NOAA Technical Memorandum NMFS-NE-131

Essential Fish Habitat Source Document:

Pollock, *Pollachius virens*, 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:

Pollock, *Pollachius virens*, 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 pollock, *Pollachius virens* (Figure 1), is a gadoid species inhabiting both sides of the North Atlantic. In the northwest Atlantic they are most common on the Scotian Shelf, Georges Bank, in the Great South Channel, and in the Gulf of Maine. There is considerable movement of the species between the Scotian Shelf, Georges Bank and the Gulf of Maine. Thus, although some differences in meristic and morphometric characters have been shown, there are no significant genetic differences among areas (Mayo *et al.* 1989). As a result, the Scotian Shelf, Georges Bank and the Gulf of Maine pollock (NAFO divisions 4V, 4W, 4X and subareas 5, 6) are assessed as a single unit. In U.S. waters, the species is managed under the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan (NEFMC 1993).

This Essential Fish Habitat source document provides information on the life history and habitat requirements of pollock inhabiting the Gulf of Maine, Georges Bank, and the Scotian Shelf.

LIFE HISTORY

A brief synopsis of the life history characteristics of pollock is provided in Amendment #5 to the Northeast Multispecies Fishery Management Plan (NEFMC 1993). More detailed information is provided here and in reviews by Bigelow and Schroeder (1953), Hardy (1978), and Collette and Klein-MacPhee (in prep.).

EARLY LIFE HISTORY

Pollock eggs are buoyant, rising into the water column after fertilization. The pelagic larval stage lasts for three to four months, at which time the small juveniles or "harbor pollock" migrate inshore where they inhabit rocky subtidal and intertidal zones. They undergo a series of inshore-offshore movements linked to temperature (Ojeda and Dearborn 1990; Rangeley and Kramer 1995; Collette and Klein-MacPhee, in prep.) until near the end of their second year (summarized in Figure 2). At this point the juveniles move offshore where they remain throughout the adult stage.

ADULTS

Adult pollock can attain maximum lengths of 120 cm, but are usually less than 110 cm (Collette and Klein-MacPhee, in prep.). A maximum age of 18 years has been recorded, although the major portion of the catch consists of 3-6 year old fish (Mayo 1994). Growth rate is rapid until sexual maturity, at which time it declines (Steele 1963). Pollock are a schooling species and are found throughout the water column (Hardy 1978). With the exception of short migrations due to temperature changes and north-south movements for spawning, pollock are fairly stationary in the Gulf of Maine and along the Nova Scotian coast (Hardy 1978; Collette and Klein-MacPhee, in prep.).

REPRODUCTION

Male pollock reach sexual maturity at a larger size and older age than females (Table 1). Age and size at maturity of pollock have declined in recent years, a trend which has also been reported in other marine fish species (e.g., haddock, witch flounder). During 1985-1990, male and female pollock attained sexual maturity more than a year earlier than during 1970-1984. Data from the Bay of Fundy (Steele 1963) provide further evidence of a decline: during 1960-1961, females attained maturity at 62.5 cm and 5-7 years, and males attained maturity at 58 cm and 4-7 years. The decline in size and age at maturity is potentially an effect of size-selective overfishing and/or recent declines in stock abundance or density (see Status of the Stocks below).

The principal pollock spawning sites in the northwest Atlantic are in the western Gulf of Maine, Great South Channel, Georges Bank, and on the Scotian Shelf (Figure 3). In the Gulf of Maine, spawning is concentrated in Massachusetts Bay, Stellwagen Bank, and from Cape Ann to the Isle of Shoals (Steele 1963; Hardy 1978; Collette and Klein-MacPhee, in prep.). Spawning is believed to occur throughout the Scotian Shelf; Emerald, LaHave, and Browns banks are the principal sites (Mayo *et al.* 1989).

Spawning takes place from September to April. Spawning time is more variable in northern sites than in southern sites. In the Gulf of Maine spawning occurs from November to February (Steele 1963; Colton and Marak 1969), peaking in December (Collette and Klein-MacPhee, in prep.). On the Scotian Shelf, spawning occurs from September to April (Markle and Frost 1985; Clay *et al.* 1989) and peaks from December to February (Clay *et al.* 1989).

Spawning occurs over hard, stony or rocky bottom (Hardy 1978). Spawning activity begins when the water column cools to near 8°C, and peaks when temperatures are approximately 4.5-6°C (Collette and Klein-MacPhee, in prep.). Thus, most spawning occurs within a comparatively narrow range of temperatures. There is little information on salinity, but in Massachusetts Bay, spawning is reported to occur at salinities of 32-32.8 ppt (Collette and Klein-MacPhee, in prep.).

FOOD HABITS

Pollock initially inhabit the water column and therefore feed on pelagic prey. The primary prey of small larvae (4-18 mm) are larval copepods (Marak 1960; Steele 1963) while larger larvae (> 18 mm) feed primarily on adult copepods (Marak 1960). The primary prey of juvenile pollock are crustaceans. Euphausiids, in particular *Meganyctiphanes norvegica*, are the most important crustacean prey of juveniles (Tyler 1972; Bowman and Michaels 1984; Collette and Klein-MacPhee, in prep.). Fish and mollusks make up a smaller proportion of the juvenile diet (Bowman and Michaels 1984); however, in some cases fish may play a more important role in the diet. For example, Ojeda and Dearborn (1991) reported that the diet of subtidal juveniles in the Gulf of Maine was dominated by fish, especially young Atlantic herring (*Clupea harengus*). The diet of adults is comprised of, in order of decreasing importance, euphausiids, fish and mollusks (Steele 1963; Bowman and Michaels 1984; Collette and Klein-MacPhee, in prep.). *M. norvegica* is the single most important prey item and Atlantic herring is the most important fish species. Bowman and Michaels (1984) found that the diet preferences of adults vary with size: crustaceans were the most important prey item among smaller adults (41-65 cm), fish were most important among medium size adults (66-95 cm), and mollusks (the squid *Loligo*) were the most important prey among the largest adults (> 95 cm).

The 1973-1990 Northeast Fisheries Science Center (NEFSC) bottom trawl survey data on food habits [see Reid *et al.* (1999) for details] verify that crustaceans, especially *M. norvegica*, are the most important prey item of juvenile and adult pollock (Figure 4). The 1973-1980 data indicate that juveniles fed primarily on crustaceans (56%), but also on nematodes (10%), fish (9%) and annelids (4%) (Figure 4a). Crustaceans were also the most important food item of adults. However, they were less common than for juveniles (37% vs. 56%), while fish (16%) and nematodes (15%) were more common in the adult diet. The 1981-1990 data also indicate that crustaceans are the most important food item of pollock, and that fish are more important in the diet of adults than juveniles (Figure 4b). Crustaceans (mostly euphausiids) made up 69% of the juvenile diet and 60% of the adult diet. Fish comprised only 12% of the juvenile diet, but made up 28% of the adult diet. Sand lance (*Ammodytes* sp.) was the most common fish prey for both juveniles and adults, and Atlantic herring were also common.

STOCK STRUCTURE

Tagging studies have shown that there is considerable movement of pollock across the Scotian Shelf and the Gulf of Maine (Mayo *et al.* 1989). For most of the year, adult pollock undergo minor inshore-offshore movements linked to temperature (Collette and Klein-MacPhee, in prep.). However, mixing of stocks occurs in winter when adults undergo migrations to the spawning grounds. For example, Bay of Fundy pollock are thought to migrate south or southeast and spawn with fish from the Gulf of Maine and possibly the Scotian Shelf (Steele 1963). Eggs and larvae undergo significant movement away from the spawning area as they drift with currents (Hardy 1978). For example, larvae from the northern Gulf of Maine are thought to originate from spawning grounds in the southern Gulf of Maine (Bigelow and Schroeder 1953). Thus, although some morphometric and meristic differences have been reported among pollock from different areas, electrophoretic analyses show no significant genetic differences (Mayo *et al.* 1989).

There is evidence that different age classes do not mix, forming large size-segregated schools throughout the water column (Hardy 1978). In the Bay of Fundy, 0+ and 1+ schools are distinct, with 1+ juveniles inhabiting slightly deeper water (Steele 1963).

HABITAT CHARACTERISTICS

Information on the habitat characteristics of pollock is presented here and is summarized in Table 2. This information is restricted to pollock inhabiting U.S. waters and the Scotian Shelf in Canadian waters since they are considered a single stock for assessment and management purposes (Mayo *et al.* 1989). Information from other stocks (e.g., European) was not considered.

EGGS

Pollock eggs are spawned over broken substrate at salinities of 32-32.8 ppt (Collette and Klein-MacPhee, in prep.). They are pelagic and free-floating, usually found in water 50-250 m in depth (Hardy 1978).

Pollock eggs taken during NEFSC Marine Resources Monitoring, Assessment and Prediction (MARMAP) ichthyoplankton surveys (see Geographical Distribution below) were at temperatures ranging from 2-17^{o}C, although most were at temperatures of 5-11^{o}C. Eggs were taken at depths ranging from 30-270 m, but most were at 50-90 m (Figure 7).

LARVAE

Larvae are also pelagic, commonly found at temperatures of 3-9^{o}C (Bigelow and Schroeder 1953), and normally occur from the shore out to the 200 m depth contour, but have been reported in waters as deep as 1550 m (Hardy 1978).

Pollock larvae taken during MARMAP

ichthyoplankton surveys (see Geographical Distribution below) were at temperatures ranging from 2-17^{o}C, but this varied seasonally and temperatures of 5-10^{o}C were most common. Larvae were taken at depths ranging from 10 to > 1000 m, but most were at 50-90 m (Figure 9).

JUVENILES

Juveniles have been reported over a wide variety of substrates, including sand, mud, or rocky bottom and vegetation (Hardy 1978). They are found at temperatures ranging from 0-16^{o}C and prefer salinities of around 31.5 ppt (Hardy 1978). Inshore subtidal and intertidal zones are utilized by age 0+ and 1+ juveniles and serve as important nursery areas (Steele 1963; Ojeda and Dearborn 1990; Rangeley and Kramer 1995). Age 2+ juveniles move offshore, inhabiting depths of 130-150 m (Steele 1963).

Juvenile haddock taken during NEFSC trawl surveys (see Geographical Distribution below) were at temperatures ranging from 1-18^{o}C, but most were taken at 3-12^{o}C. They were taken at depths ranging from 5-125 m, but most were taken at 25-75 m (Figure 11). Juveniles taken during Massachusetts trawl surveys (see Geographical Distribution below) were at 6-13^{o}C and 0-75 m (Figure 13).

ADULTS

Adults show little preference for bottom type (Scott 1982b). They are found at high salinities, 31-34 ppt (Scott 1982a), and temperatures of 0-14^{o}C (Hardy 1978; Scott 1982a; Collette and Klein-MacPhee, in prep.), although they tend to avoid temperatures > 11^{o}C and < 3^{o}C. They inhabit a wide range of depths, 35-365 m (Hardy 1978; Scott 1982a), but most occur within the 137 m depth contour and depths of 100-125 m are preferred (Hardy 1978). Adults tend to inhabit deeper waters in spring and summer than in winter and they are typically found further offshore than juveniles (Mayo *et al.* 1989; Collette and Klein-MacPhee, in prep.).

Adult haddock taken during NEFSC trawl surveys (see Geographical Distribution below) were at temperatures ranging from 1-12^{o}C, but most were taken at 6-8^{o}C. Adults were taken at depths ranging from 15-325 m, but most were taken at 75-175 m (Figure 11). Most adults taken during Massachusetts trawl surveys (see Geographical Distribution below) were at 5-7^{o}C and 10-30 m (Figure 13).

GEOGRAPHICAL DISTRIBUTION

Pollock in the northwest Atlantic were distributed from the Delmarva Peninsula north to the Gulf of St. Lawrence and the Grand Banks during 1975-1994 (Figure 5). The areas of highest abundance of the species are the Scotian Shelf and the Gulf of Maine.

EGGS

The 1978-1987 MARMAP offshore ichthyoplankton surveys [see Reid *et al.* (1999) for details] collected eggs during October to June from off Delaware Bay to southwest Nova Scotia (Figure 6). Highest monthly mean egg densities occurred in November (24.4 eggs/10 m^2), December (36.8 eggs/10 m^2), January (86.1 eggs/10 m^2) and February (19.6 eggs/10 m^2) in Massachusetts Bay, Georges Bank, and Browns Bank. Egg densities were considerably lower in months prior to and after this period (≤ 1.40 eggs/m^2). This concurs with reports that peak spawning occurs during November to February (Hardy 1978; Fahay 1983; Clay *et al.* 1989).

Eggs were collected at temperatures ranging from about 2-17^{o}C (Figure 7). From October to February, eggs were found at increasingly lower temperatures, with most eggs found at 10-11^{o}C in October and most eggs found at 5-6^{o}C in February. From March to June the majority of eggs were found at temperatures from around 5-7^{o}C. Optimal development of eggs occurs at 3.3-8.9^{o}C (Hardy 1978).

Eggs were found over depths ranging from 30-270 m, but the majority of eggs were collected at a more restricted range, 50-90 m (Figure 7). Hardy (1978) reported that eggs are found in water 50-250 m deep.

LARVAE

The 1977-1987 MARMAP offshore ichthyoplankton surveys [see Reid *et al.* (1999) for details] found larvae during September to July from off Chesapeake Bay to southwest Nova Scotia (Figure 8). The highest monthly mean larval densities occurred in December (3.6 larvae/10 m^2), January (9.0 larvae/10 m^2) and February (10.3 larvae/10 m^2). Larval densities were considerably lower in months prior to and after this period (≤ 0.72 larvae/10 m^2). This corresponds to peak spawning occurring from November to February (Hardy 1978; Fahay 1983; Clay *et al.* 1989). The highest densities in December and January appear to be in Massachusetts Bay, Georges Bank, and the western edge of Browns Bank; by Febraury the highest abundances are in Massachusetts Bay, off the east coast of Cape Cod, and in the vicinity of Jeffreys Ledge.

