NOAA Technical Memorandum NMFS-NE-136

Essential Fish Habitat Source Document:

White Hake, *Urophycis tenuis*,
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:

White Hake, *Urophycis tenuis*, 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

The white hake, *Urophycis tenuis* (Figure 1), is an eurythemal and eurybathic fish that inhabits the continental shelf and slope; juveniles occur in estuaries and nearshore waters. White hake are caught incidentally and by directed operations for demersal species in mixed groundfish fisheries. White hake is managed by the New England Fishery Management Council (NEFMC) under the Multispecies Fishery Management Plan (NEFMC 1993). This report is a source document for designation of Essential Fish Habitat in the Multispecies Fishery Management Plan.

LIFE HISTORY

White hake occur from the Gulf of St. Lawrence to the Middle Atlantic Bight and from estuaries across the continental shelf to the submarine canyons along the upper continental slope and the deep, muddy basins in the Gulf of Maine (Bigelow and Schroeder 1953; Musick 1974; Beacham and Nepszy 1980; Markle *et al*. 1982; Cooper *et al*. 1987; Scott and Scott 1988). The eggs, larvae, and early juveniles are pelagic; older juveniles and adults are demersal (Fahay and Able 1989).

EGGS

The eggs are buoyant and 0.7-0.8 mm in diameter with a 0.04-0.12 mm perivitelline space and a 0.19-0.28 mm oil globule (Markle and Frost 1985). A key to the eggs is given in Markle and Frost (1985).

LARVAE

It is difficult to distinguish the larvae of white hake (4-16 mm) from the larvae of red hake (*Urophycis chuss*) and longfin hake [*Phycis* (= *Urophycis*) *chesteri*]. These species can be identified by differences in caudal fin ray and epibranchial gillraker counts, body depth, and pigmentation. A key to larvae is provided by Methven (1985).

JUVENILES

Estimates of larval and pelagic juvenile growth rates range from 10-22 to 35 mm per month (Markle *et al.* 1982; Fahay and Able 1989). Based on otolith analyses, juveniles (40-80 mm TL) on Georges Bank grew 0.71 mm per day in June 1986; and juveniles (40-190 mm TL) from coastal New England grew 0.99 mm per day in 1982 (Lang *et al.* 1996). Pelagic juveniles become demersal at 50-60 mm TL (Markle *et al*. 1982) or > 64 mm SL (Fahay and Able 1989). The pelagic juvenile stage lasts about two months (Lang *et al*. 1996).

Demersal juveniles have been reported from the Bay of Fundy (4-16 cm TL) from June to October (Markle *et al.* 1982), in Passamaquoddy Bay and lower Bay of Fundy (< 15 cm TL) in July-August (MacDonald *et al*. 1984), in the Damariscotta River in May (mean 57 mm TL) and July (94 mm TL; Fahay and Able 1989), in Nauset Marsh (Massachusetts) in June (56-107 mm TL) and October (191-295 mm TL) (Fahay and Able 1989), and in Little Egg Inlet (New Jersey) in June-July (5-10 cm TL) and November-December (30-32 cm TL) (Thomas and Milstein 1973).

ADULTS

White hake attain a maximum length of 135 cm and weigh up to 22 kg; females are larger than males (Hunt 1982; Markle *et al*. 1982). Ages of 20+ years have been documented (Langton *et al.* 1994). Other age-growth studies of white hake were done by Beacham and Nepszy (1980), Hunt (1982), Clay and Clay (1991), and Lang *et al*. (1996).

REPRODUCTION

The northern stock of white hake spawns in late summer (August-September) in the southern Gulf of St. Lawrence and on the Scotian Shelf (Markle *et al.* 1982). The timing and extent of spawning in the Georges Bank-Middle Atlantic Bight stock has not been clearly determined. Based on the distribution and abundance of pelagic juveniles, as well as circulation patterns throughout the region, Fahay and Able (1989) suggested that the southern stock spawns in early spring (April-May) in deep waters along the continental slope, primarily off southern Georges Bank and the Middle Atlantic Bight (Lang *et al*. 1996). The spawning contribution of the Gulf of Maine population is negligible (Fahay and Able 1989).

Mean lengths at sexual maturity of white hake in the Gulf of St. Lawrence were 40 cm for males and 43 cm for females (Beacham and Nepszy 1980). For the Georges Bank-Middle Atlantic Bight stock, the median age at sexual maturity (L_{50}) is 1.5 years when females are 35 cm TL and males are 32 cm TL (O'Brien *et al.* 1993). Growth of white hake is sexually dimorphic; females grow larger and live longer than males (Bigelow and Schroeder 1953).

FOOD HABITS

Demersal juveniles feed primarily on polychaetes, shrimps, and other crustaceans (Bowman 1981), but adults feed on fish, including juveniles of their own species

(Langton *et al.* 1994) and shrimps and other crustaceans (Figure 2).

PREDATION

Data from seabird feeding studies off the coast of Maine indicate that Atlantic puffin and Arctic tern prey on pelagic juveniles that occur at the surface during the day in June-July (Fahay and Able 1989). Smaller juveniles are eaten by adults of their own and other species.

MIGRATION

Small juveniles occur near the edge of the continental shelf while the largest juveniles (> 60 mm TL) occur near the coast, suggesting an inshore migration (Fahay and Able 1989; Comyns and Grant 1993). In the Gulf of Maine, white hake of all ages tend to migrate inshore or shoalward in warmer months and disperse into deeper waters in colder months (Figures 7, 8; Musick 1974; MacDonald *et al*. 1984; Chang 1990; Langton *et al.* 1994).

STOCK STRUCTURE

White hake are thought to exist as two stocks: Georges Bank-Middle Atlantic Bight and Gulf of St. Lawrence-Scotian Shelf, with mixing in the Gulf of Maine (Musick 1974; Fahay and Able 1989). The stocks are not clearly separable in commercial landings (Sosebee *et al.* 1998).

HABITAT CHARACTERISTICS

Information on the habitat characteristics and life history of all life stages of white hake is summarized in Table 1. The methods used to collect the fishery-independent survey data for this characterization are summarized in Reid *et al.* (1999).

EGGS

Eggs remain near the surface; hatching occurs in 3-7 days at typical spawning temperatures and new larvae (2 mm TL) are difficult to distinguish from red hake and spotted hake (Fahay 1983; Able and Fahay 1998). Eggs of white hake could not be separated from eggs of the other hakes in the Northeast Fisheries Science Center (NEFSC) Marine Resources Monitoring, Assessment and Prediction (MARMAP) ichthyoplankton surveys (1978-1987). *Urophycis-Phycis* spp. eggs were collected across the continental shelf, on Georges Bank and, to a lesser degree, in the Gulf of Maine. *Urophycis-Phycis* spp. eggs were collected from 4-25^{o}C; most eggs were collected between 7-20^{o}C in water depths of 10-250 m (Figure 3; Berrien and Sibunka 1999).

LARVAE

Small white hake larvae have been collected in early summer in a Gulf Stream warm core ring seaward of southern Scotian Shelf and southeast of Georges Bank (Wroblewski and Cheney 1984; Methven 1985). Recent studies reported small larvae (< 5.0 mm TL) in slope waters off the Middle Atlantic Bight during May 1993 providing evidence of spawning offshore (Able and Fahay 1998). The possibility that white hake spawn in nearshore waters, and that the eggs and larvae escape detection by ichthyoplankton surveys on the shelf, seems remote (Fahay and Able 1989).

Most of the hake larvae collected during NEFSC MARMAP ichthyoplankton surveys were identified as *Urophycis* spp. (96%); the remaining larvae were identified as red hake (3%) and spotted hake (1%). *Urophycis* spp. larvae were collected from 8-23^{o}C; most larvae were collected at 10-18^{o}C over water depths from 10-150 m, with some deeper occurrences (Figure 4).

JUVENILES

Most pelagic juveniles that were spawned offshore cross the shelf and enter Canadian and New England-Middle Atlantic estuarine nursery areas. Some juveniles may descend to as yet unknown habitats on the shelf (Thomas and Milstein 1973; Markle *et al.* 1982; Fahay and Able 1989).

Larger demersal juveniles were collected offshore at a wide range of temperatures (4-19^{o}C) and depths (5-325 m), but were most abundant at 4-9^{o}C in spring and 7-16^{o}C in autumn at depths < 225 m (Figure 5). Smaller juveniles (< 20 cm TL) collected in the Massachusetts inshore trawl surveys were most abundant at of 4-14^{o}C in spring and 8-19^{o}C in autumn at depths < 75 m (Figure 6).

Eelgrass is an important habitat for demersal juveniles (Bigelow and Schroeder 1953; Fahay and Able 1989; Heck *et al.* 1989). Younger fish are spatially segregated from older year classes by occupying shallow areas, but they are not tied to eelgrass, other vegetation, or structured habitats (Markle *et al*. 1982; Able and Fahay 1998). In nearshore habitats of southwest Nova Scotia, demersal juveniles collected in an otter trawl survey were associated with warmer, less saline, more turbid water and finer grained substrates (Horne and Campana 1989).

