NOAA Technical Memorandum NMFS-NE-175

Essential Fish Habitat Source Document:

Little Skate, *Leucoraja erinacea*, 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.

Essential Fish Habitat Source Document:

Little Skate, *Leucoraja erinacea*, Life History and Habitat Characteristics

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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 little skate [*Leucoraja erinacea* (Mitchill 1825); formerly *Raja erinacea*, see McEachran and Dunn (1998); Figure 1] occurs from Nova Scotia to Cape Hatteras and is one of the dominant members of the demersal fish community of the northwest Atlantic (Bigelow and Schroeder 1953; Richards *et al*. 1963; McEachran and Musick 1975; Michalopoulos 1990). Its center of abundance is in the northern section of the Mid-Atlantic Bight and on Georges Bank, where it is found year-round over almost the entire range of temperatures recorded for those areas (McEachran and Musick 1975). Little skate make no extensive migrations, although where it occurs inshore the species moves onshore and offshore with seasonal temperature changes (Bigelow and Schroeder 1953; Merriman *et al*. 1953; Fitz and Daiber 1963; Richards 1963; Richards *et al*. 1963; Schaefer 1967; Tyler 1971a, b). It also moves north and south with seasonal temperature changes along the southern fringe of its range (McEachran and Musick 1975).

Smaller little skate are often confused with its sympatric species, winter skate (*Leucoraja ocellata*); the distinctions are size-dependent (McEachran and Musick 1973; McEachran 2002). Number of tooth rows, length at maturity, and location of pelvic denticles are the characters most commonly used to differentiate the two species (Michalopoulos 1990).

LIFE HISTORY

EGGS

The single fertilized egg is encapsulated in a leathery, greenish-brown case or capsule known as a “mermaid’s purse” which is deposited on the bottom and often washes up on beaches. The egg cases are laid in pairs. They are rectangular in shape, 44-63 mm long and 30-45 mm wide, with a hollow curved horn at each corner (Figure 2; Vladykov 1936; Fitz and Daiber 1963). The anterior horns are curved inward and are about half the length of the case while the posterior horns are more or less straight or slightly curved outwardly and are about as long as the case [McEachran (2002); see also Johnson (1979) for a comprehensive description of the egg case]. Walls of the case are smooth but have longitudinal striations. The cases have sticky filaments that allow them to adhere to the bottom substrates.

External gills appear from the walls of the gill slits 25-30 days to 90-95 days after spawning but these disappear before hatching (Pelster and Bemis 1992). Gestation is at least six months or more. Aquarium studies mentioned by Bigelow and Schroeder (1953) showed that eggs laid in May-July hatched between the end of November and beginning of January, about 5-6 months. Richards *et al*. (1963) also determined that eggs spawned in the late spring and early summer required five to six months to hatch. Since the water temperature of the aquarium in which the eggs were kept was slightly above that of the natural environment, it is possible that the incubation time was underestimated. Perkins (1965) in a study conducted at Boothbay Harbor, Maine, found under aquarium conditions where the water temperature closely approximated that of the inshore waters, eggs deposited in November and December hatched after twelve months of incubation. Johnson (1979) performed flow-through seawater system studies using ambient temperatures resembling those of the inshore waters of Block Island Sound at 20 m. The incubation period ranged from 112-366 d and was dependent on month of deposition. Eggs deposited in September 1975 hatched after an average of 360 d. Incubation time decreased progressively from September, and eggs deposited in July 1977 developed and hatched in an average of 122 d. The rate of embryonic growth appeared to be directly related to temperature. In Perkins (1965) study, incubation of eggs deposited in November and December showed the first embryonic activity in March when the water temperature had risen to 7°C.

JUVENILES

The young are 93-102 mm TL at hatching (Richards *et al*. 1963; McEachran 2002) and are fully developed, resembling the adult in both shape and coloration.

ADULTS

Bigelow and Schroeder (1953) reported adult little skate to have an average size of 41-51 cm TL, with a maximum length of 53 cm TL. Waring (1984) calculated the maximum size to be 53 cm TL; McEachran (2002) reports the maximum size as 54 cm TL. Johnson calculated the maximum size for little skate from Block Island Sound to be 60 cm TL for males and 62 cm TL for females. Maximum size and size at maturity increases toward the northern end of their range (Richards *et al*. 1963; McEachran and Martin 1977).

AGE AND GROWTH

Age and growth of little skate have been estimated from length frequency plots and by counting rings on vertebral centra (Richards *et al*. 1963; Johnson 1979; Waring 1984). Johnson (1979) reported mean length at age for male little skate from Block Island Sound was 20.0 cm TL at age 1, 30.3 cm TL at age 2, 38.7 cm TL at age 3, 45.1 cm TL at age 4, and 48.8 cm TL at age 5. For females the mean length at age was 21.0 cm TL at age 1, 31.3 cm TL at age 2, 38.3 cm TL at age 3, 45.8 cm TL at age 4, and 48.3 cm TL at age 5. Little skate from Georges Bank to Delaware Bay averaged 21.5 cm TL at age 1, 29.3 cm TL at age 2, 36.4 cm TL at age 3, 42.0 cm TL at age 4, 46.1 cm TL at age 5, 47.2 cm TL at age 6, 47.5 cm TL at age 7, and 48.1 cm TL at age 8 (Waring 1984). Bigelow and Schroeder (1953) originally reported that skate 20 cm long may be 1-1.5 yrs old, 30 cm long may be 2-3 yrs old, 40 cm long may be 3-4 yrs old, and 50 cm long may be 6-8 yrs old.

Richards *et al*. (1963), who examined skates from Long Island and Block Island Sounds, determined that they grow approximately 10 cm/yr for the first three years; between the third and fourth years, growth decreases to around 5 cm/yr [Merriman *et al*. (1953) generally concurs]. Richards *et al*. (1963) also noted that differences in size between the sexes were unnoticeable until skates reached adolescence. Then the males from both Sounds became longer and heavier than the females. Adult males were also larger than females and the majority of those > 50 cm TL were males.

Natanson (1990) performed age and growth experiments on skate from Narragansett Bay, Rhode Island that were held in an experimental tank with a mean temperature of 18°C and a control tank with temperatures that fluctuated with the seasons (range from 1-23°C). The fish in the experimental tank were 41.0-44.7 cm TL and the fish in the control tank were 34.0-47.7 cm TL. The growth rates of skates from the experimental tank ranged from 1.3-3.4 cm TL/yr and rates in the control tank ranged from 1.0-4.9 cm TL/yr. Growth of individuals from both tanks was considered slow compared to field estimates for little skate by Johnson (1979), but similar to estimates by Waring (1984). Waring's (1984) study showed skates of this size growing from 2.30-4.65 cm TL/yr and Johnson's (1979) study showed faster growth of 4.22-8.26 cm TL/yr. The size at age in the Natanson (1990) study was also lower than in Johnson (1979) and Waring's (1984) studies. The size at age from the Natanson (1990) study supported the growth rates observed in her laboratory. Data from the Natanson (1990) study also indicates that growth would be slow over the life of the individual as compared to growth rates in Johnson's (1979) or Waring's (1984) studies. The difference is probably related to differences in vertebrae preparation and criteria for an annual band (Natanson 1990).

SIZE AT MATURITY

Bigelow and Schroeder (1953) reported that females mature when 32-43 cm TL, and males at 36-45 cm TL, based on information supplied by others, while McEachran (2002) states that maturity is reached between 35-50 cm TL. McEachran (1973) studied skates collected from Nova Scotia and the Gulf of Maine to Cape Hatteras between 1967-1970 and found that about a third of the little skate between 42-44 cm TL as well as all those > 50 cm TL were mature; the smallest mature little skate was a male 41 cm TL. Richards *et al*. (1963) reported the average total length at maturity for male and female little skate in Block Island Sound was 46.3 cm TL and 45.9 cm TL, respectively. Johnson (1979) used females > 47 cm TL in his laboratory studies because that was the length that the largest percentage of females had reached maturity.

Based on the predictive equations from Frisk *et al*. (2001) and the Northeast Fisheries Science Center (NEFSC) survey maximum observed length of 62 cm TL, L_{mat} is estimated at 50 cm TL and A_{mat} is estimated at 4 years (Northeast Fisheries Science Center 2000b).

REPRODUCTION

Mating in little skate may take place at any time throughout the year and frequently (Bigelow and Schroeder 1953; Richards *et al*. 1963; Johnson 1979). Egg cases are also found partially to fully developed in mature females year-round but several authors report that they are most frequently encountered from late October-January and from June-July (Fitz and Daiber 1963; Richards *et al*. 1963; Scott and Scott 1988); Bigelow and Schroeder (1953) also mention that eggs are taken off southern New England mostly from July to September.

In Block Island Sound, Johnson (1979) also reported pregnant little skate were present during all months of the year, but again the seasonal percentages of pregnant females varied. Periods of relatively high pregnancy-frequency were October-December and April-May, while low periods occurred in August-September and February-March. Peaks in egg production were in November and May when 34% and 44% of the females examined were pregnant, respectively. The lowest levels of production came in September and March when approximately 1% of the females were pregnant.

Johnson (1979) found the mean number of mature and maturing eggs per fish increased significantly prior to and during the spawning peaks, reaching maxima in October and May. The average number of mature and maturing eggs decreased significantly between what appears to be two spawning seasons with minima in August and January. The greatest ovarian production occurred in the spring. In Delaware Bay, Fitz and Daiber (1963) also showed that the greatest ovarian production occurred in the spring, while the size and number of eggs was at a minimum in February and March.

Johnson (1979) reported that ovarian weight also increased significantly during two spawning seasons. Comparison of the female gonad weight expressed as a percentage of total body weight demonstrated two seasonal peaks with maxima occurring in October and May; these seasonal peaks represented and increase in ovarian production. After the height of spawning, the female gonad weight dropped off significantly, reaching a minima in January and August.

Rate of egg laying in Johnson's (1979) study varied from 0.20-0.67 eggs/d, with an average rate of 0.39

eggs/d. Johnson (1979) suggests that an average female little skate which spawns twice annually (once during fall and spring) produces approximately 30 eggs/yr. Bigelow and Schroeder (1953) observed that eggs in aquaria were laid at intervals of from five days to several weeks, and were partially buried in sand.

FOOD HABITS

Generally, invertebrates such as decapod crustaceans and amphipods are the most important prey items, followed by polychaetes (Bigelow and Schroeder 1953; Tyler 1972; McEachran 1973; McEachran *et al*. 1976; Bowman and Michaels 1984; Nelson 1993; Bowman *et al*. 2000; Garrison 2000; Garrison and Link 2000a, b; Scharf *et al*. 2000). Isopods, bivalves, and fishes are of minor importance. Bigelow and Schroeder (1953) reported hermit and other crabs, shrimps, polychaetes, amphipods, ascidians, bivalves, squid, fishes, and even copepods. Little skate from the Woods Hole region contained mostly crabs, followed by shrimp (*Crangon septemspinosa*), and squid. The fishes that were eaten included sand lance, alewives, herring, cunners, silversides, tomcod, and silver hake. Hydroids are also ingested (Avent *et al*. 2001).

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

Crangon septemspinosa, *Pagurus acadianus*, *Cancer irroratus*, and *Dichelopandalus leptocerus* were the most frequently eaten decapods in the Mid-Atlantic Bight and on Georges Bank. *C. septemspinosa* was the most numerous decapod in the stomachs while *P. acadianus* and *C. irroratus* accounted for most of the stomach volume. In the Gulf of Maine and on the Nova Scotian shelf *Pagurus pubescens*, *C. septemspinosa*, *Hyas* sp., and *Eualus pusiolus* were the most frequently eaten decapods.

The most frequently consumed amphipods in the Mid-Atlantic Bight and on Georges Bank were *Monoculoides* sp., *Unciola* sp., *Leptocheirus pinguis*, ampeliscids, haustoriids, and *Dulichia* (= *Dyopedos*) *monacantha*. *L. pinguis* predominated in the Mid-Atlantic Bight and *Monoculodes* sp. and *Unciola* predominated in little skate from Georges Bank. Haustoriid amphipods were abundant only in the little skate from Georges Bank and contributed significantly to the stomach contents only during the autumn survey. *Pleustes panoplus*, *L. pinguis*, *Hippomedon serratus*, *Monoculodes* sp., and *Unciola* sp. were the most frequently eaten amphipods in the Gulf of Maine and on the Nova Scotian shelf.

Eunice pennata and *Nereis* spp. were the most numerous polychaetes, with *E. pennata* abundant only on the Nova Scotian shelf and *Nereis* spp. numerous only in the Mid-Atlantic Bight. Other major polychaetes consumed in the Mid-Atlantic Bight and on Georges Bank were *Nepthys* spp., *Lumbrineris fragilis*, *Aphrodite hastata*, maldanids, (mostly *Clymenella torquata*), *Glycera* spp., and *Pherusa affinis*. *A. hastata* contributed most to the stomach volume. The polychaetes *Ophelia denticulata*, *Nothria conchylega*, and *Pectinaria* sp. predominated in stomachs from the Gulf of Maine and the Nova Scotian shelf.

Among the minor prey items consumed included the isopods *Cirolana* (= *Politolana*?) *polita* and *Chiridotea tuftsi*. The former species accounted for almost the entire volume of isopods. Most of the bivalves eaten were in the family Solenidae, with *Ensis directus* the only species of this family identified. *Solemya* sp. was the only other bivalve recognized. The most numerous fishes that were eaten included yellowtail flounder and longhorn sculpin.

Nelson (1993) studied the diet of little skate at two stations on Georges Bank, his results were similar to McEachran (1973) and McEachran *et al*. (1976) in terms of the major phyla consumed in that area. Amphipods dominated the diets numerically and decapods dominated the diets by weight, followed by (depending on site) polychaetes, bivalves, fish, isopods, and cnidarians.

In Sheepscot Bay, Maine, little skate ate a variety of prey, but seemed to focus most on crustaceans (Packer and Langton, unpublished manuscript) and Atlantic herring, at least on a percent weight basis (Langton and Watling 1990). *C. septemspinosa*, the jonah crab *Cancer borealis*, the amphipods *L. pinguis* and *U. inermis*, and several other varieties of crustaceans were important in the diet, followed by polycheates such as *Nephtys* spp. (Packer and Langton, unpublished manuscript). In Johns Bay, Maine, little skate fed primarily on the decapod crustaceans *C. septemspinosa* and *C. irroratus*, followed by the amphipods *L. pinguis*, *Unciola* spp. and *Monoculodes* spp. (Hacunda 1981). Polychaetes were the next major prey group.

Smith (1950) conducted diet studies on little skate from Block Island Sound; the diet was similar to that of little skate in the McEachran (1973) and McEachran *et al*. (1976) studies. *L. pinguis* was most abundant in the diet, followed by *C. irroratus*, *C. septemspinosa*, *Upogebia affinis* (a mud shrimp), *Glycera dibranchiata*, *Byblis serrata* (an amphipod), *Unciola irrorata*, *Nephtys incisa*, and *E. directus*.

Carlson (1991) found that decapods made up 76% of the diet by weight in New Haven Harbor. *C. septemspinosa* and *C. irroratus* were the most important prey items, followed by mantis shrimp, *Squilla empusa*. Other crustacean groups did not constitute a major portion of the diet. Fish were the next major group, but only made up 10% of the diet by weight and only 4% by number. There was a high diet overlap with other predators including striped searobin, tautog, and windowpane because of their similar dependence on crustaceans.

Fitz and Daiber (1963) conducted diet studies on little skate in Delaware Bay. *C. septemspinosa* made up > 70% of the diet, followed by *E. directus* and *Euceramus* *praelongus* (a burrowing crab). In the fall, the latter two prey items, along with the polychaete *Nereis limbata* (= *Neanthes succinea*), were more prominent in the skates' diet than in the spring.

In the inshore diet studies mentioned above, the skates generally depended more on a few major prey species than skates from the McEachran (1973) and McEachran *et al*. (1976) studies. This may be attributable to the benthic faunal composition in these inshore areas; these areas have a less diverse fauna than the wide region sampled as part of the McEachran (1973) and McEachran *et al*. (1976) studies. But it is clear that the food habits of little skate are fairly generalized, and it is an opportunistic predator (McEachran 1973; McEachran *et al*. 1976; Nelson 1993; Packer and Langton, unpublished manuscript).

McEachran (1973) and McEachran *et al*. (1976) showed that the diet of little skate is size-dependent. Skate < 41 cm TL consumed considerably fewer decapods and more amphipods than those that were ≥ 41 cm TL. Most decapods eaten by skates ≤ 30 cm TL were *C. septemspinosa*. Haustoriid amphipods were almost never found in skates > 30 cm TL. Cumaceans and copepods were also limited to the smaller skates. All sizes fed on fishes, but the frequency of occurrence increased with the size of the skate. Polychaetes were eaten by all sizes.

The 1973-1990 NEFSC food habits database for little skate [Figure 3; see Reid *et al*. (1999) for details] generally confirms the McEachran (1973) and McEachran *et al*. (1976) studies. Crustaceans dominated the diet overall, but declined in importance with increasing skate size while the percent occurrence of polychaetes increased with increasing skate size. Amphipods occurred more frequently than decapods until the skates were > 41 cm TL. *C. septemspinosa* was the major decapod prey for all sizes of skate. The following is a description of the diet from the NEFSC food habits database broken down by little skate size class (Figure 3).

For little skate 1-10 cm TL, 97% of the diet consisted of crustaceans, with 42% of the diet consisting of identifiable amphipods. The most abundant amphipod species included *B. serrata*, *U. irrorata*, *Monoculodes intermedius*, *Synchelidium* sp., as well as several unidentifiable Gammaridea. Identifiable cumaceans made up 27% of the diet, notable species included *Cyclaspis varians* and *Diastylis* spp. Identifiable decapods made up only 8% of the diet, all of which were either *C. septemspinosa* or classified as unidentifiable Crangonidae.

For skate 11-20 cm TL, 90% of the diet consisted of crustaceans, and at least half of the diet consisted of identifiable amphipods. Major amphipod species included *B. serrata*, *U. irrorata*, *L. pinguis*, *Ericthonius rubricornis*, and several unidentifiable gammarids, ampeliscids, oedicerotids, and caprellids. Identifiable decapods made up 18-20% of the diet, most of which were *C. septemspinosa*; other important decapods included pagurid and *Cancer* crabs.

The percentage of crustaceans in the diet of little skate 21-30 cm TL dropped to 83%, although almost half of the diet still consisted of identifiable amphipods. The major amphipod prey species were similar to the 11-20 cm TL size class, with the addition of *M. edwardsi*. Identifiable decapods again made up 18-20% of the diet, the majority of which were again *C. septemspinosa* along with *Cancer* and pagurid crabs. Identifiable polychaetes made up only 10-11% of the diet, most of which were terebellids.

The percent occurrence of crustaceans in the diet of little skate 31-40 cm TL dropped further, down to 73-78%, with identifiable amphipods making up only 32-36% of the overall diet. The usual amphipods were dominant; in order of abundance they were *U. irrorata*, *L. pinguis*, unidentifiable gammarids, *B. serrata*, unidentifiable ampeliscids, *M. edwardsi*, and unidentifiable caprellids, haustoriids, and oedicerotids. Identifiable decapods made up 25-28% of the diet; *C. septemspinosa* was again the dominant decapod prey, followed by *Cancer* and pagurid crabs, and *Dichelopandalus leptocerus*. Identifiable polychaetes made up only 14-15% of the diet; the majority were terebellids and maldanids.

The percent occurrence of crustaceans in the diet continued to decline for little skate 41-50 cm TL: down to 66-71%, with identifiable amphipods making up only 22-28% of the diet, while identifiable decapods made up 29-32%. The usual amphipods were dominant, especially *L. pinguis* and *U. irrorata*, followed by the others previously mentioned. *C. septemspinosa* continued to be the dominant decapod prey, followed by *Cancer* and pagurid crabs. Identifiable polychaetes made up 17-18% of the diet, with the dominant family being the Terebellidae. Other abundant families included the Nephtyidae, Maldanidae, Aphroditidae, and the Flabelligeridae.

Finally, the percent occurrence of crustaceans in the diet declined to 64-69% for skate 51-60 cm TL, with identifiable amphipods making up only 19-22% of the diet, while identifiable decapods 29-34%. *L. pinguis* was the dominant amphipod; *C. septemspinosa*, *Cancer*, and pagurid crabs were the dominant decapods. Identifiable polychaetes made up 19-20% of the diet, with the dominant family being the Terebellidae.

Other authors also show similar size-dependent trends in the diet of little skate. Bowman and Michaels (1984) and Bowman *et al*. (1987) reported that while crustaceans were the dominant prey of all sizes of little skate, skate < 35 cm TL preyed mostly on amphipods (including *Unciola*) and those > 35 cm TL ate large quantities of decapods (including *C. septemspinosa*). Polychaetes, mollusks, and fish were found primarily in little skate > 20 cm TL. Again, using NEFSC data from 1977-1980, Bowman *et al*. (2000) also found that in terms of percent weight, crustaceans were important for all size classes of skate. Skate < 15-30 cm TL fed mostly on amphipods, including *L. pinguis*, *Unciola* spp, *Gammarus annulatus*, and Oedicerotidae. Skate 36 to > 51 cm TL fed mostly on decapods, including *C. irroratus*, *C. borealis*, *P. acadianus*, and *C. septemspinosa* [although, as in the McEachran (1973) and McEachran *et al*. (1976) studies, *C. septemspinosa* was eaten mostly by skates ≤ 30 cm TL]. On Georges Bank, Nelson (1993) discovered that colonial amphipods and small epibenthic decapods dominated the diets of little skate < 39 cm TL at both of his study sites, but species composition was site and size dependent. At one site, *Ericthonius fasciatus* and *U. inermis* comprised the largest portions of the diet of skates < 39 cm TL. As skate length increased, *E. fasciatus* declined while *U. inermis* became increasingly important in the diets. For skates > 40 cm TL, the epibenthic decapods *C. septemspinosa* and young-of-the-year *C. irroratus* and the isopod *C. polita* were large components of the diet. The polychaete *Glycera dibranchiata* and young-of-the-year hakes (eaten mostly in summer) also increased in the diet. At a second site, the dominant prey items for skate < 39 cm TL was *C. septemspinosa,* followed by (except for skates 10-19 cm TL) the amphipod *Protohaustorius wigleyi*. Other notable amphipods were *Monoculodes edwardsi*, *Rhepoxynius hudsoni*, *Pontogeneia inermis*, and *Aeginina longicornis; C. polita* and *C. irroratus* were the most important epibenthic arthropods. For skates > 40 cm TL, *M. edwardsi*, *C. septemspinosa*, *C. polita*, and *P. inermis* were dominant; the cnidarian *Cerianthus* spp. dominated in terms of weight.

In Sheepscot Bay, a study by Packer and Langton (unpublished manuscript) again indicated that the percentage of crustacean prey in the diet decreased as the skate size increased. This was due to decreases in amphipods, cumaceans, and *C. septemspinosa*. Polychaetes (including *Nephtys* spp.) were a small but important part of the diet for skate > 20 cm TL. Atlantic herring occurred only in the stomachs of fish > 40 cm TL, but were only prominent in terms of percent weight. Richards (1963) found that amphipods and *C. septemspinosa* were more important to smaller skates. Tyler (1972) also noted that smaller skates (≤ 44 cm TL) ate mysids and amphipods and larger skate consumed decapods, euphausids, and polychaetes.

Nelson (1993) calculated the predation impact of little skate on their Georges Bank prey. Annual estimates of consumption for little skate increased as they grew larger. Consumption ranged from 0.085 kg/fish/year for skate 10-19 cm TL to 0.860 kg/fish/year for skate 50-59 cm TL. The percentage of benthic production consumed by little skate from 1969-1990 ranged from 5-15%. Nelson (1993) suggests that in relation to the total macrofauna production on Georges Bank, little skate (along with winter skate) consume < 0.02% of the total. These results indicate that only a small to moderate proportion of benthic biomass vulnerable to skate predation is consumed by both little and winter skate, and their consumptive impact will be dependent on the levels of invertebrate biomass and/or production.

PREDATORS AND SPECIES ASSOCIATIONS

Eggs of little skate in the Gulf of Maine can be preyed upon by sea urchins (*Strongylocentrotus drobachiensis*) and whelks (*Buccinum undatum*) (Cox and Koob 1991, 1993). Juveniles and adults are preyed upon by sharks, other skates (including winter skates), teleost fishes (including cod, goosefish, sea raven, longhorn sculpin, bluefish, summer flounder), gray seals, and rock crabs (*Cancer irroratus*) (McEachran *et al*. 1976; Reilly and Saila 1978; Scott and Scott 1988; Rountree 2001).

McEachran and Musick (1975) state that little and winter skate co-occurred significantly in surveys from Nova Scotia to Cape Hatteras between 1967-1970; little skate was also associated with barndoor skate (*Dipturus laevis*). Although little and winter skate are sympatric species with similar habitat requirements, there does not appear to be a high degree of competitive interaction between them because they are positively correlated by abundance and where the two species are most abundant (Georges Bank) they have the most similar diets and highest diversity of assemblages of prey species (McEachran 1973; McEachran and Musick 1975; McEachran *et al*. 1976).

Also, even though the two species do consume the same large taxonomic groups of benthic fauna (amphipods, decapods, and polychaetes), little skate feeds largely on epifauna, while winter skate predominately selects infaunal organisms (McEachran 1973; McEachran *et al*. 1976). McEachran (1973) and McEachran *et al*. (1976) show that epifaunal decapods were eaten more frequently by little skate and large burrowing polychaetes and bivalves were consumed more frequently by winter skate. Little skate consumed more surface dwelling amphipods such as *Unciola* sp., *D. monacantha*, ampeliscids and caprellids while winter skate ate more burrowing amphipods, especially haustoriids and *Trichophoxus epistomus.* The division of food resources between the skates is not complete because some individuals of little skate consumed large numbers of infauna and some winter skate ate large numbers of epifauna. Both species ate considerable numbers of *L. pinguis* and *C. septemspinosa*. Little skate occasionally fed on haustoriids, and deep burrowing polychaetes (*Nereis* spp., *Nephtys* spp. and *Glycera* spp.) were regular prey items. The infaunal and epifaunal preferences of the two skates may be more distinct in areas where they may coexist than in areas where they occur separately because in Delaware Bay (Fitz and Daiber 1963) little skate consumed relatively more infauna than it did in the areas sampled in Smith's (1950) study or the McEachran (1973) and McEachran *et al*. (1976) studies. Winter skate does not regularly occur in Delaware Bay (Fitz and Daiber 1963).

In addition, differences in the shape and size of the mouth and the number of tooth rows between the two species were used as evidence by McEachran and Martin (1977) to suggest that the sympatric populations of little and winter skate underwent character displacement in order to avoid direct competition for food resources. In sympatric populations, winter skate has a greater number of tooth rows in the upper jaw and a wider and less arched mouth, thus allowing them to feed more efficiently and deeper in the bottom than little skate. Little skate has a relatively smaller and more arched mouth with fewer tooth rows in the upper jaw.

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 (2000a) investigated the dietary guild structure of the fish community. Both small (10-30 cm TL) and medium (31-60 cm TL) sized little skate belonged to the "Amphipod/shrimp eaters" group, along with winter skate and cusk eel; prey included amphipods, polychaetes, shrimp, and zooplankton.

The resilience of demersal fish assemblages on Georges Bank was investigated by Overholtz and Tyler (1985) using seasonal NEFSC trawl survey data from 1963-1978. Of the five assemblage species groups or associations present on Georges Bank in spring and fall throughout the survey period, little skate belonged to the "Intermediate" and "Shallow" assemblage groups. In the Shallow assemblage the other major species present besides little skate included Atlantic cod, winter skate, longhorn sculpin, yellowtail flounder, and haddock; in the Intermediate assemblage, winter skate, red and silver hake, Atlantic cod, and haddock were some of the other major species. Overholtz and Tyler (1985) considered little skate to be a "resident" species, since they were only present in two out of the five assemblages in abundance. The Shallow assemblage covered most of Georges Bank in the spring and was slightly smaller in the fall. The Intermediate assemblage occurred mostly south of the Shallow assemblage and inside the southern edge of Georges Bank; it was somewhat larger in the fall, suggesting a migration of the species in this area to shallower water as the year progressed. The assemblages in the spring appeared to follow depth contours.

Garrison (2000) and Garrison and Link (2000b) have also investigated spatial assemblages and trophic groups from the Georges Bank region. Using 1963-1997 NEFSC trawl survey data from Georges Bank, as well as the same NEFSC food habits database discussed above [Garrison and Link (2000b) used 1973-1997 data while Garrison (2000) used 1991-1997 data], they found that the major predator groups were consistent across decades, with the boundaries of the assemblages similar to Overholtz and Tyler (1985). Garrison (2000) investigated the spatial assemblages during spring and autumn. He found that during autumn, 31-60 cm TL little skate was in the assemblage found in the deep habitats on southern Georges Bank, which also included spiny dogfish, butterfish, red hake, fourspot flounder, yellowtail flounder, and winter skate. The main shallow portion of Georges Bank assemblage included 31-60 cm TL little skate, winter skate, spiny dogfish, Atlantic cod, windowpane, winter flounder, and sea raven. In spring, the assemblage from southern New England included 31-60 cm TL little skate, spiny dogfish, and Atlantic herring. In terms of dietary guilds or trophic groups, the two studies had slightly different viewpoints, but the diets of little skate in both studies are similar to what was previously discussed in the Food Habits section above. In the Garrison and Link (2000b) study, little skate fell into the "Bentho-pelagic" group, which included 10 cm to > 30 cm TL little skate, winter skate, longhorn sculpin, and Atlantic cod. The diets of these species included shrimp such as pandalids and *C. septemspinosa*, and benthic invertebrates including polychaetes, gammarid amphipods, and bivalves. Garrison (2000) had slightly different trophic groups. In autumn, 31-60 cm TL little skate was in the "Shrimp predators" group, which included fourspot flounder, hakes, longhorn sculpin, and Atlantic cod. Prey included pandalids and *C. septemspinosa*, and benthic invertebrates including *Cancer* crabs and gammarid amphipods. Small little skate (10-30 cm TL) was also in the "Demersal predators" group, along with flatfish, haddocks, winter skate, and thorny skate (*Amblyraja radiata*). Prey included gammarid amphipods, polychaetes, isopods, and *Cancer* crabs, as well as *C. septemspinosa*. During spring, 10-60 cm TL little skate was in the "Shrimp/amphipod predators" group, along with hakes, longhorn sculpin, Atlantic cod, fourspot flounder, winter skate, and thorny skate. Prey included gammarid amphipods, pandalids and *C. septemspinosa*, polychaetes, and *Cancer* crabs.

On the Scotian Shelf and in the Bay of Fundy, however, Scott (1989), using research trawl survey data from roughly 1970-1984 determined that little skate was locally abundant but did not associate closely with any other species.

GEOGRAPHICAL DISTRIBUTION

In Canada, little skate occurs around Nova Scotia, but contrary to Bigelow and Schroeder (1953), McKenzie (1959), Templeman (1965), and Leim and Scott (1966), is rare north of La Have Bank and probably does not occur in the Gulf of St. Lawrence [McEachran 1973; McEachran and Musick 1975; McEachran and Martin 1977; Scott and Scott 1988; see also Strong and Hanke (1995) for the 1970-1993 distribution of little skate in the Scotia-Fundy region]. They are considered to be very abundant on both sides of the Bay of Fundy, and are the most common skate inshore in the Gulf of Maine (Bigelow and Schroeder 1953; McEachran and Musick 1975). Previous authors also report them to be very abundant along the entire coastline of the Gulf of Maine and Massachusetts and on Georges Bank, although McEachran and Musick (1975) state that they are rarely taken in the western Gulf of Maine. Bigelow and Schroeder (1953) remark that they are not found in the deeper basins and troughs of the Gulf; however, McEachran and Musick (1975) caught them there at depths > 183 m during surveys from 1967-1970. Little skate are common on the southwestern part of Georges Bank and off Nantucket; Bigelow and Schroeder (1953) state they are far less common on the northeastern part of Georges Bank, but the NEFSC trawl surveys show little skate to be fairly well distributed throughout Georges Bank (see below). Little skate are considered common or abundant in Sheepscot Bay, Maine, the New Hampshire coast, Massachusetts Bay, and in New Haven Harbor (Nelson *et al*. 1983; Collette and Hartel 1988; Carlson 1991; Packer and Langton, unpublished manuscript). Their range extends from southern New England and down the Mid-Atlantic Bight to Cape Hatteras.

