NOAA Technical Memorandum NMFS-NE-198

Essential Fish Habitat Source Document:

Bluefish, *Pomatomus saltatrix,* Life History and Habitat Characteristics

Second Edition

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

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Essential Fish Habitat Source Document:

Bluefish, *Pomatomus saltatrix*, Life History and Habitat Characteristics

Second Edition

Gary R. Shepherd[1] and David B. Packer[2]

Postal Addresses: [1]National Marine Fisheries Serv., 166 Water Street, Woods Hole, MA 02543-1026
[2]National Marine Fisheries Serv., 74 Magruder Rd., Highlands, NJ 07732

E-Mail Addresses: gary.shepherd@noaa.gov
dave.packer@noaa.gov

U. S. DEPARTMENT OF COMMERCE

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

Editorial Production

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

Internet Availability and Information Updating

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

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

Species Names

The NMFS Northeast Region's policy on the use of species names in all technical communications is generally to follow the American Fisheries Society's lists of scientific and common names for fishes (*i.e.*, Nelson *et al*. 2004[a]; Robins *et al.* 1991[b]), mollusks (*i.e.*, Turgeon *et al.* 1998[c]), and decapod crustaceans (*i.e.*, Williams *et al.* 1989[d]), and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals (*i.e.*, Rice 1998[e]). Exceptions to this policy occur when there are subsequent compelling revisions in the classifications of species, resulting in changes in the names of species.

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[a]Nelson, J.S.; Crossman, E.J.; Espinosa-Pérez, H.; Findley, L.T.; Gilbert, C.R.; Lea, R.N.; Williams, J.D. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico. 6th ed. *Amer. Fish. Soc. Spec. Publ.* 29; 386 p.

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

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

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

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

PREFACE TO SECOND EDITION

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

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

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

NMFS Strategic Plan for Fisheries Research (February 1998)

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

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

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

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

The initial series of EFH species source documents were published in 1999 in the *NOAA Technical Memorandum NMFS-NE* series. Updating and review of the EFH components of the councils' Fishery Management Plans is required at least every 5 years by the NOAA Fisheries Guidelines for meeting the Sustainable Fisheries Act/EFH Final Rule. The second editions of these species source documents were written to provide the updated information needed to meet these requirements. The second editions provide new information on life history, geographic distribution, and habitat requirements via recent literature, research, and fishery surveys, and incorporate updated and revised maps and graphs. This second edition of the Bluefish EFH source document is based on the original by Michael P. Fahay, Peter L. Berrien, Donna L. Johnson and Wallace W. Morse, with a foreword by Jeffrey N. Cross (Fahay *et al*. 1999).

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

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INTRODUCTION

The bluefish, *Pomatomus saltatrix* (Figure 1), ranges in the western North Atlantic from Nova Scotia and Bermuda to Argentina, but it is rare between southern Florida and northern South America (Robins *et al*. 1986). They travel in schools of like-sized individuals and undertake seasonal migrations, moving into the Middle Atlantic Bight (MAB) during spring and south or farther offshore during fall. Within the MAB they occur in large bays and estuaries as well as across the entire continental shelf. Juvenile stages have been recorded from all estuaries surveyed within the MAB, but eggs and larvae occur in oceanic waters (Able and Fahay 1998). Bluefish growth rates are fast and they may reach a length of 1.1 m (3.5 ft) and a weight of 12.3 kg (27 lbs) (Bigelow and Schroeder 1953). They live to ages 12 and greater (Salerno *et al*. 2001).

A bimodal size distribution of young-of-the-year (YOY) bluefish during the summer in the New York Bight suggests that there are two spawning events along the east coast. Recent studies suggest that spawning is a single, continuous event, but that young are lost from the middle portion resulting in the appearance of a split season. As a result of the bimodal size distribution of juveniles, young are referred to as the *spring-spawned cohort* or *summer-spawned cohort* in the habitat discussion and distribution maps presented below.

LIFE HISTORY

EGGS

Eggs from the MAB are pelagic and spherical with a diameter of 0.95-1.00 mm. They have a smooth, transparent shell and a homogeneous yolk. The single oil globule is 0.26-0.29 mm in diameter and the perivitelline space is narrow (Fahay 1983). Incubation times depend on temperature. At 18.0-22.2^{o}C, hatching occurs after 46-48 h (Deuel *et al.* 1966). Eggs from the South Atlantic Bight (SAB) have not been described.

LARVAE AND PELAGIC-JUVENILES

Larvae are 2.0-2.4 mm long when they hatch; the eyes are unpigmented and the mouth parts are undeveloped. Characteristic pigment includes parallel lines of melanophores along the dorsal fin base, body midline, and anal fin base. Teeth are well developed at 4.3 mm and fin rays are complete at a size of about 13-14 mm (Fahay 1983). Larvae rarely occur deeper in the water column than 15 m; most are concentrated at a depth of about 4 m during the day, but they are about equally distributed between that depth and the surface at night (Kendall and Naplin 1981). The bluefish transforms from a larva to a "pelagic-juvenile" stage that is specially adapted for an oceanic, near-surface existence after completion of fin ray development (Figure 2). This specialized stage is characterized by a silvery, laterally compressed body, with dark blue counter-coloration on the dorsum. This transition occurs at an age of 18-25 d and at a size of 10-12 mm SL (Hare and Cowen 1994). Scales begin to form at about 12 mm on the posterior part of the lateral line region, then proceed forward, until the head is completely scaled at about 37 mm (Silverman 1975). Swimming ability in many fish species dramatically improves during this transformation (e.g. Hunter 1981; Stobutzki and Bellwood 1994; Leis *et al.* 1996) and this improvement presumably applies to bluefish as well. It is during this stage that bluefish arrive at nursery areas in the central part of the MAB, after advection via the Gulf Stream from spawning areas in the SAB and after crossing the Slope Sea (Hare and Cowen 1996; Hare *et al.* 2001) and the continental shelf (Cowen *et al.* 1993). Active larval migration across the shelf is believed to be aided by oceanographic features such as warm-core ring streamers and Gulf-Stream filaments (Hare *et al*. 2001), or Eckman transport (Munch and Conover 2000). This transport (active or passive) is crucial to the recruitment of these progeny to vital estuarine nursery areas, and therefore this life history stage might be considered a critical bottleneck.

JUVENILES (INCLUDING YOUNG-OF-THE-YEAR

Juveniles have a usual fish shape without unusual features. The caudal fin is forked and the body is somewhat laterally compressed, with a silvery, unpatterned color. The mouth is large and oblique and all fin spines are strong. Two distinct dorsal fins touch at their bases; the second dorsal fin is about the same length as the anal fin base (Able and Fahay 1998). The *spring-spawned cohort* is 60-76 d old with a mean size of 60 mm when they recruit to estuarine habitats in the MAB in late May to mid-June (McBride and Conover 1991; Cowen *et al.* 1993). The *summer-spawned cohort* either remains in coastal nursery areas (Kendall and Walford 1979; Able and Fahay 1998; Secor *et al*. 2002; Able *et al*. 2003) or enters estuarine nurseries in mid- to late August when they are 33-47 d old with a mean length of 46 mm (McBride and Conover 1991). Juveniles of both cohorts depart MAB estuaries and coastal areas in October and migrate to waters south of Cape Hatteras, North Carolina. At this time, members of both cohorts range from 4-24 cm long (Able and

Fahay 1998, Able *et al*. 2003). During most years, the *spring-spawned cohort* dominates in the emigrating young-of-the-year, although during the past decade, the summer-spawned cohort was dominant (Conover *et al*. 2003).

ADULTS

Adult bluefish are blue-green above, silvery below, moderately stout-bodied, and armed with stout teeth along both jaws. The snout is pointed and the mouth is large and oblique. The caudal fin is large and forked. The fin ray formulae are first dorsal: 7-9 spines; second dorsal: 1 spine and 23-26 rays; anal: 2-3 spines and 25-28 rays. Vertebrae number 26. The maximum length is about 115 cm and maximum weights are 4.5-6.8 kg, although an occasional heavier fish has been taken. The maximum age is 12 years. The sex ratio is 1:1 for all age groups (Boreman 1982), although Lassiter (1962) reported a ratio of two females per male in North Carolina and Hamer (1959) found a ratio of three females to two males in New Jersey.

REPRODUCTION

A seminal study, based largely on the distribution of eggs and larvae, concluded that there were two discrete spawning events in western Atlantic bluefish. The first occurs during March-May near the edge of the continental shelf of the SAB. The second occurs between June and August in the MAB (Kendall and Walford 1979). Recent studies have re-examined this conclusion and refined our knowledge of a complex reproductive pattern, and support the concept of a single, migratory spawning stock (Hare and Cowen 1993; Smith *et al.* 1994).

Sexual maturity and gonad ripening occur in early spring off Florida, early summer off North Carolina, and late summer off New York (Hare and Cowen 1993). In the New York Bight, gonadosomatic studies indicate that both sexes are ripe or ripening between June and September with a strong peak in July (Chiarella and Conover 1990). Larvae re-occur in the SAB in the fall (Collins and Stender 1987) and there are also indications that gonads reach a second peak in ripeness in fish off Florida in September. Most bluefish are mature by age 2 (Deuel 1964). A recent study using histological methods indicates that bluefish are likely group-synchronous batch spawners (Reiss *et al*. 2002). In South Africa, individuals may spawn repeatedly over a period of 5-6 months (Van der Elst 1976), but there is no comparable information for the U.S. population.

FOOD HABITS

During their oceanic larval stage, bluefish primarily consume copepods. Fish begin to be included in their diet at sizes of 30 mm, and by 40 mm, fish are the major diet item. Soon after this shift in diet, juveniles migrate inshore to occupy estuarine habitats (Marks and Conover 1993).

The results of several studies suggest that bluefish juveniles and adults eat whatever taxa are locally abundant (Table 1). The components of young-of-the-year bluefish diet in Sandy Hook Bay, New Jersey and the effects of those components on condition were studied over a three-year period (Friedland *et al.* 1988). Fish dominated the diet during 1981, while crustaceans and polychaetes were more important during 1983 and 1984. Weight-length relationships indicated that weight at length was significantly greater in 1981 than in the other two years. Thus, not only does the quality of diet differ between estuaries, but the method of foraging may also differ; more benthic foraging was evident in bluefish from Sandy Hook Bay than in bluefish sampled in estuaries in Delaware (Grant 1962) and North Carolina (Lassiter 1962). In the Chesapeake Bay, oyster bar and reef habitats provide an important source of benthic prey, particularly during time periods when preferred small pelagic fish prey are less abundant (Harding and Mann 2001). Depending on age class, diets might change through a season. Spring spawned young-of-the-year prey on invertebrates such as small and shrimp in early summer when the preferred fish prey are less available (Juanes *et al*. 2001). In Chesapeake Bay, diets of three age classes differed through the summer (Table 1), but all three concentrated on *Brevoortia tyrannus* in the fall (Hartman and Brandt 1995a, b).

In ocean habitats, young-of-the-year bluefish switch to piscivory with increasing size, similar to estuarine habitats. By 80-100 mm FL bay anchovy become the primary fish prey along ocean beaches in New Jersey (Able *et al*. 2003). Similar dietary patterns have been observed in juvenile bluefish utilizing ocean habitat in coastal Maryland (Secor *et al*. 2002) and throughout the MAB (Table 1). During offshore residence as larger adults, bluefish target larger schooling species of prey such as squids, clupeids and butterfish (Table 1) (Buckel *et al*. 1999).

PREDATION

Sharks, tunas, and billfishes are the only predators large and fast enough to prey on adult bluefish. They are a major component in the diet of shortfin mako shark, composing 77.5% of the diet by volume (Stillwell and Kohler 1982; Wood 2002). Stillwell and

Kohler (1982) estimated that this shark may consume between 4.3 and 14.5% of the bluefish resource between Georges Bank and Cape Hatteras. Bluefish also ranked fourth in number and occurrence and third in volume in swordfish diets, especially off the Carolinas (Stillwell and Kohler 1985). A study of bluefin tuna diet in New England ranked bluefish as one of the top prey items (Chase 2002). Blue sharks and sandbar sharks also prey on bluefish (Kohler 1988; Medved *et al.* 1985). Young-of-the-year are preyed upon by four oceanic bird species, the Atlantic puffin, Arctic tern, common tern, and roseate tern (Creaser and Perkins 1994; Safina *et al.* 1990). Cannibalism has only rarely been reported, but occurs in age 1 and older year classes in North Carolina (Lassiter 1962), and bluefish compose a minor component of the diet of larger bluefish collected during Northeast Fisheries Science Center (NEFSC) bottom trawl surveys on the continental shelf from the Gulf of Maine to Cape Hatteras [NEFSC food habits database; see Link and Almeida (2000) for details on methodology].

MIGRATIONS

Bluefish are warm water migrants and do not occur in MAB waters at temperatures < 14-16°C (Bigelow and Schroeder 1953). They generally move north in spring-summer to centers of abundance in the New York Bight and southern New England and south in autumn-winter to the waters in the SAB as far as southeastern Florida. There is a trend for larger individuals to occur farther north during the summer (Wilk 1977). Larger adults may limit their southward migration and spend the winter on the outer part of the continental shelf of the MAB, culminating in an aggregation of fish near Cape Hatteras, NC by March. This winter distribution is suggested by the occurrence of bluefish in commercial catches as reported in vessel logbooks (Shepherd *et al*., in press). This conclusion is also supported by historical anecdotal evidence. One report witnessed a single fish landed from about 100 m deep off Martha's Vineyard during mid-January 1950 and several hauls of 80-640 kg from the vicinity of Hudson Canyon during early February of the same year (Bigelow and Schroeder 1953). Another study simply reported "boats engaged in the winter trawl fishery for fluke and scup along the outer margin of the continental shelf often bring in a few bluefish" (Hamer 1959). These reports have been perpetuated since (Lund 1961; Miller 1969; Lund and Maltezos 1970; Hardy 1978). Recent winter trawl surveys indicate the presence of bluefish in the MAB during winter near the shelf edge off Cape Hatteras (see Geographical Distribution).

STOCK STRUCTURE

The bluefish is presently managed as a single stock (MAFMC 1997). Although there is evidence of separate spawning events (see Reproduction), fish from these spawning groups mix extensively during their lives, and recent conclusions have ascertained that bluefish year classes are composed of seasonal cohorts (Chiarella and Conover 1990). Recent studies have re-examined this conclusion and refined our knowledge of a complex reproductive pattern, supporting the concept of a single, migratory spawning stock (Hare and Cowen 1993; Smith *et al.* 1994). A mitochondrial DNA study of *spring-* and *summer-spawned* bluefish also concluded that bluefish along the east coast of the United States comprise a single genetic stock (Graves *et al.* 1992).

GEOGRAPHICAL DISTRIBUTION

EGGS

Spring-spawned cohort: The spring spawning occurs near the edge of the continental shelf in the SAB. However, bluefish eggs have not been collected or identified from this region.

Summer-spawned cohort: Eggs were collected from May to August over the MAB continental shelf during the NEFSC Marine Resources Monitoring, Assessment and Prediction (MARMAP) program surveys [see Reid *et al*. (1999) for methods]. Bluefish eggs were most abundant in July (Figure 3). Eggs were distributed near Cape Hatteras in May and their occurrences expanded rapidly northward during the summer. In July, eggs were distributed as far as southern New England waters with a center of abundance off Delaware Bay and New Jersey (Berrien and Sibunka 1999). Eggs were not collected after August. Bluefish eggs do not occur in estuarine waters. During the NEFSC MARMAP surveys, eggs occurred across the entire shelf, but were most concentrated in mid-shelf depths (Berrien and Sibunka 1999). Eggs in the southern part of the MAB may be advected south and offshore; most (80%) eggs collected in a study off the Chesapeake Bay mouth were > 55 km from shore, with peak spawning occurring in the evening (Norcross *et al.* 1974).

LARVAE

The distribution of all larvae collected in the MAB and SAB is shown in Figure 4. There has been a critical lack of sampling in the area immediately south of Cape Hatteras.

Spring-spawned cohort: Our understanding of the distribution of larvae in the SAB (corresponding to the *spring-spawned cohort*) is limited. The NEFSC MARMAP ichthyoplankton program sampled there from 1973-1980; bluefish larvae generally were collected in low densities, both in water column sampling with bongo nets (Figure 5) or Isaacs-Kidd midwater trawls (Table 2), and at the surface with two types of neuston net (Figure 6). Most larvae occurred near the 200 m depth contour, placing them close to the Gulf Stream and presumably enhancing their chances of advection to the north as proposed by Kendall and Walford (1979), Powles (1981), and Hare and Cowen (1993, 1996). The collection of bluefish eggs in April and May is consistent with back-calculated birth dates determined from estuarine recruits in the New York Bight (NYB) (see Juveniles). The densest concentrations of larvae in NEFSC MARMAP cruises in the SAB occurred over the outer half of the continental shelf during April and May. Currents there flow toward the northeast and are affected by the Gulf Stream (Lee and Atkinson 1983), while on the inner shelf, wind-driven currents are important in affecting the drift of larvae (Powles 1981; Lee and Atkinson 1983). A secondary concentration of larvae was detected during late summer/early fall of one year (1976) and may indicate the existence of an isolated spawning event (Figure 5). During 1979, all sampling was done by Isaacs-Kidd midwater trawl and was restricted to the shelf area near Charleston, South Carolina between February and August (Table 2). Larvae were collected with this gear in low densities between February and mid-May; two tows in April yielded somewhat higher densities.

Summer-spawned cohort: The distribution of larvae in the MAB is similar to that of the eggs (Figure 7). Larvae < 11 mm (the size when they become pelagic-juveniles) first occurred near Cape Hatteras and along the shelf edge in the Wilmington Canyon area during May, and were present through the summer in increasing numbers throughout the southern and central parts of the MAB. Although larvae are only rarely collected in estuarine waters, they have been reported from a few large systems in the MAB; e.g., one larva, one occurrence in Narragansett Bay (Herman 1963) and several estuaries in New York/New Jersey (Table 3). During June, peak larval abundance occured between Cape Hatteras and Chesapeake Bay and off New Jersey. Larvae are most dense in the central part of the MAB in July and remain dense during August. Few larvae occurred in the MAB during September. Larvae rarely occurred deeper in the water column than 15 m and most are concentrated at a depth of about 4 m during the day, but are about equally distributed between that depth and the surface at night. Neuston sampling, therefore, is likely to drastically undersample bluefish when done during the day.

PELAGIC-JUVENILES (LARVAL TO JUVENILE TRANSITION)

There are no available data that adequately describe the distribution of this transformation stage in bluefish life history; however, limited observations have been made in the NYB (Shima 1989; Hare and Cowen 1996). These observations support the view that temperatures below 13-15°C impede the progress of this stage into MAB estuaries. In early June, these pelagic-juveniles mass at the shelf-slope temperature front, and resume their inshore migration when that front dissipates (Hare and Cowen 1996). Transport of larvae and/or juveniles across the shelf-slope region may be aided by wind-driven surface flow (Munch and Conover 2000).

JUVENILES

It is presently unknown if bluefish are "estuarine dependant" since the distribution of juveniles over the continental shelf has not been described. The distribution and relative abundance of juveniles has been documented for estuaries along the east coast of the United States (Table 3) and for estuaries in Maine (Table 4). In addition to estuaries, juvenile bluefish in the MAB utilize coastal oceanic habitats (Secor *et al*. 2002; Able *et al*. 2003).

