NOAA Technical Memorandum NMFS-NE-177

Essential Fish Habitat Source Document:

Smooth Skate, *Malacoraja senta*, 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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This series represents a secondary level of scientific publishing. All issues employ thorough internal scientific review; some issues employ external scientific review. Reviews are -- by design -- transparent collegial reviews, not anonymous peer reviews. All issues may be cited in formal scientific communications.

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Smooth Skate, *Malacoraja senta*, Life History and Habitat Characteristics

David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano

National Marine Fisheries Serv., James J. Howard Marine Sciences Lab., 74 Magruder Rd., Highlands, NJ 07732

U. S. DEPARTMENT OF COMMERCE
Donald L. Evans, Secretary
National Oceanic and Atmospheric Administration
Vice Admiral Conrad C. Lautenbacher, Jr., USN (ret.), Administrator
National Marine Fisheries Service
William T. Hogarth, Assistant Administrator for Fisheries
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts

March 2003

Editorial Notes on Issues 122-152, 163, and 173-179 in the *NOAA Technical Memorandum NMFS-NE* Series

Editorial Production

For Issues 122-152, 163, and 173-179, 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 staff of the Ecosystems Processes Division.

Internet Availability

Issues 122-152, 163, and 173-179 have been copublished, *i.e.*, both as paper copies and as Web postings. All Web postings are available at: *www.nefsc.noaa.gov/nefsc/habitat/efh*. Also, all Web postings are in "PDF" format.

Information Updating

By federal regulation, all information specific to Issues 122-152, 163, and 173-179 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, 163, and 173-179 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]; McEachran and Dunn 1998[f]).

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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.

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

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 38 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 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 understandably have 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 38 EFH source documents – available to the public through publication in the *NOAA Technical Memorandum NMFS-NE* series.

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

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

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INTRODUCTION

The smooth skate [*Malacoraja senta* (Garman 1885); formerly *Raja senta*, see McEachran and Dunn (1998); Figure 1] occurs along the Atlantic coast of North America from the Gulf of St. Lawrence and Labrador Shelf to as far south as South Carolina (Bigelow and Schroeder 1953; McEachran 1973; McEachran and Musick 1975; Kulka *et al.* 1996). However, it is a boreal species whose center of abundance is in the Gulf of Maine (McEachran and Musick 1975).

McEachran (2002) distinguishes smooth skates from other skates in the Gulf of Maine by a combination of the following characters: the rostrum is relatively stout and extends anterior to anterior-most pectoral rays. The snout is only moderately obtuse. The midline of the disc and proximal 1/2 to 2/3 of the tail bear an irregular row of small thorns. The distal 1/2 to 1/3 of tail of medium to large specimens lacks thorns. The dorsal surface is dark-colored without a distinct color pattern. The ventral side of disc is uniform white or mostly white with darker blotches. Small specimens have two light yellow bands on the dorsal side of the tail.

LIFE HISTORY

Not much is known about the life history of smooth skate.

The single fertilized egg is encapsulated in an amber to brown case or capsule (Vladykov 1936). The capsules are rectangular in shape, 50-61 mm long and 35-46 mm wide, and have a strongly convex dorsal surface and a nearly flat ventral surface. The anterior horns, which curve inward, are about 1/2 the length of the posterior horns and the posterior horns are slightly less than the length of the capsule exclusive of the horns (McEachran 2002). The capsules are striated and covered with fibrous tendrils.

McEachran (2002) reports that smooth skate reaches a maximum size of 57.7 cm TL. For their size at maturity, using the predictive equations of Frisk *et al.* (2001) and the Northeast Fisheries Science Center (NEFSC) survey maximum observed length of 71 cm TL, L_{mat} is estimated at 56 cm TL and A_{mat} is estimated at 5 years (Northeast Fisheries Science Center 2000b).

Females with fully formed egg capsules are found both in summer and winter (McEachran 2002).

FOOD HABITS

Generally, the diet of smooth skate is limited to epifaunal crustaceans (McEachran *et al*. 1976). Decapod shrimps and euphausids are the primary food items although amphipods and mysids are also important (McEachran 1973; McEachran *et al*. 1976; Bowman *et al*. 2000; McEachran 2002). Larger smooth skate also feed on small fish (Garrison and Link 2000; see also the discussion on the NEFSC food habits database, below).

McEachran (1973) studied skates collected from Nova Scotia to Cape Hatteras during 1967-1970; the following diet description is from him and McEachran *et al*. (1976).

On Georges Bank, *Pagurus pubescens*, *Dichelopandalus leptocerus*, *Crangon septemspinosa*, and *Eualus pusiolus* were the major decapods eaten, while on the Nova Scotian shelf, *P. pubescens*, *Pandulus* spp., and *C. septemspinosa* were the most numerious decapod prey consumed. *Meganyctiphanes norvegica* was the only euphausid eaten, and was eaten more frequently during the winter than during the autumn. *Monoculodes* sp. was the major amphipod eaten on Georges Bank and *Dulichia* (= *Dyopedos*) *monacantha* and *Pontogeneia inermis* were the most frequently eaten amphipods eaten in the Gulf of Maine and on the Nova Scotian shelf. The mysids *Erythrops erythrophthalma* and *Neomysis americana* were also consumed in large numbers.

As smooth skate grow, the diet shifts from amphipods and mysids to decapods, and euphausids appear to be directly correlated to the size of the skate (McEachran *et al*. 1976). Using NEFSC data from Georges Bank and the Gulf of Maine from 1977-1980, Bowman *et al*. (2000) reported that that in terms of percent weight, the major decapods consumed by skate 36-51 cm TL included *Pandalus borealis* and *D. leptocerus*. Skate 51-55 cm TL consumed pagurid crabs. *M. norvegica* was eaten by skate 56-60 cm TL, but also by skate < 31 cm TL.

The 1981-1990 NEFSC food habits database for smooth skate [Figure 2; see Reid *et al*. (1999) for details] generally confirms the McEachran (1973) and McEachran *et al*. (1976) studies, even though the sample sizes are often quite small. Decapods and crustaceans are the major components of the skates' diet, particularly for skates > 21 or 31 cm TL. Several fish species are minor, but important components of the diet of skates > 31 cm TL. Amphipods, which are a major part of the diet of skates 11-20 cm TL, rapidly decrease in occurrence for larger skates. However, there doesn't seem to be a remarkable increase in the occurrence of decapods or euphausids with increasing skate size. It is interesting to note though the rather high (54%) occurrence of euphausids in the stomachs of skates 21-30 cm TL, this may mirror the previously mentioned presence of *M. norvegica* in skate < 31 cm TL as reported by Bowman *et al*. (2000).

The following is a description of the diet from the NEFSC food habits database broken down by smooth skate size class (Figure 2).

For smooth skate 11-20 cm TL, 39% of the diet consisted of identifiable amphipods. Identifiable euphausids made up 23% of the diet, while pagurid crabs and pandalid shrimp, both decapods, together made up 15% of diet. Identifiable mysids and isopods each made up only 8% of the diet. For skate 21-30 cm TL, 54% of

the diet consisted of identifiable euphausids, and 23% of the diet identifiable amphipods.

The percent occurrence of identifiable amphipods in the diet of smooth skate 31-40 cm TL dropped to 17% and identifiable euphausids dropped to 29% of the diet. Identifiable decapods made up 21% of the diet; they included pagurid crabs, pandalid shrimp, and *C. septemspinosa*. Identifiable fish made up 13% of the diet, among which were a yellowtail flounder and a hake. Minor prey items included polychaetes (4%) and stomatopods (4%).

The percent occurrence of identifiable euphausids in the diet of skate 41-50 cm TL increased to 38%, while identifiable amphipods continued to decrease, down to 7%. Identifiable decapods, including pandalid shrimp and *C. septemspinosa*, made up 21% of the diet. Identifiable fish increased to 17% of the diet, species included silver hake and witch flounder.

The percent occurrence of identifiable euphausids in the diet of 51-60 cm TL skate decreased to 32%, while identifiable amphipods dropped down to 2%. Identifiable decapods, including pagurid crabs, pandalid shrimp, and *C. septemspinosa*, increased to 29%. Identifiable fish, including silver hake and sand lance, made up 13% of the diet.

Finally, for smooth skate 61-70 cm TL, identifiable euphausids made up 38% of the diet, identifiable pandalid shrimp 25% of the diet, identifiable fish 13%, and identifiable polychaetes 13%. However, only 7 skate stomachs were examined, making any conclusions about diet preference for this size class suspect.

PREDATORS AND SPECIES ASSOCIATIONS

Not much is known concerning the predators of smooth skate, but other skates probably eat them, at least as embryos within the egg capsules (McEachran 2002).

McEachran and Musick (1975) report that smooth and thorny skate (*Amblyraja radiata*) had a high coefficient of associaton during 1967-1970 surveys from Nova Scotia to Cape Hatteras, and these two species were often negatively associated with little (*Leucoraja erinacea*) and winter (*Leucoraja ocellata*) skates. They consider smooth and thorny skate to be sympatric species.

Co-occurrence, and possibly competition with thorny skate may have led to food specialization in smooth skate and could have caused the low abundance and low diversity of prey species in the diet of smooth skate (McEachran 1973; McEachran *et al*. 1976). Thorny skate has a diverse diet consisting of both infauna and epifauna while smooth skate has a very specialized diet consisting largely of epifauna, mostly amphipods, euphausids, decapods, and mysids (McEachran 1973; McEachran *et al*. 1976). Thorny skate also feeds on these prey items over part of the year, perhaps when the prey are in high abundance. Thorny skate is also the more widespread and abundant of the two.

Using 1973-1997 NEFSC data from Nova Scotia to Cape Hatteras, as well as the same NEFSC food habits database discussed above, Garrison and Link (2000) investigated the dietary guild structure of the fish community. Medium (31-60 cm TL) sized smooth skate belonged to the "Shrimp/small fish eaters" group, along with pollock, redfish, and silver, red, and white hakes. The most important prey included euphausiids, pandalid shrimps, and various other shrimps as well as fish prey such as silver hake, sand lance, and Atlantic herring.

Mahon (1997), in surveys of the Scotian Shelf and Bay of Fundy from 1970-1993, discovered that smooth skate belongs to an assemblage found mainly in the eastern Scotian Shelf and also in the mouth of the Bay of Fundy. Major species in the assemblage besides smooth skate included American plaice, thorny skate, and Vahl's eelpout.

GEOGRAPHICAL DISTRIBUTION

In Canada, smooth skate is distributed around the Newfoundland Banks, Labrador Shelf and Grand Banks; Kulka *et al.* (1996) noted a southerly shift in distribution: it appeared to be more common on the southern Grand Bank during 1991-1994 (collected during 1981-1994). It also occurs from the St. Lawrence River estuary, the Gulf of St. Lawrence, the Nova Scotian Banks, and the Gulf of Maine (Bigelow and Schroeder 1953; McEachran 1973; McEachran and Musick 1975; see also Strong and Hanke (1995) for the 1970-1993 distribution of smooth skate in the Scotia-Fundy region.). McEachran and Musick (1975) found it to be fairly abundant on the offshore banks of Banquereau, Sable Island, and Western, contrary to reports by Bigelow and Schroeder (1953) and Leim and Scott (1966). In the Bay of Fundy near Passamaquoddy Bay, Macdonald *et al*. (1984) determined them to be a common, regular resident, and within Passamaquoddy Bay itself smooth skate increased in abundance during summer and declined after late fall.

Smooth skate is found throughout the Gulf of Maine, its reported center of abundance (Bigelow and Schroeder 1953; McEachran and Musick 1975; McEachran 2002). Bigelow and Schroeder (1953) reported it from the southeast slope of Browns Bank, the western side of the Gulf, and the offshore Banks, in deep waters near Jeffrey's and Cashes Ledges, and in the basin east and southeast of Cape Cod. It has also been found in Massachusetts Bay (Collette and Hartel 1988).

It occurs on Georges Bank and along the upper slope of southern New England, New York, and New Jersey, and has been captured off northern Virginia, off Chesapeake Bay, and off Charleston, South Carolina (Bigelow and Schroeder 1953; McEachran 1973; McEachran and Musick 1975; McEachran 2002).

McEachran and Musick (1975) reported that there are no seasonal trends in abundance.