Along the inshore edge of its range, little skate moves onshore and offshore seasonally. They generally move into shallow water during spring, and move into deeper water in winter (Bigelow and Schroeder, 1953; McEachran 2002). In Passamaquoddy Bay, Macdonald *et al*. (1984) determined them to be both a regular and occasional resident, and fairly abundant, with the juveniles often occurring at beach sites during summer. Tyler (1971a) found little skate in deeper waters (37-55 m) of Passamaquoddy Bay from November to April with a few remaining until May or June, while during the remainder of the year, Tyler (1971b) found them in shallower water. Hacunda (1981) considered little skate to be a summer periodic in Johns Bay, Maine, while in Sheepscot Bay, Maine they were found mostly in the fall and early winter (Packer and Langton, unpublished manuscript). Merriman *et al.* (1953) noted a 3-5 mile or more seasonal onshore-offshore migration in Block Island Sound. Little skate moved inshore during spring, offshore in mid- to late summer, inshore in autumn, and offshore in midwinter. In Johnson's (1979) study, however, little skate did not make extensive migrations from this region; the movement of the tagged population was limited to Long Island Sound, and seasonal onshore and offshore migrations were not evident. Richards (1963) noted a change in little skate seasonal abundance at two stations in Long Island Sound. They were absent from a sand bottom station during midwinter and midsummer and were absent from a mud bottom station during midsummer. Schaefer (1967) collected little skate in the surf waters of Long Island during the spring and summer; peak abundances were in May and June. Recent surveys of Long Island Sound [1984-1994; Gottschall *et al.* (2000)] show that little skate were most abundant in spring and fall on transitional and sand bottoms; abundances were lowest in July, August, and September (see the discussion in the Habitat Characteristics section, below). Fitz and Daiber (1963) reported that little skate occurs in Delaware Bay when temperatures are < 15°C (late October-May); the 1966-1999 Delaware Division of Fish and Wildlife bottom trawl surveys (see below) generally confirm this (except in summer, when the few that were caught were found between 16-24°C). In the Chesapeake Bight they are most abundant during the winter; those that remain in the Chesapeake Bight during the summer move into deeper water (McEachran and Musick 1975). Massman (1962) and Hildebrand and Schroeder (1928) reported little skate in lower Chesapeake Bay in December and in March, respectively, while Geer (2002) found them mostly around the Bay mouth in high salinity waters during April and May.

JUVENILES

McEachran and Musick (1975) seldom caught smaller specimens (they do not delineate what "smaller" means) in surveys of the northwest Atlantic from 1967-1970. They suggested the young might lie outside their sampling region or may be less vulnerable to the gear used; also, small specimens of little and winter skates are difficult to distinguish (McEachran and Musick 1973). Richards *et al*. (1963) also noted the absence of young little skate on the fishing grounds of Block Island and Long Island sounds where the larger individuals were abundant.

NEFSC bottom trawl surveys [see Reid *et al*. (1999) for details] captured juvenile (≤ 49 cm TL) little skate year-round and show some of the seasonal onshore/offshore movements mentioned above. (Note that winter and summer distributions are presented as presence/absence data, precluding a discussion of abundances.) In winter, juveniles were found from Georges Bank to Cape Hatteras, out to the 200 m depth contour (Figure 4); they were almost entirely absent from the Gulf of Maine. In spring they were also found from Georges Bank to Cape Hatteras, but were also heavily concentrated nearshore throughout the Mid-Atlantic Bight and southern New England as well as in Cape Cod and Massachusetts Bays (Figure 5). Smaller numbers were also found along the coast of Maine and southwest Nova Scotia and near Browns Bank and the Northeast Channel. Juveniles showed a more limited distribution in the summer, with small concentrations along Long Island (Figure 6). Juveniles were more widely distributed in the fall (Figure 7), and were collected from Georges Bank to the Delmarva Peninsula and, as in the spring, were again concentrated along Long Island, southern New England, and in Cape Cod and Massachusetts Bays. Small numbers were again found along the coast of Maine and near Browns Bank and the Northeast Channel.

Both the spring and fall 1978-2002 Massachusetts inshore trawl surveys [see Reid *et al*. (1999) for details] show nearly identical abundances and distributions of juveniles around Nantucket and in Nantucket Sound, in Cape Cod Bay, along the Massachusetts coast and Broad

Sound, and north of Cape Ann, with higher concentrations west and south of Martha's Vineyard (Figure 8).

The distributions and abundances of both juveniles and adults in Long Island Sound (Figures 9-11) as described by Gottschall *et al*. (2000) will be discussed in the Habitat Characteristics section.

Occurrence of juveniles in the Hudson-Raritan estuary appears to have the same seasonal pattern that Fitz and Daiber (1963) noted for little skate in Delaware Bay and McEachran and Musick (1975) noted for little skate in the Chesapeake Bight; i.e., they're generally absent from the estuary during the summer months. Juveniles were fairly well distributed throughout the Hudson-Raritan estuary in winter and spring (Figure 12). In summer the few that were left were mostly confined to the deeper and warmer waters of the Ambrose Channel (see Figure 22 for temperature and depth distributions). In the fall, the juveniles were again fairly well distributed throughout the Hudson-Raritan estuary (Figure 12).

The 1966-1999 Delaware Bay trawl surveys (adults and juveniles combined; Figure 13) again confirm the seasonal trends noted previously for little skate. Few were caught in summer, while the greatest numbers were found in the winter. The skate were more abundant in the center of lower Delaware Bay, near the mouth (Figure 13).

ADULTS

NEFSC bottom trawl surveys [see Reid *et al*. (1999) for details] captured adult little skate (> 49 cm TL) during all seasons. The numbers of adults in spring and fall were much lower than for juveniles of the same two seasons (winter and summer distributions are presented as presence/absence data, precluding a discussion of abundances), but again showed some of the seasonal onshore/offshore movements mentioned above. In winter, they were caught from Georges Bank to the North Carolina; very few occurred in the Gulf of Maine (Figure 14). In spring they were also found from Georges Bank to North Carolina and, as with the juveniles, were also distributed nearshore throughout the Mid-Atlantic Bight and along Long Island as well as in Cape Cod and Massachusetts Bays (Figure 15). Small numbers were also found along the coast of Maine and southwest Nova Scotia and near Browns Bank and the Northeast Channel. They had a limited distribution in the summer, being found mostly in southern New England, Georges Bank, Cape Cod Bay, in the Gulf of Maine near Penobscot Bay, and near Browns Bank and the Northeast Channel (Figure 16). Distributions in the fall were similar to those in the spring, but few little skate were found in the Mid-Atlantic Bight south of the Hudson Canyon (Figure 17).

The distributions of adult little skate from both the spring and fall Massachusetts inshore trawl surveys were similar to that of the juveniles, but with fewer numbers collected in all areas (including west and south of Martha's Vineyard) (Figure 18).

Very few adults were caught in the Hudson-Raritan estuary, particularly in spring and summer (Figure 19). Most of that were caught in winter were in the middle of the estuary while in the fall they were a little more widely distributed throughout the estuary.

The seasonal distribution and abundance of both adults and juveniles in Delaware Bay were discussed previously (Figure 13).

HABITAT CHARACTERISTICS

Information on the habitat requirements and preferences of little skate (based on both the pertinent literature and the most recent NEFSC and state surveys) are presented here and summarized in Tables 1 and 2.

Little skate are generally found on sandy or gravelly bottoms, but also occur on mud (Bigelow and Schroeder 1953; McEachran and Musick 1975; Langton *et al*. 1995; Packer and Langton, unpublished manuscript). In southern New England, at a depth of 55 m, little skate was associated with particular microhabitat features on the surface of the sediment during the day, including biogenic depressions and flat sand, but were randomly distributed at night (Auster *et al*. 1995). Skates are known to remain buried in depressions during the day and are more active at night (Michalopoulos 1990). This is probably not due to diel foraging, since McEachran *et al*. (1976) observed no diel periodicity in feeding intensity by little skate and suggested that they may feed at any time during a 24 hour period.

Bigelow and Schroeder (1953) found most little skate < 73-91 m deep, with an overall depth range of 0-137 m and down to 146 m off southern New England. McEachran and Musick (1975) generally found them at depths < 111 m, but they were occasionally taken at depths > 183 m, especially in the northern section of the Mid-Atlantic Bight and on Georges Bank where they occurred as deep as 329 m. On the Scotian Shelf, Scott (1982) reported the depth preference of little skate to be between 37-108 m. Merriman and Warfel (1948) found little skate to be a permanent resident off southern New England at depths between 15-46 m, with greatest abundances occurring in August. Edwards *et al.* (1962) captured little skate as deep as 384 m off New Jersey. The 1963-2002 NEFSC trawl surveys from the Gulf of Maine to Cape Hatteras (see below) indicated that during spring and fall most juveniles occurred at depths < 70 m, although a few occurred as deep as 400 m (Figure 20), while most adults were found < 120 m and a few were also as deep as 400 m (Figure 24).

Their temperature range is generally 1-21°C, although most are found between 2-15°C (Bigelow and Schroeder 1953; Tyler 1971a; McEachran and Musick 1975). It was usually caught at 5-10°C on the Scotian Shelf during the summers of 1970-1979 (Scott 1982).

McEachran and Musick (1975), in surveys in the Gulf of Maine and Georges Bank from 1967-1970, found little skate at temperatures between 3-12°C during the winter, 6-14°C during the summer, and 7-14°C in the autumn. Edwards *et al*. (1962) captured little skate during the winter from Nantucket Shoals to Cape May, New Jersey at 6-12°C. The 1963-2002 spring and fall NEFSC trawl surveys from the Gulf of Maine to Cape Hatteras (see below) collected juvenile little skate over a temperatures range of 2-22°C, with most found between 4-6°C in the spring and about 8-16°C in the fall (Figure 20). Adults were also found over a temperature range of 2-21°C, with most found between 4-6°C in the spring and about 9-15°C in the fall (Figure 24). As stated previously, Fitz and Daiber (1963) reported that little skate occurs in Delaware Bay when temperatures are < 15°C (late October-May), which generally agrees with the Delaware Division of Fish and Wildlife bottom trawl surveys (see below). In the Hudson-Raritan estuary, they're generally found in waters < 16-18°C, (Figures 22 and 26). McEachran and Musick (1975) also note that in the southern section of the Mid-Atlantic Bight little skate was usually caught in the lower part of the area's temperature range, and on the Nova Scotian shelf in the upper part of the temperature range. In the southern periphery of their range they move southward during the colder months of the year and offshore and northward during the warmer months of the year.

Scott (1982) mentions that on the Scotian Shelf during the summers of 1970-1979, little skate was found at preferred salinities of 31-34 ppt. In Delaware Bay, Fitz and Daiber (1963) collected little skate at salinities as low as 20 ppt, the Delaware Division of Fish and Wildlife bottom trawl surveys (see below) even collected a few as low as 15 ppt.

EGGS

Bigelow and Schroeder (1953) mention studies that suggest little skate deposit eggs in water not deeper than 27 m on sandy bottoms.

The rate of embryonic growth appears to be directly related to temperature. In the Perkins (1965) study, incubation of eggs deposited in November and December showed the first embryonic activity in March when the water temperature had risen to 7°C. Johnson (1979), as stated previously, performed flow-through seawater system studies using ambient temperatures resembling those of the inshore waters of Block Island Sound at 20 m. Johnson's (1979) laboratory study supports the findings of both Perkins (1965) and Richards *et al*. (1963). Eggs deposited in the late fall and winter, when water temperatures in Johnson's (1979) lab were < 8°C did not show signs of development until temperatures were greater than that in the middle of April. When eggs were deposited in water > 8°C, embryonic development was evident shortly thereafter. For eggs deposited in September-October 1976 when temperatures were > 8°C, embryonic growth was obvious but slowed with decreasing temperatures. Growth resumed in the early spring when the water temperature increased.

Johnson (1979) therefore concludes that embryonic growth takes place when temperatures are > 7-8°C and increases with increasing temperature. For those eggs that were laid when the water temperature was increasing, the incubation time became progressively shorter as the temperature of deposition rose. April spawned eggs hatched after an average incubation of 181 d, whereas July deposited eggs took only an average of 122 days to develop and hatch. Eggs spawned in the fall overwintered, hatching the following fall. Eggs deposited in the summer took about a third of the maximum time to develop, hatching out during the fall of the same year. Thus Johnson (1979) concludes that although water temperature may be lower at greater depths, it appears that the eggs of little skate may hatch out in autumn regardless of the month of deposition. However, Steves *et al*. (1999) found that in the New York Bight during 1996-1997 little skate hatched on the continental shelf starting in mid-winter.

JUVENILES

Steves *et al*. (1999) surveyed the New York Bight during 1996-1997 and collected juvenile little skate (mean size of 11.8 cm SL) mostly on the inner continental shelf at mean depths of < 40-45 m. They were also collected at a mean temperature of 8.5°C and a mean salinity of 32 ppt.

The spring and fall distributions of juvenile little 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 20. In spring, they were found in waters between 2-13°C, with the majority at about 4-6°C. Their depth range during that season was between 1-300 m, with most spread between about 11-70 m and the majority of those between 11-30 m. They were found at salinities of between 26-36 ppt, with > 60 between 32-33 ppt. During the fall, juvenile little skate were caught over a temperature range of about 5-22°C, with most found between roughly 8-16°C. They were found over a depth range of 1-400 m, although most were caught at depths between 11-70 m. They were found at salinities of between 30-36 ppt, with the majority at 32-33 ppt.

The spring and autumn distributions of juveniles in Massachusetts coastal waters relative to bottom water temperature and depth based on 1978-2002 Massachusetts inshore trawl surveys are shown in Figure 21. In the spring they were found in waters ranging from 3-16°C, with the greatest percentages spread between about 8-12°C. Their depth range was from 6-65 m, with the majority between 6-25 m. During the autumn they were found in waters ranging from 5-22°C, with the highest percentages found between about 16-18°C. Their depth range was from 1-65 m, with the majority found between 6-25 m.

The distributions and abundances of both juvenile and adult little skate in Long Island Sound from April to November 1984-1994, based on the Connecticut Fisheries Division bottom trawl surveys, are shown in Figures 9-11. The following description of their distributions relative to depth and bottom type is taken verbatim from Gottschall *et al*. (2000).

Little skate taken in the survey ranged from 8-51 cm (Figure 10). When abundance was high during the spring period (Figure 11A), little skate were most abundant on transitional and sand bottom (Figure 11B) in the Eastern Basin and along the Mattituck Sill between Guilford, Connecticut and Mattituck, New York (Figure 9). Abundance decreased west of the Mattituck Sill where mud bottom is more common. However, little skate were abundant in some areas in the Central Basin where transitional and sand bottom exists, such as an area south of New Haven, and along the Long Island shore near Shoreham, New York. In April, little skate abundance was highest in depths < 9 m and low in depths > 27 m (Figure 11C). During June the reverse occurred – abundance was highest in depths > 27 m and low in depths < 9 m. During the summer, a period of low abundance, little skate still occurred in the same areas as in the spring, but the largest catches occurred in the Eastern Basin. Abundance increased during the fall months and November. When abundance peaked in November, skate were again concentrated on transitional bottom in depths between 9-27 m near Mattituck, and in depths < 18 m near Guilford. In contrast with spring, large catches were not recorded over the large sand lobe that extends from the Eastern Basin onto the Mattituck Sill (Gottschall *et al*. 2000).

The seasonal distributions of juveniles in the Hudson-Raritan estuary relative to bottom water temperature, depth, salinity, and dissolved oxygen based on 1992-1997 Hudson-Raritan trawl surveys are shown in Figure 22. The surveys show that during the winter juveniles were found mostly between 0-7°C, with the majority at 4-5°C. Their depth range during that season was between 4-24 m, with most caught between 5-8 m. Their salinities ranged between about 20-35 ppt, most were found roughly between 25-26 ppt and between 30-32 ppt. They were found over a range of dissolved oxygen levels of between 9-14 ppm; most were found between 10-12 ppm with a peak at 12 ppm. In spring, little skate were found over a wider temperature range of between 2-18°C, with bimodal peaks between approximately 6-9°C and 15-17°C. The bimodality may be a function of the greater number of trawls done within those temperature intervals. Their depth range was between 4-22 m, with most found between 6-8 m. Their salinities ranged between 15-33 ppt, the majority were found between 25-28 ppt. They were found over a range of dissolved oxygen levels of between 6-13 ppm; most were found between 10-11 ppm. In summer, when the juveniles were mostly found around the Ambrose Channel (Figure 12), their temperature distribution was between 14-22°C, with peaks at 16° and 18°C. They were found between 7-22 m deep, with peaks at 10 m and at 20 m. Their salinities ranged between 23-32 ppt; most were between about 29-32 ppt with a slight peak at 29 ppt. They were found over a lower range of dissolved oxygen levels of between 5-9 ppm; most were found between 6-8 ppm. In the fall they were found between 5-17°C, with most concentrated around 7-13°C. Their depth range during the fall was between 4-21 m, with the majority at 5-8 m. Their salinities ranged between 17-33 ppt, with peaks between 27-29 ppt. They were found over a range of dissolved oxygen levels of between about 6-12 ppm, with peaks at 8-9 ppm.

The seasonal distributions of both juveniles and adults in Delaware Bay relative to bottom water temperature, depth, salinity, and dissolved oxygen based on 1966-1999 Delaware Division of Fish and Wildlife bottom trawl surveys are shown in Figure 23. During the winter they were found between 3-12°C, with the majority between 7-8°C. Their depth range during winter was between 7-18 m, with bimodal peaks between approximately 8-10 m and 14-15 m. Their salinities ranged between about 18-30 ppt and 34-35 ppt, most were found between 25-30 ppt. They were found over a range of dissolved oxygen levels of between 9-12 ppm; most were found between 9-10 ppm. In spring, they were found over a wider temperature range of between 4-17°C, with peaks scattered throughout the range (e.g., 7°C and 13°C). Their depth range was between about 4-21 m, again with peaks scattered throughout (e.g., 8 m and 13 m). Their salinities ranged between 21-33 ppt, with a few at 15 ppt and 19 ppt. There was a peak, in terms of catch, of close to 30% at 30 ppt. They were found over a range of dissolved oxygen levels of between 6-14 ppm, most were found between 9-10 ppm. In summer, the juveniles and adults were found over a temperature range of about 16-24°C, with a peak at 22°C. They were found at depths of between 13-18 m, with a few at 9 m; most were at 13 m and 15 m. Their salinities ranged between 24-32 ppt, with a peak at 31 ppt. They were found over a lower and narrower range of dissolved oxygen levels than in spring: 5-8 ppm. During the fall they were found between 8-21°C, with a peak at 10°C. Their depth range during that season was between 7-19 m, with a few at 24 m; most were between 7-9 m and 13-14 m. Their salinities ranged between about 20-32 ppt, with a few at 16 ppt and a peak at 28 ppt. They were found over a range of dissolved oxygen levels of between 6-10 ppm, the majority were between 8-9 ppm.

ADULTS

The spring and fall distributions of adult little 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 24. In spring, adult little skate were caught at temperatures between 2-13°C, with most between 4-6°C and close to 40% of the total caught in 5°C waters. During that period they were found at a depth range of 1-300 m, with the majority spread between 11 m to about 101-120 m. They were found at a salinity range of between 29-35 ppt, with the majority found at 33 ppt. During the fall, they were found over a temperature range of 5-21°C, with most caught between about 9-14°C. They were found over a depth range of 1-400 m, with most caught at depths between about 41-80 m. They were found at a salinity range of between 31-36 ppt, with the majority found at 32-33 ppt.

The spring and autumn distributions of adults in Massachusetts coastal waters relative to bottom water temperature and depth are shown in Figure 25. In the spring they were found in waters ranging from 3-16°C; the majority were found between approximately 5-12°C. During that same season the adults were found from about 6-75 m, with most found between 6-30 m. In autumn they were found between 5-21°C. The distribution was somewhat bimodal, with peaks at 10°C and 16°C. The depth range of the adults during autumn was between about 1-65 m, with most found between 6-25 m.

The distributions and abundances of both juvenile and adult little skate in Long Island Sound relative to depth and bottom type were discussed previously (Figures 9-11; Gottschall *et al*. [2000]).

Few adults were caught during the 1992-1997 Hudson-Raritan estuary trawl surveys, their seasonal distributions relative to bottom water temperature, depth, salinity, and dissolved oxygen are shown in Figure 26. During the winter they were found in a narrow range of temperatures: 1-5°C with the majority at 3-4°C. They were found in a depth range of about 5-16 m, with most at 7 m. Their salinities ranged between 20-34 ppt, most were found roughly between 25-27 ppt, between 29-30 ppt, and at 34 ppt. They were found over a range of dissolved oxygen levels of between 10-13 ppm, with most found between 10-12 ppm. In spring, they were found over a wider range of temperatures from about 7-11°C and between 14-16°C, with a peak at 9°C. They were caught at depths between 7-8 m and between 14-15 m with the majority at 8 m. Their salinities ranged between 25-26 ppt and 28-29 ppt, with peaks at 25 ppt and 29 ppt. They were found over a range of dissolved oxygen levels of between 8-9 ppm and 11-12 ppm, with most found between 11-12 ppm. Only two adult little skate were caught in the summer, at 17-18°C and at a depth of 7 m and 10 m. They were found at salinities of 28-29 ppt, and at dissolved oxygen levels of 6 ppm and 9 ppm. During the fall they were spread over a temperature range of 5-17°C, with a peak at 12°C. Their depth range was between 5-16 m, most were caught at 6 m and 9 m. Their salinities during that time period ranged between 18-32 ppt, with a peak between 28-29 ppt. They were found over a range of dissolved oxygen levels of between 7-12 ppm, with most found at 8 ppm.

The seasonal distributions of both juveniles and adults in Delaware Bay relative to bottom water temperature, depth, salinity, and dissolved oxygen based on Delaware Division of Fish and Wildlife bottom trawl surveys were discussed previously (Figure 23).

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 [little, barndoor, winter, thorny, clearnose (*Raja eglanteria*), rosette (*Leucoraja garmani*), smooth (*Malacoraja senta*)] 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 27). 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 27). In terms of total recreational landings for little skate, they varied between < 1000 and 56,000 fish, equivalent to < 1 to 15 mt, during 1981-1998.

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, which, in 1999, was at its highest abundance (Figure 27). Little skate is not considered to be overfished (Northeast Fisheries Science Center 2000a, b).

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; it is also necessary to work out any identification problems between little and winter skate.

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

- More life history studies (including studies on age, growth, maturity, and fecundity) 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.

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Table 1. Summary of habitat parameters for little skate, based on the pertinent literature.

Life Stage	Depth	Substrate	Salinity	Temperature
Eggs [1]	Egg capsule is deposited on the bottom, perhaps in water < 27 m deep.	Egg capsule is deposited on the bottom. In aquaria, eggs were partially buried in sand.		Rate of embryonic growth directly related to temperature. Incubation of eggs deposited in November/December show first embryonic activity in March when water temperature rises to 7°C. Embryonic growth takes place when temperatures are > 7-8°C and increases with increasing temperature.
Juveniles [2]	Along the inshore edge of its range, little skate moves onshore and offshore seasonally. Generally move into shallow water during spring, deeper water in winter. May leave some estuaries for deeper water during warmer months. Generally caught at depths < 111 m, but occasionally at depths > 183 m, especially in northern section of the Mid-Atlantic Bight and on Georges Bank where they can be as deep as 329 m; caught as deep as 384 m off New Jersey. <u>Juveniles</u> (mean size 11.8 cm SL) collected in the New York Bight (1996-1997) at mean depths of < 40-45 m. In Long Island Sound (1984-1994) during spring, abundance highest in depths < 9 m, low in depths > 27 m. During summer, abundance highest in depths > 27 m, low in depths < 9 m. During fall, most between 9-27 m near Mattituck, and in depths < 18 m near Guilford.	Sandy or gravelly bottoms, but also on mud. Southern New England at 55 m: little skate associated with particular microhabitat features on surface of sediment during the day, including biogenic depressions and flat sand, but randomly distributed at night. Skates are known to remain buried in depressions during the day and are more active at night. In Long Island Sound (1984-1994) in spring and fall, most abundant on transitional and sand bottoms.	In Delaware Bay, little skate were collected at salinities as low as 15-20 ppt. <u>Juveniles</u> (mean size 11.8 cm SL) collected in the New York Bight (1996-1997) at a mean salinity of 32 ppt.	Overall temperature range is 1-21°C, although most are found between 2-15°C. Gulf of Maine and Georges Bank (1967-1970): caught at temperatures between 3-12°C during winter, 6-14°C during summer, 7-14°C in autumn. Nantucket Shoals to Cape May, New Jersey during winter: 6-12°C. <u>Juveniles</u> (mean size 11.8 cm SL) collected in the New York Bight (1996-1997) at a mean temperature of 8.5°C. Occurs in Delaware Bay when temperatures are < 15°C (late October-May). In southern section of Mid-Atlantic Bight usually caught in the lower part of the area's temperature range, and on the Nova Scotian shelf in the upper part of temperature range. Inshore they move onshore/offshore with seasonal temperature changes; also moves north and south with seasonal temperature changes along southern fringe of their range. May leave some estuaries for deeper water during warmer months.
Adults [3]	Same as for juveniles.	Same as for juveniles.	Same as for juveniles.	Same as for juveniles.

[1] Bigelow and Schroeder (1953); Perkins (1965); Johnson (1979).
[2] Bigelow and Schroeder (1953); Merriman *et al*. (1953); Edwards *et al.* (1962); Fitz and Daiber (1963); Richards (1963); Richards *et al*. (1963); Schaefer (1967); Tyler 1971(a, b); Langton *et al*. (1995); McEachran and Musick (1975); Hacunda (1981); Michalopoulos (1990); Auster *et al*. (1995); Steves *et al*. (1999); Gottschall *et al*. (2000); McEachran (2002); Packer and Langton (unpublished manuscript); Delaware Division of Fish and Wildlife bottom trawl surveys (1966-1999).
[3] Bigelow and Schroeder (1953); Merriman *et al*. (1953); Edwards *et al.* (1962); Fitz and Daiber (1963); Richards (1963); Richards *et al*. (1963); Schaefer (1967); Tyler 1971(a, b); Langton *et al*. (1995); McEachran and Musick (1975); Hacunda (1981); Michalopoulos (1990); Auster *et al*. (1995); Gottschall *et al*. (2000); McEachran (2002); Packer and Langton (unpublished manuscript); Delaware Division of Fish and Wildlife bottom trawl surveys (1966-1999).

Table 1. cont'd.

Life Stage	Prey	Predators/Species Associations
Eggs[1]	N/A	Eggs of little skate in the Gulf of Maine can be preyed upon by sea urchins (*Strongylocentrotus drobachiensis*) and whelks (*Buccinum undatum*).
Juveniles [2]	Food habits fairly generalized; little skate an opportunistic predator although inshore skates generally depend more on a few major prey species. Decapod crustaceans and amphipods are the most important prey items, followed by polychaetes. Isopods, bivalves, hydroids, and fishes are of minor importance. Decapod prey include: *Crangon septemspinosa*, *Pagurus* spp., *Cancer spp.* Amphipods: *Monoculoides* spp., *Unciola* spp., *Leptocheirus pinguis*, *Byblis serrata*, ampeliscids, haustoriids. Polychaetes: *Eunice pennata*, *Nereis* spp., *Nepthys* spp., *Lumbrineris fragilis*, *Aphrodite hastata*, maldanids, *Ophelia denticulata*, terebellids. Fish: sand lance, yellowtail flounder, longhorn sculpin, Atlantic herring. Generally, skates ~ < 30-40 cm TL consumed more amphipods than larger skates; skates ~ > 30-40 cm TL consumed more decapods, as well as polychaetes and fish. Depending on the study, *C. septemspinosa* was a prominent component of the diet of either large or small skates, or both.	Predators: sharks, other skates (including winter skates), teleost fishes (including cod, goosefish, sea raven, longhorn sculpin, bluefish, summer flounder); gray seals, and rock crabs (*Cancer irroratus*). Little and winter skate co-occur from Nova Scotia to Cape Hatteras; little skate also associated with barndoor skate. Although little and winter skate are sympatric species with similar habitat requirements, there's not a high degree of competitive interaction between them because they are positively correlated by abundance. Also, little skate feeds largely on epifauna, while winter skate predominately selects infauna. Sympatric populations of little and winter skate also undergo character displacement in order to avoid direct competition for food resources. Using 1973-1997 NEFSC data from Nova Scotia to Cape Hatteras and NEFSC food habits database, both small (10-30 cm TL) and medium (31-60 cm TL) sized little skate belonged to the "Amphipod/shrimp eaters" group, along with winter skate and cusk eel; prey included amphipods, polychaetes, shrimp, and zooplankton. On Georges Bank, little skate belongs to assemblages that include Atlantic cod, winter skate, longhorn sculpin, yellowtail flounder, red and silver hake, haddock, spiny dogfish, fourspot flounder, butterfish, windowpane, winter flounder, sea raven, Atlantic herring. Also on Georges Bank, little skate falls into various dietary guilds or trophic groups, depending on the study. Garrison and Link (2000b): "Bentho-pelagic" group included 10 cm to > 30 cm TL little skate, winter skate, longhorn sculpin, Atlantic cod. Diets of these species included shrimp such as pandalids and *C. septemspinosa*, and benthic invertebrates including polychaetes, gammarid amphipods, bivalves. Garrison (2000): In autumn, "Shrimp predators" group included 31-60 cm TL little skate, fourspot flounder, hakes, longhorn sculpin, Atlantic cod. Prey included pandalids and *C. septemspinosa*, and benthic invertebrates including *Cancer* crabs and gammarid amphipods. "Demersal predators" group included 10-30 cm TL little skate, flatfish, haddocks, winter skate, thorny skate. Prey included gammarid amphipods, polychaetes, isopods, *Cancer* crabs, *C. septemspinosa*. During spring, "Shrimp/amphipod predators" group included 10-60 cm TL little skate, hakes, longhorn sculpin, Atlantic cod, fourspot flounder, winter skate, thorny skate. Prey included gammarid amphipods, pandalids, *C. septemspinosa*, polychaetes, *Cancer* crabs.
Adults [3]	Same as for juveniles; however, note that larger skates consume more decapods as well as polychaetes and fish rather than amphipods.	Same as for juveniles, but note differences between larger and smaller skates.

[1] Cox and Koob (1991, 1993).
[2] Smith (1950); Bigelow and Schroeder (1953); Fitz and Daiber (1963); Richards (1963); Tyler (1972); McEachran (1973); McEachran and Musick (1975); McEachran *et al*. (1976); McEachran and Martin (1977); Reilly and Saila (1978); Hacunda (1981); Bowman and Michaels (1984); Overholtz and Tyler (1985); Bowman *et al*. (1987); Scott and Scott (1988); Langton and Watling (1990); Carlson (1991); Nelson (1993); Bowman *et al*. (2000); Garrison (2000); Garrison and Link (2000a, b); Scharf *et al*. (2000); Avent *et al*. (2001); Rountree (2001); Packer and Langton (unpublished manuscript); NEFSC 1973-1990 food habits database.
[3] Smith (1950); Bigelow and Schroeder (1953); Fitz and Daiber (1963); Richards (1963); Tyler (1972); McEachran (1973); McEachran and Musick (1975); McEachran *et al*. (1976); McEachran and Martin (1977); Reilly and Saila (1978); Hacunda (1981); Bowman and Michaels (1984); Overholtz and Tyler (1985); Bowman *et al*. (1987); Scott and Scott (1988); Langton and Watling (1990); Carlson (1991); Nelson (1993); Bowman *et al*. (2000); Garrison (2000); Garrison and Link (2000a, b); Scharf *et al*. (2000); Avent *et al*. (2001); Rountree (2001); Packer and Langton (unpublished manuscript); NEFSC 1973-1990 food habits database.

Table 2. Summary of habitat parameters for little skate, based on the most recent NEFSC and state surveys mentioned in the text.