Larvae were collected within a temperature range of about 2-17^{o}C (Figure 9). There appears to be a seasonal difference in larval occurrence with bottom temperatures.

In fall, larvae were found at temperatures of 8-17°C. Larvae were bimodally distributed relative to temperature in October and November. In winter, larvae were found at colder temperatures, approximately 2-13°C. In spring and summer larvae were collected in slightly warmer temperatures ranging from 3-15°C, although the majority were at 5-10°C.

Larvae were collected at depths ranging from 10-250 m from October to July (Figure 9). For most of the year, the majority of larvae were found at 50-90 m. Hardy (1978) reported that larvae are normally found out to the 200 m depth contour, but that they have been found as deep as 1550 m.

JUVENILES

NEFSC Bottom Trawl Surveys

In the winter, NEFSC bottom trawl surveys [see Reid *et al.* (1999) for details] captured juveniles from throughout the Gulf of Maine, Browns Bank, and along the edges of Georges Bank (Figure 10). In summer, they were spread along the inshore areas of the Gulf of Maine, off the coast of Rhode Island and Long Island, the western edge of the Great South Channel, off Massachusetts, and the northern edge of Georges Bank. In spring, the highest densities of pollock were found along the fringes of the Gulf of Maine, as well as the western edge of the Great South Channel, the northeastern edge of Georges Bank, Browns Bank, and southwest Nova Scotia. Densities were similar in the autumn, with highest densities in Massachusetts Bay.

Juveniles were found at temperatures ranging from 1-18°C, although most were found at 4-12°C (Figure 11). There is a slight seasonal difference in juvenile occurrence with bottom temperatures: juveniles were found at colder temperatures in spring than in autumn. In the spring > 60% were collected at temperatures of around 4-6°C, while in autumn > 60% were collected at temperatures of 8-11°C (Figure 11). Murawski and Finn (1988) found a similar trend for age 0+ and age 1+ juveniles.

In the spring and fall, juveniles were caught at depths ranging from 5-250 m, but most were found between 25-75 m (Figure 11).

Massachusetts Inshore Trawl Survey

In spring, the 1978-1996 Massachusetts inshore surveys [see Reid *et al.* (1999) for details] captured high densities of juveniles north of Cape Ann, in the vicinity of Boston Harbor, and the western shore of Martha's Vineyard (Figure 12). In the autumn, densities were lower and juveniles were concentrated around the tip of Cape Cod (Figure 12). Juveniles were more abundant in inshore Massachusetts waters in spring than in autumn.

There is a seasonal difference in juvenile occurrence with bottom temperature. Juveniles were found over a wider range of temperatures in spring than in autumn. In the spring, juveniles occurred primarily between 6-13°C, while in the fall they occurred mostly at temperatures between 8 and 11°C (Figure 13).

There is also a seasonal difference in juvenile occurrence with depth, with slightly deeper waters inhabited in autumn. In the spring, juveniles were found from 0-75 m, but roughly 90% of juveniles were caught at depths of ≤ 20 m. In autumn they occurred from 0-70 m with 40% caught at 45 m (Figure 13).

Rhode Island Bottom Trawl Survey

A total of only 336 pollock, all juveniles, were caught in Narragansett Bay from 1990-1996 [see Reid *et al.* (1999) for details]. They were caught in all seasons, but the vast majority (97%) were caught in spring (Figure 14).

Connecticut Fisheries Division Survey

Pollock are not commonly caught in the surveys of Long Island Sound, and none have been recorded since 1989 (Gottschall *et al.*, in review). In surveys conducted from 1984-1990 throughout Long Island Sound, just 24 juveniles were caught. All were caught during summer (July-August), at all depths and bottom types except sand.

ADULTS

NEFSC Bottom Trawl Survey

In winter, NEFSC bottom trawl surveys [see Reid *et al.* (1999) for details] captured adults mostly in the offshore regions of the Gulf of Maine, Great South Channel, and along the northern edges of Georges Bank (Figure 10). The distribution of adults was similar in summer, although they were also present in nearshore areas of the Gulf. In spring, adult pollock were spread throughout the Gulf of Maine with highest densities in the central Gulf, along the northeastern edge of Georges Bank, the Great South Channel, and Browns Bank. In autumn, the highest densities of adults were in the southwestern Gulf of Maine, the northeastern edge of Georges Bank, and Browns Bank. Adults were distributed further south in winter and spring than in summer and autumn.

Adults were found at temperatures of 1-12°C (Figure 11). There does not appear to be a significant seasonal difference in adult occurrence with bottom temperature, although in spring most adult pollock were found at 6-7°C while in autumn most were found at 8°C. These results support previous reports that adults occur from 1-14°C and that temperatures > 3.3°C are optimal (Collette and Klein-MacPhee, in prep.).

There also does not appear to be a major seasonal difference in adult occurrence with depth. Adults were caught at depths ranging from about 15-325 m, with the majority at 75-175 m (Figure 11).

Massachusetts Inshore Trawl Survey

Few adults were caught during the spring 1978-1996 Massachusetts inshore surveys [see Reid *et al.* (1999) for details]. Those that were caught were mostly found north of Cape Ann; lower numbers were found in Massachusetts Bay and around Cape Cod (Figure 12). No adults were caught in the autumn surveys.

In the spring, adults occurred at temperatures ranging from 3-13°C, but approximately 60% were caught at temperatures of around 5-7°C (Figure 13). Approximately 55% of adult pollock were caught at depths ranging from 10-30 m, while the remainder were found at 45-75 m (Figure 13).

STATUS OF THE STOCKS

Commercial catches from the entire Scotian Shelf, Gulf of Maine and Georges Bank increased from an annual average of 38,200 mt during 1972-1976 to 68,900 mt during 1986, but have since steadily declined to historic lows. The total landings in 1996 were 12,300 metric tons (mt), a 7.5% decrease from 1995 (13,300 mt), a 35% decrease from 1994 (18,900 mt), and a 82% decrease from the 1986 peak (Figure 15; Mayo 1998). Total stock size, after increasing throughout the late 1970's and early 1980's, has since markedly declined. Biomass indices for the Gulf of Maine-Georges Bank increased during the mid-1970's but declined sharply during the early 1980's and have remained low. Spawning stock biomass increased from 90,000 mt in 1974 to over 200,000 mt in 1985; SSB declined by 36% between 1986-1991 (Mayo 1995).

The September 1997 report to congress "Status of Fisheries of the United States" (National Marine Fisheries Service 1997) reports that the state of overfishing of U.S. pollock stocks is currently unknown.

RESEARCH NEEDS

Many details of the biology of pollock from the northwest Atlantic are not well known. No information is available on the actual spawning event. This is potentially important information for understanding or modelling the genetics and population dynamics of pollock stocks. Information on predation of the various life history stages is lacking, and data on species interactions in general are needed. More information is needed on the importance of inshore areas, specifically rocky subtidal and intertidal zones and salt marshes, as nursery grounds for juvenile pollock. A better understanding of the role of these areas to recruitment and year-class strength is necessary. These habitats may be critical bottleneck areas.

Finally, the genetic differentiation of stocks should be investigated further using more advanced and powerful genetic (e.g., microsatellite DNA markers) and biochemical (e.g., elemental fingerprinting of otoliths) techniques. Currently, the management of Gulf of Maine area pollock as a single unit stock is based on allozyme electrophoresis analyses which indicate that the stocks are genetically uniform (Mayo *et al.* 1989). Newer, more powerful methods may reveal significant differences.

Most of the available information on northwest Atlantic pollock is restricted to distribution and abundance (EFH Level 2). Growth and survival (Level 3) and production rates (Level 4) by habitat are necessary in order to accurately designate the essential habitat of pollock.

ACKNOWLEDGMENTS

The literature review was greatly aided by the draft update to the Bigelow and Schroeder (1953) section on pollock provided by Bruce Collette. Joseph Vitaliano provided gut contents data from the food habits database. The authors also wish to thank C. Steimle, J. Berrien, and R. Ramsey-Cross for help with the literature reviews.

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Table 1. Size and age at maturity of U.S. pollock, *Pollachius virens*.

Time Period	**L_{50} (cm)**		**A_{50} (years)**		**Reference**
	Male	*Female*	*Male*	*Female*	
1986-1988	41.8	39.1	2.3	2.0	O'Brien *et al.* 1993
1970-1984	50.5	47.9	3.5	3.2	Mayo *et al.* 1989

Table 2. Summary of life history and habitat parameters for pollock, *Pollachius virens*. 'MARMAP' and 'NEFSC' refer to data discussed in the Geographical Distribution section of this report.

Life Stage	Size Range and Growth	Habitat	Substrate	Temperature
Eggs [1]	Egg diameter ranges from 1.0-1.22 mm, mean = 1.14 mm.	Eggs are pelagic; usually in water 50-250 m deep. MARMAP: found at 30-270 m, but most at 50-90 m.		Incubation time ranges from 5 to 15 days; 9-12 days at 6-7^{o}C, 6 days at 9.4^{o}C; optimal development at 3.3-8.9^{o}C. MARMAP: found at 2-17^{o}C, but most at 5-11^{o}C.
Larvae [2]	Size at hatch ranges from 3.0-4.2 mm; mean = 4.0 mm. Size at transformation ranges from 23-30 mm.	Youngest larvae found nearest the surface. Normally occur from shore out to the 200 m line, but reported as deep as 1550 m. MARMAP: found at 10-1250 m, most at 50-90 m. From Jan-Feb are found in southern Gulf of Maine and Cape Cod; from Mar-May are found throughout the Gulf of Maine and south and east of Cape Cod. On the Scotian Shelf, larvae (0.3-1.1 cm) are offshore in Nov; by May the largest (4.2 cm) start to move inshore. One study has reported larvae in the Bay of Fundy; may be limited to years with high larval abundance.		In Massachusetts Bay, newly hatched larvae found in temperatures ranging from 3-9^{o}C. MARMAP: found at 2-17^{o}C, most at 5-10^{o}C. Yolk sac is absorbed in 5 days at 6.1^{o}C.
Juveniles [3]	Overall size range is approximately 2.5-40 cm. Descend to bottom at 3-4 months (< 50 mm length). Two distinct length groups inshore during July to November: (1) first year fish (mean 17-18 cm by end of 1st year); and (2) second year fish (mean 27-30 cm by end of 2nd year).	Average depths inhabited on Georges Bank (m): age 0: spring: 73, summer: 191, fall: 69; age 1+: winter: 132, spring: 106, summer: 109, fall: 136. NEFSC: found at 5-250 m, but most at 25-75 m. Young juveniles typically found inshore but can also be found on offshore banks. In MA Bay swarm at inshore areas after early April; move offshore in June to avoid warm temps; return again in fall. But remain abundant inshore during summer/fall from Cape Ann to Nova Scotia; seek deeper water in winter. On the Scotian Shelf, 7-11cm juveniles are inshore in July; remain inshore until temp drops to < 4^{o}C from Jan-April (16-24 cm); return inshore in May and remain until ~30 cm in their 2nd year. In the Bay of Fundy, 0+/1+ fish are in the shallow sublittoral zone by first summer; 20-25 cm fish move away to deeper water. 2+ fish are found nearshore or on offshore banks in 130-150 m of water; move offshore after first summer. Overwinter in large pelagic schools. In southern New Jersey, YOY were prominent in spring collections in subtidal marsh creeks.	Juveniles have been reported over substrates varying from sand, mud, rocky bottom or aquatic vegetation.	In the NW Atlantic, juveniles occur from 0-15.6^{o}C. Average water temp (^{o}C) for Georges Bank: age 0: spring 4.4, summer 8.2, autumn 11.5; age 1+: winter 4.8, spring 5.5, summer 6.8, autumn 7.5. NEFSC: most found at 4-6^{o}C in spring and 8-11^{o}C in autumn. There is evidence for seasonal inshore-offshore migration linked to temperature - juveniles in the Gulf of Maine are more abundant inshore in summer/fall (warm) than in winter/spring (cold). Juveniles enter rocky subtidal zone when temperatures increase to 8-12^{o}C and reach maximum abundance in midsummer or early fall.
Adults [4]	Maximum length is 120 cm, but usually < 110 cm. Mean length (1969-1972) in Gulf of Maine (66.4 cm) was greater than Georges Bank (38.2 cm) and western Nova Scotia (44.6 cm). Sexual maturity: <u>Bay of Fundy</u> (1960-1961): female 5-7 yrs, 55-70 cm; male 4-7 yrs, 50-65 cm. <u>Gulf of Maine/Scotian Shelf</u> (1970-1984): female A_{50}=3.2 yrs, L_{50}= 47.4-47.9 cm; male A_{50}= 3.5 yrs, L_{50}=50.5 cm. <u>Gulf of Maine/Georges Bank</u> (1986-1988): female A_{50}=2 yrs, L_{50}=39.1 cm; male A_{50}=2.3 yrs, A_{50}=41.8 cm.	Occur from Gulf of St. Lawrence to Cape Lookout, NC, inshore and on offshore banks, usually at edges of shoals and banks. Location governed by prey movements. Commonly range from the surface to 180 m. NEFSC: found at 15-325 m, but most at 75-175 m. Pollock school throughout the water column. In the Gulf of Maine adults are further offshore than juveniles and in more specific locations. From Dec-March adults in western Gulf of Maine concentrate in relatively shallow water (< 100 m); in spring/summer they disperse to deeper offshore waters (100-200 m). Mean depth of occurrence is greatest in eastern Scotian Shelf and lowest in Bay of Fundy. Adults are segregated by size into schools: 65-85 cm off New Brunswick, 60-75 cm near Grand Manan, NB, and 45-60 cm off western Nova Scotia.	Pollock are unselective for bottom type on the Scotian Shelf; associated with sediments ranging from gravels to clay. Spawning is generally over hard bottom near coastal slopes and banks.	Occur from 0-14.0^{o}C; > 3.3^{o}C is optimal, preferred range 6-10^{o}C. Large fish avoid the surface when temperature is > 11.1^{o}C. Spawning activity starts when water column has cooled to ~8.3^{o}C; peaks at 4.4-6.1^{o}C; the majority of egg production is complete before water reaches winter minimum of 1.7-2.2^{o}C. NEFSC: found at 1-12^{o}C, but most at 6-8^{o}C.

