NOAA Technical Memorandum NMFS-NE-203

Essential Fish Habitat Source Document:

Spiny Dogfish, *Squalus acanthias*, Life History and Habitat Characteristics

Second Edition

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

December 2007

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NOAA Technical Memorandum NMFS-NE-203

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Essential Fish Habitat Source Document:

Spiny Dogfish, *Squalus acanthias*, Life History and Habitat Characteristics

Second Edition

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Woods Hole, Massachusetts

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

Editorial Production

For "Essential Fish Habitat Source Documents" issued in the *NOAA Technical Memorandum NMFS-NE* series, staff of the Northeast Fisheries Science Center's (NEFSC's) Ecosystems Processes Division largely assume the role of staff of the NEFSC's Editorial Office for technical and copy editing, type composition, and page layout. Other than the four covers (inside and outside, front and back) and first two preliminary pages, all preprinting editorial production is performed by, and all credit for such production rightfully belongs to, the staff of the Ecosystems Processes Division.

Internet Availability and Information Updating

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

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

Species Names

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

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

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

[c]Turgeon, D.D. (chair); Quinn, J.F., Jr.; Bogan, A.E.; Coan, E.V.; Hochberg, F.G.; Lyons, W.G.; Mikkelsen, P.M.; Neves, R.J.; Roper, C.F.E.; Rosenberg, G.; Roth, B.; Scheltema, A.; Thompson, F.G.; Vecchione, M.; Williams, J.D. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. 2nd ed. *Amer. Fish. Soc. Spec. Publ.* 26; 526 p.

[d]Williams, A.B. (chair); Abele, L.G.; Felder, D.L.; Hobbs, H.H., Jr.; Manning, R.B.; McLaughlin, P.A.; Pérez Farfante, I. 1989. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. *Amer. Fish. Soc. Spec. Publ.* 17; 77 p.

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

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

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

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PREFACE TO SECOND EDITION

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

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

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

NMFS Strategic Plan for Fisheries Research (February 1998)

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

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

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

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

The initial series of EFH species source documents were published in 1999 in the *NOAA Technical Memorandum NMFS-NE* series. Updating and review of the EFH components of the councils' Fishery Management Plans is required at least every 5 years by the NOAA Fisheries Guidelines for meeting the Sustainable Fisheries Act/EFH Final Rule. The second editions of these species source documents were written to provide the updated information needed to meet these requirements. The second editions provide new information on life history, geographic distribution, and habitat requirements via recent literature, research, and fishery surveys, and incorporate updated and revised maps and graphs.

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

INTRODUCTION

The spiny dogfish, *Squalus acanthias* Linnaeus, 1758 (Squalidae) (Figure 1) is a coastal shark with a circumboreal distribution. There are populations of spiny dogfish on the continental shelves of northern and southern temperate zones throughout the world (Compagno 1984). The northwest Atlantic Ocean population is not believed to mix with populations from Europe, Asia, the northeast Pacific, or the southern hemisphere, although these other populations are not considered to consist of separate species. However, DNA analysis may be able to resolve the question of genetic relationships in the future (McCauley *et al.* 2004).

In addition to being the most abundant shark in the western north Atlantic, the spiny dogfish is also one of the most highly migratory (Compagno 1984). It ranges from Labrador to Florida, but is most abundant from Nova Scotia to Cape Hatteras, North Carolina (Figure 2) (Rago *et al.* 1998). Its major migrations on the northwest Atlantic shelf are north and south, but it also migrates inshore and offshore seasonally in response to changes in water temperature (Garrison 2000).

From the 1960s through the 1990s, spiny dogfish and skates became the dominant piscivores on the northwest Atlantic shelf, replacing Atlantic cod and haddock (Link and Garrison 2002). In autumn trawl surveys by the Northeast Fisheries Science Center (NEFSC) covering the Georges Bank region in 1991-1997, spiny dogfish composed large proportions of the biomass of the faunal assemblages: 80% of the inshore southern New England assemblage, 51% of that on the north flank, and 13-23% of the other Georges Bank assemblages (Garrison 2000). In 1991-1997 spring trawl surveys, spiny dogfish composed 21-71% of the biomass of all faunal assemblages (Garrison 2000).

The Mid-Atlantic Fishery Management Council adopted a draft Fishery Management Plan (FMP) for spiny dogfish in August 1998. The management unit in this FMP is the entire spiny dogfish population along the Atlantic coast of the United States (Mid- Atlantic Fishery Management Council 1998). In summer months these fish also inhabit Canadian waters, and are collected in Canadian trawl surveys (Shepherd *et al*. 2002). A review of the status of the dogfish population was done at the 43rd Stock Assessment Workshop (Northeast Fisheries Science Center 2006).

LIFE HISTORY

Spiny dogfish have a long life, late maturation, a long gestation period, and low fecundity. Animals with this life history strategy are particularly vulnerable to population collapse, as they cannot quickly rebuild their numbers once depleted. It is difficult to maintain a sustainable harvest of a species with this type of life history (Musick 1999; Cortes 2000).

Spiny dogfish school by size. Small fish of both sexes, medium-sized fish (including immature females and mature males), and large mature females travel separately. They are rarely seen alone, nearly always occurring in groups. They have been described as slow, inactive swimmers in comparison to other sharks, and are nomadic and irregular in their local movements (Compagno 1984). They do not attain fast swim speeds compared with other sharks because of their caudal structure, but they are highly maneuverable, flexible, and agile (Domenici *et al*. 2004).

JUVENILES

Birth occurs offshore in fall or winter (Soldat 1979; Nammack *et al*. 1985; Burgess 2002). The pups at birth range from 20-33 cm in total length, with the majority at 26-27 cm (Burgess 2002). Ford (1921) and Templeman (1944) report a sex ratio of 1:1 among newborn pups. Fish < 1 yr old and < 36 cm are considered recruits (Northeast Fisheries Science Center 2006). Spiny dogfish may remain immature for ten years or more. Parameters for the von Bertalanffy growth equation for spiny dogfish are provided by Nammack *et al*. (1985) from middle Atlantic and southern New England waters and by Burgess (2002) from the Gulf of Maine. From these parameters, both sources predict that the mean lengths of males and females at five years of age would be approximately 56 cm.

ADULTS

Females grow larger than males and may reach a maximum length of 125 cm and a maximum weight of 10 kg (Northeast Fisheries Science Center 2006). In some populations such as those of the southwest Atlantic off Argentina, maximum length does not reach 100 cm (Alonso *et al*. 2002). In the Black Sea, the largest spiny dogfish reported are 121 cm for males and 136 cm for females (Avsar 2001). Nammack *et al*. (1985) estimated that the maximum age of males was 35 years and the maximum age of females was 40 years in the northwest Atlantic, based on growth rings in dorsal spines. In the northeast Pacific, spiny dogfish may live as long as 80 years (McFarlane and Beamish 1987).

MATURITY

Maturity in female spiny dogfish is determined by the presence of developing eggs or embryos. On the northwest Atlantic shelf, the mean length at which 50% of female spiny dogfish attain maturity varies with year and location (Table 1). Burgess (2002) summarizes that most females from the Gulf of Maine mature at 12 years at a length of 78 cm. As population size in the northwest Atlantic declined during the 1990s and early 2000s, length at 50% maturity in females declined from 82 cm in 1998 to 79 cm in 2002 (Sosebee 2005). Off Ireland, 50% of females were mature at 78 cm and 50% of males at 58 cm (Henderson *et al*. 2002); in the Black Sea 50% of females were mature at 88 cm and 50% of males at 83 cm (Avsar 2001). On the west coast of the United States and Canada, female spiny dogfish mature at greater length and age than on the east coast (Tribuzio *et al*. 2005; V. Gallucci, U. Washington, Seattle, WA, pers. comm.). Mature and immature fish overlap considerably in size (Alonso *et al*. 2002).

Maturity in males is determined by clasper length relative to body length. Most males mature at six years and approximately 60 cm (Burgess 2002). Differences in reported size or age in populations around the world may be real or apparent due to differences in sampling by season, vessel type, and collection gear, and because studies have been conducted in various decades (Holden 1966; Jacob *et al*. 1998, Shepherd *et al*. 2002).

REPRODUCTION

Mating occurs in fall, either after giving birth or while partially developed young from the previous year's mating are being carried in the female's womb (Jensen 1966). It is not known if spiny dogfish spawn in aggregations. The sperm is inserted along grooves on the males' claspers and fertilization takes place internally. Spiny dogfish are ovoviviparous. In early stage development, the ova in each oviduct are encased in a membranous, horny capsule called a candle. This membrane breaks down four to six months after fertilization and leaves the embryos without placental attachment to the uterine wall (Burgess 2002). The entire internal development takes place over 18-22 months (Northeast Fisheries Science Center 2006). Dogfish "pups" are born head-first. Litter sizes range from 1-15 pups, but usually average 6-7; larger females carry a greater number of pups (Burgess 2002). Data on number of pups per fish have been obtained from shipboard dissections. The mean number of pups per litter has been decreasing recently, probably as a result of a decline in the mean size of females in recent years (Sosebee 2005; Northeast Fisheries Science Center 2006).

FOOD HABITS

Spiny dogfish feed diurnally and nocturnally (Alonso *et al*. 2002). Sharks detect food by olfaction, vision, acoustics (sound, vibrations), and by sensing electrical fields of living organisms at close range. Therefore they are able to locate prey in lightless ocean depths. Schooling dogfish benefit from the sensory efforts of many individuals to locate food sources.

Fish, squid, and ctenophores dominate the stomach contents of spiny dogfish collected during the Northeast Fisheries Science Center (NEFSC) bottom trawl surveys [Table 2 and Table 3, Figure 3; see Link and Almeida (2000) for methodology]. The diversity of prey supports observations from other NEFSC studies and the literature. All data are reported as percent of stomach contents by weight. Table 2 and Table 3 originate from a study by Bowman *et al*. (2000) including stomach contents from fish collected in all four seasons, 1977-1980, from Nova Scotia to Cape Fear, NC. Taxa of fish consumed include many families (Table 2 and Table 3; Jensen 1966; Maurer and Bowman 1975; Bowman *et al*. 1984). Table 2 divides the fish into 10 cm size classes, of which Bowman *et al*. (2000) remarked that change in diet is gradual and there is little difference from one size class to the next.

Spiny dogfish feed on squid and fish throughout life. They tend to eat small size classes or young fish, and as they grow they eat larger individuals of the same species (Bowman *et al*. 1984). Squid are a major part of the diet in all geographical areas except for the Mid-Atlantic (Table 3). Bivalvia particularly Pectinidae (scallops) are consumed in the Mid-Atlantic, off southern New England (waters from Cape Cod to south of Long Island), and on Georges Bank. Scombridae (mackerel) are consumed on the Scotian Shelf, while Clupeidae (herring) are eaten inshore and off southern New England. Gadidae (hakes) are mainly consumed off southern New England and on Georges Bank. Ammodytidae (sand lances) are consumed in the Gulf of Maine. In NEFSC trawl surveys north of Cape Hatteras, Atlantic menhaden *Brevoortia tyrannus* are consumed only in small quantities (Table 3); however, menhaden were major prey of spiny dogfish in the early 1960s off South Carolina (Bearden 1965). The opportunistic nature of spiny dogfish is supported by their consumption of flatfishes, blennies, sculpins, capelin, ctenophores, jellyfish, polychaetes, sipunculids, amphipods, shrimps, crabs, snails, octopods, squids, and sea cucumbers off the U.S. east coast (Templeman 1944; Jensen *et al*. 1961; Jensen 1966; Burgess 2002). Occurrence of ctenophores in diets has increased over the last decade as the availability of these organisms in the oceans has increased (Link and Ford 2006).

In Figure 3, data on the major prey types from the contents of 46,000 dogfish stomachs obtained during NEFSC trawl surveys from 1973-2001 are grouped into three size classes: small, < 36 cm; medium, 37-79 cm; and large, > 79 mm total length. The predator length classes chosen for the figure are not strictly related to maturity stage. Spiny dogfish < 36 cm are immature, 37-79 cm fish include immature females and immature and mature males, and fish > 79 cm are mature females. Small dogfish consume mainly ctenophores, squid, and euphausiids (shrimplike crustaceans); medium-sized dogfish consume these prey plus bivalves, decapod crustaceans, and fish. Large dogfish decrease plankton consumption and eat a greater variety of fish taxa. In deep basins off Nova Scotia, dogfish even as large as 40-80 cm consume some euphausiids and copepods (Sameoto *et al*. 1994).

Garrison and Link (2000a) grouped common predator species on the northeast United States shelf into trophic guilds using cluster analysis. Small (<41 cm) and medium (41-60 cm) spiny dogfish were placed in the planktivorous trophic guild, consuming cephalopods, ctenophores, and euphausiids. Large (61-80 cm) spiny dogfish were characterized as piscivores or fish consumers. On Georges Bank, despite changes in the identity of the dominant predators during the 1960s through 1990s, the trophic guild structure remained the same (Garrison and Link 2000a, b). During that time, piscivores such as Atlantic cod, haddock, and yellowtail flounder were replaced in biomass by spiny dogfish and skates, as mentioned previously (Garrison 2000).

In the northwest Atlantic, there is a complex web of piscine predators and their prey. Over the past 40 years, the major piscine prey of spiny dogfish has changed (Bowman *et al*. 1984; Spencer and Collie 1996; Overholtz *et al*. 2000; Link and Garrison 2002). Haddock and Atlantic herring were major prey in the 1960s, Atlantic mackerel the major prey in the early 1970s and then again in the 1990s, and sand lance was the major prey in the late 1970s to 1980s. Herring spp., particularly Atlantic herring, made a strong comeback in spiny dogfish diets in 1987 though the 1990s. The abundance of prey species changes in response to environmental factors and fishing pressure, but the relationship between the most abundant prey fish and the most frequently consumed fish in the diet is not direct. For example, Atlantic herring abundance peaked in the 1990s yet consumption (as estimated from dogfish stomach contents) did not correspondingly increase (Overholtz *et al*. 2000). Predators such as dogfish may eat smaller individuals that may not be sampled adequately by trawling (Link and Garrison 2002). A predator-prey model of spiny dogfish and haddock was generated for Georges Bank, but no direct relationship between the biomass of these two species was found (Spencer and Collie 1996). Although fewer haddock were available as prey, dogfish numbers increased substantially due to their ability to prey upon many other species outside the scope of the model.

In other regions of the world, spiny dogfish have similar diets to those in the northwest Atlantic. They pursue pelagic crustaceans and fish and they progress to eating mostly fish as they mature. In British Columbia waters, dogfish < 79 cm prey mainly upon euphausiids, fish, and lesser amounts of other crustaceans and mollusks, while larger males and females prey upon all those taxa but concentrate predominantly on fish, such as herring and hake (Jones and Geen 1977; Tanasichuk *et al*. 1991). In British waters, Ammodytidae are the most important prey in four locations, herring and mackerel in another (Holden 1966). In the Irish Sea, 40% of the diet of spiny dogfish < 60 cm is crustaceans, while dogfish > 60 cm have a diet of 80% fish, mainly Clupeidae and Gadidae (Ellis *et al*. 1996). On the continental shelf of Argentina, immature spiny dogfish feed mainly upon ctenophores, while mature fish feed mainly upon squid and Argentine hake, and mature fish feed on larger squid than immature fish (Alonso *et al*. 2002). In the Black Sea immatures and matures opportunistically consume whiting, red mullet, black goby, sprat, crangonid shrimp, and other crustaceans (Avsar 2001). Off New Zealand, all size classes of spiny dogfish prefer squat lobster postlarvae, euphausiids, and lesser amounts of other crabs and fish, with more fish in the diet as size increases (Hanchet 1991). Cannibalism upon small juveniles was also observed.

GEOGRAPHICAL DISTRIBUTION

Spiny dogfish are distributed worldwide on the continental shelves of boreal and temperate zones. The distribution of spiny dogfish on the northwest Atlantic shelf is described below, based on NEFSC and state inshore trawl surveys. For the NEFSC and Massachusetts Bay distribution maps in this document, dogfish were separated into juvenile and adult classes by length: 83 cm for females and 60 cm for males (see Life History). Some data may not be included in the plots if sex was not noted. Many years' data have been combined, but among years, changes occur. As spiny dogfish became more abundant from 1970 through the late 1990s, their range expanded to include all of Georges Bank (Garrison and Link 2000b).

JUVENILES

The seasonal distributions and abundances of juvenile spiny dogfish collected during NEFSC bottom trawl surveys [see Reid *et al*. (1999) for details] from the Gulf of Maine to Cape Hatteras are shown in Figure 4. Note that winter and summer distributions are presented as presence data only, precluding a discussion of abundances. In winter, juveniles were widespread across the shelf from North Carolina to the eastern edge of Georges Bank, as shown by presence or positive tows (Figure 4). Juveniles were scarce on the western portions of Georges Bank and rare on Nantucket Shoals. The Gulf of Maine was not adequately sampled to allow us to describe juvenile distribution during winter. In the spring NEFSC surveys, juvenile spiny dogfish were concentrated in offshore waters from North Carolina to the eastern edge of Georges Bank (Figure 4). The largest catches were made along the outer shelf (60-200 m). Juveniles were nearly absent in the northwestern Gulf of Maine. In summer, the NEFSC trawl stations in which sex of spiny dogfish was determined are limited in number, but presence information is presented (Figure 4). In the autumn NEFSC surveys, the greatest catches were around Nantucket Shoals, on Georges Bank, and in waters between Lurcher Shoal and German Bank south of the coast of Nova Scotia. Juveniles were widespread throughout the Gulf of Maine (Figure 4).

The distributions and abundances of juveniles in Massachusetts coastal waters, based upon the spring and fall 1978-2003 Massachusetts inshore trawl surveys, are shown in Figure 5. In the spring, juveniles were common in the waters southwest of Martha's Vineyard, south of Nantucket Island, along the northeast edge of Cape Cod, and in Cape Cod Bay. They were not captured in the Gulf of Maine and were rarely captured in Buzzards Bay or Nantucket Sound (Figure 5). The northward migration of juveniles in the warm season was evident in the autumn (Figure 5). The only noteworthy abundance south of Cape Cod was on Great Round Shoal, just northeast of Nantucket Island. Juveniles were captured along the eastern shore of Cape Cod from Nauset Beach northward around the tip of the Cape and into Cape Cod Bay. They were also caught in large numbers around Cape Ann, throughout Ipswich Bay, and north and offshore of Plum Island.

ADULTS

The seasonal distributions and abundances of adult spiny dogfish collected during NEFSC bottom trawl surveys are shown in Figure 6. (Again, note that winter and summer distributions are presented as presence data only.) In winter, the distribution of adult spiny dogfish was similar to the distribution of juveniles. Adults occurred across the shelf from Cape Hatteras to the eastern edge of Georges Bank. Adults were rare in the New York Bight, Nantucket Shoals, and the western portion of Georges Bank. In the spring, the distribution and relative abundances of adults were somewhat similar to that of the juveniles. Adults were abundant along the outer shelf from North Carolina to the Northeast Peak of Georges Bank and onto Browns Bank (Figure 6). Lesser numbers occurred inshore from Cape Hatteras to Long Island, the western portion of Georges Bank, and central Gulf of Maine. In the summer NEFSC trawl surveys, stations in which sex of spiny dogfish was determined are limited in number, but a small amount of presence information is presented (Figure 6). In autumn, adults were not collected on the shelf from North Carolina to just south of Hudson Canyon. Low numbers were captured south of Long Island (Figure 6). The highest catches occurred off Nantucket Shoals, along the eastern edge of Cape Cod, and in Cape Cod and Massachusetts Bays. Adults were also abundant southwest of Nova Scotia. Adults were collected sporadically throughout the Gulf of Maine and along the northwest edge of Georges Bank, although to a lesser degree than the juveniles.