Life Stage	Survey	Depth	Temperature	Salinity/DO
Juveniles	1963-2002 spring and fall NEFSC trawl surveys from Gulf of Maine to Cape Hatteras.	*Spring*: range of 1-300 m, most spread between about 11-70 m and majority of those between 11-30 m. *Fall*: range of 1-400 m, most between 11-70 m.	*Spring*: range of 2-13°C, with majority at about 4-6°C. *Fall*: range of about 5-22°C, most between roughly 8-16°C.	*Spring*: range of 26-36 ppt, > 60 between 32-33 ppt. *Fall*: range of 30-36 ppt, majority at 32-33 ppt.
	1978-2002 Massachusetts inshore trawl surveys.	*Spring:* range of 6-65 m, majority between 6-25 m. *Fall*: range of 1-65 m, majority between 6-25 m.	*Spring:* range of 3-16°C, greatest percentages spread between about 8-12°C. *Fall*: range of 5-22°C, highest percentages between about 16-18°C.	
	1992-1997 NEFSC trawl surveys of the Hudson-Raritan estuary.	*Winter*: range of 4-24 m, most between 5-8 m. *Spring:* range of 4-22 m, most between 6-8 m. *Summer:* range of 7-22 m, peaks at 10 m and at 20 m. *Fall*: range of 4-21 m, most between 5-8 m.	*Winter*: range of 0-7°C, most between 4-5°C. *Spring*: range of 2-18°C, with bimodal peaks between 6-9°C and 15-17°C. *Summer*: range of 14-22°C, with peaks at 16° and 18°C. *Fall:* range of 5-17°C, most concentrated around 7-13°C.	*Winter*: range of 20-35 ppt, most between 25-26 ppt and 30-32 ppt / range of 9-14 ppm, most between 10-12 ppm, peak at 12 ppm. *Spring*: range of 15-33 ppt, most between 25-28 ppt / range of 6-13 ppm, most between 10-11 ppm. *Summer*: range of 23-32 ppt, most between about 29-32 ppt, slight peak at 29 ppt / range of 5-9 ppm, most between 6-8 ppm. *Fall:* range of 17-33 ppt, peaks between 27-29 ppt / range of about 6-12 ppm, peaks at 8-9 ppm.
	1966-1999 Delaware Division of Fish and Wildlife bottom trawl surveys of Delaware Bay (juveniles and adults combined)	*Winter*: range of 7-18 m, bimodal peaks between approximately 8-10 m and 14-15 m. *Spring:* range of about 4-21 m, peaks scattered throughout (e.g., 8 m and 13 m). *Summer:* range of 13-18 m, a few at 9 m; most at 13 m and 15 m. *Fall*: range of 7-19 m, a few at 24 m; most between 7-9 m and 13-14 m.	*Winter*: range of 3-12°C, majority between 7-8°C. *Spring*: range of 4-17°C, peaks scattered throughout (e.g., 7°C and 13°C). *Summer*: range of about 16-24°C, peak at 22°C. *Fall:* range of 8-21°C, peak at 10°C.	*Winter*: range of 18-30 ppt and 34-35 ppt, most between 25-30 ppt / range of 9-12 ppm, most between 9-10 ppm. *Spring*: range of 21-33 ppt, a few at 15 ppt and 19 ppt; a peak, in terms of catch, of close to 30% at 30 ppt / range of 6-14 ppm, most between 9-10 ppm. *Summer*: range of 24-32 ppt, peak at 31 ppt / range of 5-8 ppm. *Fall:* range of about 20-32 ppt, a few at 16 ppt, peak at 28 ppt / range of about 6-10 ppm, majority between 8-9 ppm.

Table 2. cont'd.

Life Stage	Survey	Depth	Temperature	Salinity/DO
Adults	1963-2002 spring and fall NEFSC trawl surveys from Gulf of Maine to Cape Hatteras.	*Spring*: range of 1-300 m, majority spread between 11 m to about 101-120 m. *Fall*: range of 1-400 m, most between about 41-80 m.	*Spring*: range of 2-13°C, most between 4-6°C and close to 40% of the total caught in 5°C waters. *Fall*: range of 5-21°C, most between about 9-14°C.	*Spring*: range of 29-35 ppt, majority at 33 ppt. *Fall*: range of 31-36 ppt, majority at 32-33 ppt.
	1978-2002 Massachusetts inshore trawl surveys.	*Spring:* range of about 6-75 m, most between 6-30 m. *Fall*: range of about 1-65 m, most between 6-25 m.	*Spring:* range of 3-16°C, majority between approximately 5-12°C. *Fall*: range of 5-21°C, distribution somewhat bimodal, with peaks at 10°C and 16°C.	
	1992-1997 NEFSC trawl surveys of the Hudson-Raritan estuary.	*Winter*: range of about 5-16 m, most at 7 m. *Spring*: range of 7-8 m and 14-15 m, majority at 8 m. *Summer*: only two adults found at 7 m and 10 m. *Fall*: range of 5-16 m, most at 6 m and 9 m.	*Winter*: range of 1-5°C, majority at 3-4°C. *Spring*: range of about 7-11°C and 14-16°C, peak at 9°C. *Summer*: only two adults found at 17-18°C. *Fall*: range of 5-17°C, peak at 12°C.	*Winter*: range of 20-34 ppt, most between 25-27 ppt, between 29-30 ppt, and at 34 ppt / range of 10-13 ppm, most between 10-12 ppm. *Spring*: range of 25-26 ppt and 28-29 ppt, peaks at 25 ppt and 29 ppt / range of 8-9 ppm and 11-12 ppm, most between 11-12 ppm. *Summer*: only two adults caught at 28-29 ppt / 6 ppm and 9 ppm. *Fall*: range of 18-32 ppt, peak between 28-29 ppt / range of 7-12 ppm, most at 8 ppm.
	1966-1999 Delaware Division of Fish and Wildlife bottom trawl surveys of Delaware Bay (juveniles and adults combined).	*See juveniles.*	*See juveniles.*	*See juveniles.*

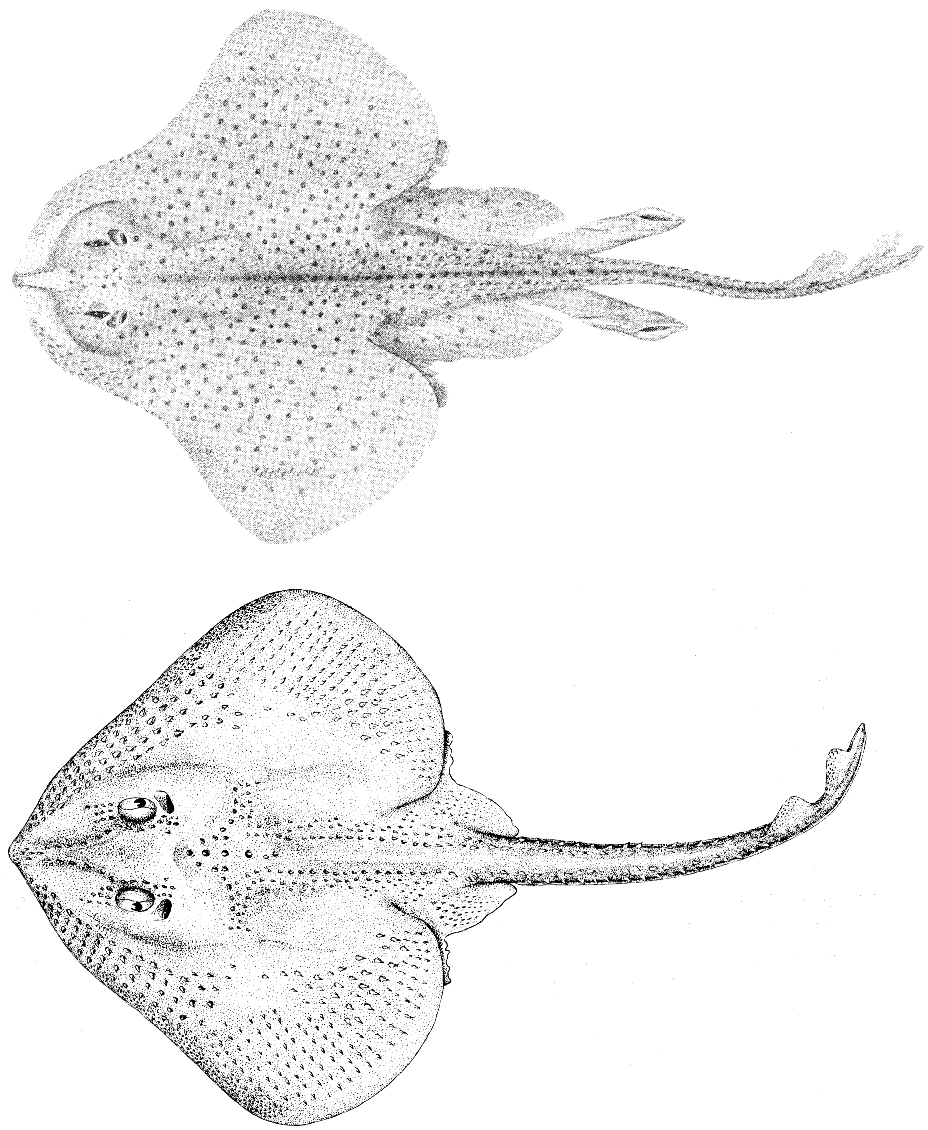


Figure 1. The little skate, *Leucoraja erinacea* (Mitchill 1825). Top: male, from Murdy *et al*. (1997). Bottom: female, from Scott and Scott (1988).

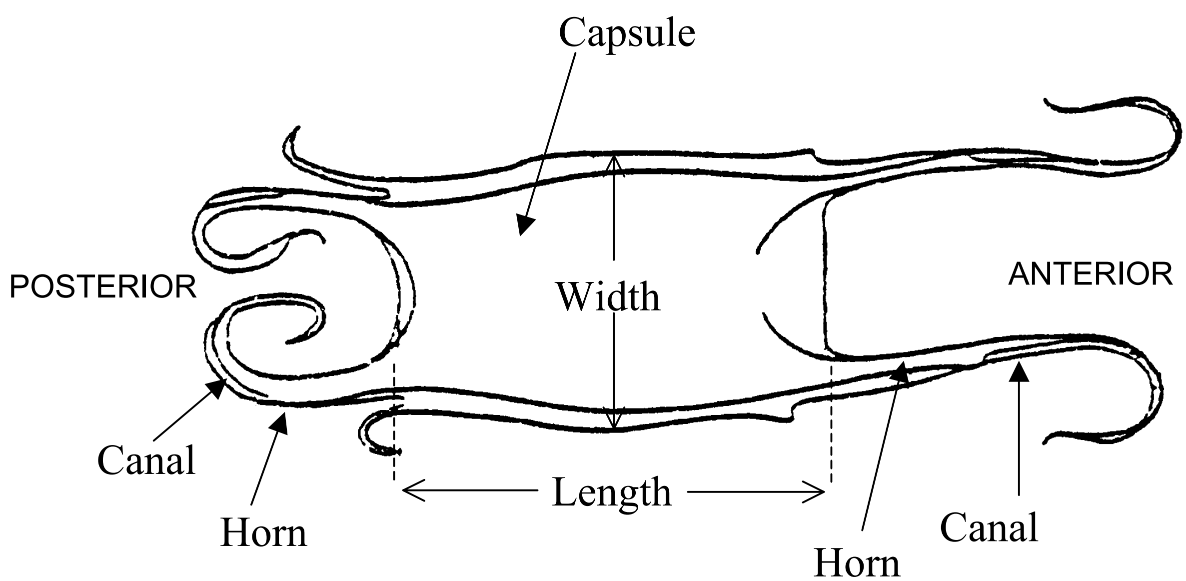


Figure 2. Egg case of little skate, from Johnson (1979).

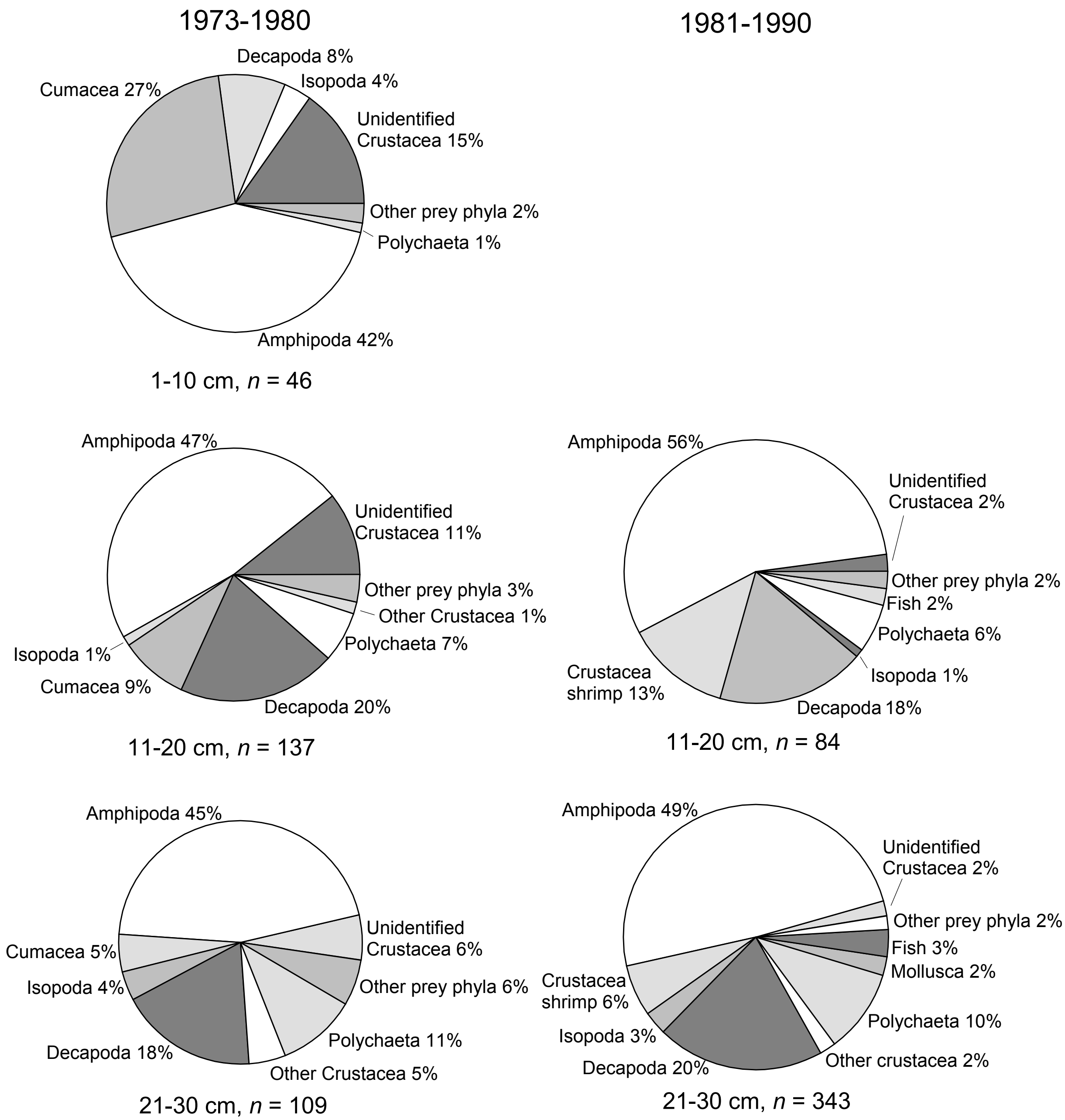


Figure 3. Abundance (% occurrence) of the major prey items of little skate collected during NEFSC bottom trawl surveys from 1973-1980 and 1981-1990. Methods for sampling, processing, and analysis of samples differed between the time periods [see Reid *et al.* (1999) for details].

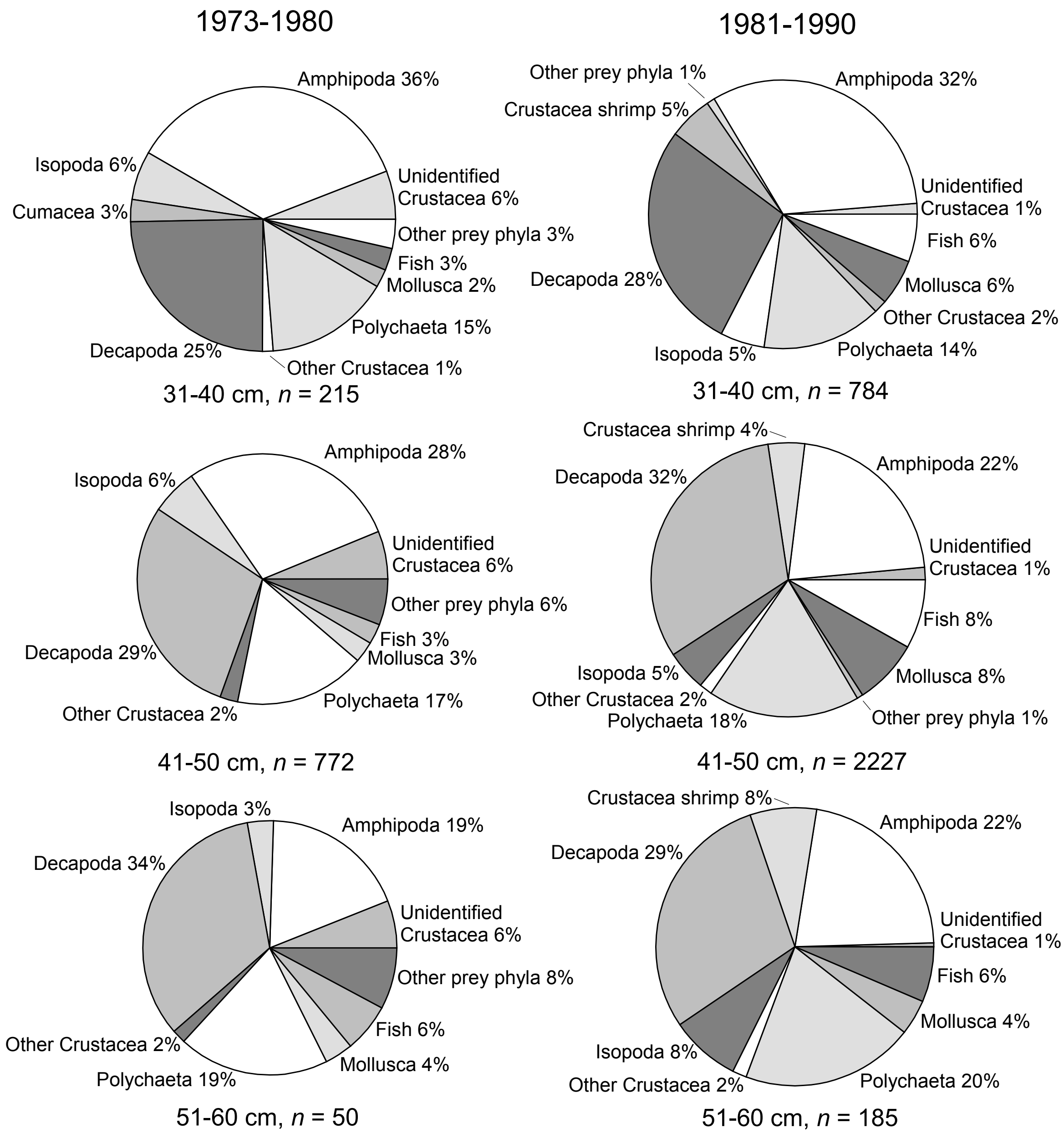


Figure 3. cont'd.

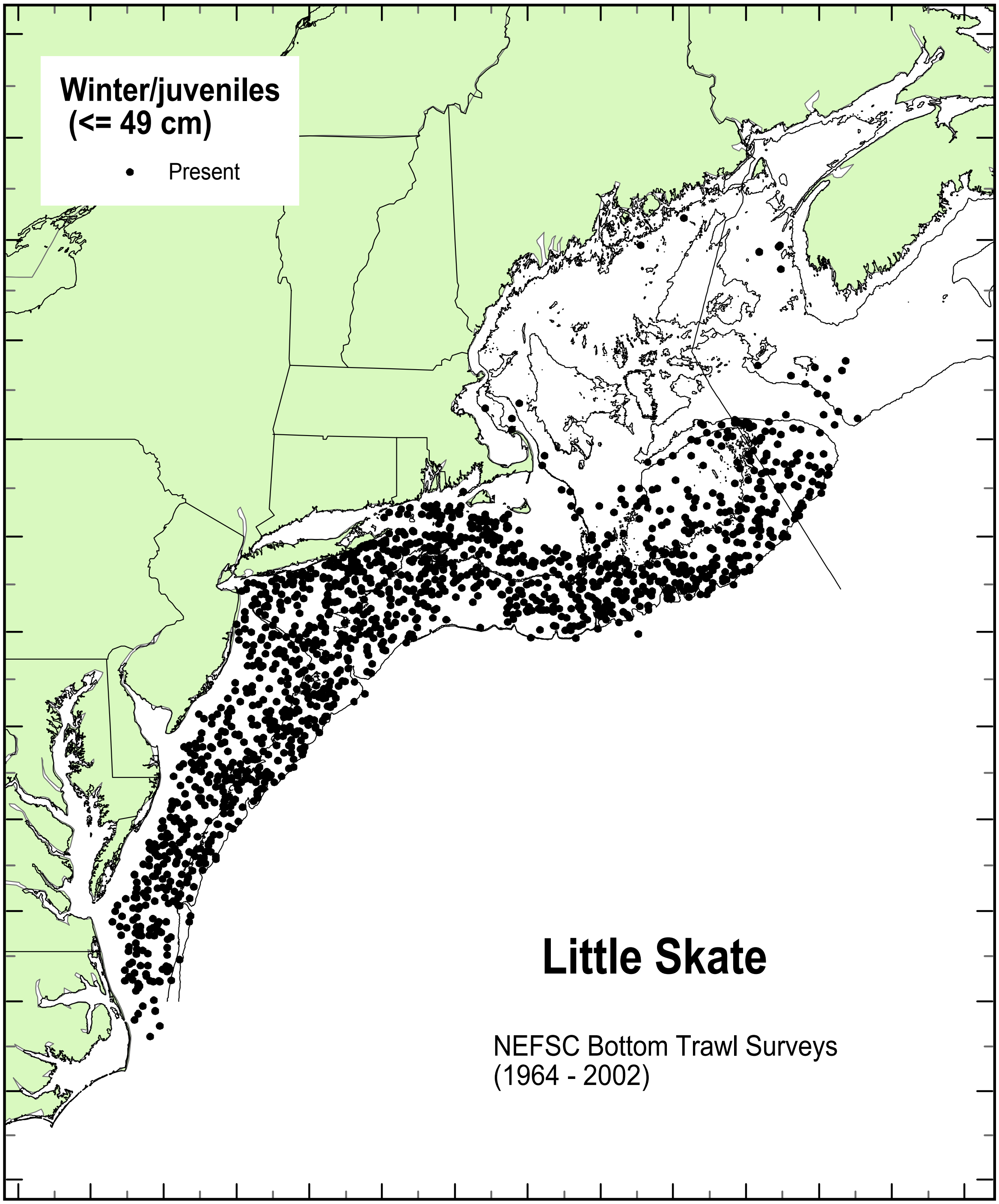


Figure 4. Distribution of juvenile little skate collected during winter NEFSC bottom trawl surveys [1964-2002, all years combined; see Reid *et al.* (1999) for details]. Survey stations where juveniles were not found are not shown.

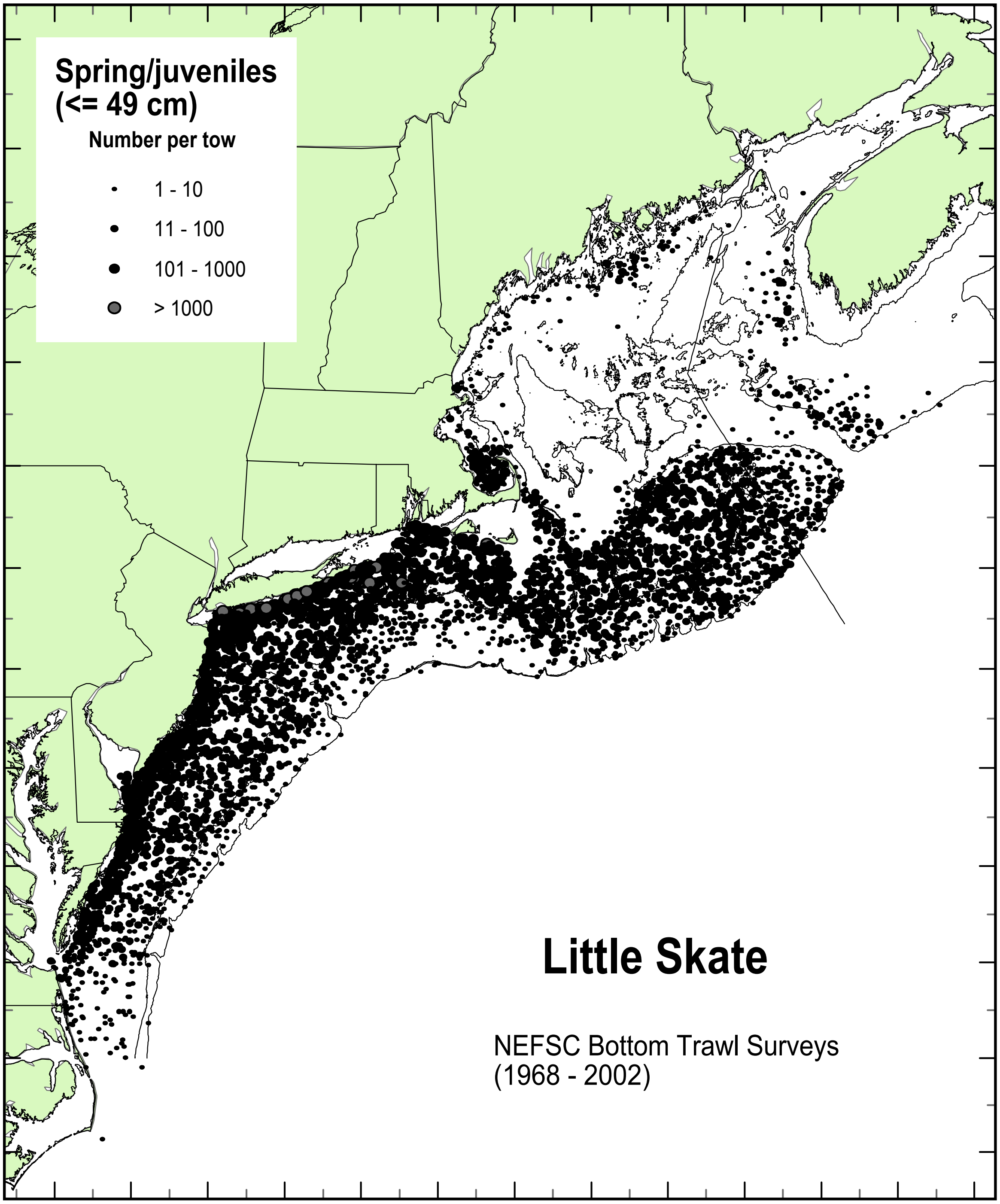


Figure 5. Distribution and abundance of juvenile little skate collected during spring NEFSC bottom trawl surveys [1968-2002, all years combined; see Reid *et al.* (1999) for details].

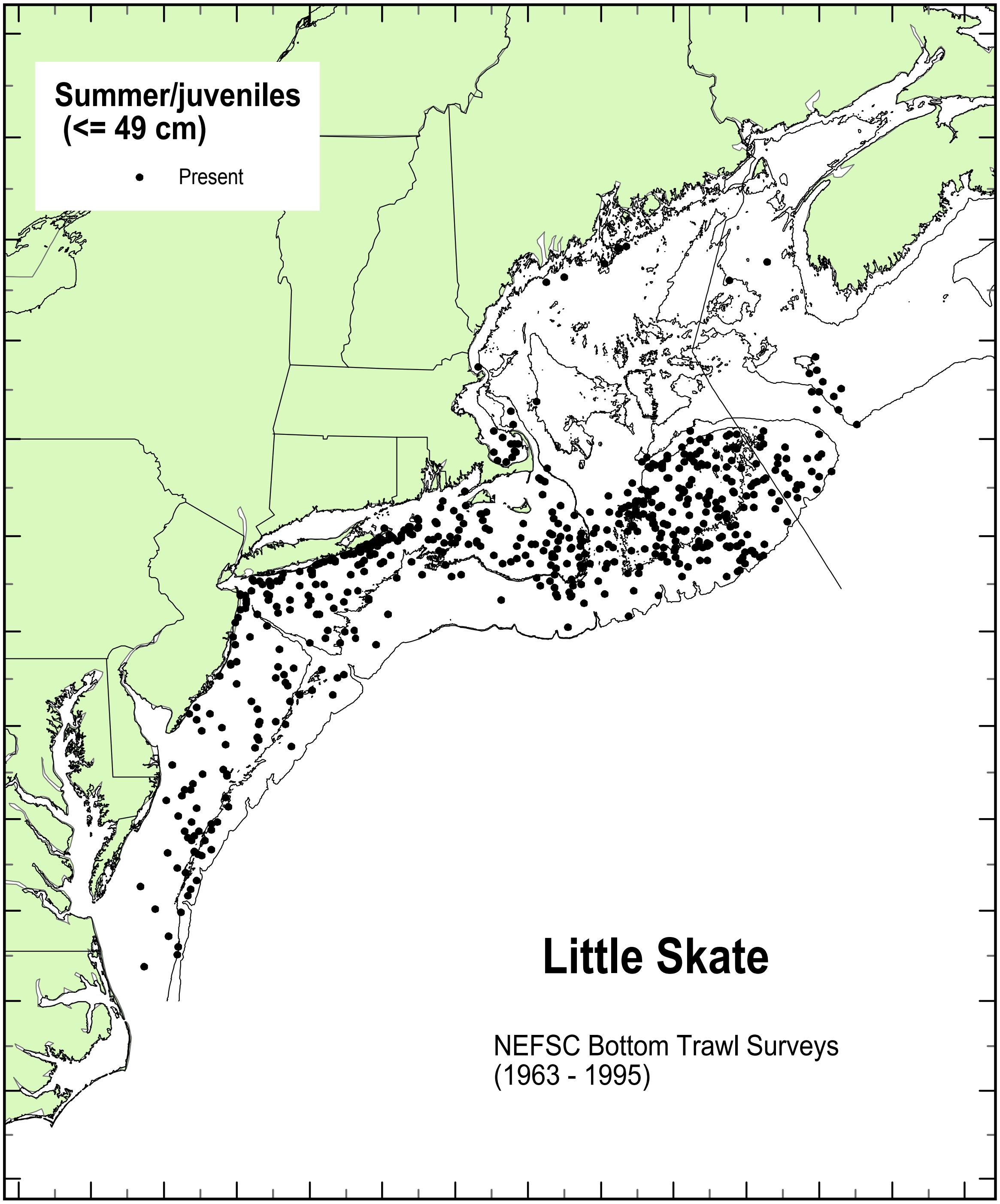


Figure 6. Distribution of juvenile little skate collected during summer NEFSC bottom trawl surveys [1963-1995, all years combined; see Reid *et al.* (1999) for details]. Survey stations where juveniles were not found are not shown.

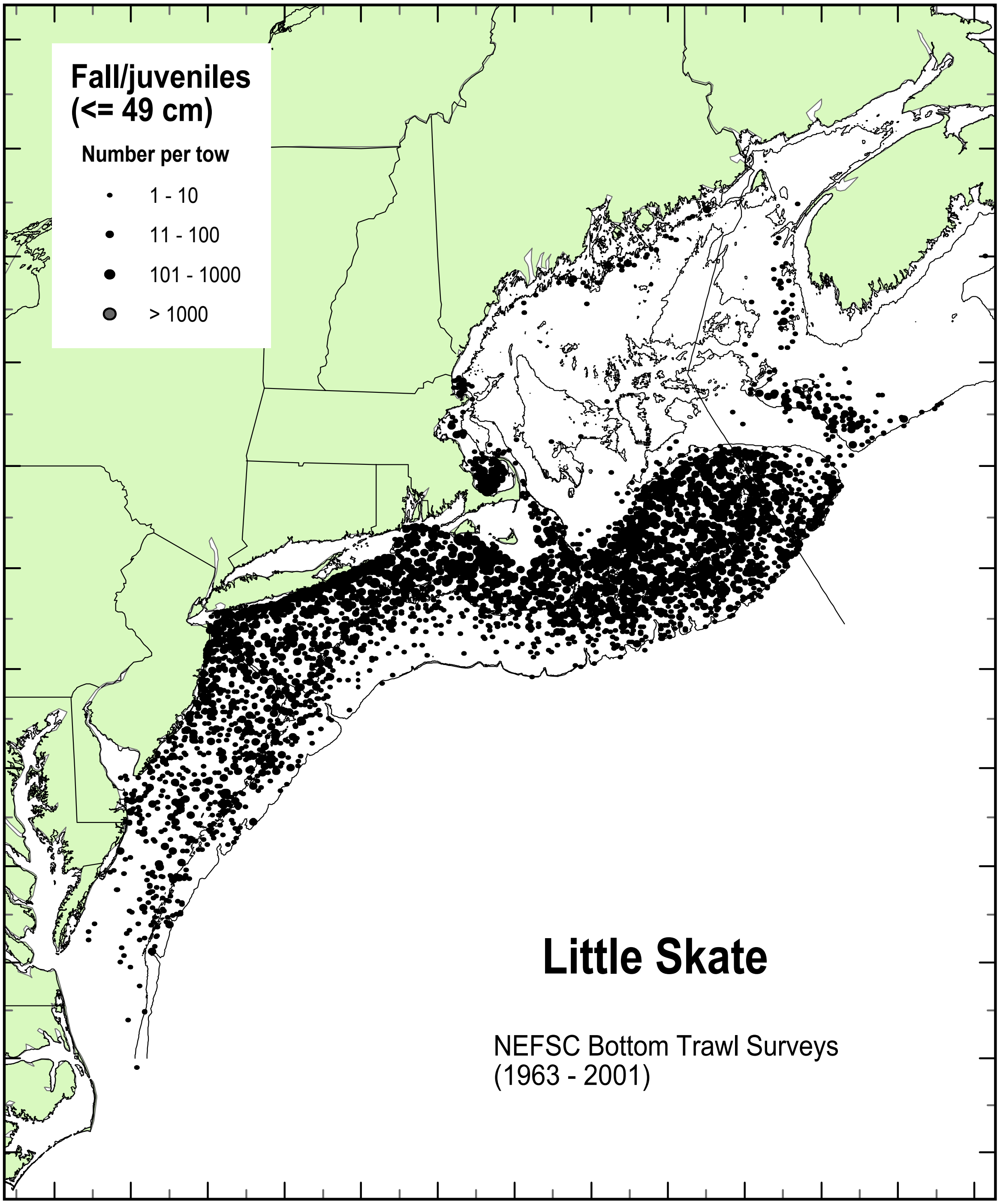


Figure 7. Distribution and abundance of juvenile little skate collected during fall NEFSC bottom trawl surveys [1963-2001, all years combined; see Reid *et al.* (1999) for details].