ADULTS

Adult white hake are demersal and prefer fine grained, muddy substrates (MacDonald *et al*. 1984; Scott 1982). During the NEFSC bottom trawl surveys, adults were caught at temperatures from 6-11^{o}C in spring and autumn, and were most abundant at depths of 50-325 m in spring and of 50-275 m in autumn (Figure 5). During the Massachusetts inshore trawl surveys, adults were caught at temperatures from about 5-14^{o}C in spring and autumn (Figure 6). In the spring, they were most abundant at depths of around 15-30 m, with a range of 5-80 m. In the autumn, they were most abundant at depths of around 35-75 m, with a range of 15-80 m (Figure 6). In Passamaquoddy Bay, white hake were caught at salinities of 29.5-32.5 ppt (MacDonald *et al*. 1984). The depth distribution of adults in the Gulf of Maine varies with age and season; they tend to move inshore in summer-autumn and disperse to the deeper basins in winter-spring (Figure 8).

Using data from the NEFSC bottom trawl surveys, Colvocoresses and Musick (1984) found that white hake commonly occur with two upper slope species, offshore hake (*Merluccius albidus*) and blackbelly rosefish (*Helicolenus dactylopterus*), during spring. In the fall, white hake are more widely distributed across the outer shelf and are associated with goosefish (*Lophius americanus*) and witch flounder (*Glyptocephalus cynoglossus*). Auster *et al.* (1995), using video transects taken from submersibles, observed white hake with blackbelly rosefish, Jonah crab (*Cancer borealis*), and various flounders (Pleuronectiformes) on the outer shelf off southern New England.

GEOGRAPHICAL DISTRIBUTION

White hake in the northwest Atlantic are distributed from the Gulf of St. Lawrence to Cape Hatteras (Figure 9). The areas of highest abundances are the Gulf of St. Lawrence, the southern edge of the Grand Bank, the Scotian Shelf, the Gulf of Maine, and Georges Bank.

EGGS

White hake eggs were collected in the southern Gulf of St. Lawrence in August and September (Markle and Frost 1985). Eggs collected on the Scotian Shelf in August and September were assumed to include white and red hakes (Markle *et al.* 1982). During the NEFSC MARMAP ichthyoplankton surveys (1978-1987), *Urophycis-Phycis* spp. eggs were collected across the continental shelf, on Georges Bank, and to a lesser degree, in the Gulf of Maine (Figure 10).

LARVAE

Collections of white hake larvae have been limited to the northern stock (Chenoweth 1973; Colton and St. Onge 1974; Bolz *et al*. 1981; Laroche 1982; Townsend 1984). Few larval data for white hake are available in the NEFSC MARMAP ichthyoplankton surveys. The distribution of *Urophycis* spp. larvae are summarized in Figure 11.

JUVENILES

Pelagic juveniles were distributed over Georges Bank and in the Gulf of Maine in May-June (Fahay 1987); they were collected in the Middle Atlantic Bight in June 1976 and May 1977 (Comyns and Grant 1993).

The NEFSC bottom trawl surveys did not collect white hake less than about 20 cm TL. Commercial landings (including discards) do not provide information on fishes less than about 25 cm TL (Burnett *et al.* 1984). Demersal juveniles in the Gulf of Maine and Georges Bank move inshore in the warmer months **(**Figure 7). In Massachusetts inshore waters, there is little difference between the distribution patterns of juveniles between spring and autumn (Figure 12).

Despite the reported presence of juvenile white hake in a southern New Jersey estuary (Thomas and Milstein 1973), they were not collected in recent studies in the Hudson-Raritan estuary (Wilk *et al.* 1996) or in Long Island Sound (Gottschall *et al.*, in review). A few juveniles (n = 48) were caught in Narragansett Bay during the 1990-1997 Rhode Island trawl surveys (T. Lynch, Rhode Island Department of Environmental Management, Divison of Fish and Wildlife, Marine Fisheries Section, Wickford, RI, personal communication).

ADULTS

The spatial distribution of adults in the Gulf of Maine and on Georges Bank indicates pronounced inshore movement in warmer months **(**Figure 8). In Massachusetts inshore waters, there is a difference in the distribution patterns of adults in spring and autumn (Figure 12). No white hake were reported in recent surveys of the Hudson-Raritan estuary (Wilk *et al.* 1996), Long Island Sound (Gottschall *et al.*, in review), or Narragansett Bay (T. Lynch, Rhode Island Department of Environmental Management, Divison of Fish and Wildlife, Marine Fisheries Section, Wickford, RI, personal communication).

STATUS OF THE STOCKS

The NEFSC bottom trawl surveys have been used to estimate the relative abundance and biomass of white hake. The autumn biomass index of white hake from the Gulf of Maine and Georges Bank-Middle Atlantic Bight stock has fluctuated without a consistent trend since the early 1970s (Figure 13).

The white hake stock is managed by the New England Fishery Management Council in accordance with the Multispecies Fishery Management Plan (NEFMC 1993). The stock is considered overfished when the 3-year moving average of the autumn index of stock abundance falls below the lowest quartile of the time series. Thus, white hake stocks in the Gulf of Maine and Georges Bank-Middle Atlantic Bight are not currently overfished (National Marine Fisheries Service 1997). However, the most recent survey suggests a decline in the index (Sosebee *et al*. 1998).

RESEARCH NEEDS

- Studies (e.g., genetics, otolith, cohort analysis, etc.) to determine whether white hake is a unit stock or multiple stocks and whether northern and southern stocks are truly separate.
- Times and locations of white hake spawning on Georges Bank and in the Middle Atlantic Bight and the habitat requirements of spawning adults.
- Identification of white hake eggs and larvae.
- Spatial and temporal distribution of white hake eggs and larvae.
- Habitat requirements for white hake eggs, larvae, and juveniles.
- Studies (e.g., tagging, more efficient gear to catch juveniles) to determine seasonal use of estuaries (e.g., residency during colder months) and nearshore waters.

ACKNOWLEDGMENTS

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Table 1. Summary of life history and habitat parameters for white hake, *Urophycis tenuis*.

Life Stage	Size and Growth	Geographic Location	Habitat	Substrate	Temperature	Prey	Predators	Time of Year
Eggs [1]	0.7-0.8 mm	Southern Gulf of St. Lawrence, Scotian Shelf	Planktonic; found in water column at 10-250 m depth.	not applicable	Most abundant at water column temperatures of 7-20^{o}C.		Eaten by own and other species.	Aug.-Sept.
Larvae [2]	4-16 mm	Scotian Shelf, Georges Bank, Gulf of Maine, Middle Atlantic Bight	Planktonic; found in water column at 10-150 m depth.	not applicable	Most abundant at water column temperatures of 10-18^{o}C.		Eaten by adults of own and other species.	Aug.-Sept. Aug.-Sept. May
Pelagic Juveniles [3]	< 60 mm TL	Georges Bank, Gulf of Maine, Middle Atlantic Bight	Found in some New England and Canadian estuaries. Located in water column until settlement; in upper water column during daytime.	not applicable	Not available		Eaten by adults of own and other species, also sea birds.	May-June June-Sept.
Demersal Juveniles [4]	< 35 cm TL	Little Egg Inlet, NJ Gulf of Maine Georges Bank Middle Atlantic Bight	Found in eelgrass beds in estuaries. Most abundant inshore at depths of 5-75 m (spring), and 5-50 m (autumn); and offshore at 50-225 m (spring), and 5-175 m (autumn).	Muddy and fine grained sandy bottom sediment.	Most abundant inshore at 4-14^{o}C (spring), and 8-19^{o}C (autumn); most abundant offshore at 4-9^{o}C (spring), and 7-16^{o}C (autumn).	Prey on polychaetes, small shrimps and other crustaceans.	Eaten by adults of own and other species.	May-June June-Sept.
Adults [5]	$\geq$ 35 cm TL	Gulf of St. Lawrence, Scotian Shelf, Georges Bank, Gulf of Maine, Middle Atlantic Bight	Oceanic current and circulation are critical for white hake distribution and recruitment. Most abundant inshore at depths of 5-45 m (spring), and 30-75 m (autumn); and offshore at 50-325 m (spring), and 50-275 m (autumn).	Muddy and fine grained sandy bottom sediment.	Most abundant inshore at 5-14^{o}C (spring), and 5-14^{o}C (autumn); most abundant offshore at 5-12^{o}C (spring), and 6-11^{o}C (autumn).	Prey on small fishes (including own species), shrimps and other crustaceans.		Year round

[1] Markle *et al.* (1982), Markle and Frost (1985)
[2] Markle *et al.* (1982), Wroblewski and Cheney (1984), Methven (1985), Fahay and Able (1989), Able and Fahay (1998)
[3] Fahay (1987), Fahay and Able (1989), Comyns and Grant (1993), Lang *et al.* (1996)
[4] Thomas and Milstein (1973), Markle *et al.* (1982), MacDonald *et al.* (1984), Heck *et al.* (1989)
[5] Markle and Frost (1985), Fahay and Able (1989), Chang (1990)

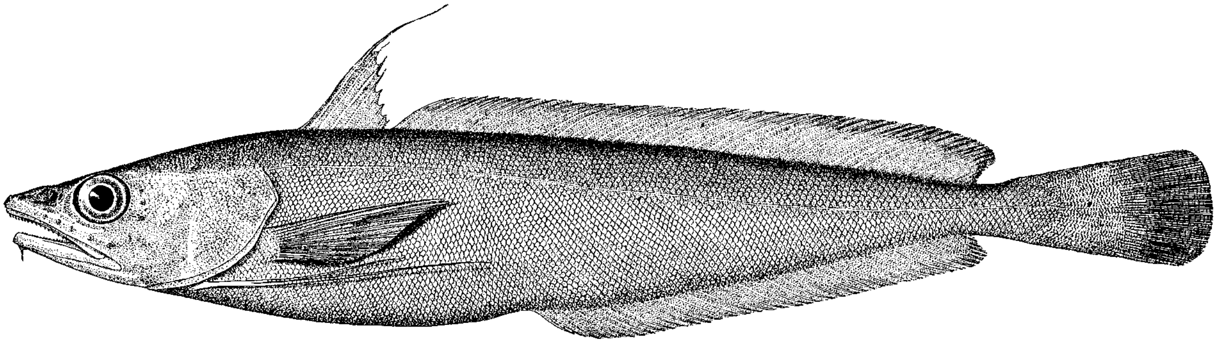


Figure 1. The white hake, *Urophycis tenuis* (from Goode 1884).