[1] Colton and Marak (1969), Hardy (1978), Fahay (1983), Markle and Frost (1985), Collette and Klein-MacPhee (in prep.)
[2] Bigelow and Schroeder (1953), Steele (1963), Colton and Marak (1969), Hardy (1978), Scott (1980), Fahay (1983), Clay *et al.* (1989)
[3] Steele (1963), Tyler (1972), Hardy (1978), Fahay (1983), MacDonald *et al.* (1984), Murawski and Finn (1988), Clay *et al.* (1989), Ojeda and Dearborn (1990), Rountree and Able (1992), Rangeley and Kramer (1995), Collette and Klein-MacPhee (in prep.)
[4] Hoberman and Jensen (1962), Steele (1963), Hardy (1978), Langton and Bowman (1980), Scott (1982a, b), Mayo *et al.* (1989), O'Brien *et al.* (1993), Collette and Klein-MacPhee (in prep.)

Table 2. cont'd.

Life Stage	Salinity	Currents	Prey	Spawning	Notes
Eggs [1]	In MA Bay, spawning occurs at salinities ranging from 32-32.8 ppt.	Eggs sometimes drift far from spawning grounds.			Eggs are buoyant, spherical, transparent, nonadhesive and do not possess an oil globule. Hatching peaks in mid-November.
Larvae [2]		Small larvae drift with currents, generally away from the spawning grounds. Larger larvae can direct their movements. Counter-clockwise spring/summer circulation patterns in the Gulf of Maine, suggest that larvae off the eastern coast of Maine probably originate from spawning grounds off the western coast of Maine (south of Cape Elizabeth). Other studies suggest that larvae are retained within the Gulf and on the Scotian Shelf by the Gulf of Maine eddy.	Size selective feeders. Larvae generally ate the most abundant species of prey within the appropriate size range. Primary prey for 4-18 mm larvae were larval copepods; primary prey for > 18 mm larvae were adult copepods.	Drift patterns suggest that larvae in the Bay of Fundy region originate from spawning locations outside the Bay of Fundy, possibly in southern Gulf of Maine and/or the Scotian Shelf.	Pollock migrate inshore as they grow.
Juveniles [3]	In the NW Atlantic, juveniles have been found at salinities ranging from an average of 29-32 ppt.	Drift patterns suggest that juveniles at the mouth of the Bay of Fundy originate from spawning locations outside the Bay of Fundy, possibly in southern Gulf of Maine and/or the Scotian Shelf.	Crustaceans are the most important prey (66.1-99.9% by weight; Euphausiids, especially *Meganyctiphanes norvegica*, are most important), followed by fish (0.0-31.0%) and mollusks (0-1.1%). Local abundance of juveniles related to plankton concentrations.		The intertidal zone may be an important nursery area; juveniles present in the shallow intertidal zone at all stages of the tide throughout the summer. Subtidal marsh creeks, such as those in Little Egg Harbor, NJ, are also seasonally important as nursery areas. Size segregation in the Bay of Fundy shows schooling is an important aspect of pollock behavior. 0+ and 1+ schools segregated by size, with 1+ in slightly deeper water.
Adults [4]	Range 31-34 ppt, mean 33.7 ppt, preferred 33-34 ppt (lower in Bay of Fundy). In MA Bay, salinity at spawning ranges from 32-32.8 ppt.		Major prey on Georges Bank, western Nova Scotia and the Bay of Fundy region are crustaceans (primarily the Euphausiid *Meganyctiphanes norvegica*) and fish. In the Gulf of Maine primary prey are fish (mostly Atlantic herring, but also pollock, redfish, hake) and crustaceans. On the Scotian Shelf and Gulf of St. Lawrence fish are most important. Diet varies with size of fish: 41-65 cm: crustaceans (31-97%), fish (0.7-54%) and mollusks (0-1%); 6-95 cm: fish (29-74%), crustaceans (12-63%) & mollusks (0-12%); > 95 cm: mollusks (76% *Loligo* spp.), crustaceans (15%) & fish (7%). Pollock are cannibalistic.	Spawning occurs from Sept-April; peaks in early Nov to mid-Jan. Spawn as temperature is falling, at depths of 42-140 m, possibly to 170 m; but generally shallower than 110 m. Spawning locations: from Nova Scotia to Cape Cod, in the vicinity of coastal slopes and banks; highest concentration is in MA Bay; also Stellwagen Bank, Cape Ann to Isle of Shoals, western Gulf of Maine and on the Scotian Shelf. Bay of Fundy and northern Gulf of Maine pollock probably spawn in southern Gulf of Maine and possibly on the Scotian Shelf.	Pollock complete short migrations linked to temperature changes and north-south movements for spawning. Otherwise, are fairly stationary in the Gulf of Maine and along the Nova Scotian coast. In the summer, Bay of Fundy fish are a distinct group from w. Nova Scotia and southern Gulf of Maine fish. However, in winter, they migrate south, spawn & probably mix with s. Gulf of Maine and Scotian Shelf fish. Growth curves for pollock from the SW Grand Banks show a faster rate of growth than those from the Gulf of Maine. Growth rate is rapid until sexual maturity, then slows. Fecundity ranges from 200,000-8,260,000 eggs. The primary predator of pollock is goosefish.

[1] Hardy (1978), Fahay (1983), Markle and Frost (1985), Campana (1989), Collette and Klein-MacPhee (in prep.)
[2] Bigelow and Schroeder (1953), Marak (1960), Steele (1963), Hardy (1978), Scott (1980), Clay *et al.* (1989)
[3] Steele (1963), Tyler (1972), Bowman and Michaels (1984), Ojeda and Dearborn (1991), Rountree and Able (1992), Rangeley and Kramer (1995), Collette and Klein-MacPhee (in prep.)
[4] Hoberman and Jensen (1962), Steele (1963), Maurer & Bowman (1975), Hardy (1978), Langton and Bowman (1980), Bowman and Michaels (1984), Mayo *et al.* (1989), Collette and Klein-MacPhee (in prep.)

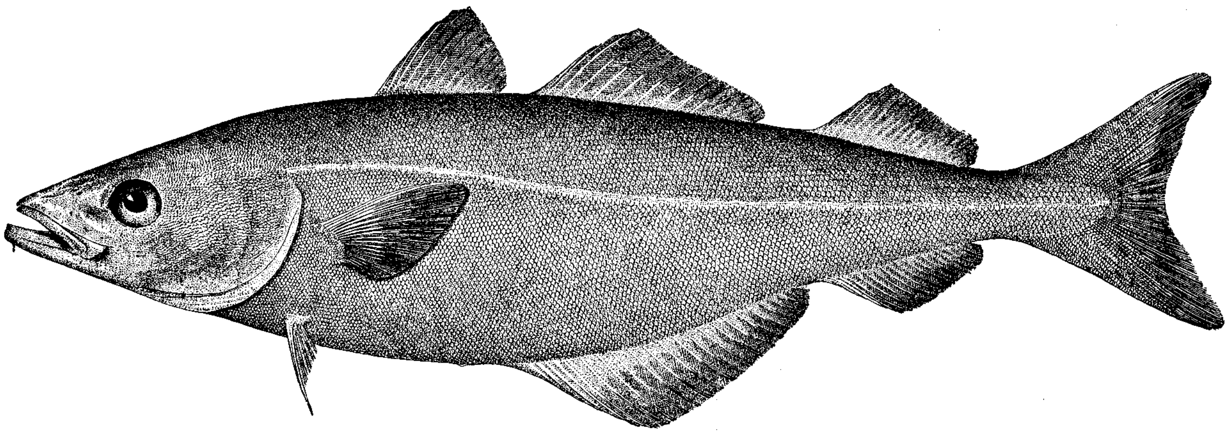


Figure 1. The pollock, *Pollachius virens* (from Goode 1884).

December - January

Peak Spawning
Spawning ranges from September to March[1, 2, 3, 4, 5]
Eggs hatch in 6-9 days after fertilization[3]
Resulting larvae are 3.0-4.2 mm[2, 4, 6, 7]
Transformation occurs at 23-30 mm[5,7,8]
Remain pelagic for 3-4 months[9] (< 50 mm)[7]

May

Move Inshore
Small juveniles (mean size 3.7-4.2 cm[4,10]) begin to appear in the intertidal and subtidal zones[11]

June

In southern Massachusetts Bay, move offshore to avoid rising temperatures; return inshore in autumn. However, north of Cape Ann, remain inshore[5]

July

Remain Inshore
Range in size from 7-11 cm[4]

October

Remain Inshore
Average size of 17-18 cm[4,10]

January

Move Offshore
In large pelagic schools[1]
When temperatures drop to $< 4^{o}$C, move to more stable offshore temperatures[4]
Range in size from 16-24 cm[4]

May

Return Inshore
When water temperatures have warmed up[4] to $> 4^{o}$C
Range in size from 20-25 cm[5]
Size-segregated schools (0+ and 1+ do not mix)[1]

October

Begin To Move Offshore
Mean length of 27-30 cm[4,10] (in Bay of Fundy, 20-25 cm[1])
Largest begin to move offshore permanently[4,10]

Figure 2. Summary of the early life history of pollock. References: [1] Steele (1963), [2] Colton and Marak (1969), [3] Markle and Frost (1985), [4] Clay *et al.* (1989), [5] Collette and Klein-MacPhee (in prep.), [6] Scott (1980), [7] Fahay (1983), [8] Hardy (1978), [9] Mayo *et al.* (1989), [10] Rangeley and Kramer (1995), [11] MacDonald *et al.* (1984).

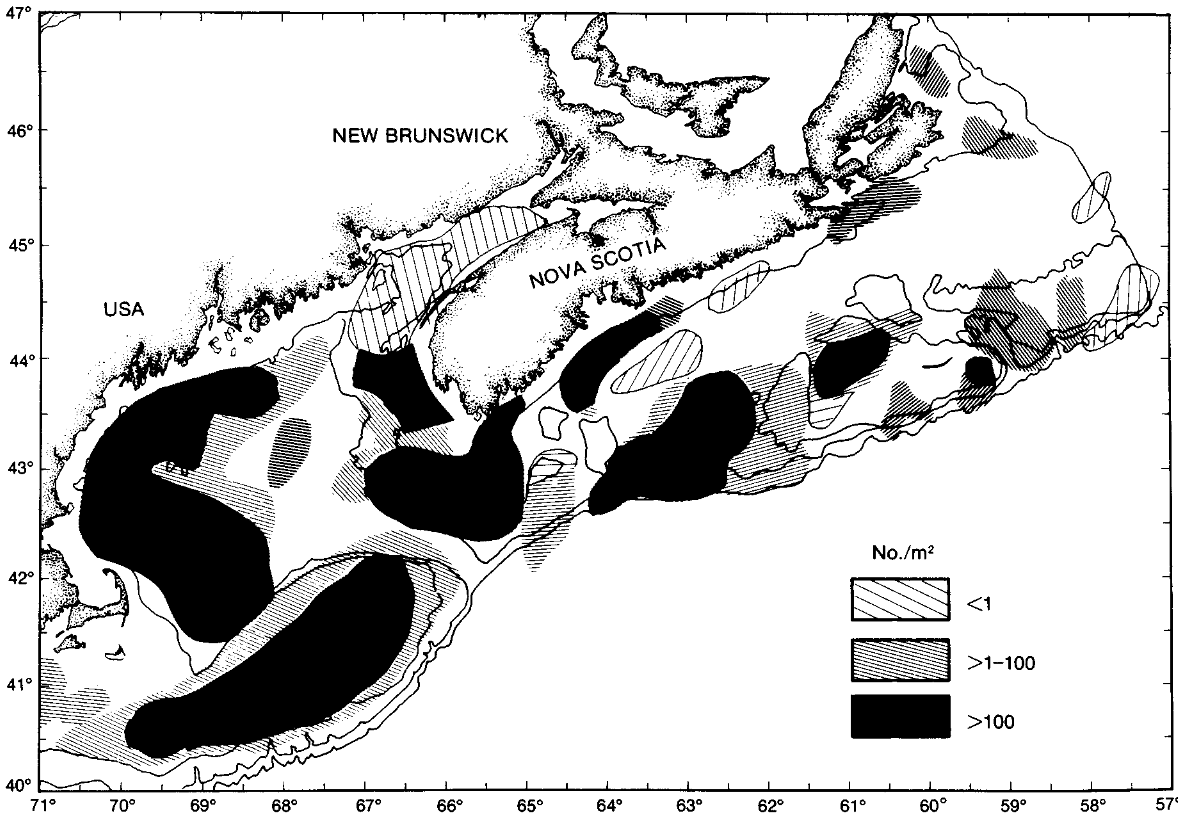


Figure 3. Pollock spawning locations based upon the distribution of eggs and larvae (number/m^2) from American and Canadian ichthyoplankton surveys (from Mayo *et al.* 1989).

