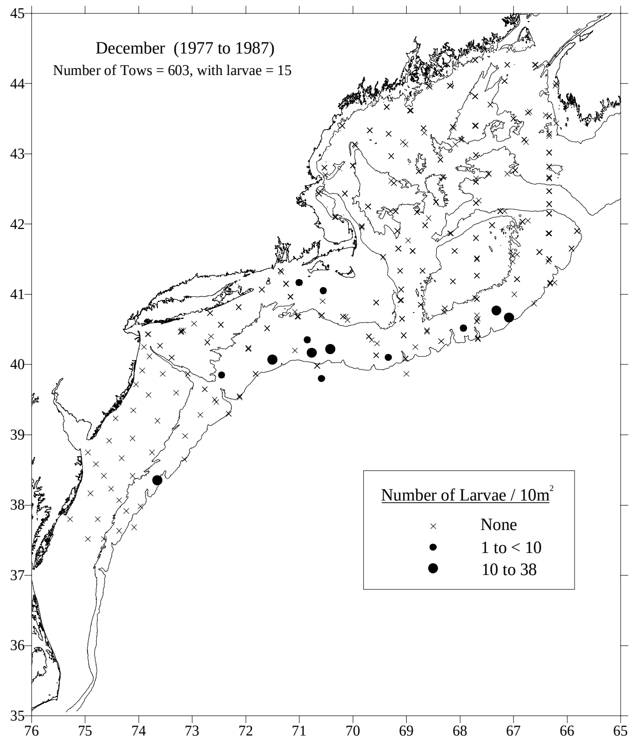

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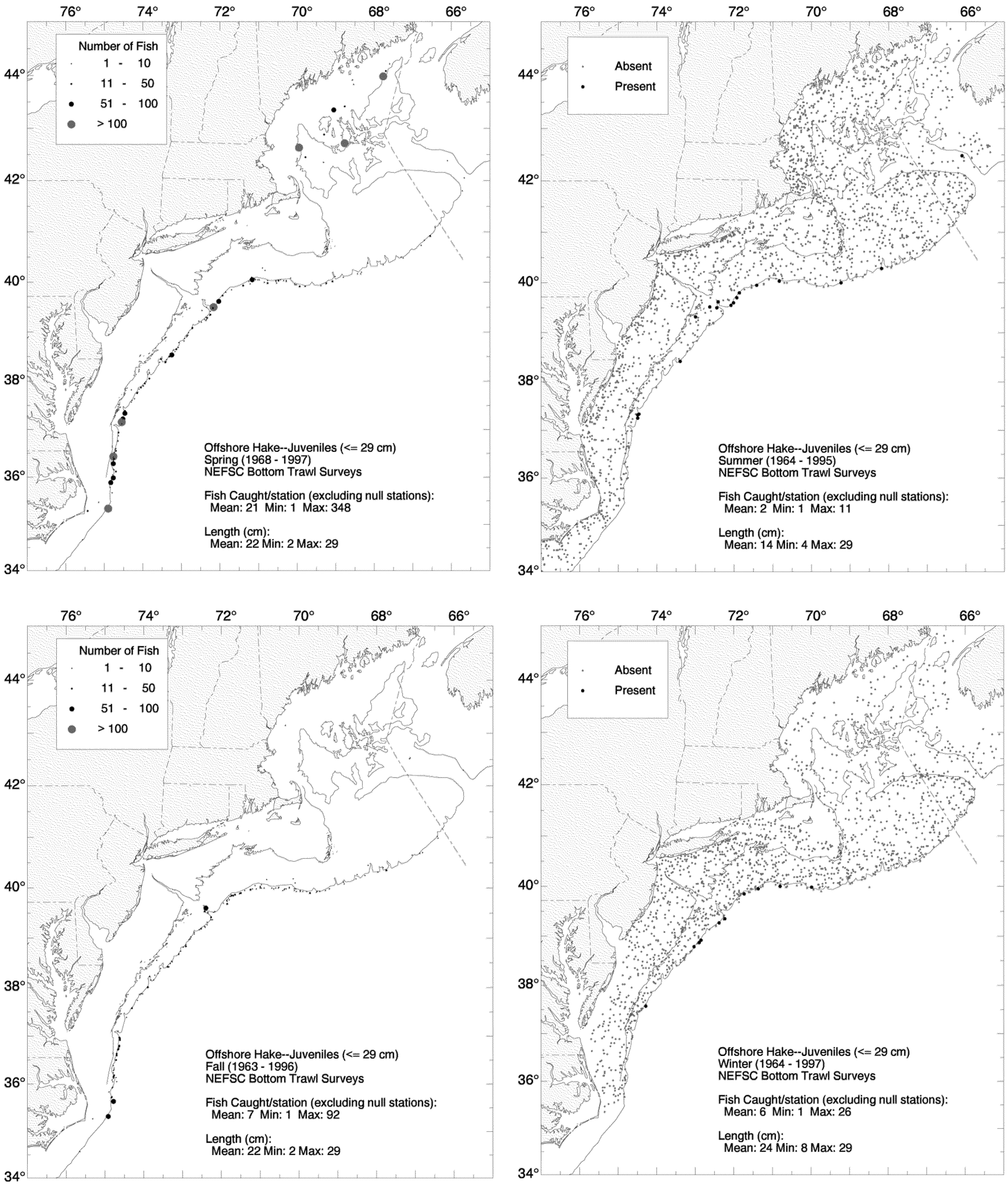