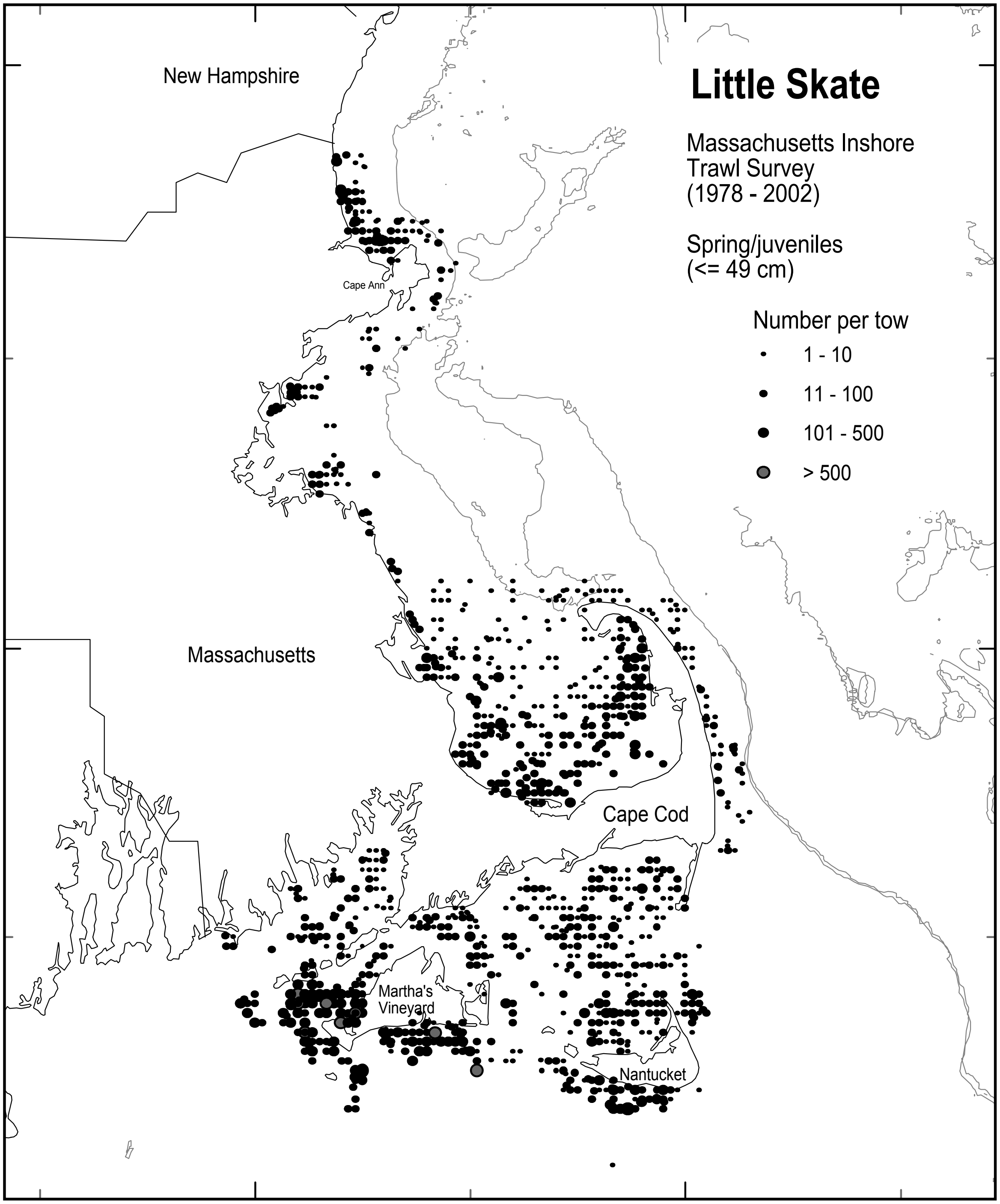
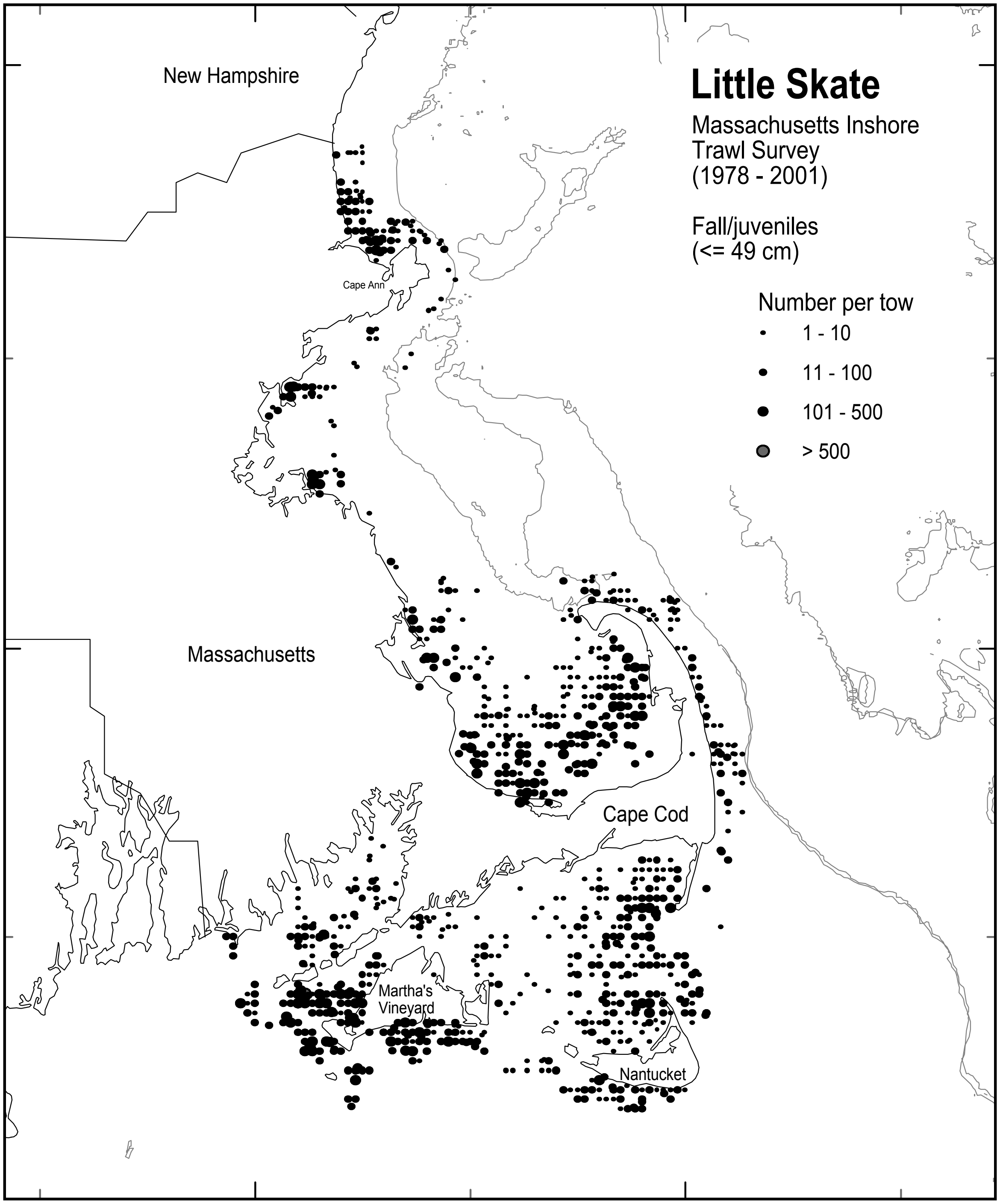


Figure 8. Distribution and abundance of juvenile little skate in Massachusetts coastal waters collected during the spring and autumn Massachusetts inshore trawl surveys [1978-2002, all years combined; see Reid *et al.* (1999) for details].



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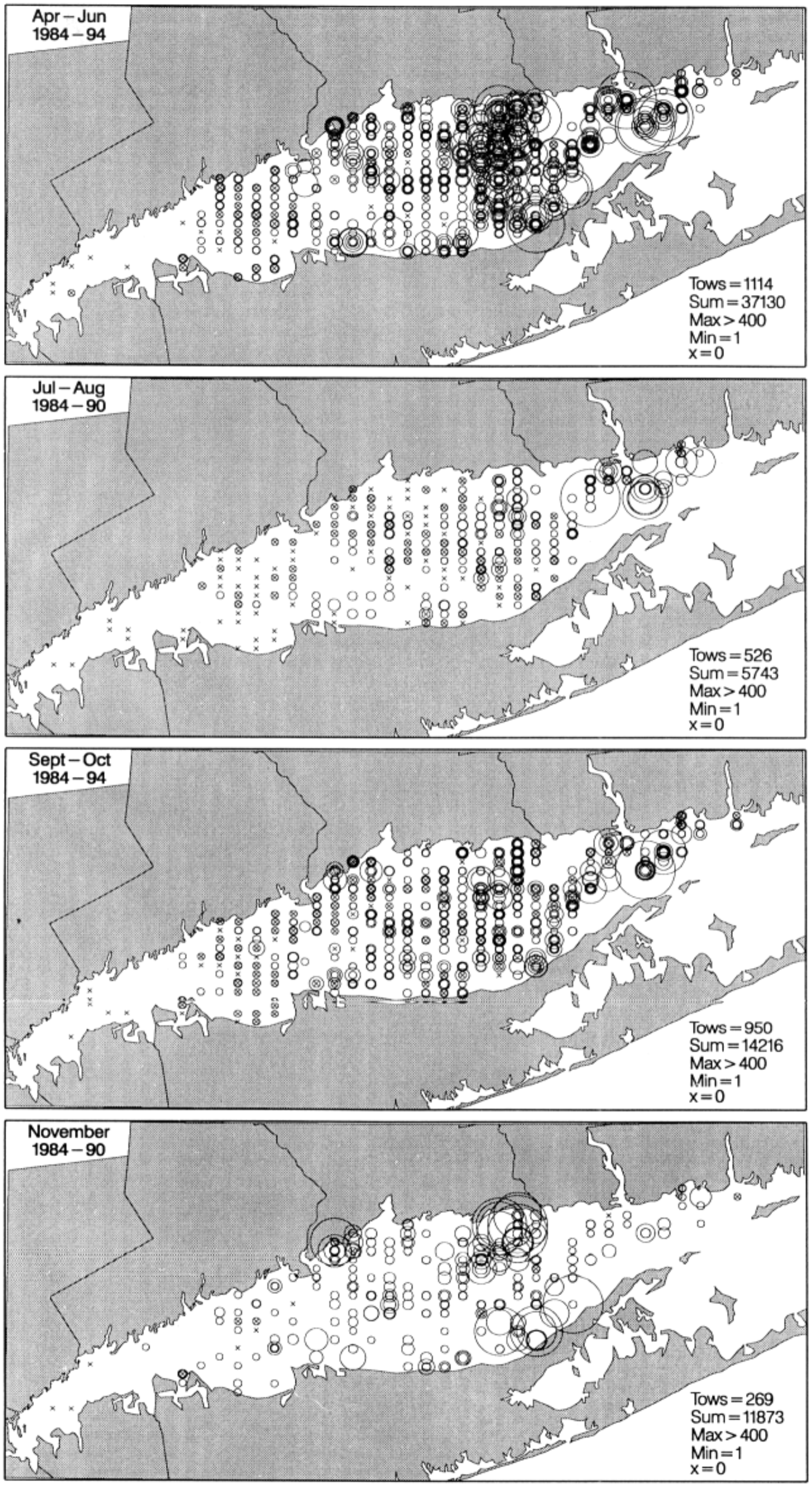


Figure 9. Distribution and abundance of juvenile and adult little skate (8-51 cm TL) collected in Long Island Sound, based on the finfish surveys of the Connecticut Fisheries Division, 1984-1994 [from Gottschall *et al.* (2000)]. Circle diameter is proportional to the number of fish caught, and is scaled to the maximum catch (indicated by "max>"). Collections were made with a 14 m otter trawl at about 40 stations chosen by stratified random design.

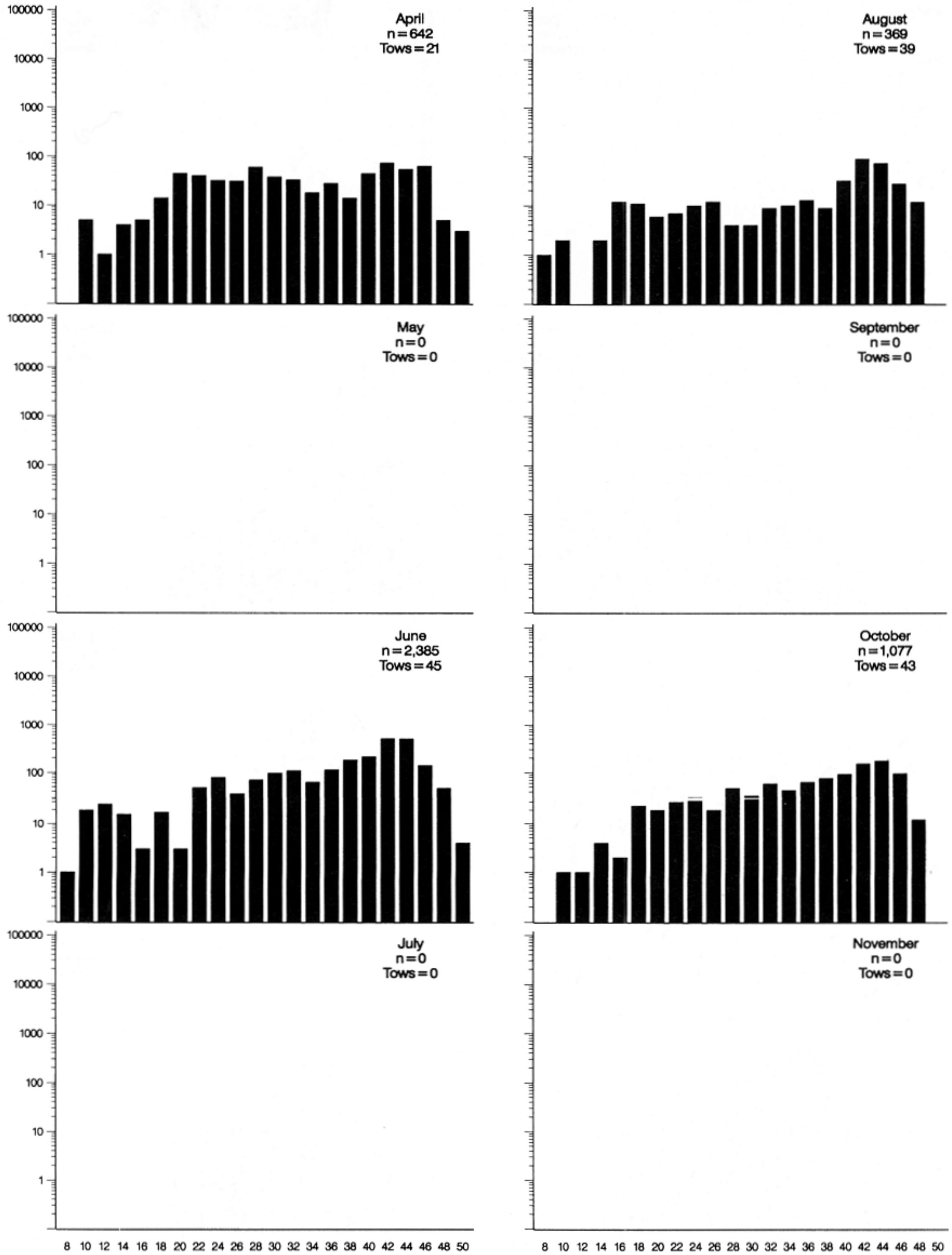


Figure 10. Monthly $\log_{10}$ length frequencies (cm) of juvenile and adult little skate collected in Long Island Sound, based on 4,473 fish taken in 148 tows between 1989-1990. From Gottschall *et al.* (2000).

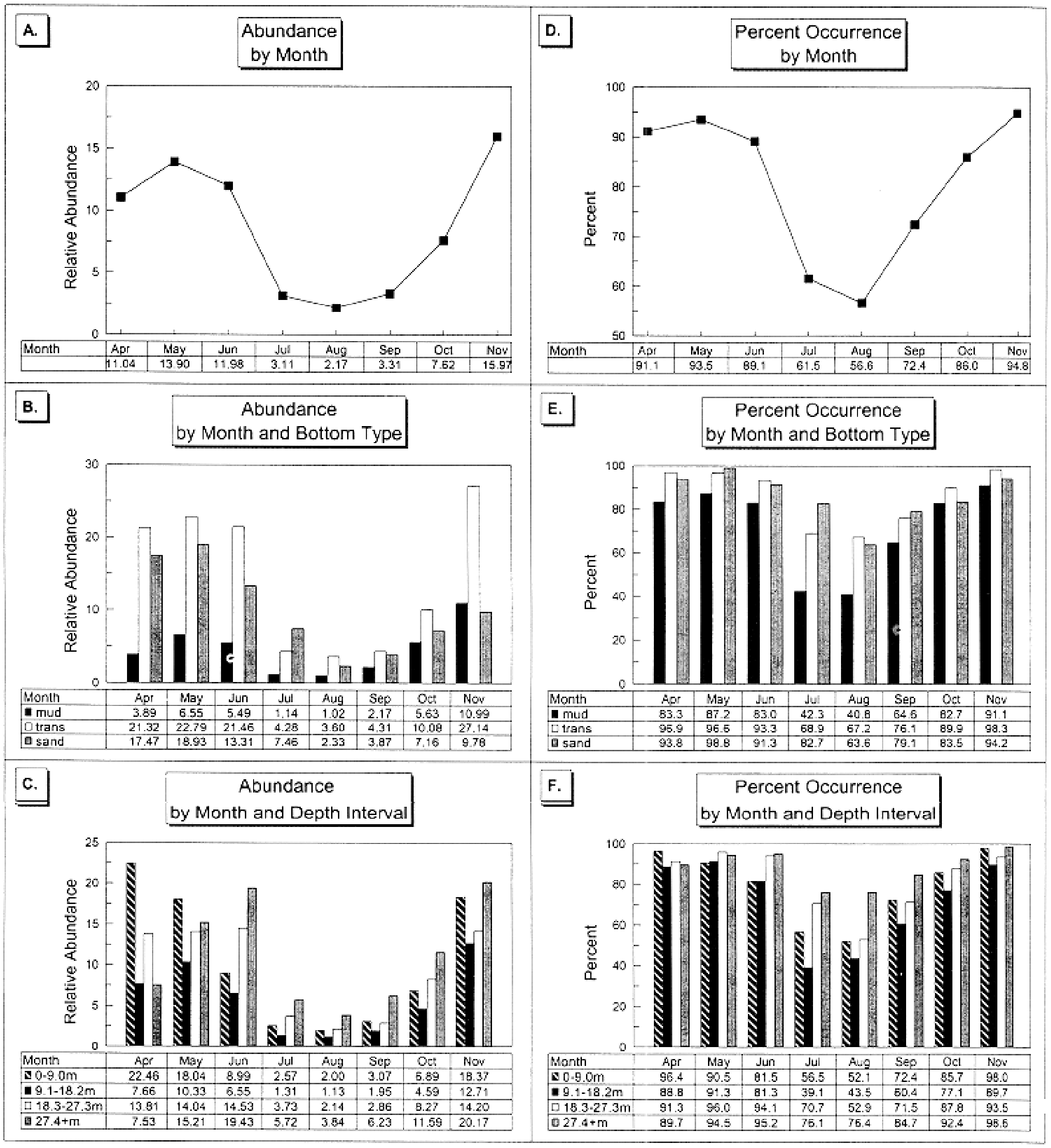


Figure 11. Relative abundance (geometric mean catch/tow) catch/tow and percent occurrence (proportion of samples in which at least one individual was observed) for juvenile and adult little skate in Long Island Sound by month, month and bottom type, and month and depth interval. From Gottschall *et al.* (2000).

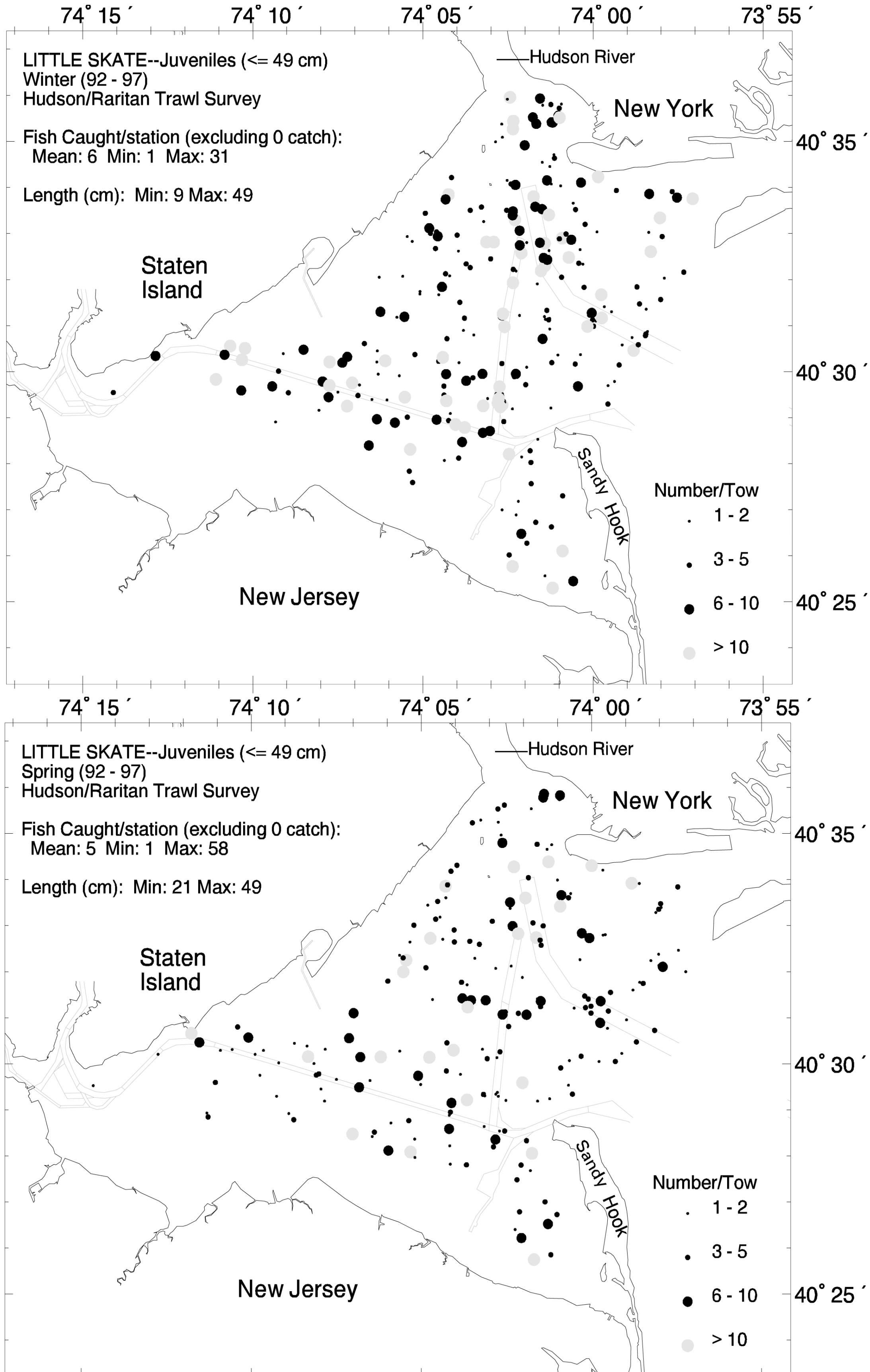
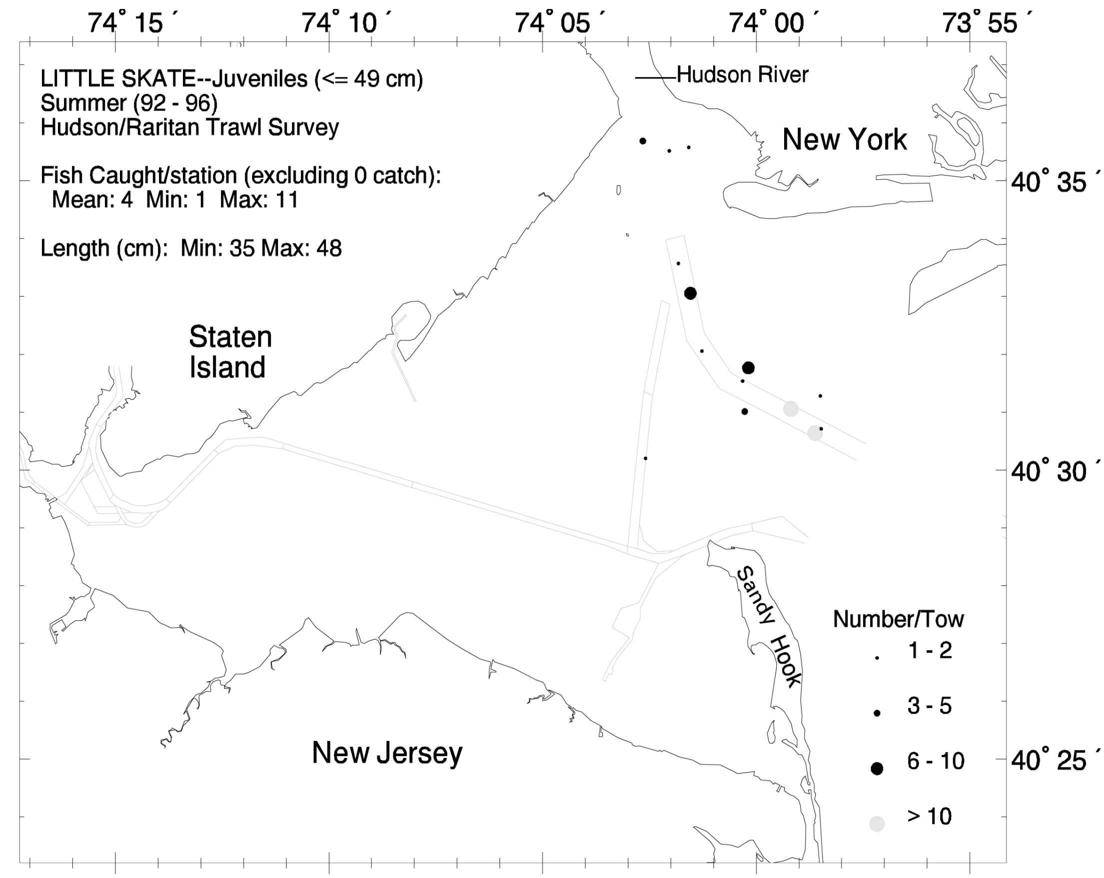
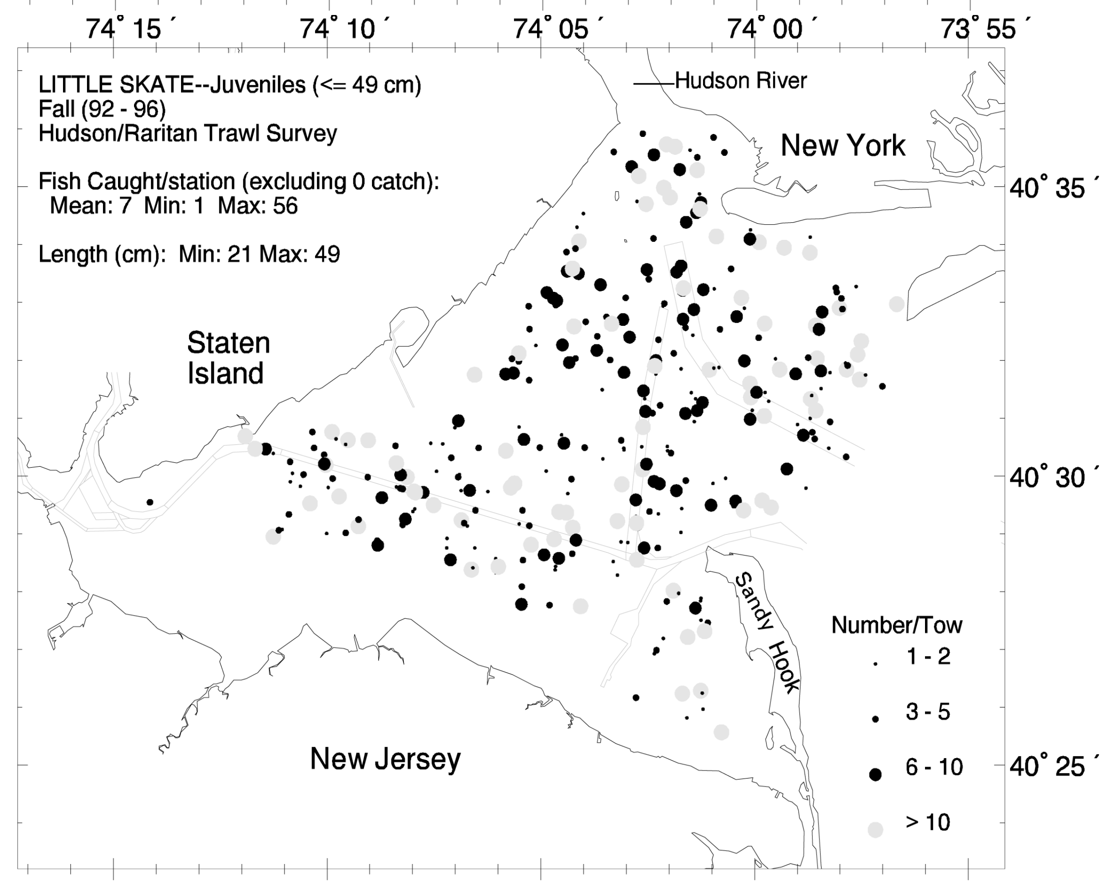


Figure 12. Seasonal distribution and abundance of juvenile little skate in the Hudson-Raritan estuary, based on Hudson-Raritan trawl surveys, 1992-1997 [all years combined; see Reid *et al.* (1999) for details].