A survey of juvenile bluefish published in the early 1970s (Clark 1973) noted that their distribution differed from historical observations (Figure 8). Bluefish were not observed south of Daytona Beach through the 1970s, although juveniles were reported from estuaries as far south as Palm Beach, Florida in the early part of the century (Evermann and Bean 1898; Nichols 1913). This author also suggested that the apparent high densities of juveniles in certain regions (e.g., New Jersey and South Carolina) were due to greater sampling effort. Remaining enigmatic occurrences include those in the freshwaters of the upper Chesapeake Bay (Mansueti 1955; Lund 1961), although the Chesapeake and Delaware Canal may play a role in their presence there.

Several young-of-the-year surveys (or surveys that adequately sample young stages) are conducted within MAB states (Figure 9). Several caveats pertaining to these results prevent these state data from being compared directly. Some surveys are conducted throughout the year, while others are limited in their seasonal extent, and the resultant densities are therefore unequal. Although most results are expressed as "number per tow," tow lengths and gear characteristics vary between states, thus making comparisons among state surveys difficult. Finally, the definition of "juvenile" can vary between states; in some cases, it is based solely on length frequency distributions, in some cases it is based on an arbitrary length cutoff. In most states, all fish < 30 cm are considered juveniles, although in the Chesapeake Bay region, some of these could be age 1+ if they were collected early in the year (Munch 1997).

Despite these caveats, certain trends are evident in the data. There are signs of strong year classes in each state data set, but these do not necessarily match temporally. In general, abundances are greater in states between Rhode Island and New Jersey, and considerably lower in states in the southern part of the MAB, further emphasizing the importance of the former.

The distributions and abundances of juveniles in Massachusetts coastal waters, based upon the fall 1978-2003 Massachusetts inshore trawl surveys, are shown in Figure 10 (none were found during the spring surveys). They were abundant south of Cape Cod, especially in Buzzards Bay.

The seasonal distributions and abundances of juveniles (< 35 cm) in Narragansett Bay, based upon the 1990-1996 Rhode Island bottom trawl surveys, are shown in Figures 11 and 12. Juveniles were collected in summer and autumn.

The distributions and abundances of both juvenile and adult bluefish in Long Island Sound from April to November 1984-1994, based on the Connecticut Fisheries Division bottom trawl surveys, are shown in Figures 13–19. The following description of bluefish distribution and abundance in Long Island Sound comes from Gottschall *et al*. (2000).

Bluefish first appeared in the survey in May (7% occurrence), but were relatively rare until June when the occurred in 28% of samples (Figure 13D) and were taken throughout the Sound (Figure 14). Bluefish taken in May ranged from 40-76 cm, whereas in June they ranged from 24-78 cm (Figure 15) (Gottschall *et al*. 2000).

Juveniles first appeared in the survey in July. They comprised 46% of the bluefish catch, but only appeared in 8.3% of samples (Figure 16D). Juvenile abundance increased quickly during summer – by August they comprised 94% of the catch and occurred in 63.1% of samples. During the summer period juveniles were primarily distributed on the Connecticut side of the Sound from New Haven to Norwalk (Figure 17), whereas adults appeared to be more abundant in the deeper portions of the Central and Western Basins (Figure 18 and 19C) (Gottschall *et al*. 2000). When abundance peaked in September (Figure 13A), bluefish were found throughout the Sound (93.3% occurrence), although about 93% of the bluefish taken were juveniles. While juvenile abundance decreased rapidly after September (Figure 19A), adult abundance increased to a peak in October before declining (Figure 19A). By November, juveniles only comprised 60% of the bluefish catch, down from a high of 94% in September. The remaining bluefish in November were distributed throughout the Sound (Figure 14) (Gottschall *et al*. 2000).

Most bluefish collected during surveys of the Hudson-Raritan estuary (1992-1997) were juveniles (Figure 20). There were no occurrences during winter, while in summer and fall, juveniles occurred throughout the area. The largest collections were made near navigation channels or in a basin near Graves End Bay.

The New Jersey Department of Environmental Protection assessment survey samples coastal New Jersey inside state waters. Bottom trawling is conducted five times per year and bluefish are encountered primarily in August and October. The fish collected are juveniles and appear as two distinct length modes, presumably the result of the spring and summer cohorts.

The Virginia Institute of Marine Science (VIMS) trawl surveys from 1988-1999 of Chesapeake Bay and its tributaries captured almost exclusively juveniles (Geer 2002). They were caught from May to November, with an increase in catch during October and November as juveniles began to migrate out of the Bay (Figure 21). Catches were concentrated in the main-stem of the Bay with some catches up the tributaries to near the freshwater interface (Figure 22). There was a clear southward movement towards the Bay mouth during the fall months (Figure 22) (Geer 2002).

The VIMS 1994-1999 beach seine surveys of Chesapeake Bay captured only juveniles during every month of sampling (May to October), with June and September being the peak months (Figure 23). Juveniles were captured throughout the brackish range of the survey, with highest catches occurring at the seaside sites and Bay mouth (Figure 24) (Brooks and Geer 2001; Geer 2002).

The Southeast Area Monitoring and Assessment Program (SEAMAP) surveys sampled the coastal region between Cape Hatteras, North Carolina and Cape Canaveral, Florida [see Reid *et al.* (1999) for details]. After an initial several years when gear and methods were not standardized, methodology became synoptic and standardized between 1990 and 1996 (Beatty and Boylan 1997; Boylan *et al.* 1998). Bluefish collected during the latter survey period are shown in Figure 25. Length frequencies of these collections indicate most were young-of-the-year or age 1 (Figure 26). Information on distributions over the offshore portions of the SAB shelf are lacking for any size class. Monthly occurrences of these bluefish are shown in Figure 27. Occurrences decreased during spring, were at low levels during summer, and increased during October beginning in the northern part of the bight, which suggests an influx of migrating young-of-the-year from the MAB.

ADULTS

The distributions and abundances of adults in Massachusetts coastal waters, based upon the spring and fall 1978-2003 Massachusetts inshore trawl surveys, are shown in Figure 28. During spring, a few adults were found south of Cape Cod in the vicinity of Nantucket and Vineyard sounds and in Buzzards Bay. They were slightly more abundant in the fall; a few were also found in Cape Cod Bay.

Adults were rarely collected during summer and autumn in a survey of Narragansett Bay (Figures 29 and 12).

The distribution and abundance of both adults and juveniles in Long Island Sound were discussed previously (Gottschall *et al*. 2000).

Very few adults were collected in the Hudson-Raritan estuary and Sandy Hook Bay. There were no occurrences during winter and only a few adults were collected during spring and summer (Figure 30).

JUVENILES AND ADULTS

Bluefish are migratory and their distribution varies seasonally and according to age and size of individuals composing schools. Length frequencies of trawl-collected bluefish were examined to determine age and size composition of catches in the NEFSC bottom trawl surveys (Figure 31). Modes were separable into spawning cohorts and year classes based on published studies and are the bases for the NEFSC distribution and abundance maps.

The distribution of all lengths during all seasons of the NEFSC surveys indicates that bluefish occurred most densely along the coast of the MAB and through the central part of Georges Bank, although these results may reflect the increased efficiency of the trawl in shallower waters. Winter occurrences during the NEFSC surveys were limited to the outer continental shelf near Cape Hatteras and these few occurrences were larger fish [Figure 32; note that winter and summer distributions are presented as presence data only, precluding a discussion of abundances, see Reid *et al.* (1999) for details]). NEFSC spring collections included *spring-spawned* young-of-the-year off North Carolina, *spring-spawned* age 1 restricted to coastal areas south of Cape Hatteras, age 2 individuals along the continental shelf edge off North Carolina, and older year classes distributed between Cape Hatteras and the Delmarva Peninsula (Figure 33). Figure 34 shows the NEFSC spring distributions and abundances separated into juvenile (< 30 cm) and adult ($\geq$ 30 cm) size classes.

In summer, juveniles were widely distributed along the coast from New York to Cape Hatteras. Adults were less concentrated along the Mid-Atlantic coast, occurring mostly along Long Island, offshore south of Cape Cod, and on Georges Bank (Figure 35). NEFSC fall surveys are most important for measuring relative year-class strength. Young-of-the-year of both *spring-* and *summer-spawned cohorts* and age 1 individuals were abundant along the coast between Long Island and Cape Hatteras. Older year-classes were also found offshore in southern New England and on Georges Bank (Figure 36). Figure 37 shows the fall distributions and abundances separated into juvenile and adult size classes.

HABITAT CHARACTERISTICS

The habitat characteristics for eggs, larvae, pelagic-juveniles, juveniles, and adults based on results of this compendium and pertinent published reports are presented in Table 5. Included are observations of habitat use by young-of-the-year in estuaries. When studies of juvenile abundance have been related to environmental variables, such as eelgrass presence/absence or a substrate type, they have usually been conducted with seines where catch-per-unit-of-effort is difficult to establish. Comparing the results of these studies between locations is usually not possible, and further details of essential habitats are therefore not yet available. Appendix 1 contains more complete data from various studies reported in the literature.

EGGS

Bluefish eggs were collected at near-surface temperatures ranging from about 8-26°C during the NEFSC MARMAP surveys in the months from May to August (Figure 38). During May, 100% of the eggs were found at 22°C, while in June they were found from 13-22°C, with the majority at 13 and 17°C. In July, most were caught over a range of 14-26°C, while in August the majority of eggs were found at 22°C. Their depth range during those months was confined mostly from 30-70 m, with the majority at 30 m.

LARVAE AND PELAGIC JUVENILES

Larvae in the MAB occur in open oceanic waters, near the edge of the continental shelf in the southern Bight and over mid-shelf depths farther north (Norcross *et al.* 1974; Kendall and Walford 1979). They migrate vertically in the water column, occurring near the surface at night, but centered at about 4 m during daylight (Kendall and Naplin 1981). Larvae spawned in the SAB (*spring-spawned cohort*) are subject to advection north via the Gulf Stream (Hare and Cowen 1996; Kendall and Walford 1979), but some recruit successfully to estuaries in the SAB (Collins and Stender 1987; McBride *et al.* 1993).

During NEFSC MARMAP sampling from May to September, most larvae were collected at surface temperatures between 17-26°C and were concentrated over water depths of about 30-70 m (Figure 39).

The transport of pelagic-juveniles was outlined by Kendall and Walford (1979) and elaborated by Hare and Cowen (1996). Many are found in the vicinity of Cape Hatteras as early as April. In May, several have been collected on the shelf in the SAB (Fahay 1975; Kendall and Walford 1979). By June, they occur in the MAB between the shore and the shelf/slope front, actively crossing the shelf (Hare and Cowen 1996). In both the SAB and MAB, there is a strong negative correlation between fish size and depth indicating an offshore origin and onshore migration with growth. Transport of larvae and/or juveniles across the shelf-slope region may be aided by wind-driven surface flow (Munch and Conover 2000).

Limited observations on pelagic-juveniles by Shima (1989) and Hare and Cowen (1996) have been made in the New York Bight. These observations support the view that temperatures below 13-15°C impede the progress of this stage into MAB estuaries. In early June, these pelagic-juveniles mass at the shelf-slope temperature front, and resume their inshore migration when that front dissipates (Hare and Cowen 1996).

JUVENILES (INCLUDING YOUNG-OF-THE-YEAR)

Juveniles occur in estuaries, bays, and the coastal ocean of the MAB and SAB, where they are less common. They occur in many habitats, but do not use the marsh surface. The range of physical and structural conditions in which they are found is summarized in Table 5. Juveniles begin to depart MAB estuaries in October and migrate south to spend the winter months south of Cape Hatteras.

The spring and fall distributions of juvenile bluefish (< 30 cm) relative to bottom water temperature, depth, and salinity based on 1963-2003 NEFSC bottom trawl surveys from the Gulf of Maine to Cape Hatteras are shown in Figure 40. In the spring, they were found over a temperature range of 8-23°C, with most spread between about 10-19°C. They were found at shallow depths ranging from 1-40 m, with the majority at 1-30 m. Their salinity range was between 33-36 ppt, with a peak in occurrence and catch at 33 ppt. In the fall, the juveniles were spread over a temperature range of 10-28°C, with most between about 17-25°C. They were also found at shallow depths of 1-50 m, with > 60% found at 11-20 m. Their salinity range was between 29-35 ppt, with the majority at 31-32 ppt.

The autumn distributions of juvenile bluefish in Massachusetts coastal waters relative to bottom water temperature and depth based on 1978-2003 Massachusetts inshore trawl surveys are shown in Figure 41. Juveniles were collected at temperatures ranging from about 9-22°C, with the majority between 16-21°C. They were found over depths of 6-45 m, with most at 6-15 m.

The seasonal distributions of juvenile bluefish relative to bottom water temperature and depth based on 1990-1996 Rhode Island Narragansett Bay trawl surveys are shown in Figure 42. The few juveniles that were caught were found in waters from 19-25ºC in summer and 17-23ºC in autumn. The majority were found at 22ºC in summer and 19ºC in the autumn. In summer their depth range was from 10-70 ft (3-21 m) and in the autumn it was from about 20-110 ft (6-34 m). Most were caught at 20-30 (6-9 m) in summer and 20-50 ft (6-15 m) in the autumn.

The distributions and abundances of juveniles in Long Island Sound relative to depth and bottom type, based on the Connecticut Fisheries Division bottom trawl surveys (Gottschall *et al*. 2000), are shown in Figures 13, 16, and 19. Juvenile abundance was highest in depths between 9-27 m over mud bottom in several broad areas in the Sound: the Connecticut side from New Haven to Mattituck. Adult abundance was also high in some these areas, but in contrast with juveniles, abundance tended to generally increase with depth in September, and in October abundance was similar in depths > 9 m (Figure 19C) (Gottschall *et al*. 2000).

The distributions of juvenile bluefish relative to bottom water temperature, dissolved oxygen, depth, and salinity based on 1992-1997 NEFSC Hudson-Raritan estuary trawl surveys are shown in Figure 43. Over the entire survey, juveniles were found in waters ranging from 12-24ºC, with a peak catch of 45%at 21ºC. They were found in dissolved oxygen levels of 5-9 mg/l, with 50% of the catch at 6 mg/l. They were found over a depth range of 15-65 ft (5-20 m), with over 40% found at 20 ft (6 m) and at about 30% found at 40-45 ft (12-14 m). Juveniles were found in salinities ranging from 19-32 ppt, with peaks at 20, 24-26, and at 29 ppt.

The hydrographic preferences of bluefish (almost exclusively juveniles) in Chesapeake Bay and tributaries from the 1988-1999 VIMS trawl surveys are shown in Figure 44 (all years and months combined). According to Brooks and Geer (2001) and Geer (2002), bluefish prefer salinities > 16 ppt and depths between 8-10 m. There appears to be two peaks associated with water temperature, one between 14-18ºC, and the second at 22-26ºC. Most were found where dissolved oxygen levels were 6-9 mg/l. The hydrographic preferences of juveniles caught in the 1994-1999 seine surveys are shown in Figure 45 (all years and months combined) (Geer 2002). Although captured throughout the sampling range, nearly 90% occur in waters > 18 ppt. Dissolved oxygen is rarely a problem in shallow waters of the Bay (Geer 2002), but the juveniles occurred more at dissolved oxygen levels of 6-8 mg/l. Most juveniles occur at temperatures > 20ºC, with the majority between 24-26ºC. The majority were found at a pH of 8.2.

ADULTS

Adult bluefish occur in the open ocean, large embayments, and most estuarine systems within their range. Although they occur in a wide range of hydrographic conditions, they prefer warmer temperatures and are not found in the MAB when temperatures decline below 14-16^{o}C. See Table 5 for a summary of habitat requirements of adult bluefish.

The spring and fall distributions of adult bluefish relative to bottom water temperature, depth, and salinity based on NEFSC bottom trawl surveys are shown in Figure 46. In the spring, they were found over a temperature range of 8-20°C, with most spread between about 9-16°C. They were found at much deeper depths than the juveniles; they were spread over a depth range of 1-400 m. Their salinity range was between 33-36 ppt, with the majority at 35 ppt. In the fall, the adults were spread over a temperature range of 8-28°C, with most spread between about 14-24°C. They were also found at shallower depths than in the spring: 1-100 m, with most found at 11-30 m. Their salinity range was between 29-35 ppt, with the majority at 31-32 ppt.

The spring and autumn distributions of adults in Massachusetts coastal waters relative to bottom water temperature and depth are shown in Figure 47. The few that were caught in the spring were found in a temperature range of 10-14°C, with a depth range of 6-25 m. In the fall, their temperature range was from 10-22°C, with most between 17-20°C. Their depth range during that season was from about 6-40 m, with the majority at 6-15 m.

The distributions of the few adults found during summer and fall in Narragansett Bay relative to bottom water temperature and depth are shown in Figure 48. They were collected in bottom water temperatures of 15-26^{o}C during summer and 17-21^{o}C in autumn, and depths of 10-70 ft (3-21 m) in summer and 10-110 ft (3-34 m) in autumn.

RESEARCH NEEDS

LIFE HISTORY AND BIOLOGY

We lack information on the reproductive biology of bluefish. Observed patterns of spawning may be based on the population level rather than on information on individual reproductive traits. We presently do not know whether individuals spawn serially, and if so, how many times they are capable of spawning in a year. We also do not know if these reproductive characteristics vary with age. It is apparent that more study of the distribution of older stages needs to be correlated with spawning events. Since bluefish school in like-sized (and supposedly like-aged) groups, we need to know what groups are where and when, and how those aggregations are associated with the observed densities of eggs. Simply describing how many spawning events are occurring can not solve the issue of the number of manageable stocks.

Our understanding of the "pelagic-juvenile" stage is limited despite its obvious importance. We need to better understand the details of transport mechanisms that provide progeny of reproduction in the SAB to nurseries in the MAB. Increased sampling of the neuston or near-surface layers of the ocean between production areas and estuarine nursery areas, associated with appropriate oceanographic observations, would provide much-needed insight into factors affecting transport and estuarine recruitment.

There has been a tight correlation between population size and the contribution of the *spring-spawned cohort* to fall trawl collections in the last three decades. Yet our knowledge of reproduction in the SAB is limited to a brief, under-sampled period in the 1970s when the population was at a relatively low level of abundance. Furthermore, larvae produced in June in the southern part of the MAB appear not to survive [unless recruits to Maine estuaries result from this output, see Creaser and Perkins (1994)], the fate of the remaining MAB summer offspring remains enigmatic.

There is some evidence for spawning during the fall in the Cape Canaveral region of Florida that appears to be discrete, rather than a continuation of spawning in the MAB. This evidence has been demonstrated in this document with larval occurrences and a disjunct autumn distribution of fish between 26 and 40 cm. Hare and Cowen (1993) present gonadosomatic data that suggest the same thing. Admittedly, some of this evidence is weak and based on incomplete sampling, and should be improved to determine the origin of these spawning fish, the magnitude of spawning, and the fate of any progeny.

HABITAT REQUIREMENTS

It is obvious from a review of the literature that we lack data to address the habitat issue at EFH information Level 3 (i.e.; data on habitat-related growth, reproduction, and/or survival by life history stage, as defined in the EFH Technical Manual [NMFS/OHC 1998] and Final Rule to implement the EFH policy [Department of Commerce, National Oceanic and Atmospheric Administration 2002]). Assessing how characteristics of habitat might affect the quality of young-of-the-year is therefore not feasible. Results of biological sampling, in estuaries or continental shelf waters, only rarely report specific characteristics of sampling sites. Therefore, data accruing from these studies are likely to be limited to EFH information Level 1; i.e., "presence/absence" data only (as defined in NMFS/OHC [1998] and Department of Commerce, National Oceanic and Atmospheric Administration [2002]). According to Miller (1984): "We need a reasonable schema of estuaries, emphasizing the factors that have the most significance to the fish. Unfortunately, the necessary physical data are often lacking for an accurate characterization. Many are also temporally unstable. Not even our attempts to classify estuaries recognize their dynamic nature…we need more complete descriptions of how biologically relevant abiotic factors within estuaries affect biologically relevant scales of time and space. Without this, we cannot hope to untangle the biological processes or to compare results from different estuaries. Biologists need to involve more physical oceanographers and meteorologists in our research." Clearly, in the future, more attention needs to be paid to the details of collecting sites, and habitat research supported, such that the linkages between habitat quality and year class success can be made.