Figure 10. Distribution of juvenile offshore hake (≤ 29 cm) collected during NEFSC bottom trawl surveys during spring (1968-1997), summer (1964-1995), fall (1963-1996), and winter (1964-1997). Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].

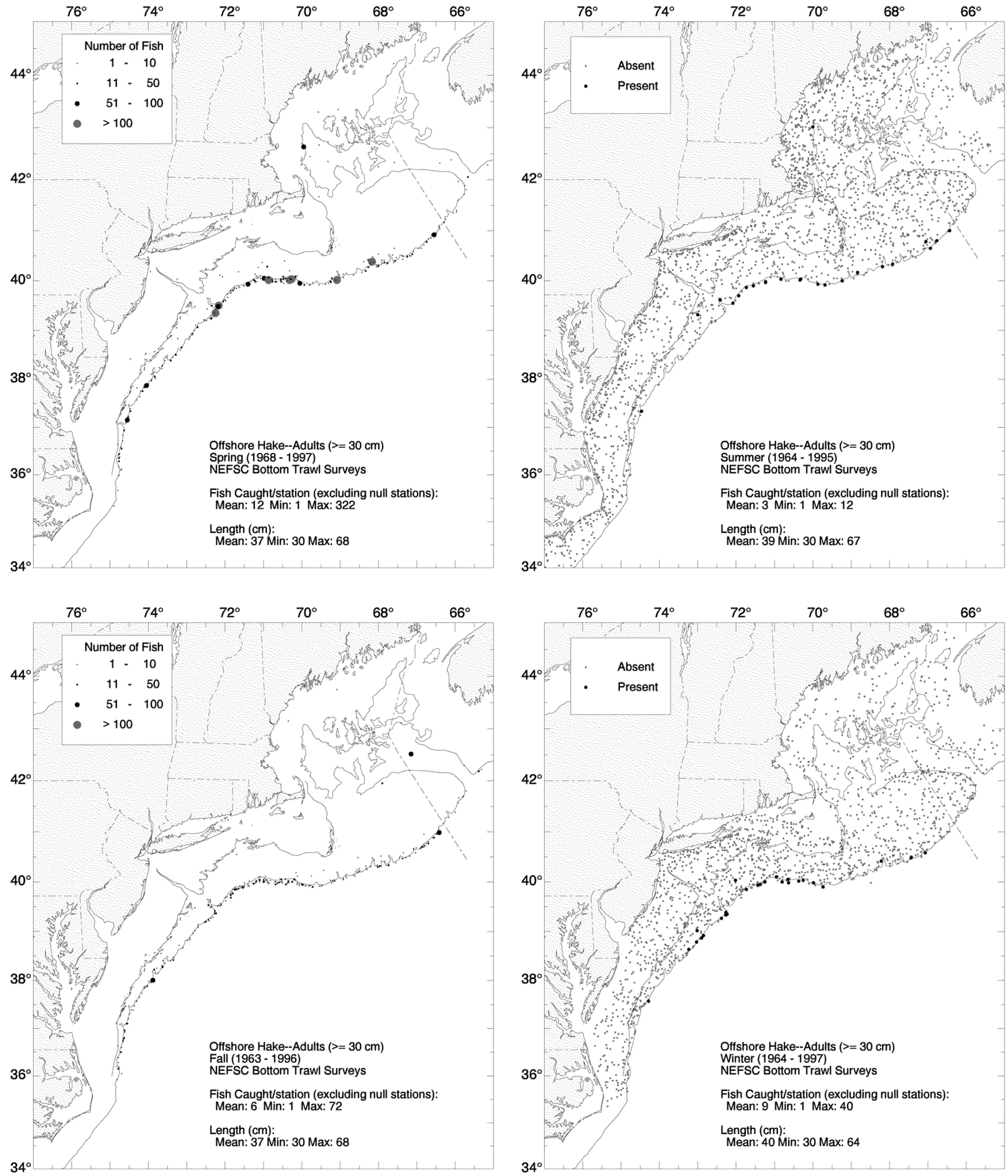

Figure 11. Distribution of adult offshore hake (≥ 30 cm) collected during NEFSC bottom trawl surveys during spring (1968-1997), summer (1964-1995), fall (1963-1996), and winter (1964-1997). Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].

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