The distributions and abundances of adults in Massachusetts coastal waters, based upon the spring and fall 1978-2003 Massachusetts inshore trawl surveys, are shown in Figure 7. In the spring, adult spiny dogfish were collected in the southern portions of the survey area and were most abundant on the south shores of Nantucket Island, northeast of Cape Cod, and in Cape Cod Bay, also in Buzzards Bay and around Martha's Vineyard (Figure 7). Adults were absent north of Cape Cod Bay due to their seasonal migration patterns. In the spring, juveniles were six times more abundant than adults in trawl catches. In the autumn Massachusetts surveys, the greatest catches of adults occurred along the eastern shore of Cape Cod near Nauset Beach, near the tip of the Cape, and within Cape Cod Bay (Figure 7). They were also caught near Cape Ann, Ipswich Bay, and Plum Island, but were rare in the southern portion of the survey area except northeast of Nantucket Island. Adults were about twice as abundant as juveniles in the autumn.

The distributions and abundances of spiny dogfish in Long Island Sound from April to November 1984-1994, based on the Connecticut Fisheries Division bottom trawl surveys (Gottschall *et al*. 2000), are shown in Figure 8 and Figure 16. Juveniles, adults, males, and females are considered together. Spiny dogfish enter Long Island Sound mostly in late spring (May and June), when they occurred in 10% of the samples (Figure 16D). Spiny dogfish depart when waters become too warm. In the autumn they return to the Sound, and the largest catches and widest distributions occur during November, with 45.7% occurrence (Figure 16A). They are caught in the deep waters of the central basin and eastern Sound, and occurred as far west as the Western Basin. Black sea bass and winter skate co-occur with dogfish at this season and location (Gottschall *et al.* 2000).

Spiny dogfish are transient visitors to the Hudson-Raritan estuary. In the Hudson-Raritan trawl survey from 1992-1997 (Figure 9), spiny dogfish of the medium size class (sex not recorded) were occasionally captured. From 1994 through 1996, they were caught in small numbers each December at stations near the estuary mouth. In 1997, a few individuals were caught in November (NOAA/NMFS/NEFSC, James J. Howard

Marine Sciences Laboratory, Highlands, NJ, unpublished data).

The Virginia Institute of Marine Science (VIMS) trawl surveys from 1988-1999 of Chesapeake Bay and its tributaries collected spiny dogfish primarily during the cold water months of November to April (Figure 10), mostly near the Bay mouth (Figure 11) (Geer 2002). Their average size was 79.4 cm. Spiny dogfish migrate offshore during the summer months and return inshore between November and January to release their young (Murdy *et al*. 1997). This inshore migration is confirmed in the VIMS data where 68% of the catch occurred in the last two months of the year (Geer 2002)

Spiny dogfish have been reported from many east coast estuaries in addition to the above. They enter estuaries in summer and fall, but only in outer portions where the water is cooler and more saline.

In summary, off the northeast United States, juvenile and adult spiny dogfish are highly migratory from north to south and vice versa. In spring the distributions of juveniles and adults overlap. In autumn, juveniles are scattered along the outer shelf south of New Jersey and in large groups on Georges Bank; meanwhile, adults are heavily concentrated on Nantucket Shoals, along the eastern edge of Cape Cod, in Cape Cod and Massachusetts Bays, along inshore waters and within estuaries.

A portion of the management unit of spiny dogfish occupies Canadian waters in summer. In summer trawl surveys of the Bay of Fundy and the Scotian Shelf, Canada, 1970-1998, spiny dogfish generally follow the same ontogenetic distribution pattern as off the United States northeast coast in the warmer months. Juveniles 40-60 cm are sparsely collected far from the coast, particularly in the Fundian Channel in summer. Dogfish > 60 cm are common midshelf in the Bay of Fundy and on the southern Scotian Shelf (Shepherd *et al*. 2002).

Cluster analysis was performed on NEFSC trawl survey data, grouping major groundfish taxa into assemblages based on their spatial distributions (Garrison 2000). In spring NEFSC trawl surveys, juvenile and adult spiny dogfish were collected mainly on the outer shelf and shelf edge (Figure 4 and Figure 6). From the spring 1991-1997 surveys, Garrison (2000) grouped medium and large spiny dogfish in the spatial assemblage found on the inner and outer southern New England shelf (waters from Cape Cod to south of Long Island) as well as in the assemblages found on the northeast flank of Georges Bank and the inshore Gulf of Maine. In autumn surveys, medium (37-80 cm) and large (> 80 cm) spiny dogfish dominated the assemblage located in the inshore portion off southern New England, as well those of the northeast flank of Georges Bank and the inshore Gulf of Maine. Medium spiny dogfish also dominated spatial assemblages on central and southern Georges Bank. Small dogfish (< 37 cm) composed little of the biomass.

HABITAT CHARACTERISTICS

Information on the habitat characteristics of spiny dogfish are presented here and summarized in Table 4 by life history stage.

The habitat of the spiny dogfish consists of physical and biological components. Physical factors such as temperature, salinity, and depth are measured where spiny dogfish have been caught geographically and are here reported in the context of each survey. Laboratory studies of temperature and salinity tolerances or preferences have not been done. The associated biological component of spiny dogfish habitat also has an influence on the species as profound as the surrounding physical conditions.

Worldwide, spiny dogfish favor the temperature range of 7-15°C (Compagno 1984). Compagno (1984) contends their migrations are governed by temperature changes. Migrations may be over great distances in order to seek out preferred conditions.

In summer trawl surveys of the Bay of Fundy and the Scotian Shelf (Shepherd *et al*. 2002), the lower limit of temperatures at which spiny dogfish are caught is 6-7°C although the survey area includes locations with temperatures as low as 1.6°C. When the cold Labrador Current flows into the area, dogfish migrate farther south. The highest temperature in the surveyed area is about 9°C, and dogfish are collected frequently at that temperature. The mean salinity in locations where they are caught is 33.5 ppt. Large females are abundant on the nearshore shelf and in lower salinities, perhaps to allow maximal growth of their embryos in warmer coastal waters. It is known that their embryos grow faster at higher temperatures (Jones and Ugland 2001).

Zamon (2003) noted the importance of tidal stages and currents to spiny dogfish. On flood tides around rocky islands, tidal rips and jets concentrate the plankton sought by schooling fish, such as Pacific herring and Pacific sandlance. Spiny dogfish follow these fish schools. On the western U.S. coast these features define migration routes as well as feeding locations, but on the northeast U.S. coast, the continental shelf is mainly flat with only some channels and canyons. Comparisons of distributions in fall and spring NEFSC bottom trawl surveys do not suggest any impediments to migration from channels or canyons.

Spiny dogfish undergo daily vertical migrations. In a midwater trawl study of offshore basins of Nova Scotia, which reach depths of 275 m, juvenile and adult dogfish were found near the bottom in daylight and rose to 150 m at night, possibly following their copepod prey (Sameoto *et al*. 1994).

Besides physical conditions, biotic habitat components (prey, predators, competitors, mates) may drive the distribution of spiny dogfish. Considering their prey (Table 2 and Table 3), essential fish habitat inferences can be made on spiny dogfish distribution based on prey distribution. Ctenophores are found in swarms, usually at the surface but descend to 30 m at times (Gosner 1978). Northwest Atlantic Cephalopoda *Illex illecebrosus* and *Loligo pealeii* migrate to offshore and waters down to 500 m in the winter, while in the summer they are found in aggregations inshore (Cargnelli *et al*. 1999; Macy and Brodziak 2001). Euphausiacea are shrimplike crustaceans which occur in aggregations, ascend to the surface at night and move down to the depths during the day, and their predators are known to migrate vertically to follow them (Thompson and Allen 2000). Sand lance school in the water column but are mainly found in and near sand and gravel (Burgess 2002). Schooling fish such as Clupeidae and Scombridae are generally found in the water column; these and other pelagic fish and squid follow their planktonic prey (Garrison *et al*. 2002). Gadidae, Sciaenidae, and other fish are demersal-pelagic. In the middle Atlantic during 1997-1980 (Table 3), 47% of the diet was the epibenthic flatfish *Symphurus* sp.

From the list of diet items, which includes bivalves and crabs, it can be concluded that dogfish spend a portion of their time feeding at the sediment surface, but there are no known published observations of their behavior. Benthic substrates suitable for epifaunal and infaunal prey must be soft rather than hard (Compagno 1984). Throughout NEFSC trawl surveys, concentrations of adult and juvenile spiny dogfish are found along shelf edges, in the Gulf of Maine, on Georges Bank, and in Massachusetts Bay, in areas of soft sediments and rock outcrops (Figure 4 and Figure 7). In Long Island Sound, dogfish are collected over sand, mud, and transitional sand-mud bottoms (Gottschall *et al*. 2000). At the edge of the Hudson Canyon spiny dogfish were collected over soft sediment (V. Guida, NOAA/NMFS/NEFSC, James J. Howard Marine Sciences Laboratory, Highlands, NJ, pers. comm.). Scott (1982b) in trawl surveys off Nova Scotia found spiny dogfish over all five types of bottom they sampled: glacial till, sand and gravel, sand, silt, and clay. Off New Zealand, spiny dogfish are distributed over sand or silt-mud bottoms (Jacob *et al*. 1998).

Off Argentina, immature spiny dogfish feed mainly upon pelagic prey, while adults feed mainly upon squid and hake which are classified as demersal-pelagic (Alonso *et al*. 2002). The authors related the change in diet with a change in dogfish habitat from pelagic to demersal as the animals matured, but could not determine if the changes were for nutritional needs or for needs associated with mating or safety from predation.

Other biological components of the habitat are predators and competitors. Large sharks, skates, silver and white hake, Atlantic cod, weakfish, tilefish, goosefish, lancetfish, bluefish, striped bass, whales, killer whales, seals, dolphins, and other large fish and mammals are known to eat spiny dogfish (Jensen *et al*. 1961; Compagno 1984; Stillwell and Kohler 1993). When teleost fish and spiny dogfish are roughly equal in body size, they act as competitors or co-occurring fauna. Within the plankton-feeding trophic guild of juvenile spiny dogfish is the shortfin squid *Illex illecebrosus,* while the piscivorous trophic guild of adult spiny dogfish includes skates, pollock, red hake, sea raven, four-spot flounder, and summer flounder (Garrison and Link 2000a; Overholtz *et al*. 2000).

JUVENILES

The spring and fall distributions of juvenile spiny dogfish relative to bottom water temperature, depth, and salinity based on 1963-2003 NEFSC bottom trawl surveys from the Gulf of Maine to Cape Hatteras are shown in Figure 12. During spring, juveniles were captured from 3-17°C; most were found between about 6-13°C. They were captured at depths between 11-500 m, with the majority found below 50 m. They were found in a salinity range of about 24-36 ppt, with the majority between 33-35 ppt. During the autumn, the juveniles were found over a temperature range of 5-18°C; most were found at about 8-14°C. Their depth range during that season was from 11-400 m; most were found below 40 m. They were found in a salinity range of 31-36 ppt, with the majority between 32-34 ppt.

The spring and autumn distributions of juvenile spiny dogfish in Massachusetts coastal waters relative to bottom water temperature and depth based on 1978-2003 Massachusetts inshore trawl surveys are shown in Figure 13. During the spring they were found in waters with bottom temperatures of 2-14°C; most were found from 6-11°C, with a large peak in catch at 7°C. Their depth range was from 6-75 m, with the majority found at < 36 m. During the autumn, they were found over a temperature range of 3-21°C. Their temperature distribution was somewhat bimodal, with one peak from about 6-11°C and a smaller peak between 12-15°C. Their autumn depth ranged from 6-85 m, with the majority between 16-45 m.

ADULTS

The spring and fall distributions of adult spiny dogfish relative to bottom water temperature, depth, and salinity based on NEFSC bottom trawl surveys from the Gulf of Maine to Cape Hatteras are shown in Figure 14. During the spring they were found over a temperature range of 3-14°C; most were found from 6-10°C. They were spread over a depth range between 1-500 m. They were found in a salinity range of 29-36 ppt, with the highest catches and occurrences, relative to the trawls, at 34-35 ppt. During the autumn, they were found over a temperature range of 5-18°C, with the majority between 6-16°C. Their autumn depth ranged from 11-400 m, with some higher catches between 21-40 m. They were found over a salinity range of 30-35 ppt, with the majority between 32-34 ppt.

The spring and autumn distributions of adults in Massachusetts coastal waters relative to bottom water temperature and depth based on Massachusetts inshore trawl surveys are shown in Figure 15. In the spring they were found in waters with bottom temperatures of 1-16°C; most were found from 6-11°C. Their depth range was from 11 m to about 85 m, with the majority found from about 16-50 m. During the fall they were found over a temperature range of 5-20°C, with most from about 6-15°C. They were spread over a depth range of 6-85 m, with the majority < 65 m.

The distributions and abundances of spiny dogfish in Long Island Sound relative to depth and bottom type, based on the Connecticut Fisheries Division bottom trawl surveys (Gottschall *et al*. 2000), are shown in Figure 16. Most spiny dogfish observed from spring through fall were found in the Eastern Basin in depths > 27 m over sand and transitional bottom (Figure 8). Of 553 spiny dogfish caught from April to August, only eight were caught in depths < 18 m (Gottschall *et al*. 2000). They were also found in deep water across the Mattituck Sill in the Central Basin, but their occurrence decreased from east to west. In late fall, as their overall abundance increased (Figure 16A), their abundance was similar on mud and transition bottoms, but they were less abundant on sand (Figure 16B). Abundance generally increased with depth (Figure 16C), but most spiny dogfish were taken in depths > 18 m (90% of total catch), with the largest catches occurring > 27 m (Gottschall *et al*. 2000).

In the Hudson-Raritan Estuary trawl survey, spiny dogfish were caught from the months of November through January at bottom depths of 13-20 m, at bottom water temperatures between 7.1-11.3°C, at bottom dissolved oxygen levels between 8.2-11.2 mg/L, and at bottom salinities between 30.7-32.2 ppt (NOAA/NMFS/NEFSC, James J. Howard Marine Sciences Laboratory, Highlands, NJ, unpublished data). The catch locations were in areas of silt, mud, and occasional sand and gravel.

The hydrographic preferences of the total catch of spiny dogfish in Chesapeake Bay and tributaries from the 1988-1999 VIMS trawl surveys are shown in Figure 17 (all years and months combined). They were found in colder waters (< 12ºC), and prefer saltier waters of the Bay mouth (> 22 ppt) at depths > 6 m (Geer 2002). They were also found in areas of high dissolved oxygen (> 7.5 mg/l) (Geer 2002).

RESEARCH NEEDS

The following research needs are suggested:

- Improve knowledge of young juvenile spiny dogfish location and causes of mortality.
- Improve modeling of life history and fisheries.
- Generate better estimates of recreational catch and mortality from fishery discards.
- Study dogfish occurrence related to currents, upwelling, and convergences.
- Model the impact of global temperature increase upon the distribution of dogfish and other carnivorous fishes on the northwest Atlantic shelf.
- Assess information from midwater trawl and hydroacoustic studies about the use of various depths by spiny dogfish, their co-occurrence with planktonic invertebrates and prey fish, and their vertical migrations.
- Assess information from seabed video of the activities and feeding behavior of spiny dogfish near various bottom types or features.
- Conduct laboratory bioassays of temperature tolerance.
- Determine if there is a relationship between energy content of the diet of juvenile dogfish and their slow growth.

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Table 1. The age and length at maturity of female spiny dogfish in the northwest Atlantic.

Area	**A_{50}** (yrs)	**L_{50}** (cm)	**Year**	**Source**
Newfoundland	7-8	74	1940s	Templeman 1944
Gulf of Maine		75	1950s	Bigelow and Schroeder 1953
Gulf of Maine and Georges Bank	12-13	76	1979-1981	Slauson 1982
Mid-Atlantic and southern New England	12.1	79.9	1980-1981	Nammack *et al*. 1985
Northwest Atlantic shelf: Gulf of Maine to Cape Hatteras		83.1	1968-1990	Marques da Silva 1993
Gulf of Maine	12	76-78		Burgess 2002
Northwest Atlantic shelf: Gulf of Maine to Cape Hatteras		79	2002	Sosebee 2005

(A_{50}) Age at which 50% of females are mature
(L_{50}) Length at which 50% of females are mature

Table 2. Diet composition of spiny dogfish by fish length category.
Data expressed as percentage of stomach content by weight. Squared brackets indicate major taxon subtotal; parentheses indicate minor taxon subtotal. Source: Bowman *et al*. (2000); from NEFSC groundfish surveys, 1977-1980.