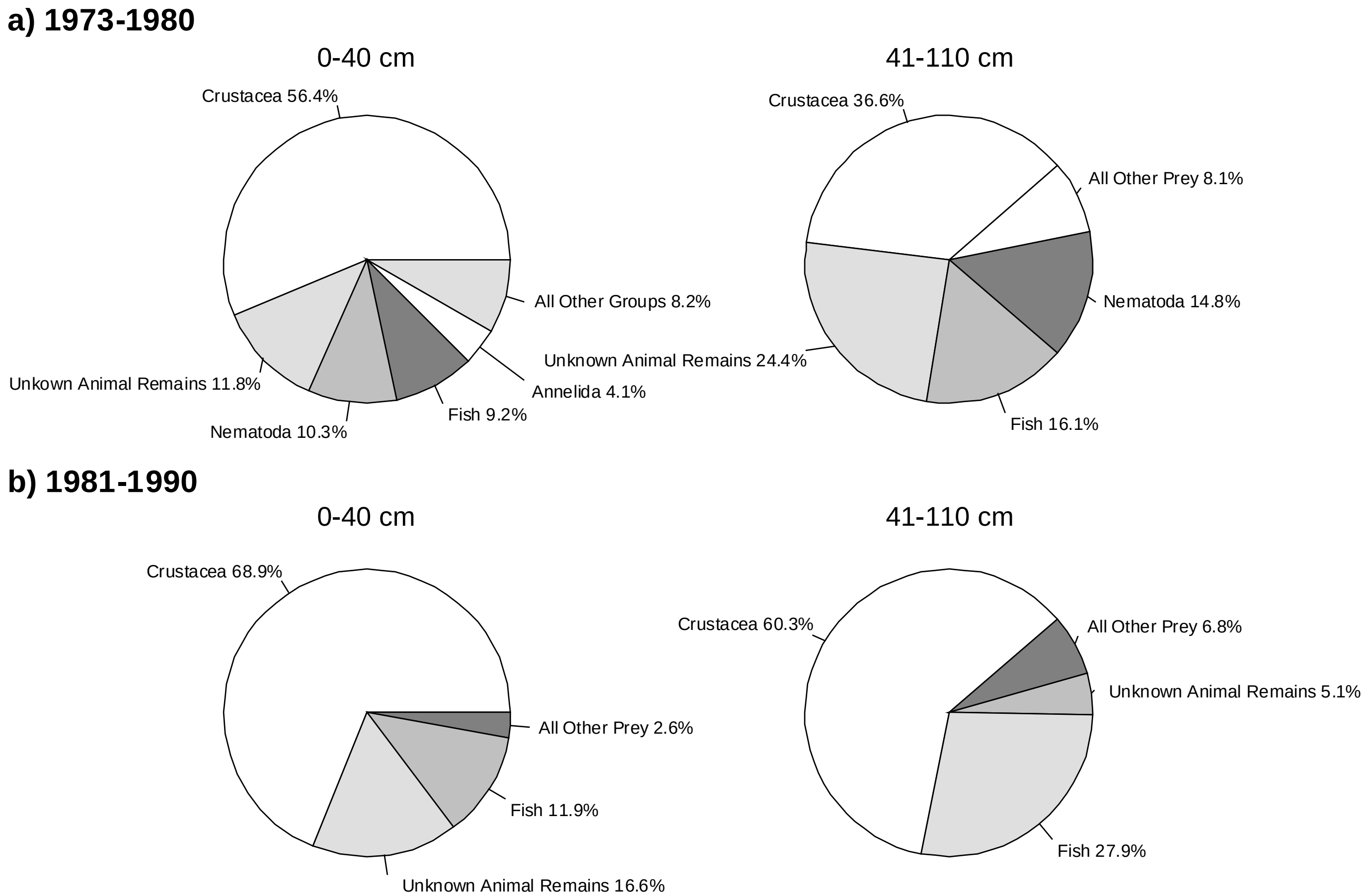


Figure 4. Abundance (% occurrence) of the major prey items in the pollock diet from NEFSC bottom trawl survey data on food habits. Methods for sampling, processing, and analysis of samples differed between the time periods [see Reid *et al.* (1999) for details]. (a) 1973-1980, 0-40 cm: n=124, 41-110 cm: n=371; (b) 1981-1990, 0-40 cm: n=413, 41-110 cm, n=686. The 0-40 cm size range corresponds, at least roughly, to juveniles, and the 41-110 cm size class corresponds to adults. The category “animal remains” refers to unidentifiable animal matter.

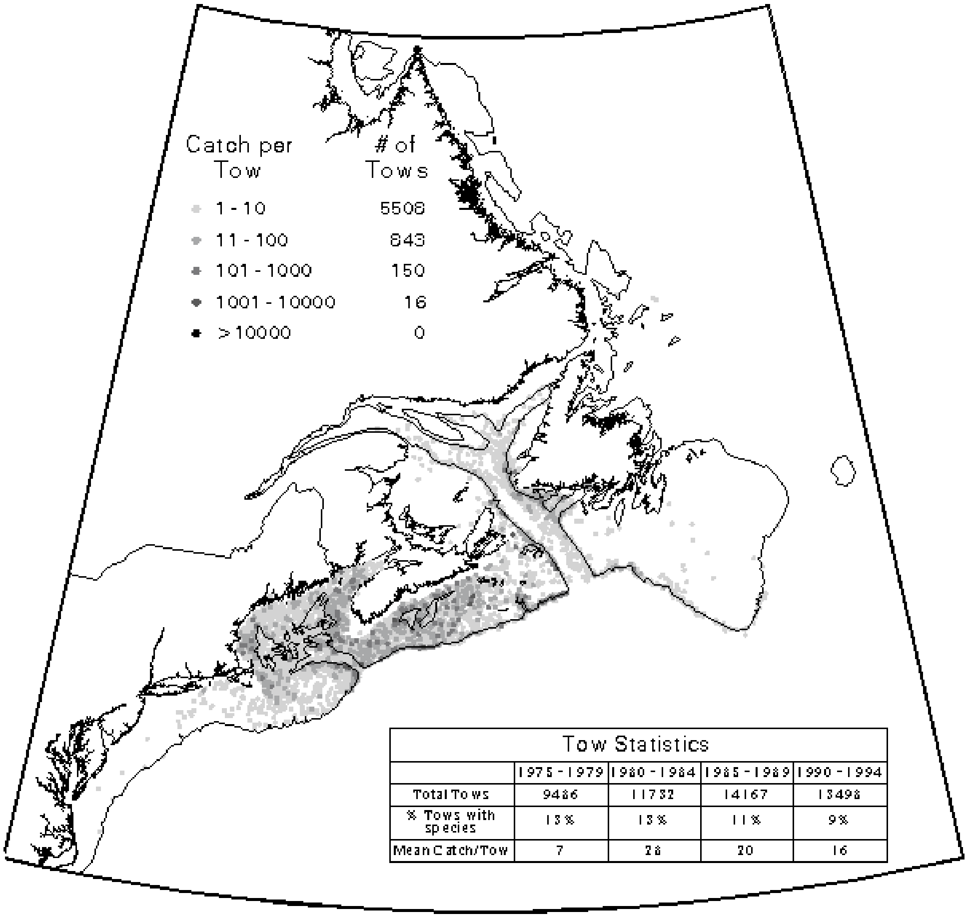


Figure 5. Distribution and abundance of polluck from Newfoundland to Cape Hatteras during 1975-1994. Data are from the U.S. NOAA/Canada DFO East Coast of North America Strategic Assessment Project (http://www-orca.nos.noaa.gov/projects/ecnasap/ecnasap_table1.html).

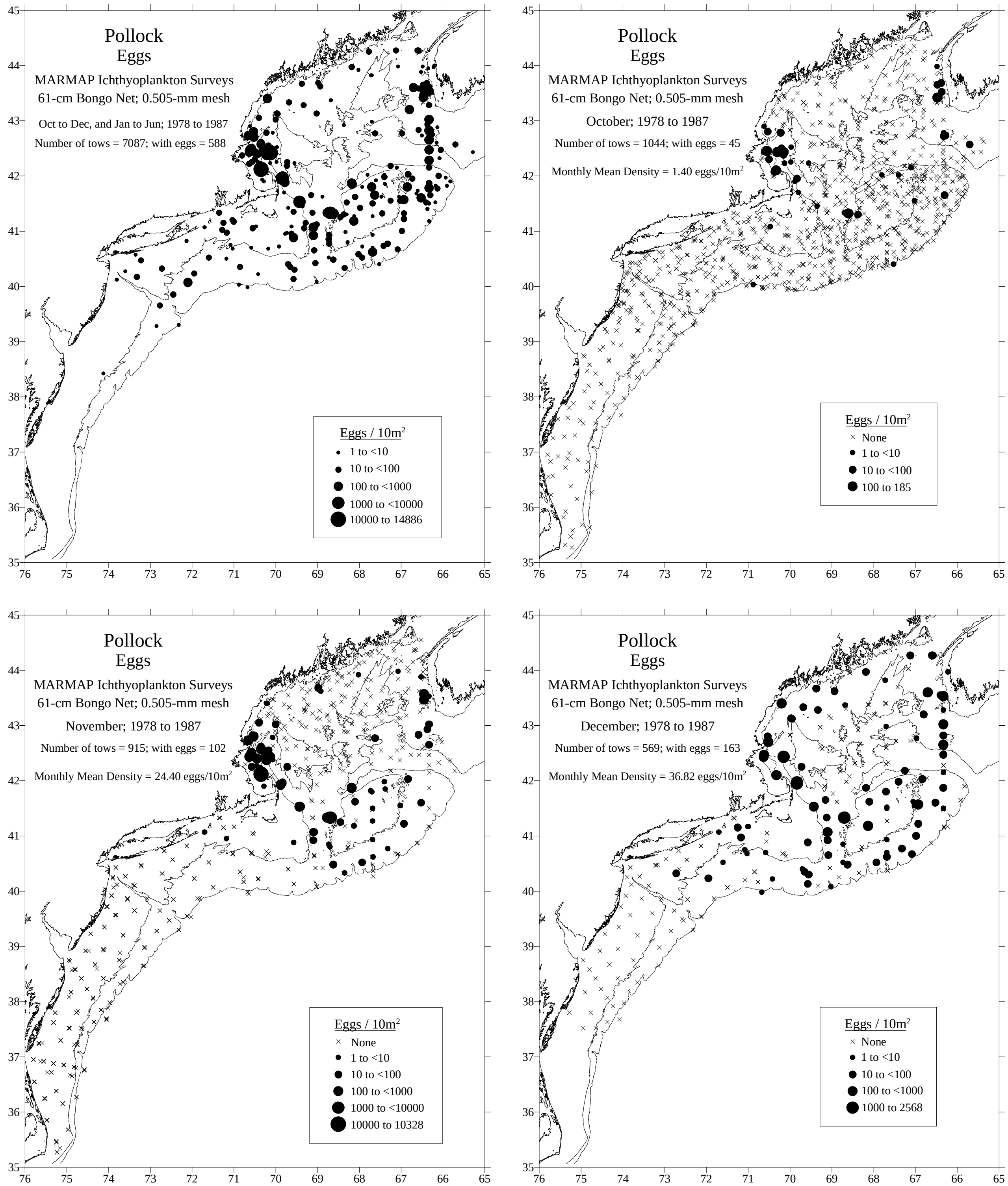
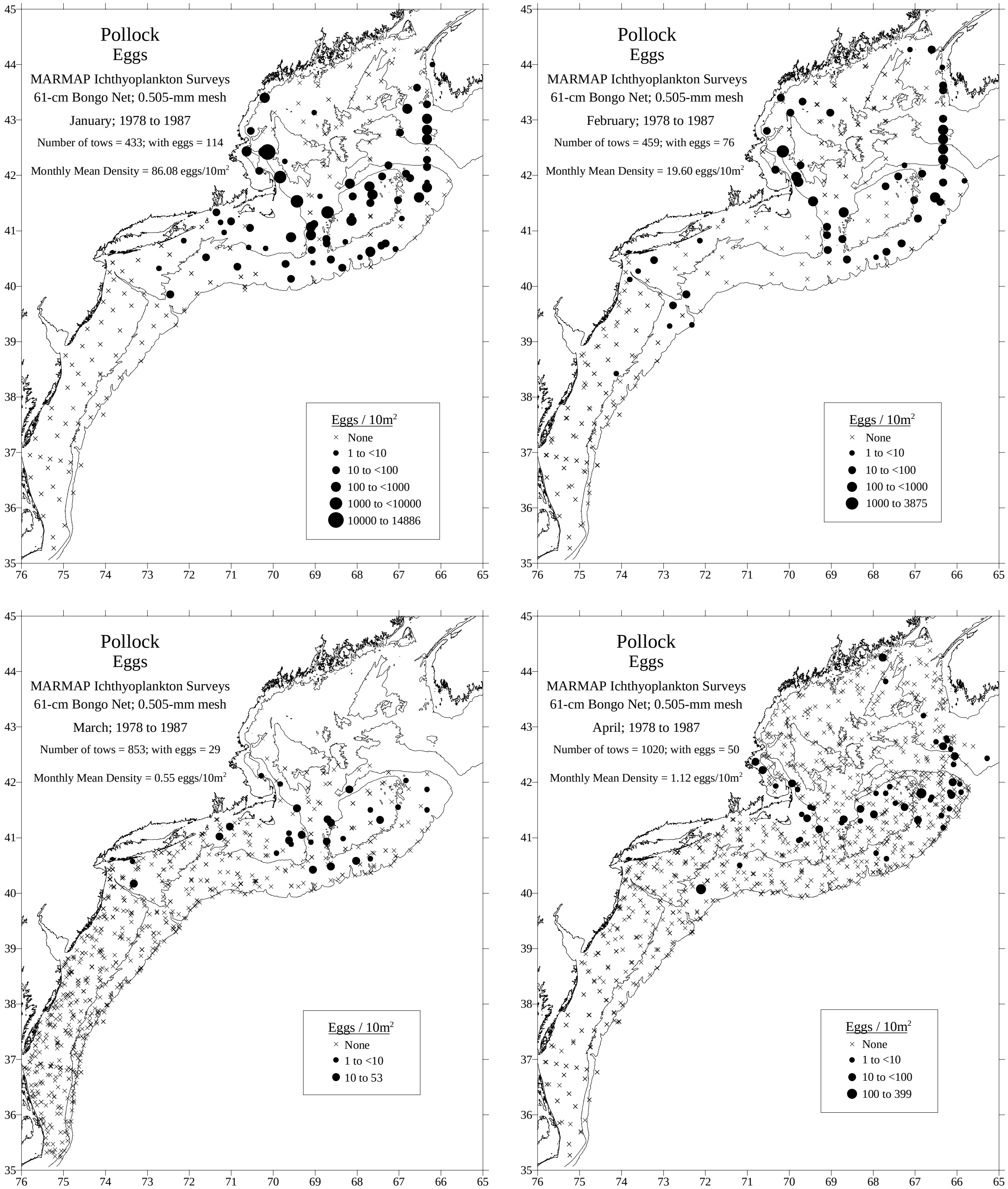


Figure 6. Distribution of pollock eggs collected during NEFSC MARMAP offshore ichthyoplankton surveys (October to December and January to June, 1978-1987). Egg densities are represented by dot size [see Reid *et al.* (1999) for details].