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Table 1. Dietary items of bluefish from several study areas.

Source	**Life History Stage and Study Location**	**Diet Items (in order of importance)**
Texas Instruments Incorporated (1976)	Young-of-the-year, Hudson River (tidal)	*Anchoa mitchilli* (dominated diet through summer), Clupeidae, *Microgadus tomcod, Alosa sapidissima, Notropis hudsonius*, Cyprinodontidae
Festa (1979)	11-20 cm, Little Egg Harbor estuary, NJ	*Fundulus* spp., Atherinidae, *Anchoa* spp., *Callinectes sapidus, Brevoortia tyrannus, Crangon septemspinosa*
Friedland *et al.* (1988)	Juvenile, Sandy Hook, NJ	1981: Teleosts, Crustacea, Polychaeta 1982: Crustacea, Teleostei, Polychaeta 1983: Crustacea, Teleostei, Polychaeta (weight at length significantly greater in 1981)
Hartman and Brandt (1995a, b)	Age 0, Age 1, and Age 2, Chesapeake Bay (Diets of all age classes changed through season)	Age 0: *Anchoa mitchilli, Menidia menidia, Brevoortia tyrannus* Age 1: *Leiostomus xanthurus, A. mitchilli, M. menidia, B. tyrannus* Age 2: *Micropogonias undulatus, A. mitchilli, B. tyrannus* (*B. tyrannus* becomes important in diets of all age classes in Sep-Oct.)
Buckel and Conover (1997)	Young-of-the-year, Hudson River estuary	Unidentified fish, *Anchoa mitchilli, Alosa* spp., *Morone saxatilis, Morone americana*
Buckel *et al*. (1999)	Young-of-the-year, Hudson River estuary	*Morone saxatilis*, *Anchoa mitchilli, Menidia menidia, Alosa* spp.
Buckel *et al*. (1999)	Georges Bank and Middle Atlantic Bight continental shelf, Young-of-the-year Adult	1994-1995 Bay anchovy, squid, butterfish, striped anchovy, round herring Squid, butterfish, and clupeids.

Table 1. Continued.

Source	**Life History Stage and Study Location**	**Diet Items (in order of importance)**
Juanes *et al*. (2001)	Young-of-the-year, Great South Bay, NY	Sand shrimp, YOY *Menidia spp*., unidentified fish, menhaden, sand worms
Harding and Mann (2001)	20 – 40 cm Chesapeake Bay	Other fish, polychaete worms, clupeids, unidentified fish, crustacea.
Buckel and McKown (2002)	New York Bight embayments (western Long Island and Staten Island) Young-of-the-year	*Menidia menidia*, *Anchoa mitchelli,* unidentified fish, sand shrimp, mysids, amphipods, polychaete worms, other invertebrates
Able *et al*. (2003)	Coastal NJ, ocean beaches Young-of-the-year	*Anchoa spp.,* unidentified fish, decapods*, Menidia spp.,* copepods, amphipods
NEFSC food habits database [sampling conducted during seasonal surveys on the continental shelf from the Gulf of Maine to Cape Hatteras from 1973 to the present; see Link and Almeida (2000) for methodology]	All ages (mean size 35.6 mm FL), continental shelf, Georges Bank and Middle Atlantic Bight Small (≤ 30 cm FL) Medium (>30 cm to ≤ 70 cm FL) Large (> 70 cm FL)	1973-1980: Unidentified fish, *Illex* spp., *Etrumeus teres, Loligo* spp., *Peprilus triacanthus*, Cephalopoda 1981-2003: *Anchoa spp*., Unidentified fish, *Peprilus triacanthus,* A*mmodytes dubius, Loligo* spp., *Clupea harengus* 1981-2003: *Clupea harengus,* Unidentified fish, squids, *Peprilus triacanthus, Anchoa spp*., 1981-2003: Unidentified fish, squids, *Clupea harengus,* gadids, *Ammodytes spp., Anchoa spp*., flatfish, sculpins, butterfish

Table 2. Sampling in 1979 ("Southern MARMAP") for bluefish larvae in the Charleston Bump area (32°37' N - 32°80' N x 78°42' W - 79°00' W). Isaacs Kidd MWT only.

Date	Sampling Depth	Sampling	Volume Sampled	Bluefish No./10m^2
February 9	15	5	308	
"	37	27	641	
"	84	33	816	
February 28	31	26	693	0.89
"	54	25	1085	
"	110	35	1052	
March 13	30	22	580	
"	74	29	995	
March 17	114	38	1258	0.91
March 18	28	20	700	
March 27	18	20	742	1.16
"	58	27	1002	0.78
"	98	34	1261	
March 28	30	26	965	
April 6	32	25	875	0.71
"	62	25	875	41.48
"	132	40	1400	0.38
April 18	27	20	700	
"	38	21	735	2.22
"	128	33	1155	
April 19	42	22	770	1.45
April 30	28	22	770	36.99
May 1	76	27	945	21.16
"	134	38	1330	
"	50	25	875	3.97
May 16	34	22	770	2.65
"	58	25	875	9.55
"	130	35	1225	0.36
June 5	28	22	770	
"	58	31	1085	
June 30	37	26	910	
July 1	58	29	1015	
"	124	47	1645	
August 12	42	24	890	
August 13	127	31	1150	
"	50	22	816	
"	22	20	742	

Table 3. Distribution of early life history stages of bluefish, *Pomatomus saltatrix*, in estuaries from Maine to Florida. Occurrences are not quantitative and may be based on one or very few specimens. Estimates of relative abundance after Nelson and Monaco (1994), Jury *et al*. (1994), and Stone *et al*. (1994). Some Middle Atlantic Bight estuaries after Able and Fahay (1998).

Estuary	**Eggs**	**Larvae**	**Juveniles**
Passamaquoddy Bay, ME	None	None	Rare
Englishman/Machias Bay, ME	None	None	Rare
Narraguagus Bay, ME	None	None	Rare
Blue Hill Bay, ME	None	None	Rare
Penobscot Bay, ME	None	None	Common
Muscongus Bay, ME	None	None	Common
Damariscotta River, ME	None	None	Common
Sheepscot River, ME	None	None	Common
Kennebec/Androscoggin Rivers, ME	None	None	Common
Casco Bay, ME	None	None	Common
Saco Bay, ME	None	None	Common
Wells Harbor, ME	None	None	Common
Great Bay, ME/NH	None	None	Common
Merrimack River, NH	None	None	Rare
Massachusetts Bay, MA	None	None	Common
Boston Harbor, MA	None	None	Common
Cape Cod Bay, MA	None	None	Common
Nauset Marsh, MA	None	None	None
Buzzards Bay, MA	None	Rare	Abundant
Narragansett Bay, RI	None	Rare/common	Abundant
Connecticut River, CT	None	None	Abundant
Long Island Sound, NY	None	None	Abundant
Gardiners Bay, NY	Rare	Rare	Abundant
Great South Bay, NY	None	None	Abundant
Hudson River, Raritan/Sandy Hook Bays, NY/NJ	Rare	Rare	Abundant
Barnegat Bay, NJ	None	Rare	Abundant
Great Bay, NJ	None	Rare	Common
Southern Inland bays, NJ	None	Rare	Abundant
Delaware Bay, NJ/DE	None	rare	Abundant
Delaware Inland bays, DE	None	None	Common
Eastern Shore, MD/VA	None	Rare	Common
Chesapeake Bay mainstem, MD/VA	None	None	Abundant
Chester River, MD	None	None	Common
Choptank River, MD	None	None	Common

Table 3. Continued.

Estuary	**Eggs**	**Larvae**	**Juveniles**
Patuxent River, MD	None	None	Common
Potomac River, MD/VA	None	None	Abundant
Tangier/Pocomoke Sound, VA	None	None	Abundant
Rappahannock River, VA	None	None	Abundant
York River, VA	None	None	Abundant
James River, VA	None	None	Abundant
Albemarle Sound, NC	None	None	Common
Pamlico Sound, NC	None	None	Abundant
Pungo River, NC	None	None	Common
Neuse River, NC	None	None	Common
Bogue Sound, NC	None	None	Common
New River, NC	None	None	Common
Cape Fear River, NC	None	None	Abundant
Winyah Bay, SC	None	None	Common
Santee Rivers (N&S), SC	None	None	Common
Charleston Harbor, SC	None	None	Common
St. Helena Sound, SC	None	None	Common
Broad River, SC	None	None	Common
Savannah River, SC/GA	None	None	Common
Ossabow Sound, GA	None	None	Common
Sapelo Sound/ St. Catherine, GA	None	None	Common
Altamaha River, GA	None	None	Common
St. Andrew/St. Simon Sound, GA	None	None	Common
St. Johns River, FL	None	None	Common
Indian River, FL	None	None	Rare
Biscayne Bay, FL	None	None	Rare

Table 4. Unpublished records of juvenile bluefish in waters of coastal Maine. Collection locations are ordered from north to south (after Creaser and Perkins 1994).

Location	**Date of Collection**	**O/E[1]**	**Number Collected**	**Size (mm TL)**	**Method[2]**
Marston Pt.	August 25, 1983	O	3	100-130	HW
Seal Island	July 1991	O	1	50	AT
Matinicus Rock	July 24-30, 1991	O	4	50-60	RT
"	July 9-17, 1991	O	14	40-50	AT
"	Mid-July 1990	O	2	30-40	AT
"	July 5, 1989	O	2	85-90	AP
"	July 18, 1986	O	1	77	AP
Foot Bridge (Boothbay Harbor)	Summer 1970-1974	O	---	Juveniles (2 modes)	HS
DMR Dock	July 4, 1984	O	3	40-50	HL
"	August 25, 1978	O	1	86	DN
"	September 14, 1971	O	5	95-105	---
Townsend Gut	September 5, 1985	O	1	Juvenile	HL
Lobster Cove	August 11, 1991	O	4	162-192	HL
"	August 30, 1990	O	1	145	HL
Sheepscot River	August 2, 1989	E	1	140	HL
Sheepscot Falls	August 1967	E	---	150-200	HL
Marsh River	July 17-Sept 17, 1991	E	60	101-217	GN
"	August 1-Sept 26, 1990	E	149	89-218	GN
"	August 8-28, 1989	E	102	92-194	GN
"	August 26, 1987	E	6	129-163	GN
"	August 14, 1986	E	28	93-121	GN
The Eddy	July 9, 1991	E	3	80-85	HS
Cross River	August 8, 1991	E	1	115	HS
Berry Island	September 8, 1974	E	4	125-140	HS
"	August 29, 1973	E	2	132-141	HS
"	August 30, 1972	E	1	112	HS
Kennebec Pt.	August 10-22, 1990	O	29	39-70	HS

Table 4. Continued.

Location	**Date of Collection**	**O/E**[1]	**Number Collected**	**Size (mm TL)**	**Method**[2]
Mouth of Abagadasset River	July 18, 1991	E	2	84-94	HS
"	July 3, 1991	E	6	112-115	HS
"	August 3, 1989	E	8	52-76	HS
"	September 11, 1987	E	2	142-150	HS
"	July 17, 1986	E	5	70-77	HS
Mouth of Androscoggin River	August 5, 1983	E	2	82-86	HS
Bath Bridge	Summer 1982	E	90	< 100	OT
Winnegance Bay	Summer 1988-1990	E	---	50-150	HL
Atkins Bay	Summer 1981	E	---	80-90	HS
Howard Point	August 1988	E	3	70-130	FK
Jenny Island	July 16, 1991	E	1	40	CT
Merepoint Bay	September 26, 1991	E	97	150-174	GN
Royal River	Summer 1988	E	---	Juvenile	---
SMVTI Dock	September 1986	O	---	130-150	HL
Union Wharf	September 1984	O	6	150-200	HL
Dunston, Libby, Nonesuch Rivers (confluence)	Summer 1987	E	---	Juvenile	HL
1 mi. off amusement pier, Old Orchard Beach	Summer 1961-1964	O	---	Juvenile	HL
Wells Harbor	August 1991	E	1	68	FN

[1] O = oceanic; E = estuarine
[2] Collection methods: OT = otter trawl; FN = fyke net; HL = hook and line; HS = haul seine; AP = Atlantic puffin; GN = gill net; AT = Arctic tern; DN = dip net; CT = common tern; HW = herring weir; RT = roseate tern

Table 5. Summary of life history and habitat characteristics for bluefish, *Pomatomus saltatrix*. See Appendix 1 for a more complete listing of habitat variables.

Life History Stage	Habitat (Spatial and Temporal)	Temperature	Salinity	Light/Vertical Distribution	Currents/ Circulation	Prey	Estuarine Use
Eggs [1]	*spring cohort*: unknown. *summer cohort*: occurs across continental shelf, southern New England to Cape Hatteras. Most in mid-shelf waters.	*spring cohort*: unknown. *summer cohort*: most in 18-22°C.	*spring cohort*: unknown. *summer cohort*: 31.0 ppt or more (minimum 26.0 ppt).	*spring cohort*: unknown. *summer cohort*: peak spawning in the evening (1900-2100 hrs).	*spring cohort*: unknown. *summer cohort*: in southern MAB, surface currents transport eggs south and offshore.	--	None
Larvae [2]	*spring cohort*: near edge of continental shelf, Cape Hatteras-Cape Canaveral, FL. Peak April-May. *summer cohort*: most 30-70 m depths, May-Sept, peak in July.	*spring cohort*: smallest larvae in > 24°C. *summer cohort*: near Cape Hatteras 22.1-22.4°C; in MAB 18-26°C.	*spring cohort*: smallest larvae in > 35 ppt. *summer cohort*: in MAB in 30-32 ppt.	*spring cohort*: > 4 mm strongly associate with surface. *summer cohort*: near surface at night, mostly at about 4 m during day.	*spring cohort*: subject to northward advection by Gulf Stream. Some retained in SAB by southerly counter-current. *summer cohort*: southwest winds in MAB may facilitate cross-shelf transport.	*summer cohort*: mostly copepod life history stages. Guts full during day.	None
Pelagic Juveniles [3]	*spring cohort*: smallest near 180 m contour; larger near shore. April-May. *summer cohort*: cross MAB shelf from Slope Sea to shore, early- to mid-June.	*spring cohort*: 19.0-24.0°C (or higher well offshore). *summer cohort*: in MAB 15.0-20.0°C (most > 18.0°C). As low as 13.0°C when cross shelf.	*spring cohort*: Near 180 m contour, > 35.0 ppt. *summer cohort*: During June, range 36.0-31.0 ppt.	*both cohorts*: strongly associated with the surface.	*spring cohort*: shoreward movement with growth unless advected north. *summer cohort*: move shoreward with growth. Currents important, but active swimming indicated.	--	*both cohorts*: enter estuarine nurseries during this stage
Juveniles [4] ***(summer cohort only)***	Several estuarine study areas between Narragansett Bay, RI and Delaware Bay and Delaware River. Also coast beaches and surf zones.	In most studies, arrive > 20°C, remain in temperatures up to 30°C, emigrate when declines to 15°C. Can not survive below 10°C or above 34°C. Fall migration in 18-22°C on inner continental shelf.	Usually 23.0-33.0 ppt but can intrude to as low as 3.0 ppt.	Day: usually near shorelines or in tidal creeks. Night: usually in open bay or channel waters.	Can occur in surf zone or clear to turbid back-estuarine zones.	Atlantic silversides, bay anchovy, clupeids, striped bass, sand shrimp, mysids, other fish, invertebrates.	Mostly sand, particularly along coast, but some mud, silt, clay. Also uses *Ulva*, *Zostera* beds, and *Spartina* or *Fucus*. In Chesapeake Bay includes oyster bars and beds.
Adults [5]	Generally oceanic, nearshore to well offshore over continental shelf.	Warm water, usually > 14-16°C. Can tolerate 11.8-30.4°C but are stressed at either extreme.	Oceanic salinities.	--	--	Sight feeders, prey on other fish almost exclusively.	Not uncommon in bays, larger estuaries, as well as coastal waters.

[1] Norcross *et al.* (1974); Berrien and Sibunka (1999); data from present report.
[2] Norcross *et al.* (1974); Kendall and Walford (1979); Kendall and Naplin (1981); Powles (1981); Collins and Stender (1987); Hare and Cowen (1996); data from present report.
[3] Fahay (1975); Kendall and Walford (1979); Powles (1981); Collins and Stender (1987); Hare and Cowen (1996).
[4] Lund and Maltezos (1970); Olla *et al*. (1975); Milstein *et al.* (1977); Nyman and Conover (1988); Rountree and Able (1992a, b); McBride *et al.* (1995); Able *et al.* (1996); Buckel and Conover (1997); Harding and Mann (2001), Buckel and McKown (2002), Secor *et al*. (2002), Able *et al*. (2003).
[5] Bigelow and Schroeder (1953); Olla and Studholme (1971).

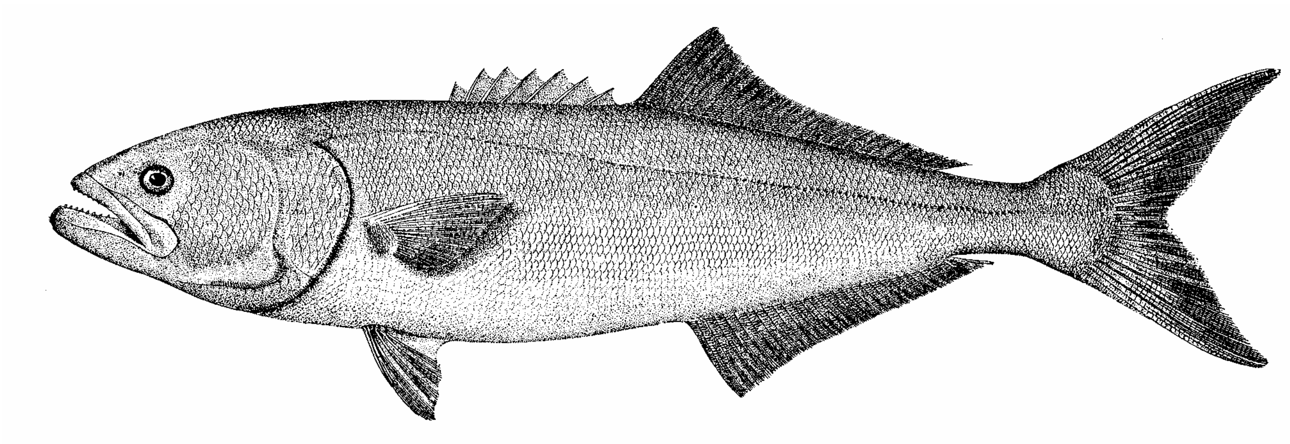


Figure 1. The adult bluefish, *Pomatomus saltatrix* (from Goode 1884).