	Length Category (cm)									
Stomach Contents	<31	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110	Total
CTENOPHORA	[2.6]	[2.3]	[1.7]	[0.8]	[0.7]	[0.6]	[0.9]	[<0.1]	-	[0.5]
MOLLUSCA	[20.2]	[51.5]	[36.5]	[58.3]	[16.6]	[28.4]	[27.3]	[23.1]	[25.1]	[26.6]
Bivalvia	(<0.1)	-27	-8.4	-1.7	-0.9	-1.9	-7.4	-11.3	-12.4	-7.7
Pectinidae	-	27	8.4	1.7	-	-	3.7	6.1	12.4	4.2
Bivalvia unid.	<0.1	-	-	-	0.9	1.9	3.7	5.2	-	3.5
Cephalopoda	-20.2	-24.5	-24	-56.6	-15.7	-23.1	-19.9	-10.9	-12.7	-17.8
Illexsp.	-	-	-	4.9	3	7.3	6.5	4.2	-	5.2
Loligosp.	-	-	-	5.3	5.2	3.4	2.6	3.3	8.9	3.4
Cephalopoda unid.	20.2	24.5	24	46.4	7.5	12.4	10.8	3.4	3.8	9.2
Mollusca unid.	-	-	-4.1	(<0.1)	-	-3.4	-	-0.9	-	-1.1
CRUSTACEA	[4.1]	[1.8]	[9.5]	[8.5]	[7.6]	[2.9]	[2.8]	[5.0]	[0.8]	[4.3]
Euphausiacea	-0.7	-1.2	-1.4	-4.4	-6.6	-2.1	(<0.1)	(<0.1)	-	-0.8
Decapoda	-1.6	-	-7.6	-3.4	-0.7	-0.8	-2.6	-5	-0.6	-3.3
Cancerspp.	0.6	-	6.8	0.2	0.3	0.2	1.9	4.5	0.6	2.5
Decapoda unid.	1	-	0.8	3.2	0.4	0.6	0.7	0.5	<0.1	0.8
Crustacea unid.	-1.8	-0.6	-0.5	-0.7	-0.3	(<0.1)	-0.2	(<0.1)	-0.2	-0.2
OSTEICHTHYES	[13.6]	[22.6]	[44.2]	[22.3]	[49.9]	[36.1]	[62.0]	[58.4]	[66.0]	[53.7]
Ophichthidae	-	-	-	-	-	-	-	1.2	-	0.5
Alosa aestivalis	-	-	-	-	-	-	3.3	-	-	0.9
Alosa pseudoharengus	-	-	-	-	-	1.7	-	4.3	-	2.1
Brevoortia tyrannus	-	-	-	-	-	0.4	-	-	-	0.1
Clupea harengus	-	-	-	-	-	2.9	-	1.3	-	1.1
Etrumeus teres	-	-	-	-	-	-	-	0.6	-	0.2
Clupeidae	-	-	-	2.5	1.6	5.4	0.3	-	-	1.3
Melanogrammus aeglefinus	-	-	-	-	-	-	1.9	-	-	0.5
Merluccius bilinearis	-	-	-	-	-	-	0.3	1.5	-	0.7
Urophycis chesteri	-	-	-	-	-	-	-	1	-	0.4
Urophycis chuss	-	-	-	-	-	-	4.3	1.5	-	1.8
Urophycissp.	-	-	-	-	-	-	5.3	-	-	1.5
Gadidae	-	<0.1	-	<0.1	<0.1	3.8	2	-	<0.1	1.4
Belonidae	-	-	-	-	8.1	-	-	-	-	0.3
Carangidae	-	-	-	-	-	-	-	1.4	-	0.5
Stenotomus chrysops	-	-	-	-	-	-	0.7	-	-	0.2
Astroscopussp.	-	-	-	-	-	-	-	0.9	-	0.4
Anarhichassp.	-	-	-	-	-	-	-	2.2	-	0.9
Ammodytes dubius	-	-	-	0.1	2.6	2.4	0.6	6.5	2	3.4
Scomber scombrus	-	-	-	-	-	-	6.3	-	-	1.8
Paralichthys dentatus	-	-	-	-	-	0.1	-	1	-	0.4
Scophthalmus aquosus	-	-	-	-	-	-	0.3	0.6	-	0.3
Symphurussp.	-	-	-	-	-	1.4	11.4	4.6	8.4	5.6
Hippoglossus hippoglossus	-	-	3.6	-	-	-	-	-	-	<0.1
Pleuronectes ferruginus	-	-	-	<0.1	-	-	-	0.4	-	0.2
Osteichthyes unid.	13.6	22.6	40.6	19.7	37.6	18	25.3	29.4	55.6	27.2
ANIMAL REMAINS AND MISC.	[59.5]	[21.8]	[8.1]	[10.1]	[25.2]	[32.0]	[7.0]	[13.5]	[8.1]	[14.9]
Number sampled	226	307	164	235	207	697	368	423	35	2662
Number empty	124	187	104	125	101	357	152	114	8	1272
Mean stomach content (g)	0.261	0.393	1.252	2.705	3.901	6.421	16.711	20.553	24.003	9.72
Mean fish length (cm)	27	34	45	55	66	75	85	94	103	78

Table 3. Diet composition of spiny dogfish by geographical area.
Data expressed as percentage of stomach content by weight. Squared brackets indicate major taxon subtotal; parentheses indicate minor taxon subtotal. Source: Bowman *et al*. (2000); from NEFSC groundfish surveys, 1977-1980.

Stomach Contents	Geographic Area						
	Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine	Scotian Shelf	Inshore South of Cape Hatteras	Inshore North of Cape Hatteras
CTENOPHORA	[0.1]	[0.4]	[0.1]	[0.3]	[<0.1]	-	[2.6]
MOLLUSCA	[22.6]	[36.7]	[25.8]	[27.9]	[26.3]	[5.3]	[12.1]
Bivalvia	-17.3	-13.6	-7.3	-	-	-1.9	-2.8
Pectinidae	3.6	9.4	4.6	-	-	-	2.1
Bivalvia unid.	13.7	4.2	2.7	-	-	1.9	0.7
Cephalopoda	-5	-22.4	-17.2	-24.7	-26.3	-3.4	-9.1
Illexsp.	-	7.3	1.7	13.9	-	-	4.2
Loligosp.	-	6.6	5.3	-	-	1.3	4.1
Cephalopoda unid.	5	8.5	10.2	10.8	26.3	2.1	0.8
Mollusca unid.	-0.3	-0.7	-1.3	-3.2	(<0.1)	-	-0.2
CRUSTACEA	[1.3]	[1.3]	[5.7]	[3.5]	[0.4]	[1.6]	[14.5]
Euphausiacea	(<0.1)	(<0.1)	(<0.1)	-3.4	-0.2	-	-1.8
Decapoda	-1.3	-1.1	-5.7	-0.1	-0.1	-1.6	-11.9
Cancerspp.	1	1.1	4.5	-	<0.1	-	9.5
Decapoda unid.	0.3	<0.1	1.2	0.1	0.1	1.6	2.4
Crustacea unid.	(<0.1)	-0.2	(<0.1)	(<0.1)	-0.1	-	-0.8
OSTEICHTHYES	[72.7]	[55.8]	[49.9]	[40.9]	[30.6]	[92.4]	[60.4]
Ophichthidae	-	-	-	-	-	14.3	-
Alosa aestivalis	-	-	3.9	-	-	-	-
Alosa pseudoharengus	-	6.6	0.9	0.7	-	-	-
Brevoortia tyrannus	-	-	-	-	1.1	-	-
Clupea harengus	-	1.9	-	-	-	-	6
Etrumeus teres	2	-	-	-	-	-	-
Clupeidae	-	1	<0.1	1	-	-	8.7
Melanogrammus aeglefinus	-	2.1	-	-	-	-	-
Merluccius bilinearis	-	1.2	1.4	-	-	-	-
Urophycis chesteri	-	1.6	-	-	-	-	-
Urophycis chuss	-	2.3	5	-	-	-	-
Urophycissp.	0.1	5.6	-	-	-	-	-
Gadidae	-	5.2	<0.1	-	-	-	-
Belonidae	-	-	-	1.7	-	-	-
Carangidae	-	-	-	-	-	-	5.5
Stenotomus chrysops	-	0.7	-	-	-	-	-
Astroscopussp.	-	-	-	-	-	10.7	-
Anarhichassp.	-	-	-	4.9	-	-	-
Ammodytes dubius	3.6	2.1	0.5	12.2	-	0.1	1
Scomber scombrus	-	-	-	-	25.8	-	-
Paralichthys dentatus	-	1.5	0.1	-	-	-	-
Scophthalmus aquosus	-	0.9	-	-	-	2.2	-
Symphurussp.	47.4	-	-	-	-	-	-
Hippoglossus hippoglossus	-	-	0.1	-	-	-	-
Pleuronectes ferruginus	-	-	-	0.9	-	-	<0.1
Osteichthyes unid.	19.6	23.1	38	19.5	3.7	65.1	39.2
ANIMAL REMAINS AND MISC.	[3.3]	[5.8]	[18.5]	[27.4]	[42.7]	[0.7]	[10.4]
Number sampled	276	735	783	417	238	17	196
Number empty	150	407	353	190	112	0	60
Mean stomach content (g)	9.464	7.787	6.783	9.395	6.351	43.469	11.083
Mean fish length (cm)	62	58	65	76	74	93	84

Table 4. Summary of habitat parameters for spiny dogfish based on the pertinent literature.

Life Stage	Depth	Substrate	Salinity	Temperature/Season
Spawning Adults [1]	Outer continental shelf, 41-400 m.	Pelagic or demersal	Oceanic	Late fall to winter
Juveniles	As in adults	Juveniles are mainly pelagic.	Oceanic	See adults
Adults [2]	In eastern Long Island Sound, 25-40 m. On the Scotian Shelf depth range 36-364 m, preferred depths 36-53 and 128-180 m. Off New Zealand caught at 100-300 m.	Adults are demersal at times, swimming over areas of sand, silt, and mud where food is available. In eastern Long Island Sound, they are found in areas of sand, sand waves, mud, and transitional sand-mud bottoms. On the Scotian Shelf, glacial till, sand and gravel, sand, silt, and clay. Off New Zealand, sand or silt-mud bottoms.	On the Scotian Shelf, salinity range 31-34 ppt, preferred 33.5 ppt. In eastern Long Island Sound, mean salinity 30-32 ppt.	In Long Island Sound, 7-13°C in spring and autumn. Scotian Shelf in summer, range 3-11°C, preferred 6-9°C. Off New Zealand 6.5-10 °C.

Table 4. Cont'd.

Life Stage	Prey	Predators / Species Associations
Juveniles[3]	On the northwest Atlantic shelf they prey upon ctenophores, salps, scallops, squid, euphausiids, *Cancer* spp. crabs, Clupeidae (herring) bay anchovies, Gadidae (hakes), Ammodytidae (sand lances), Scombridae (mackerel), butterfish, and halibut. Most fish prey are unidentifiable. On the United States and Canada west coast they eat plankton, octopus, squid, amphipods, euphausiids, shrimp, Clupeidae, and Ammodytidae. In the Irish Sea they prey upon ctenophores, amphipods, euphausiids, mud shrimps, ghost shrimps, hermit crabs, Clupeidae, Gadidae, Ammodytidae, and Scombridae. On the continental shelf of Argentina, juvenile spiny dogfish feed pelagically, mainly upon fish and ctenophores. In the Black Sea they consume whiting, red mullet, black goby, sprat, crangonid shrimp, and other crustaceans. Off New Zealand they prefer squat lobster postlarvae, euphausiids, and lesser amounts of other crabs and fish.	Predators are larger spiny dogfish and other species that prey upon adult spiny dogfish. Associated or competing species of small and medium dogfish belong, as well as they do, to a guild of mainly planktonic predators, including longfin squid, Atlantic herring, mackerel, alewife and butterfish.
Adults[4]	Throughout the northwest Atlantic shelf, adults feed on scallops, other bivalves, squid, crabs, shrimp, Clupeidae (herring), and Gadidae (hakes). Scombridae (mackerel) are among the prey consumed on the Scotian Shelf. Squid, Ammodytidae (sand lances) and Belonidae (needlefish) are important in the diets in the Gulf of Maine. On Georges Bank the primary prey are squid, *Cancer* spp. crabs, Clupeidae, and Gadidae. In southern New England and the middle Atlantic waters the prey are much the same, and additionally fish such as butterfish and Sciaenidae (spot, croaker, and weakfish). Other reported prey taxa in the northwest Atlantic include gastropods, octopus, ctenophores, jellyfish, polychaetes, sipunculids, amphipods, sea cucumbers, blennies, sculpins, and Pleuronectiformes (flatfish and tonguefish). Off South Carolina they consume menhaden, among other fish. On the west coast of the United States and Canada they consume plankton, ctenophores, euphausiids, shrimp, brachyuran crabs, Chimaeridae, Clupeidae, Gadidae, and Pleuronectiformes. In the waters surrounding Great Britain they consume ctenophores, crustaceans, Clupeidae, Gadidae, Ammodytidae, and Scombridae. On the continental shelf of Argentina, they feed mainly upon squid, Argentine hake, southern cod, Falkland herring, octopods, and comb jellies. In the Black Sea, they feed on whiting, red mullet, black goby, sprat, crangonid shrimp, and other crustaceans. Off New Zealand they eat crustaceans and fish, eating proportionally more fish as their size increases.	Predators in the northwest Atlantic include larger sharks, white hake, goosefish, Atlantic cod, striped bass, whales, killer whales, seals, dolphins, and other large fishes. Competitors include the above predator species when they are comparable in size to the dogfish. Large dogfish belong to a trophic guild of fish predators that includes thorny skate, Atlantic sharpnose shark, red hake, spotted hake, Atlantic cod, silver hake, sea raven, goosefish, summer flounder, fourspot flounder, and bluefish. These can be thought of as associated or competing species.
Spawning Adults	Same as adults.	Same as adults.

[1] NEFSC trawl surveys.
[2] Scott (1982a, 1982b); Jacob *et al*. (1998); Gottschall *et al*. (2000); Shepherd *et al*. (2002).
[3] Jones and Green (1977); Bowman *et al*. (1984); Hanchet (1991); Ellis *et al*. (1996); Garrison and Link (2000a, b); Avsar (2001); Laptikhovsky *et al*. (2001); Burgess (2002); Alonso *et al*. (2002), Link *et al*. (2002).
[4] Holden (1966); Jones and Green (1977); Bowman *et al*. (1984); Hanchet (1991); Ellis *et al*. (1996); Garrison and Link (2000a, b); Avsar (2001); Laptikhovsky *et a*l. (2001); Burgess (2002); Alonso *et al*. (2002); Link *et al*. (2002).

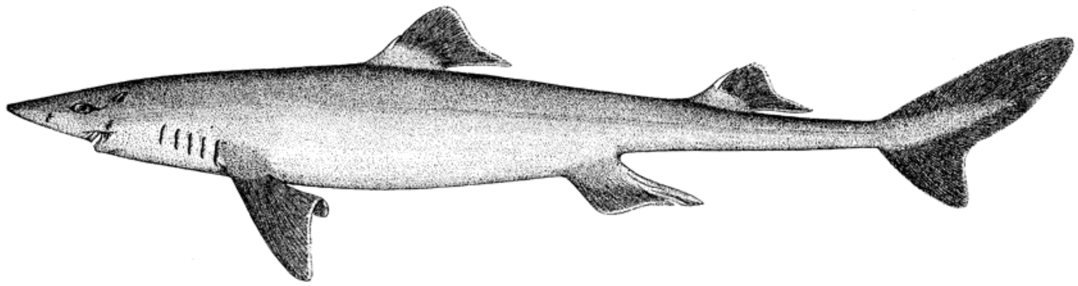
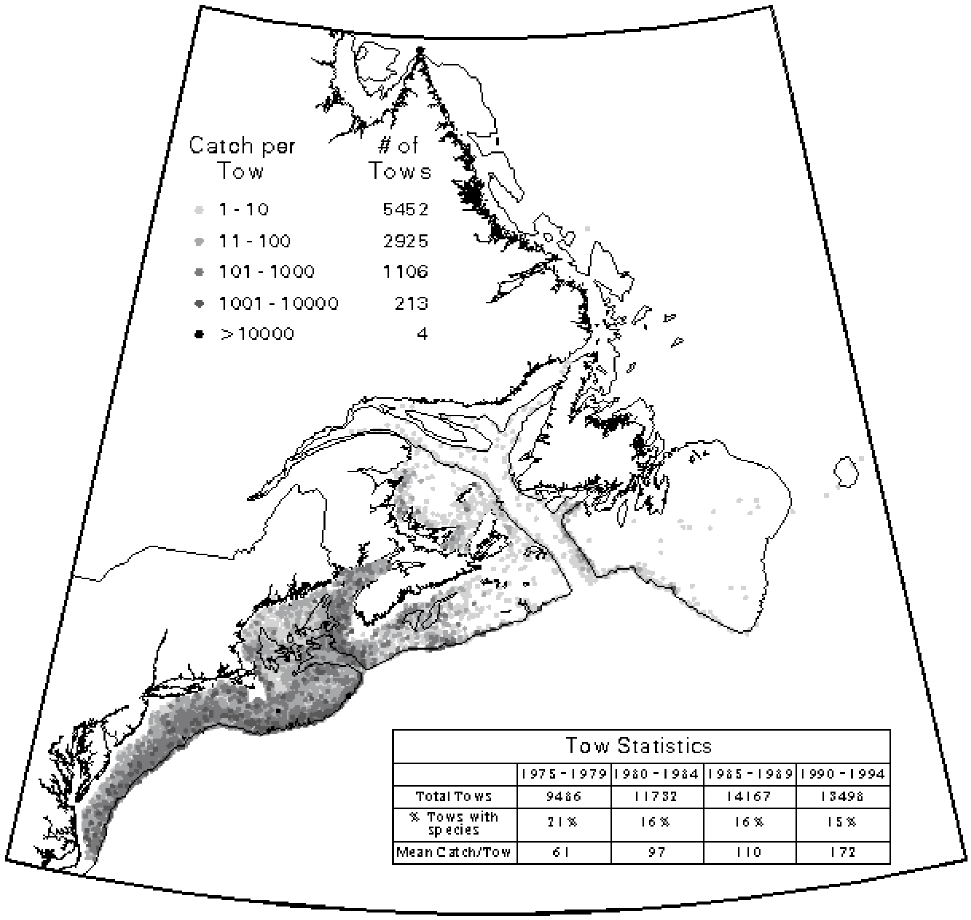


Figure 1. The spiny dogfish, *Squalus acanthias* (from Goode 1884).



Tow Statistics				
	1975 - 1979	1980 - 1984	1985 - 1989	1990 - 1994
Total Tows	9486	11732	14167	13498
% Tows with species	21 %	16 %	16 %	15 %
Mean Catch/Tow	61	97	110	172

Figure 2. Overall distribution and abundance of spiny dogfish in the northwest Atlantic Ocean. Based on research trawl surveys conducted by Canada (DFO) and the United States (NMFS) from 1975-1994.

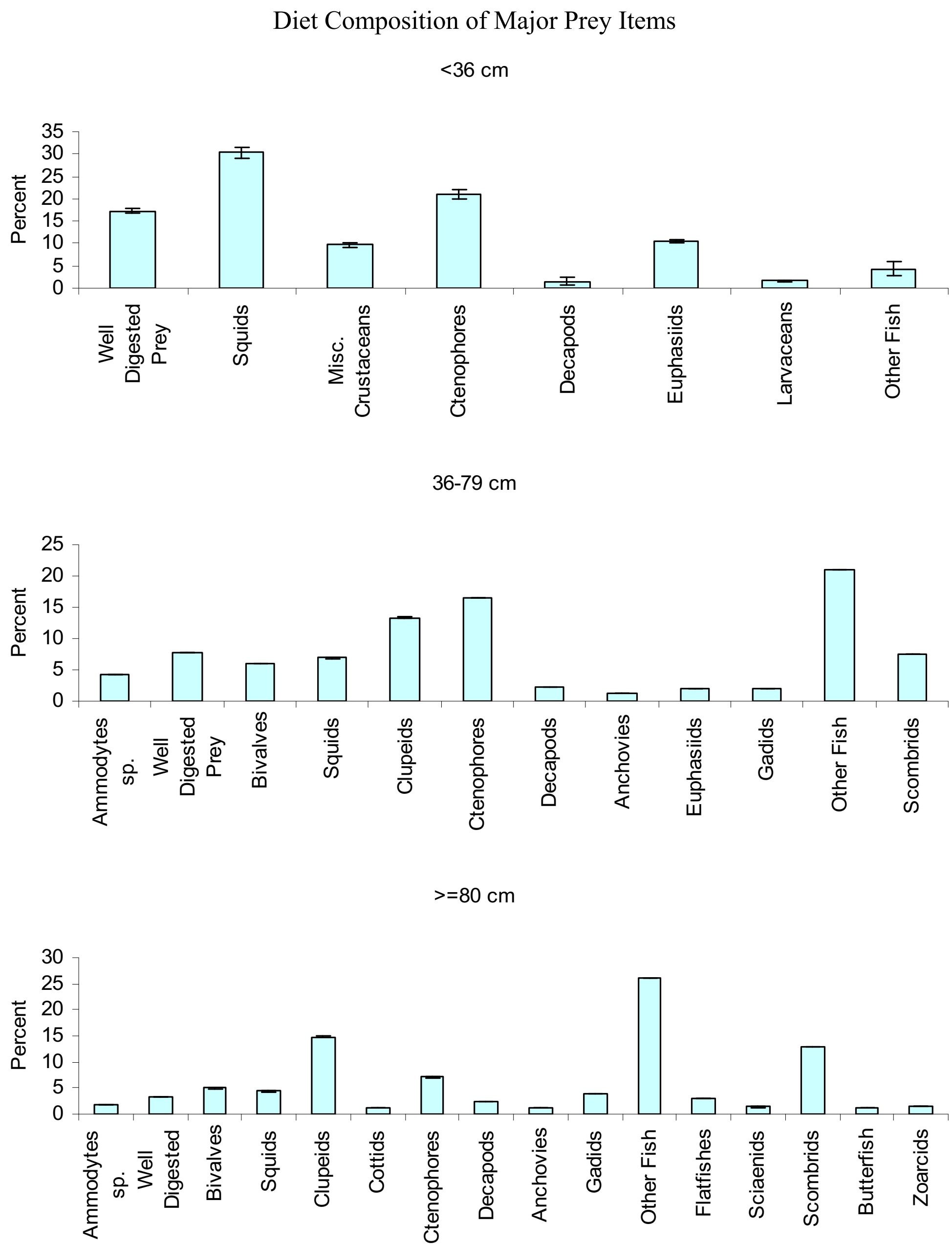


Figure 3. Percent by weight of the major prey items in the diet of three size categories of spiny dogfish. Specimens were collected during NEFSC bottom trawl surveys from 1973-2001 (all seasons). For details on NEFSC diet analysis, see Link and Almeida (2000).