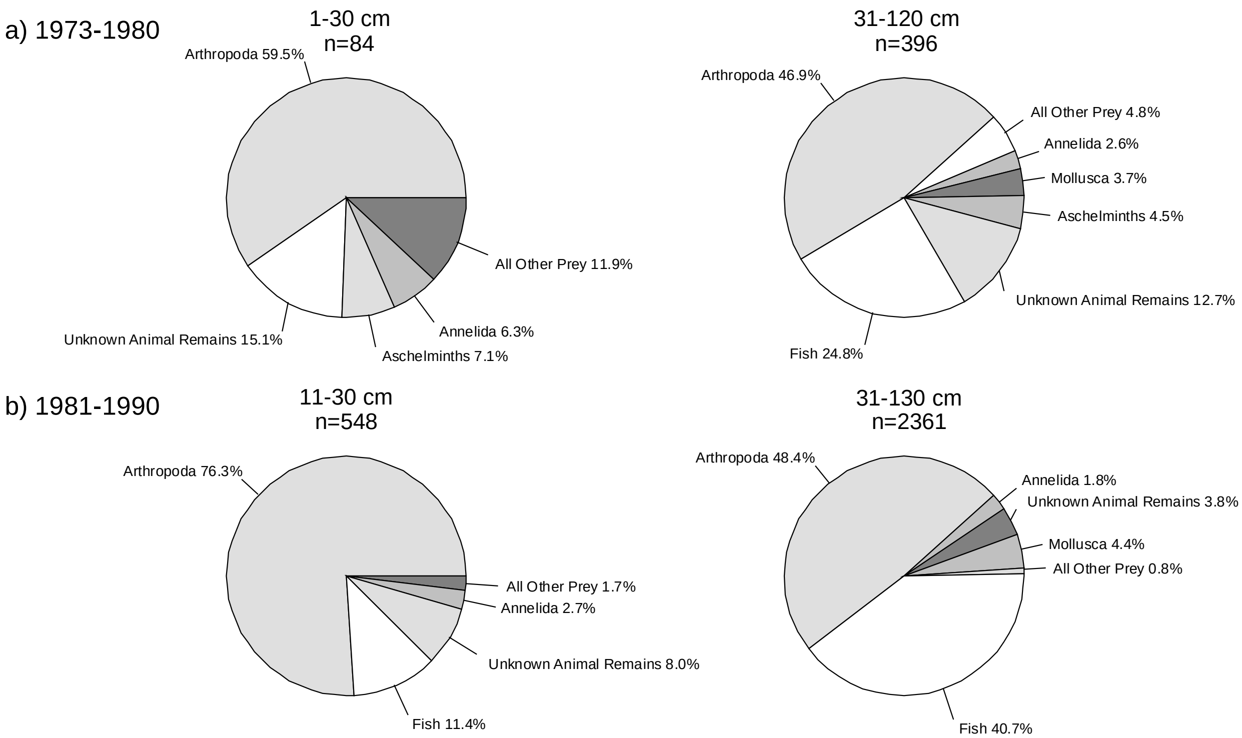


Figure 2. Abundance (percent occurrence) of the major prey items of white hake collected during NEFSC bottom trawl surveys from 1973-1980 and 1981-1990. The 1/11-30 cm size range corresponds, at least roughly, to juveniles, and the 31-120/130 cm size class corresponds to adults. The category “unknown 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].

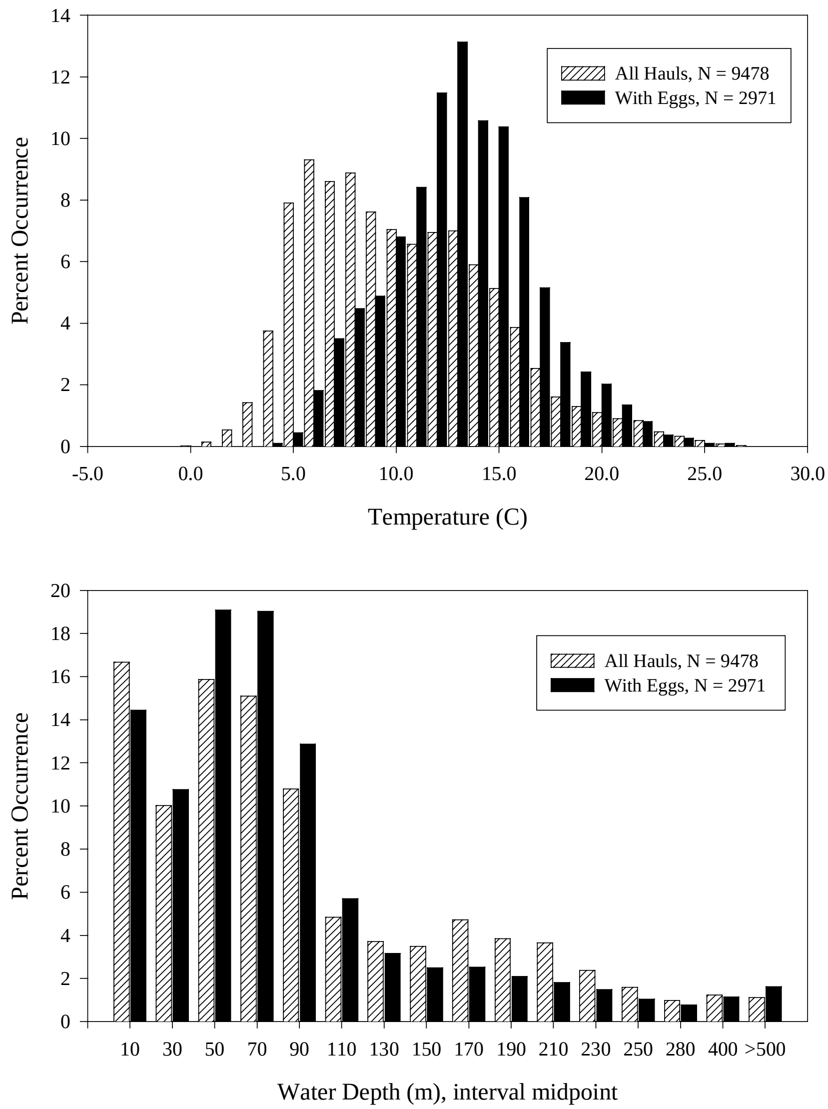


Figure 3. Abundance of hake (*Urophycis* and *Phycis* spp.) eggs relative to mean water temperature (^{o}C) and depth (m) from NEFSC MARMAP ichthyoplankton surveys, 1978-1987 (all years combined).