JUVENILES

NEFSC bottom trawl surveys [see Reid *et al*. (1999) for details] captured juvenile (< 55 cm TL) smooth skate mainly in the Gulf of Maine. (Note that winter and summer distributions are presented as presence/absence data, precluding a discussion of abundances.) In winter, concentrations were found near the Northeast Peak (Canadian side) of Georges Bank and Northeast Channel (Figure 3). In spring they were heavily concentrated in the Gulf of Maine (Figure 4). Larger numbers were found around the Northeast Channel, the mouth of the Bay of Fundy, between German Bank and Lurcher Shoal, east and southeast of Cape Cod, and on Jeffreys Ledge. A few were found out near the 200 m depth contour on the southern flank of Georges Bank down to southern New England and even near the Hudson Canyon. In summer they were again concentrated mostly in the Gulf of Maine (Figure 5). Their distributions in the fall were similar to those in the spring (Figure 6). Larger numbers were again found around the Northeast Channel, the mouth of the Bay of Fundy, and east and southeast of Cape Cod, with a few found out near the 200 m depth contour on the southern flank of Georges Bank down to southern New England and near the Hudson Canyon.

Both the spring and fall 1978-2002 Massachusetts inshore trawl surveys [see Reid *et al*. (1999) for details] show very small numbers of juveniles around Cape Ann, in Massachusetts Bay, and near Cape Cod Bay (Figure 7).

ADULTS

The overall numbers of adult smooth skate (> 56 cm TL) captured by the NEFSC bottom trawl surveys were much lower than for juveniles. (Again, winter and summer distributions are presented as presence/absence data, precluding a discussion of abundances.) In winter, small concentrations were present in the Gulf of Maine, around the 200 m depth contour near the Northeast Peak of Georges Bank, around southeast Georges Bank, on Georges Bank southeast of Cape Cod (near Cultivator Shoal), near Cape Ann, near Crowell Basin in the Gulf, and near Long Island (Figure 8). In the spring they were scattered throughout the Gulf, near the Northeast Peak again and on Georges Bank southeast of Cape Cod, around southeast Georges Bank, as well as on the Scotian Shelf (Figure 9). In the summer there were small concentrations in the Gulf of Maine (Figure 10). Distributions in the fall were similar to those in the spring, with a number caught around the Northeast Peak and southeast of Cape Cod (Figure 11).

HABITAT CHARACTERISTICS

Information on the habitat requirements and preferences of smooth skate (based on both the pertinent literature and the most recent NEFSC surveys) are presented here and summarized in Table 1.

Smooth skate has been found at depths from 31-874 m, but McEachran and Musick (1975) and McEachran (2002) considered it most abundant between 110-457 m. In the Gulf of Maine, Bigelow and Schroeder (1953) reported them to occur throughout the western side of the Gulf where water depths are > 73-91 m, 46 m being the shallowest and on the offshore Banks as well. Smooth skate were also found in the deep trough west of Jeffrey's Ledge, at 146-183 m near Cashes Ledge, and were trawled at 91-457 m off southern New England (Bigelow and Schroeder 1953). Isolated specimens have been captured off Chesapeake Bay at 190 m and off Charleston, South Carolina at 874 m (Bigelow and Schroeder 1953; McEachran 2002). The spring and fall 1963-2002 NEFSC trawl surveys from the Gulf of Maine to Cape Hatteras (see below) indicated that juveniles occurred at depths from 31-500 m with most found > 120 m (Figure 12), while adults were found between 31-400 m with most found > 100 m (Figure 14).

Bigelow and Schroeder (1953) reported the egg cases of smooth skate might have been trawled at depths of 150-300 m in the St. Lawrence River estuary in July and August. Also in Canada, Bigelow and Schroeder (1953) reported the occurrence of smooth skate in the Gulf of St. Lawrence at 150-326 m, and on La Have and Emerald Banks at 91-183 m. Scott (1982a) reported that during trawl surveys on the Scotian Shelf in the summers of 1970-1979, smooth skate were usually caught at depths of 73-163 m.

McEachran and Musick (1975) found smooth skate at temperatures from 0.5-4.8°C in the Gulf of St. Lawrence, -1.3°C to 11.8°C off northeastern Nova Scotia, and 2-10°C from southern Nova Scotia to Georges Bank. It was usually caught at 3-8°C on the Scotian Shelf during the summers of 1970-1979 (Scott 1982a). The spring and fall 1963-2002 NEFSC trawl surveys from the Gulf of Maine to Cape Hatteras (see below) found juvenile smooth skate over a temperature range of 2-13°C, with most found between about 4-8°C (Figure 12), while adults were found over a temperature range of about 3-13°C, with most also found between about 4-8°C (Figure 14).

Smooth skate is found mostly on soft mud (silt and clay) bottoms in deeper areas, but also on sand, broken shells, gravel, and pebbles on the offshore banks of the Gulf of Maine (Bigelow and Schroeder 1953; McEachran and Musick 1975). Scott (1982b) also says that smooth skate is restricted to the finer sediments of the Scotian Shelf.

Scott (1982a) also mentions that on the Scotian Shelf during the summers of 1970-1979, smooth skate was found at preferred salinities of 32-34 ppt. The spring and

fall 1963-2002 NEFSC trawl surveys from the Gulf of Maine to Cape Hatteras (see below) found juveniles over a salinity range of between 32-35 ppt, with most between 33-34 ppt (Figure 12); adults were found at salinities of 32-35 ppt, with most between 33-35 ppt (Figure 14).

JUVENILES

The spring and fall distributions of juvenile smooth skate relative to bottom water temperature, depth, and salinity based on 1963-2002 NEFSC bottom trawl surveys from the Gulf of Maine to Cape Hatteras are shown in Figure 12. In spring, they were found in waters between 2-12°C, with the majority between 4-8°C. Their depth range during that season was between 41-400 m with most between 121-300 m. Their salinity range was between 32-35 ppt, with the majority between 33-34 ppt. Juvenile smooth skate were caught over a temperature range of 4-13°C during the fall, with most found between 6-8°C. They were found over a depth range of about 31-500 m, with most caught at depths between 161-300 m. They were found over a salinity range of between 32-35 ppt, with around 40-50% caught or occurring at 34 ppt.

The fall 1978-2001 Massachusetts inshore trawl surveys found a few juvenile smooth skate at temperatures from 5-10°C and at depths from about 36-75 m (Figure 13).

ADULTS

The spring and fall distributions of adult smooth skate relative to bottom water temperature, depth, and salinity based on 1963-2002 NEFSC bottom trawl surveys from the Gulf of Maine to Cape Hatteras are shown in Figure 14. During the spring they were found in waters between 3-11°C, with most spread between 4-8°C and with a peak at 6°C. They were found at depths between 51-400 m, with the majority spread between 121-400 m. They were found at salinities of between 32-35 ppt, with a peak at 33 ppt. During the fall, they were found over a temperature range of about 4-13°C with a few at 16°C and 21°C. Most were found between 6-8°C. They were found over a depth range of 31-400 m, with most found between approximately 101-400 m. Their salinity range was between 32-35 ppt, with the majority about evenly spread between 33-35 ppt.

STATUS OF THE STOCKS

The following section is based on Northeast Fisheries Science Center (2000a, b).

The principal commercial fishing method used to catch all seven species of skates [smooth, little, barndoor (*Dipturus laevis*), winter, thorny, clearnose (*Raja eglanteria*), rosette (*Leucoraja garmani*)] is otter trawling. Skates are frequently taken as bycatch during groundfish trawling and scallop dredge operations and discarded recreational and foreign landings are currently insignificant, at < 1% of the total fishery landings.

Skates have been reported in New England fishery landings since the late 1800s. However, commercial fishery landings, primarily from off Rhode Island, never exceeded several hundred metric tons until the advent of distant-water fleets during the 1960s. Landings are not reported by species, with over 99% of the landings reported as "unclassified skates." Skate landings reached 9,500 mt in 1969, but declined quickly during the 1970s, falling to 800 mt in 1981 (Figure 15). Landings have since increased substantially, partially in response to increased demand for lobster bait, and more significantly, to the increased export market for skate wings. Wings are taken from winter and thorny skates, the two species currently used for human consumption. Bait landings are presumed to be primarily from little skate, based on areas fished and known species distribution patterns. Landings for all skates increased to 12,900 mt in 1993 and then declined somewhat to 7,200 mt in 1995. Landings have increased again since 1995, and the 1998 reported commercial landings of 17,000 mt were the highest on record (Figure 15).

The biomass for the seven skate species is at a medium level of abundance. For the aggregate complex, the NEFSC spring survey index of biomass was relatively constant from 1968-1980, then increased significantly to peak levels in the mid- to late 1980s. The index of skate complex biomass then declined steadily until 1994, but has recently increased again. The large increase in skate biomass in the mid- to late 1980s was dominated by little and winter skate. The recent increase in aggregate skate biomass has been due to an increase in small sized skates (< 100 cm max. length: little, clearnose, rosette, and smooth), primarily little skate. The abundance of smooth skate was highest during the early 1970s (Figure 15). Smooth skate was, until recently, considered to be overfished (Northeast Fisheries Science Center 2000a, b), but its status has recently been changed so that it is no longer considered to be in an overfished condition (NMFS 2002).

RESEARCH NEEDS

Imprecise reporting of fishery statistics where several skate species are lumped together under one category (e.g., "unclassified skates" or "skates spp.") can mask basic changes in community structure and profound reduction in populations of larger, slower growing species (Dulvy *et al*. 2000; Musick *et al*. 2000). Thus, it is important to have fishery-independent data on skates where the individual species are reported.

Northeast Fisheries Science Center (2000b) also suggests the following research needs:

- More life history studies (including age, growth, maturity, and fecundity studies) are necessary.
- Studies of stock structure are needed to identify unit stocks.
- Explore possible stock-recruit relationships by examination of NEFSC survey data.
- Investigate trophic interactions between skate species in the complex, and between skates and other groundfish.
- Investigate the influence of annual changes in water temperature or other environmental factors on shifts in the range and distribution of the species in the skate complex, and establish the bathymetric distribution of the species in the complex in the northwest Atlantic.
- Investigate historical NEFSC survey data from the R/V Albatross III during 1948-1962 when they become available, as they may provide valuable historical context for long-term trends in skate biomass.

ACKNOWLEDGMENTS

The authors thank Barry Shafer, John McCarthy, Tom Finneran, and Annette Kalbach for producing the maps and graphics. Thanks also to Claire Steimle and Judy Berrien for literature reviews and interlibrary loans. Frank Almeida and Kathy Sosebee of the NEFSC Woods Hole provided much needed information, input, and reviews.

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Table 1. Summary of habitat parameters for smooth skate, based on the pertinent literature and the most recent NEFSC surveys.

Life Stage	Depth	Substrate	Salinity	Temperature
Eggs [1]	Egg cases may have been trawled at depths of 150-300 m in the St. Lawrence River estuary in July and August.			
Juveniles [2]	Found at depths from 31-874 m, most abundant between 110-457 m. In the Gulf of Maine occurs throughout western side of the Gulf where water depths are > 73-91 m, 46 m being the shallowest and on the offshore Banks as well. Also found in the deep trough west of Jeffrey's Ledge, at 146-183 m near Cashes Ledge, and at 91-457 m off southern New England. Isolated specimens taken off Chesapeake Bay at 190 m and off Charleston, South Carolina at 874 m. Spring/fall 1963-2002 NEFSC trawl surveys from Gulf of Maine to Cape Hatteras indicated juveniles occurred at depths from 31-500 m with most found > 120 m. In Canada: Gulf of St. Lawrence at 150-326 m, and on La Have and Emerald Banks at 91-183 m. During trawl surveys on the Scotian Shelf in the summers of 1970-1979, smooth skate usually caught at 73-163 m. Fall 1978-2001 Massachusetts inshore trawl surveys found a few juvenile smooth skate at depths from about 36-75 m.	Found mostly on soft mud (silt and clay) bottoms in deeper areas, but also on sand, broken shells, gravel, and pebbles on the offshore banks of the Gulf of Maine. Also restricted to the finer sediments of the Scotian Shelf.	On the Scotian Shelf during the summers of 1970-1979, smooth skate was found at preferred salinities of 32-34 ppt. Spring/fall 1963-2002 NEFSC trawl surveys from Gulf of Maine to Cape Hatteras found juveniles over a salinity range of between 32-35 ppt, with most between 33-34 ppt.	Found at temperatures from 0.5-4.8°C in Gulf of St. Lawrence, -1.3°C to 11.8°C off northeastern Nova Scotia, 2-10°C from southern Nova Scotia to Georges Bank. Caught at 3-8°C on the Scotian Shelf during the summers of 1970-1979. Spring/fall 1963-2002 NEFSC trawl surveys from Gulf of Maine to Cape Hatteras found juveniles over a temperature range of 2-13°C, with most found between about 4-8°C. Fall 1978-2001 Massachusetts inshore trawl surveys found a few juvenile smooth skate at temperatures from 5-10°C.
Adults [3]	Same as for juveniles. Spring/fall 1963-2002 NEFSC trawl surveys from Gulf of Maine to Cape Hatteras indicated adults were found between 31-400 m with most found > 100 m.	Same as for juveniles.	Same as for juveniles. Spring/fall 1963-2002 NEFSC trawl surveys from Gulf of Maine to Cape Hatteras found adults at salinities of between 32-35 ppt; most between 33-35 ppt.	Same as for juveniles. Spring/fall 1963-2002 NEFSC trawl surveys from Gulf of Maine to Cape Hatteras found adults over a temperature range of about 3-13°C; most found between about 4-8°C.