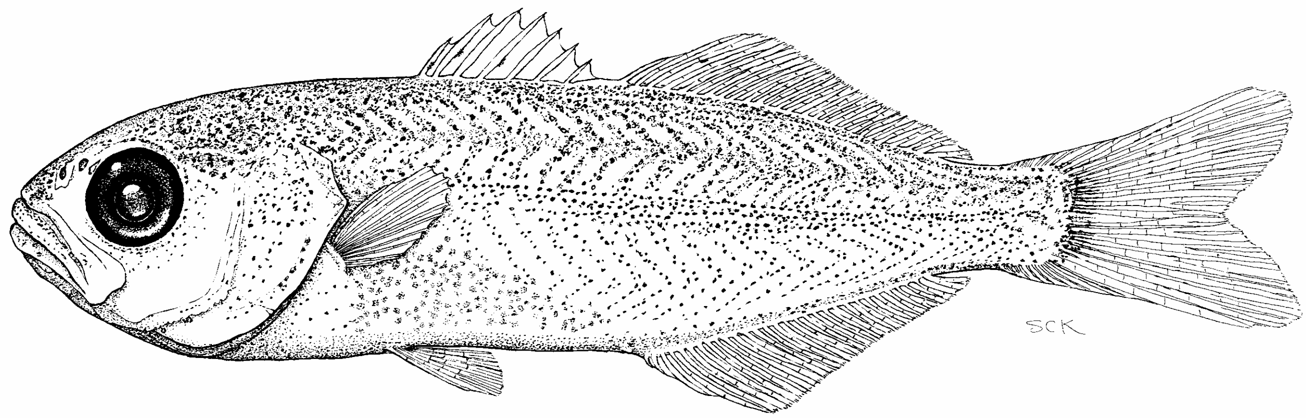


Figure 2. The pelagic juvenile bluefish, 24.3 mm SL (from Able and Fahay 1998).

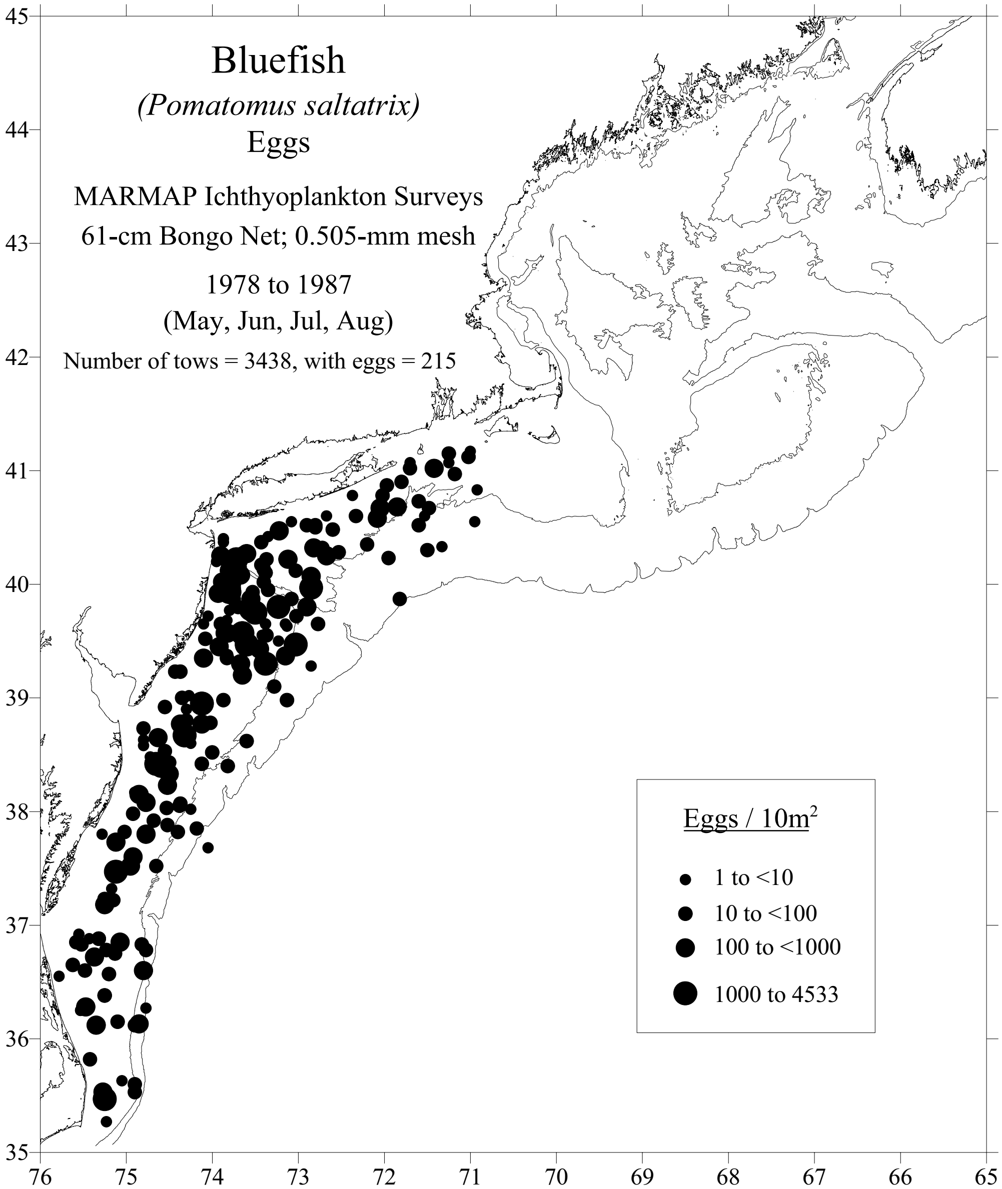


Figure 3. Distribution and abundance of bluefish eggs collected during NEFSC MARMAP ichthyoplankton surveys in the Mid-Atlantic Bight from 1978-1987 [survey also covered the Gulf of Maine and Georges Bank; see Reid *et al.* (1999) for details].

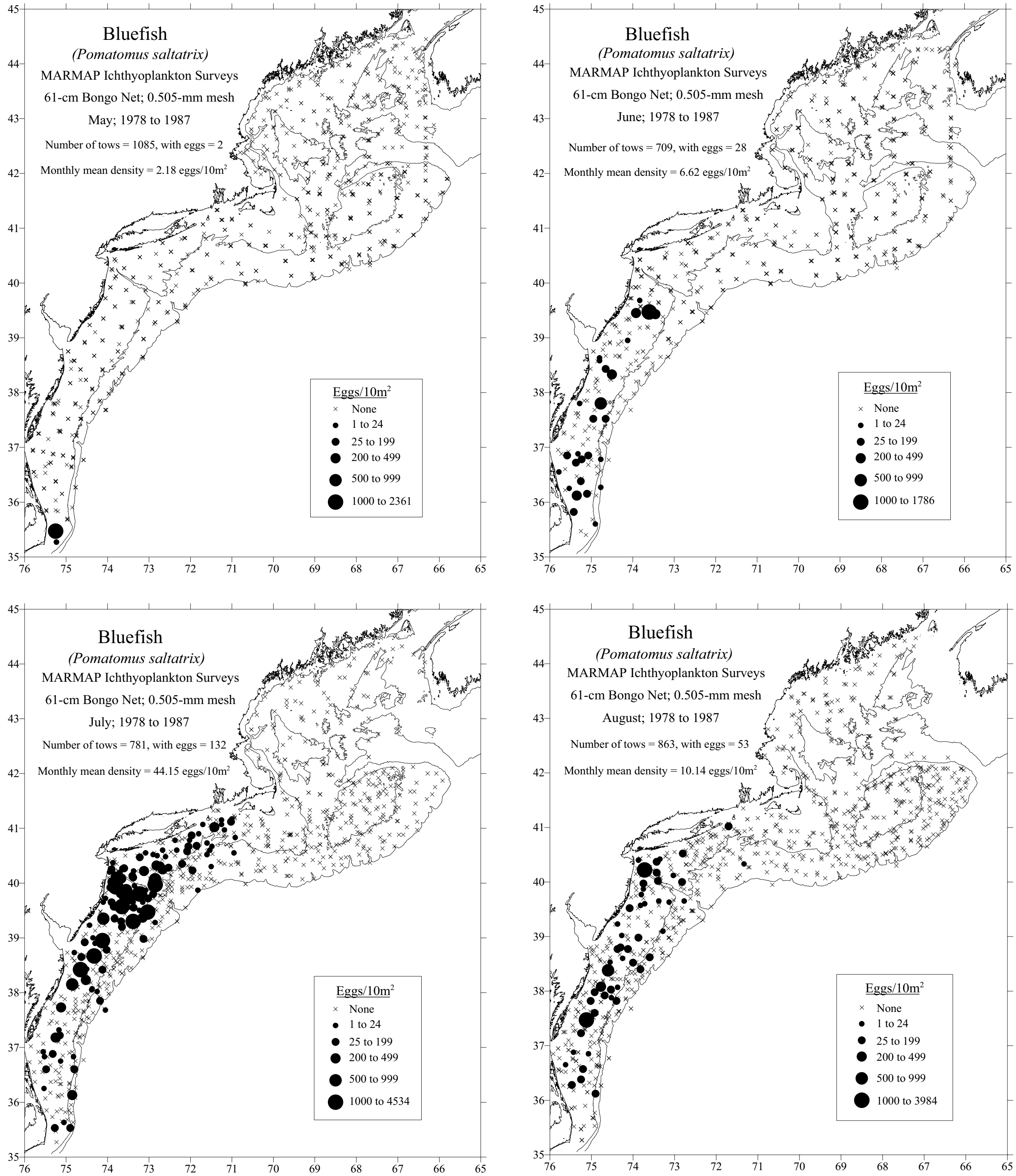


Figure 3. Continued.

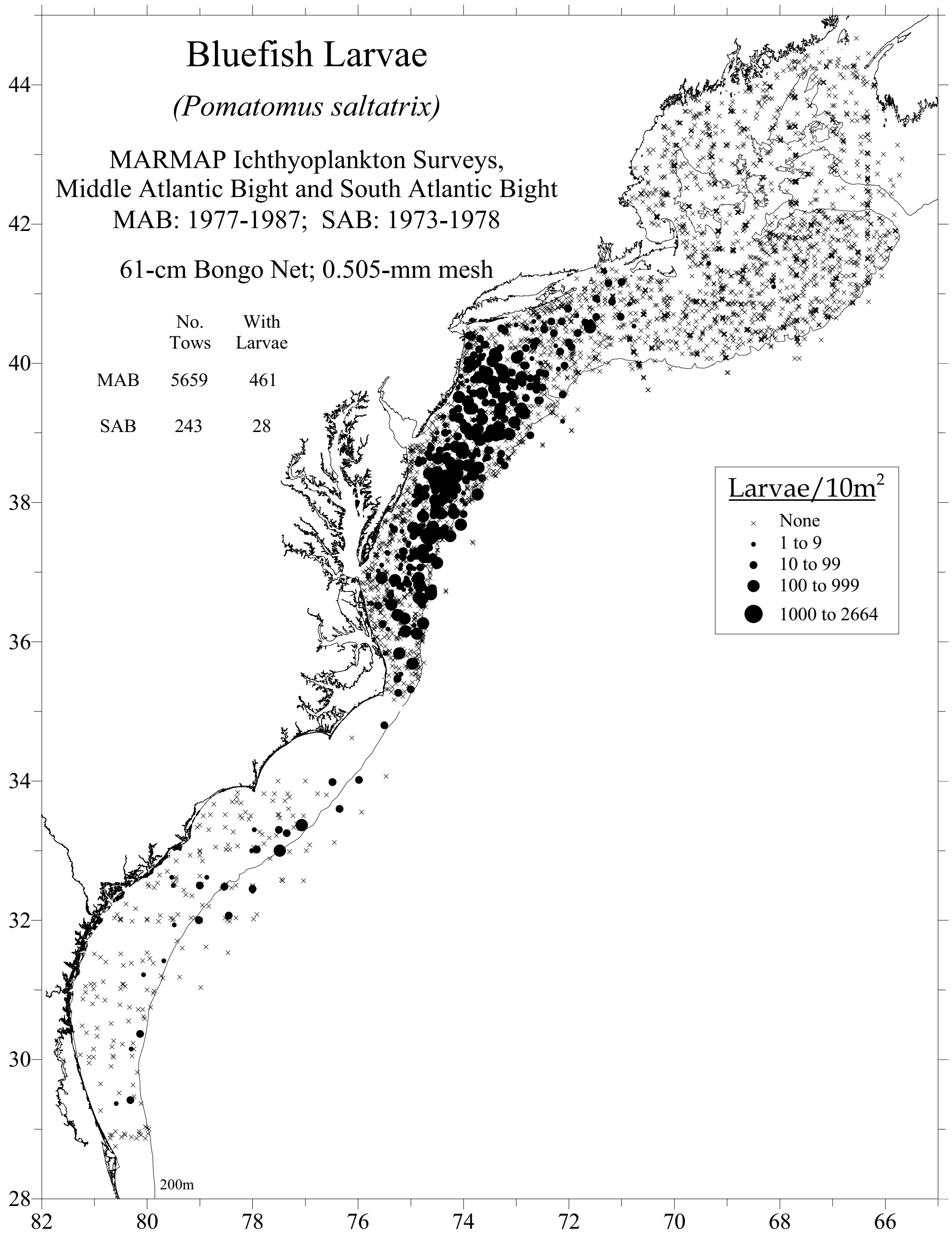


Figure 4. Distribution and abundance of bluefish larvae collected during NEFSC MARMAP ichthyoplankton surveys of both the Mid-Atlantic Bight (1977-1987) and South Atlantic Bight (1973-1978) [survey also covered the Gulf of Maine and Georges Bank; see Reid *et al.* (1999) for details].

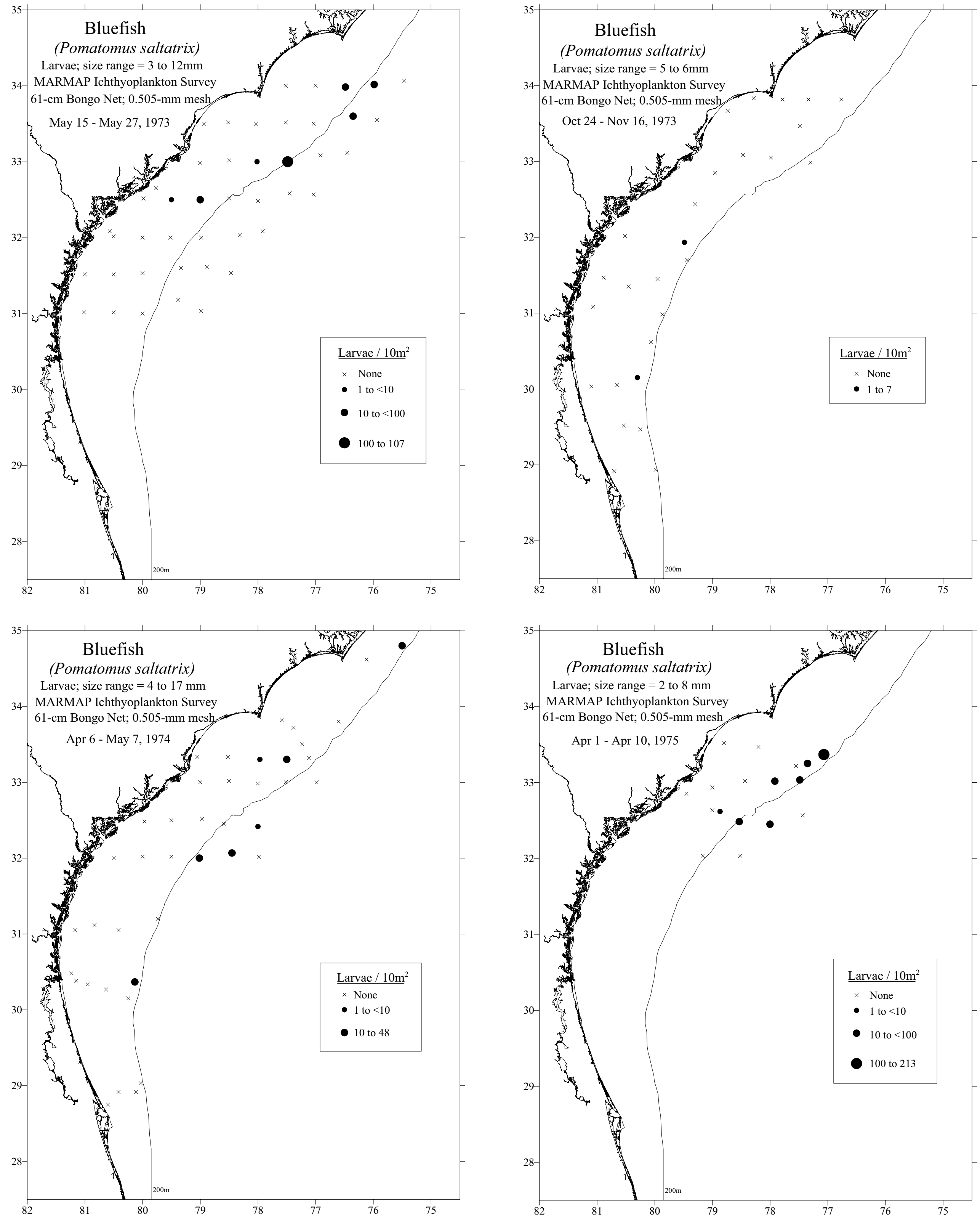
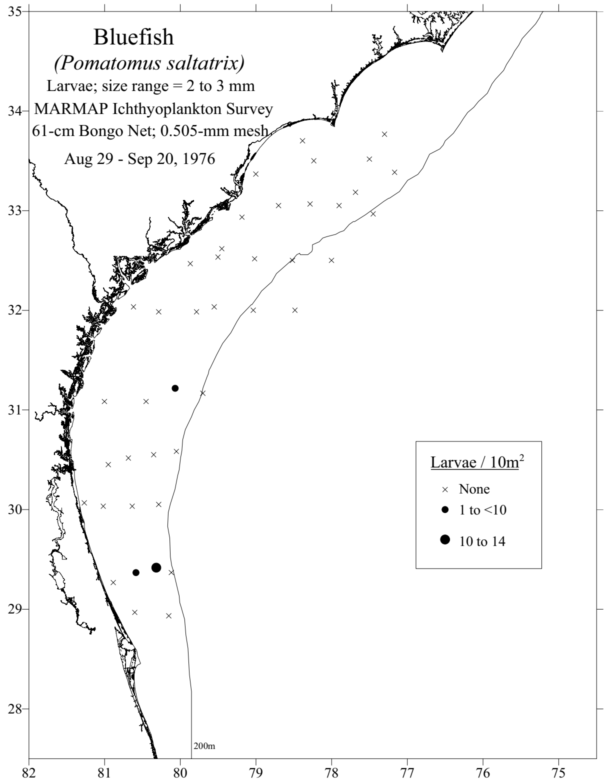
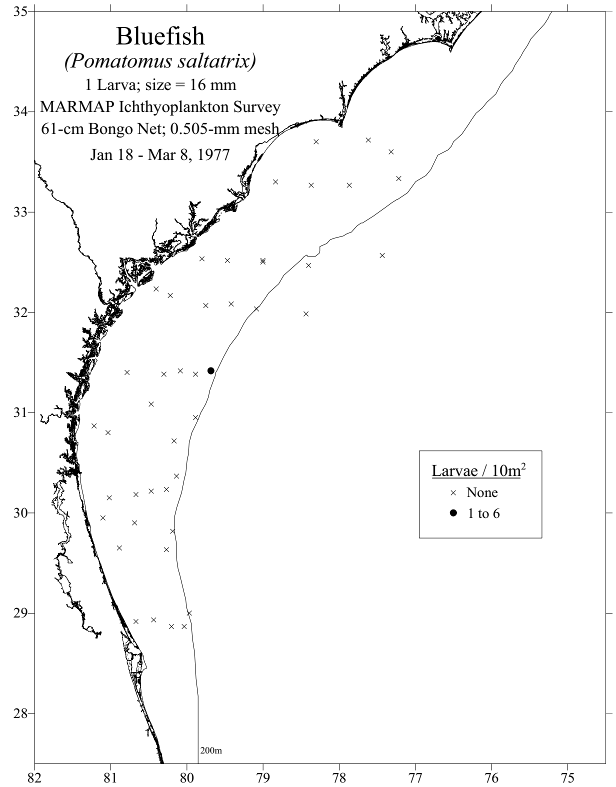


Figure 5. Distribution and abundance of bluefish larvae collected with a bongo net in the South Atlantic Bight during NEFSC MARMAP ichthyoplankton surveys [see Reid *et al.* (1999) for details].