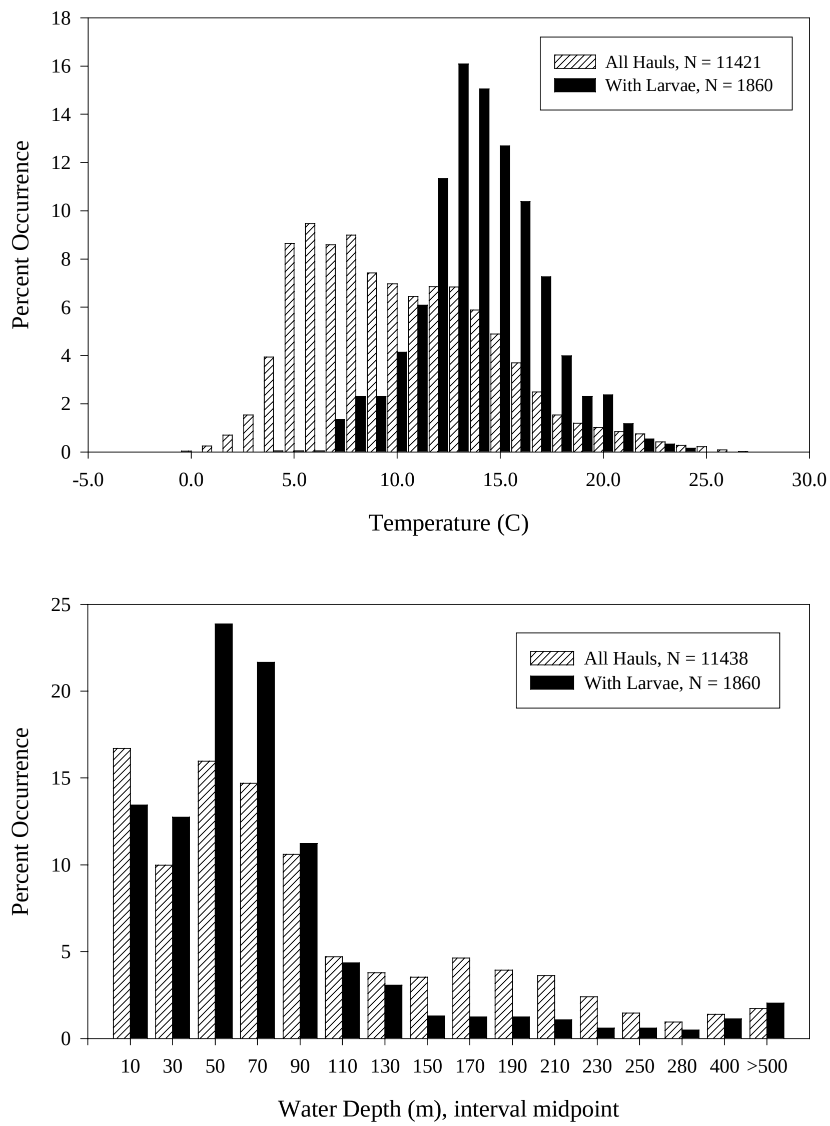


Figure 4. Abundance of white hake and *Urophycis* spp. larvae relative to mean water temperature (^{o}C) and depth (m) from NEFSC MARMAP ichthyoplankton surveys, 1977-1987 (all years combined).

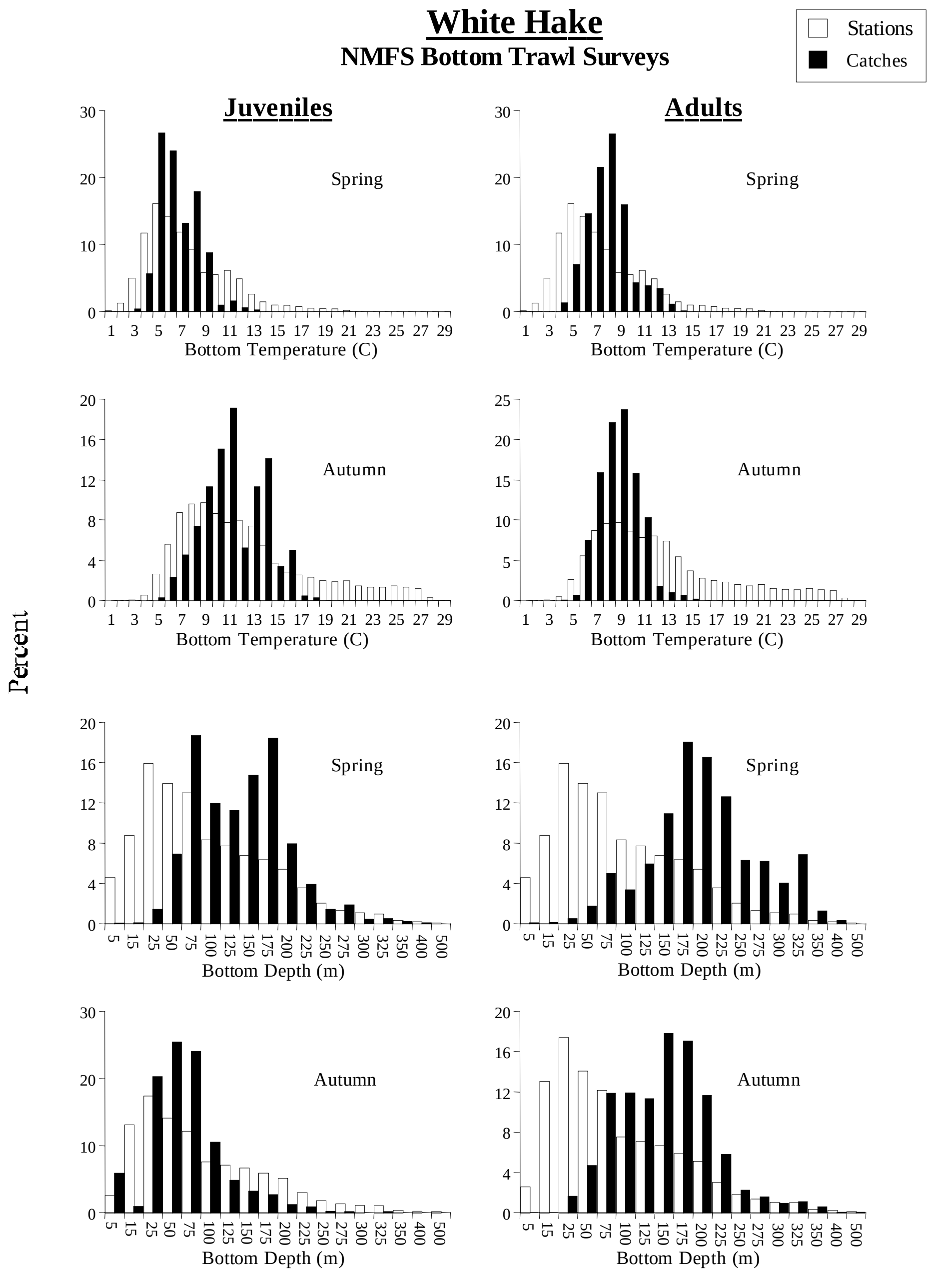


Figure 5. Abundance of juvenile and adult white hake relative to bottom water temperature (^{o}C) and depth (m) based on NEFSC bottom trawl surveys for spring (1968-1997, all years combined) and autumn (1963-1996, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

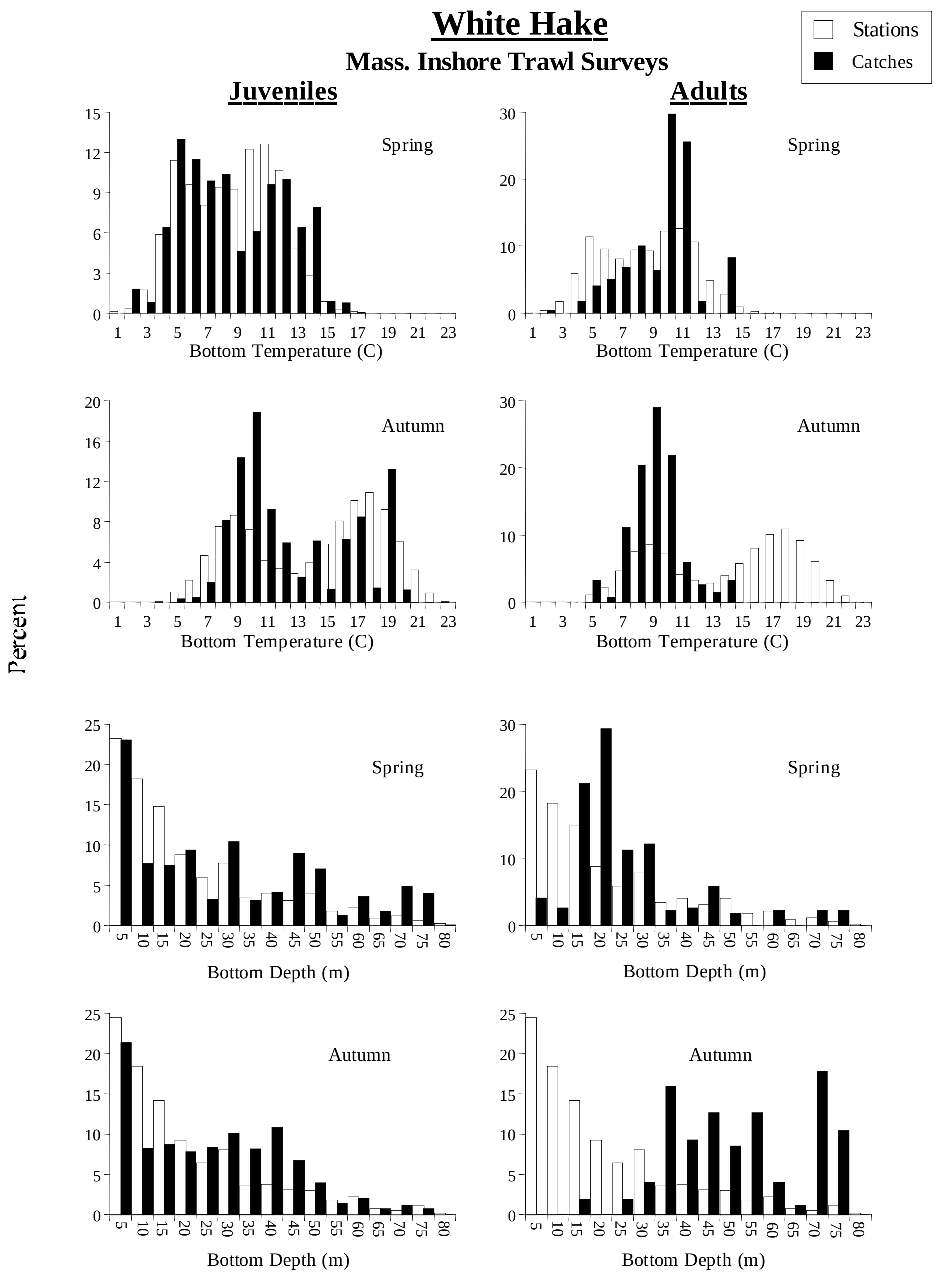


Figure 6. Abundance of juvenile and adult white hake relative to bottom water temperature (^{o}C) and depth (m) based on Massachusetts inshore bottom trawl surveys (spring and autumn 1978-1996, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