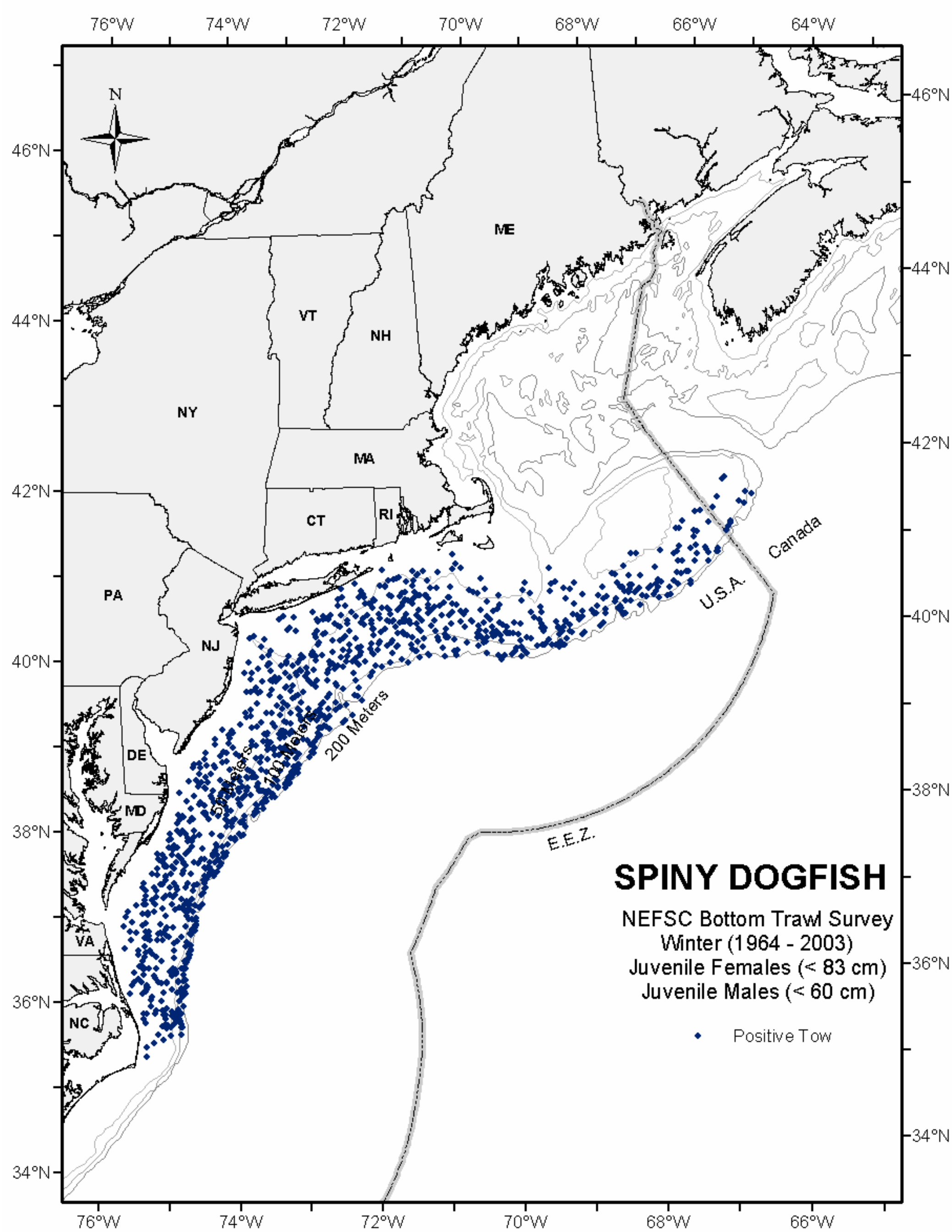


Figure 4. Seasonal distributions and abundances of juvenile spiny dogfish collected during NEFSC bottom trawl surveys.
Based on NEFSC winter bottom trawl surveys (1964-2003, all years combined). Distributions are displayed as presence (positive tows) only.

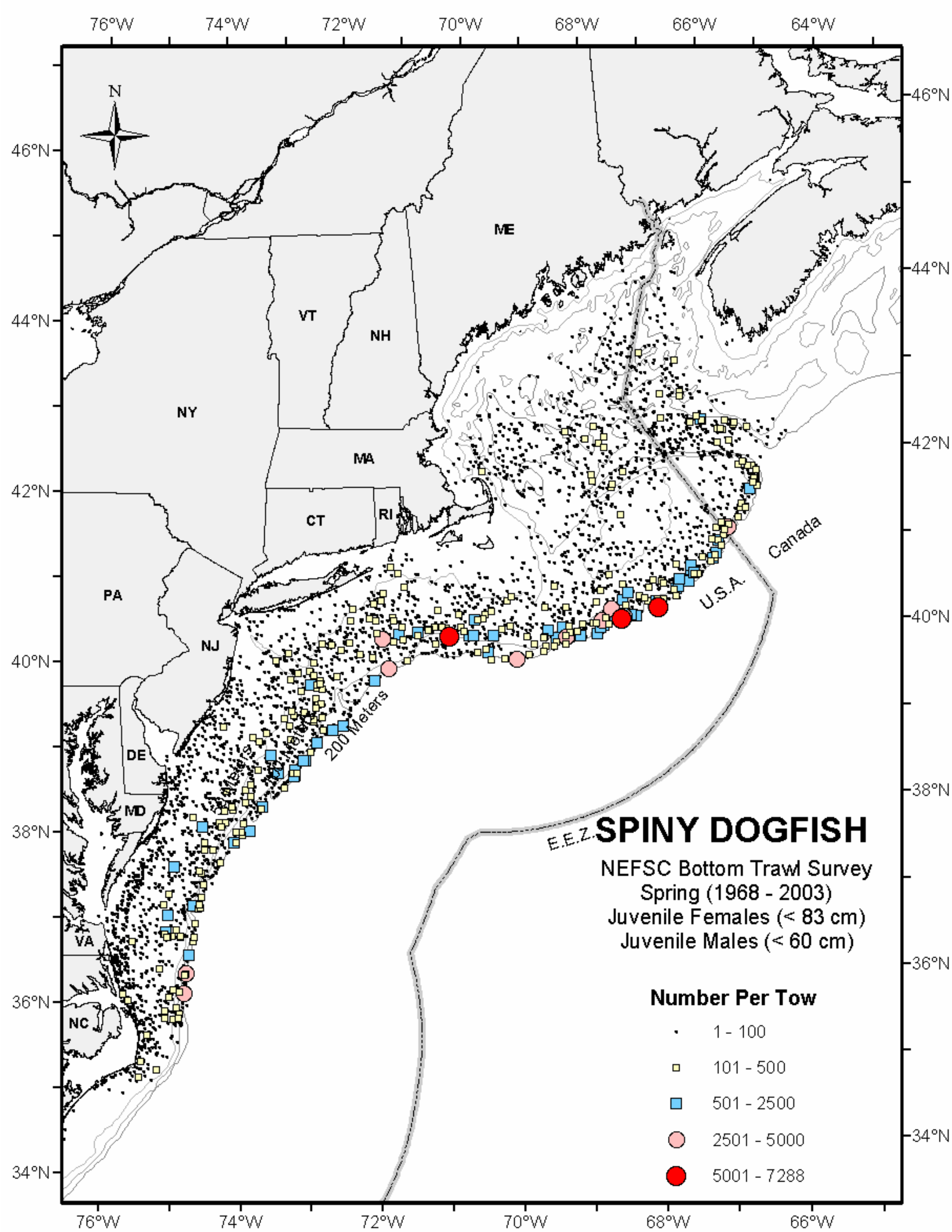


Figure 4. Cont'd.
Based on NEFSC spring bottom trawl surveys (1968-2003, all years combined). Survey stations where juveniles were not found are not shown.

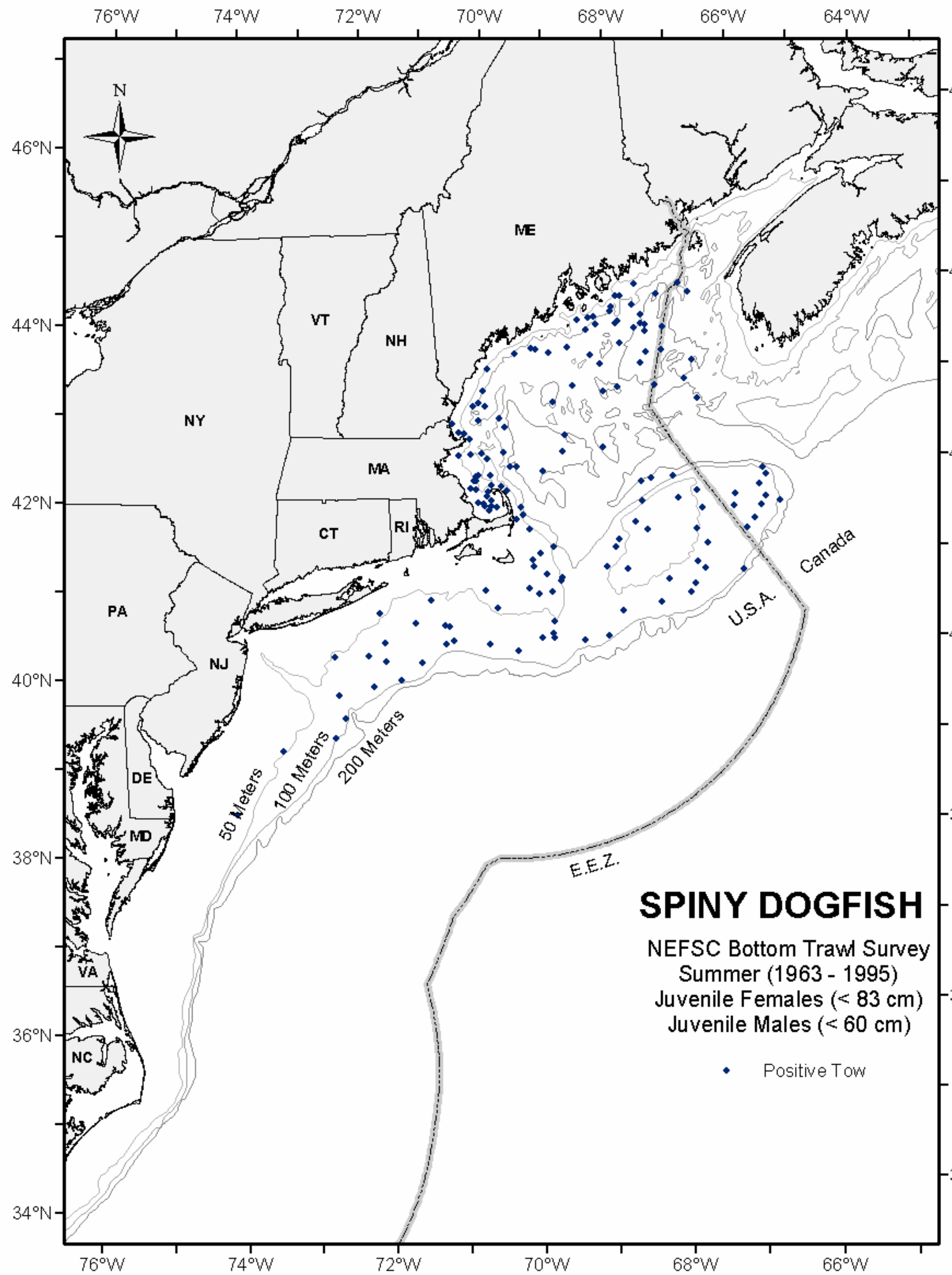


Figure 4. Cont'd.
Based on NEFSC summer bottom trawl surveys (1963-1995, all years combined). Distributions are displayed as presence only.

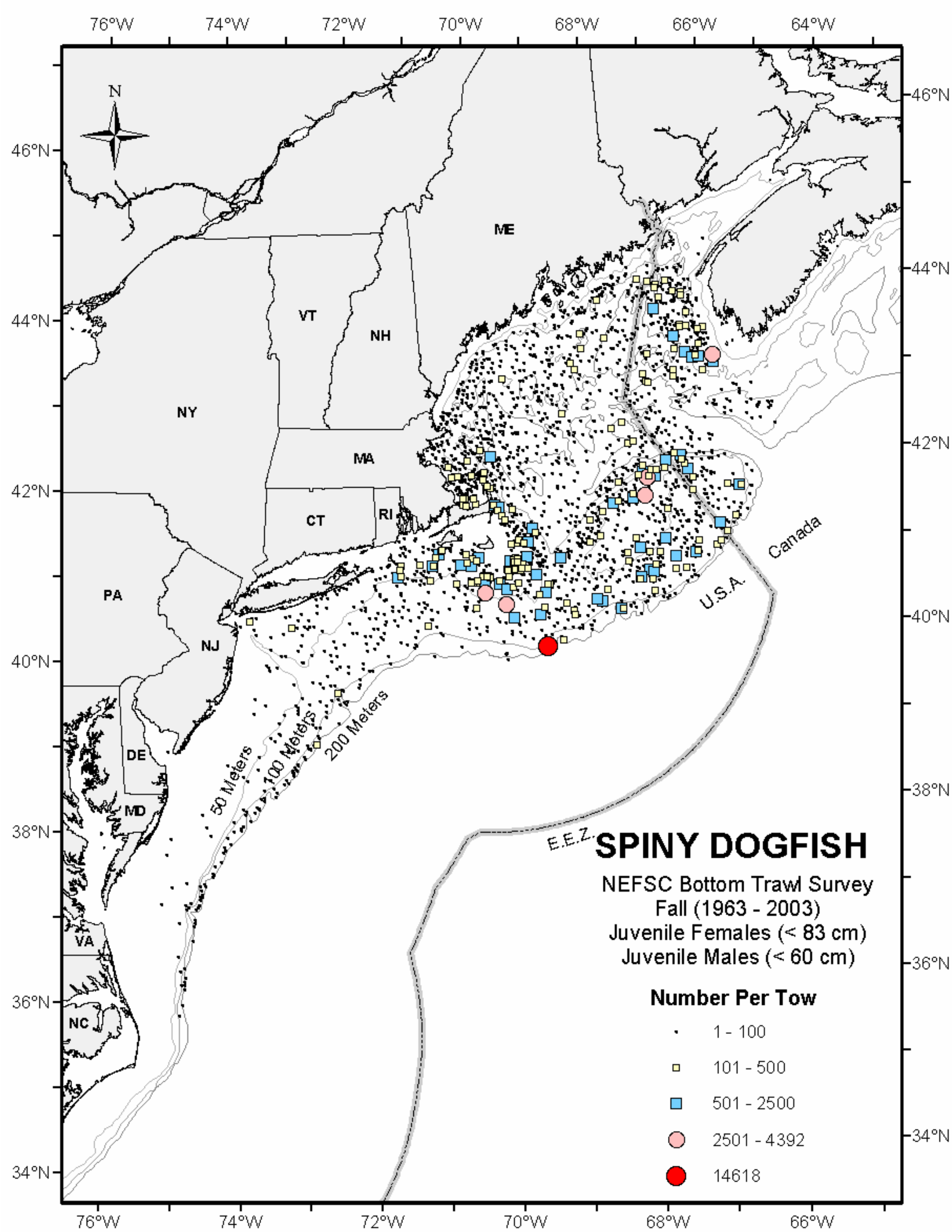


Figure 4. Cont'd.
Based on NEFSC fall bottom trawl surveys (1963-2003, all years combined). Survey stations where juveniles were not found are not shown.

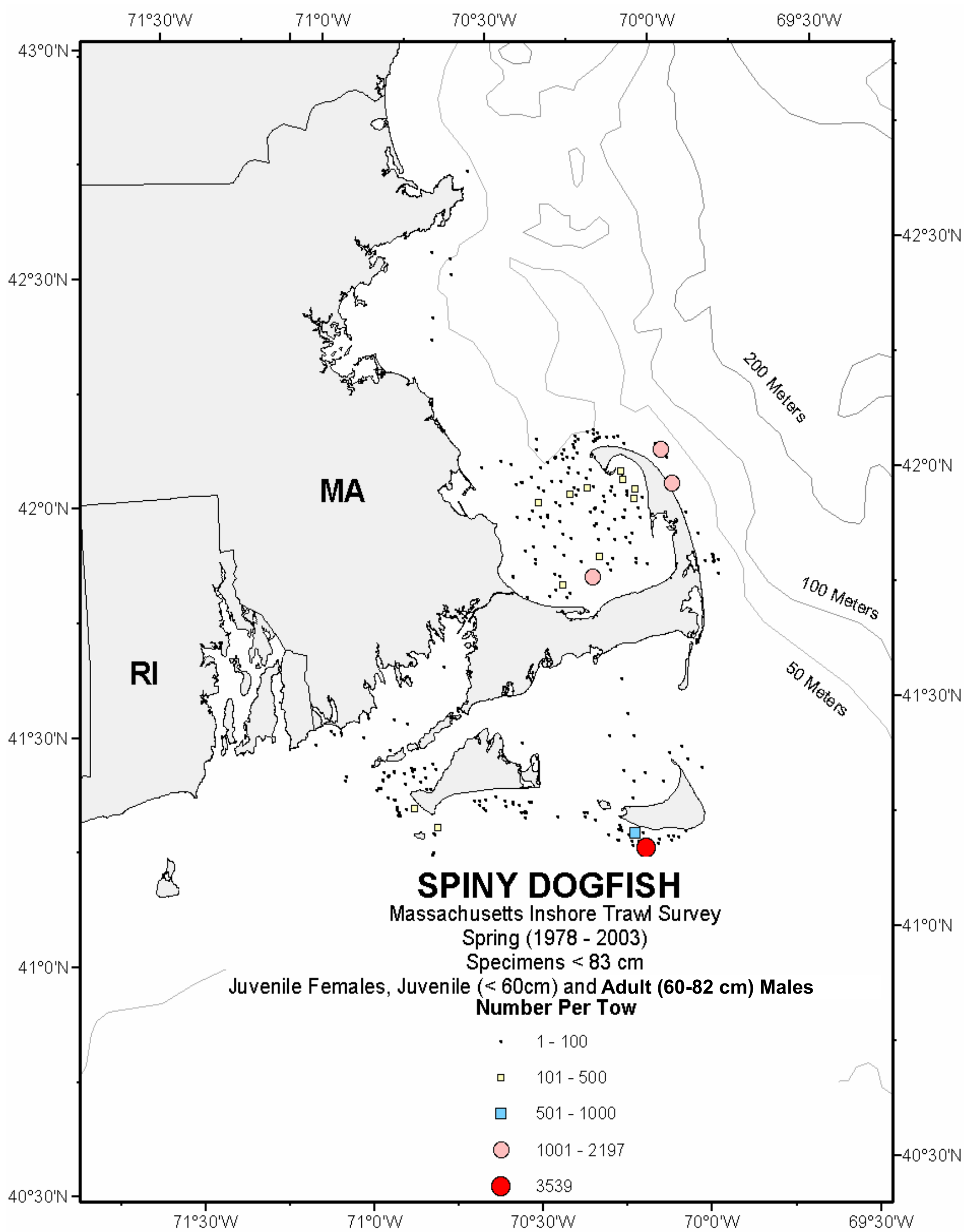


Figure 5. Seasonal distributions and abundances of juvenile and small adult male spiny dogfish in Massachusetts coastal waters.
Based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where juveniles were not found are not shown.