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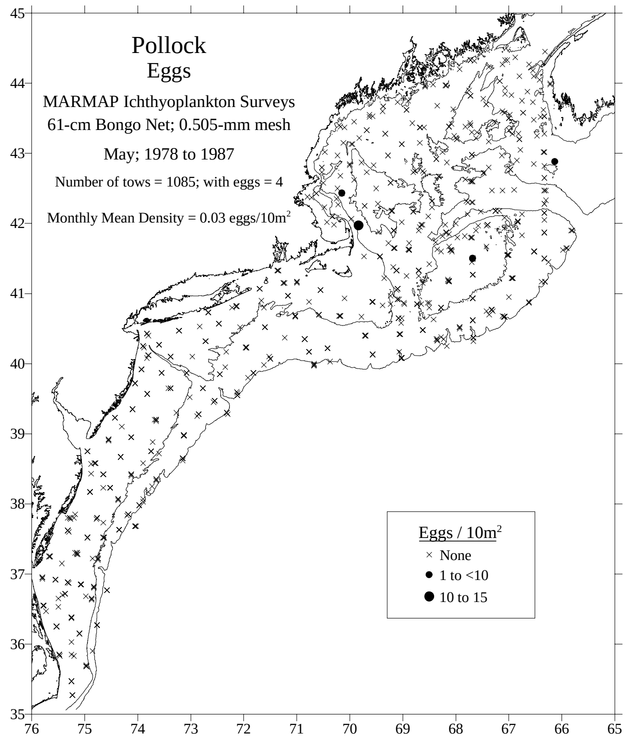


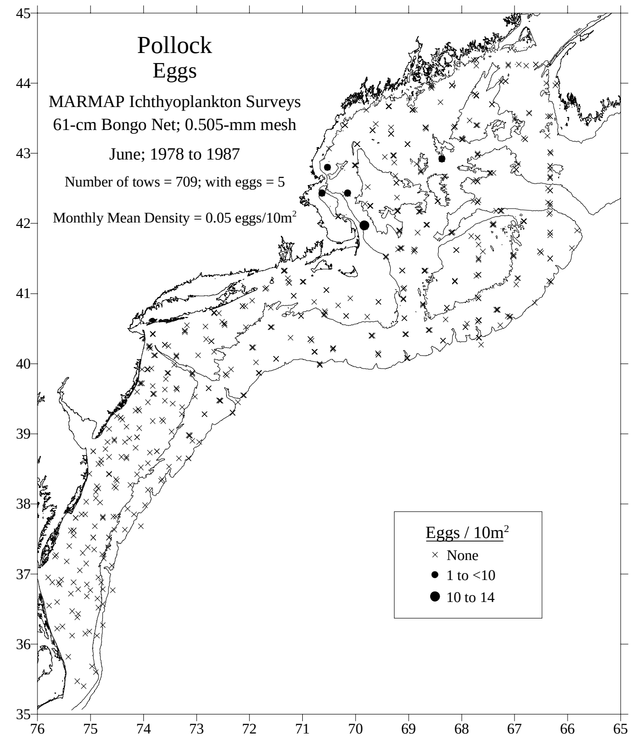


Figure 6. cont’d.

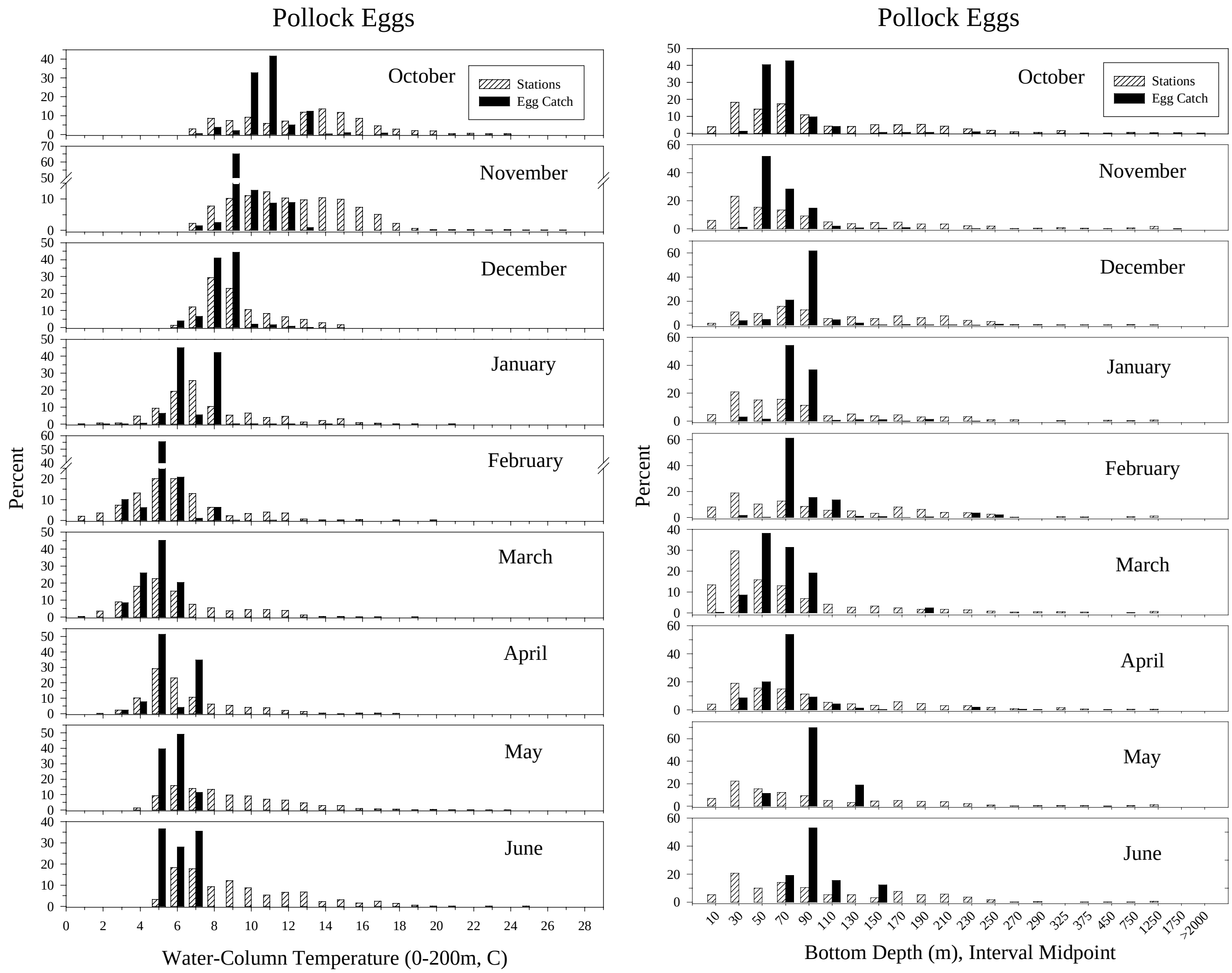


Figure 7. Abundance of pollock eggs relative to water temperature (to a maximum of 200 m) and depth based on NEFSC MARMAP surveys (October to June, 1978-1987). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

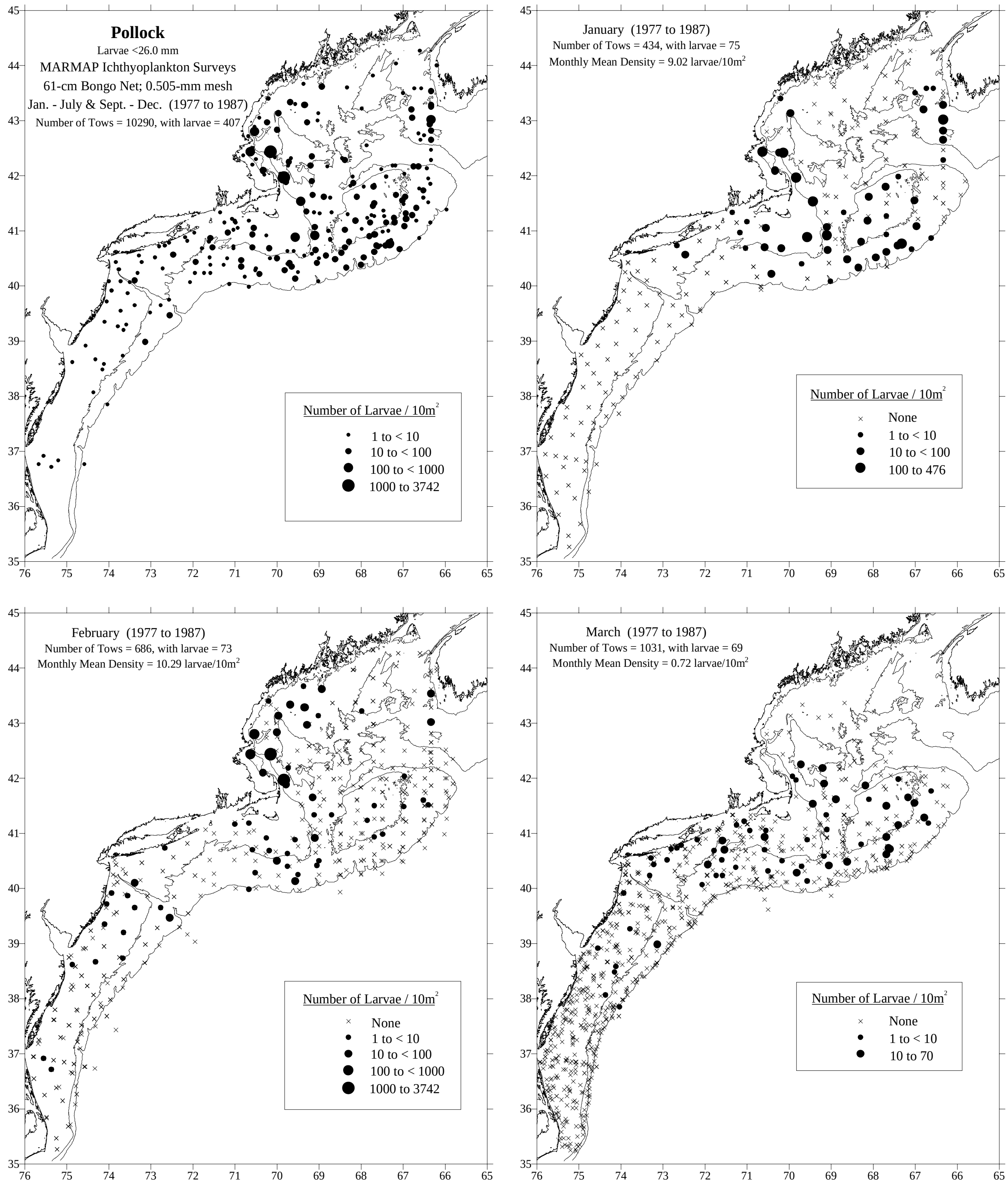
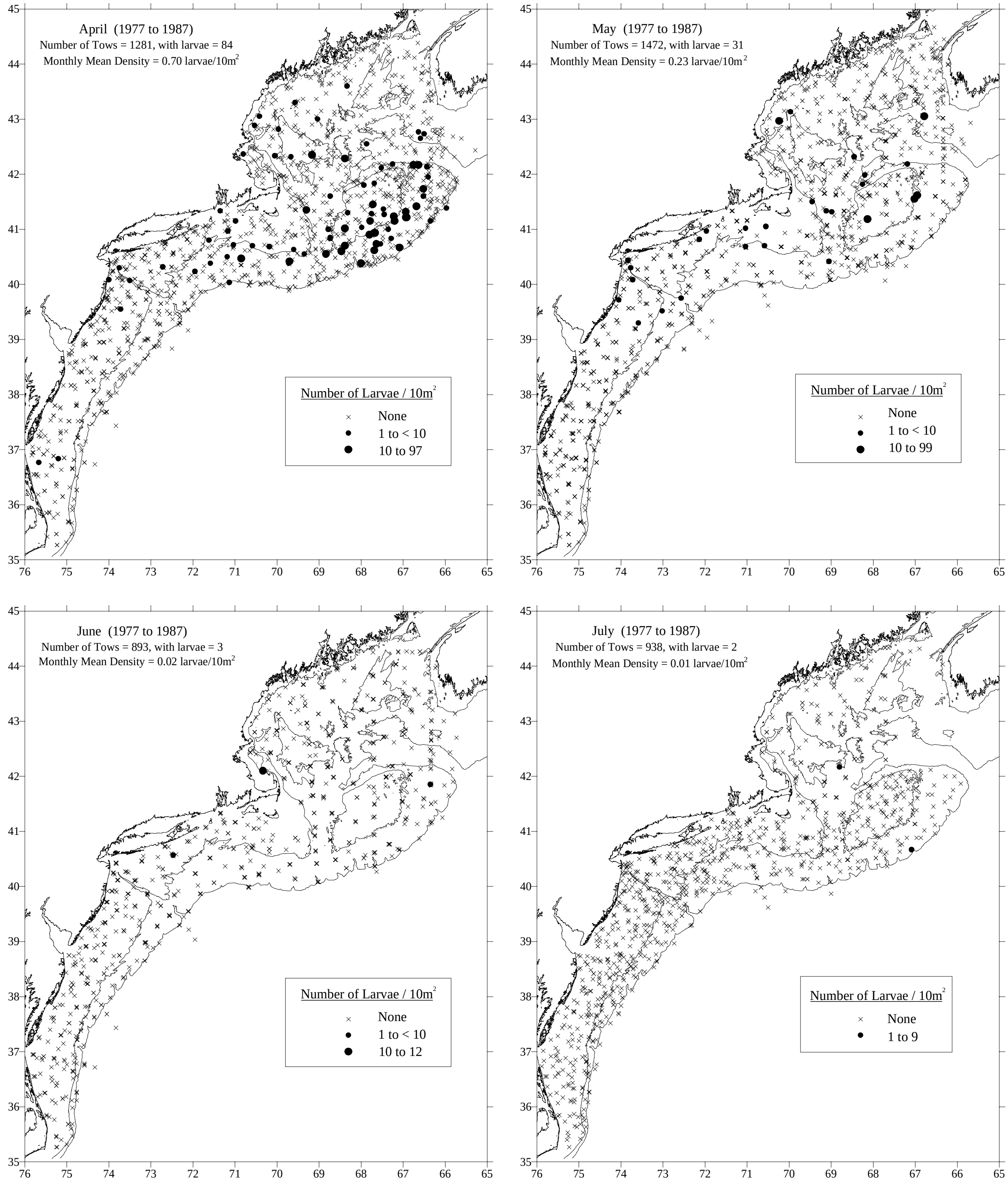