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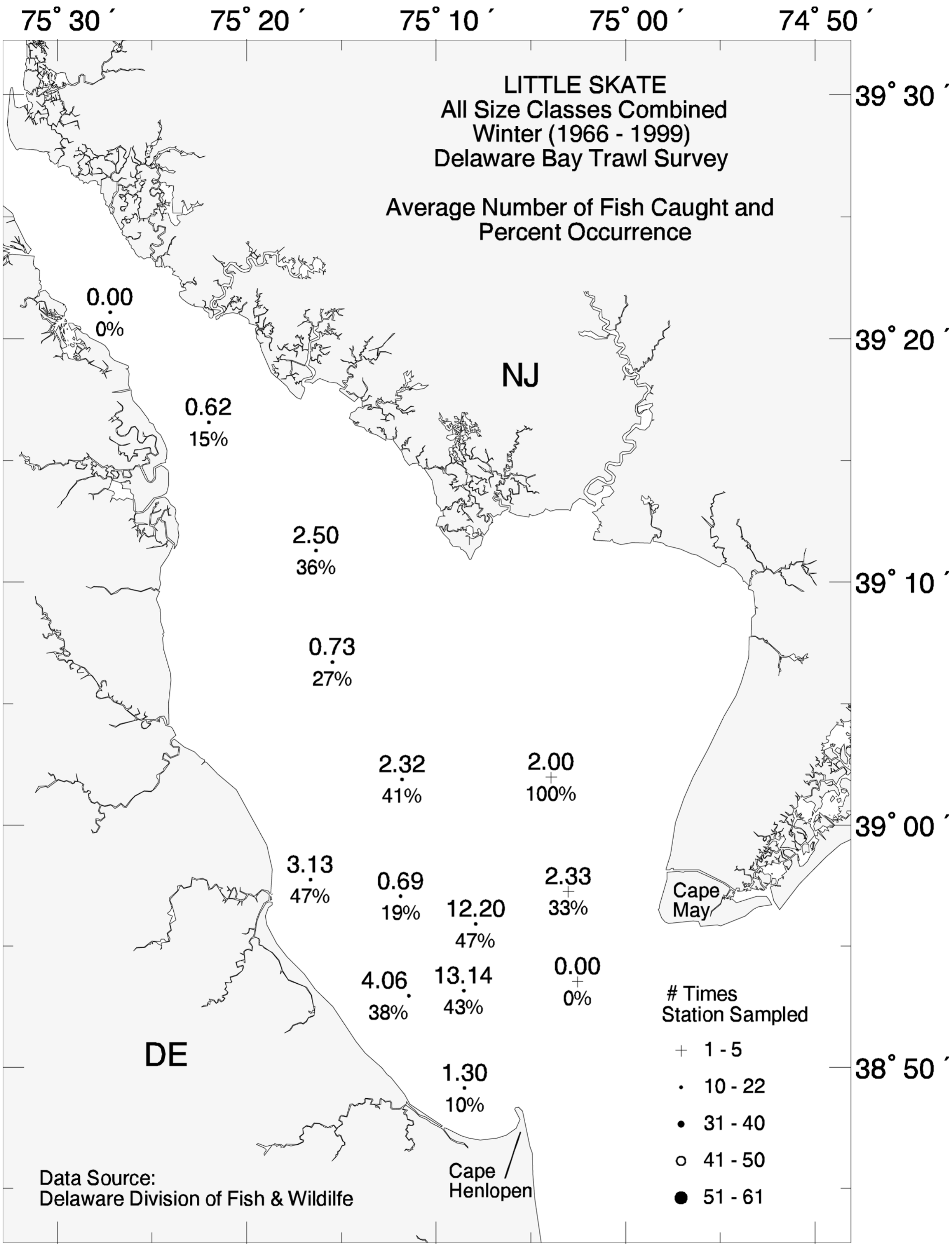
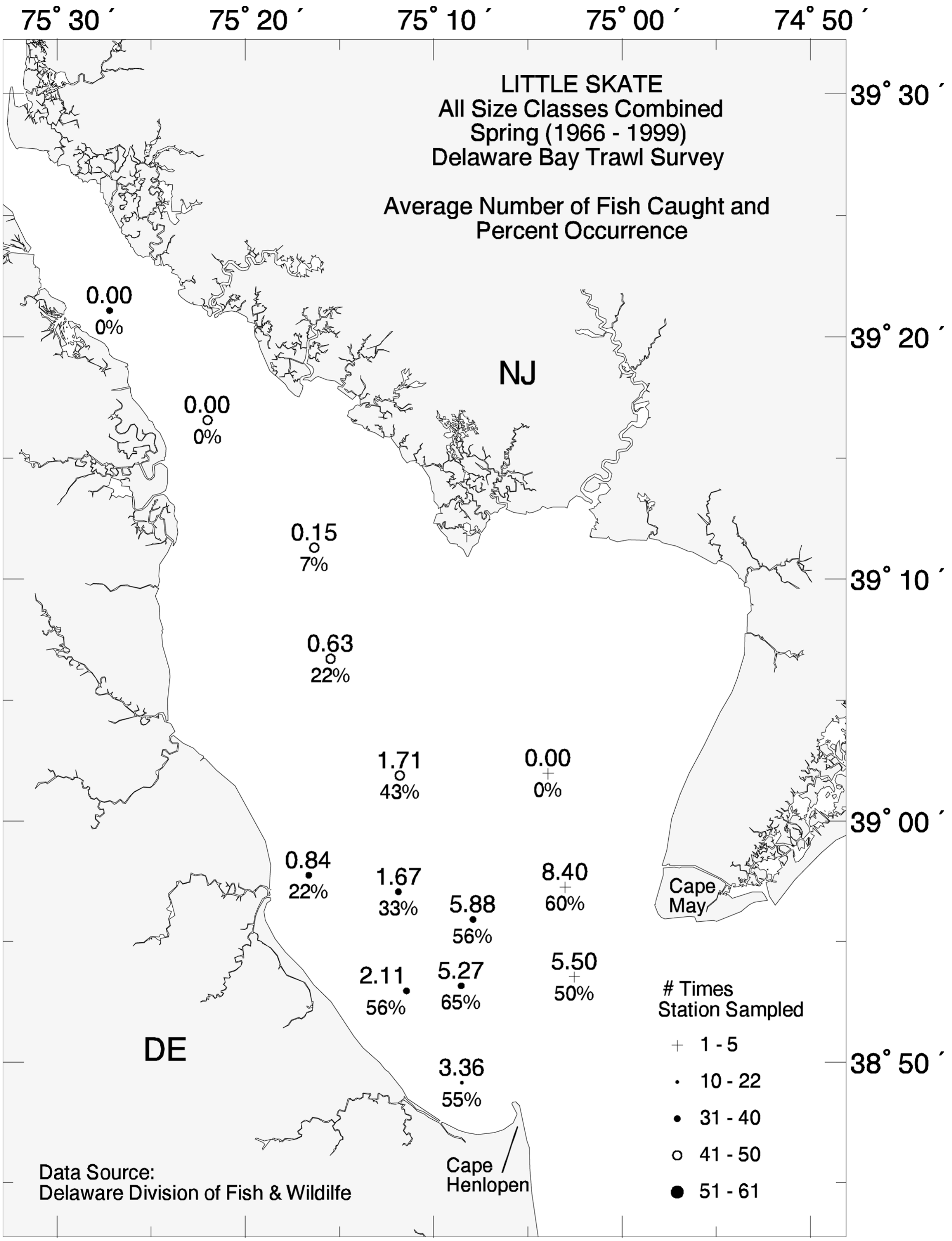


Figure 13. Seasonal distribution and abundance of juvenile and adult little skate in Delaware Bay, based on Delaware Division of Fish and Wildlife bottom trawl surveys from 1966-1999 (all years combined). Surveys were conducted monthly at 9-14 fixed stations, using a 9.1 m otter trawl towed for 20-30 min (for methods see Michels and Greco 2000).



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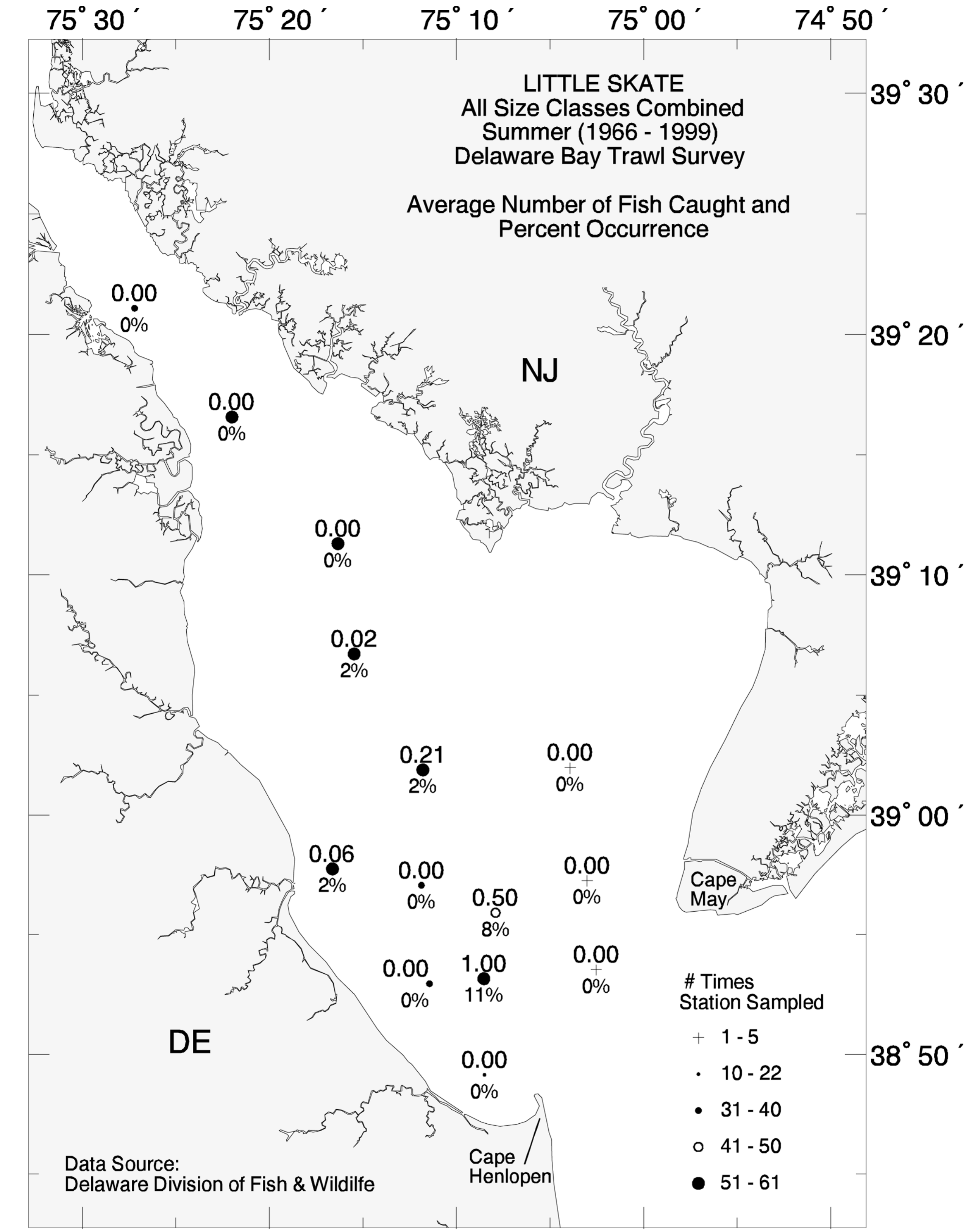

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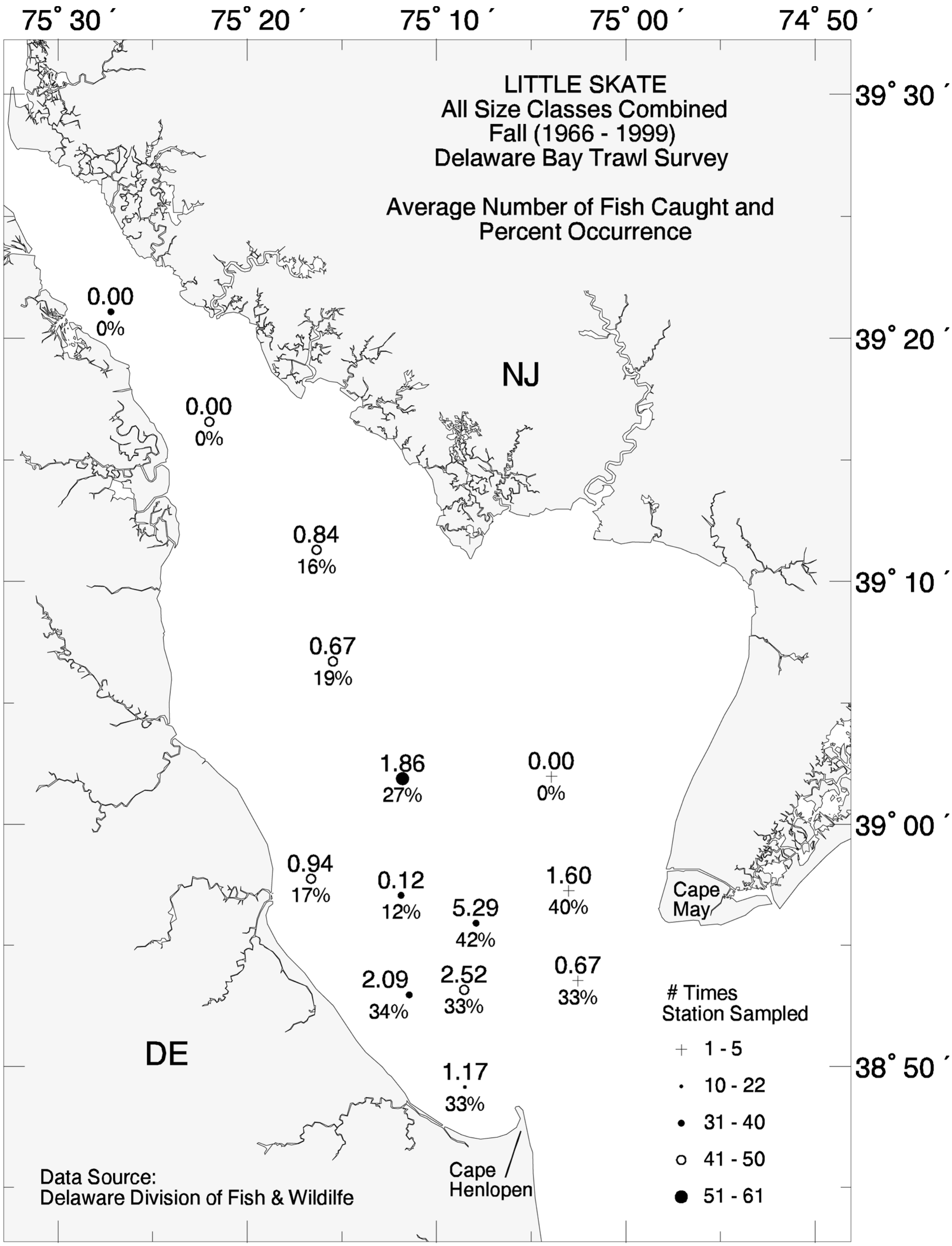

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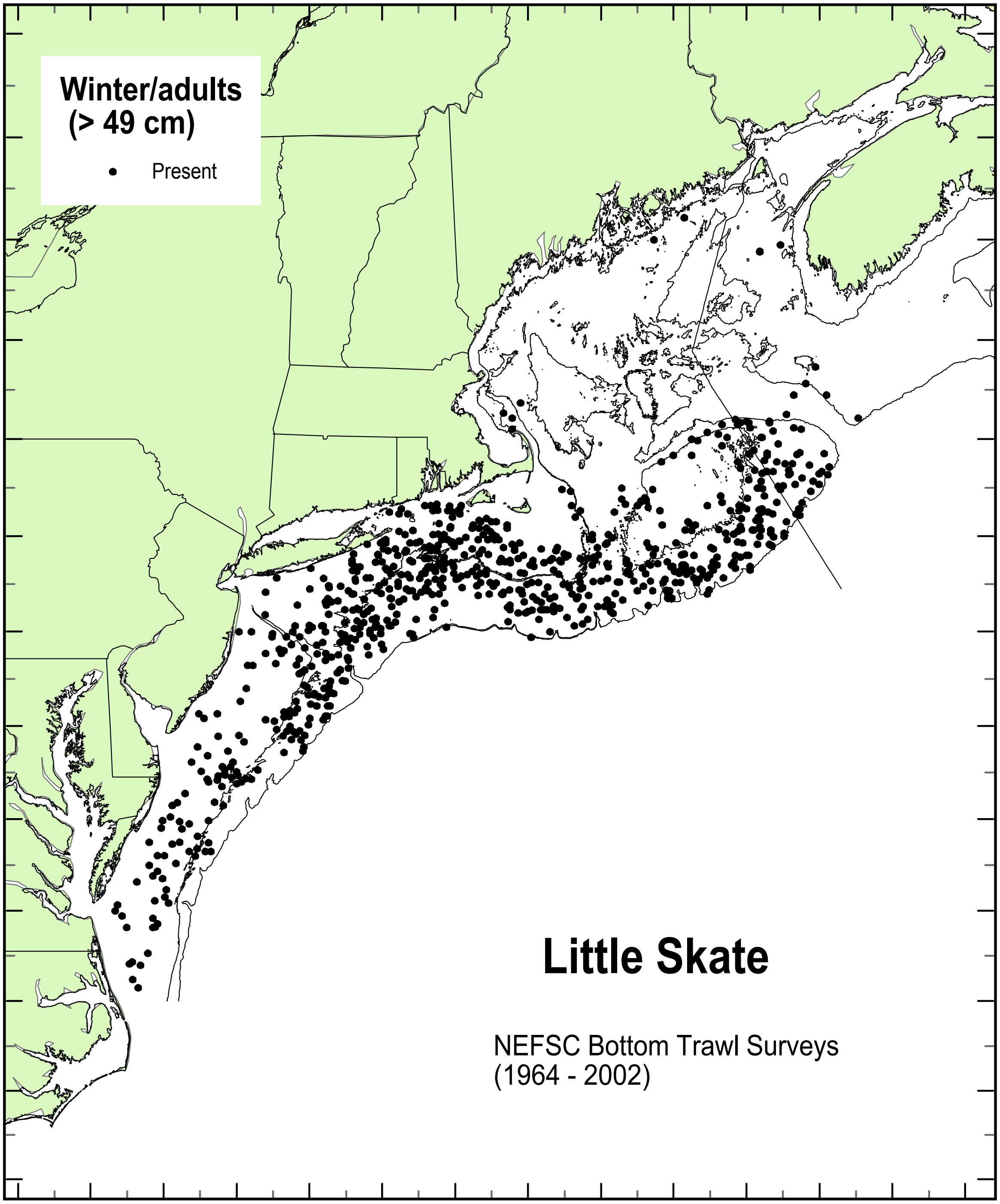


Figure 14. Distribution of adult little skate collected during winter NEFSC bottom trawl surveys [1964-2002, all years combined; see Reid *et al.* (1999) for details]. Survey stations where adults were not found are not shown.

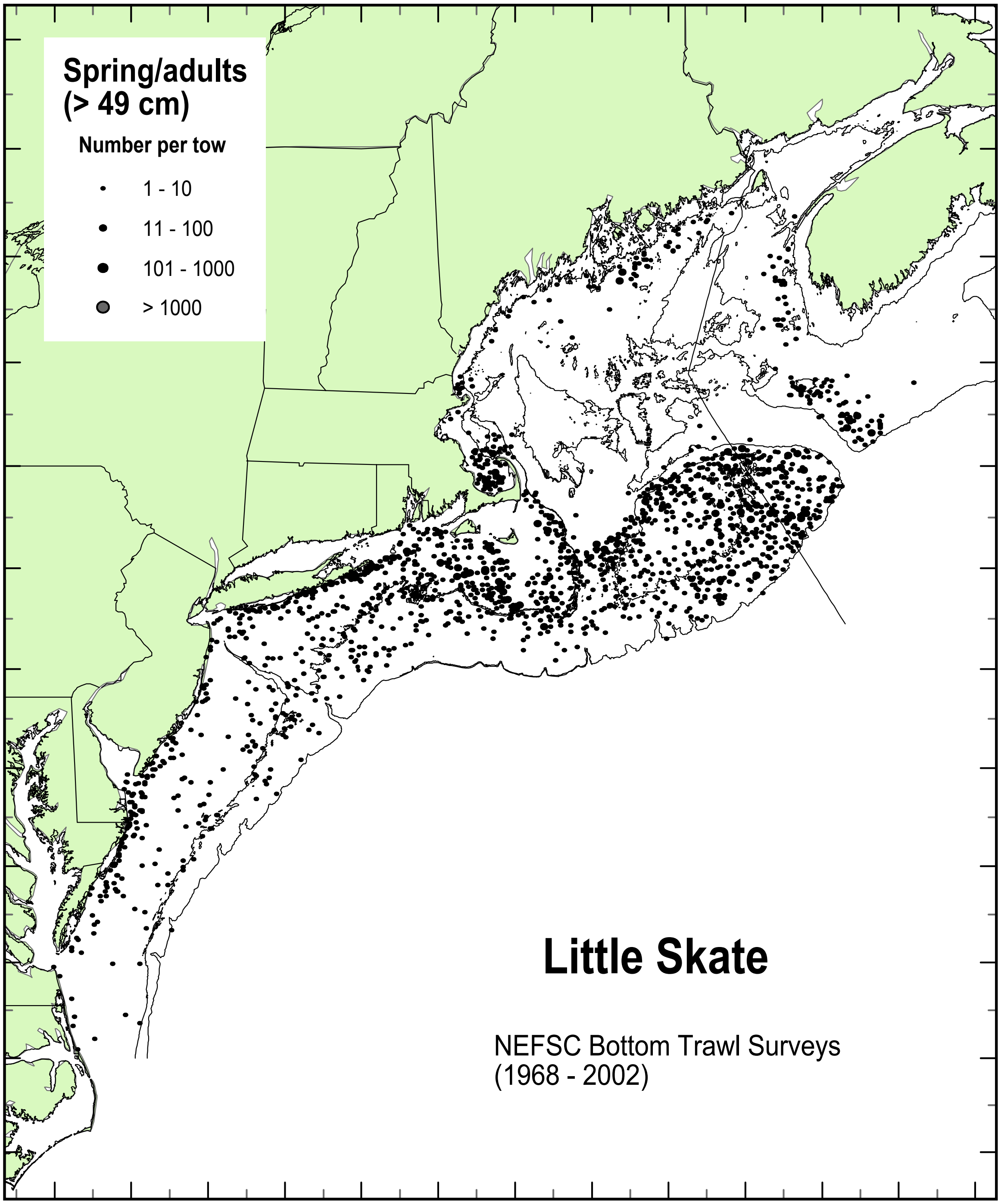


Figure 15. Distribution and abundance of adult little skate collected during spring NEFSC bottom trawl surveys [1968-2002, all years combined; see Reid *et al.* (1999) for details].

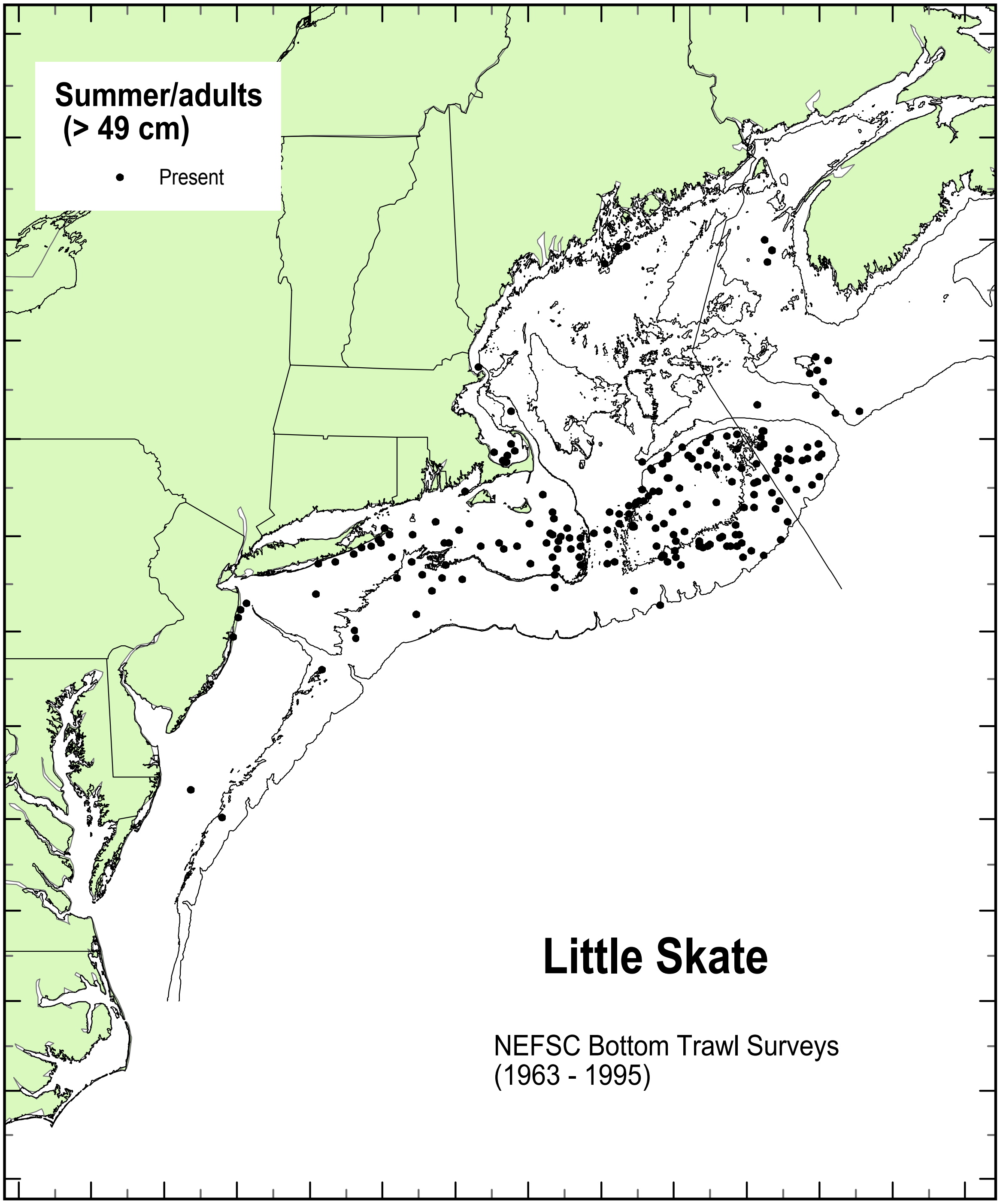


Figure 16. Distribution of adult little skate collected during summer NEFSC bottom trawl surveys [1963-1995, all years combined; see Reid *et al.* (1999) for details]. Survey stations where adults were not found are not shown.

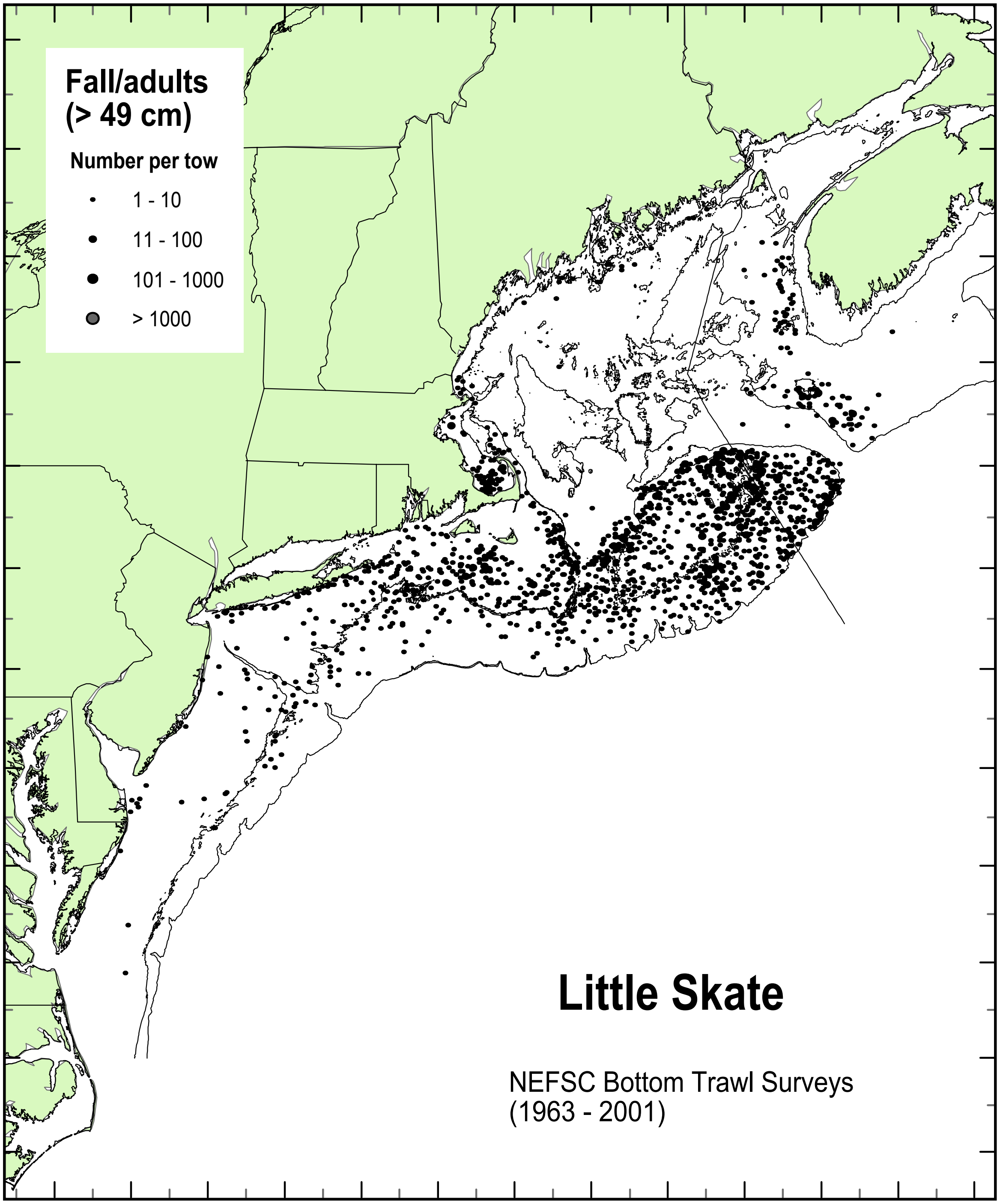


Figure 17. Distribution and abundance of adult little skate collected during fall NEFSC bottom trawl surveys [1963-2001, all years combined; see Reid *et al.* (1999) for details].