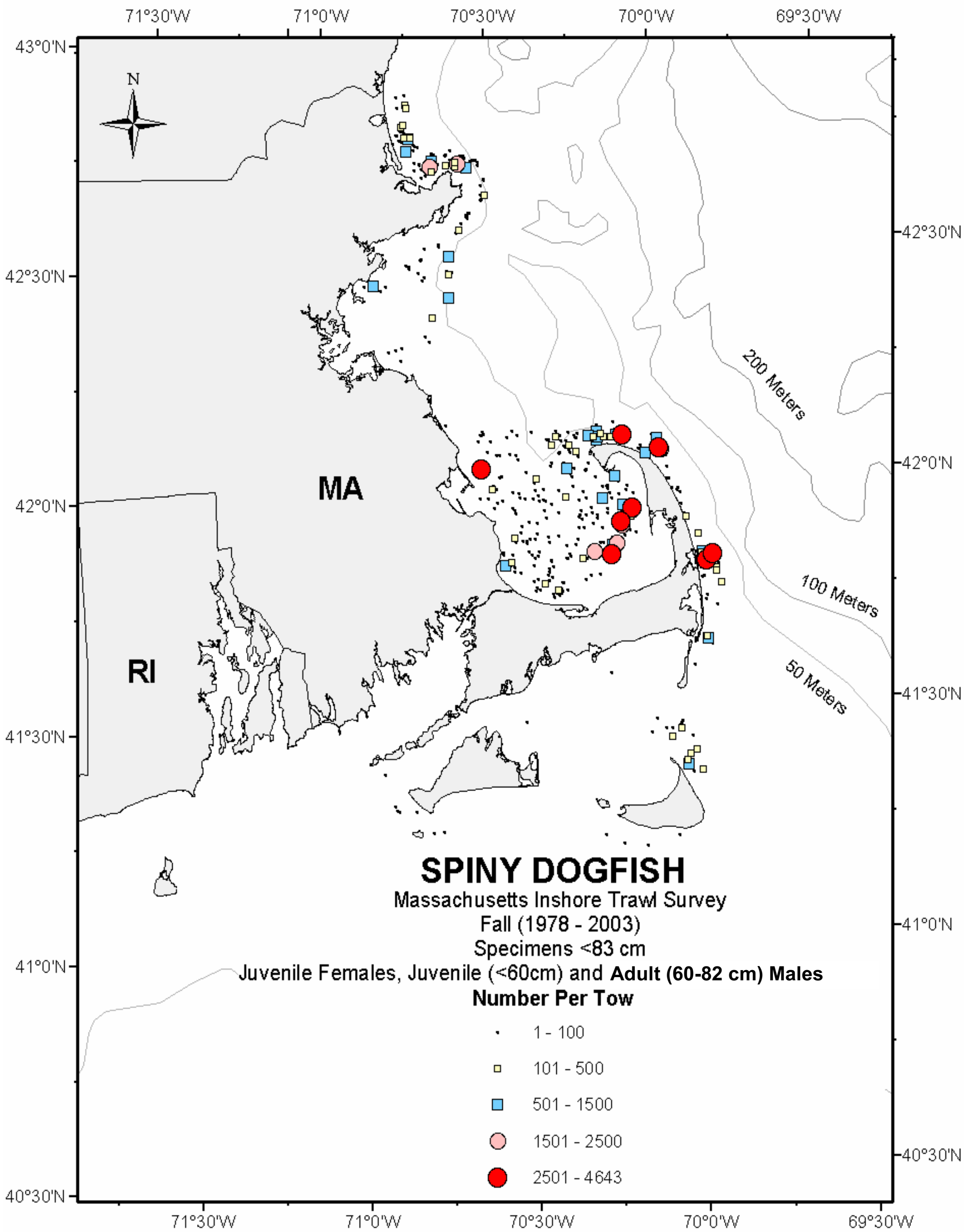


Figure 5. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where juveniles were not found are not shown.

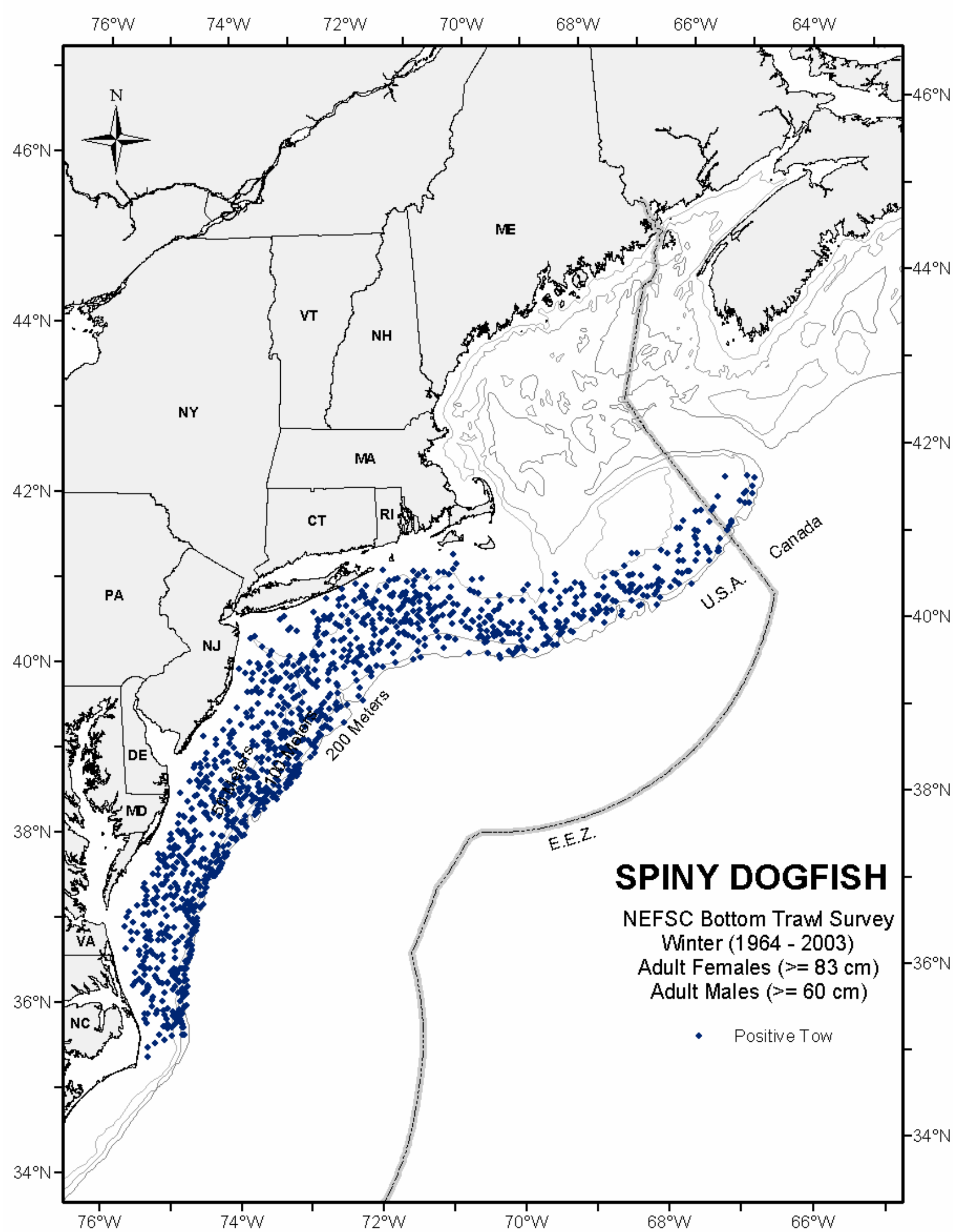


Figure 6. Seasonal distributions and abundances of adult spiny dogfish collected during NEFSC bottom trawl surveys. Based on NEFSC winter bottom trawl surveys (1964-2003, all years combined). Distributions are displayed as presence only.

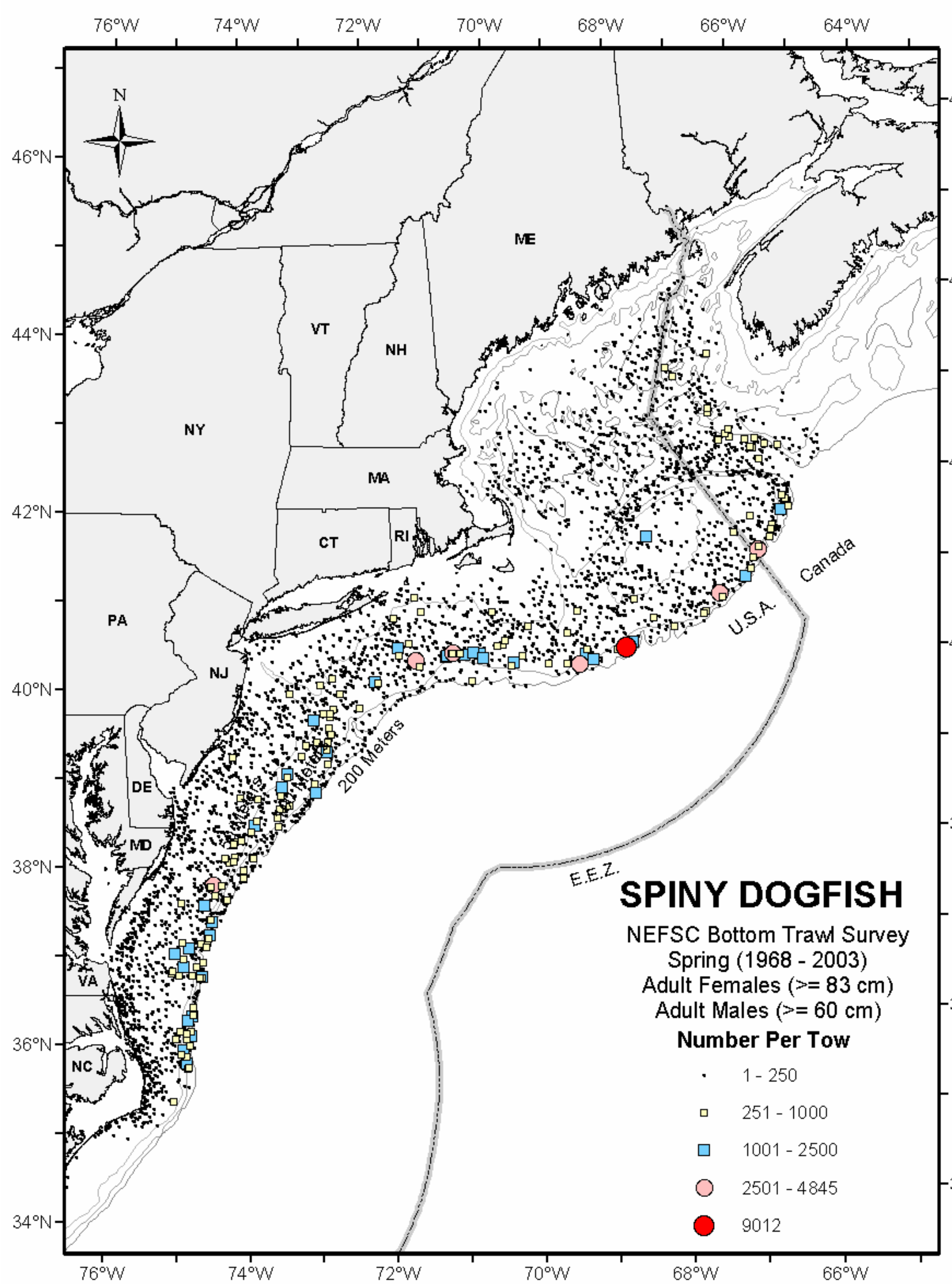


Figure 6. Cont'd.
Based on NEFSC spring bottom trawl surveys (1968-2003, all years combined). Survey stations where adults were not found are not shown.

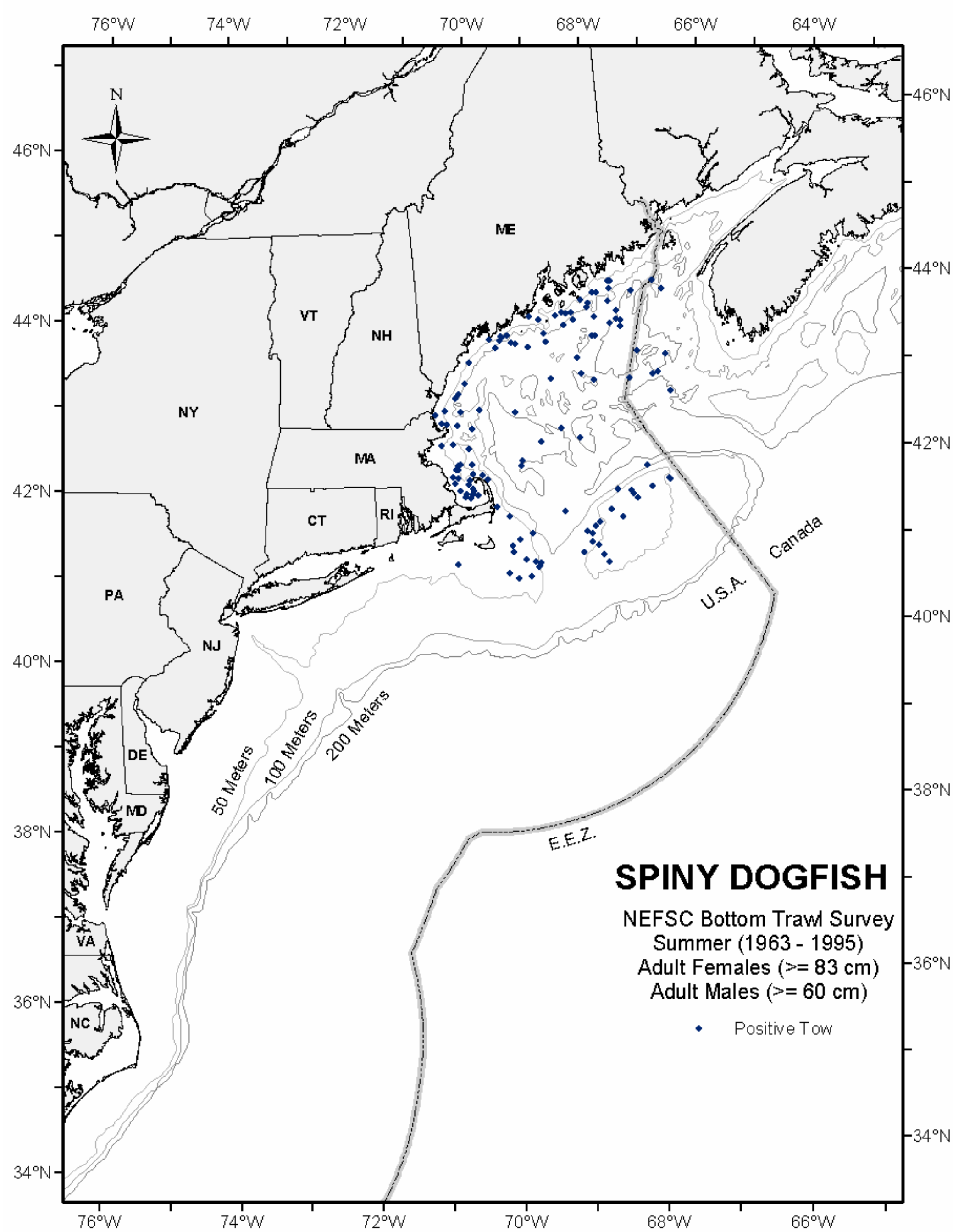


Figure 6. Cont'd.
Based on NEFSC summer bottom trawl surveys (1963-1995, all years combined). Distributions are displayed as presence only.

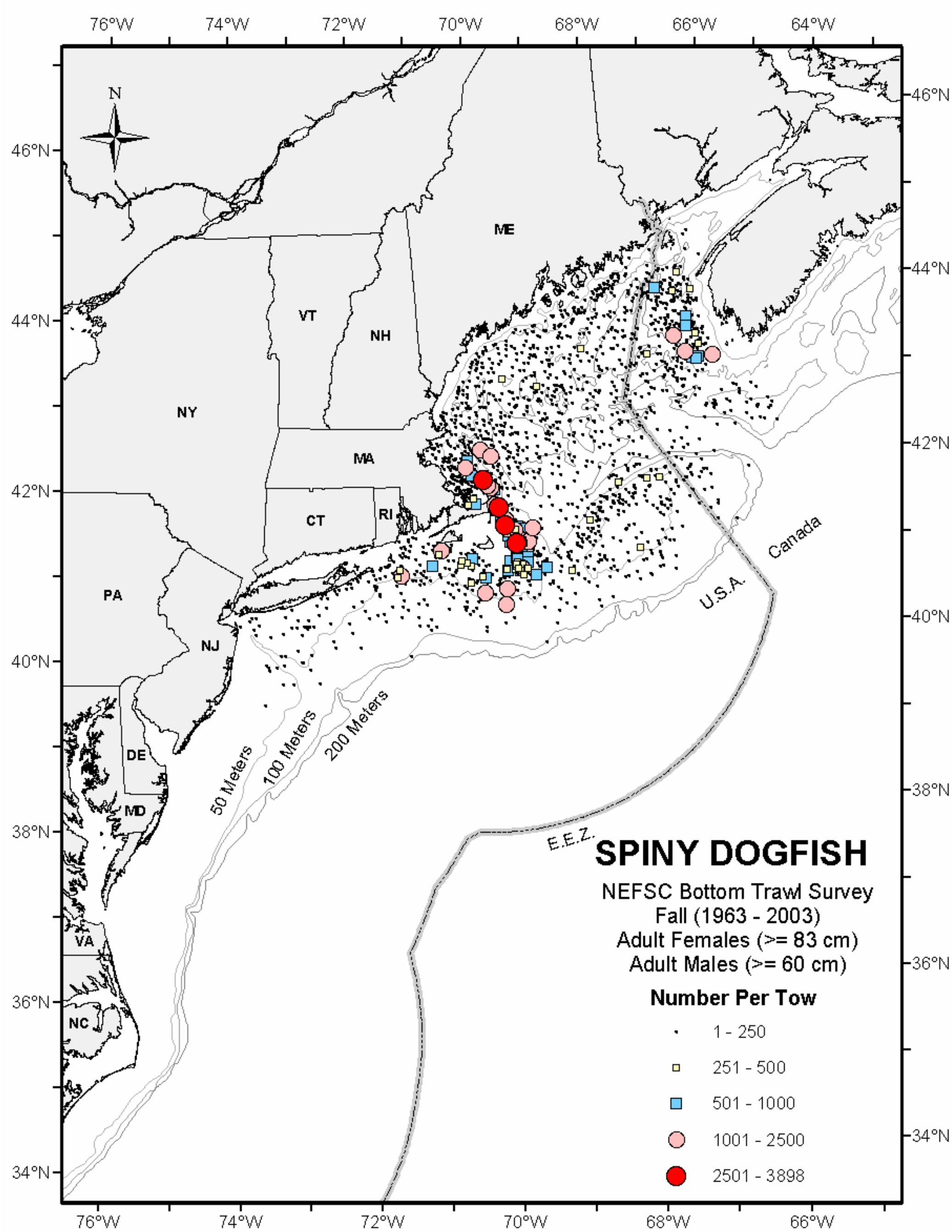


Figure 6. Cont'd.
Based on NEFSC fall bottom trawl surveys (1963-2003, all years combined). Survey stations where adults were not found are not shown.