[1] Bigelow and Schroeder (1953).

[2] Bigelow and Schroeder (1953); McEachran and Musick (1975); Scott (1982a, b); McEachran (2002); 1978-2001 Massachusetts inshore trawl surveys; 1963-2002 NEFSC trawl surveys.

[3] Bigelow and Schroeder (1953); McEachran and Musick (1975); Scott (1982a, b); McEachran (2002); 1963-2002 NEFSC trawl surveys.

Table 1. cont'd.

Life Stage	Prey	Predators/Species Associations
Eggs[1]	N/A	Other skates probably eat them, at least as embryos within the egg capsules.
Juveniles [2]	Diet limited to epifaunal crustaceans. Decapod shrimps and euphausids are primary food items although amphipods and mysids are also important. Decapod prey include: *Pagurus pubescens*, *Dichelopandalus leptocerus*, *Crangon septemspinosa*, *Eualus pusiolus*, *Pandulus* spp. Euphausids: *Meganyctiphanes norvegica*. Amphipods: *Monoculodes* sp., *Dulichia* (= *Dyopedos*) *monacantha*, *Pontogeneia inermis*. Mysids: *Erythrops erythrophthalma*, *Neomysis americana*. Minor prey items include fish (yellowtail flounder, silver hake, witch flounder, sand lance), polychaetes, stomatopods. As smooth skate grow, diet shifts from amphipods and mysids to decapods; euphausids appear to be directly correlated to size of the skate. Surveys from 1977-1980 on Georges Bank and Gulf of Maine showed that major decapods consumed by skate 36-51 cm TL included *Pandalus borealis* and *D. leptocerus*. Skate 51-55 cm TL consumed pagurid crabs. *M. norvegica* was eaten by skate 56-60 cm TL, but also by skate < 31 cm TL. 1981-1990 NEFSC food habits database for smooth skate also showed decapods and crustaceans are the major components of the skates' diet, particularly for skates > 21 or 31 cm TL. Several fish species are minor, but important components of the diet of skates > 31 cm TL. Amphipods, which are a major part of the diet of skates 11-20 cm TL, rapidly decrease in occurrence for larger skates. However, there's no real increase in the occurrence of decapods or euphausids with increasing skate size.	Smooth and thorny skate (*Amblyraja radiata*) have a high coefficient of associaton; these two species often negatively associated with little (*Leucoraja erinacea*) and winter (*Leucoraja ocellata*) skates. Smooth and thorny skate are sympatric species. Co-occurrence, and possibly competition with thorny skate may have led to food specialization in smooth skate and could have caused the low abundance and low diversity of prey species in the diet of smooth skate. Thorny skate has a diverse diet consisting of both infauna and epifauna while smooth skate has a very specialized diet consisting largely of epifauna. Using 1973-1997 NEFSC data from Nova Scotia to Cape Hatteras and NEFSC food habits database, medium (31-60 cm TL) sized smooth skate belonged to the "Shrimp/small fish eaters" group, along with pollock, redfish, and silver, red, and white hakes. The most important prey included euphausiids, pandalid shrimps, and various other shrimps as well as fish prey such as silver hake, sand lance, and Atlantic herring. Based on surveys of the Scotian Shelf and Bay of Fundy, smooth skate belongs to an assemblage found mainly in the eastern Scotian Shelf and also in the mouth of the Bay of Fundy. Major species in the assemblage besides smooth skate included American plaice, thorny skate, and Vahl's eelpout.
Adults [3]	Same as for juveniles; however, note that larger skates may consume more decapods and euphausids as well as fish rather than amphipods and mysids.	Same as for juveniles.

[1] McEachran (2002).
[2] McEachran (1973); McEachran and Musick (1975); McEachran *et al*. (1976); Mahon (1997); Bowman *et al*. (2000); Garrison and Link (2000); McEachran (2002); NEFSC 1973-1990 food habits database.
[3] McEachran (1973); McEachran and Musick (1975); McEachran *et al*. (1976); Mahon (1997); Bowman *et al*. (2000); Garrison and Link (2000); McEachran (2002); NEFSC 1973-1990 food habits database.

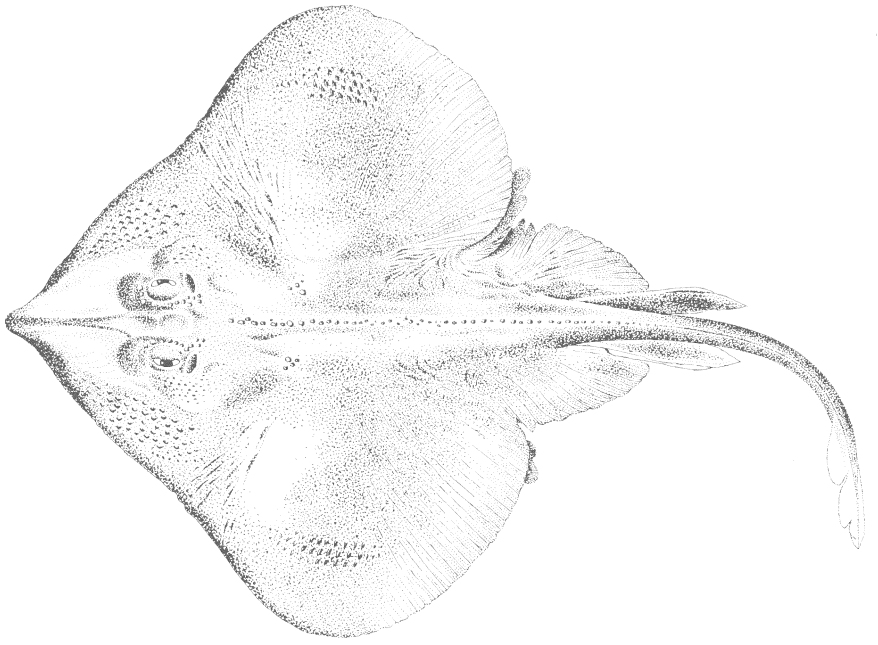


Figure 1. The smooth skate, *Malacoraja senta* (Garman 1885), male, from Scott and Scott (1988).

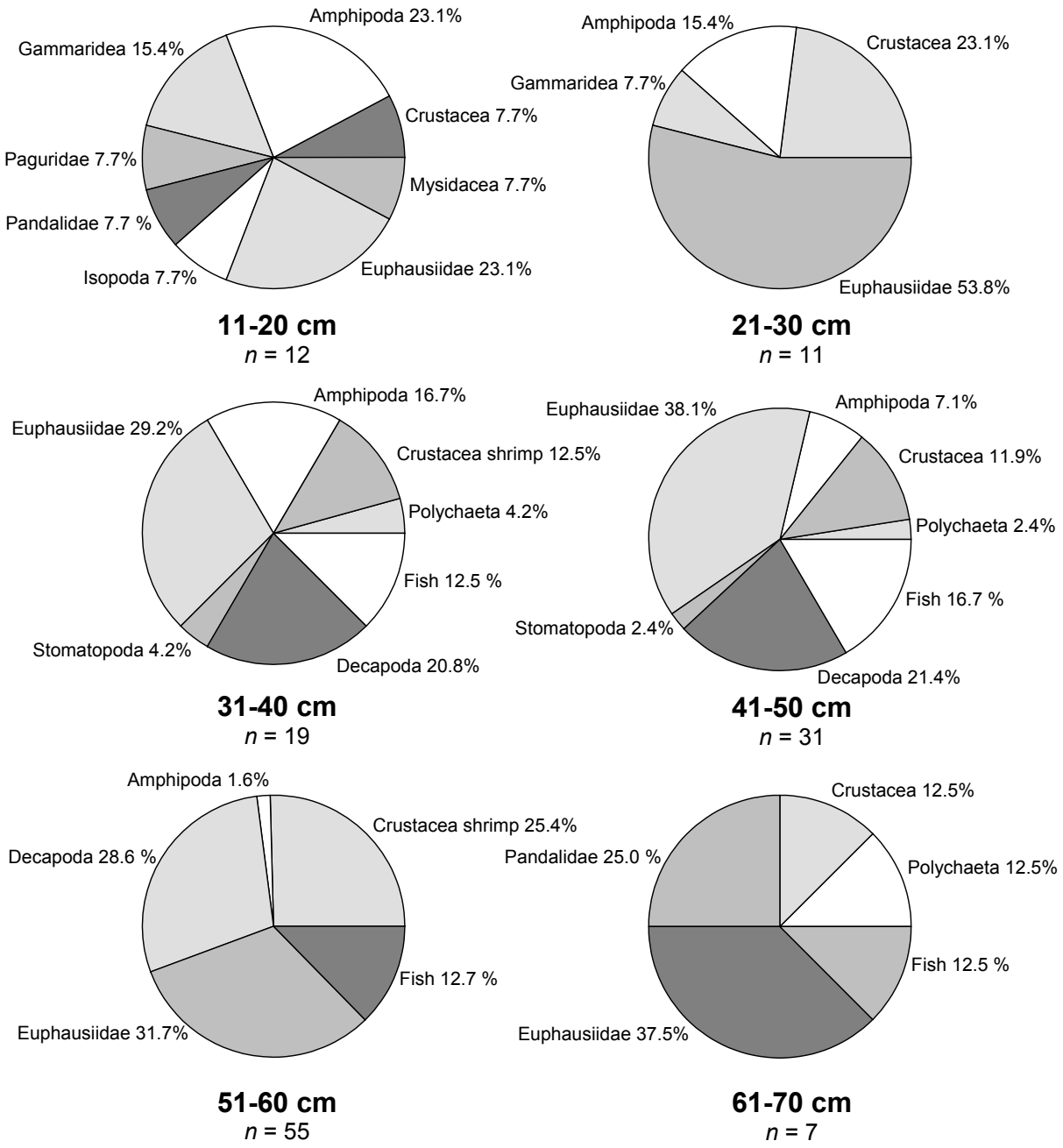


Figure 2. Abundance (% occurrence) of the major prey items of smooth skate collected during NEFSC bottom trawl surveys from 1981-1990 [see Reid *et al.* (1999) for details].

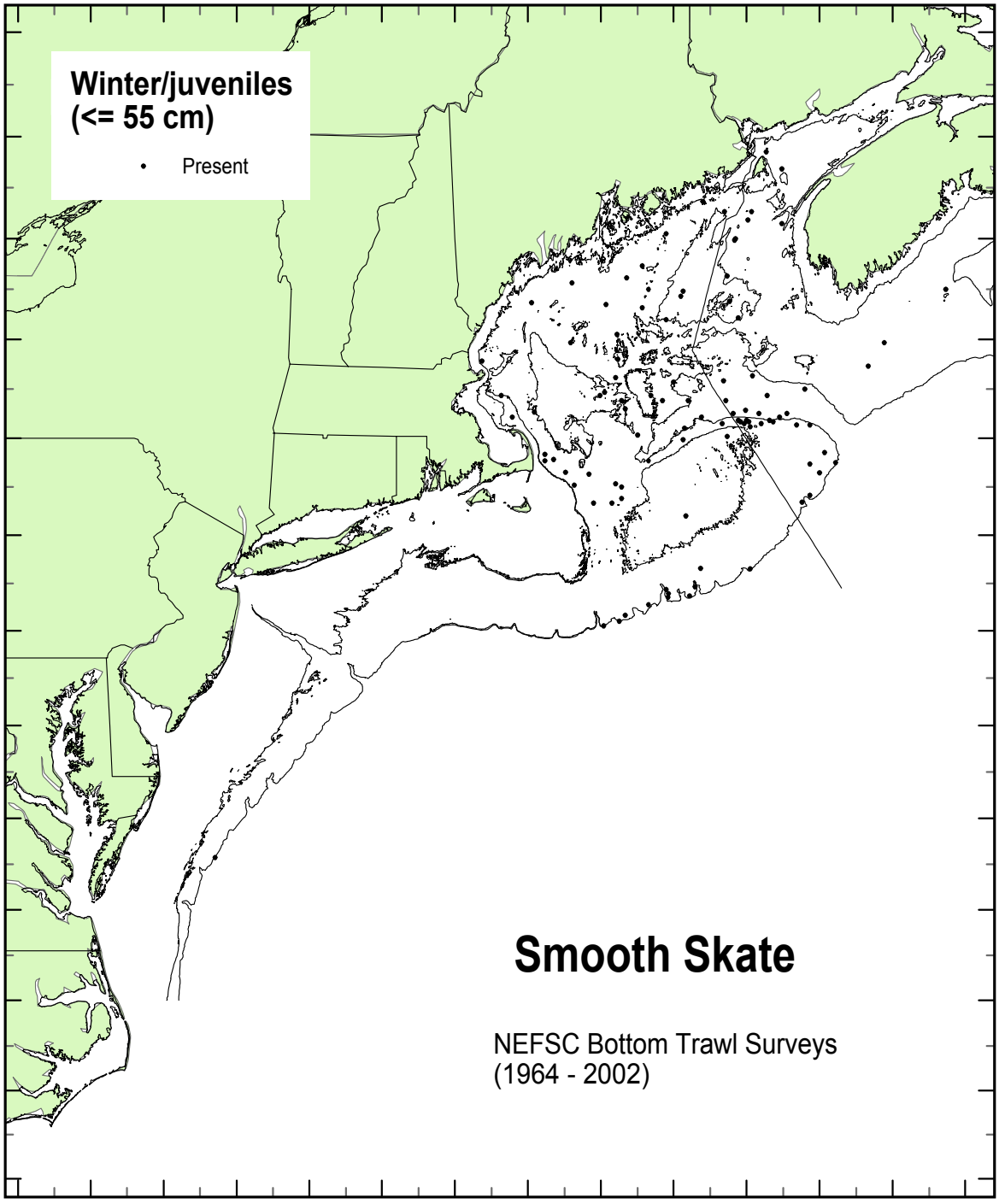


Figure 3. Distribution of juvenile smooth skate collected during winter NEFSC bottom trawl surveys [1964-2002, all years combined; see Reid *et al.* (1999) for details]. Survey stations where juveniles were not found are not shown.