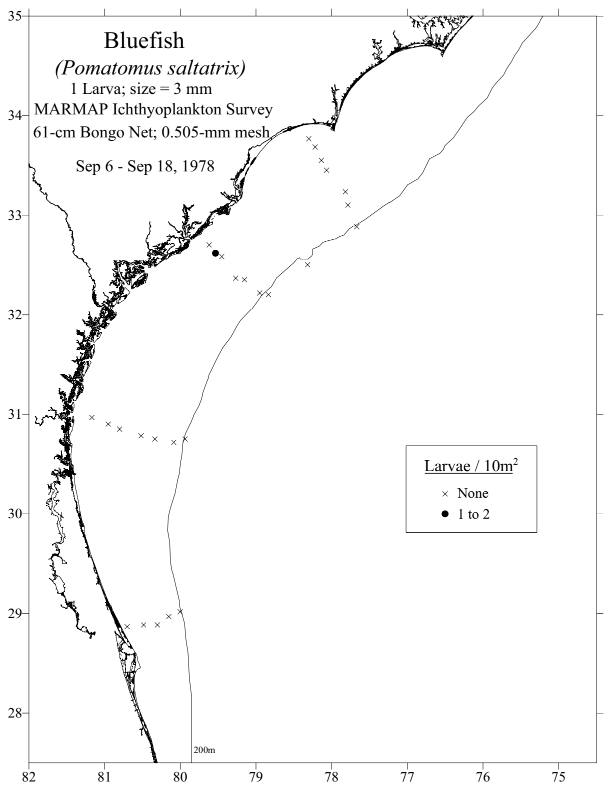


Figure 5. Continued.

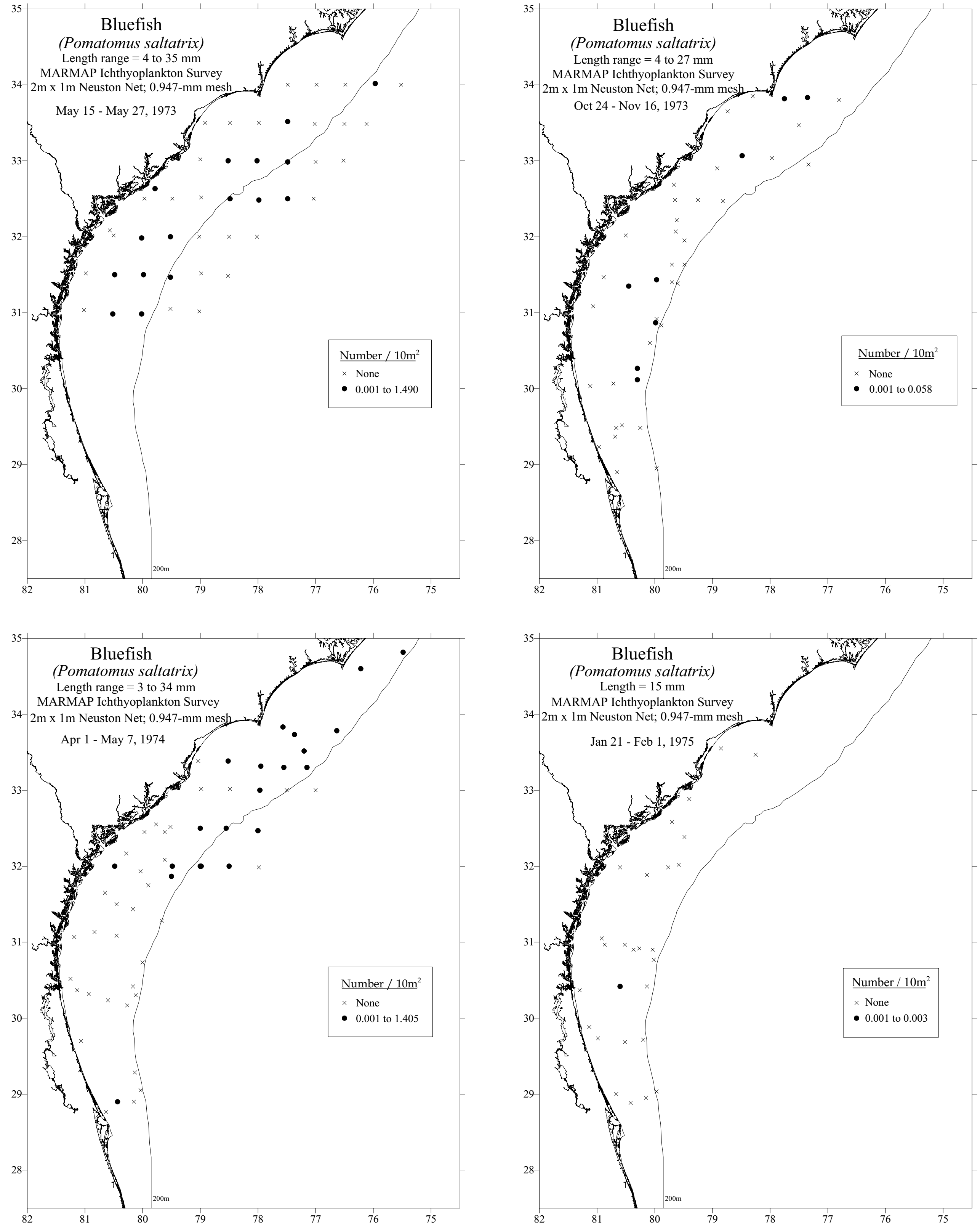


Figure 6. Distribution and abundance of bluefish larvae collected in a neuston net in the South Atlantic Bight during NEFSC MARMAP ichthyoplankton surveys [see Reid *et al.* (1999) for details].

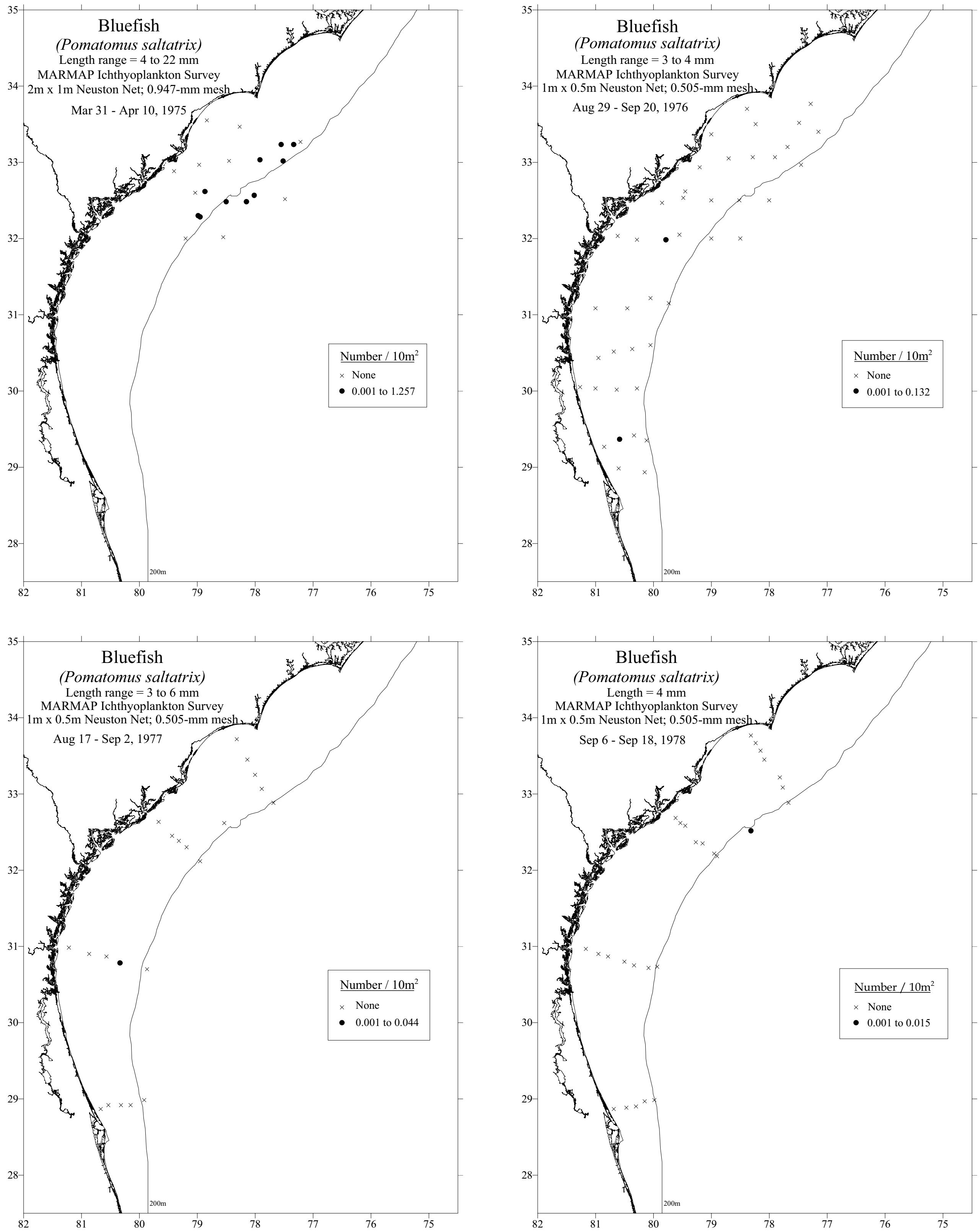


Figure 6. Continued.

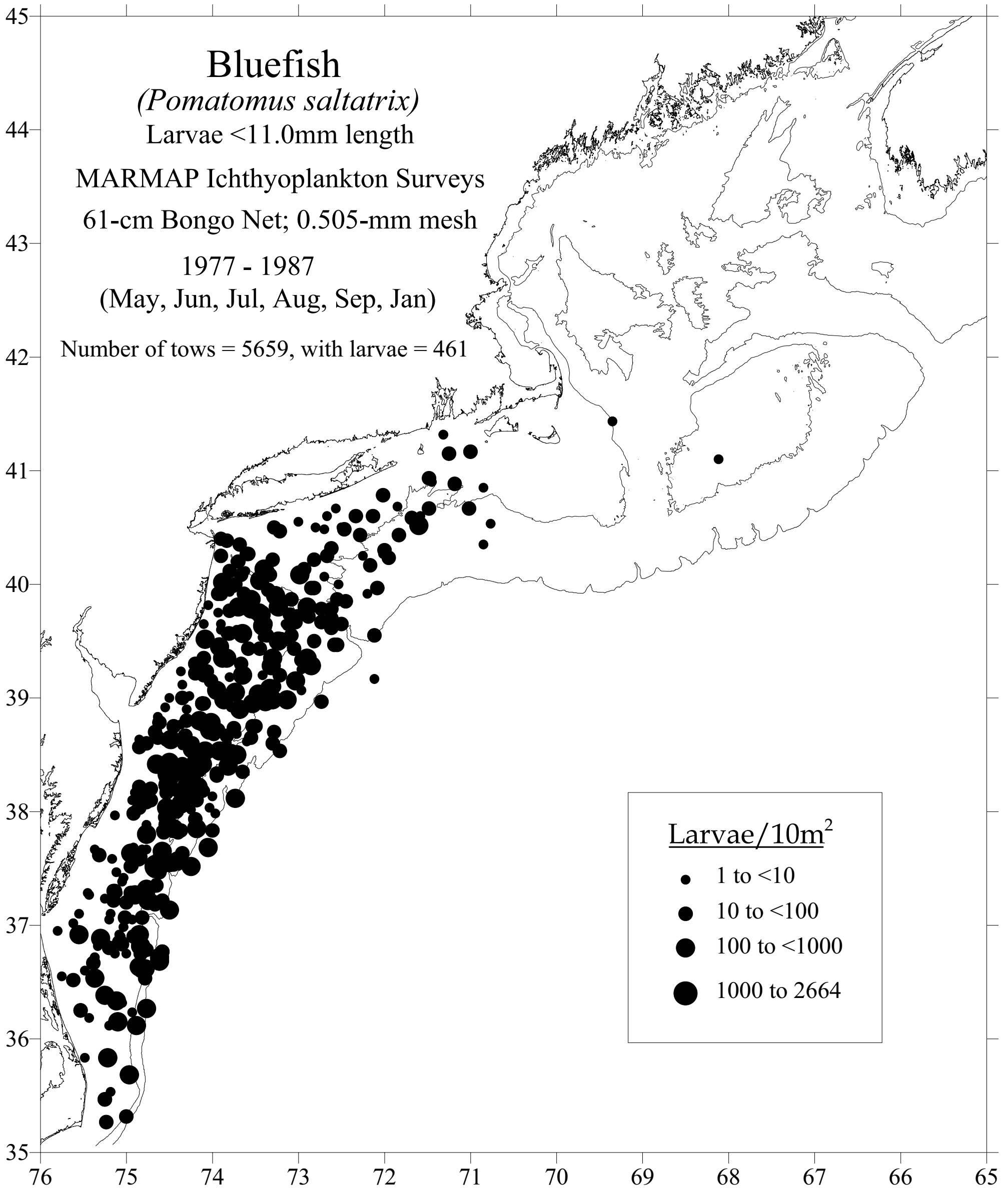


Figure 7. Distribution and abundance of bluefish larvae collected during NEFSC MARMAP ichthyoplankton surveys in the Mid-Atlantic Bight from 1977-1987 [survey also covered the Gulf of Maine and Georges Bank; see Reid *et al.* (1999) for details].

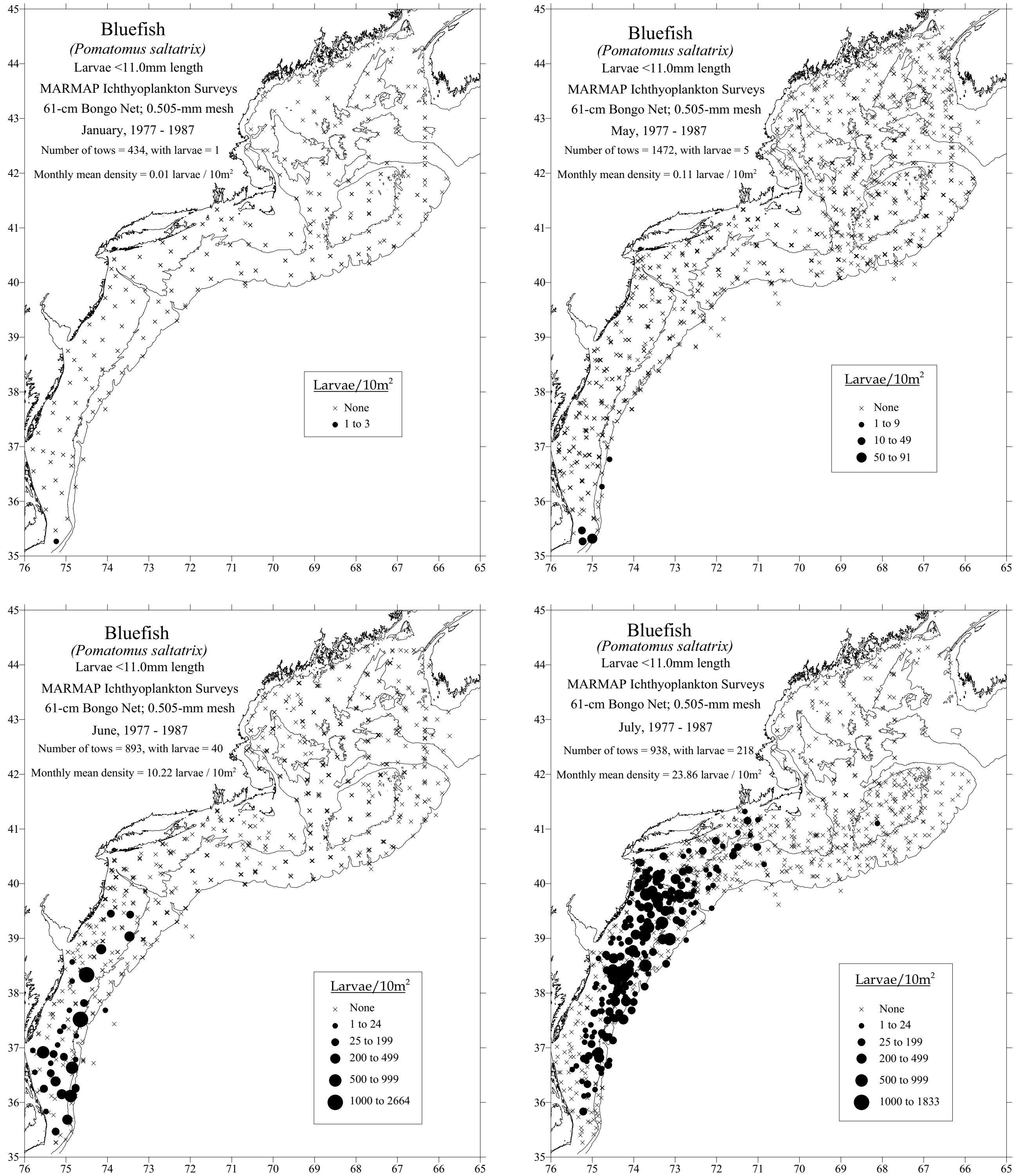
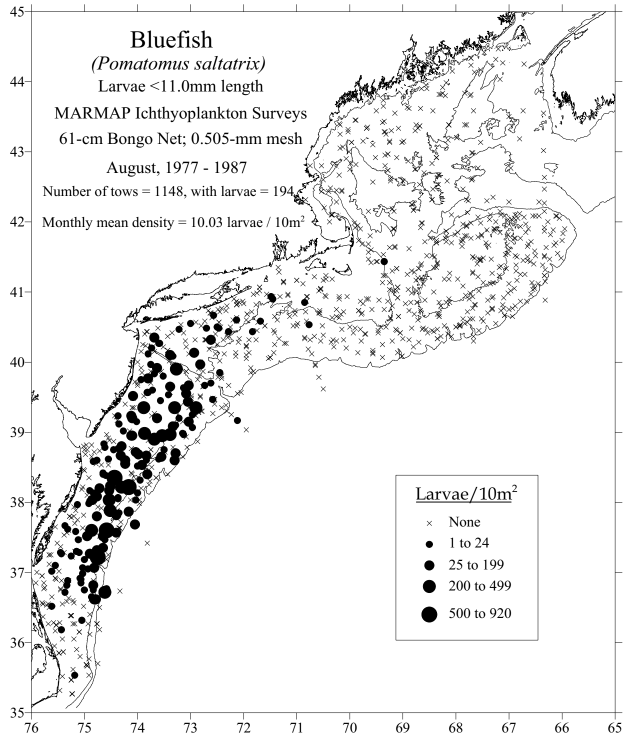


Figure 7. Continued.