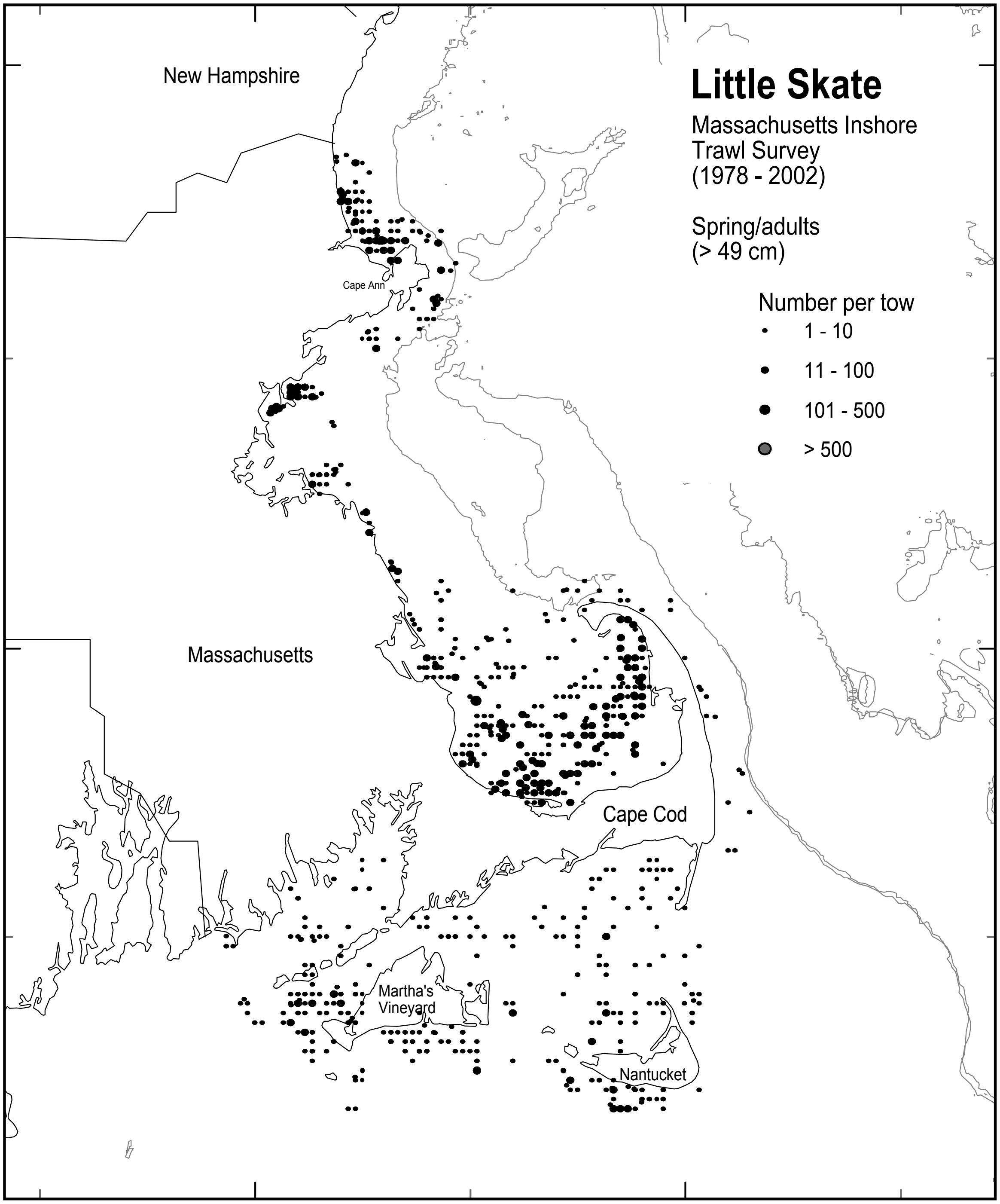
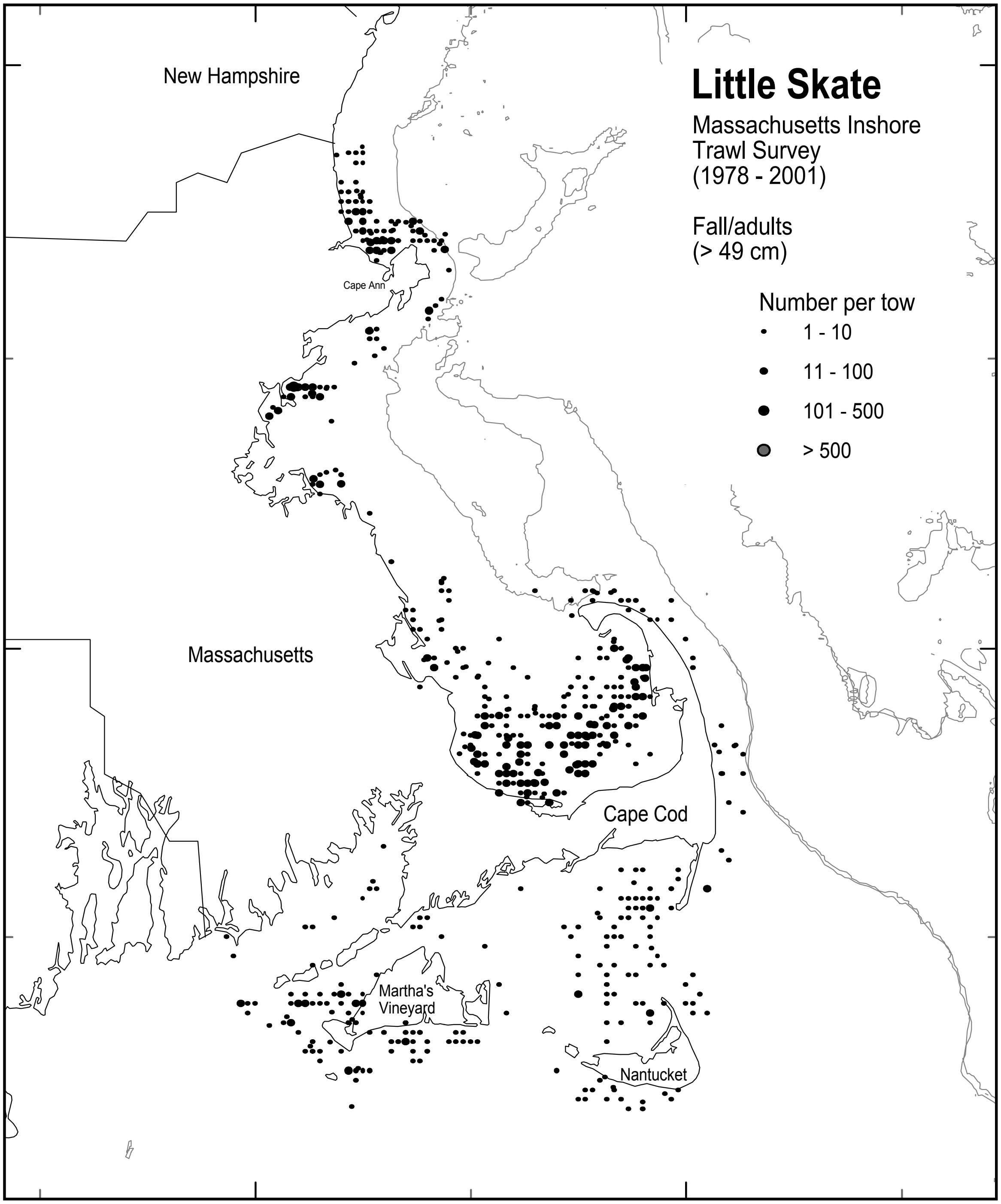


Figure 18. Distribution and abundance of adult little skate in Massachusetts coastal waters collected during the spring and autumn Massachusetts inshore trawl surveys [1978-2002, all years combined; see Reid *et al.* (1999) for details].



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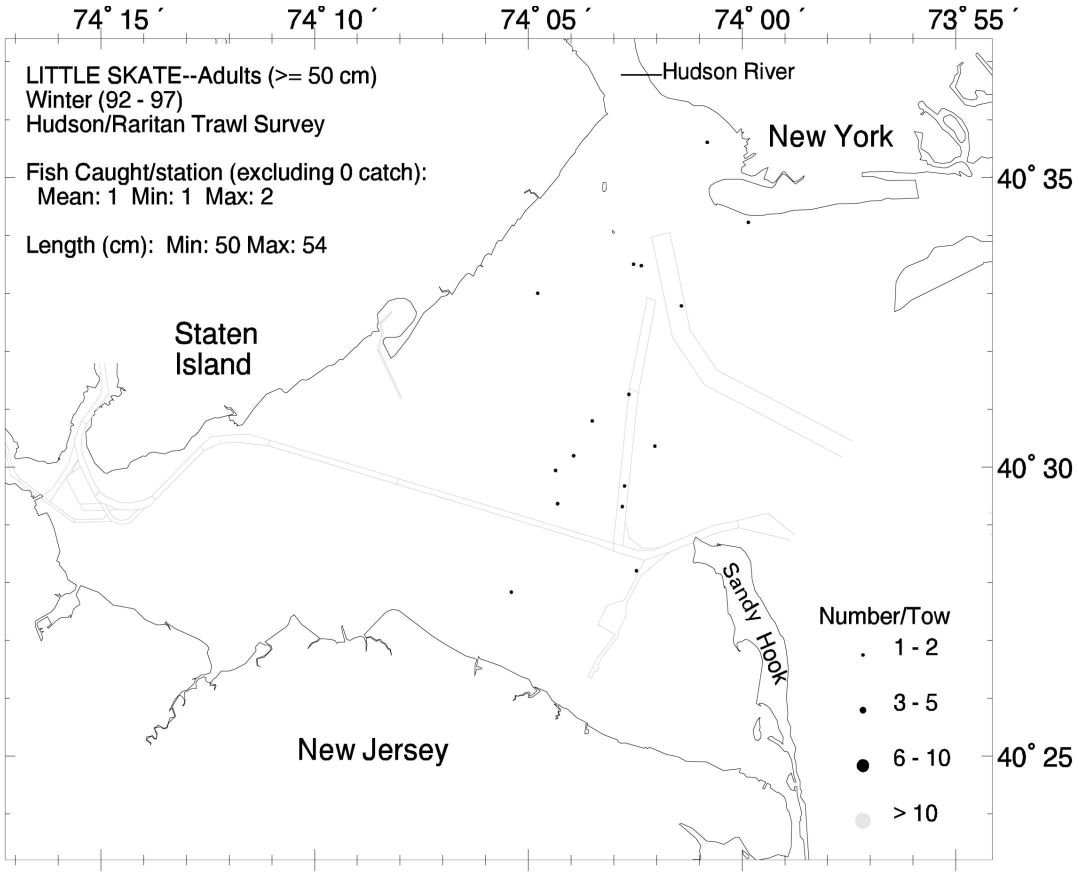


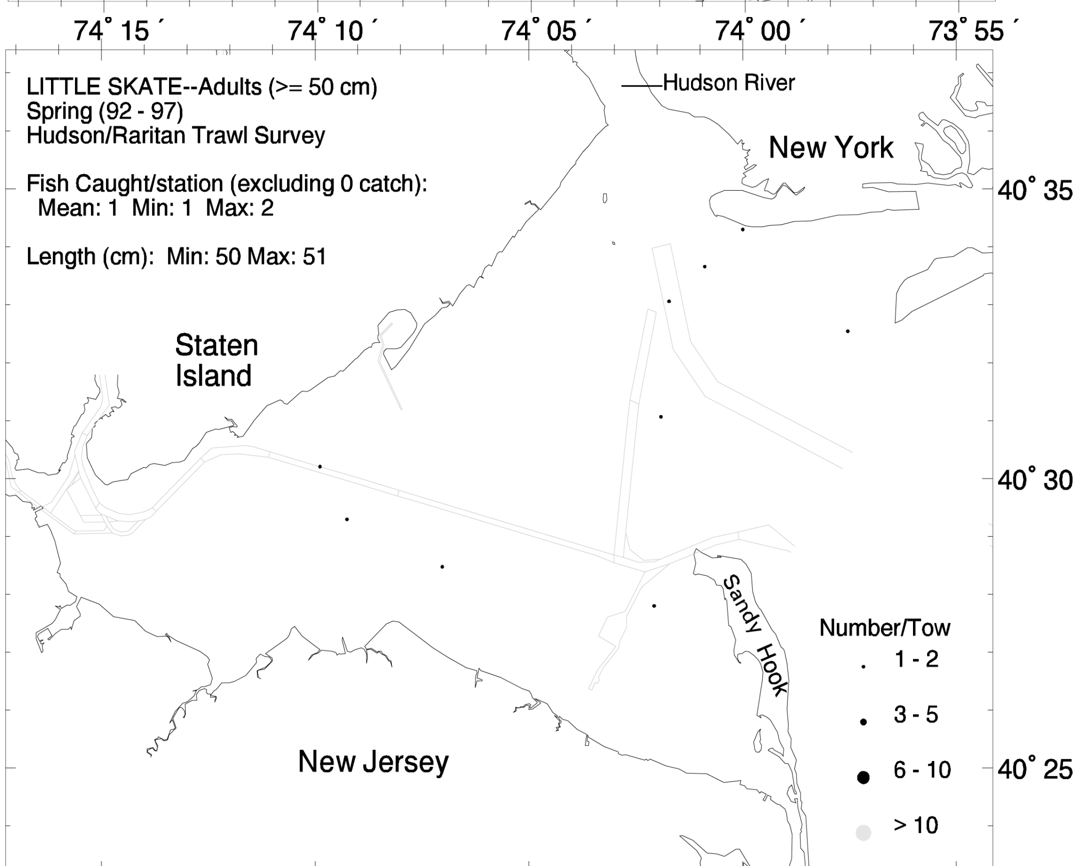
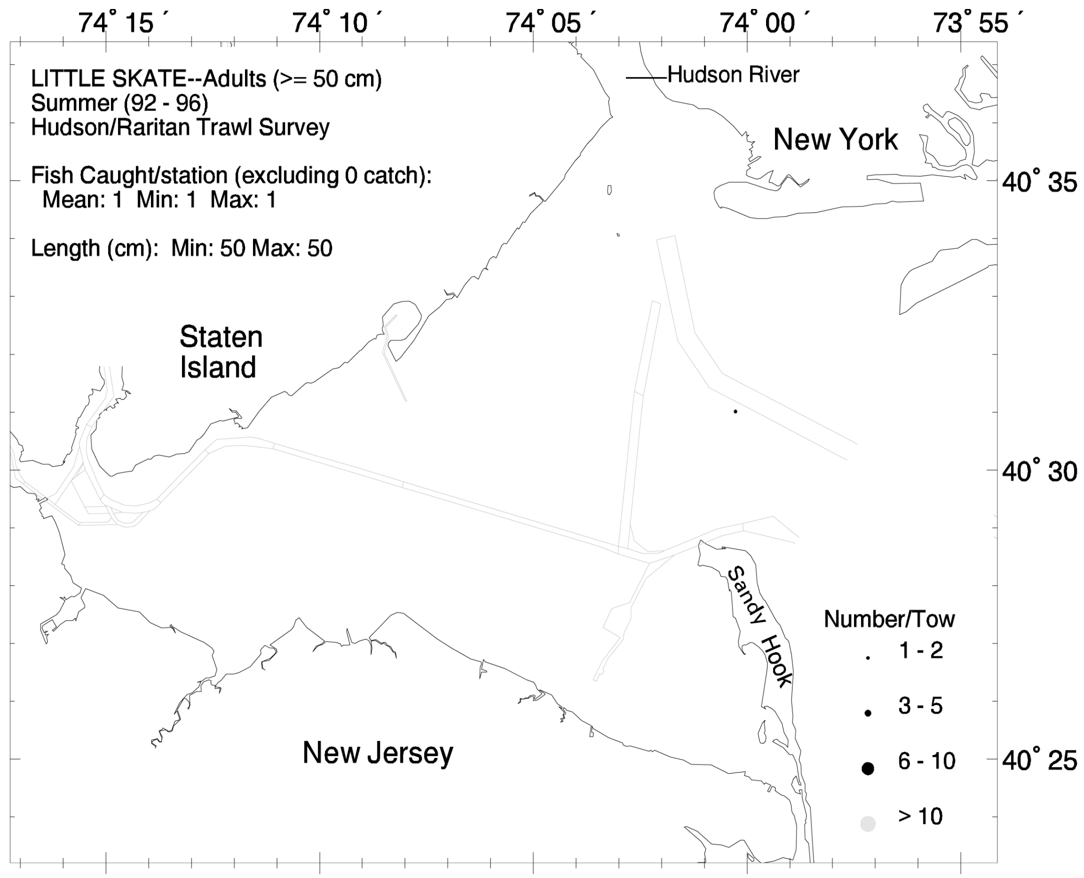


Figure 19. Seasonal distribution and abundance of adult little skate in the Hudson-Raritan estuary, based on Hudson-Raritan trawl surveys, 1992-1997 [all years combined; see Reid *et al.* (1999) for details].



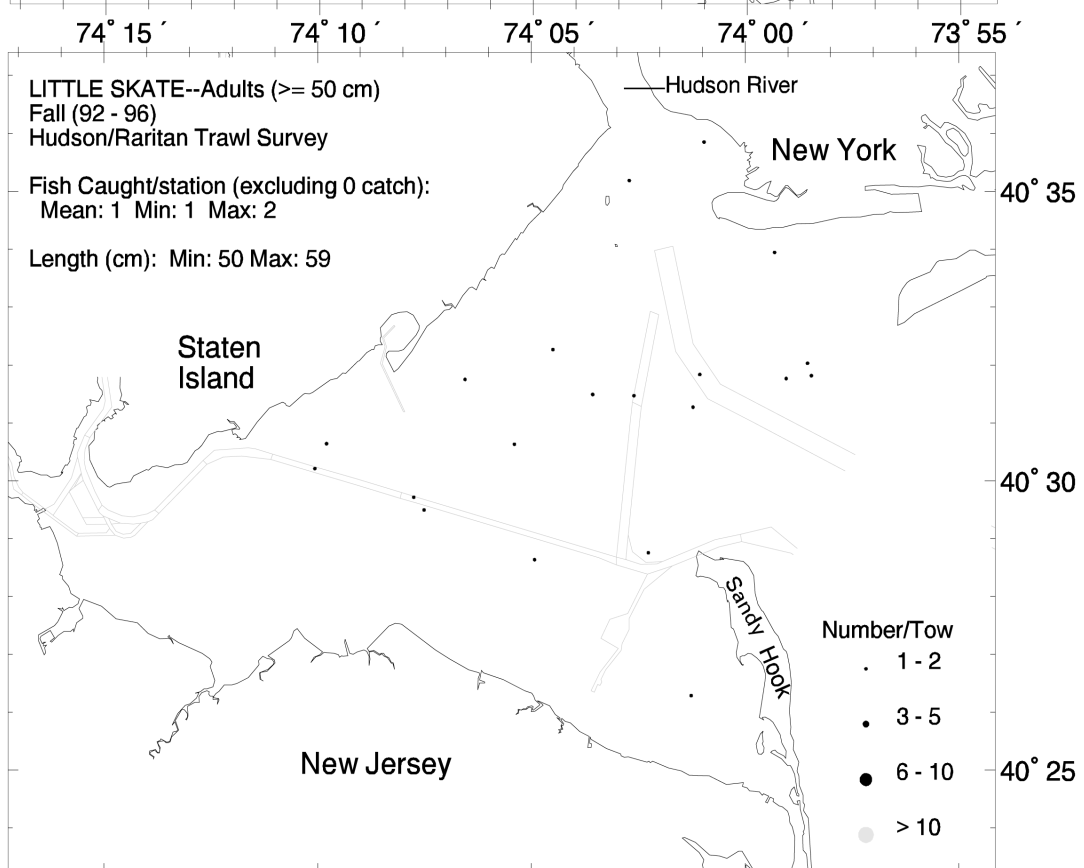


Figure 19. cont’d.

Little Skate
NEFSC Bottom Trawl Survey
Spring/Juveniles

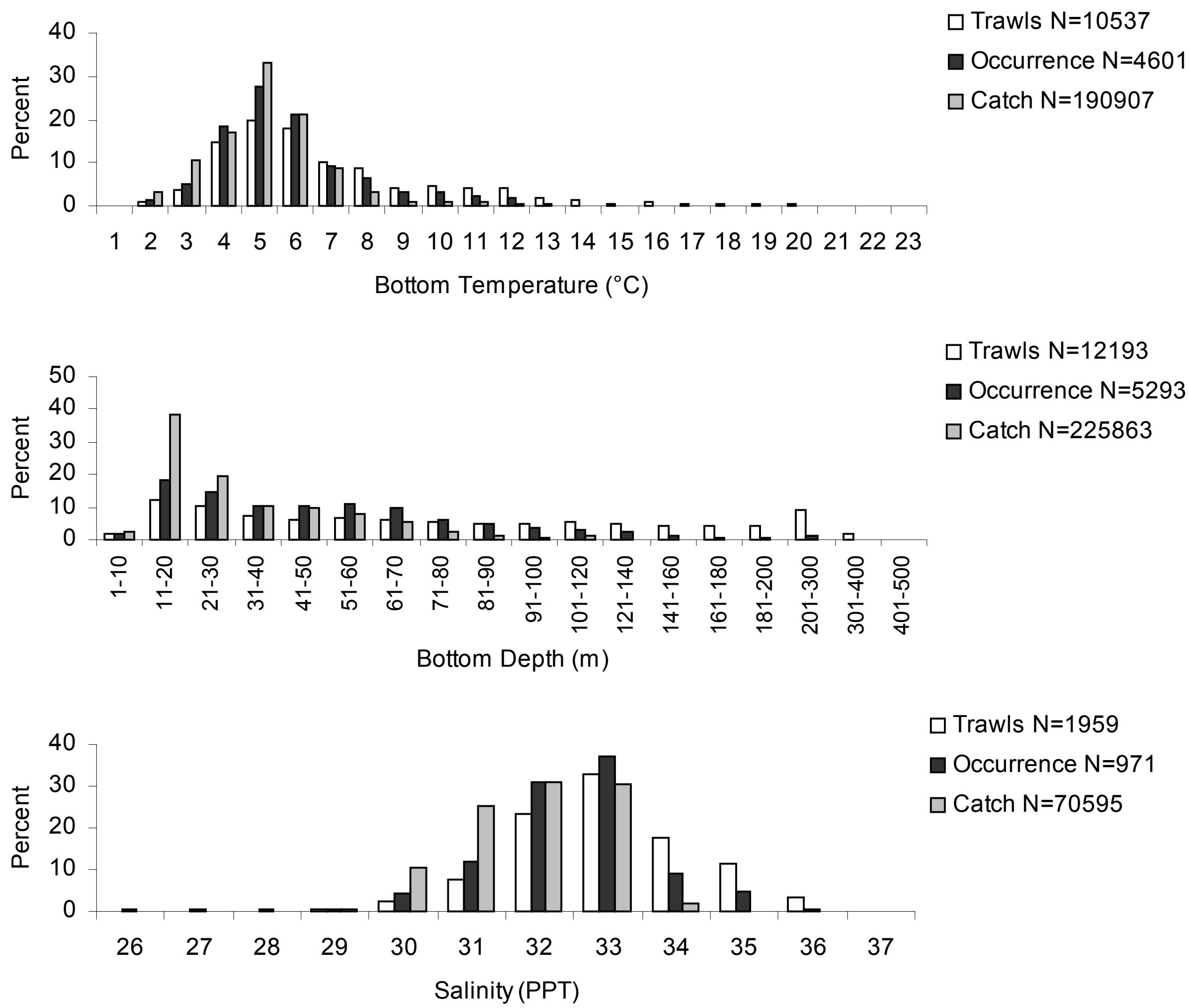


Figure 20. Spring and fall distributions of juvenile little skate and trawls relative to bottom water temperature, depth, and salinity based on NEFSC bottom trawl surveys (1963-2002; all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which little skate occurred, and gray bars represent, within each interval, the percentage of the total number of little skate caught.

Little Skate
NEFSC Bottom Trawl Survey
Fall/Juveniles

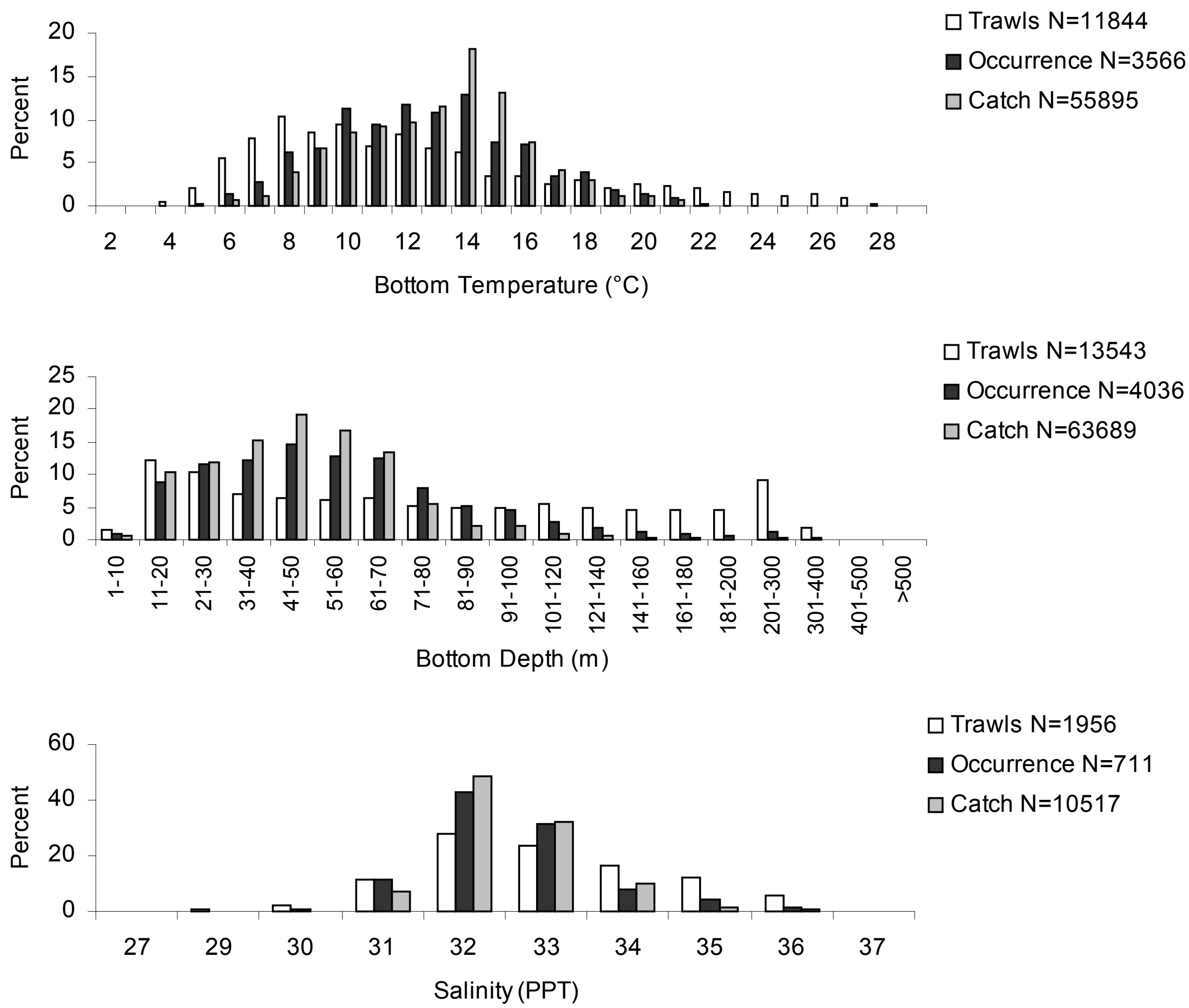


Figure 20. cont'd.

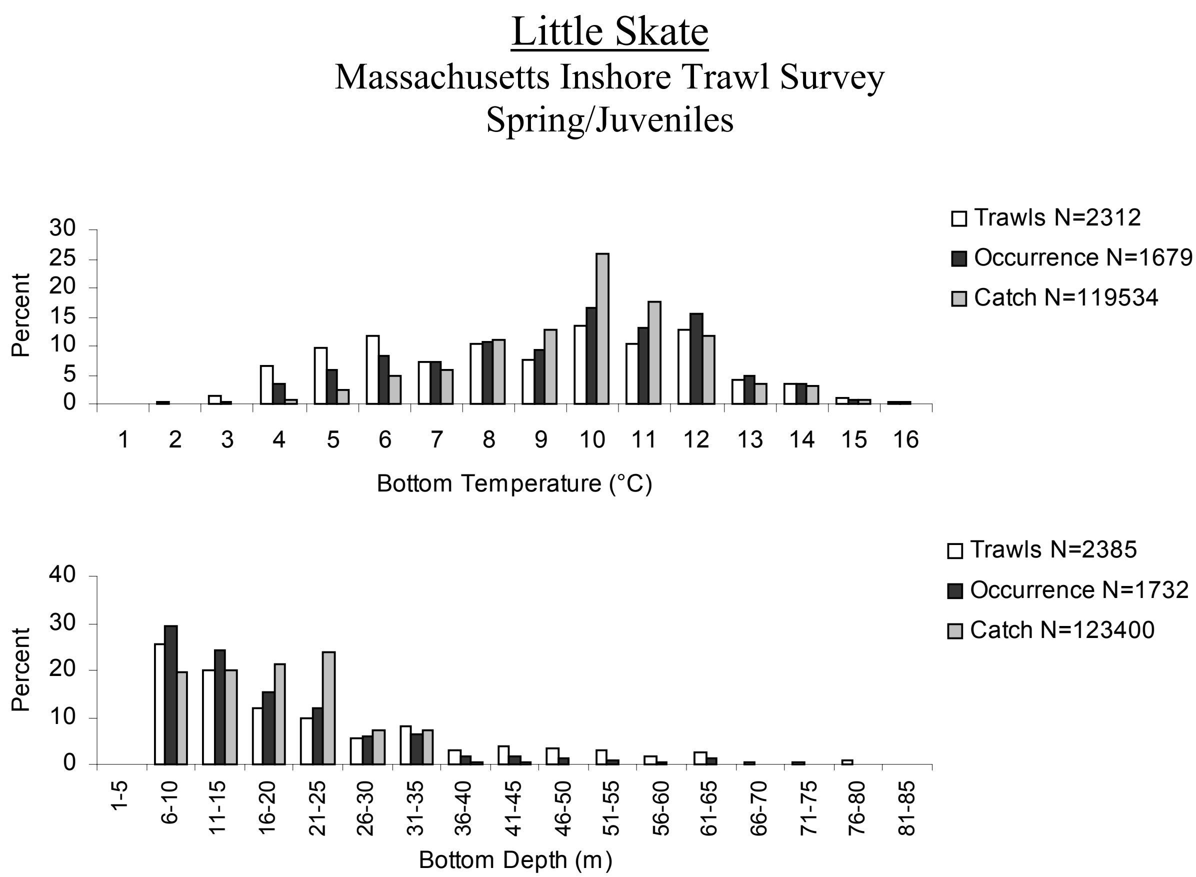
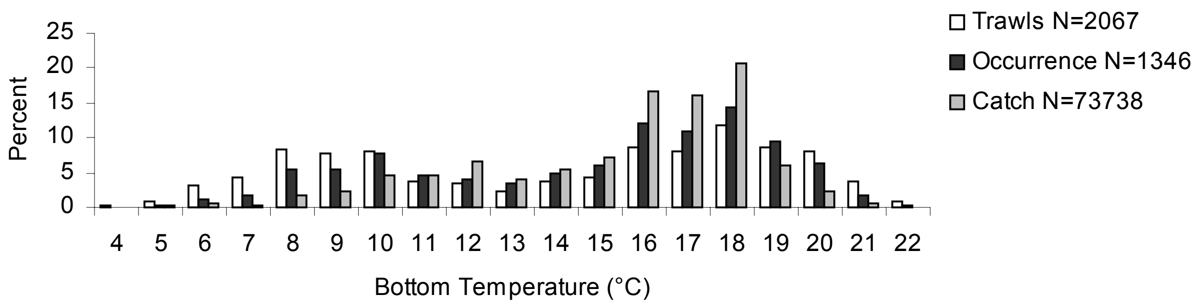


Figure 21. Spring and fall distributions of juvenile little skate and trawls relative to bottom water temperature and depth based on Massachusetts inshore trawl surveys (1978-2002, all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which little skate occurred, and gray bars represent, within each interval, the percentage of the total number of little skate caught.

Little Skate
Massachusetts Inshore Trawl Survey
Fall/Juveniles



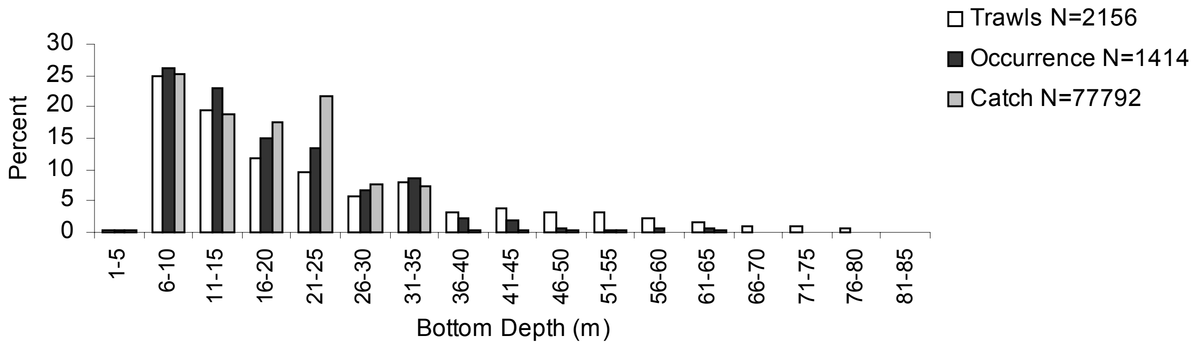


Figure 21. cont'd.