Figure 8. Distribution of pollock larvae (< 26.0 mm) collected during NEFSC MARMAP offshore ichthyoplankton surveys (September to December and January to July, 1977-1987). Larval densities are represented by dot size [see Reid *et al.* (1999) for details].



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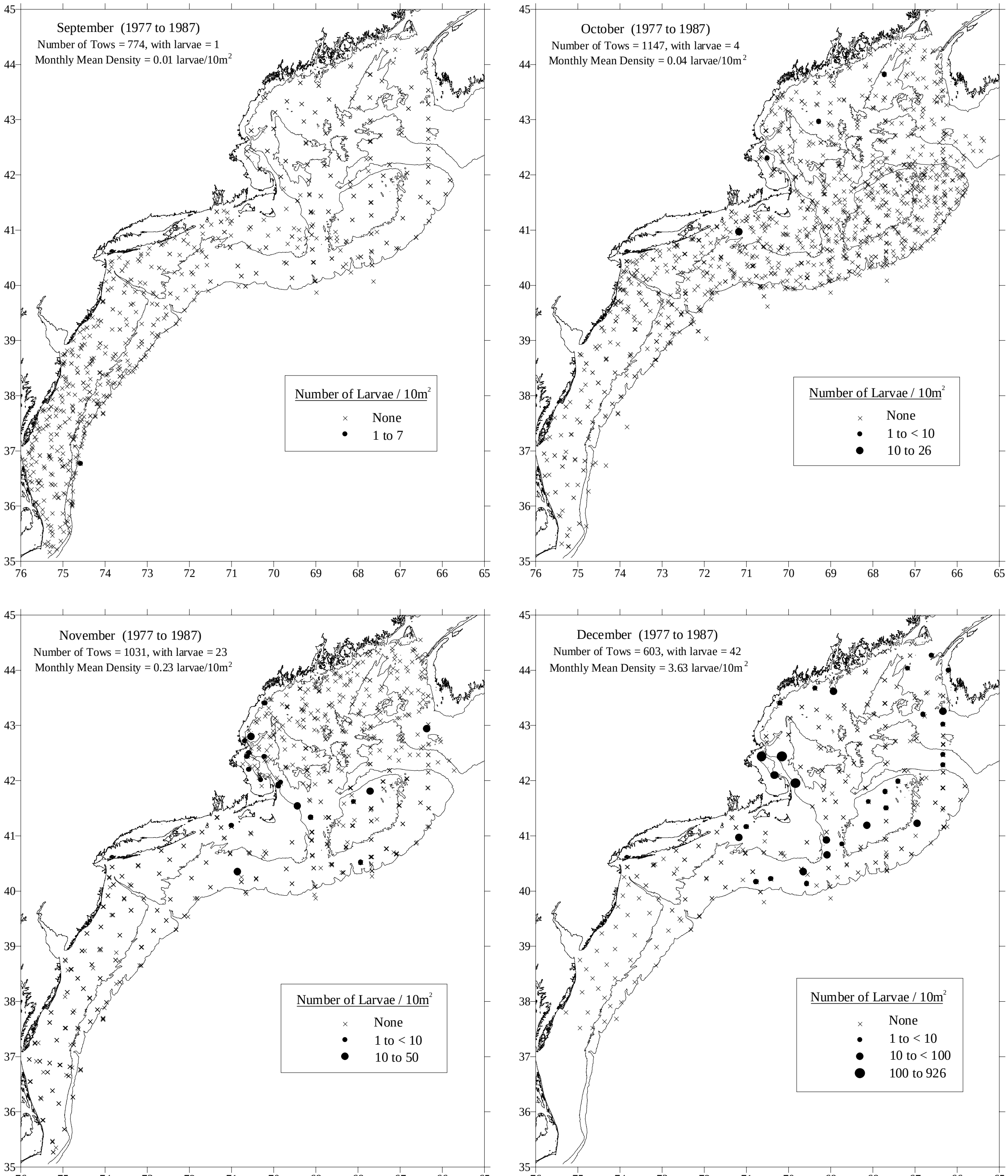

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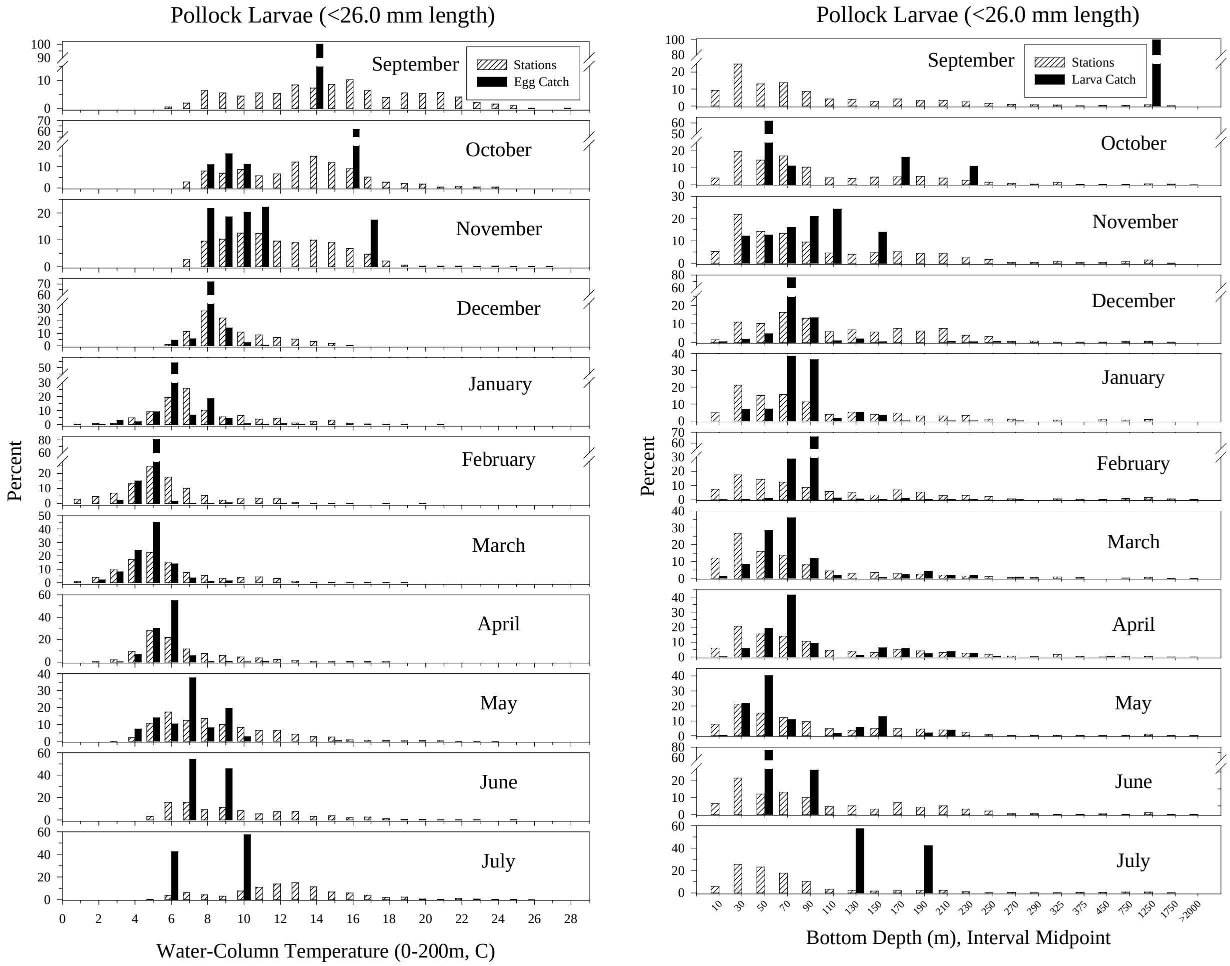


Figure 9. Abundance of pollock larvae relative to water temperature (to a maximum of 200 m) and depth based on NEFSC MARMAP surveys (September to July, 1977-1987). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