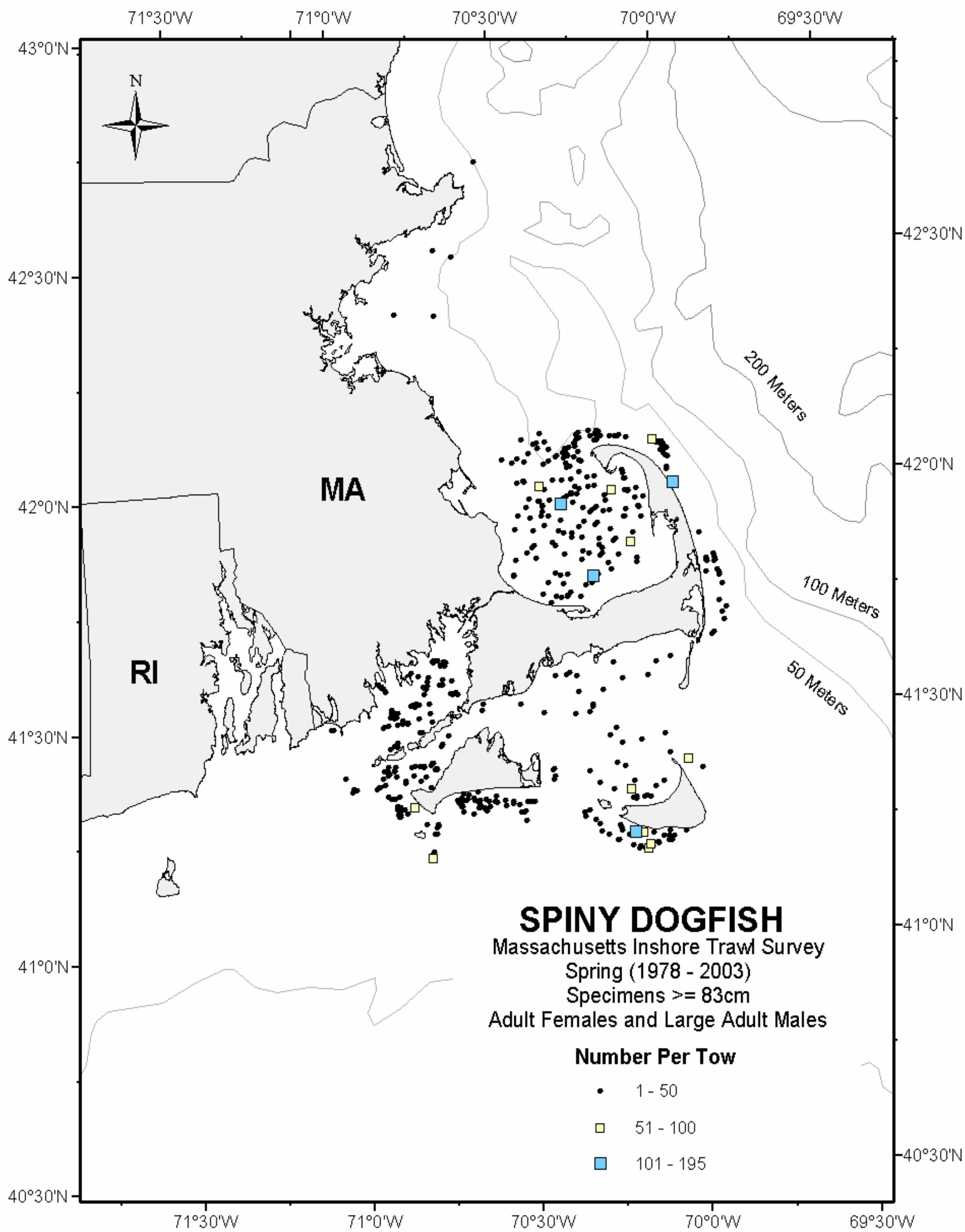


Figure 7. Seasonal distributions and abundances of adult spiny dogfish in Massachusetts coastal waters. Based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where adults were not found are not shown.

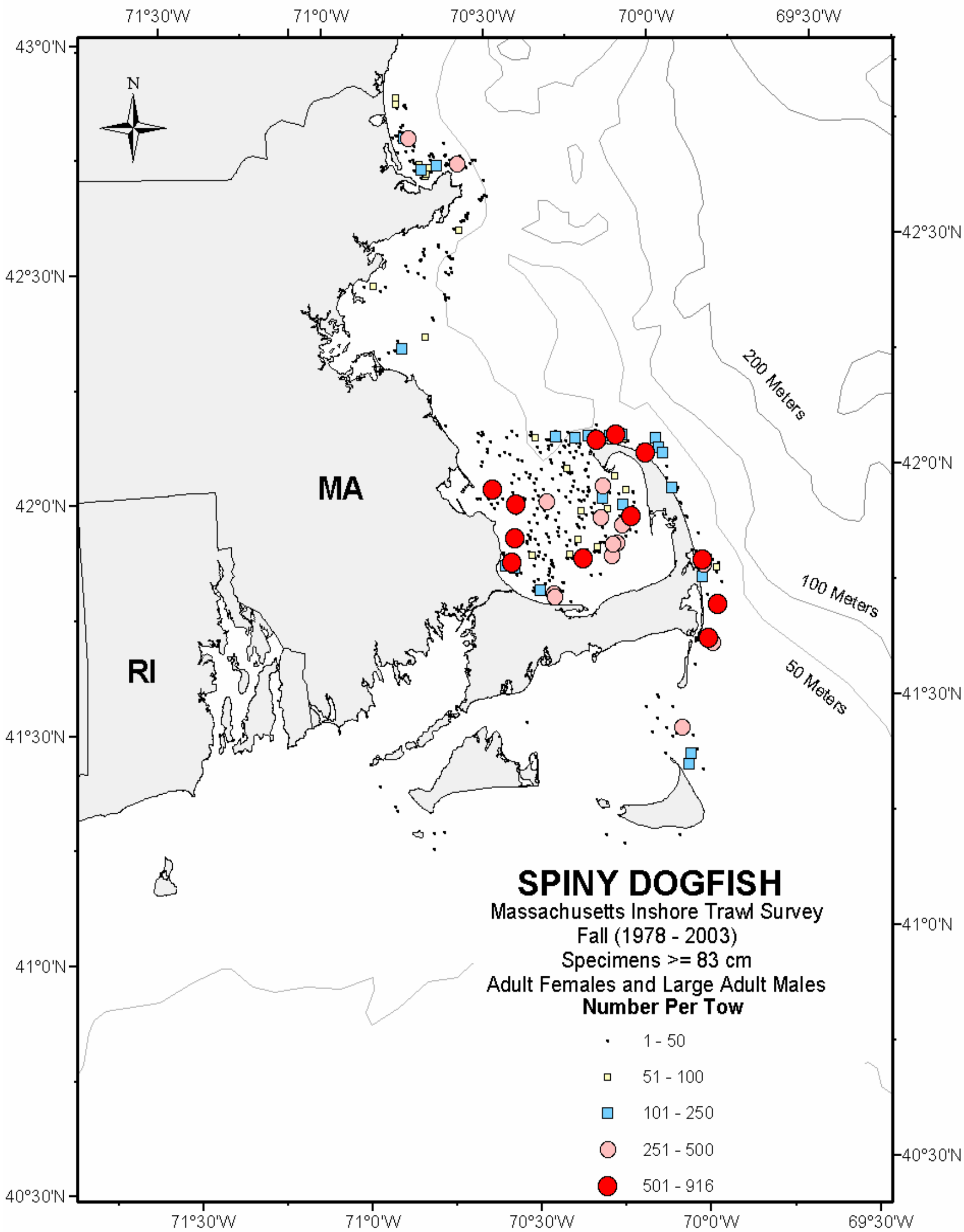


Figure 7. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where adults were not found are not shown.

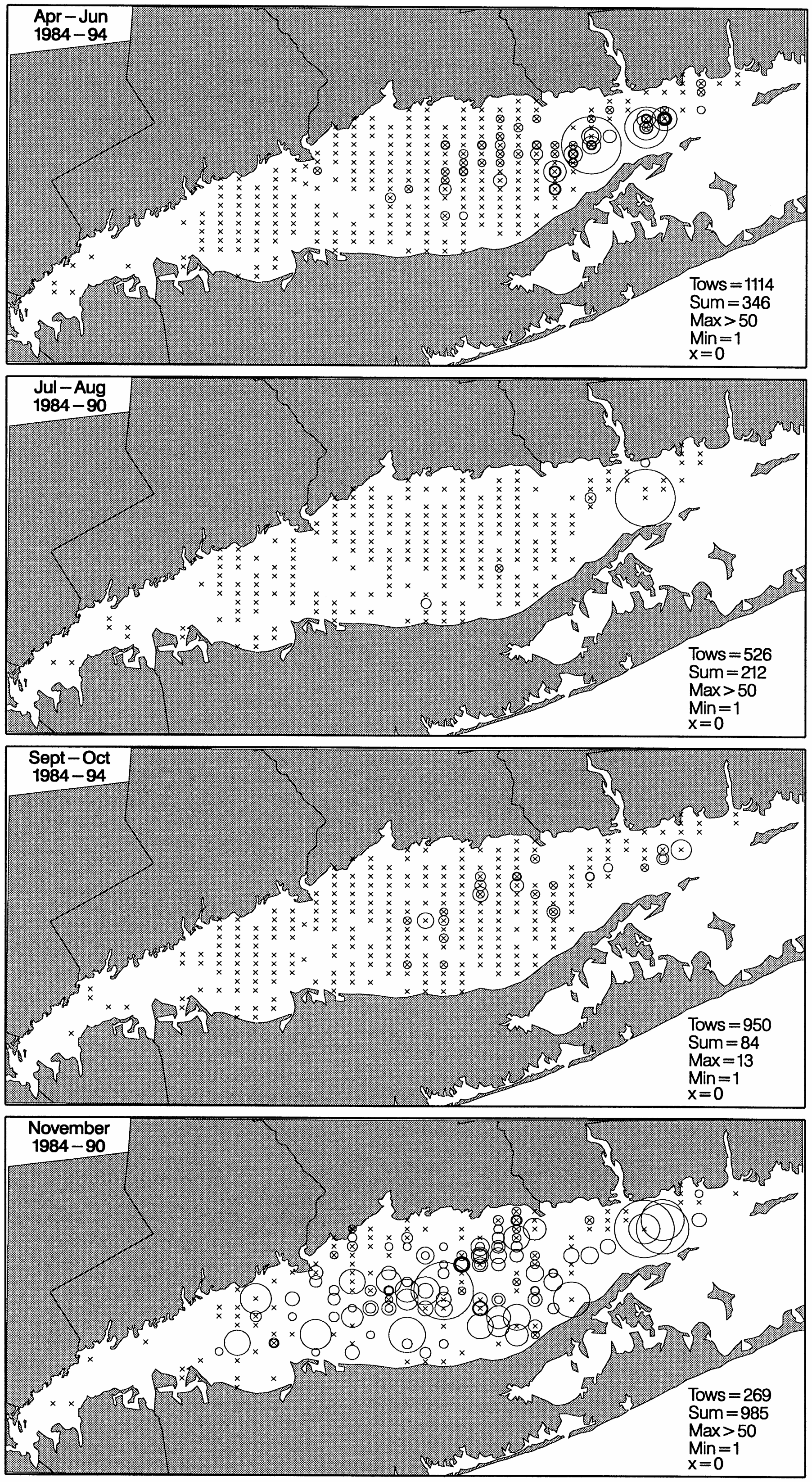
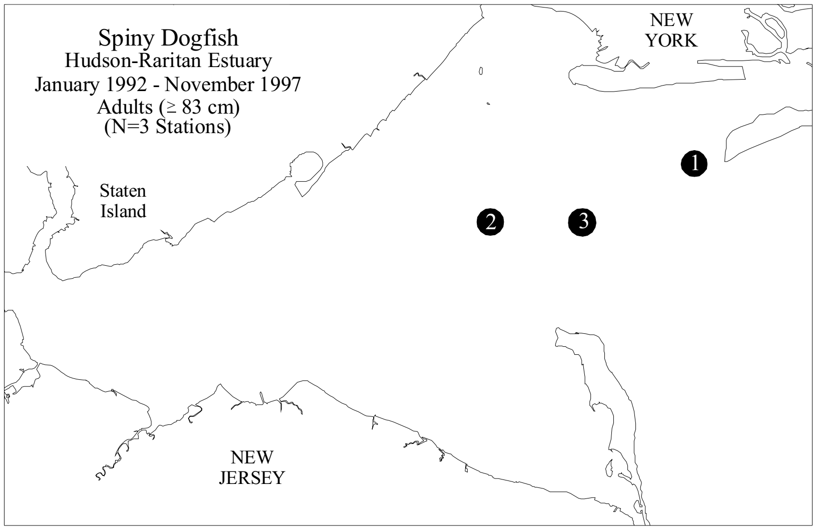


Figure 8. Distributions and abundances of juvenile and adult spiny dogfish in Long Island Sound. Based on 1,627 fish taken in 2,859 tows during the finfish surveys of the Connecticut Fisheries Division, 1984-1994. The largest circle size represents a tow with a catch of > 50 specimens. Source: Gottschall *et al.* (2000).



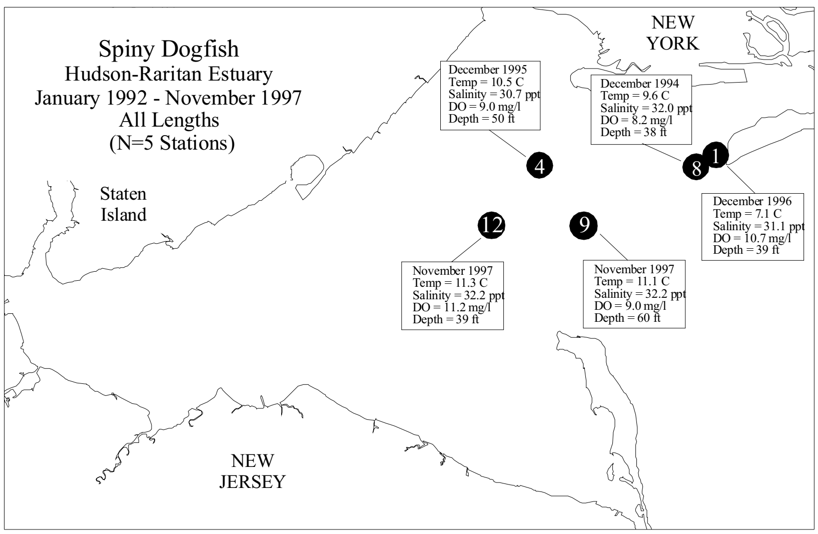


Figure 9. Distributions and abundances of adult (≥ 83 cm) and all lengths of spiny dogfish in the Hudson-Raritan estuary.
Based on Hudson-Raritan trawl surveys, 1992-1997 [see Reid *et al.* (1999) for details].

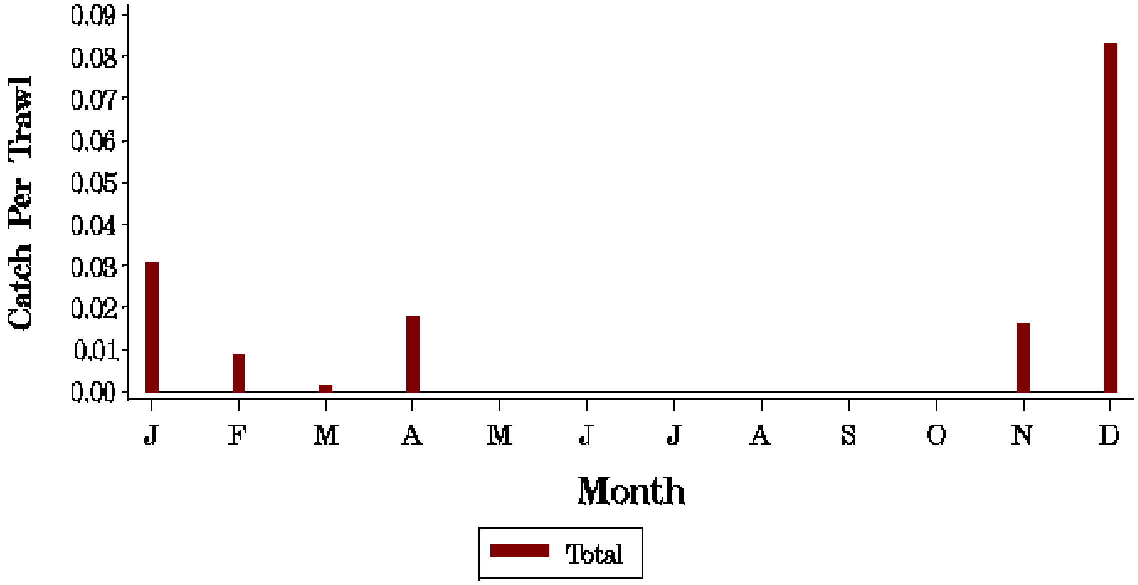


Figure 10. Catch per unit effort for total catch of spiny dogfish in the lower Chesapeake Bay and tributaries. Based on the Virginia Institute of Marine Science's (VIMS) trawl surveys, 1988-1999 (all years combined). Source: Geer (2002).