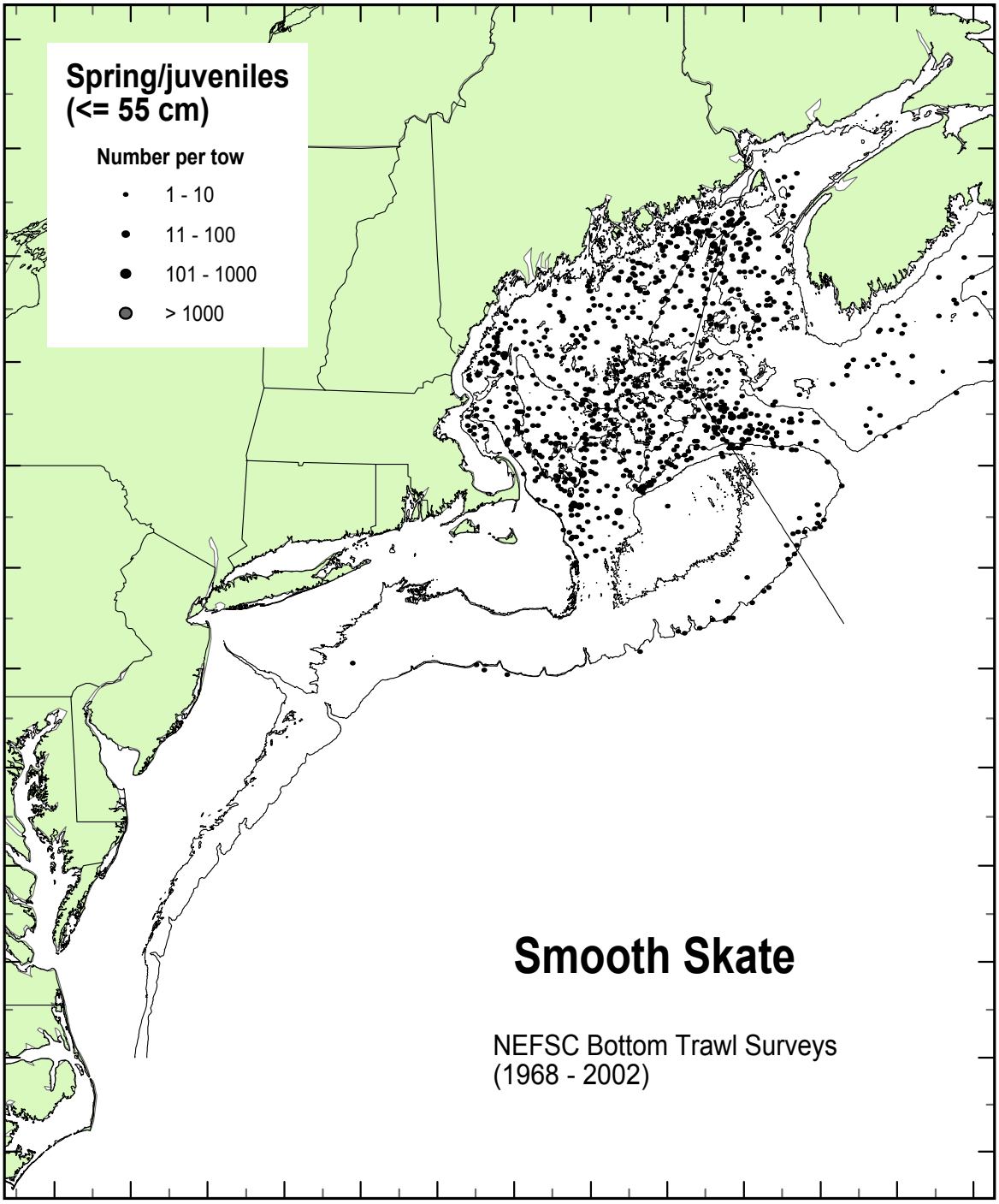


Figure 4. Distribution and abundance of juvenile smooth skate collected during spring NEFSC bottom trawl surveys [1968-2002, all years combined; see Reid *et al.* (1999) for details].

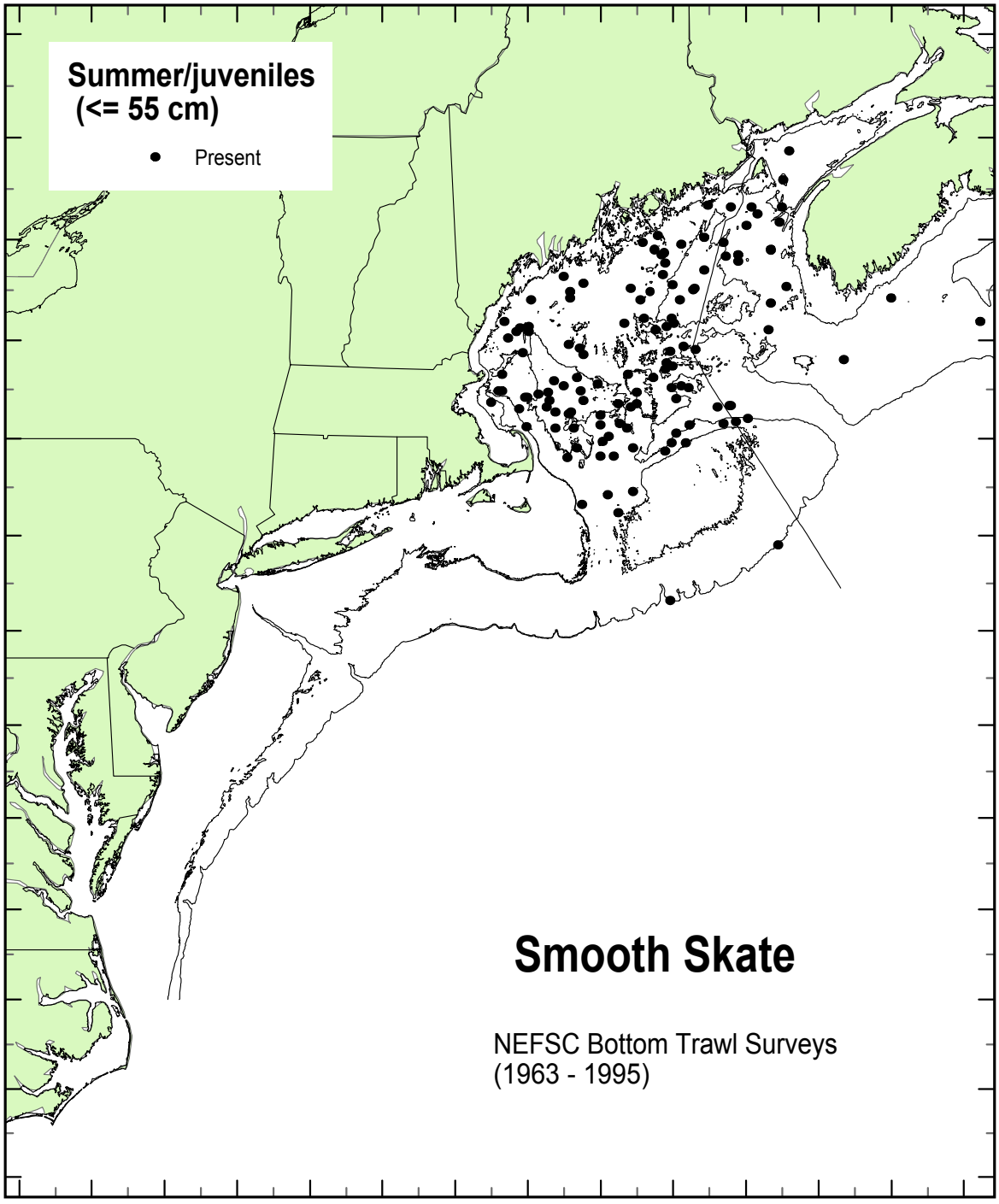


Figure 5. Distribution of juvenile smooth skate collected during summer NEFSC bottom trawl surveys [1963-1995, all years combined; see Reid *et al.* (1999) for details]. Survey stations where juveniles were not found are not shown.

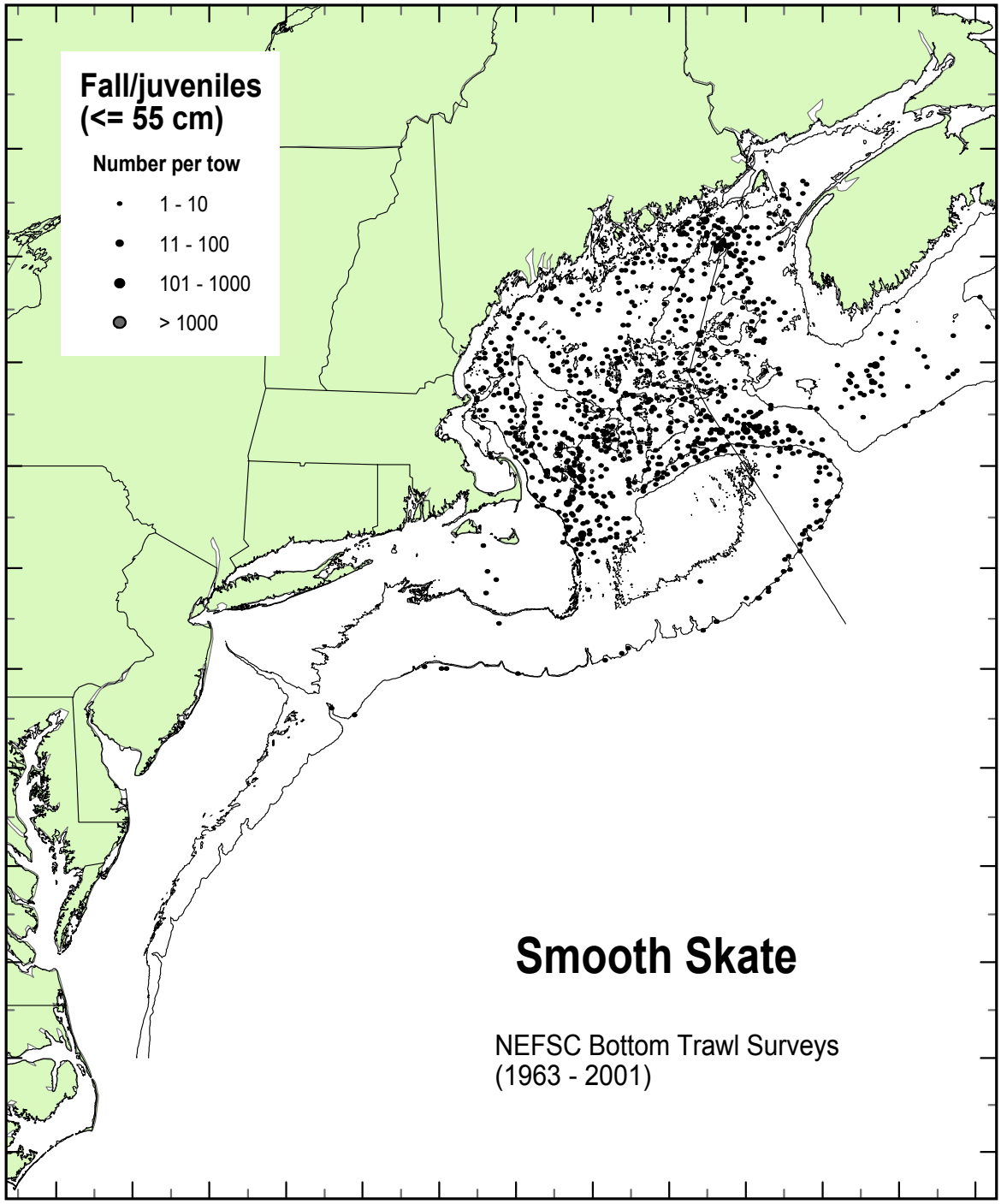


Figure 6. Distribution and abundance of juvenile smooth skate collected during fall NEFSC bottom trawl surveys [1963-2001, all years combined; see Reid *et al.* (1999) for details].