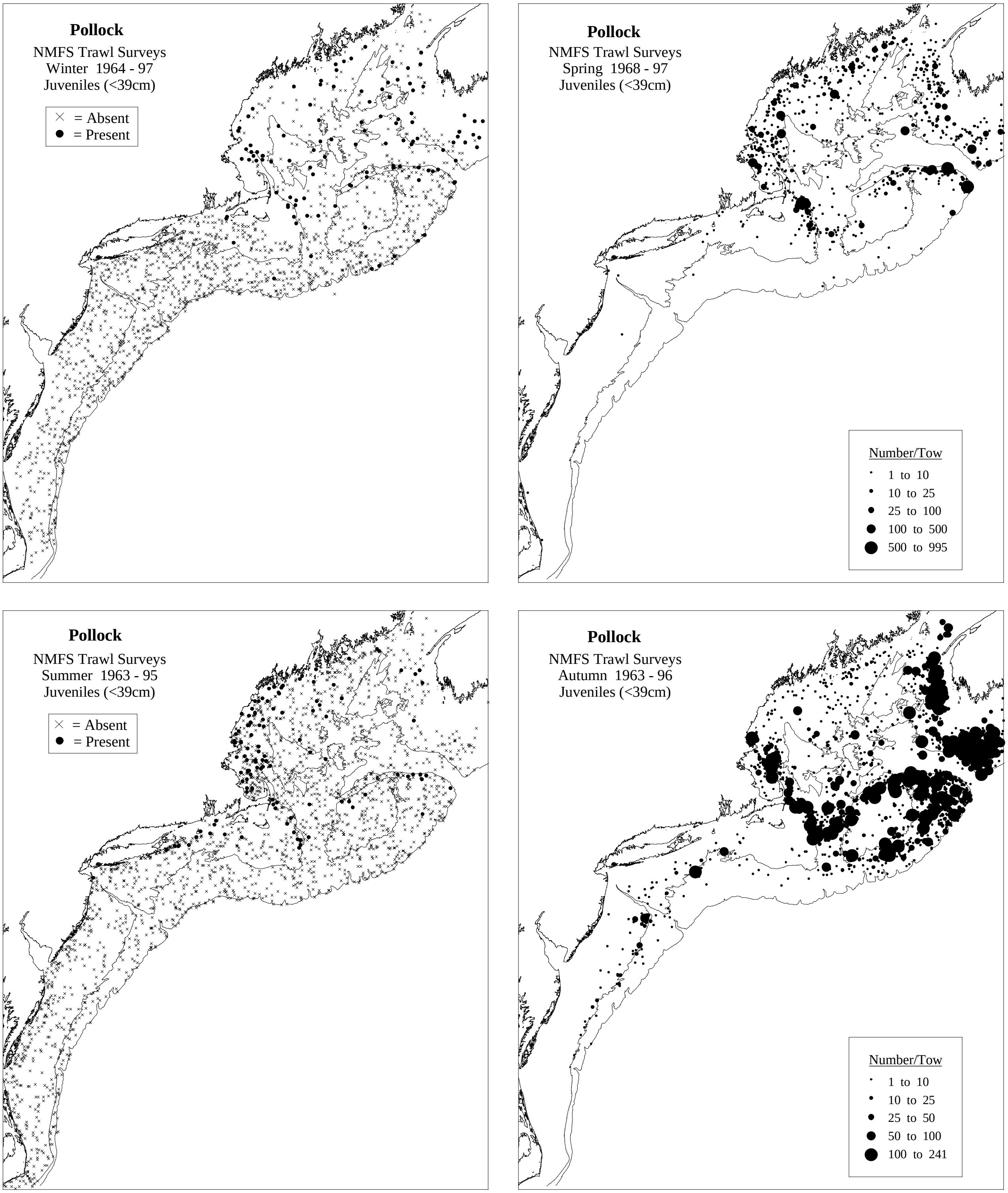
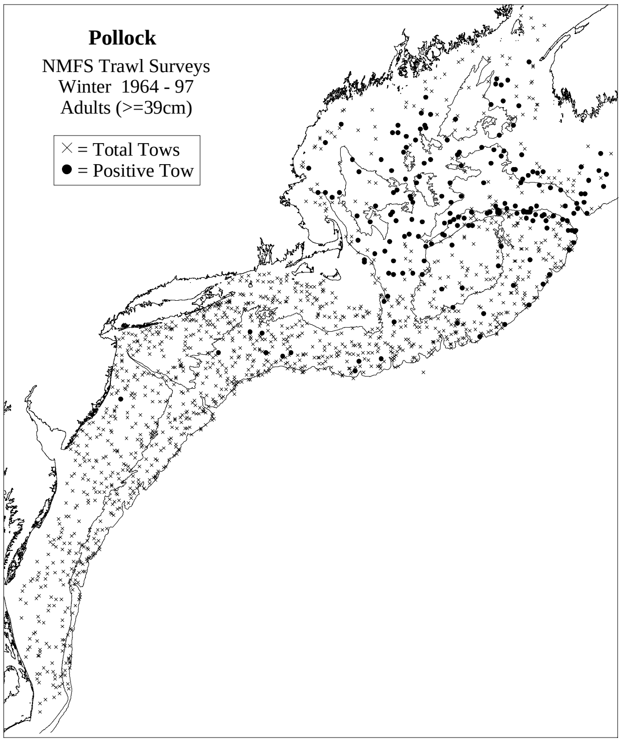
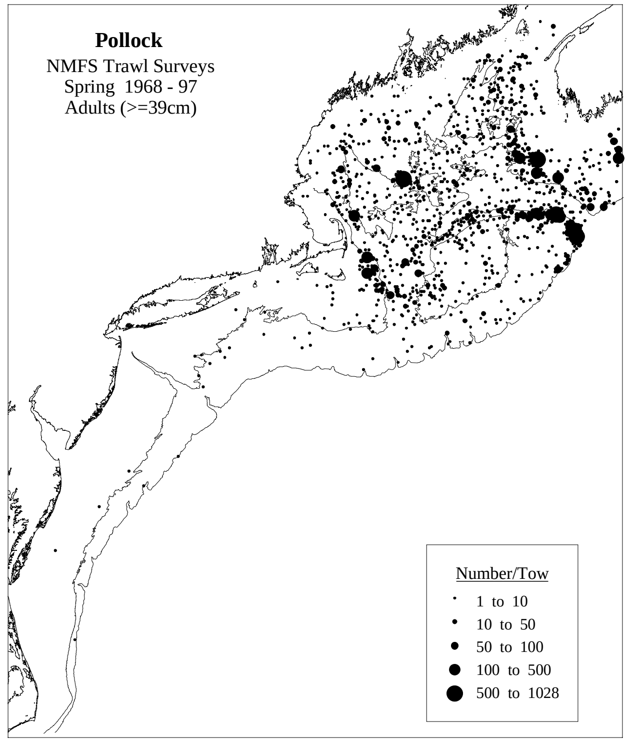
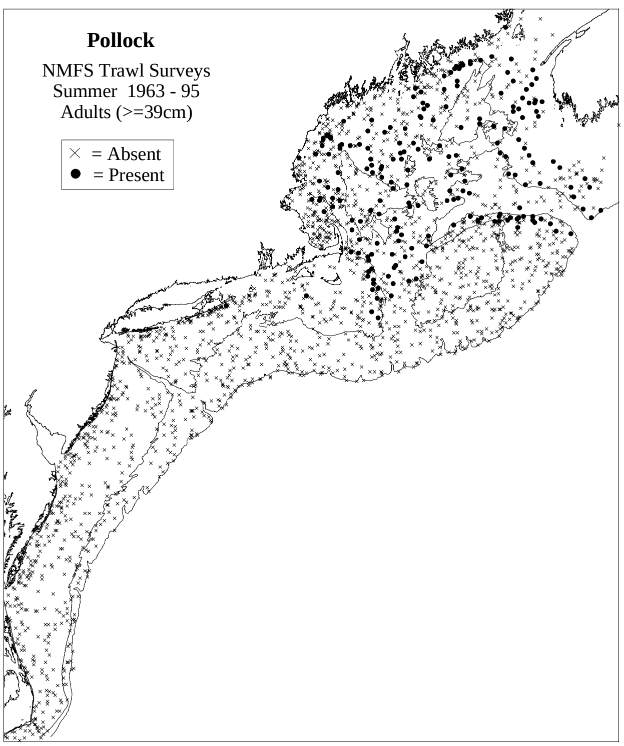


Figure 10. Distribution of juveniles and adults collected during NEFSC trawl surveys (winter, spring, summer, and autumn, 1963-1997). Densities are represented by dot size in spring and autumn plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].







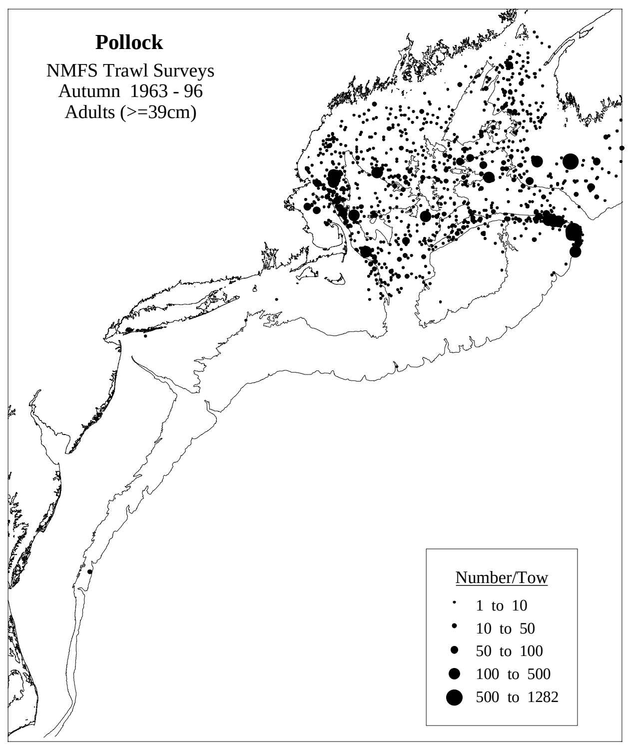


Figure 10. cont'd.

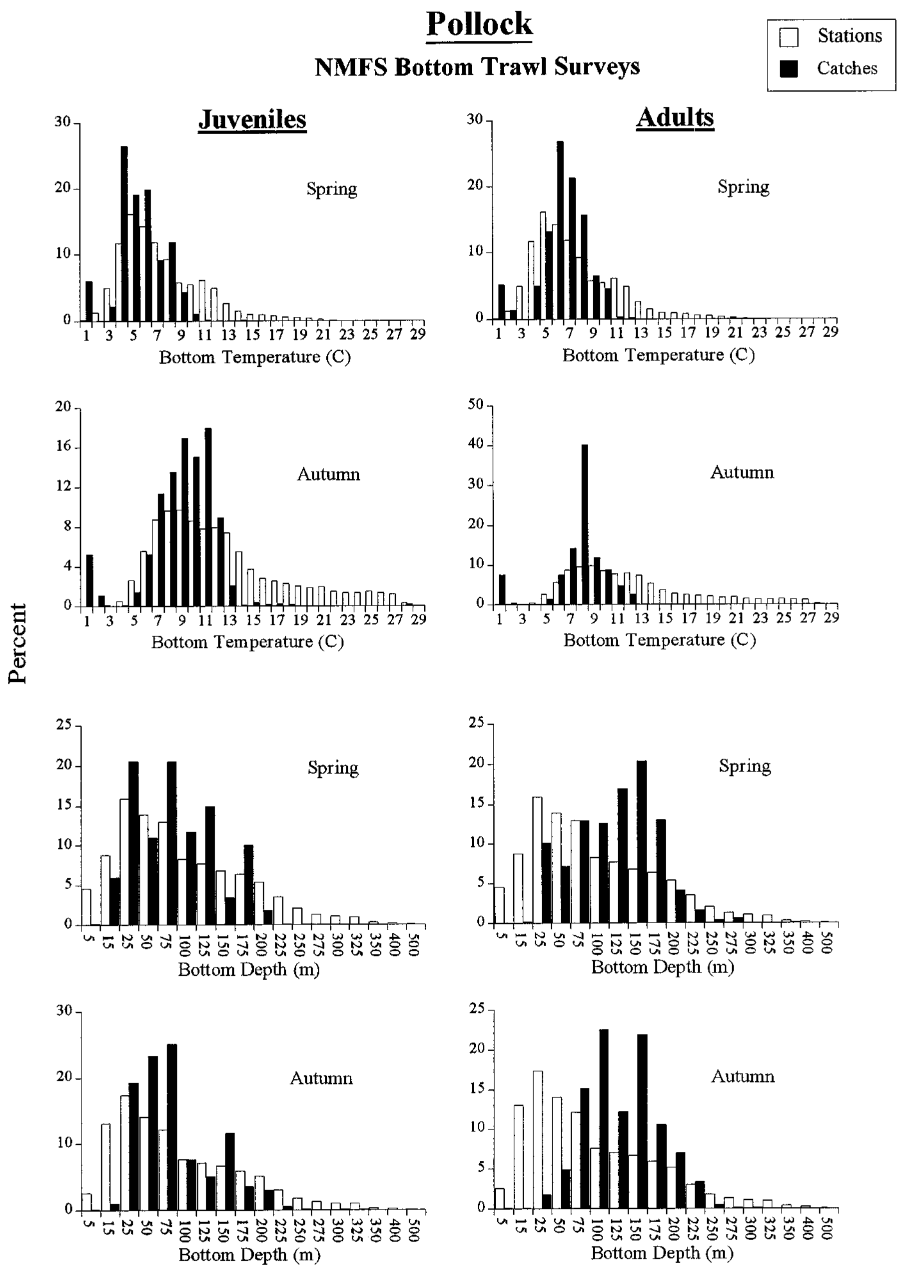
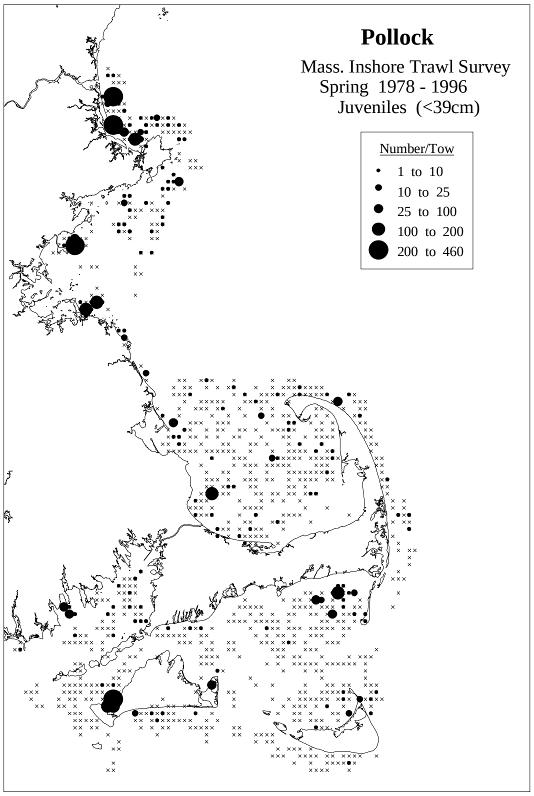
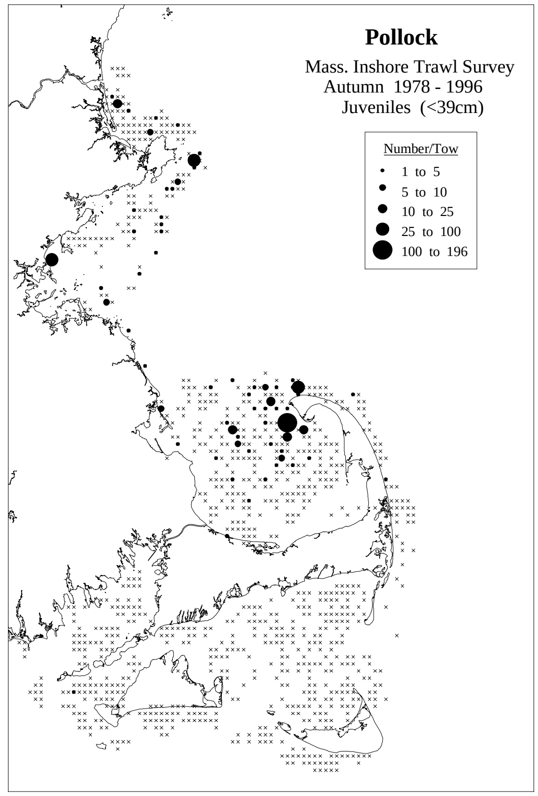


Figure 11. Abundance of juvenile and adult pollock relative to water temperature and depth based on NEFSC trawl surveys (spring and autumn, 1963-1997). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).