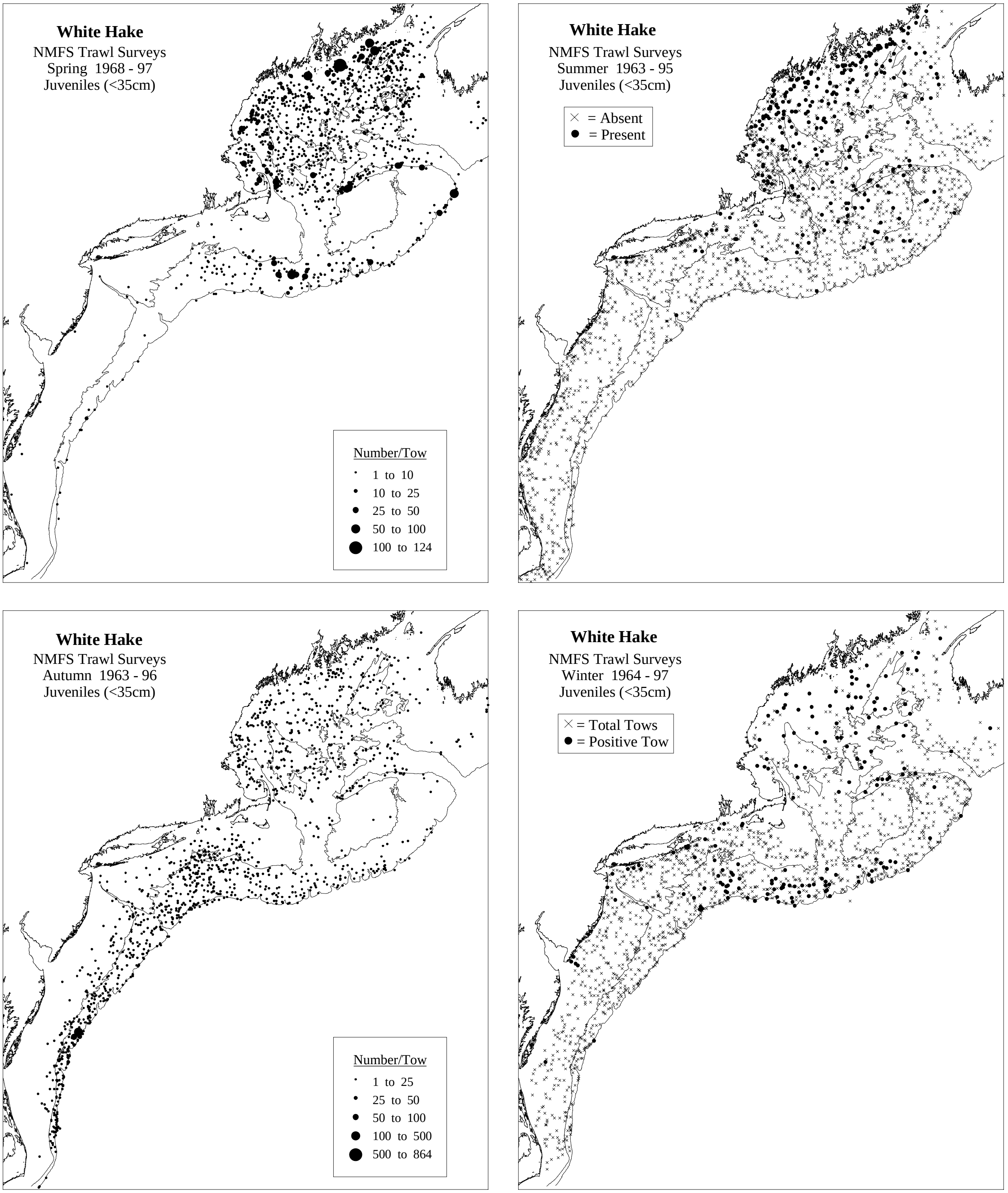


Figure 7. Distribution of juvenile white hake (< 35 cm) collected during NEFSC bottom trawl surveys during all seasons from 1963-1997. Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].

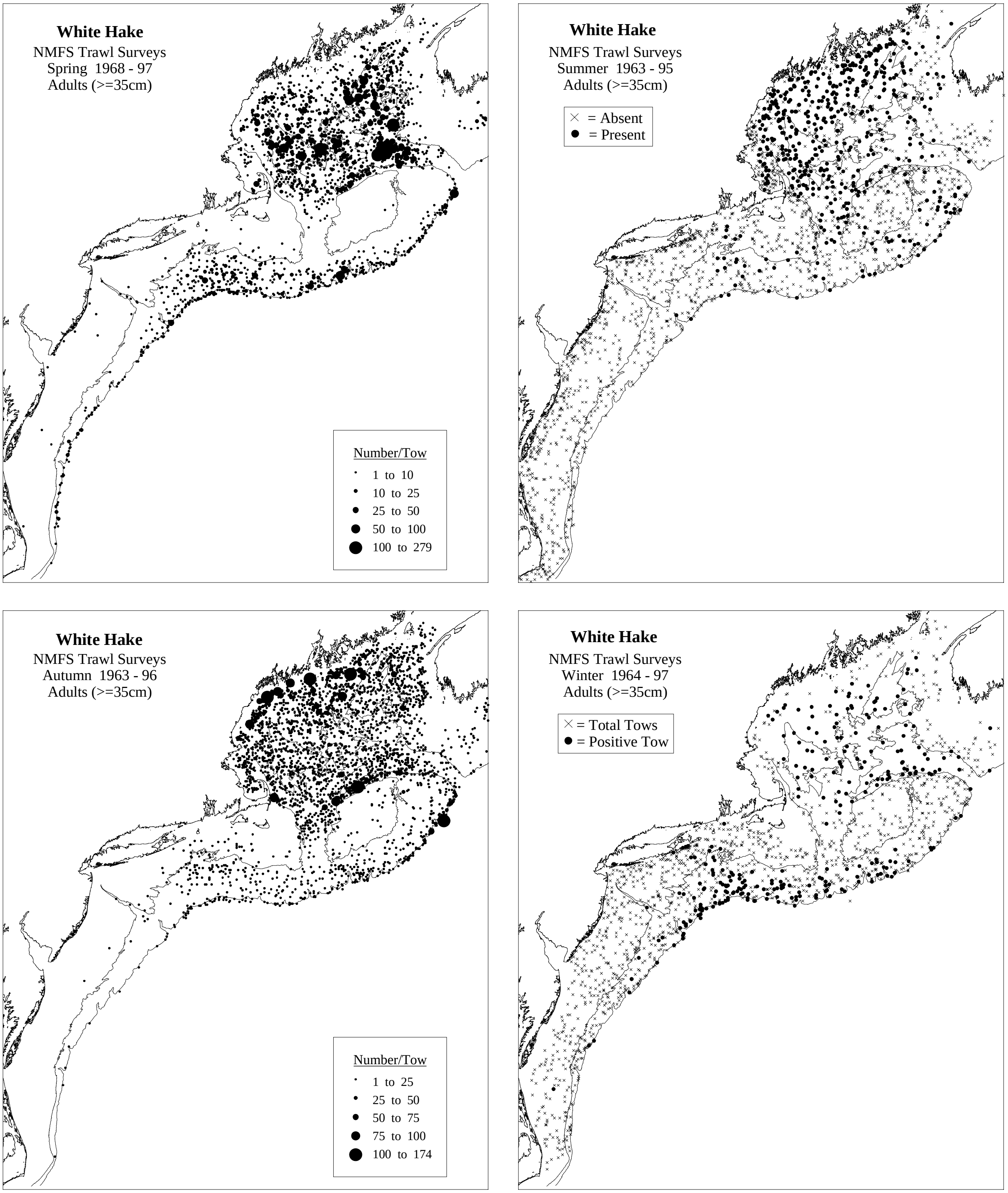
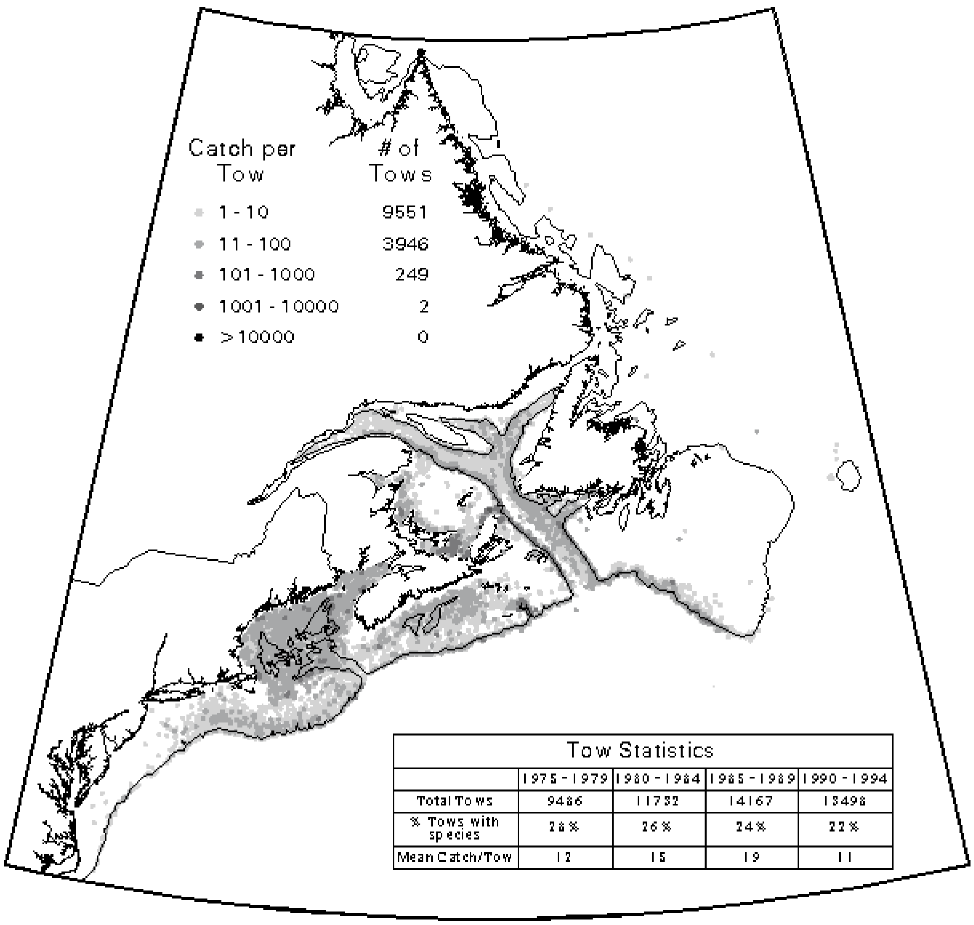