Winter

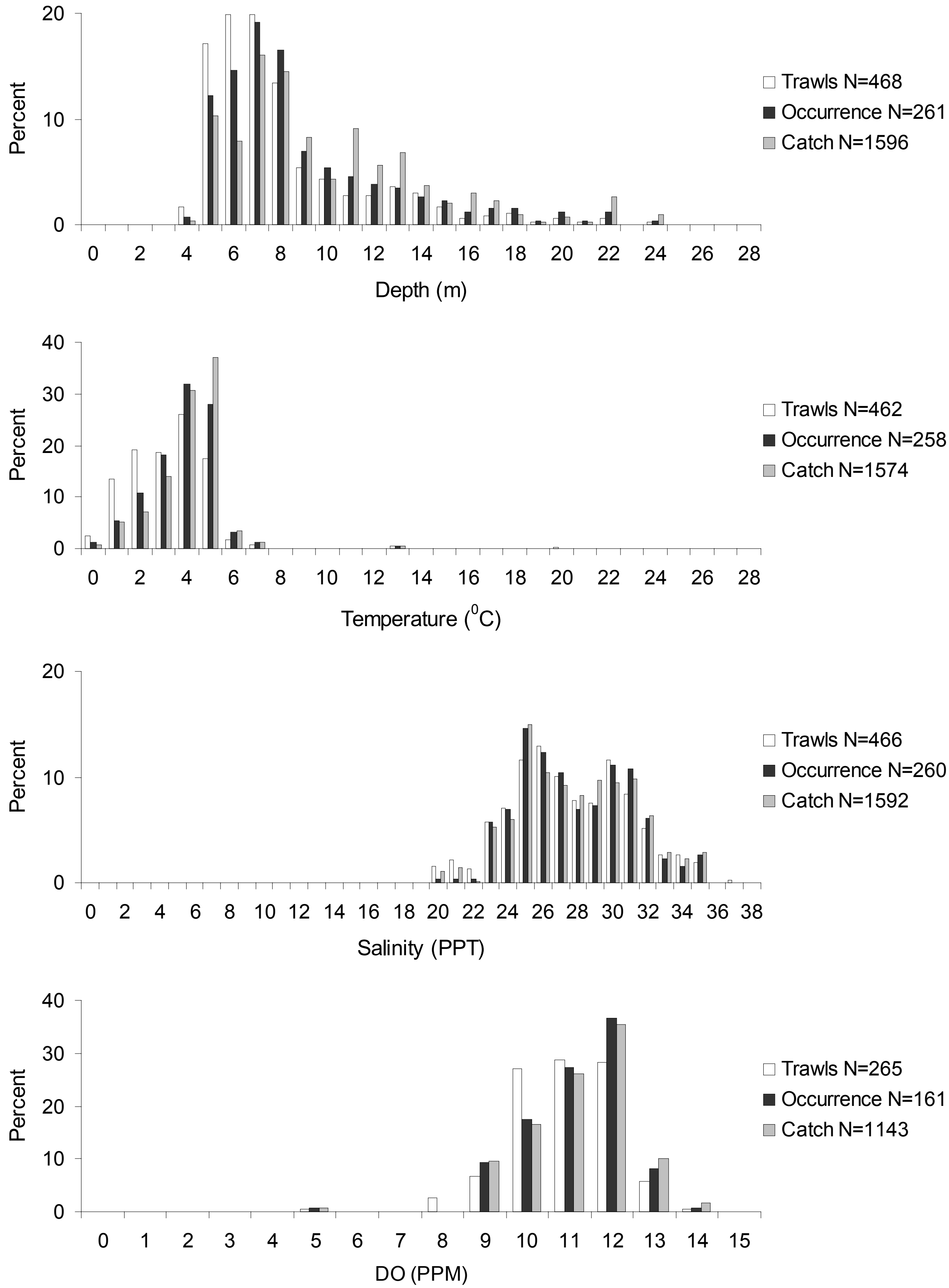
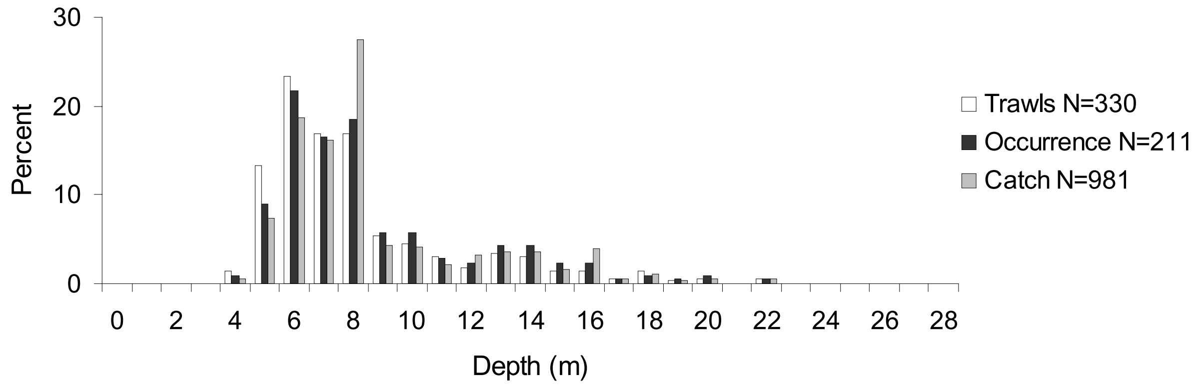
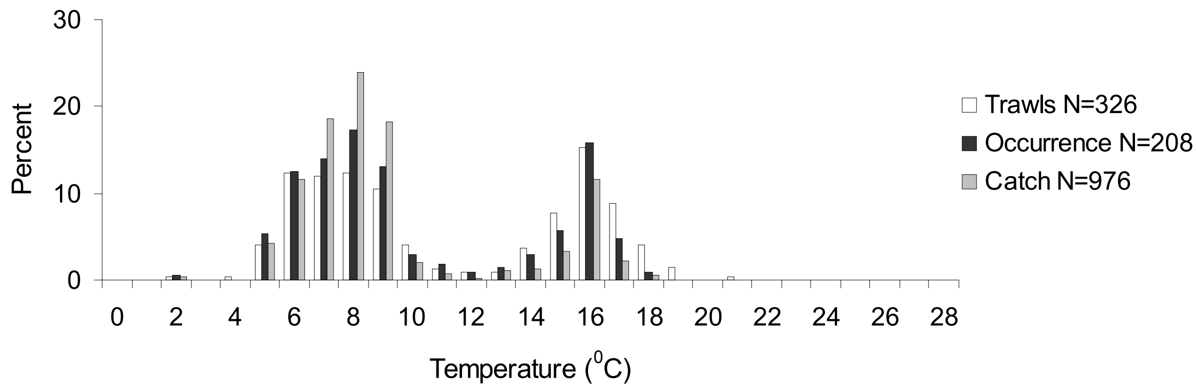
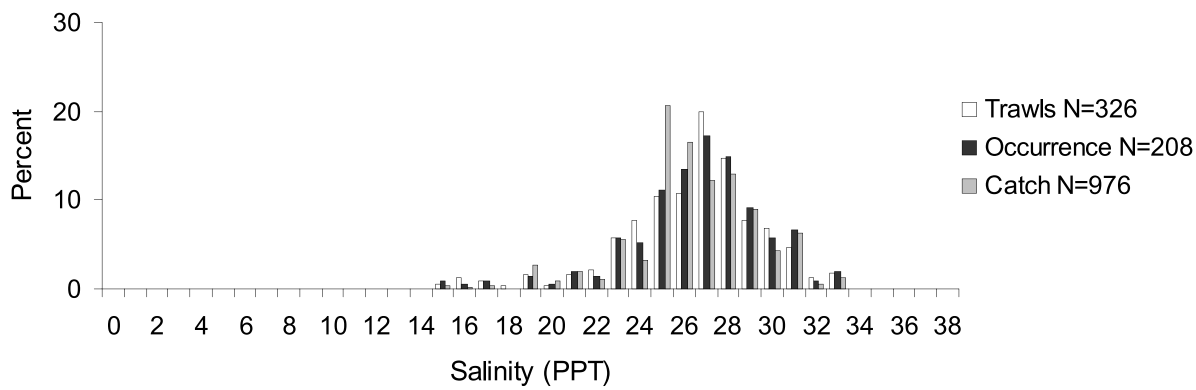


Figure 22. Seasonal distributions of juvenile little skate and trawls relative to bottom water temperature, depth, salinity, and dissolved oxygen based on NEFSC Hudson-Raritan estuary trawl surveys (1992-1997; all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which little skate occurred, and gray bars represent, within each interval, the percentage of the total number of little skate caught.

Spring







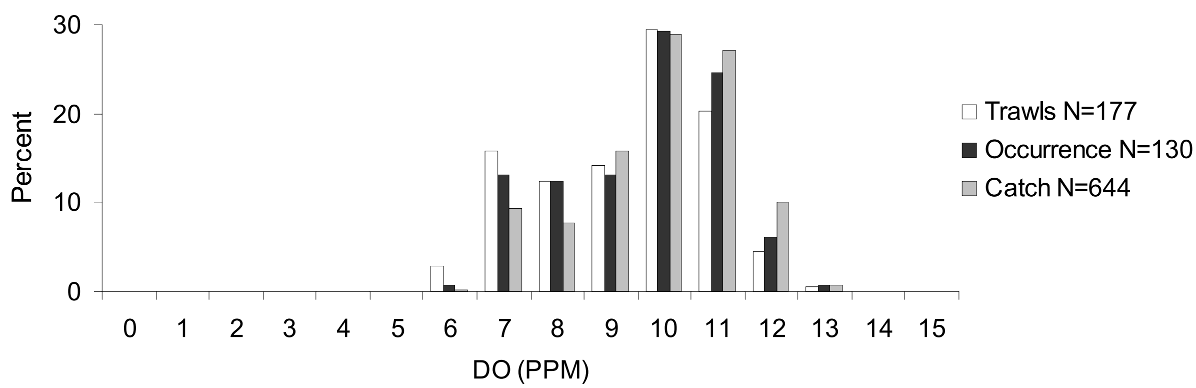


Figure 22. cont'd.

Summer

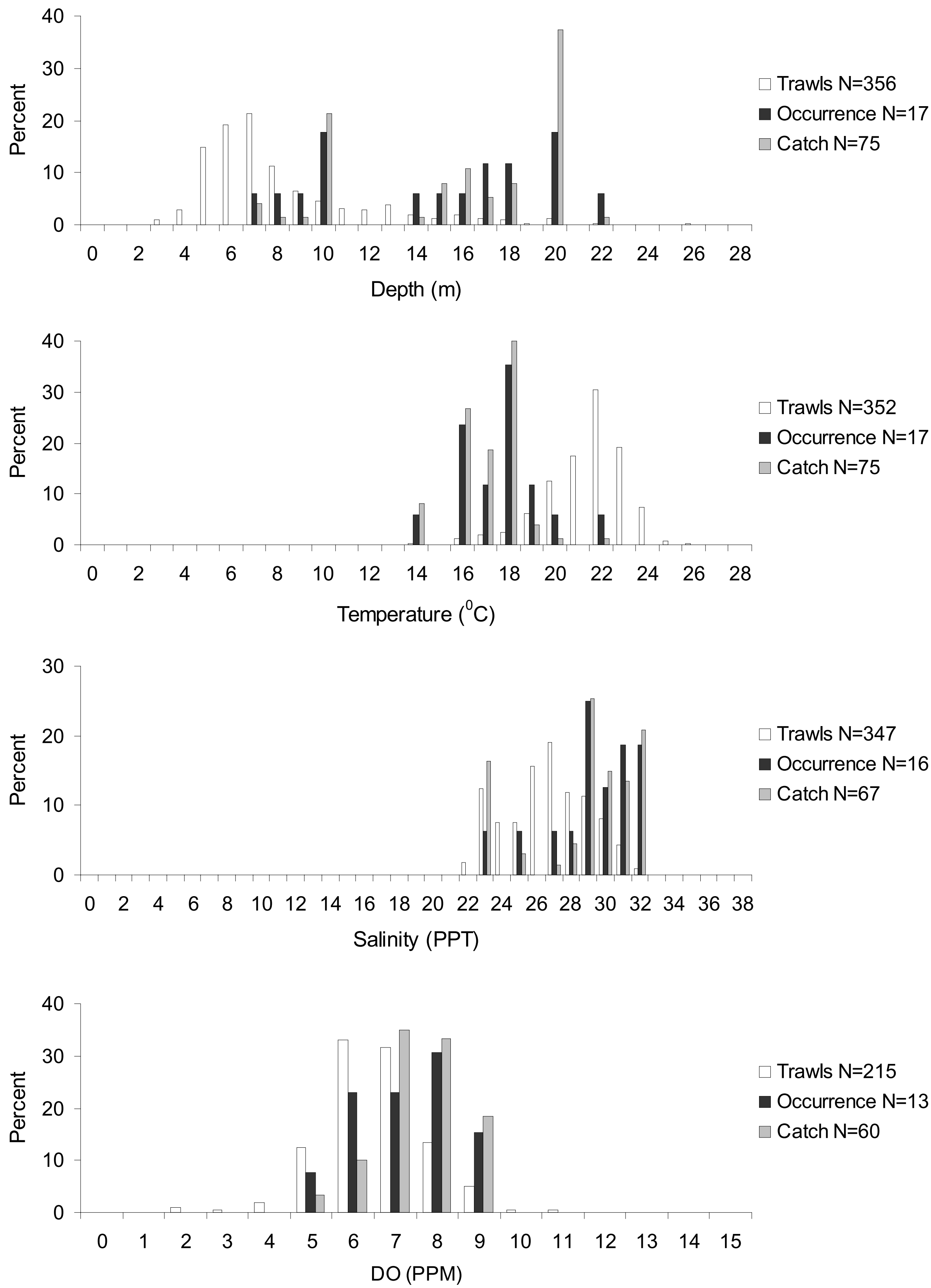
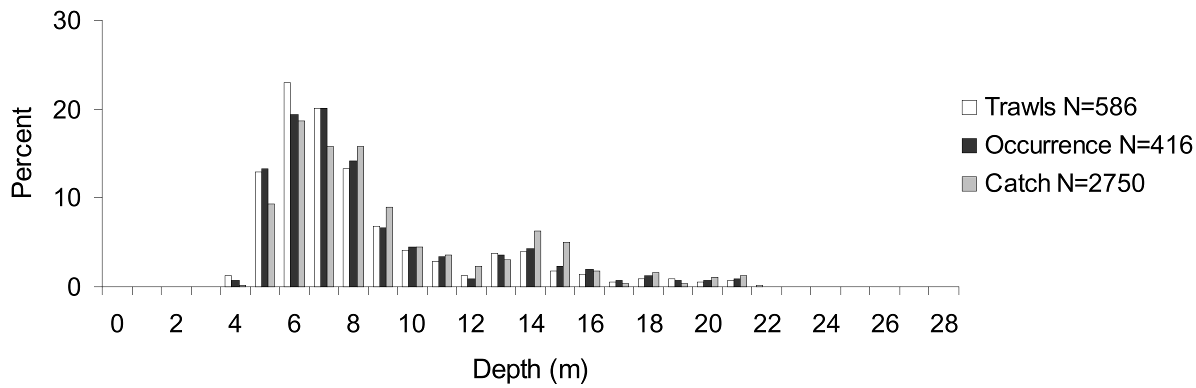
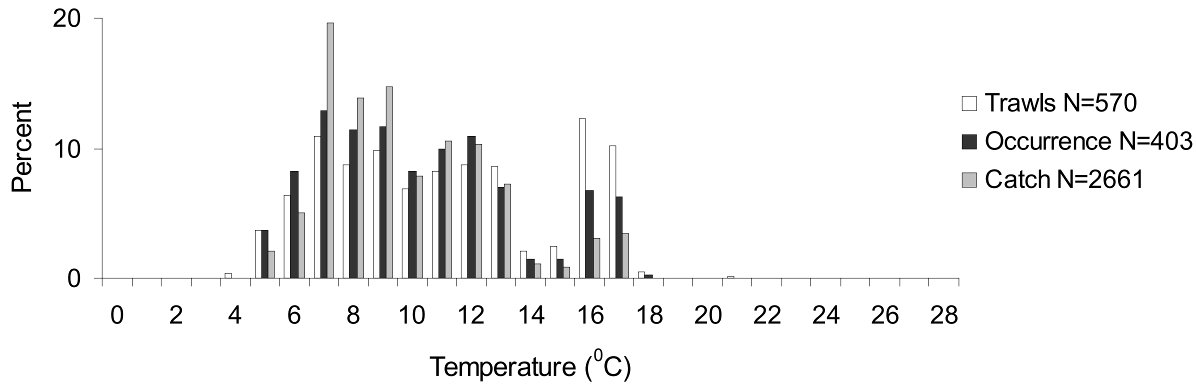
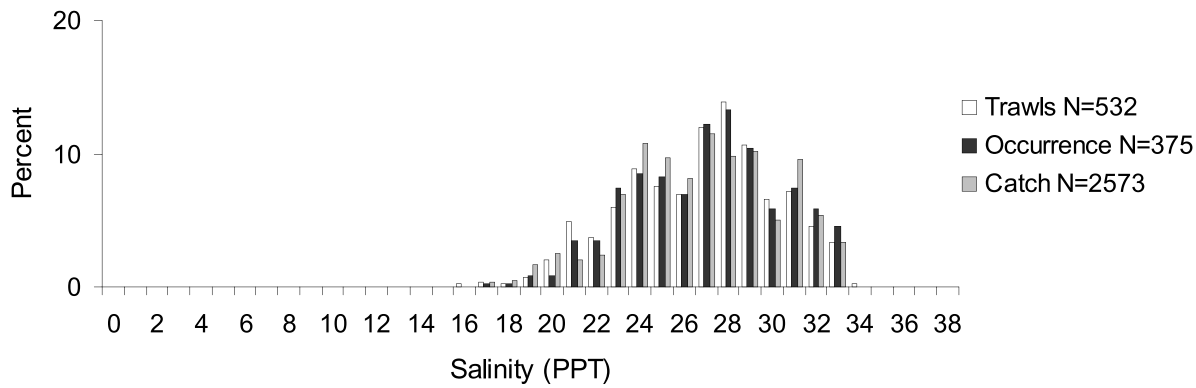


Figure 22. cont'd.

Fall







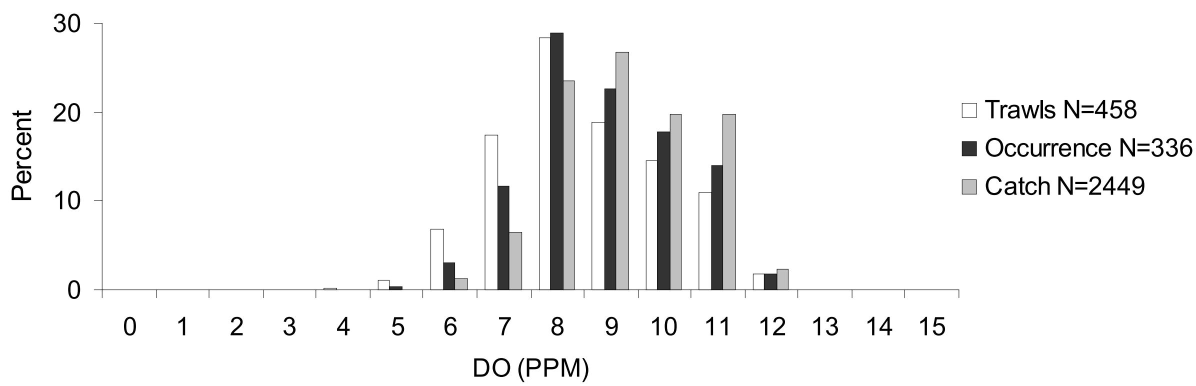


Figure 22. cont'd.

Winter

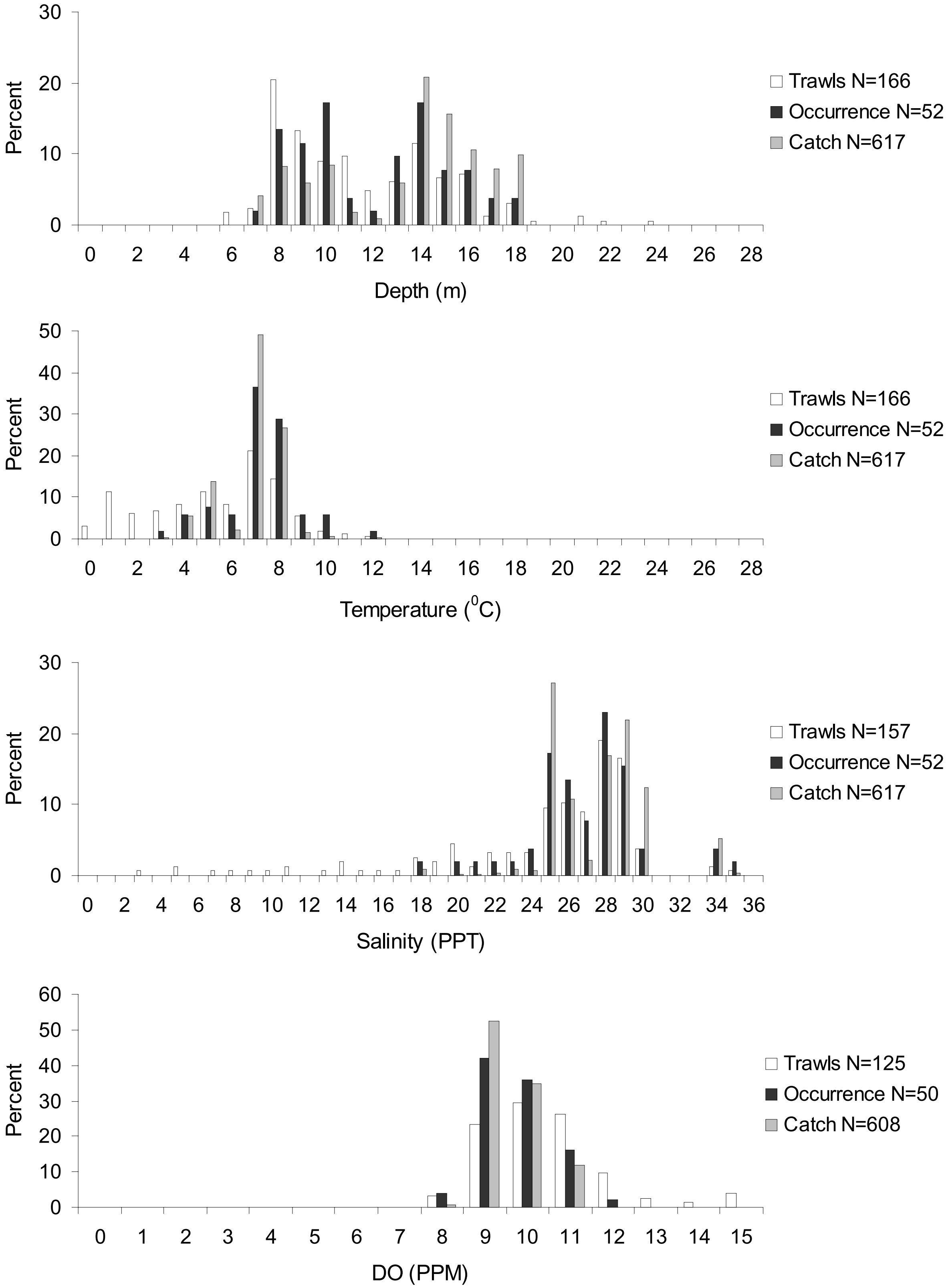


Figure 23. Seasonal distributions of juvenile and adult little skate and trawls relative to bottom water temperature, depth, salinity, and dissolved oxygen based on Delaware Division of Fish and Wildlife trawl surveys from 1966-1999 (all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which little skate occurred, and gray bars represent, within each interval, the percentage of the total number of little skate caught.

Spring

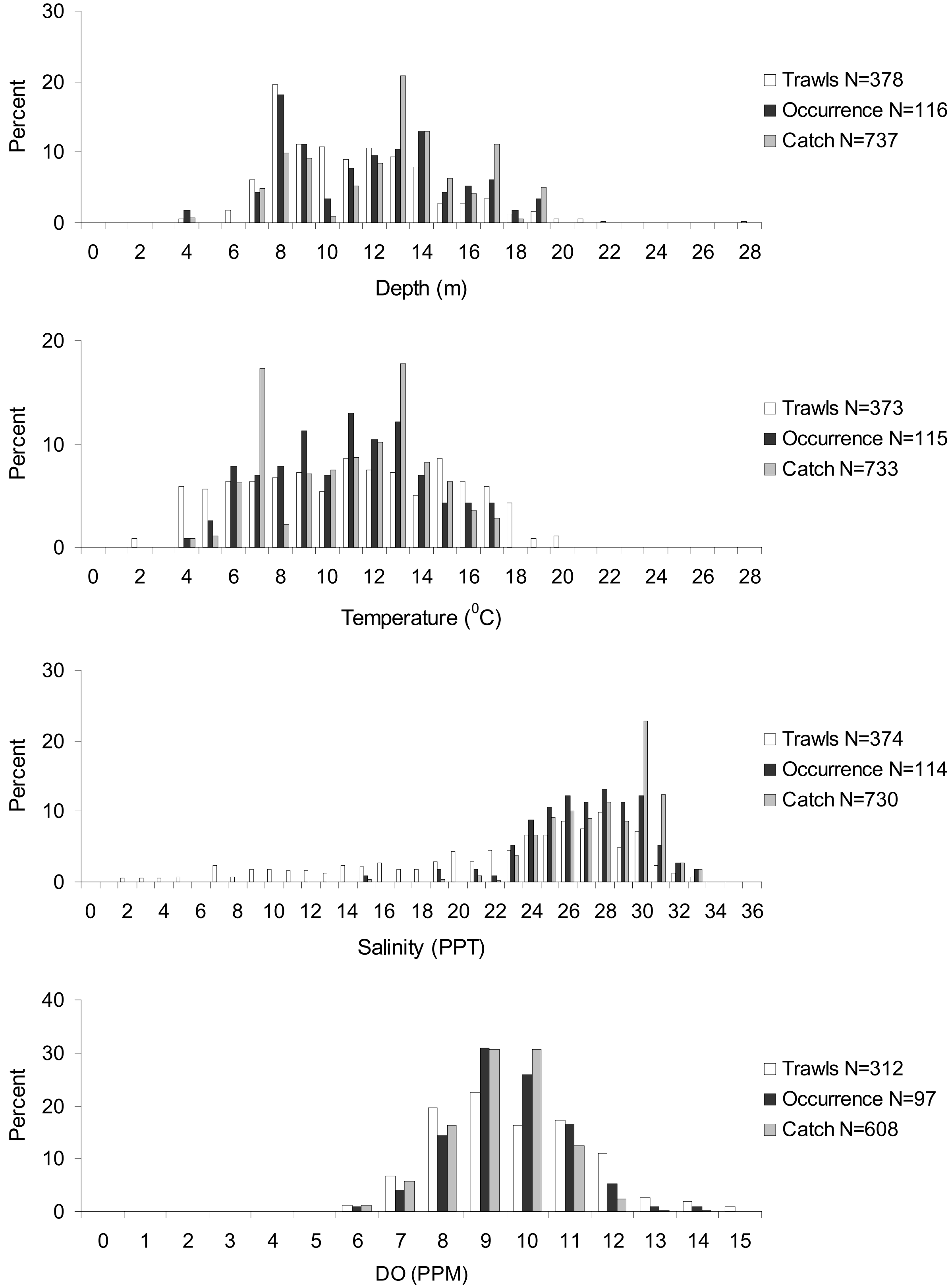
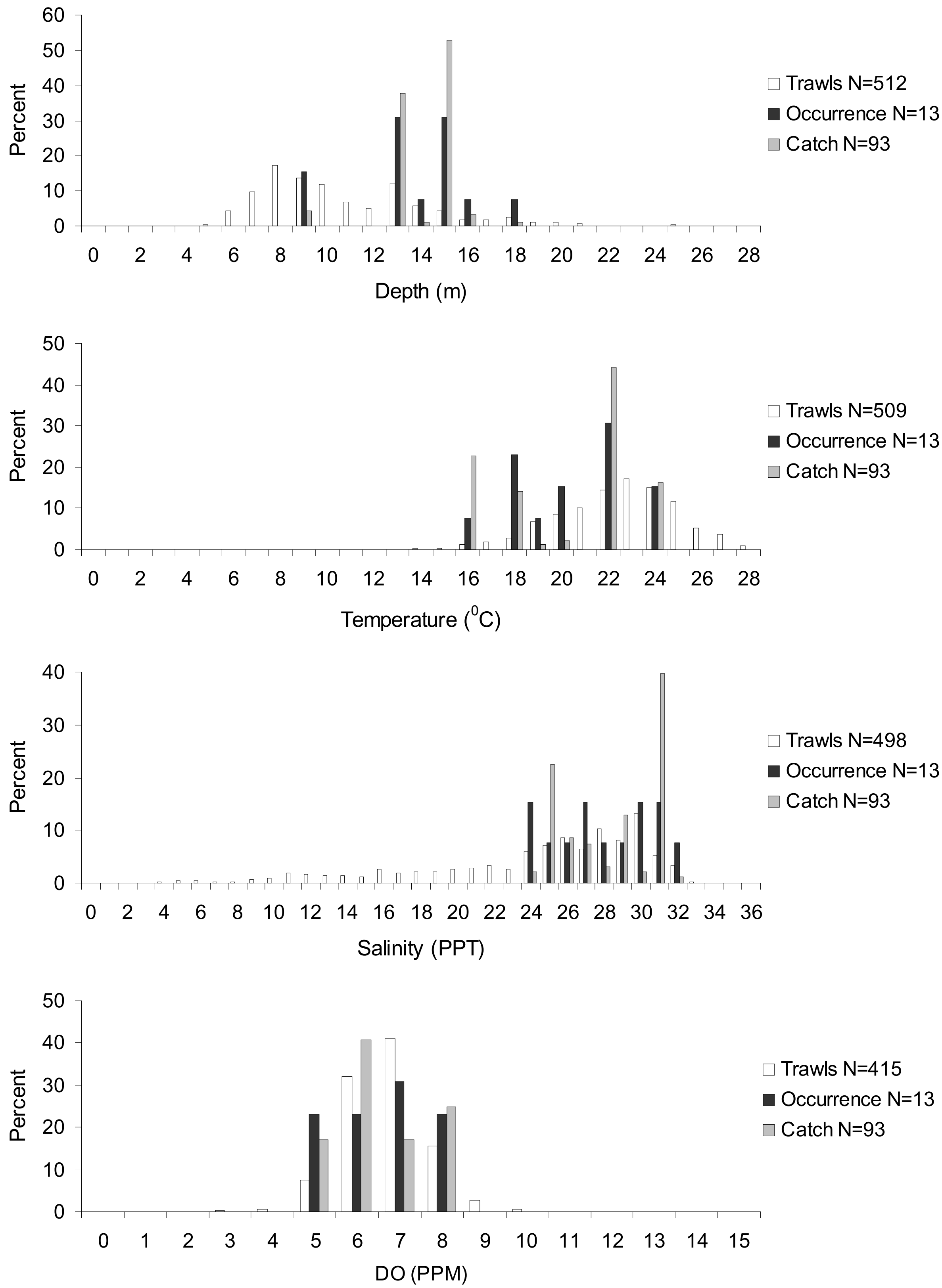


Figure 23. cont'd.

Summer



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Fall

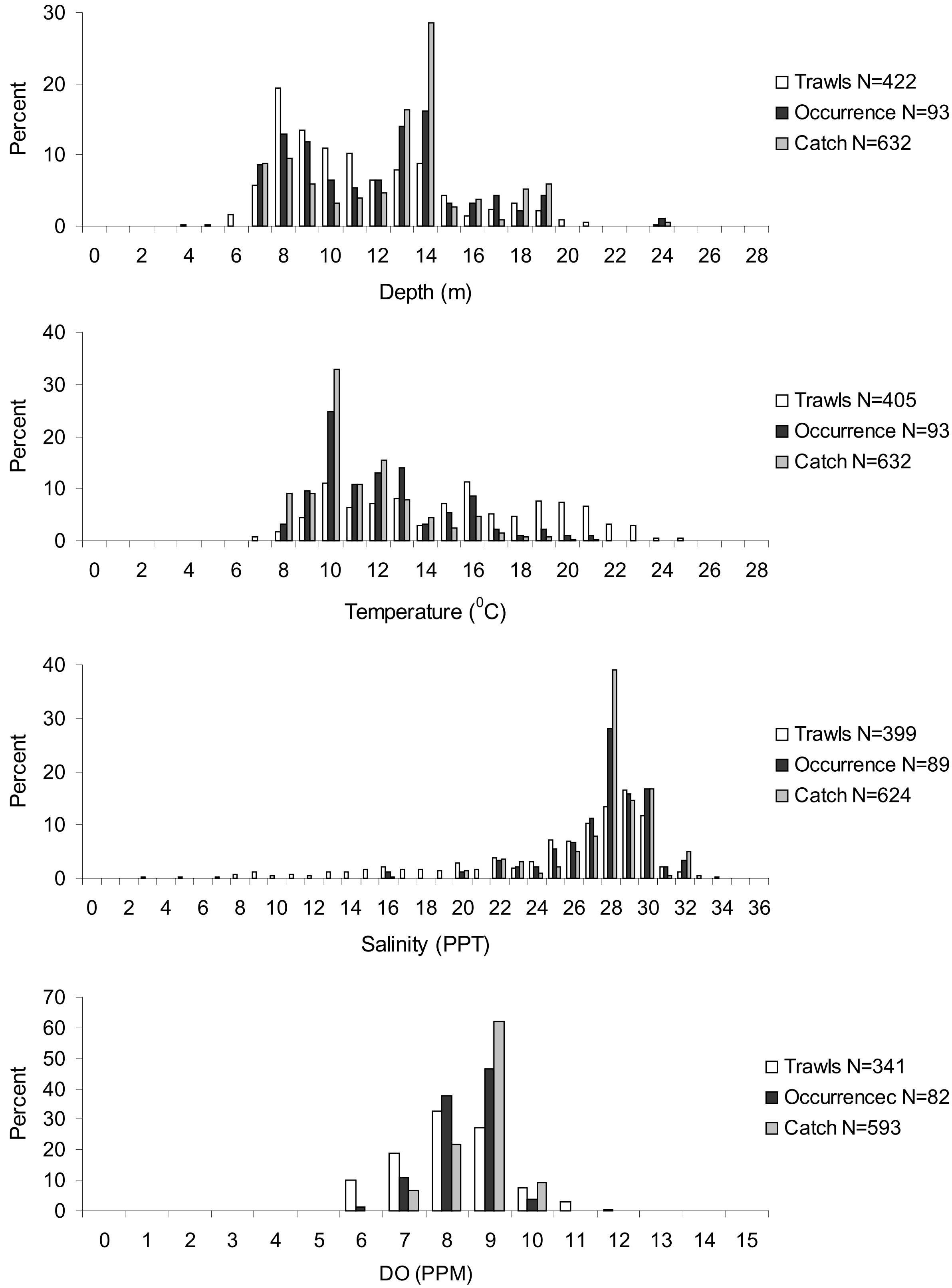


Figure 23. cont'd.