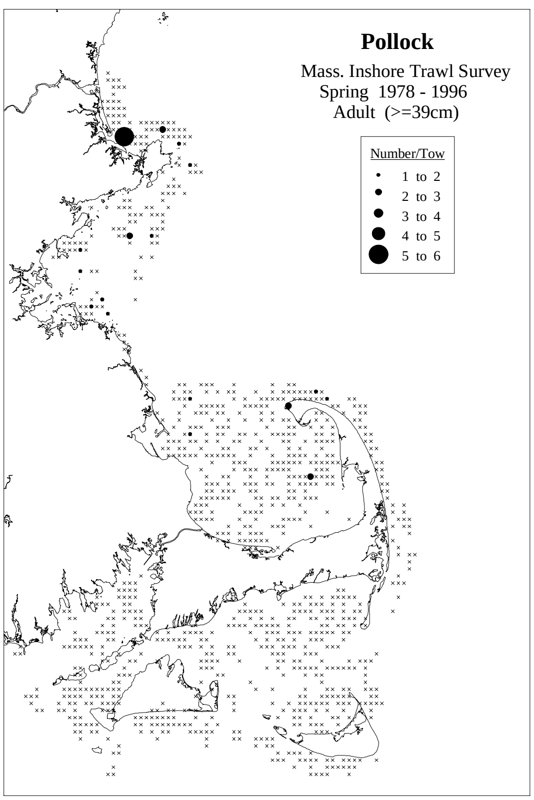


Figure 12. Distribution of juvenile and adult pollock collected in inshore waters of Massachusetts during Massachusetts inshore trawl surveys (spring and autumn, 1978-1996) [see Reid *et al.* (1999) for details].

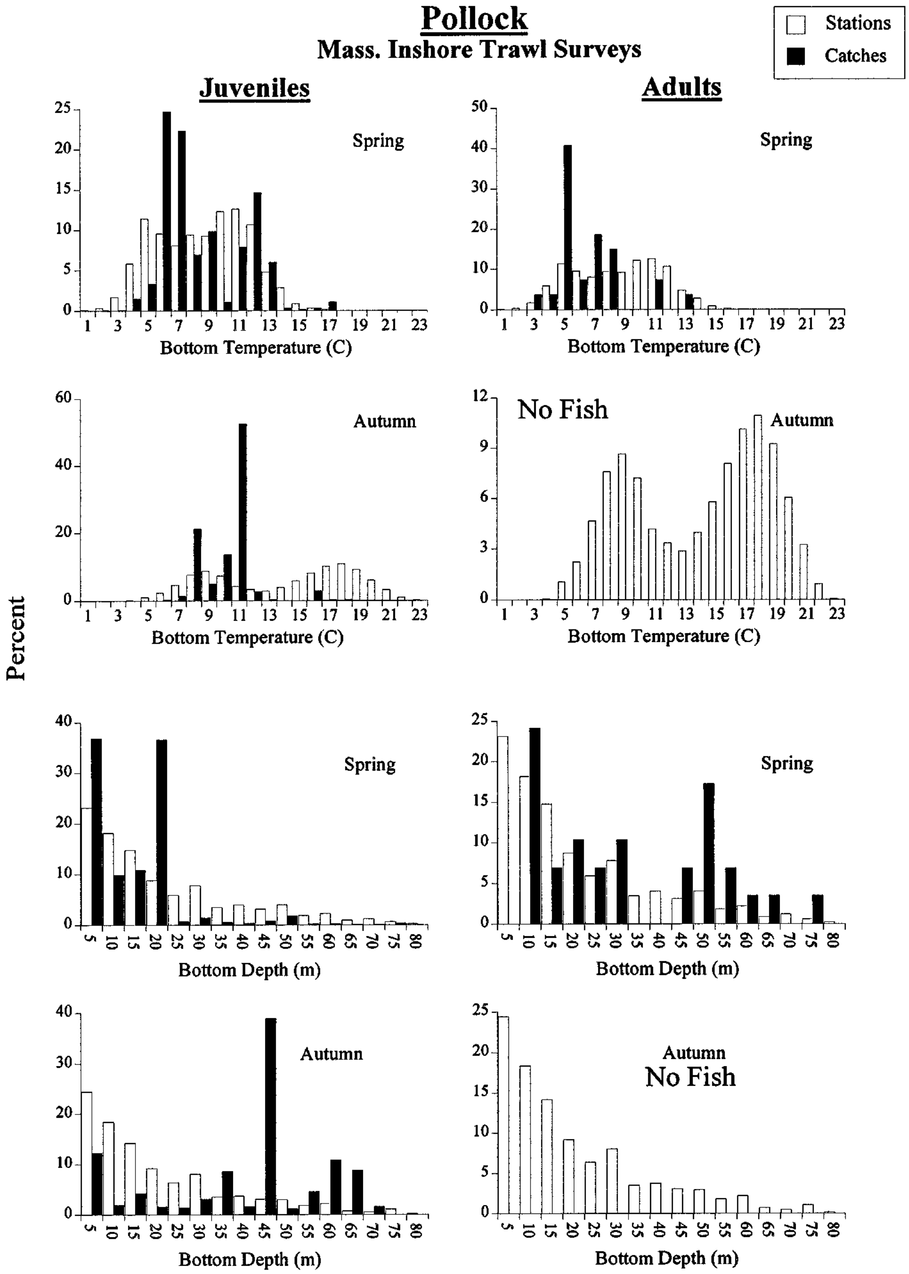


Figure 13. Abundance of juvenile and adult pollock relative to water temperature and depth based on Massachusetts inshore surveys (spring and autumn, 1978-1996). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

Rhode Island Division of Fish and Wildlife
Trawl Survey of Narragansett Bay 1990 - 1996

Pollock Juveniles (<39cm)

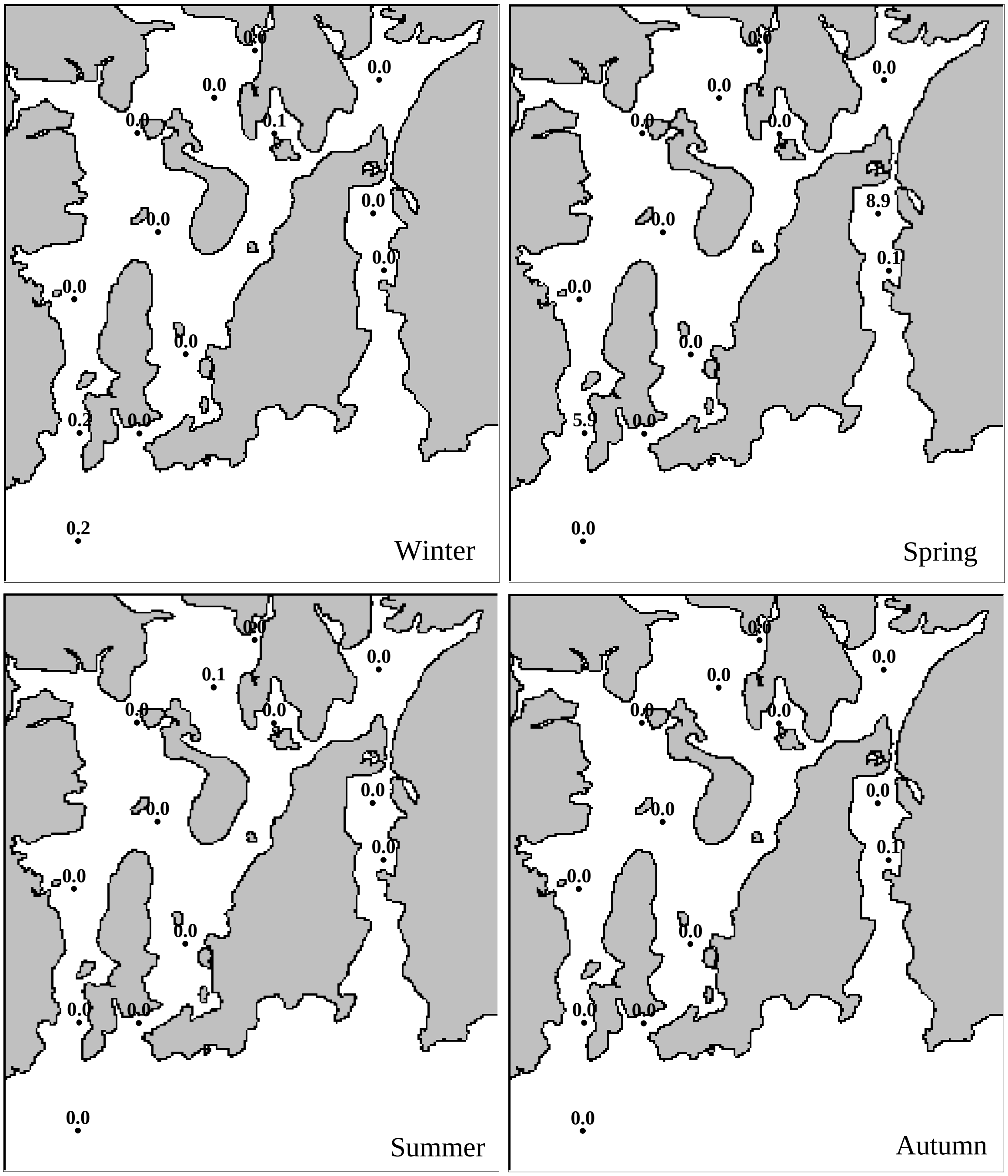


Figure 14. Occurrence of pollock in Narragansett Bay during 1990-1996. The numbers shown at each station are the average catch per tow rounded to one decimal place. Data are from the Rhode Island Division of Fish and Wildlife bottom trawl surveys conducted each month [see Reid *et al.* (1999) for details].

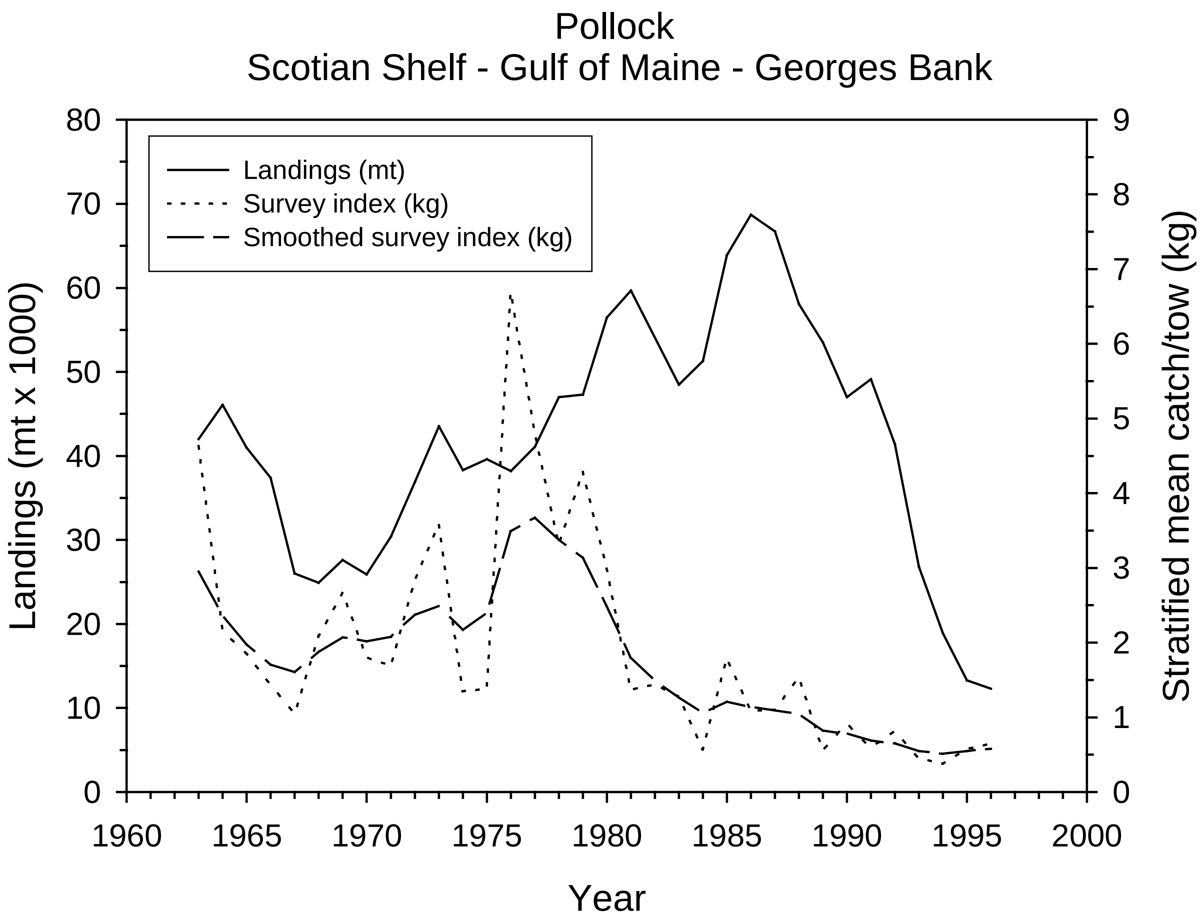


Figure 15. Commercial landings and survey indices of pollock for Gulf of Maine, Georges Bank and Scotian Shelf, 1963-1996.

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