Figure 8. Distribution of adult white hake (≥ 35 cm) collected during NEFSC bottom trawl surveys during all seasons from 1963-1997. Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].



	1975 - 1979	1980 - 1984	1985 - 1989	1990 - 1994
Total Tows	9486	11732	14167	13498
% Tows with species	28%	26%	24%	22%
Mean Catch/Tow	12	15	19	11

Figure 9. Distribution and abundance of white 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).

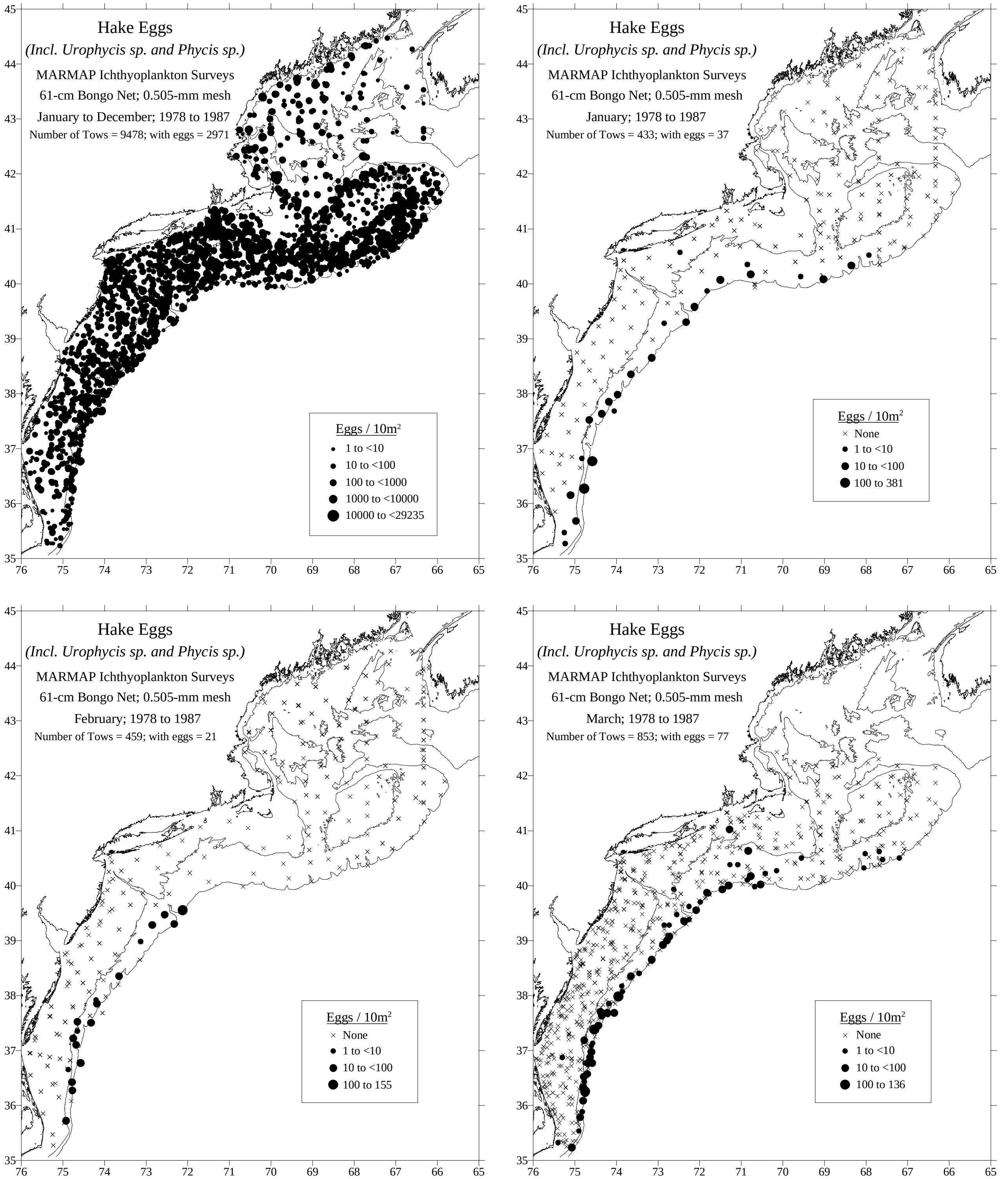
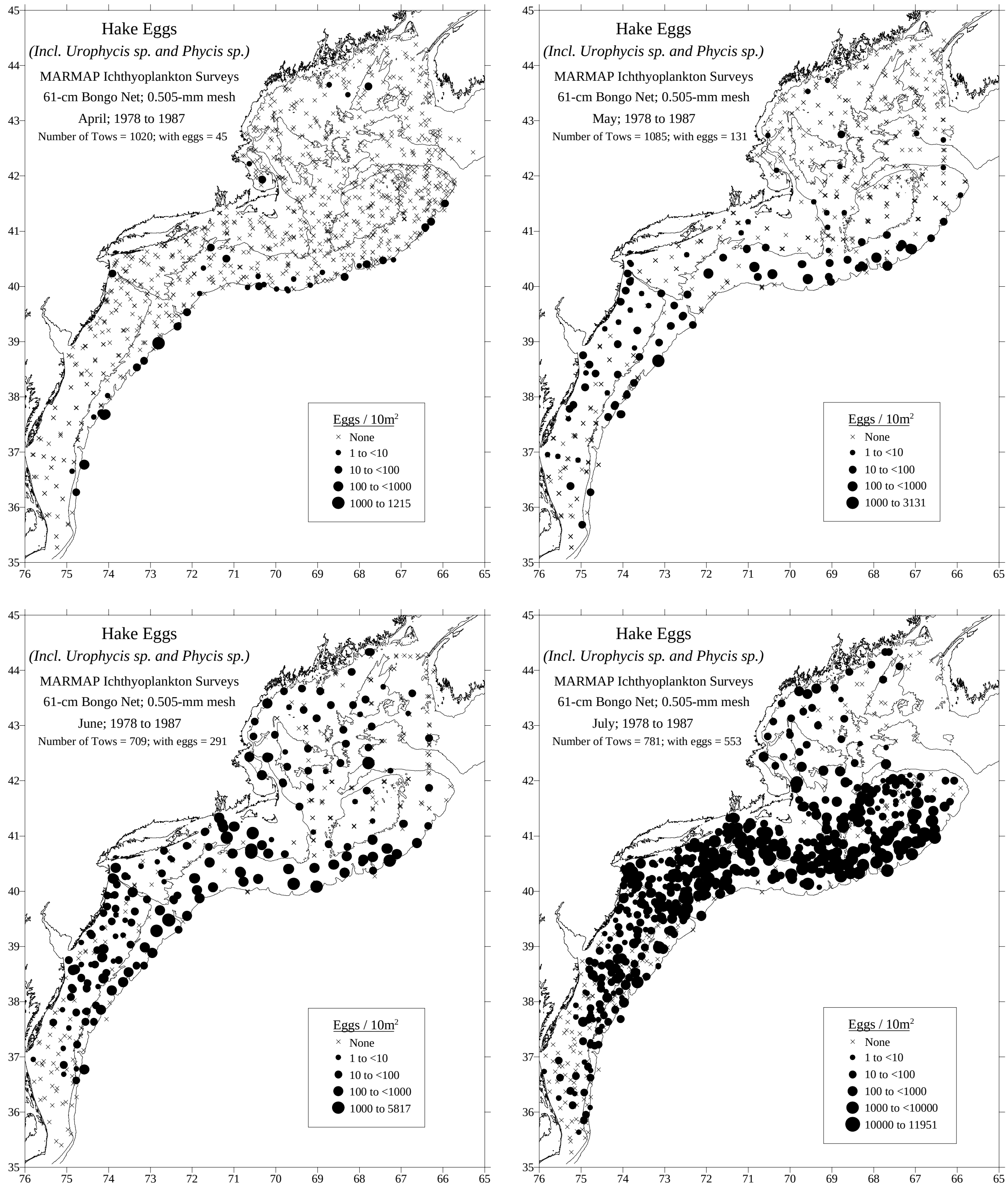