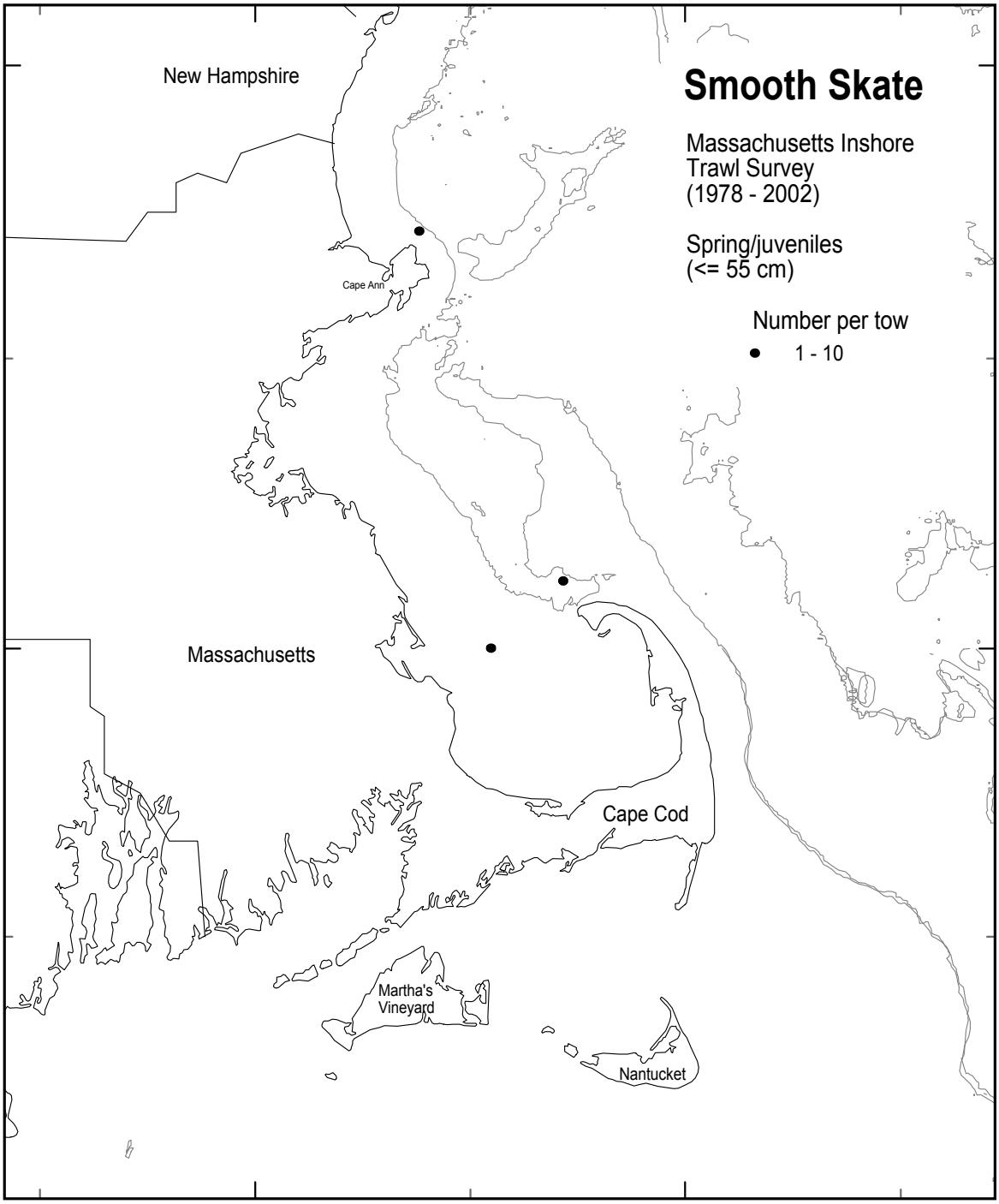


Figure 7. Distribution and abundance of juvenile smooth skate in Massachusetts coastal waters collected during the spring and autumn Massachusetts inshore trawl surveys [1978-2002, all years combined; see Reid *et al.* (1999) for details].

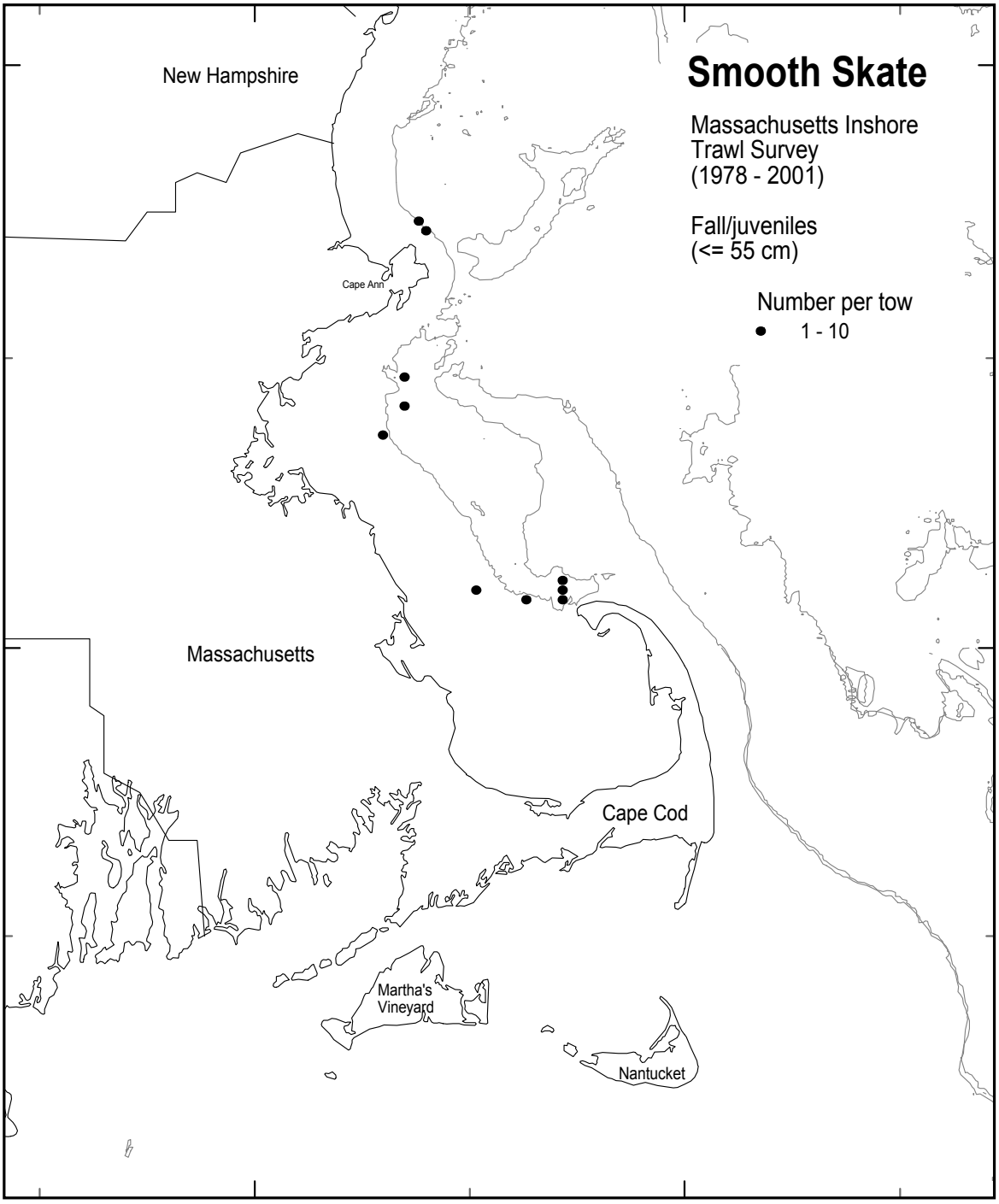


Figure 7. cont'd.

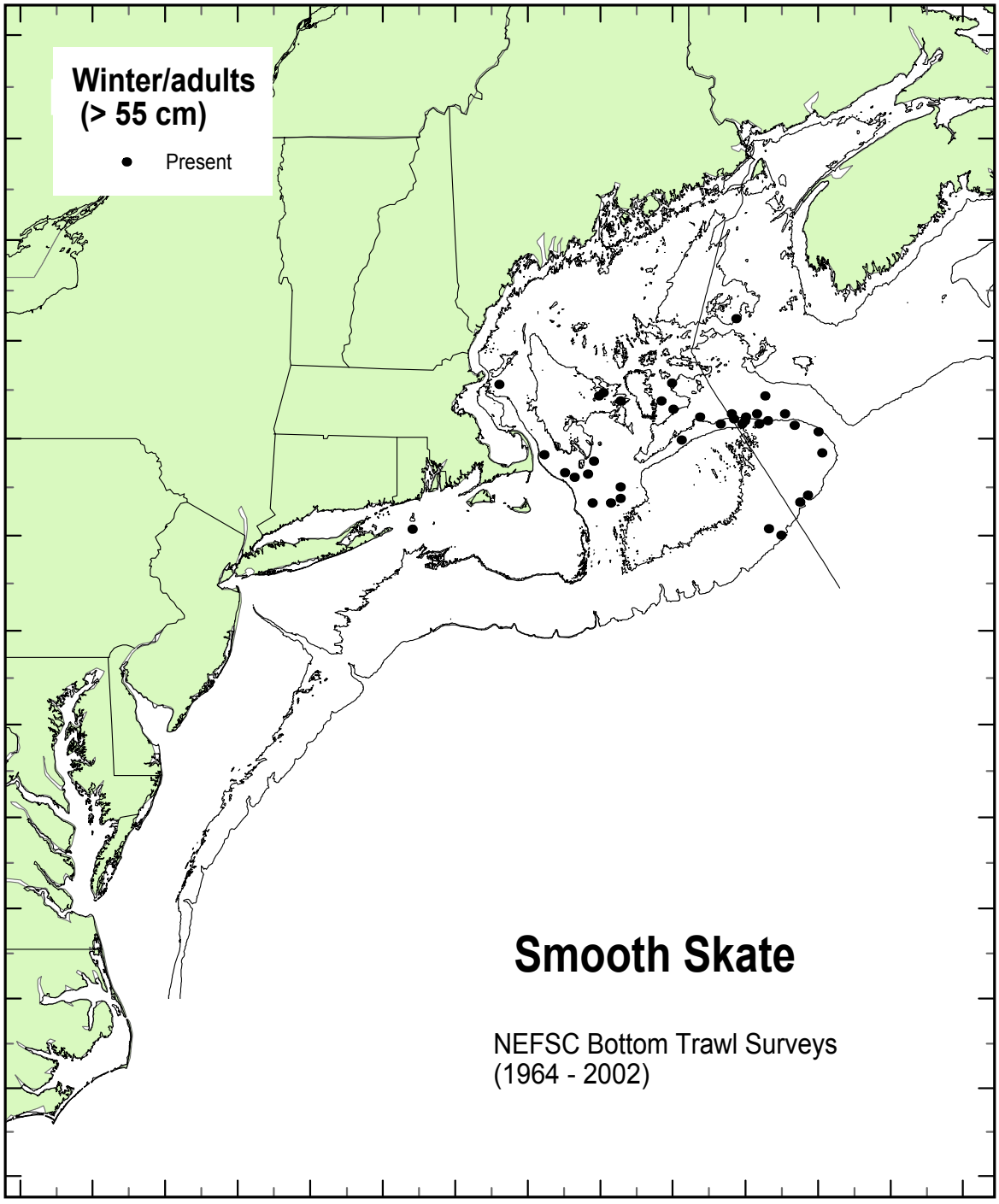


Figure 8. Distribution of adult smooth skate collected during winter NEFSC bottom trawl surveys [1964-2002, all years combined; see Reid *et al.* (1999) for details]. Survey stations where adults were not found are not shown.