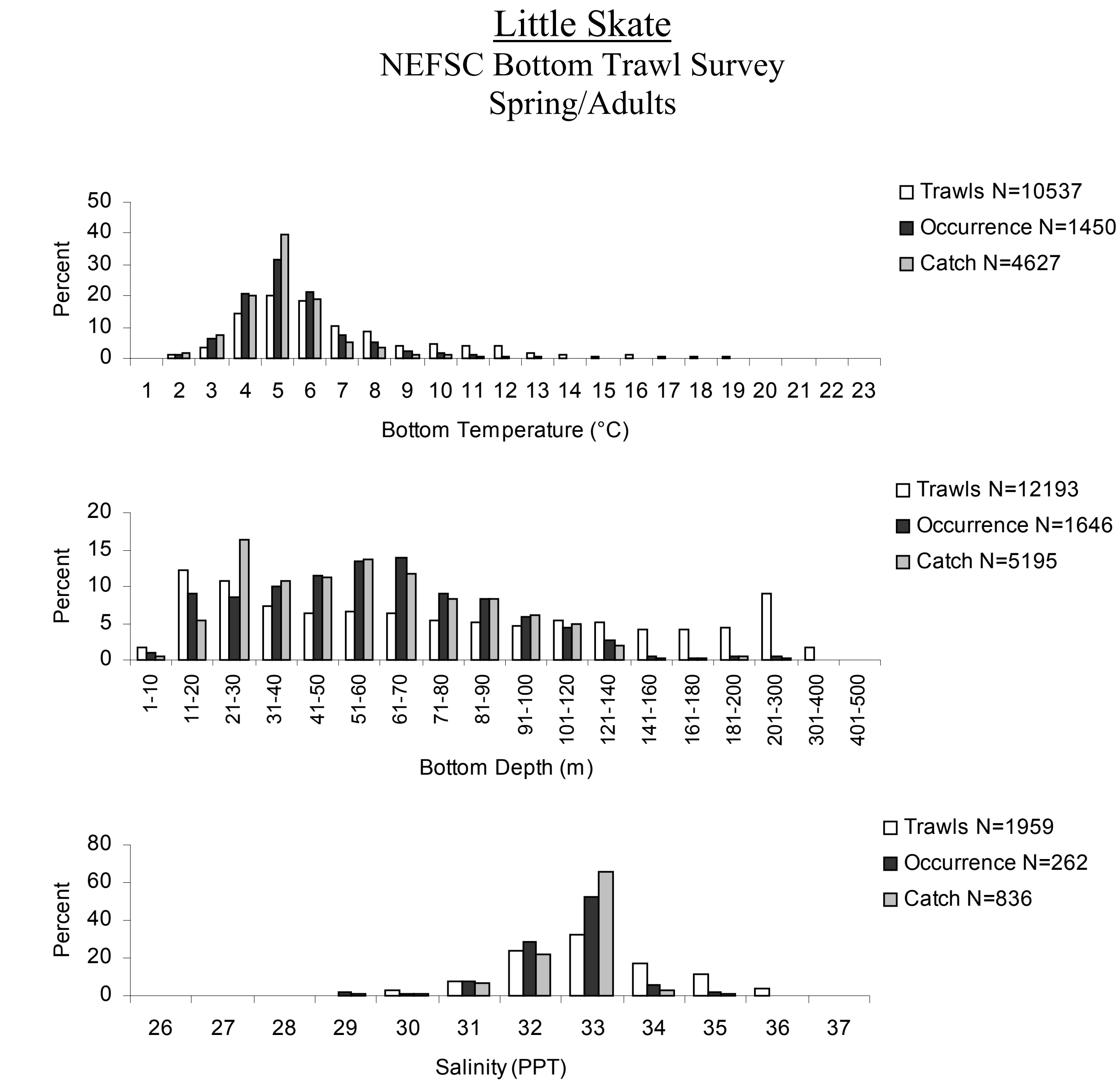


Figure 24. Spring and fall distributions of adult little skate and trawls relative to bottom water temperature and depth based on NEFSC bottom trawl surveys (1963-2002; all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which little skate occurred, and gray bars represent, within each interval, the percentage of the total number of little skate caught.

Little Skate

NEFSC Bottom Trawl Survey
Fall/Adults

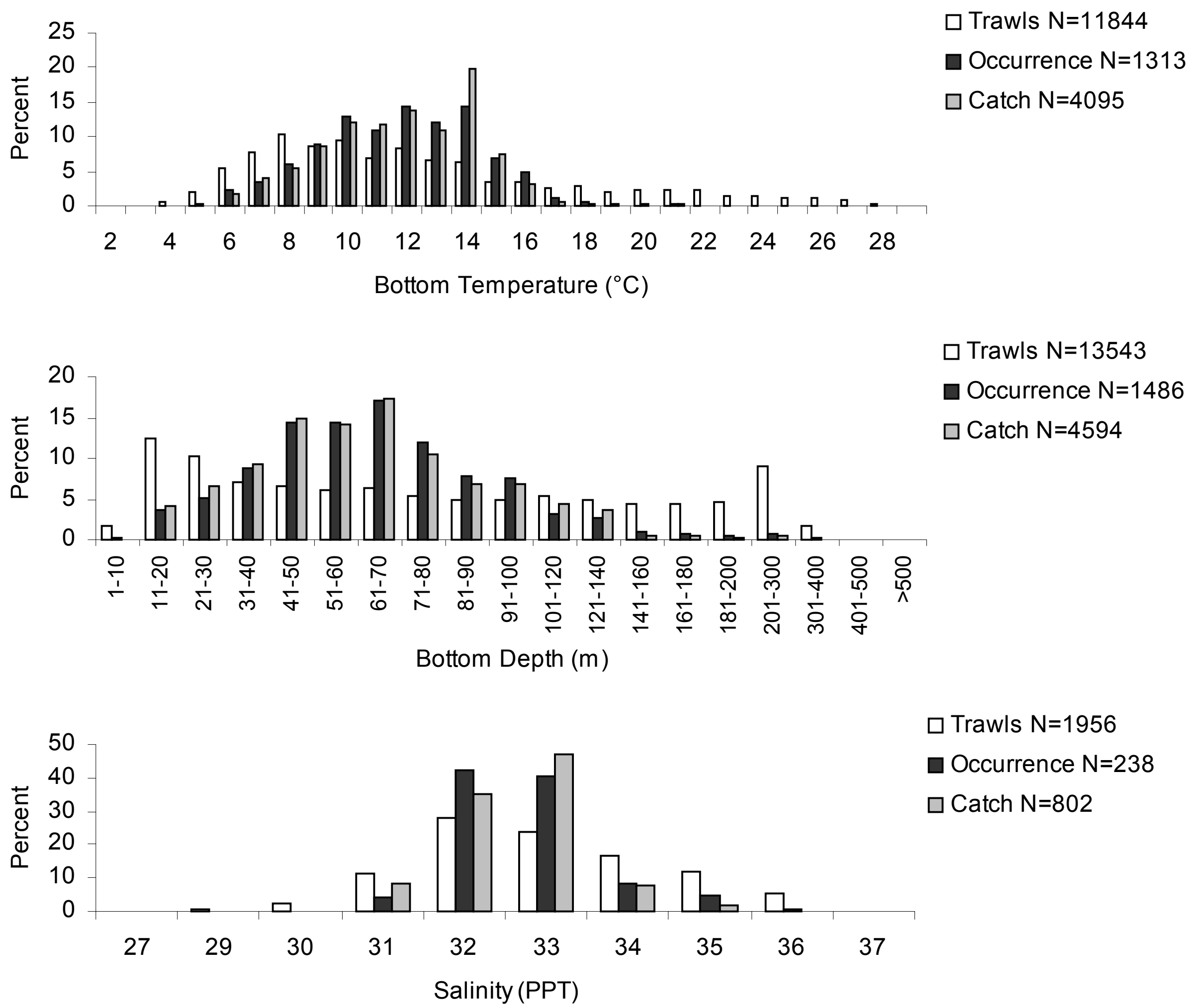


Figure 24. cont'd.

Little Skate
Massachusetts Inshore Trawl Survey
Spring/Adults

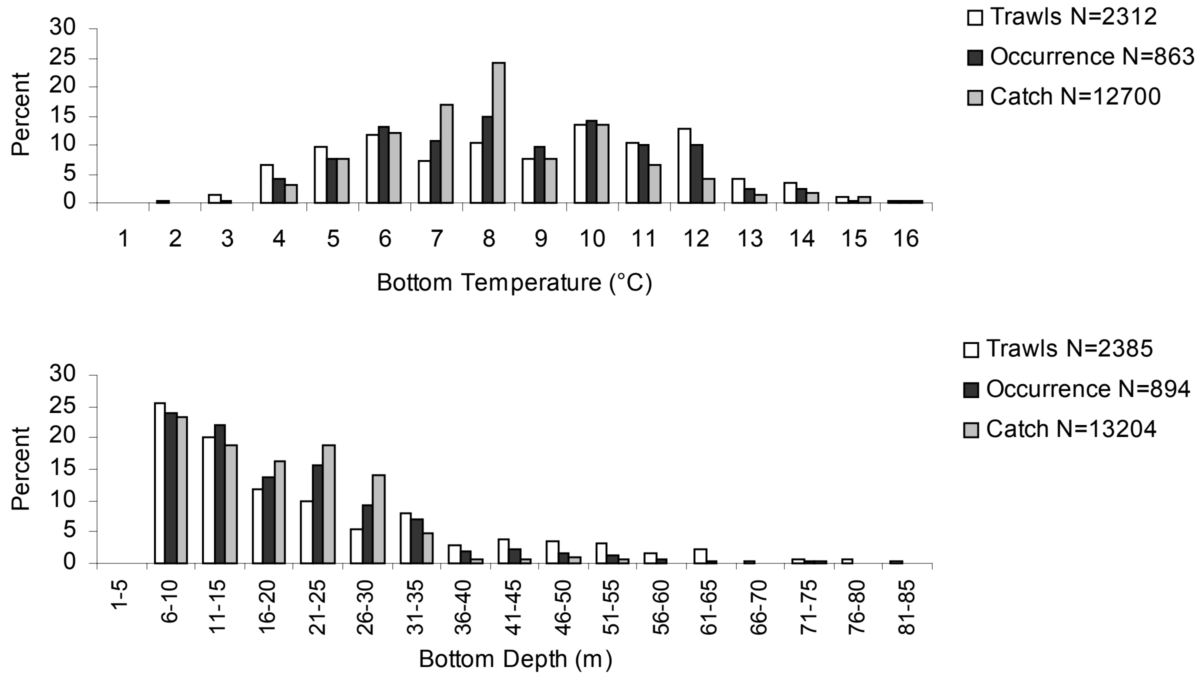
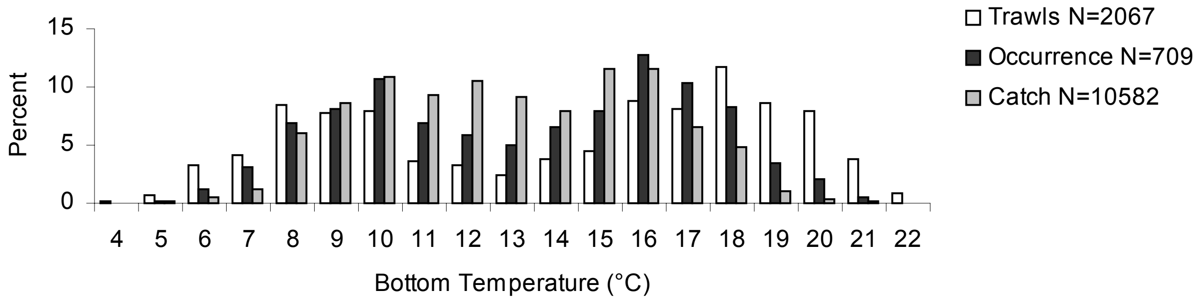


Figure 25. Spring and fall distributions of adult little skate and trawls relative to bottom water temperature and depth based on Massachusetts inshore trawl surveys (1978-2002, all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which little skate occurred, and gray bars represent, within each interval, the percentage of the total number of little skate caught.

Little Skate
Massachusetts Inshore Trawl Survey
Fall/Adults



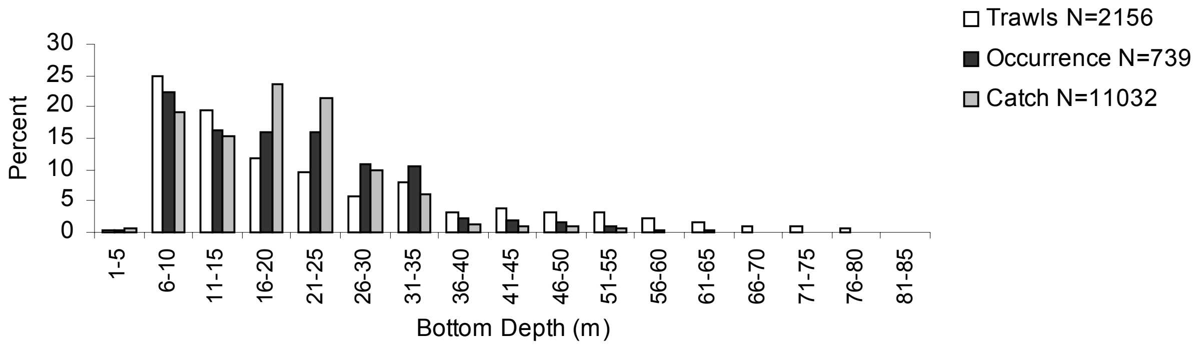


Figure 25. cont'd.

Winter

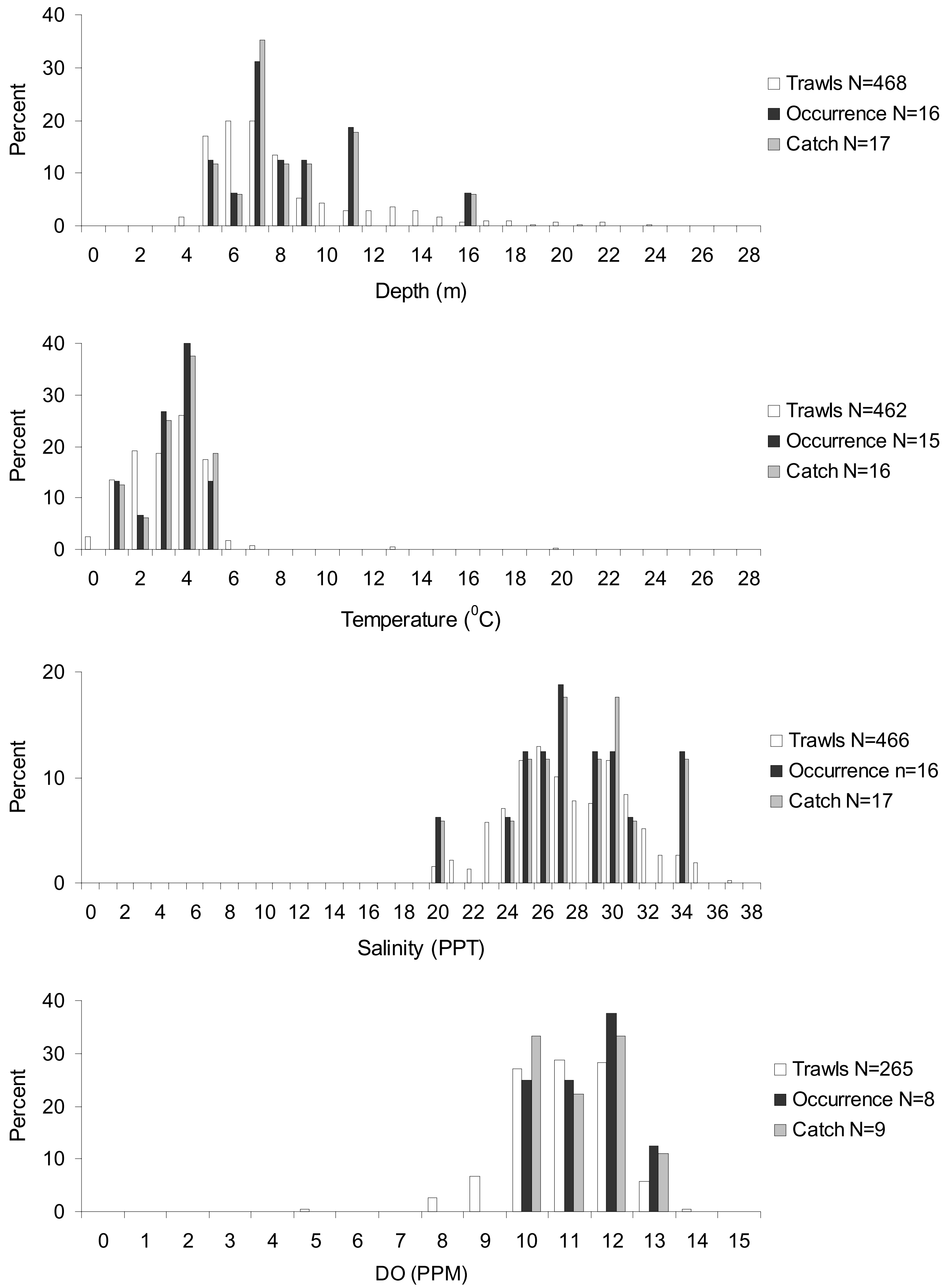


Figure 26. Seasonal distributions of adult little skate and trawls relative to bottom water temperature, depth, salinity, and dissolved oxygen based on NEFSC Hudson-Raritan estuary trawl surveys (1992-1997; all years combined). White bars give the distribution of all the trawls, black bars give the distribution of all trawls in which little skate occurred, and gray bars represent, within each interval, the percentage of the total number of little skate caught.

Spring

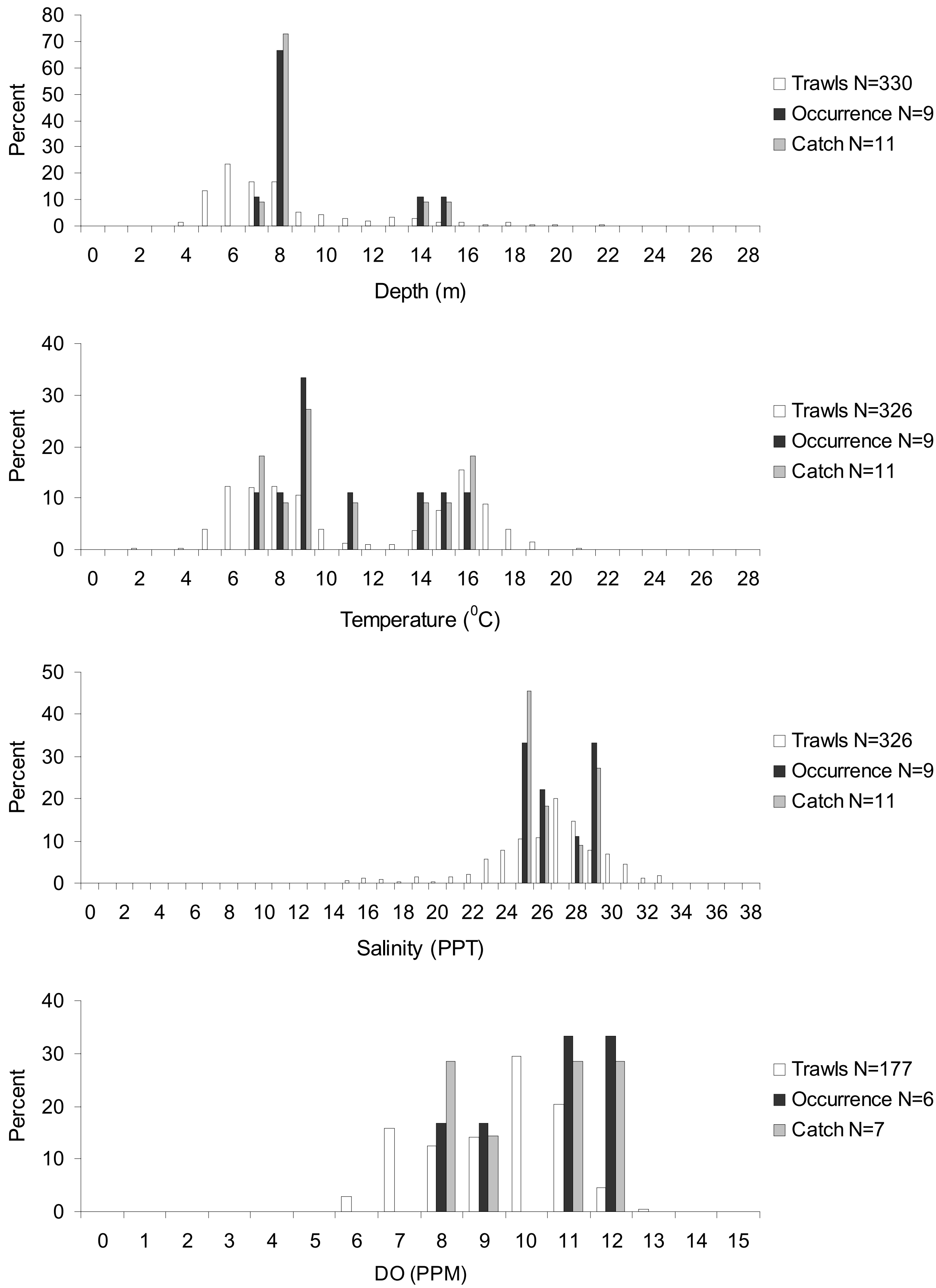


Figure 26. cont’d.

Summer

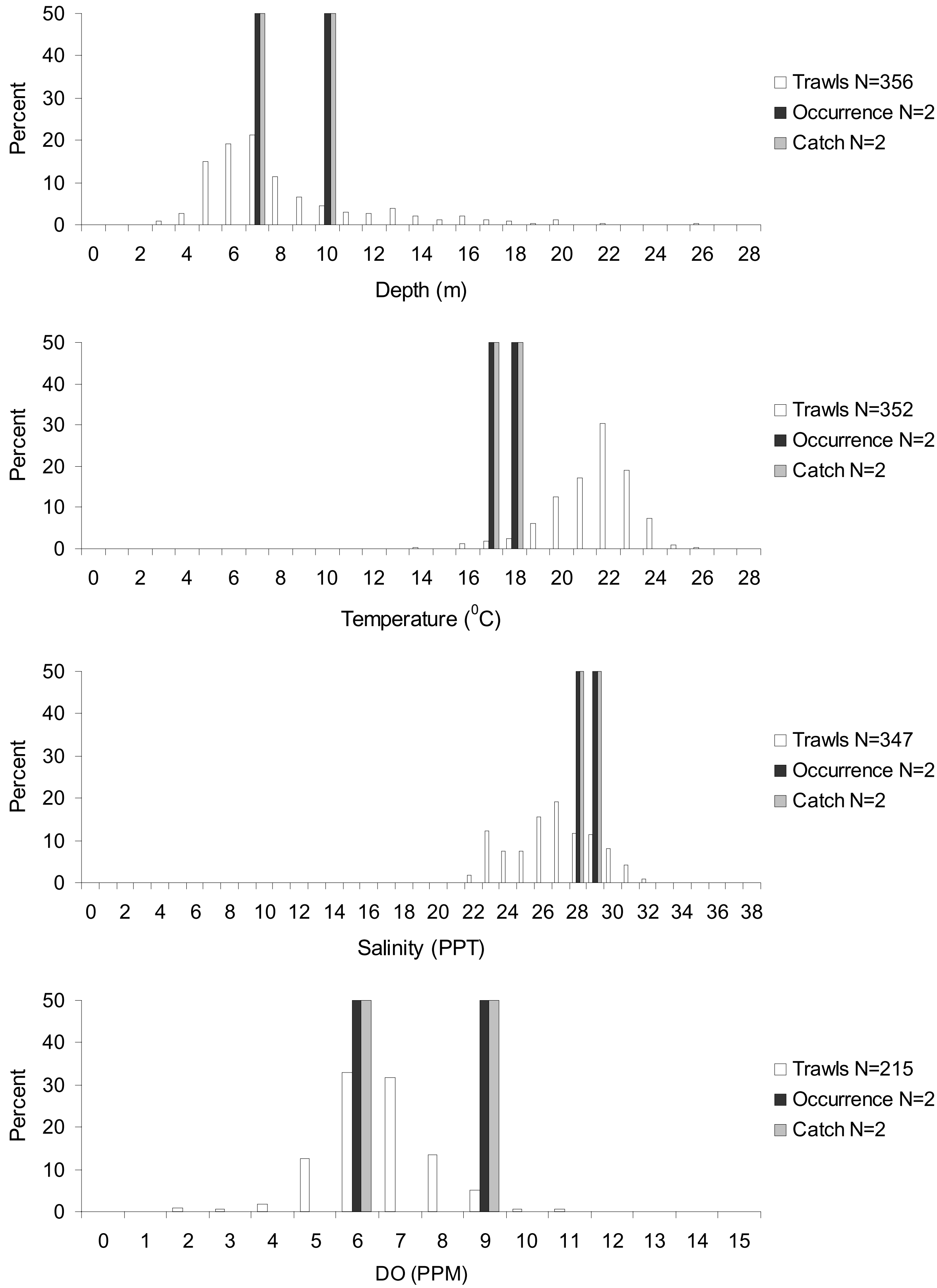


Figure 26. cont'd.

Fall

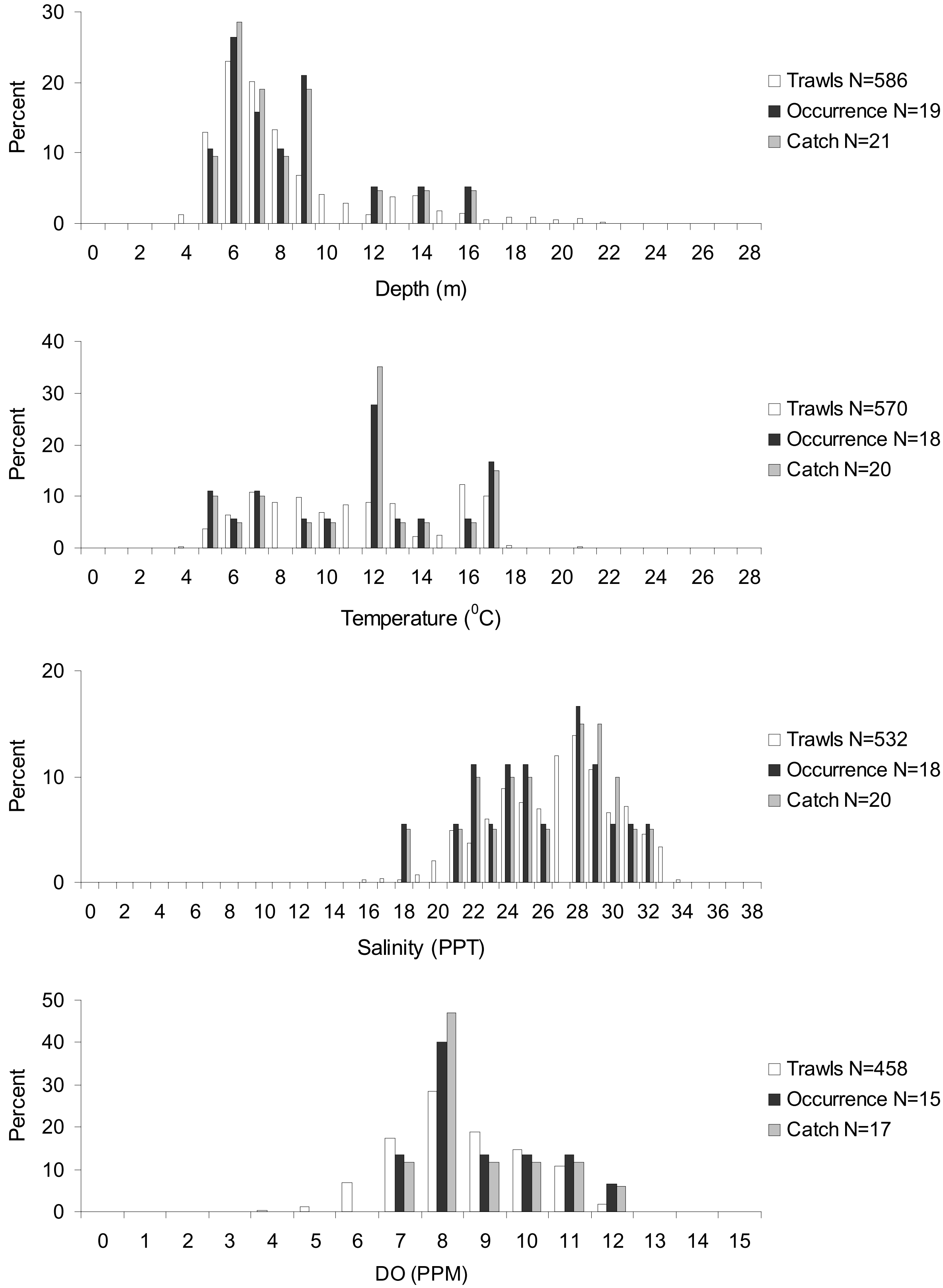


Figure 26. cont'd.

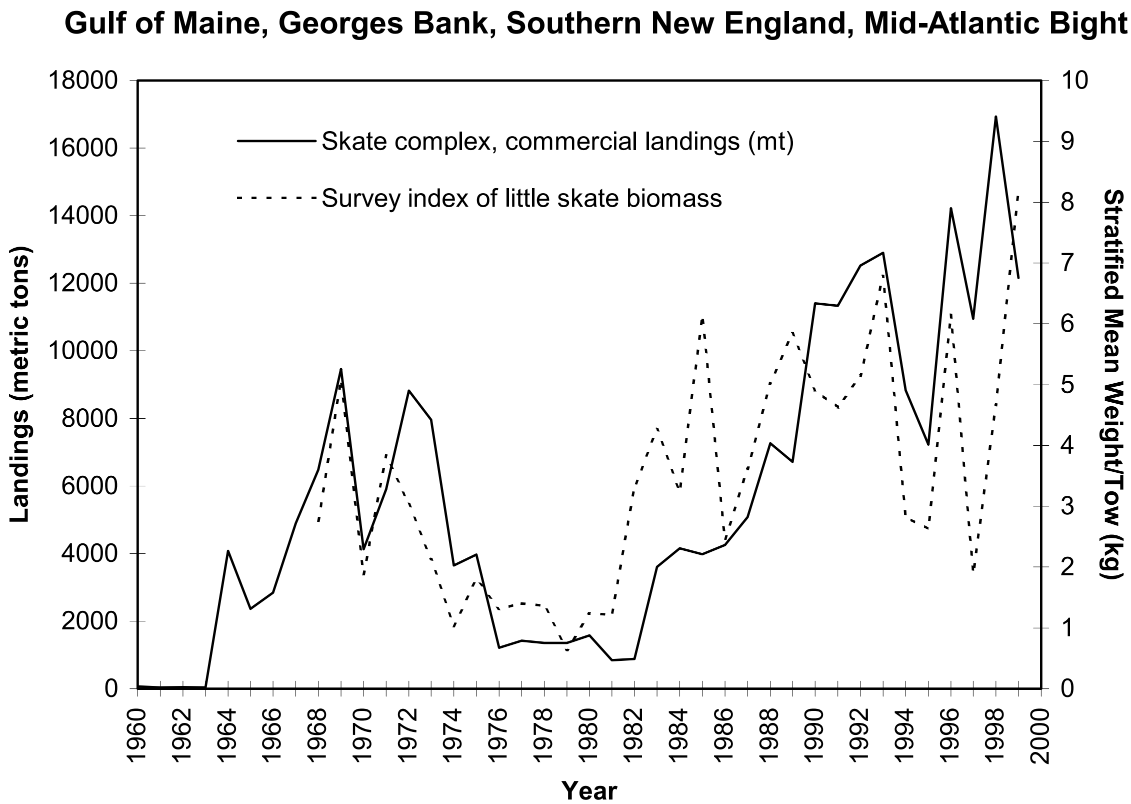


Figure 27. NEFSC spring survey index of little skate biomass and commercial landings of the seven species skate complex from the Gulf of Maine to the Mid-Atlantic Bight.

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Publications and Reports of the Northeast Fisheries Science Center

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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.

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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.

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