Figure 10. Distribution of hake (*Urophycis* and *Physcis* spp.) eggs collected during NEFSC MARMAP ichthyoplankton surveys from January to December, 1978-1987 [see Reid *et al.* (1999) for details].



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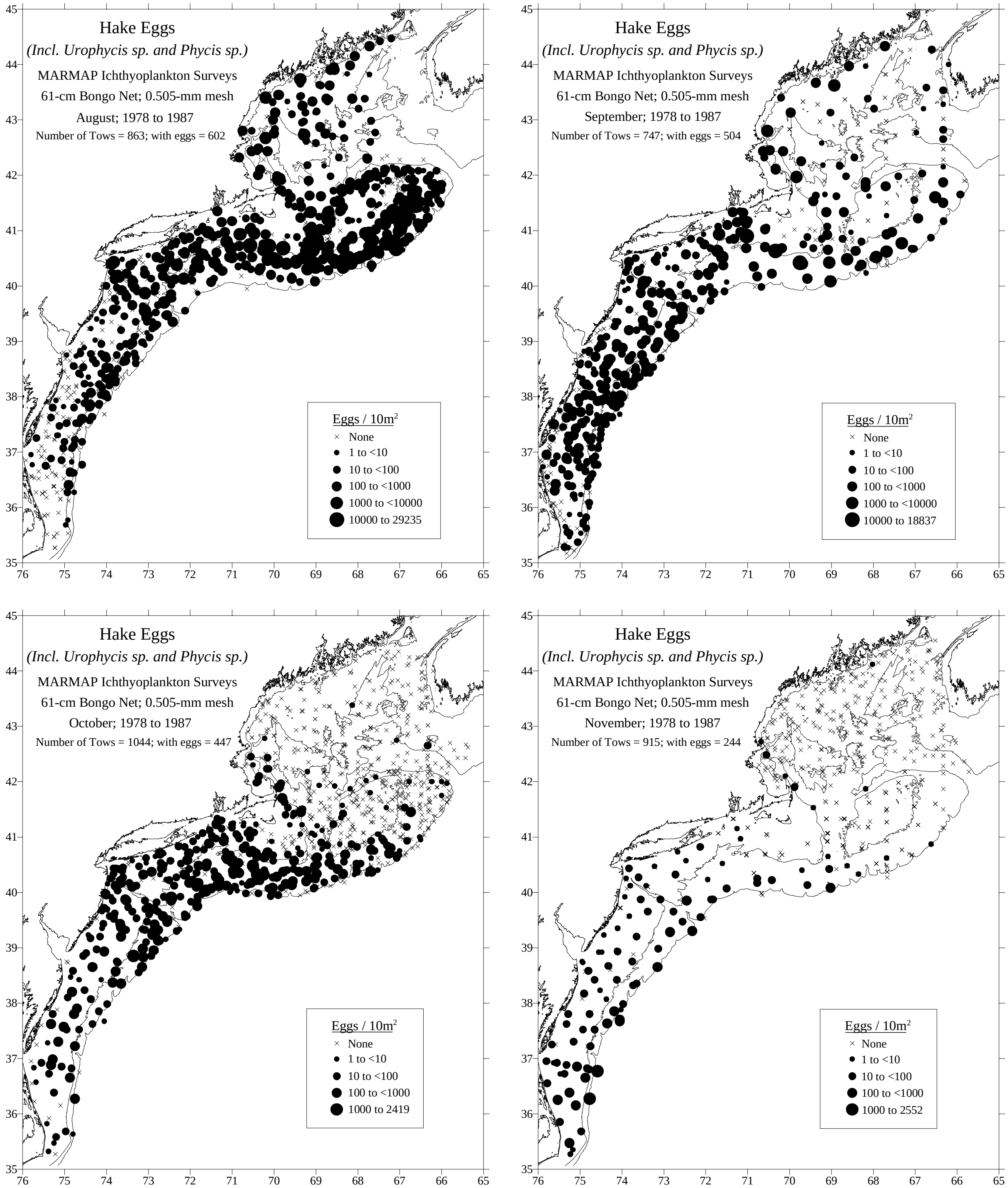

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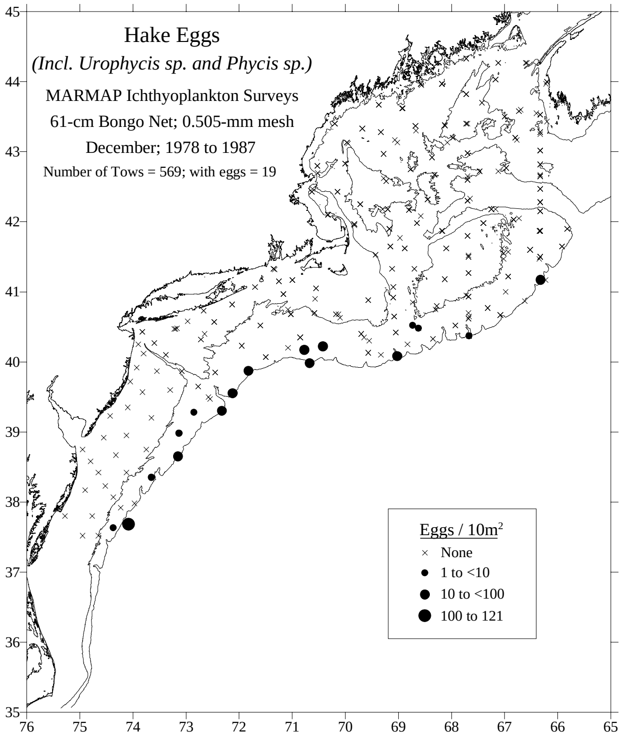

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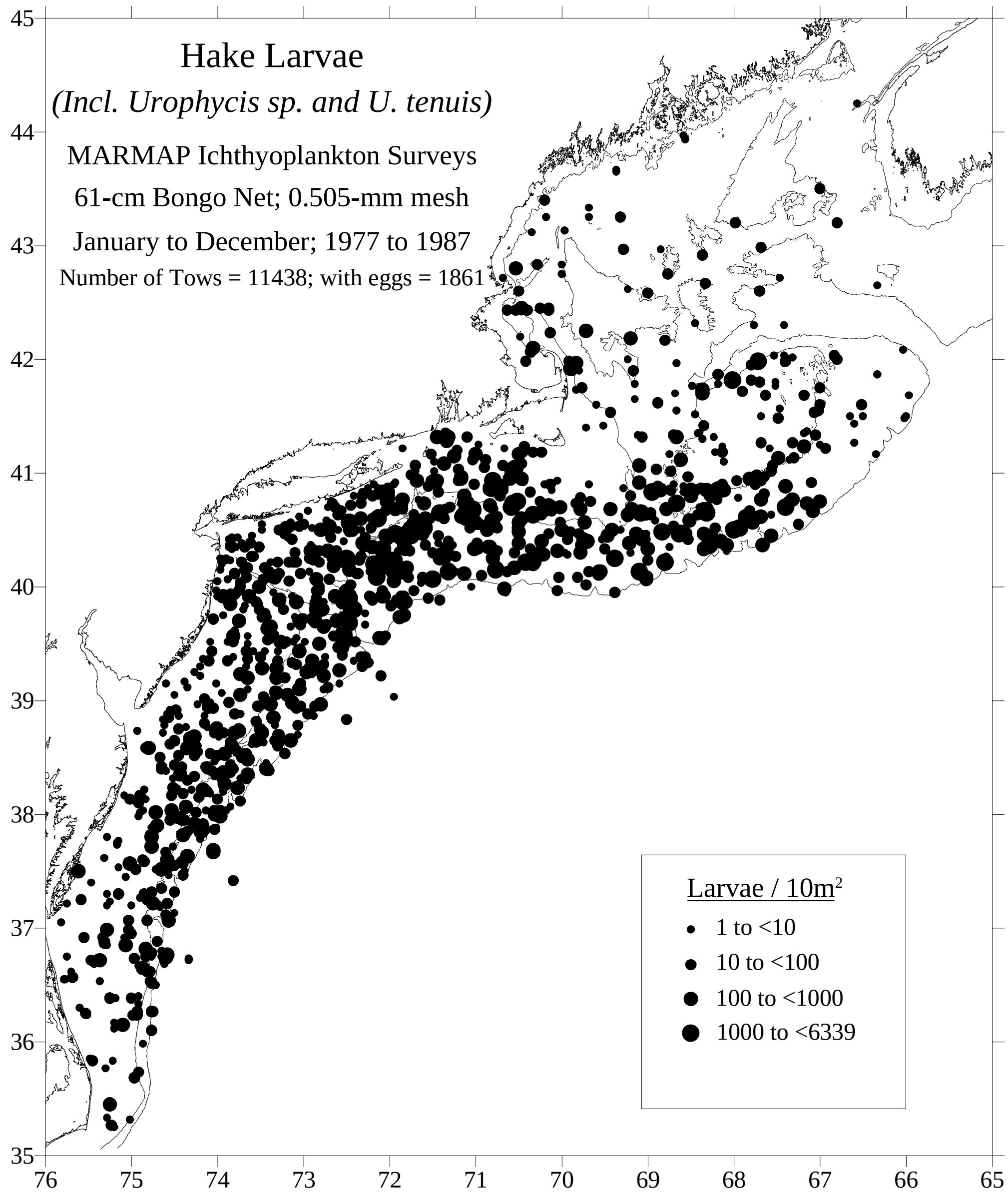