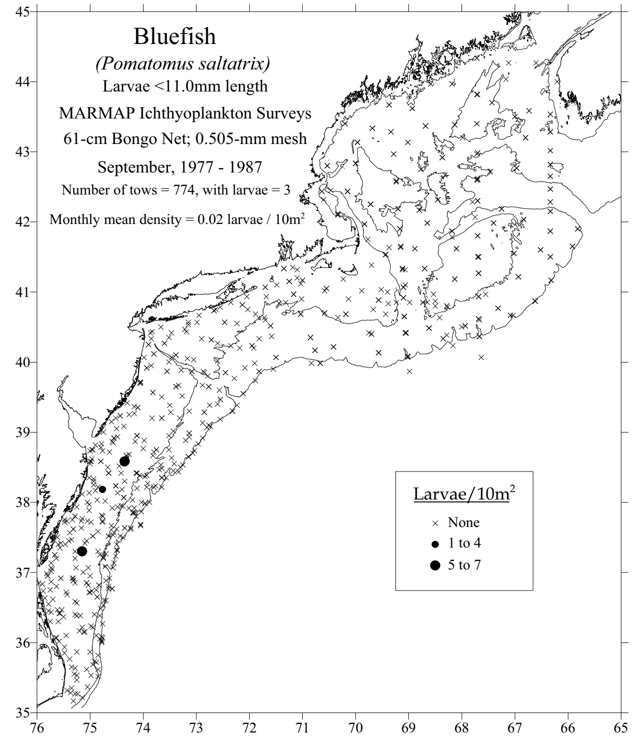


Figure 7. Continued.

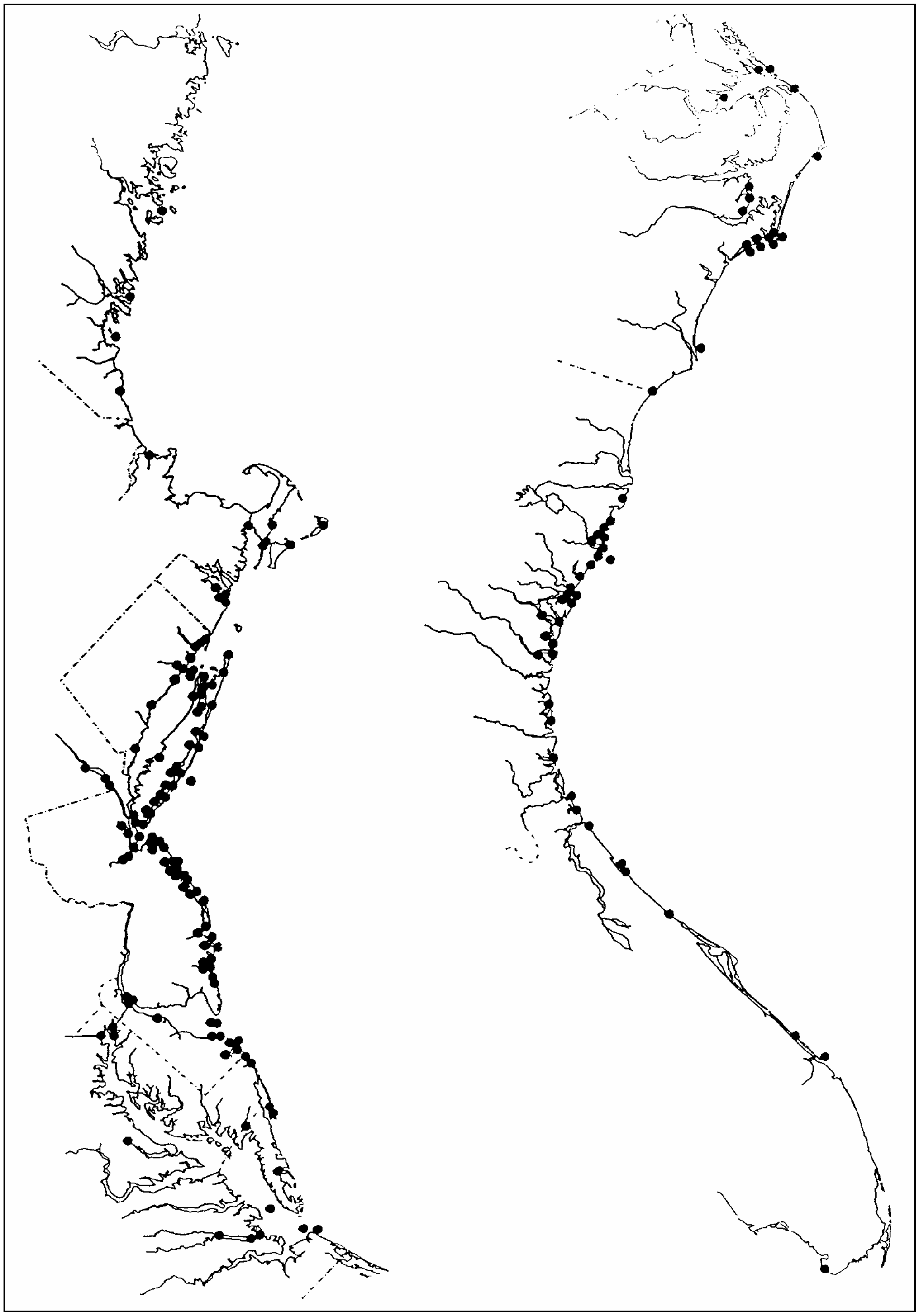


Figure 8. Reported occurrences of juvenile bluefish along the east coast of the United States (Clark 1973).

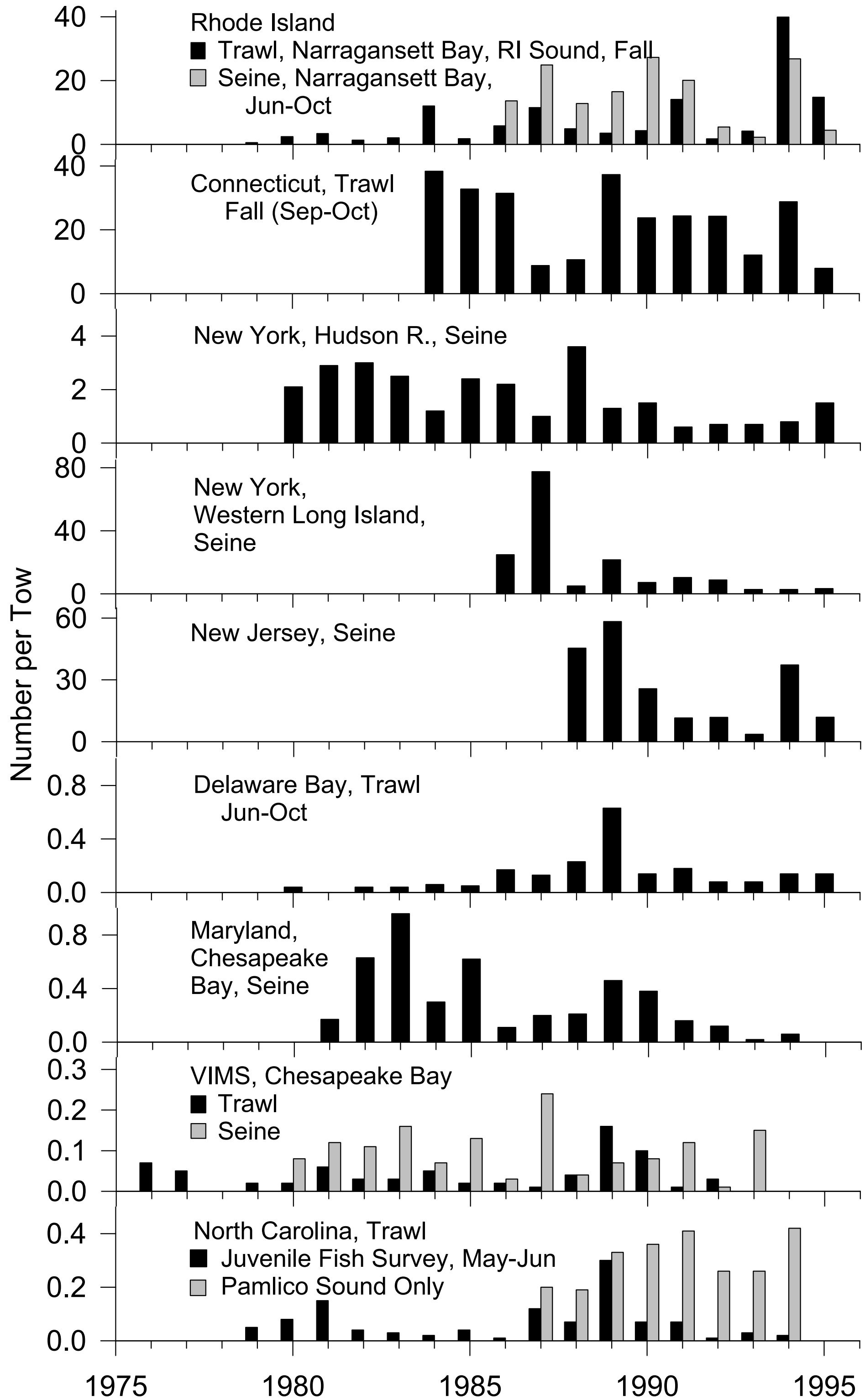


Figure 9. Abundance (number/tow) of young-of-the-year bluefish in seine and trawl surveys by state and by year.

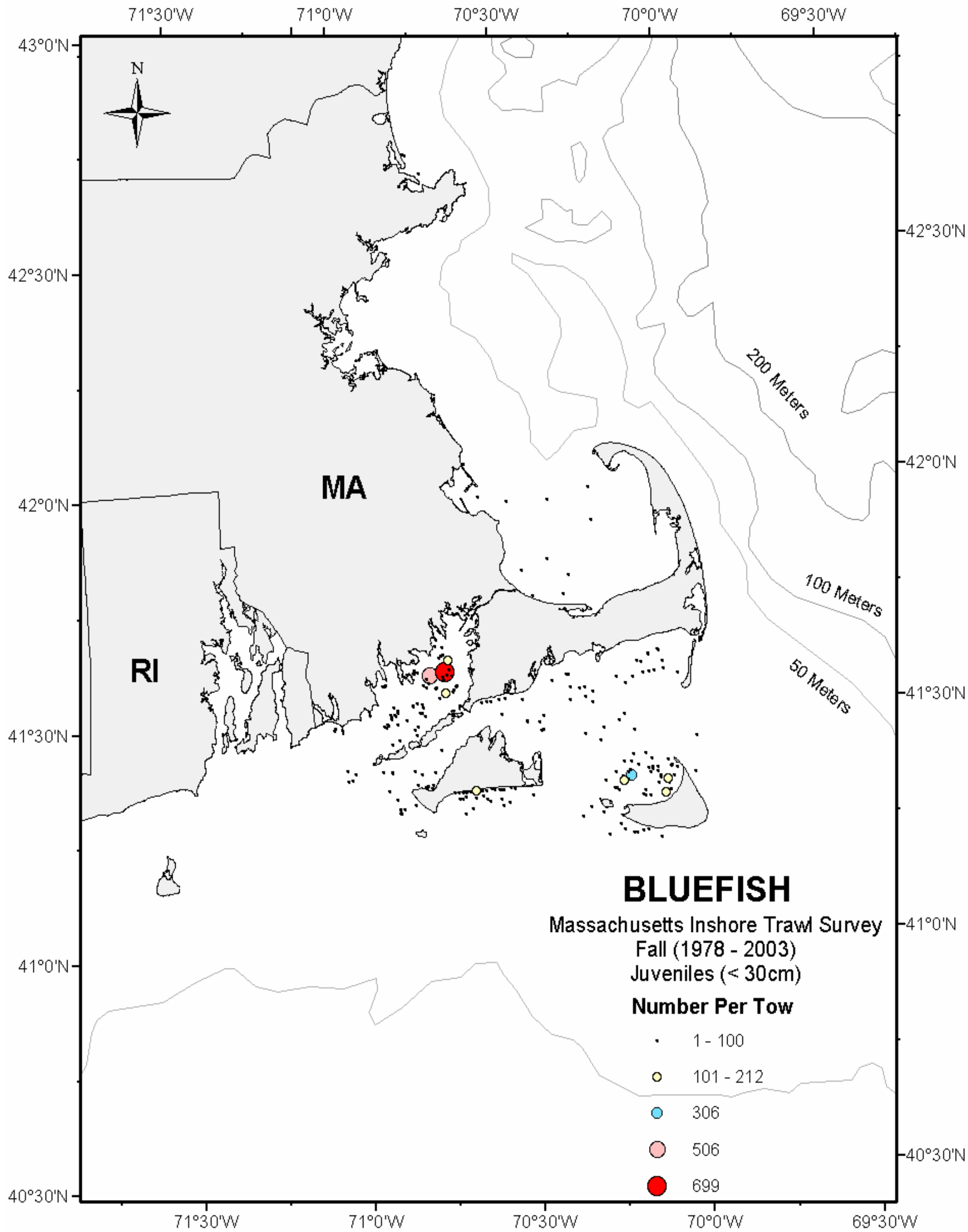


Figure 10. Distributions and abundances of juvenile bluefish in Massachusetts coastal waters collected during the fall Massachusetts inshore trawl surveys (1978-2003, all years combined). Survey stations where juveniles were not found are not shown.

Bluefish Juveniles (< 35 cm)

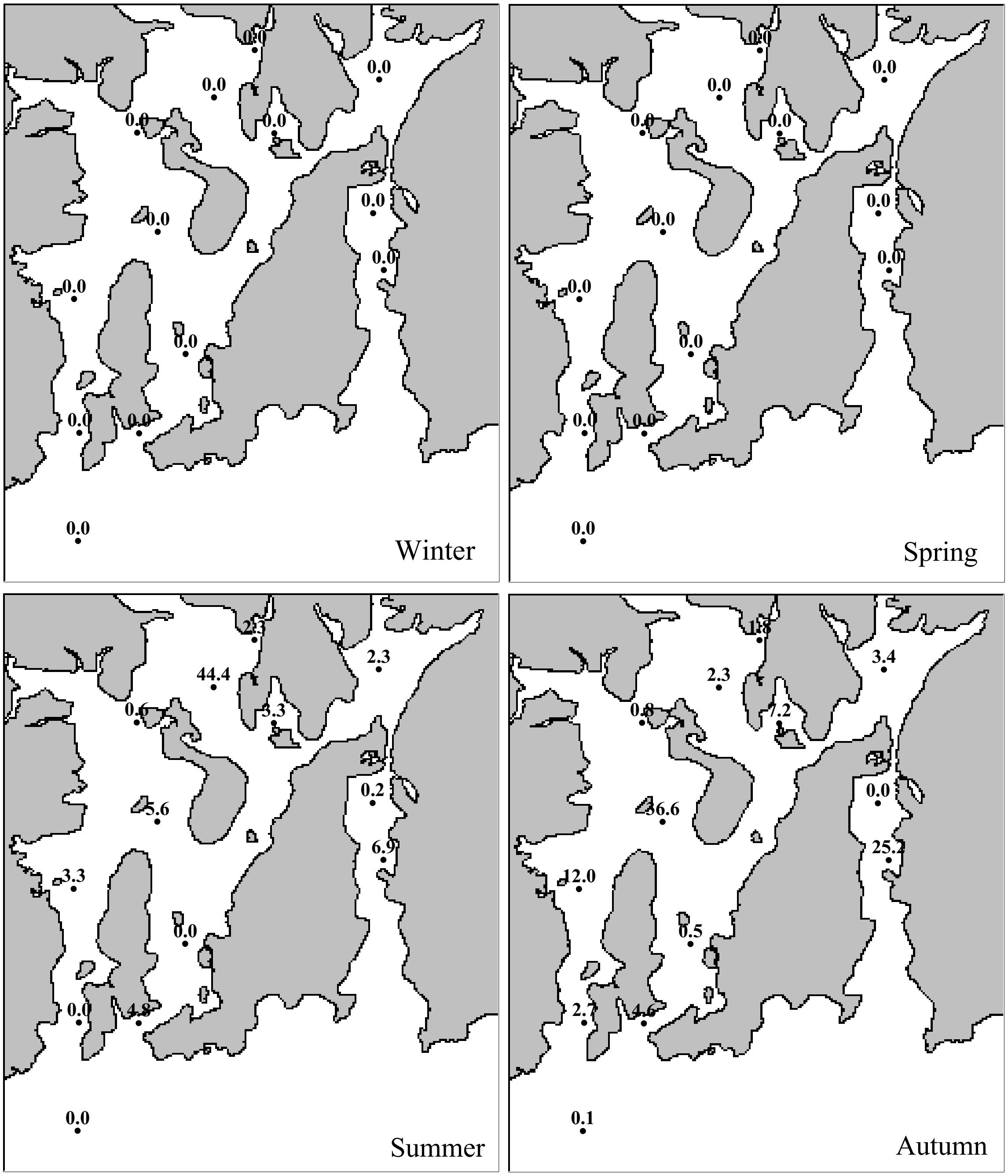


Figure 11. Distributions and abundances of juvenile bluefish collected in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid et al. (1999) for details].

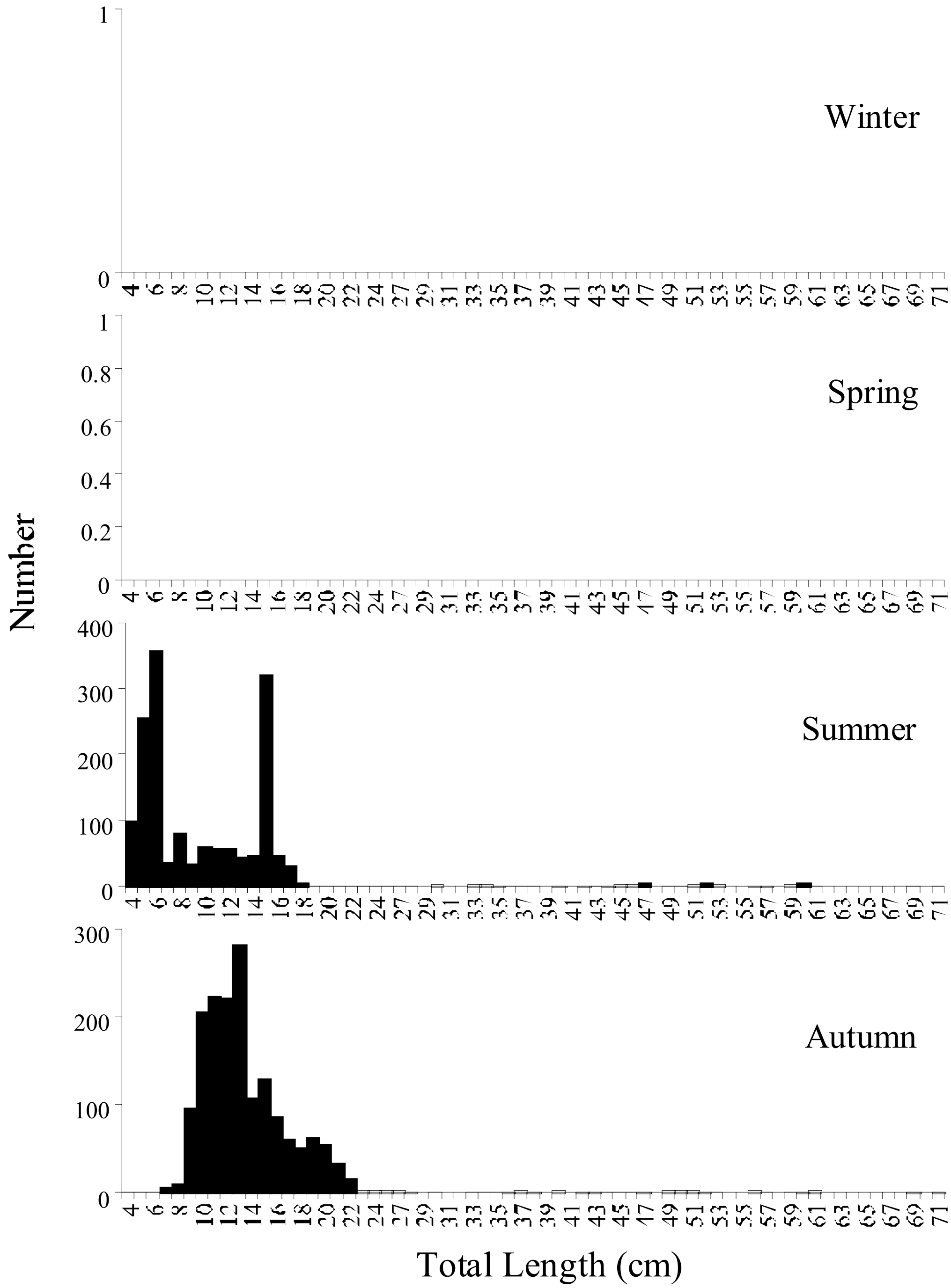


Figure 12. Seasonal length frequency distributions of bluefish collected in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys [all years combined; see Reid *et al.* (1999) for details].