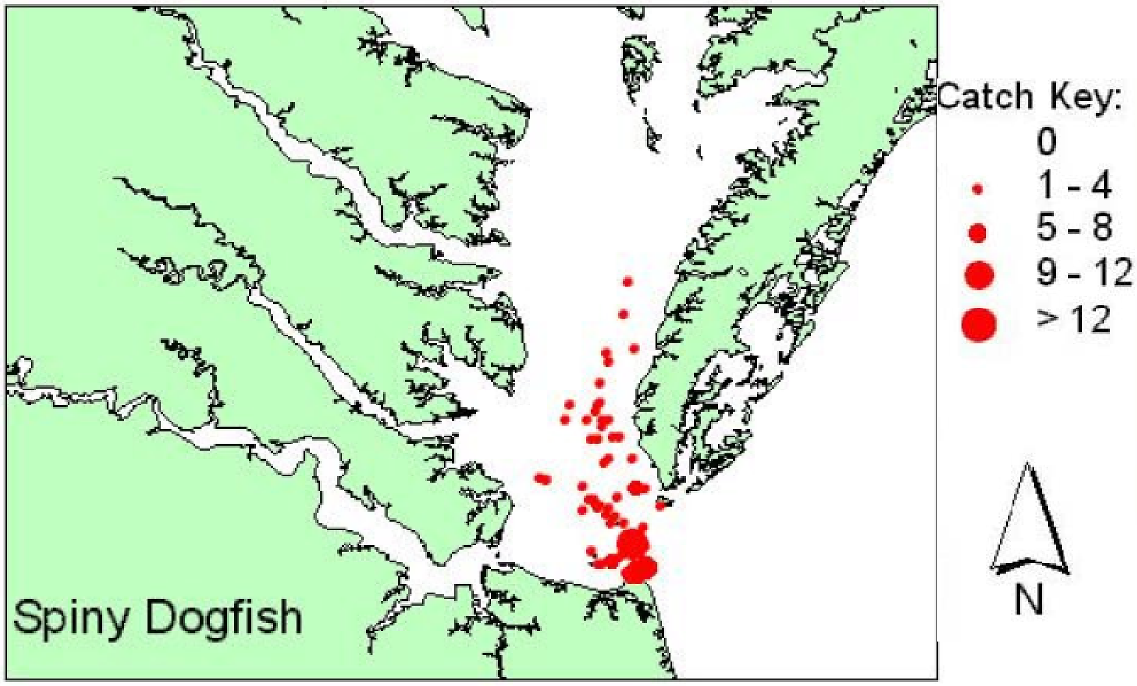


Figure 11. Distribution and abundance of spiny dogfish in the lower Chesapeake Bay and tributaries. Based on the VIMS trawl surveys, 1988-1999 (all years combined). Monthly surveys were conducted using a random stratified design of the main stem of the Bay using a 9.1 m semi-balloon otter trawl with 38 mm mesh and 6.4 mm cod end with a tow duration of five minutes. Source: Geer (2002).

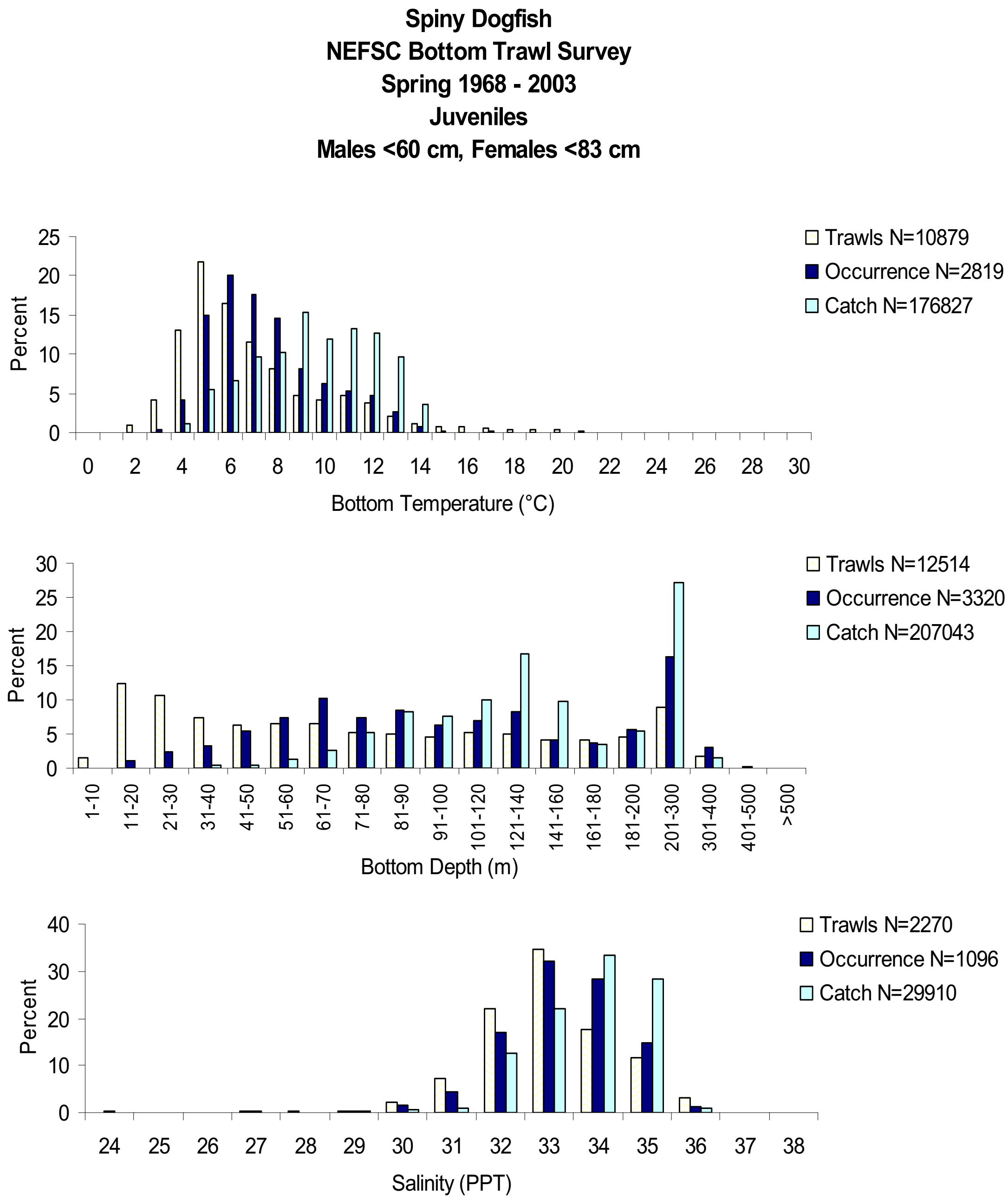


Figure 12. Distributions of juvenile spiny dogfish and trawls from NEFSC bottom trawl surveys relative to bottom water temperature, depth, and salinity.
Based on NEFSC spring bottom trawl surveys (temperature and depth: 1968-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which spiny dogfish occurred and medium bars show, within each interval, the percentage of the total number of spiny dogfish caught. Note that the bottom depth interval changes with increasing depth.

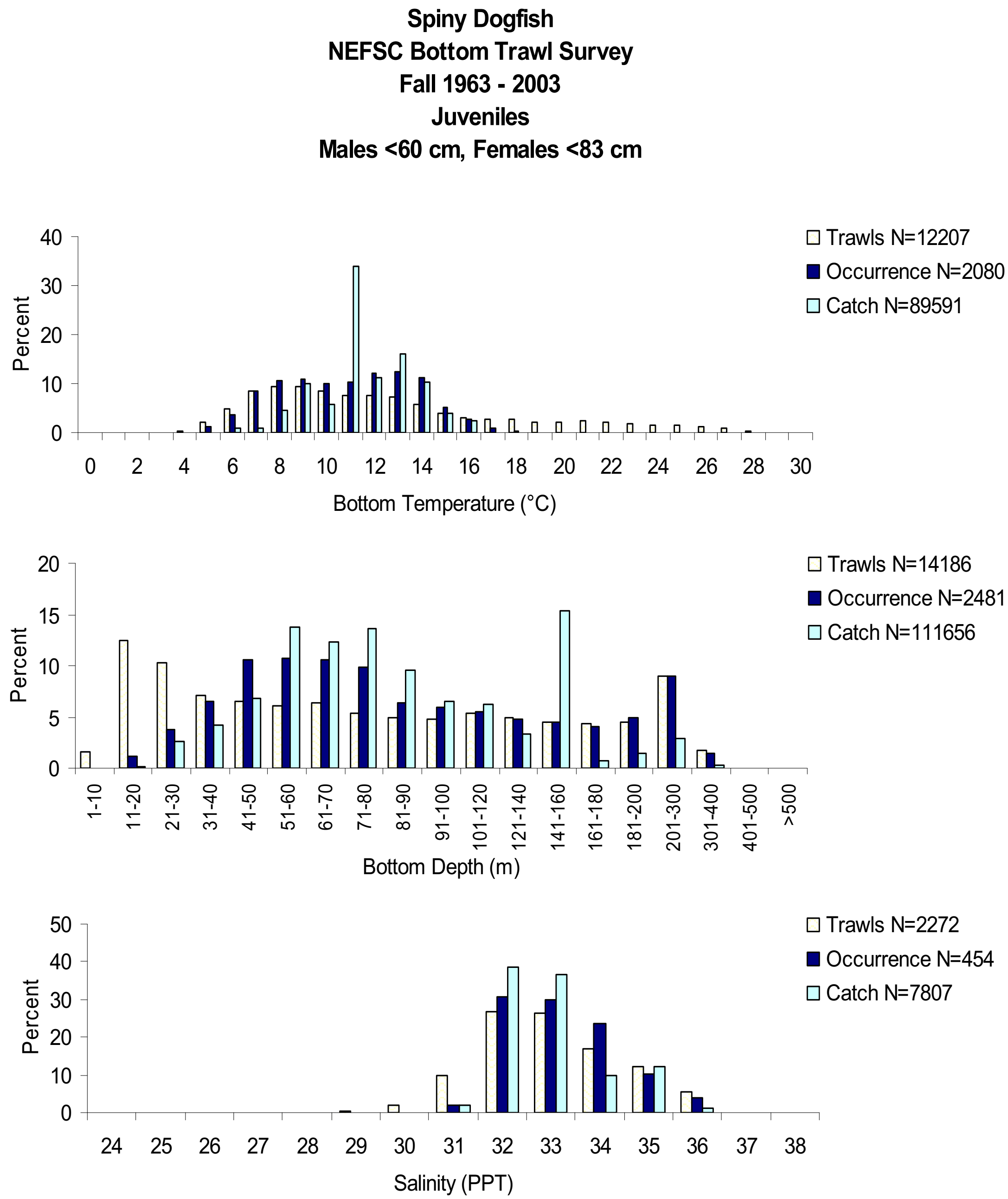


Figure 12. Cont'd.
Based on NEFSC fall bottom trawl surveys (temperature and depth: 1963-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which spiny dogfish occurred and medium bars show, within each interval, the percentage of the total number of spiny dogfish caught. Note that the bottom depth interval changes with increasing depth.

Spiny Dogfish
Massachusetts Inshore Trawl Survey
Spring 1978 - 2003
Specimens < 83 cm
Juvenile Females, Juvenile (<60 cm) & Adult (60-82 cm) Males

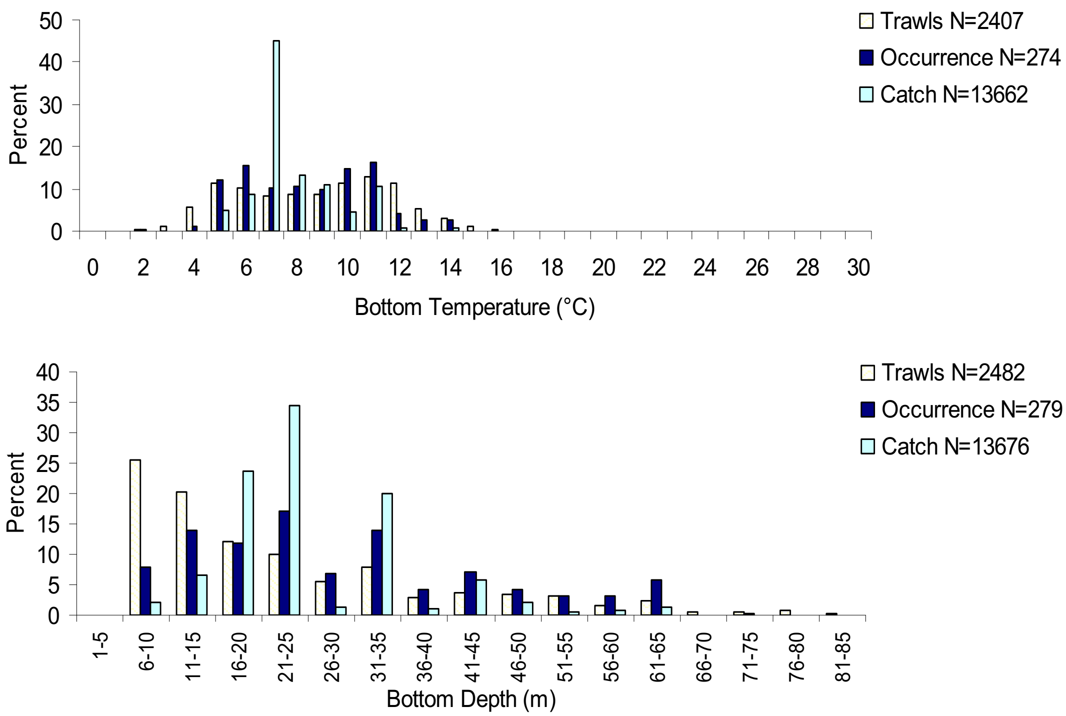


Figure 13. Distributions of juvenile and small adult male spiny dogfish and trawls in Massachusetts coastal waters relative to bottom water temperature and depth.
Based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which spiny dogfish occurred and medium bars show, within each interval, the percentage of the total number of spiny dogfish caught.

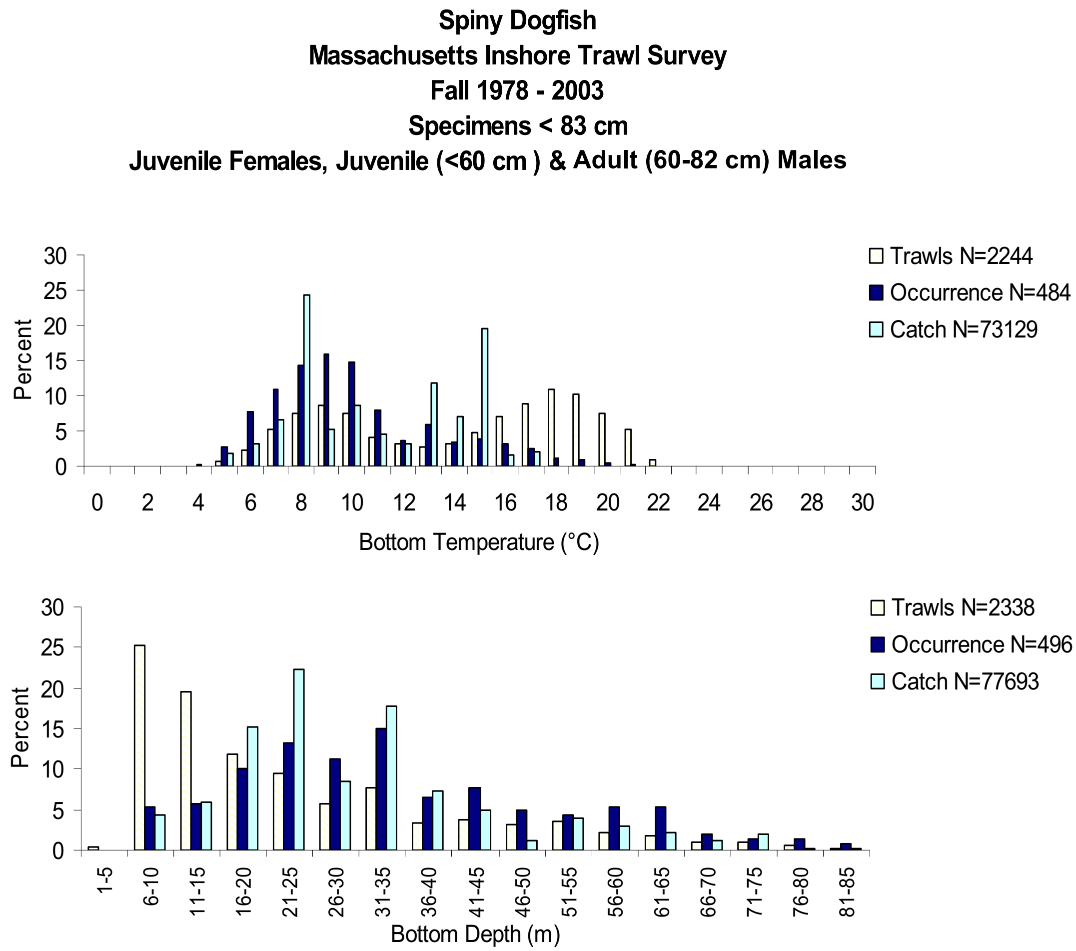


Figure 13. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which spiny dogfish occurred and medium bars show, within each interval, the percentage of the total number of spiny dogfish caught.

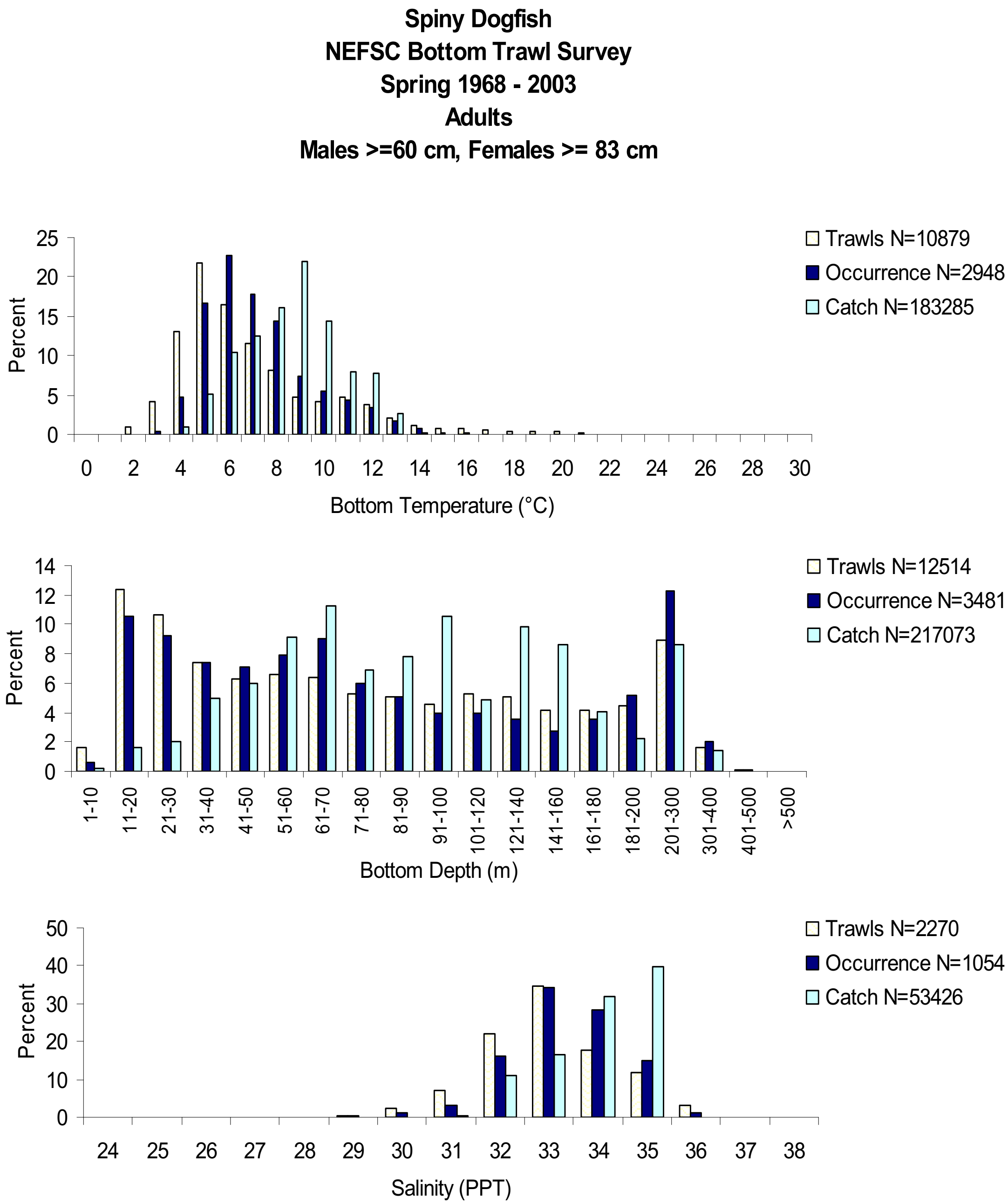


Figure 14. Distributions of adult spiny dogfish and trawls from NEFSC bottom trawl surveys relative to bottom water temperature, depth, and salinity.