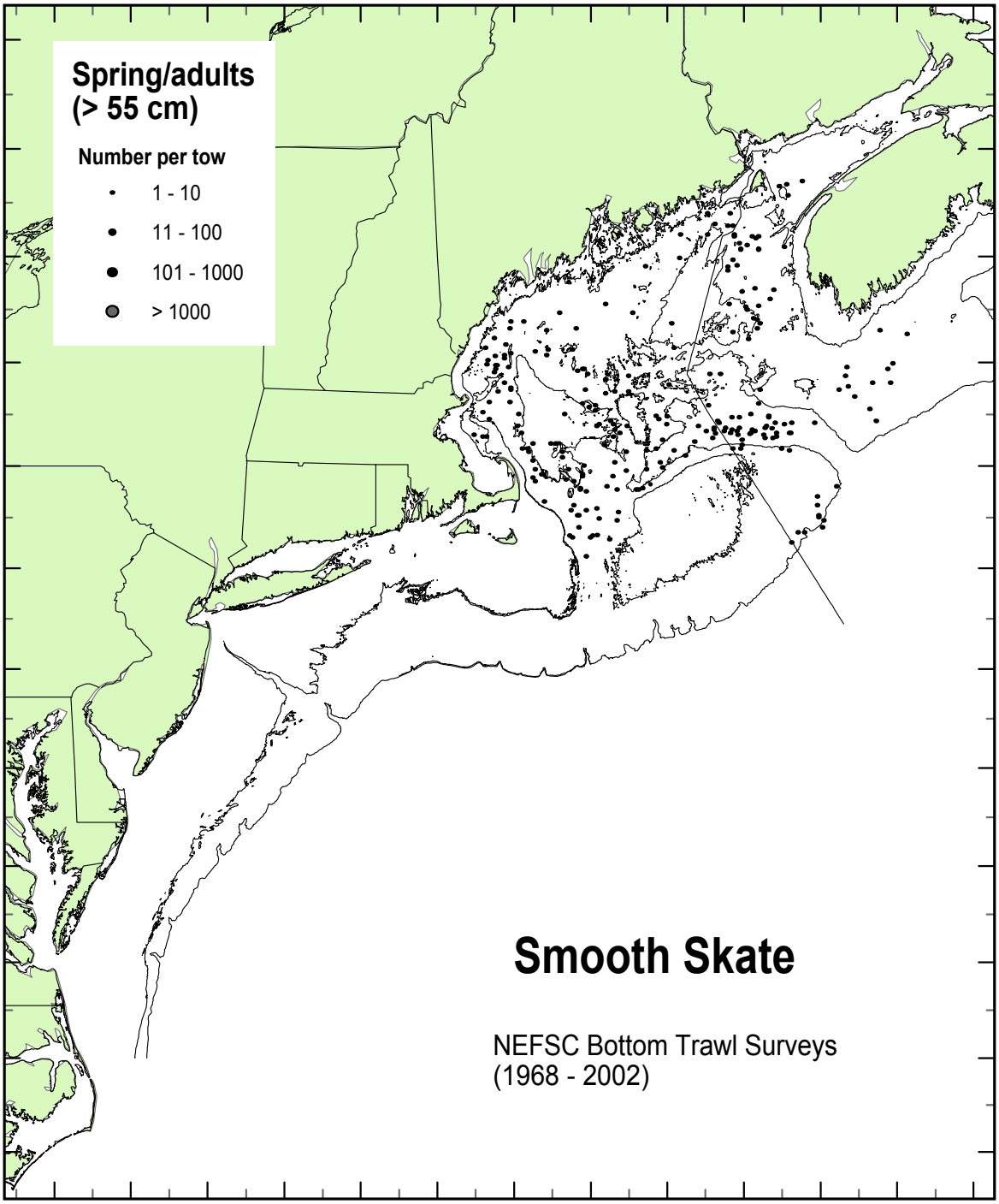


Figure 9. Distribution and abundance of adult smooth skate collected during spring NEFSC bottom trawl surveys [1968-2002, all years combined; see Reid *et al.* (1999) for details].

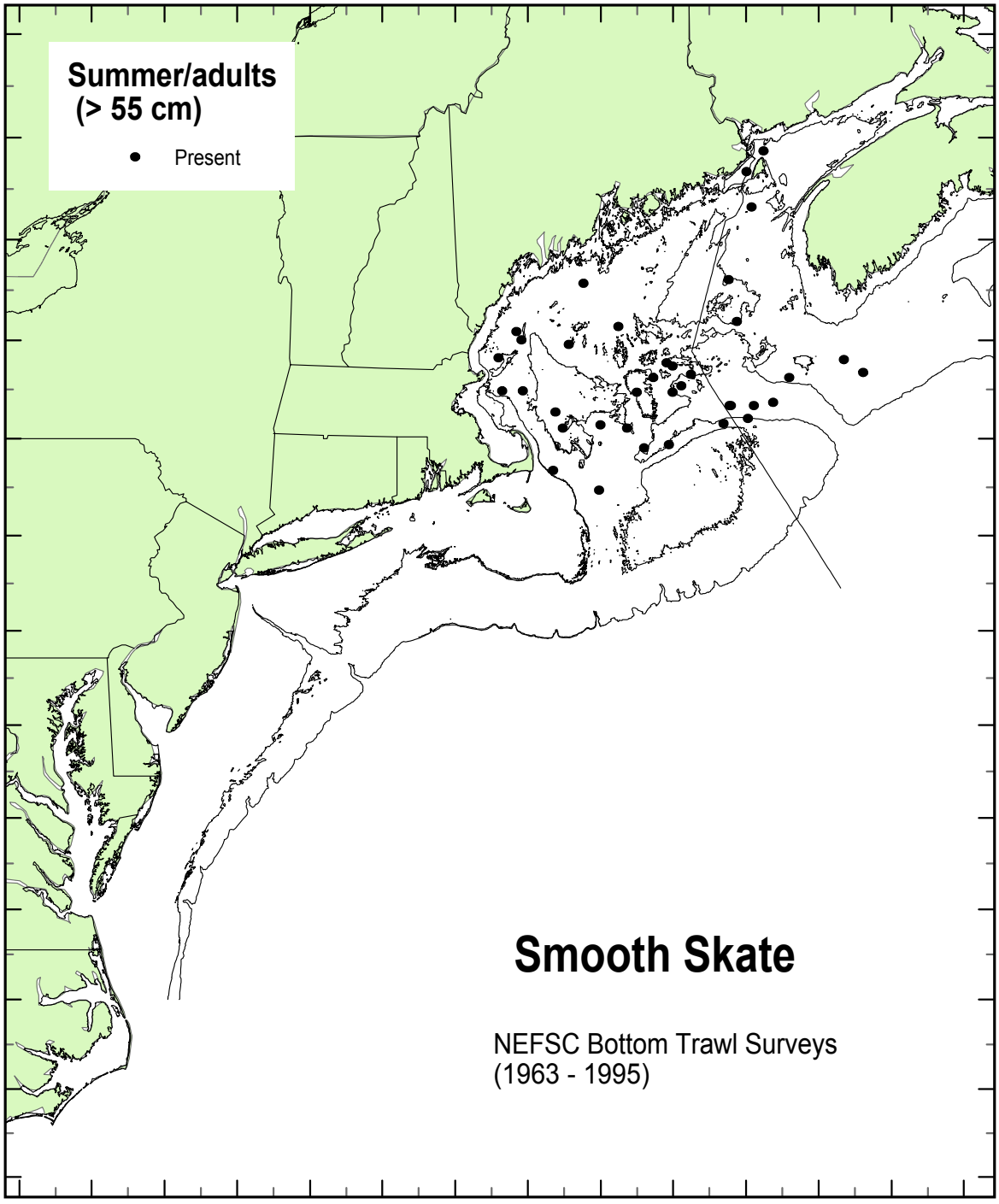


Figure 10. Distribution of adult smooth skate collected during summer NEFSC bottom trawl surveys [1963-1995, all years combined; see Reid *et al.* (1999) for details]. Survey stations where adults were not found are not shown.

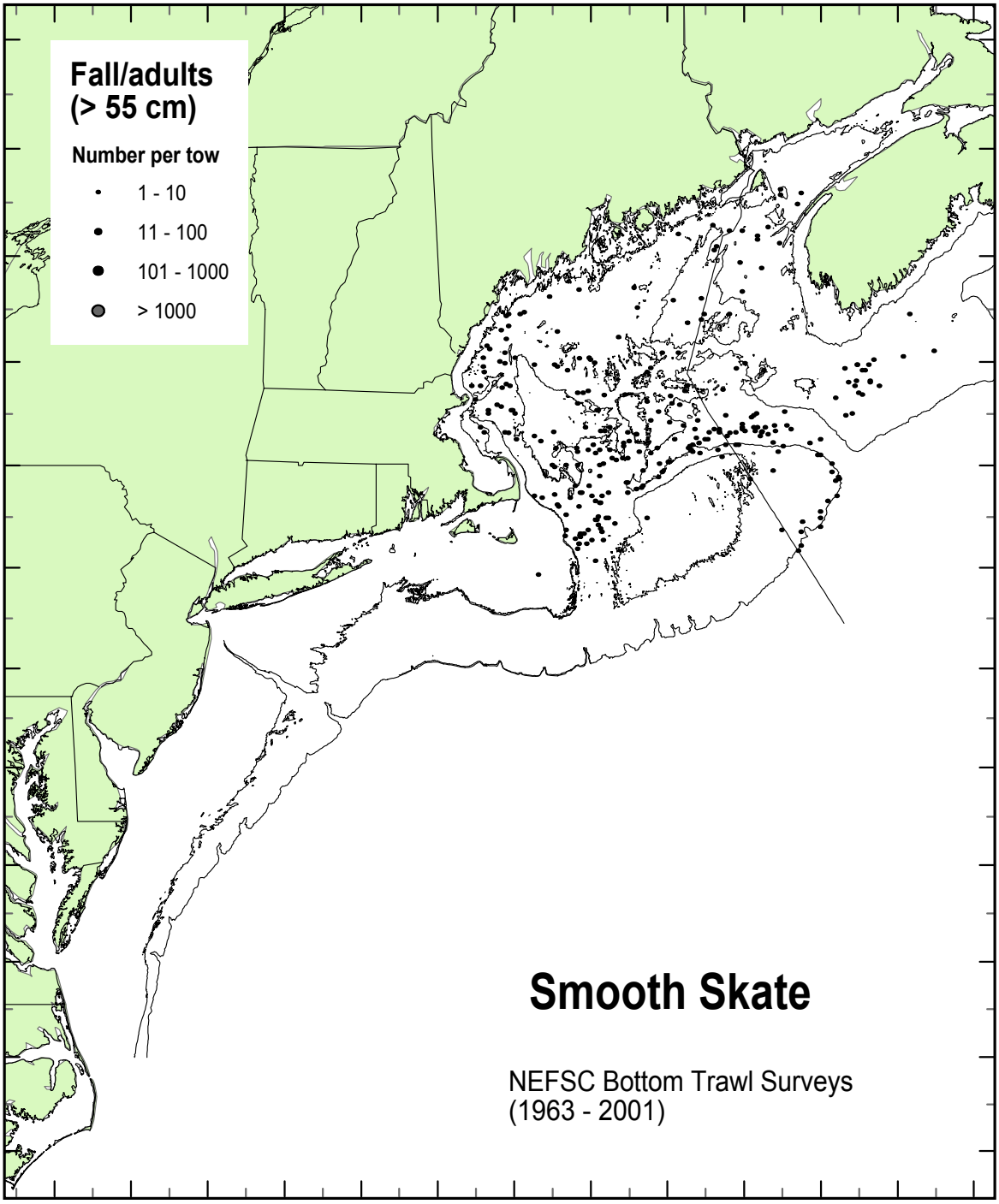


Figure 11. Distribution and abundance of adult smooth skate collected during fall NEFSC bottom trawl surveys [1963-2001, all years combined; see Reid *et al.* (1999) for details].