Figure 11. Distribution of white hake and *Urophycis* spp. larvae collected during NEFSC MARMAP ichthyoplankton surveys from January to December, 1977-1987 (all months combined) [see Reid *et al.* (1999) for details].

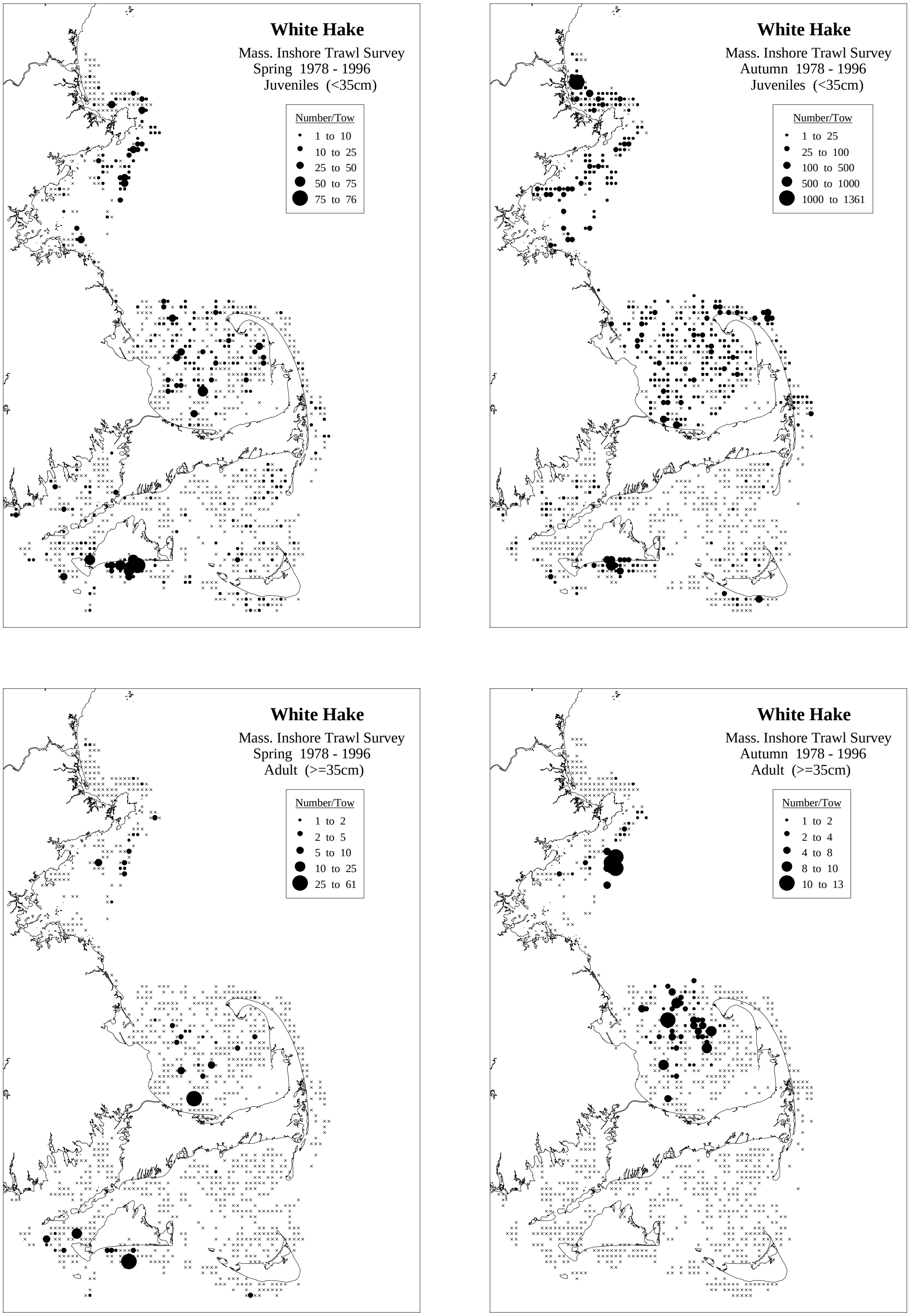

Figure 12. Distribution of juvenile and adult white hake in Massachusetts coastal waters during spring and autumn Massachusetts trawl surveys, 1978-1996 [see Reid *et al.* (1999) for details].

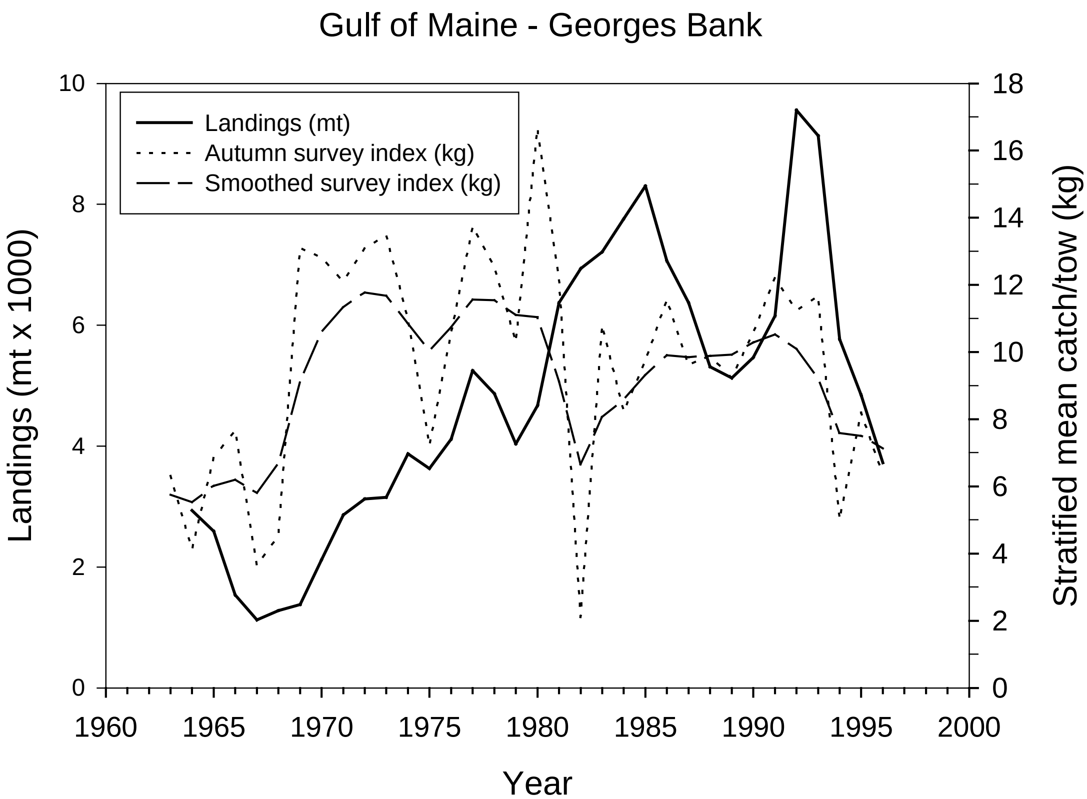

Figure 13. Commercial landings (mt), NEFSC autumn bottom trawl survey indices (stratified mean catch per tow), and smoothed survey indices (3 year moving average of first order autoregression model) for white hake in the Gulf of Maine-Georges Bank region.

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