Based on NEFSC spring bottom trawl surveys (temperature and depth: 1968-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which spiny dogfish occurred and medium bars show, within each interval, the percentage of the total number of spiny dogfish caught. Note that the bottom depth interval changes with increasing depth.

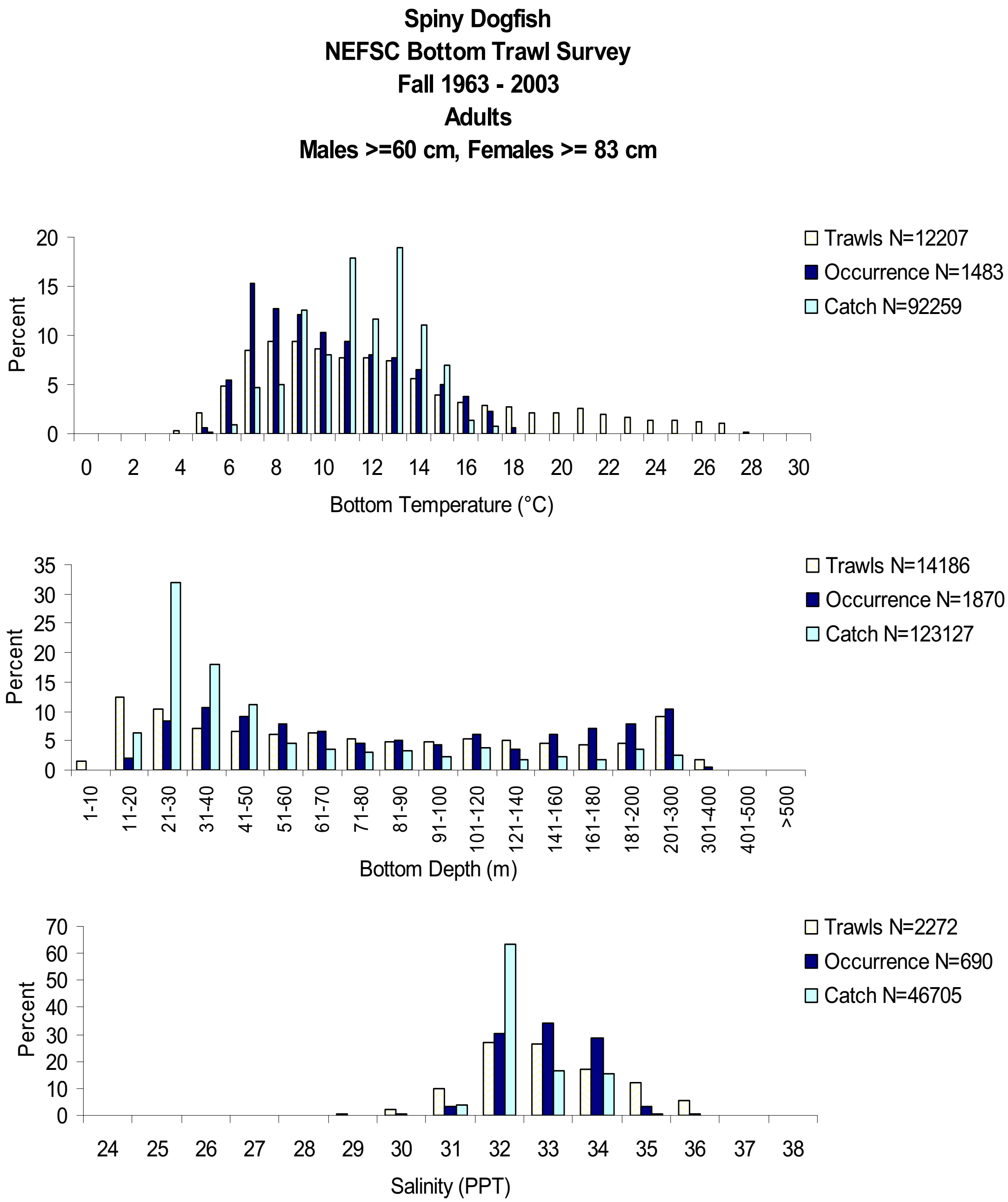


Figure 14. Cont'd.
Based on NEFSC fall bottom trawl surveys (temperature and depth: 1963-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which spiny dogfish occurred and medium bars show, within each interval, the percentage of the total number of spiny dogfish caught. Note that the bottom depth interval changes with increasing depth.

Spiny Dogfish
Massachusetts Inshore Trawl Survey
Spring 1978 - 2003
Specimens >= 83 cm
Adult Females, & Large Adult Males

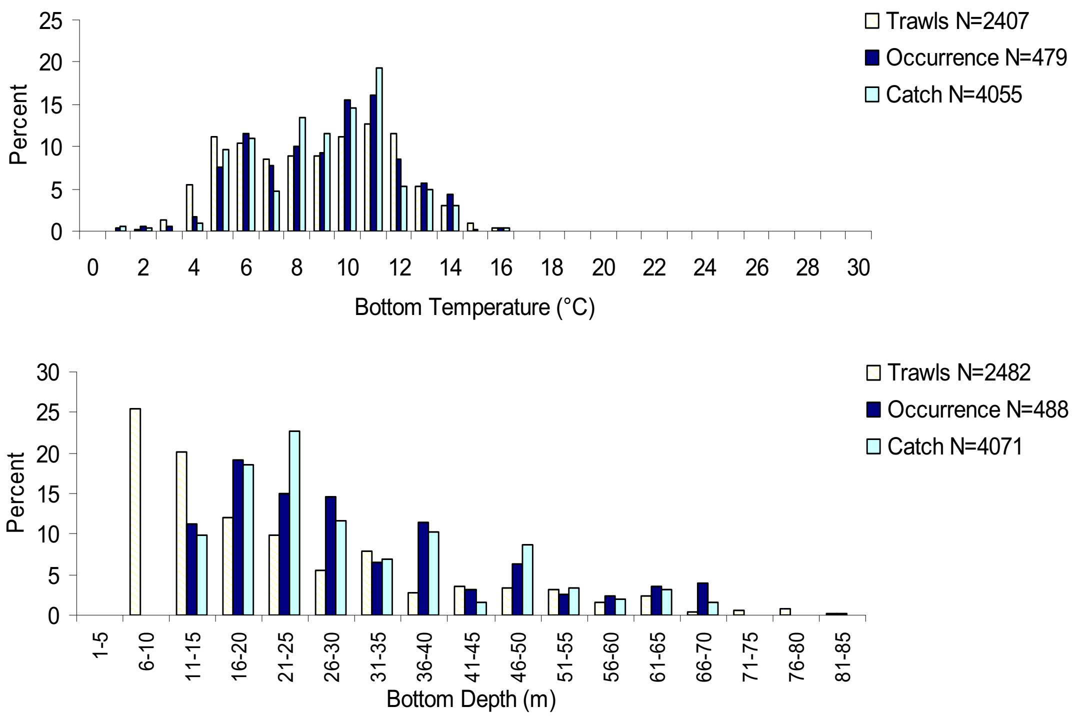


Figure 15. Distributions of adult spiny dogfish and trawls in Massachusetts coastal waters relative to bottom water temperature and depth.
Based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which spiny dogfish occurred and medium bars show, within each interval, the percentage of the total number of spiny dogfish caught.

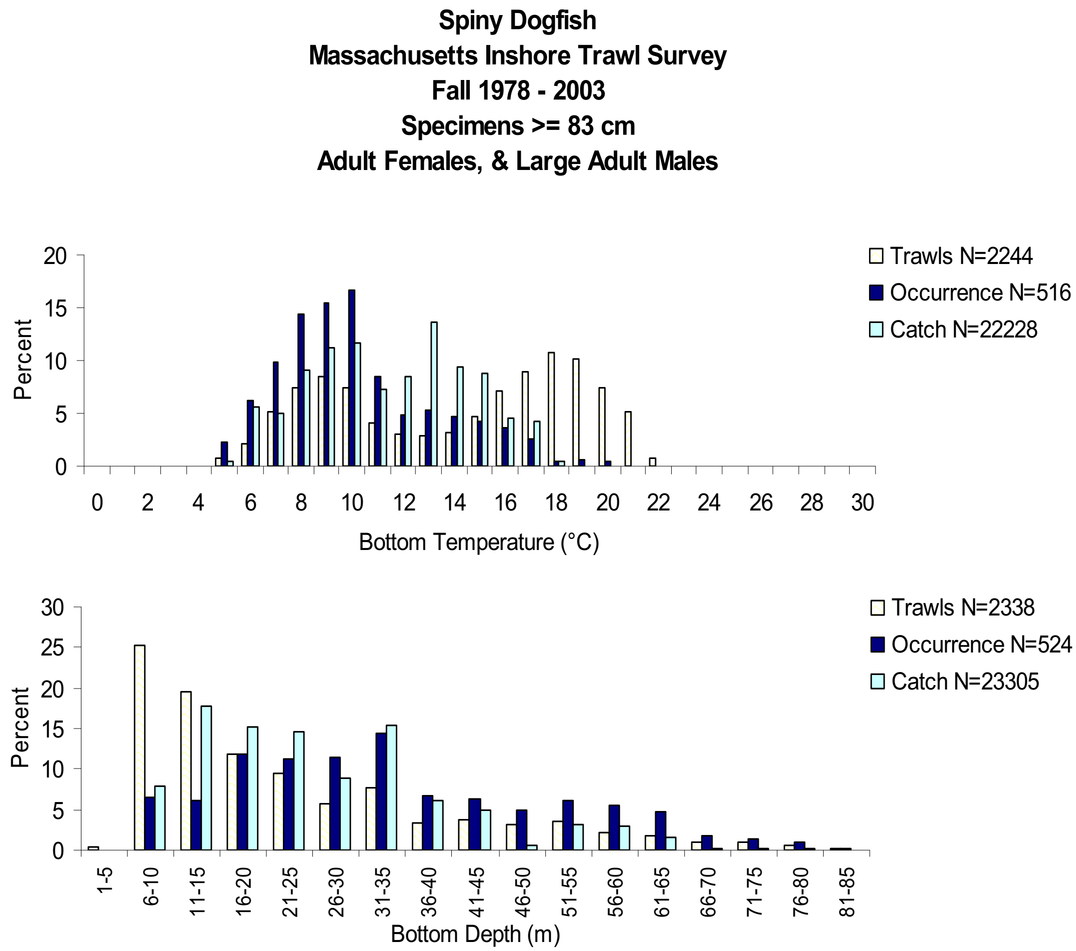


Figure 15. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which spiny dogfish occurred and medium bars show, within each interval, the percentage of the total number of spiny dogfish caught.

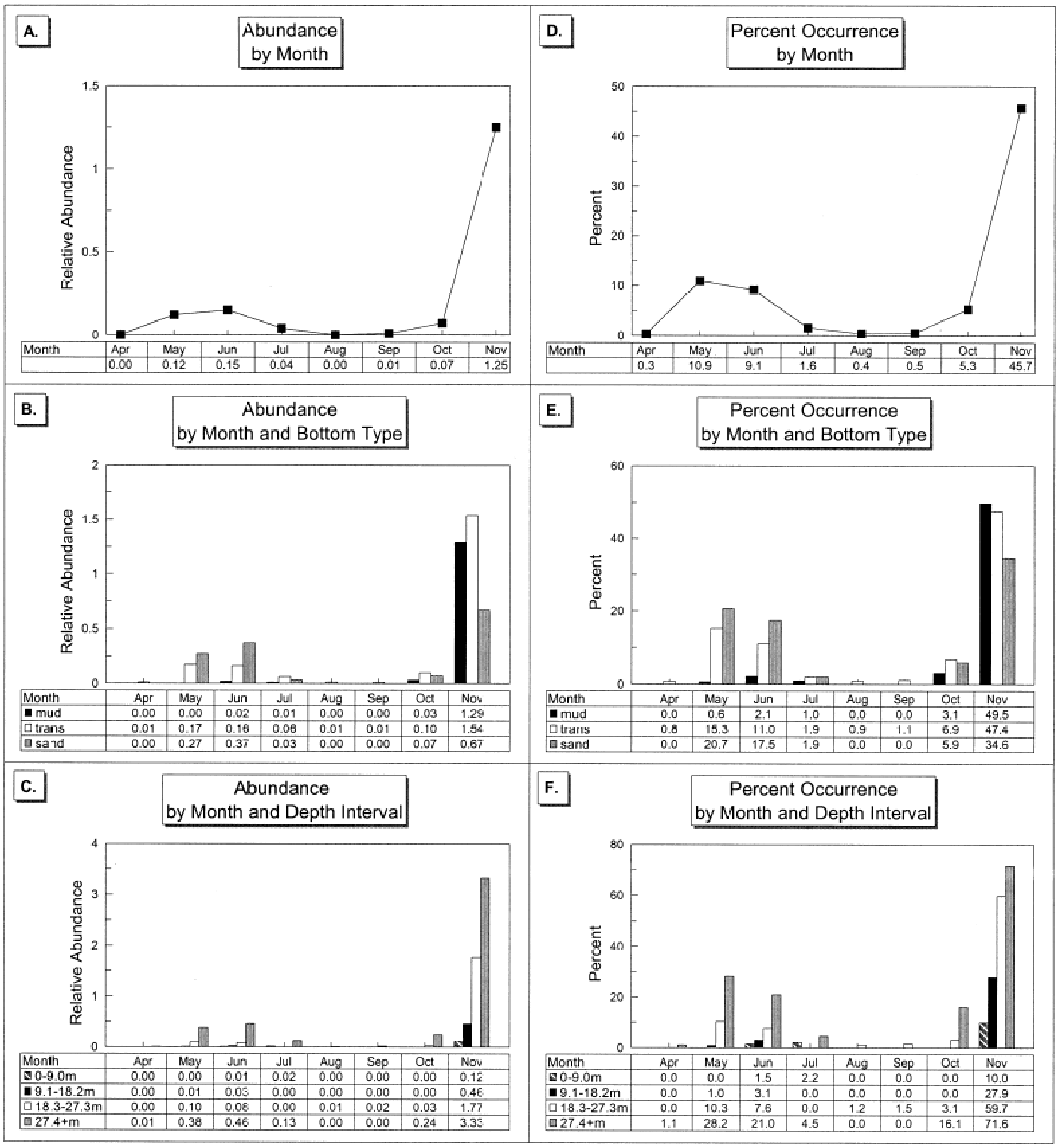


Figure 16. Relative abundance (geometric mean catch/tow) catch/tow and percent occurrence (proportion of samples in which at least one individual was observed) for spiny dogfish in Long Island Sound by month, month and bottom type, and month and depth interval.
Source: Gottschall *et al.* (2000).

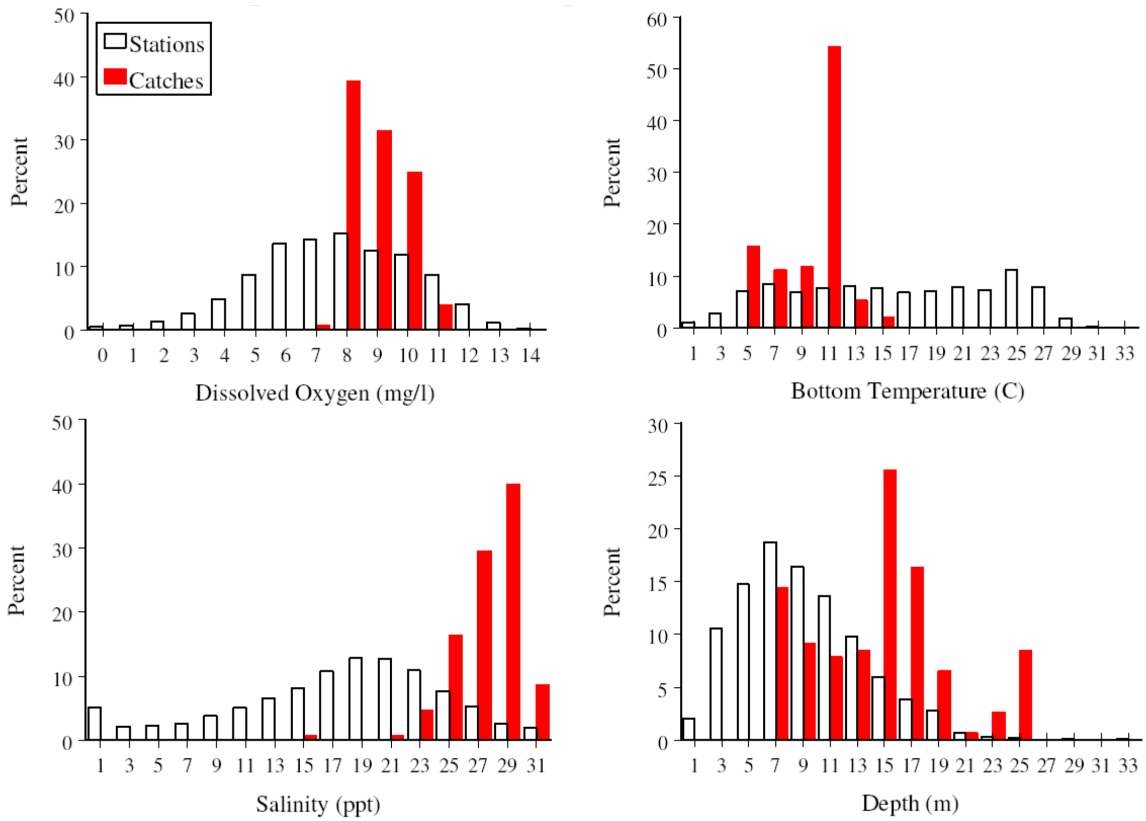


Figure 17. Hydrographic preferences for spiny dogfish total catch in Chesapeake Bay and tributaries, from the VIMS trawl surveys, 1988-1999 (all years combined).
Source: Geer (2002).

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

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