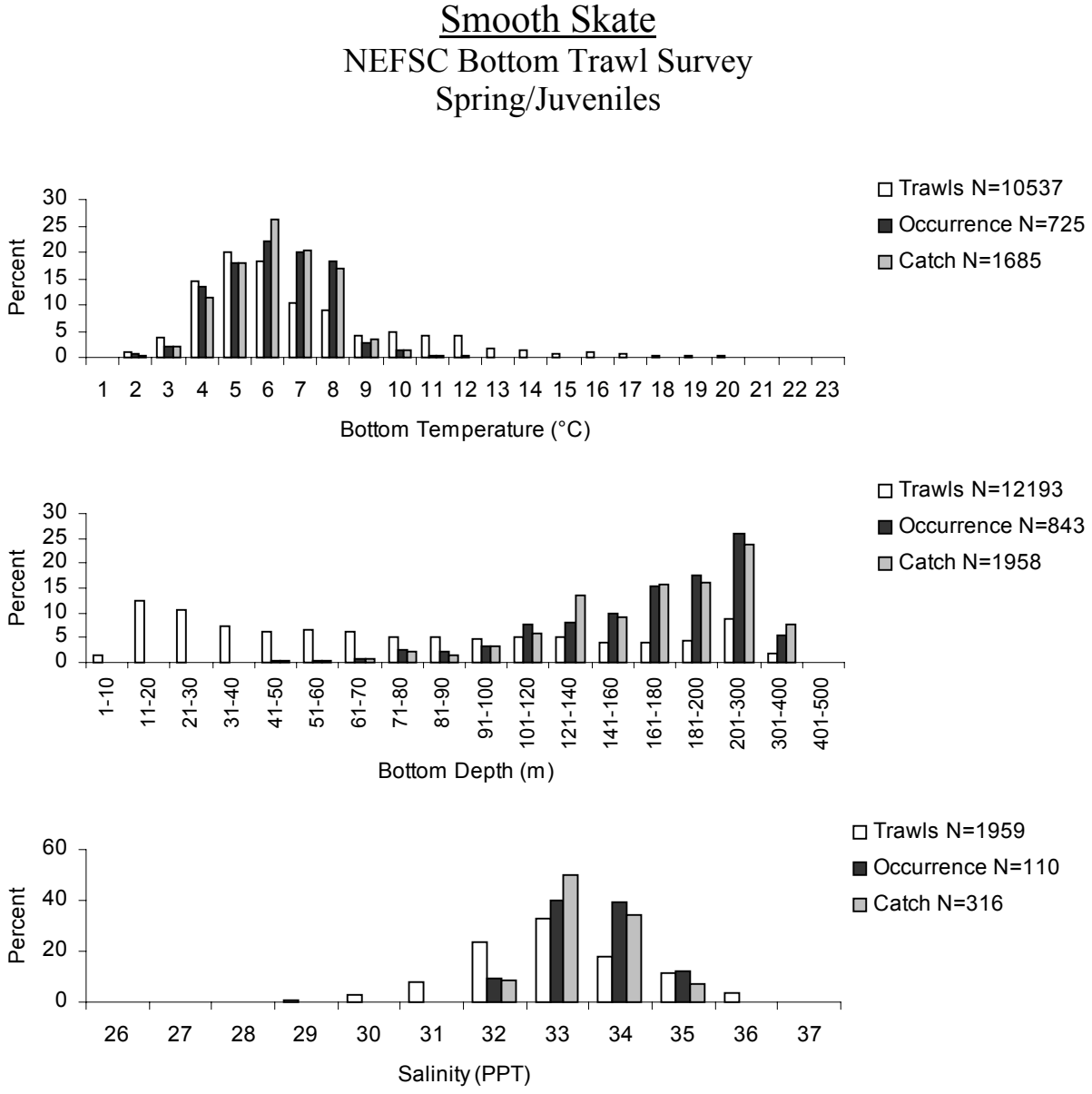


Figure 12. Spring and fall distributions of juvenile smooth skate and trawls relative to bottom water temperature, depth, and salinity based on NEFSC bottom trawl surveys (1963-2002; all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which smooth skate occurred, and gray bars represent, within each interval, the percentage of the total number of smooth skate caught.

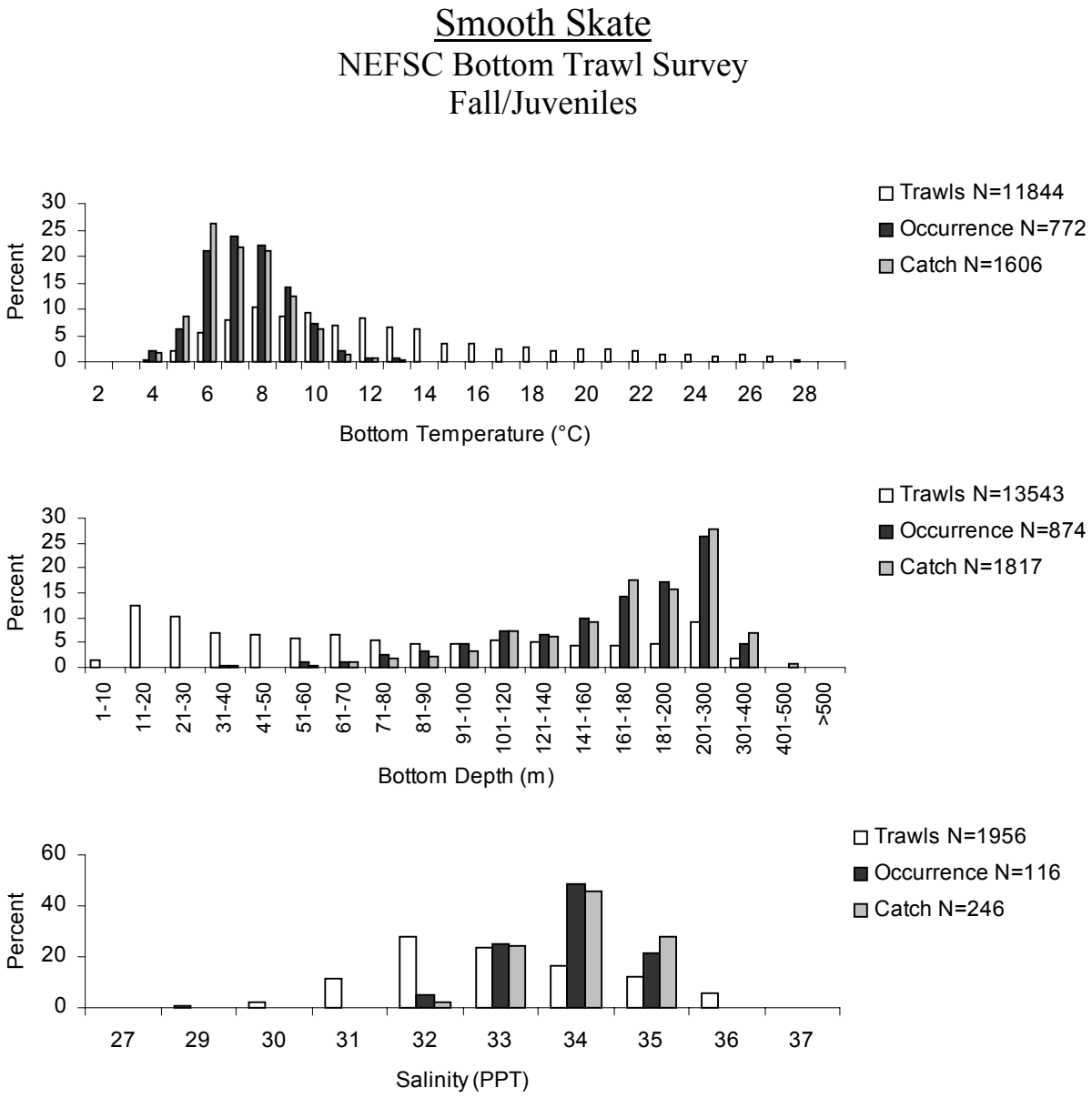


Figure 12. cont'd.

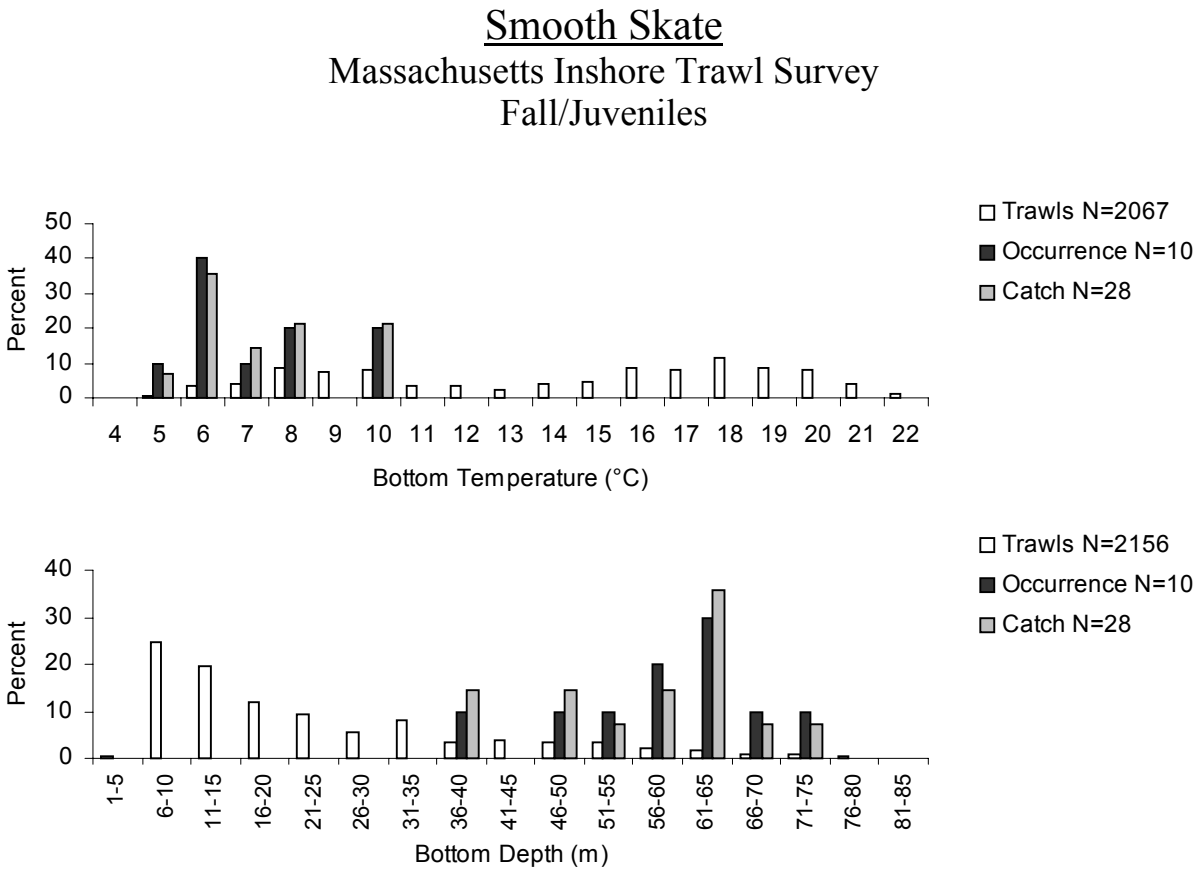


Figure 13. Fall distributions of juvenile smooth skate and trawls relative to bottom water temperature and depth based on Massachusetts inshore trawl surveys (1978-2001, all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which smooth skate occurred, and gray bars represent, within each interval, the percentage of the total number of smooth skate caught.