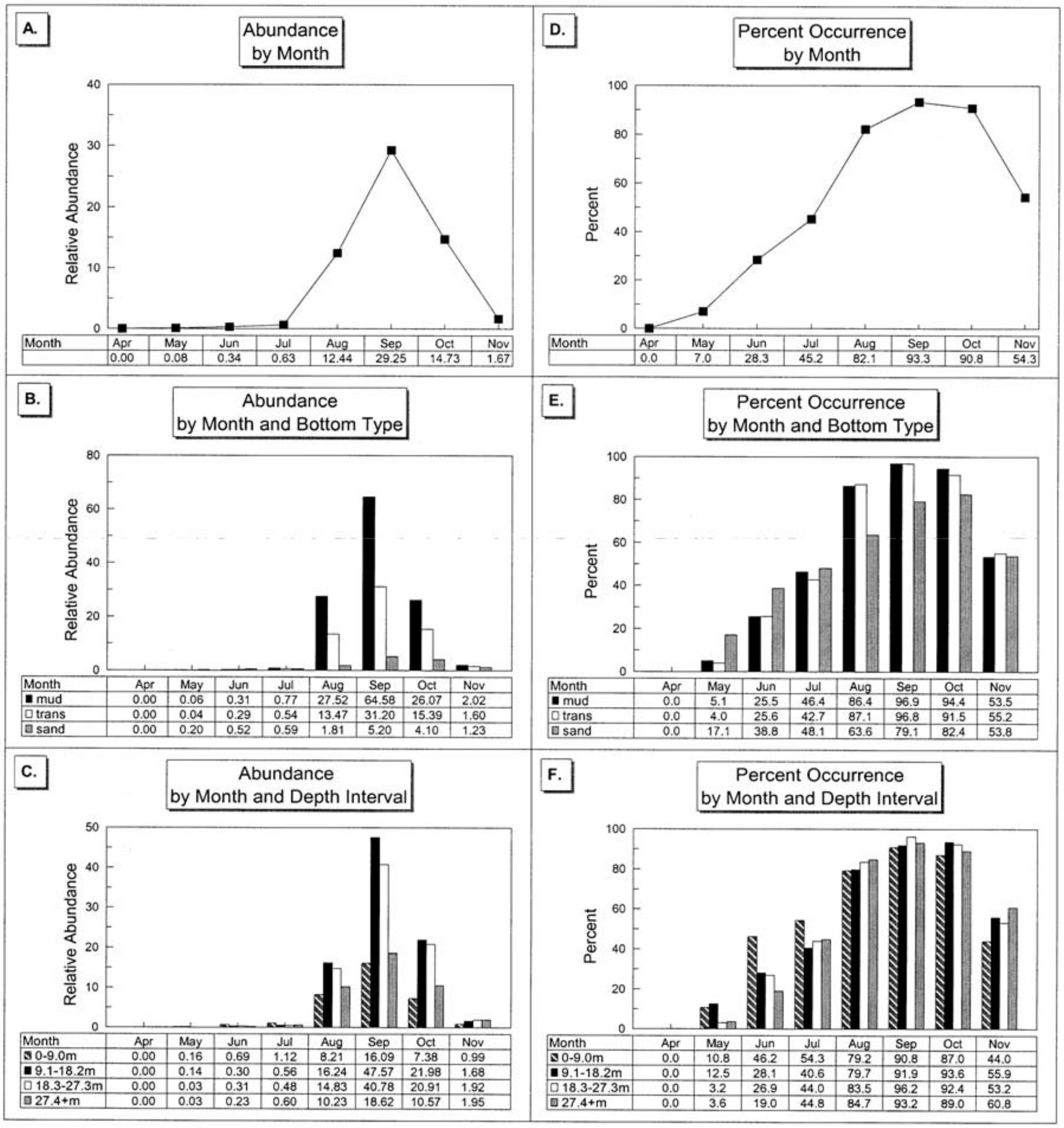


Figure 13. Relative abundance (geometric mean catch/tow) catch/tow and percent occurrence (proportion of samples in which at least one individual was observed) for juvenile and adult bluefish in Long Island Sound, by month, month and bottom type, and month and depth interval. Source: Gottschall *et al.* (2000).

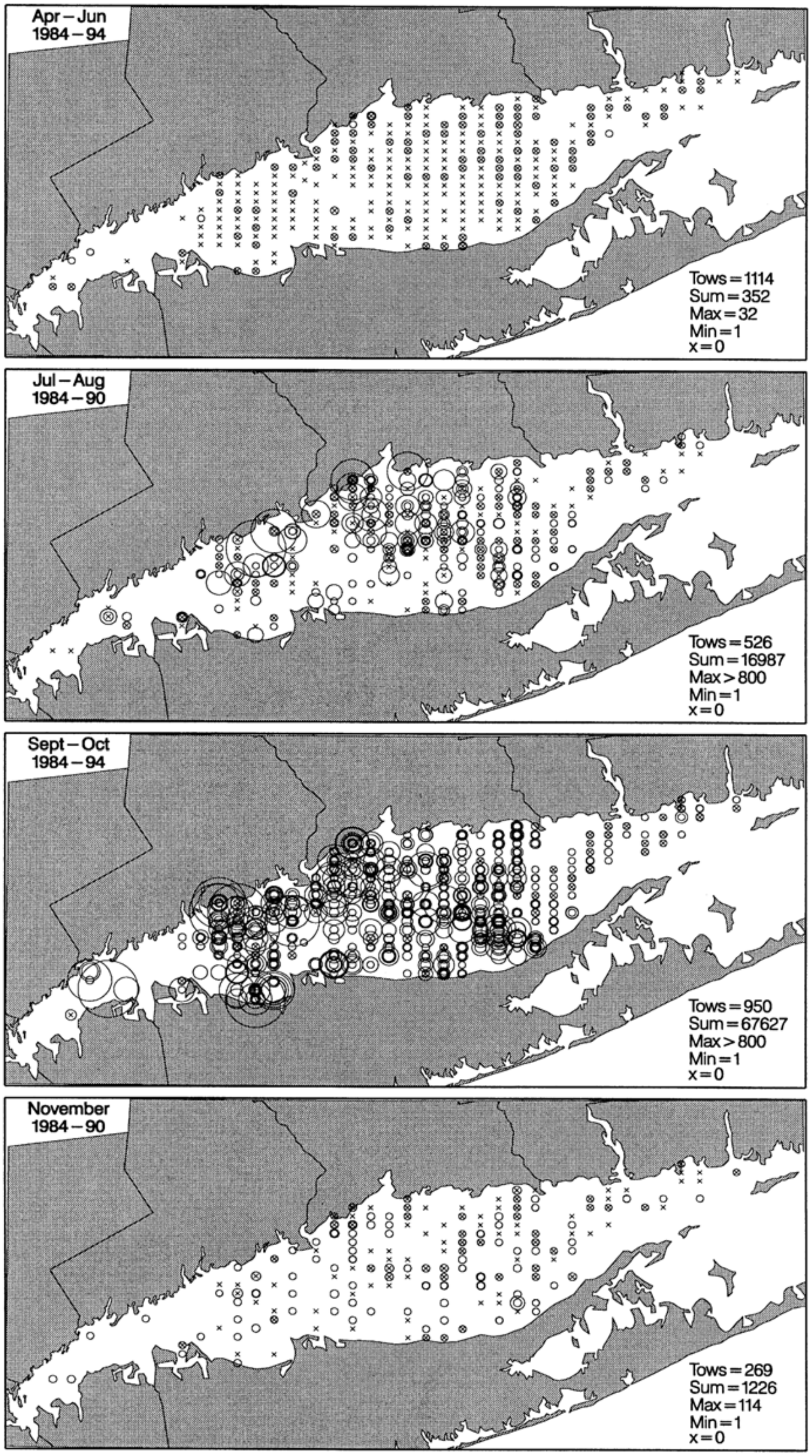


Figure 14. Distributions and abundances of juvenile and adult bluefish in Long Island Sound, based on 86,192 fish taken in 2,859 tows during the finfish surveys of the Connecticut Fisheries Division, 1984-1994. The largest circle size represents a tow with a catch of > 800 bluefish. Collections were made with a 14 m otter trawl at about 40 stations chosen by stratified random design. Source: Gottschall *et al.* (2000).

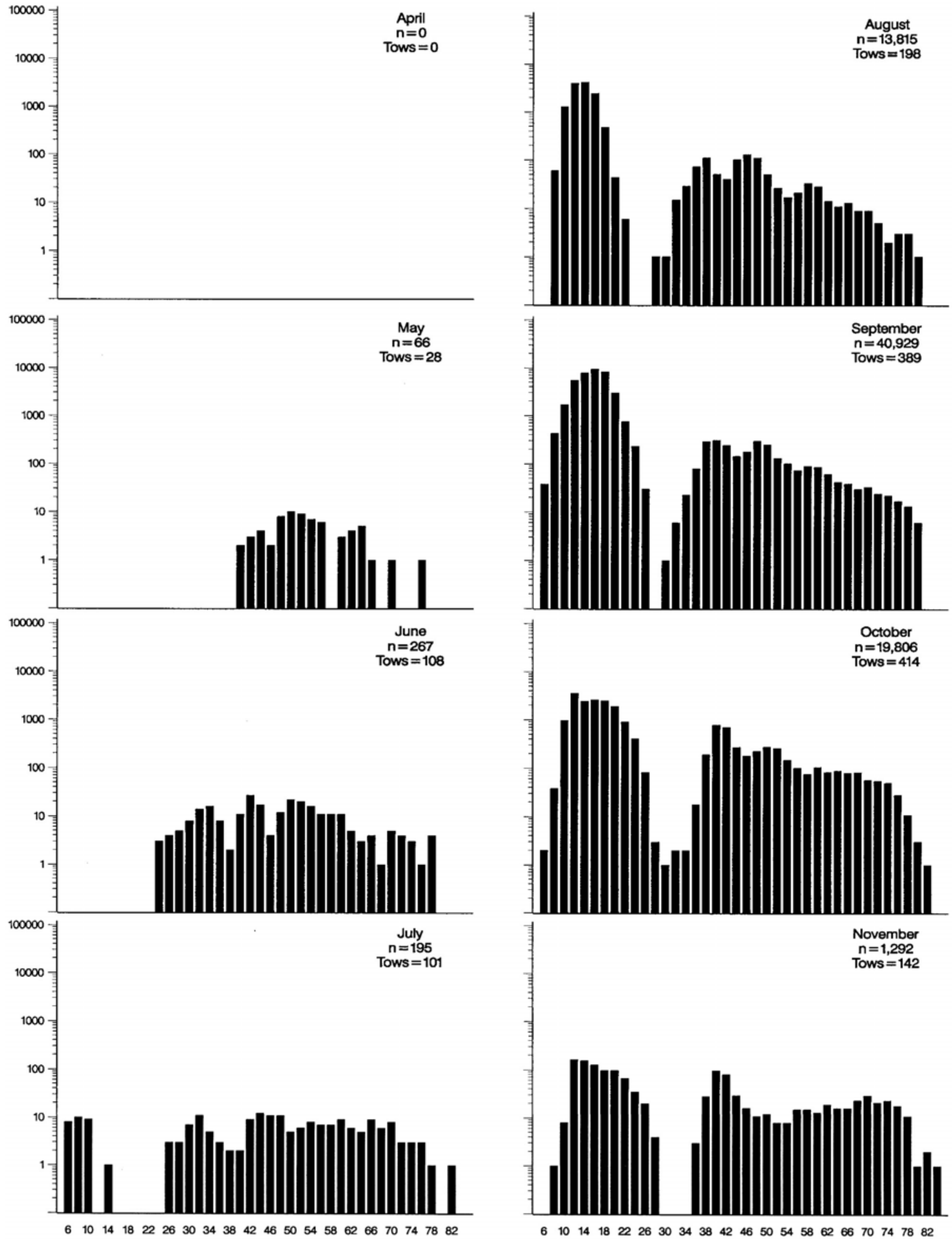


Figure 15. Monthly $\log_{10}$ length frequencies (cm) of juvenile and adult bluefish collected in Long Island Sound, based on 76,370 fish taken in 1,380 tows during the finfish surveys of the Connecticut Fisheries Division between 1989-1994. Source: Gottschall *et al.* (2000).

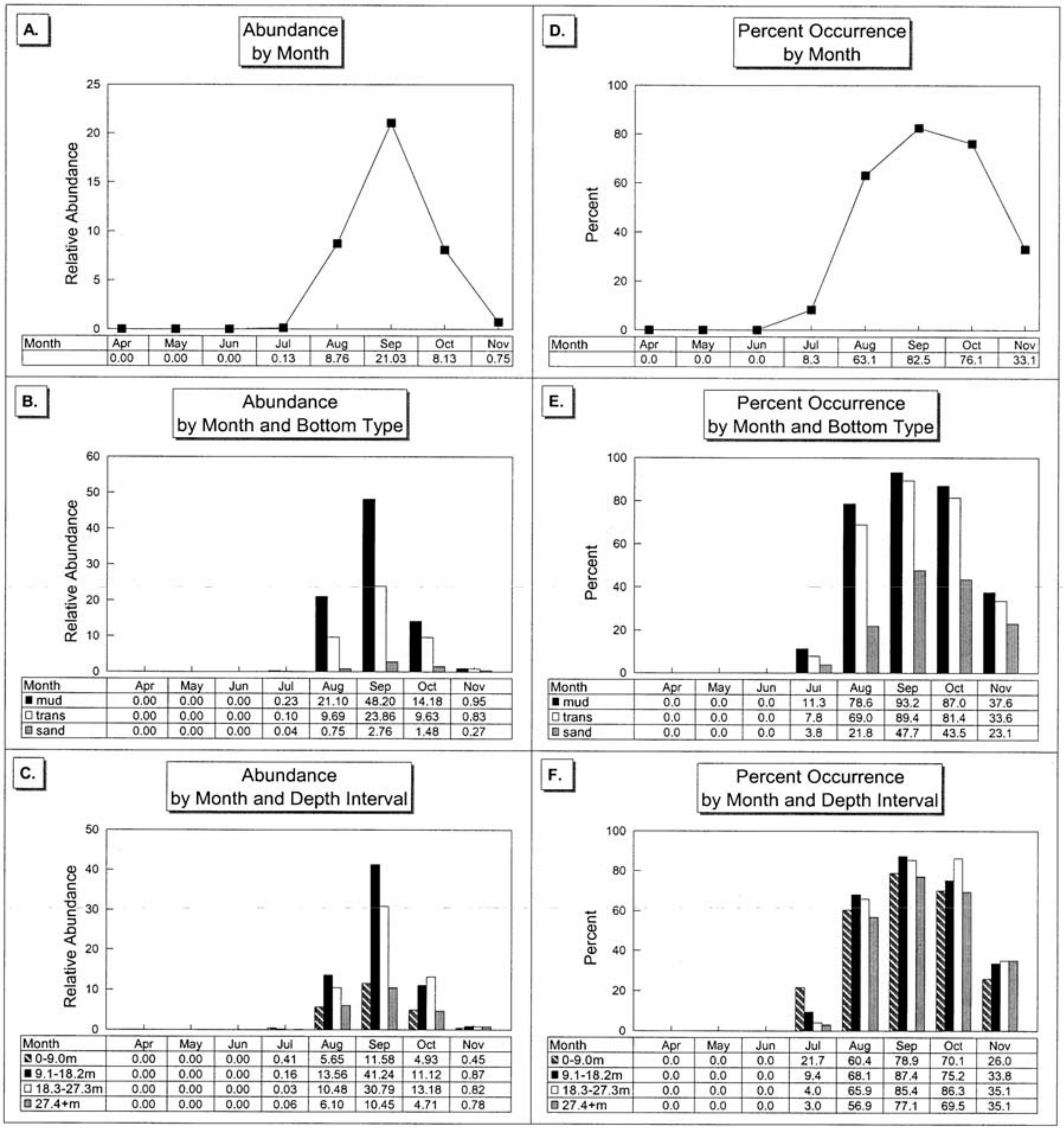


Figure 16. Relative abundance (geometric mean catch/tow) catch/tow and percent occurrence (proportion of samples in which at least one individual was observed) for young-of-year bluefish in Long Island Sound, by month, month and bottom type, and month and depth interval. Source: Gottschall *et al.* (2000).

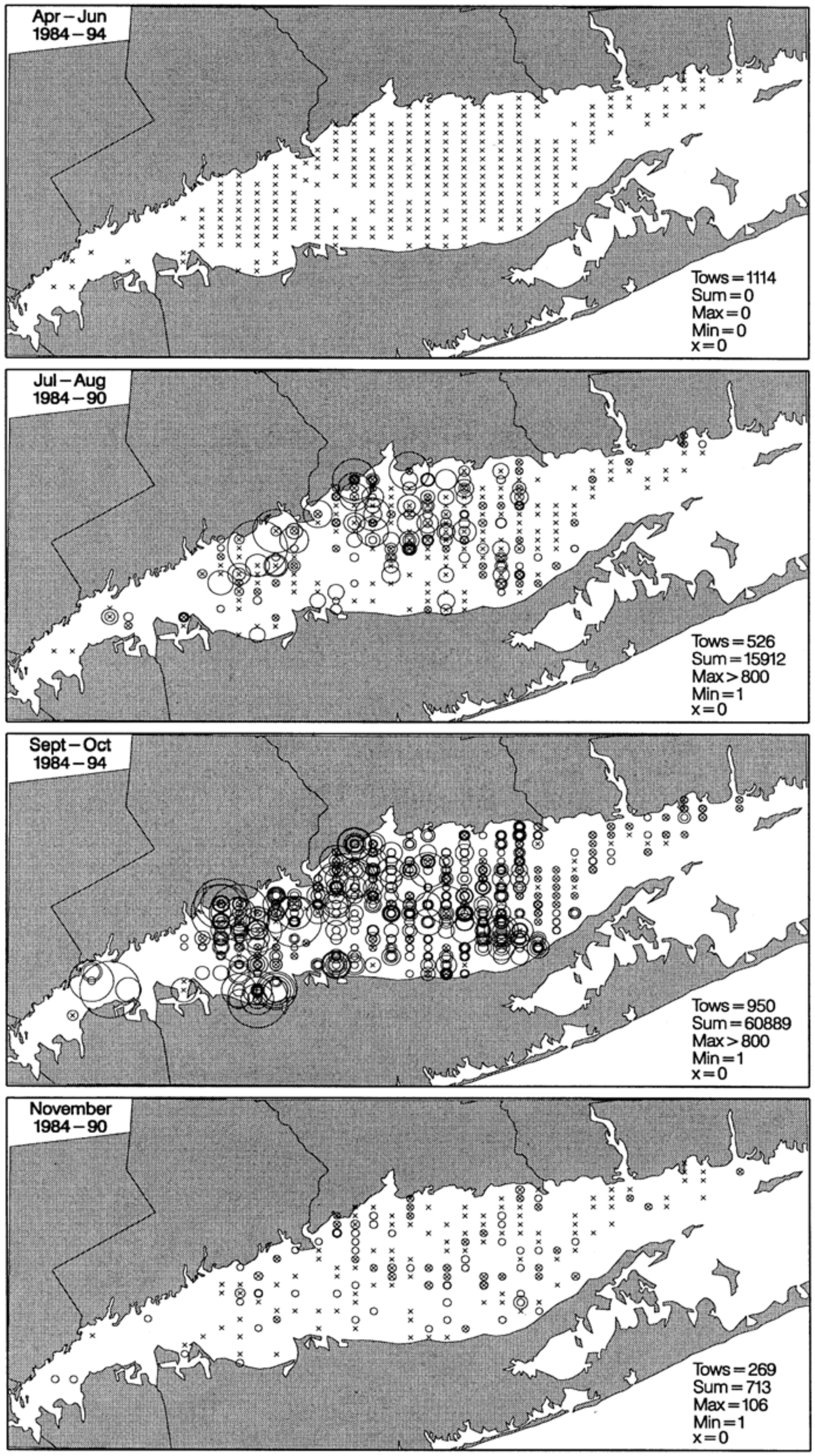


Figure 17. Distributions and abundances of young-of-year bluefish in Long Island Sound, based on 77,514 young-of-year fish taken in 2,859 tows during the finfish surveys of the Connecticut Fisheries Division, 1984-1994. The largest circle size represents a tow with a catch of > 800 bluefish. Collections were made with a 14 m otter trawl at about 40 stations chosen by stratified random design. Source: Gottschall *et al.* (2000).