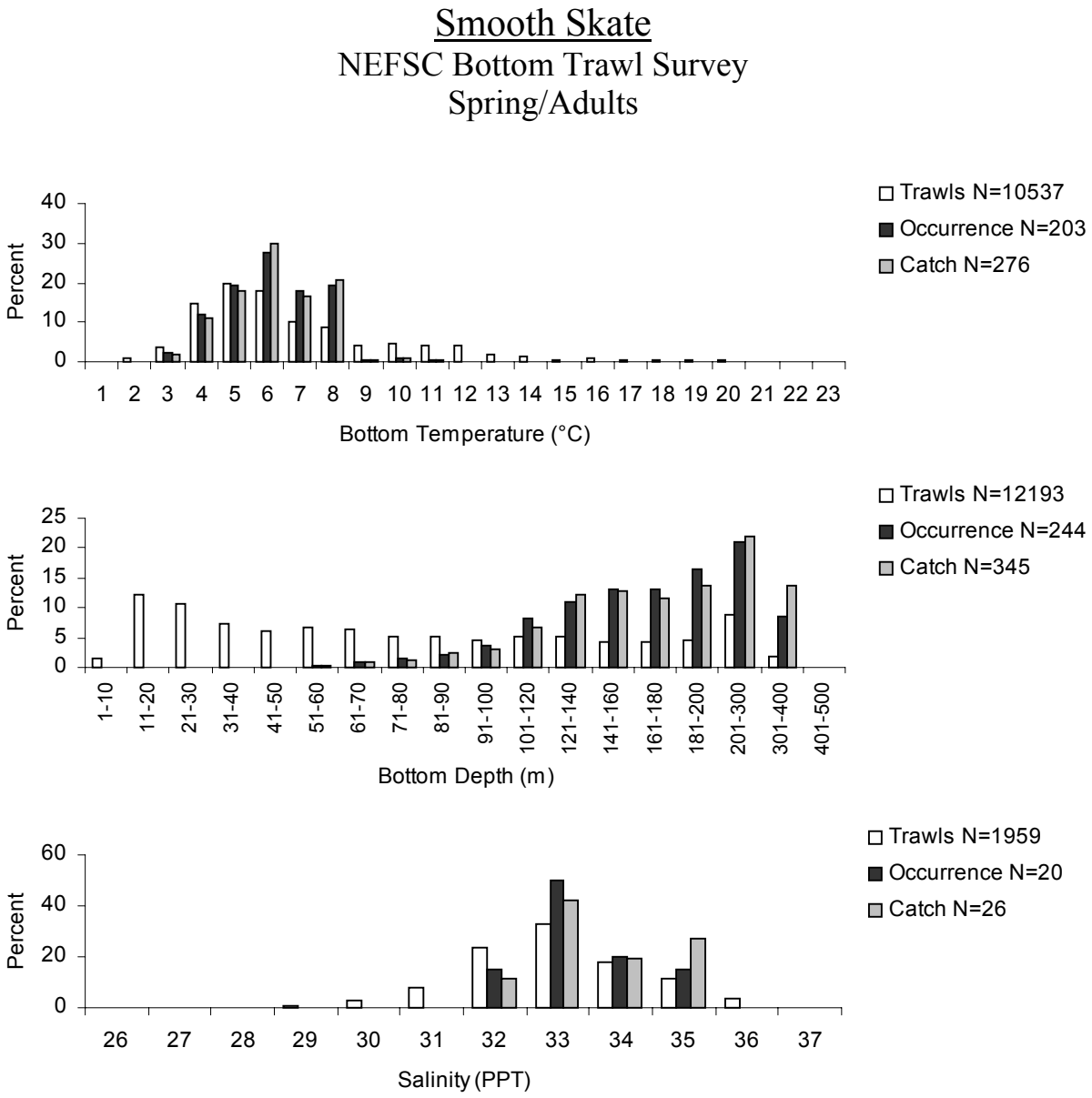
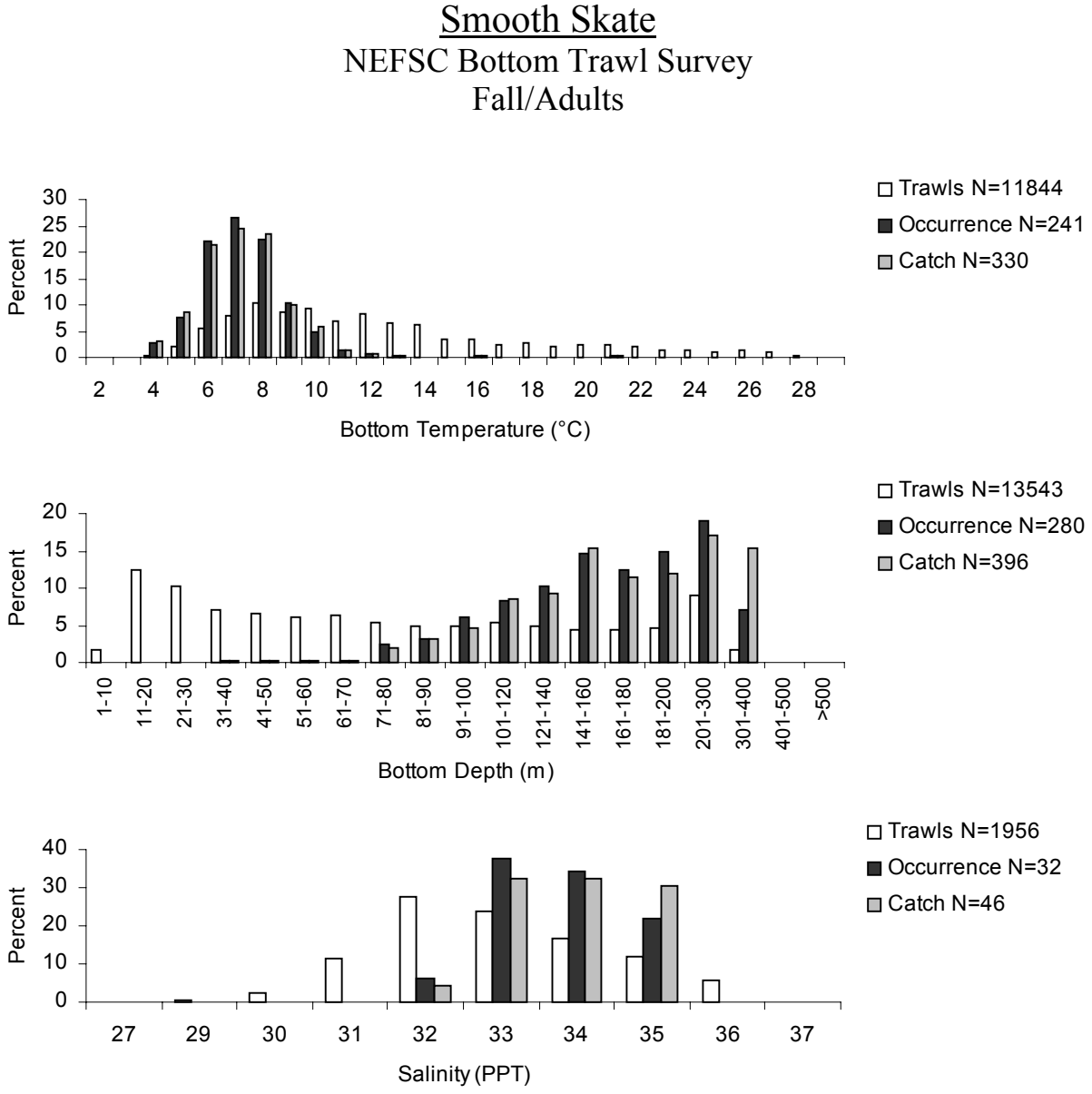


Figure 14. Spring and fall distributions of adult smooth skate and trawls relative to bottom water temperature, depth, and salinity based on NEFSC bottom trawl surveys (1963-2002; all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which smooth skate occurred, and gray bars represent, within each interval, the percentage of the total number of smooth skate caught.



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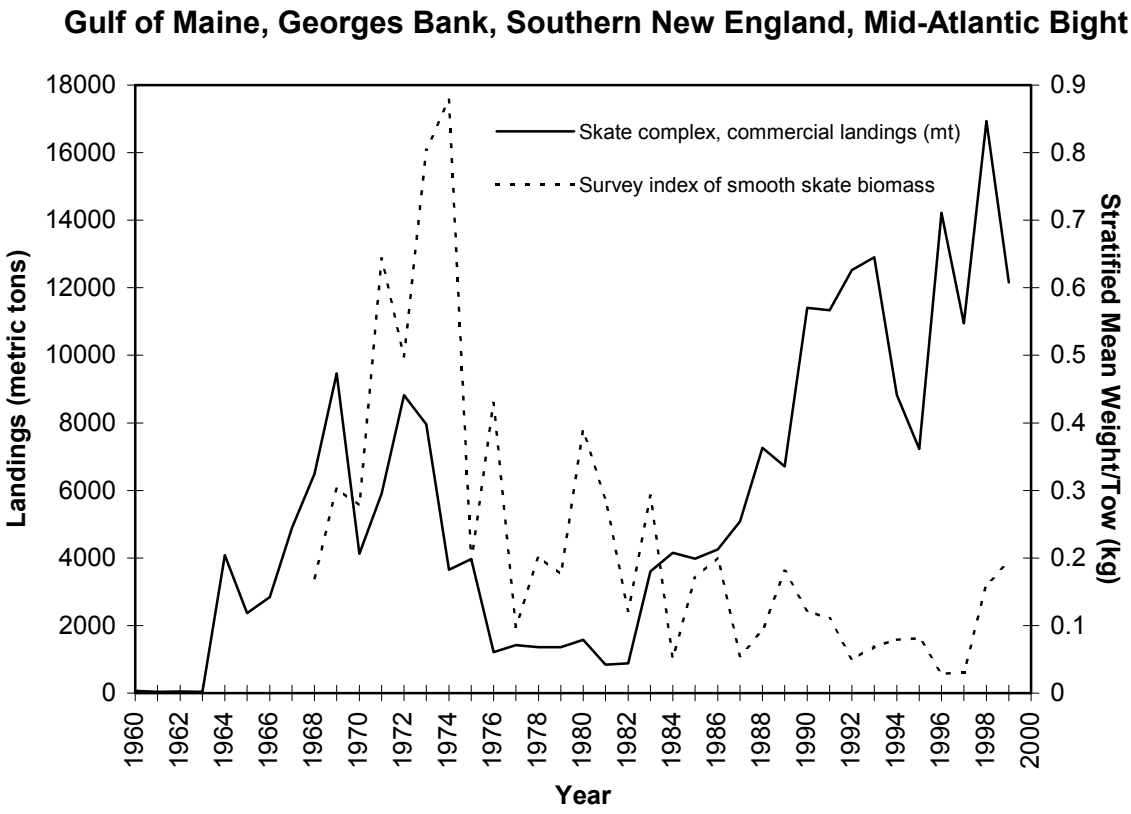

Figure 15. NEFSC spring survey index of smooth skate biomass and commercial landings of the seven species skate complex from the Gulf of Maine to the Mid-Atlantic Bight.

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For spelling of scientific and common names of fishes, mollusks, and decapod crustaceans from the United States and Canada, use *Special Publications* No. 20 (fishes), 26 (mollusks), and 17 (decapod crustaceans) of the American Fisheries Society (Bethesda, MD). For spelling of scientific and common names of marine mammals, use *Special Publication* No. 4 of the Society for Marine Mammalogy (Lawrence, KS). For spelling in general, use the most recent edition of *Webster's Third New International Dictionary of the English Language Unabridged* (Springfield, MA: G.&C. Merriam).

Typing text, tables, and figure captions: Text, tables, and figure captions must be converted to the NOAA-wide standard of WordPerfect. In general, keep text simple (*e.g.*, don't switch fonts and type sizes, don't use hard returns within paragraphs, don't indent except to begin paragraphs). Also, don't use the WordPerfect automatic footnoting function; all notes should be indicated in the text by simple numerical superscripts, and listed together in an "Endnotes" section prior to the "References Cited" section. Especially, don't use the WordPerfect graphics function for embedding tables and figures in text.

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Each figure should be supplied both on paper and on disk, unless there is no digital file of a given figure. Except under extraordinary circumstances, color will not be used in illustrations.

Manuscript Submission

Authors must submit one paper copy of the double-spaced manuscript, one disk copy, and original figures (if applicable). NEFSC authors must include a completely signed-off "NEFSC Manuscript/Abstract/Webpage Review Form." Non-NEFSC authors who are not federal employees will be required to sign a "Release of Copyright" form.

Send all materials and address all correspondence to:

Jon A. Gibson (Biological Sciences Editor)
NMFS Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543-1026 USA.

Research Communications Unit
Northeast Fisheries Science Center
National Marine Fisheries Service, NOAA
166 Water St.
Woods Hole, MA 02543-1026

MEDIA MAIL

Publications and Reports of the Northeast Fisheries Science Center

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 "planning, developing, and managing multidisciplinary programs of basic and applied research to: 1) better understand the living marine resources (including marine mammals) of the Northwest Atlantic, and the environmental quality essential for their existence and continued productivity; and 2) describe and provide to management, industry, and the public, options for the utilization and conservation of living marine resources and maintenance of environmental quality which are consistent with national and regional goals and needs, and with international commitments." 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. Those media are in four categories:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term or large-area studies; synthesis reports for major resources or habitats; analytical reports of environmental conditions or phenomena; annual reports of assessment or monitoring programs; manuals describing unprecedented field and lab techniques; literature surveys of major resource or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab observations or experiments; progress reports on continuing experiments, monitoring, and assessments; manuals describing routine surveying and sampling programs; background papers for, and summary reports of, scientific meetings; and simple bibliographies. Issues receive internal scientific review, but no technical or copy editing.

Fishermen's Report -- This information report is a quick-turnaround report on the distribution and relative abundance of commercial fisheries resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of this report.

The Shark Tagger -- This newsletter is an annual summary of tagging and recapture data on large pelagic sharks as derived from the NMFS's Cooperative Shark Tagging Program; it also presents information on the biology (movement, growth, reproduction, etc.) of these sharks as subsequently derived from the tagging and recapture data. There is internal scientific review, but no technical or copy editing, of this newsletter.

OBTAINING A COPY: To obtain a copy of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, or to subscribe to the *Fishermen's Report* or the *The Shark Tagger*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2228) or consult the NEFSC webpage on "Reports and Publications" (*http://www.nefsc.noaa.gov/nefsc/publications/*).