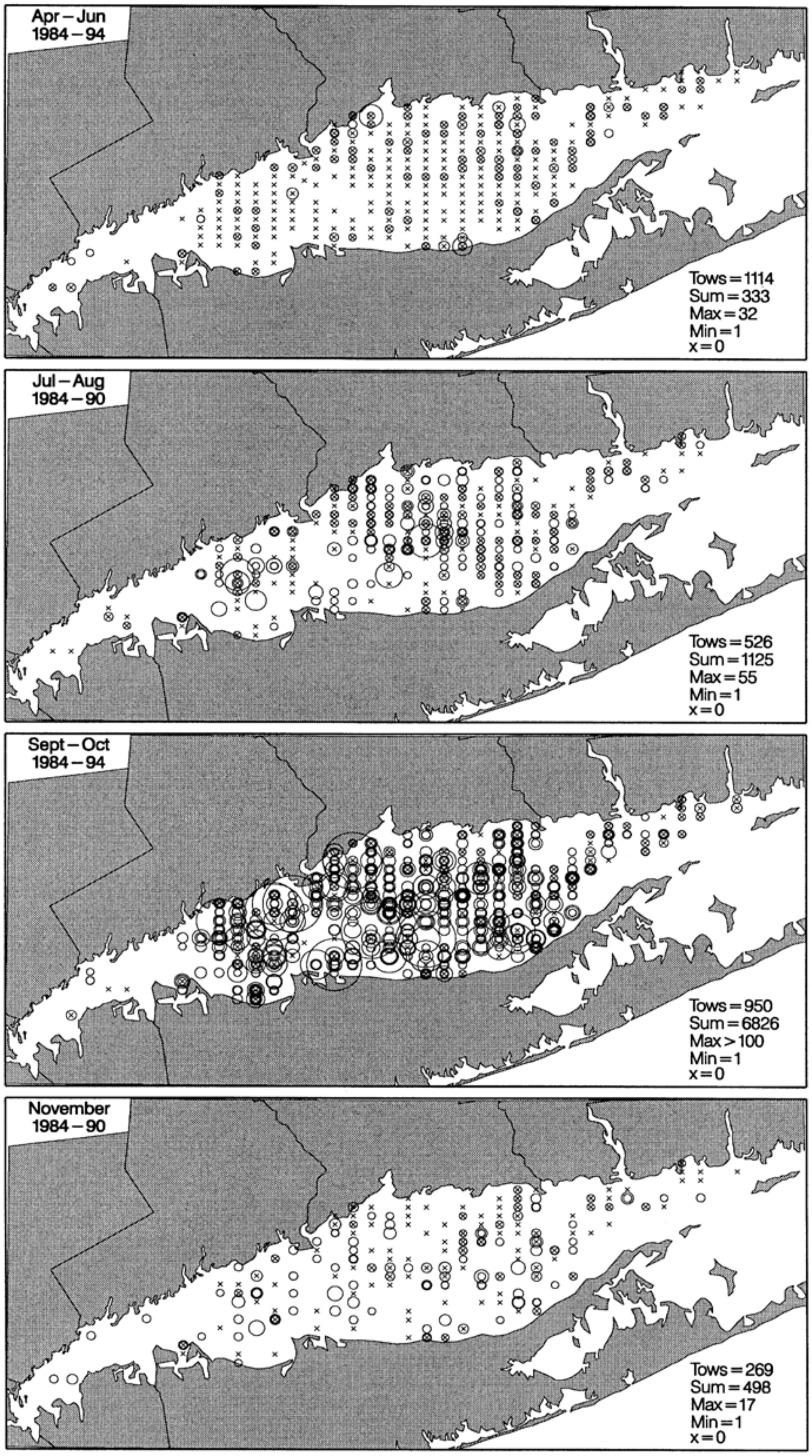


Figure 18. Distributions and abundances of age 1+ bluefish in Long Island Sound, based on 8,782 age 1+ fish taken in 2,859 tows during the finfish surveys of the Connecticut Fisheries Division, 1984-1994. The largest circle size represents a tow with a catch of > 100 bluefish. Collections were made with a 14 m otter trawl at about 40 stations chosen by stratified random design. Source: Gottschall *et al.* (2000).

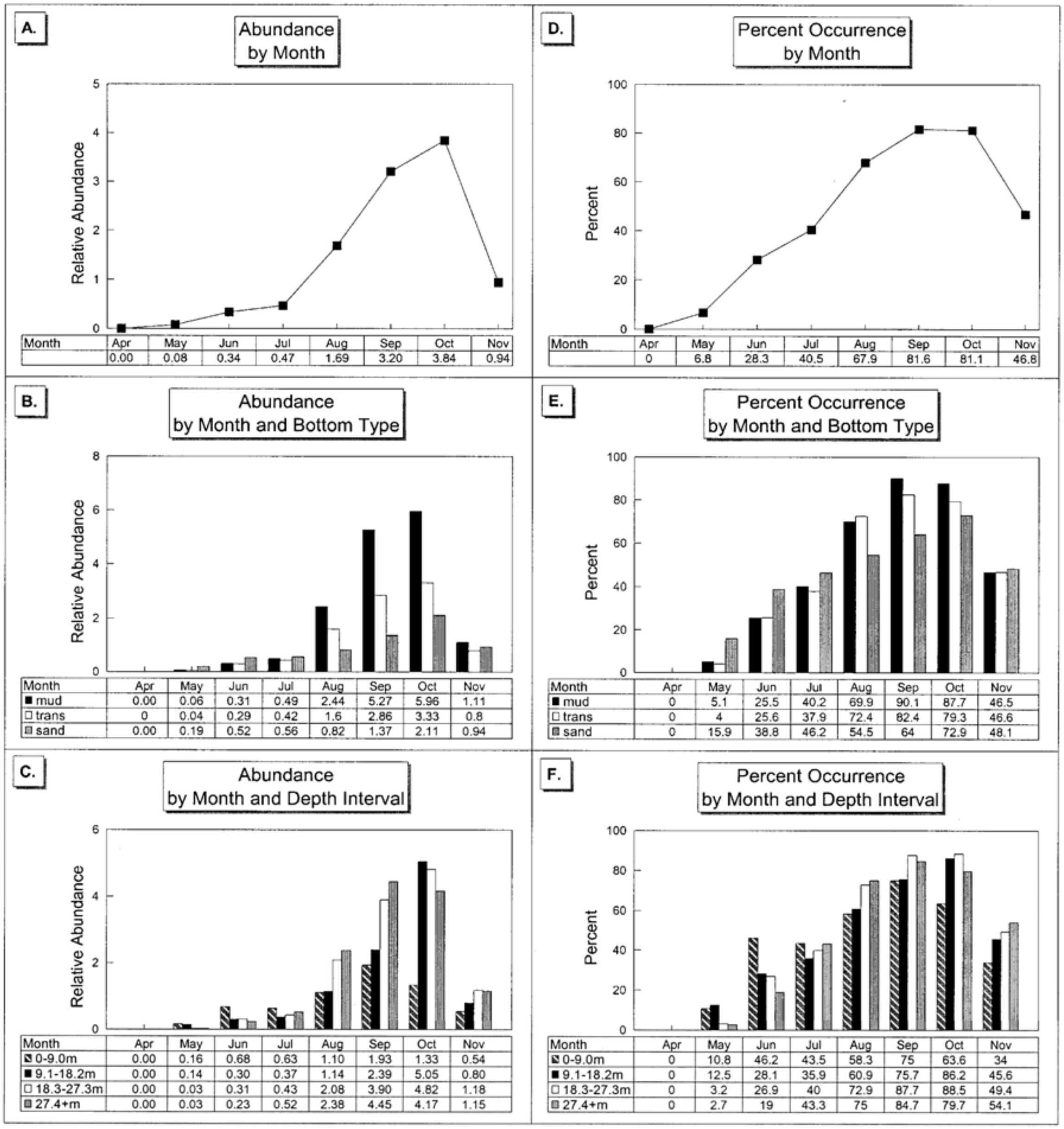


Figure 19. Relative abundance (geometric mean catch/tow) catch/tow and percent occurrence (proportion of samples in which at least one individual was observed) for age 1+ bluefish in Long Island Sound, by month, month and bottom type, and month and depth interval. Source: Gottschall *et al.* (2000).

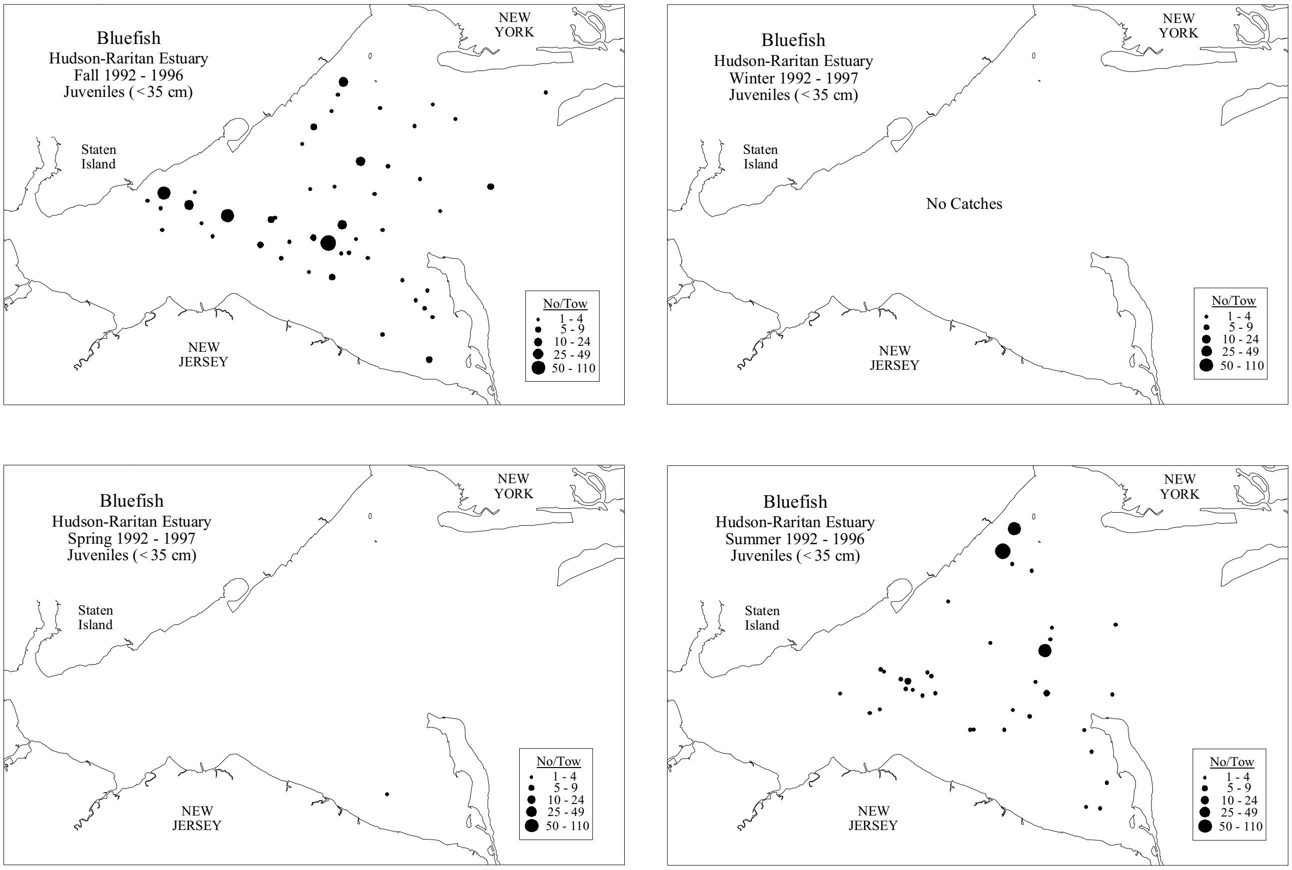


Figure 20. Seasonal distribution and abundance of juvenile bluefish in the Hudson-Raritan estuary collected during Hudson-Raritan estuary trawl surveys, 1992–1997 [see Reid *et al.* (1999) for details].

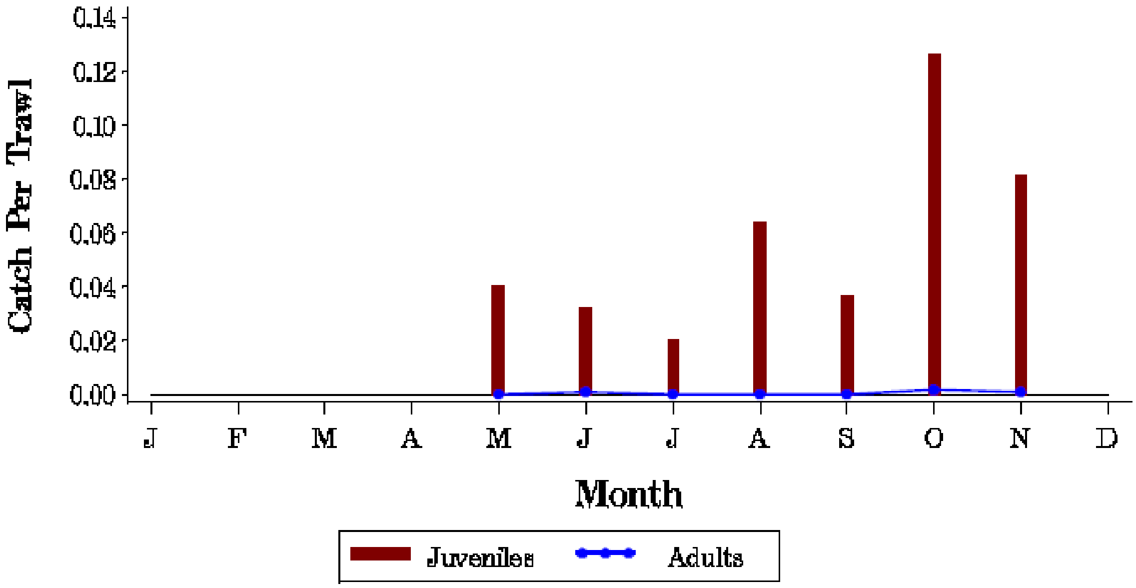


Figure 21. Catch per unit effort for total catch of juvenile and adult bluefish in Chesapeake Bay and tributaries, from the Virginia Institute of Marine Science's (VIMS) trawl surveys, 1988-1999 (all years combined). Source: Geer (2002).

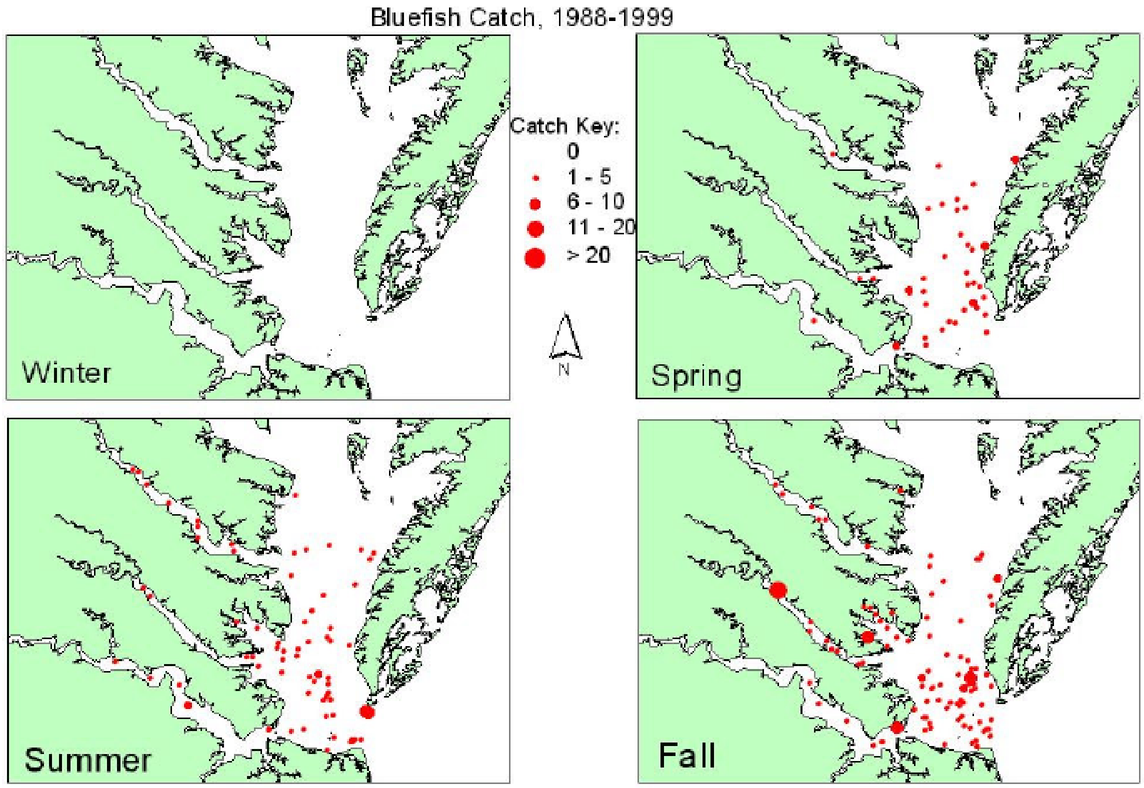


Figure 22. Seasonal distribution and abundance of bluefish in Chesapeake Bay and tributaries, from the VIMS trawl surveys, 1988-1999 (all years combined). Monthly surveys were conducted using a random stratified design of the main stem of the Bay using a 9.1 m semi-balloon otter trawl with 38 mm mesh and 6.4 mm cod end with a tow duration of five minutes. Source: Geer (2002).

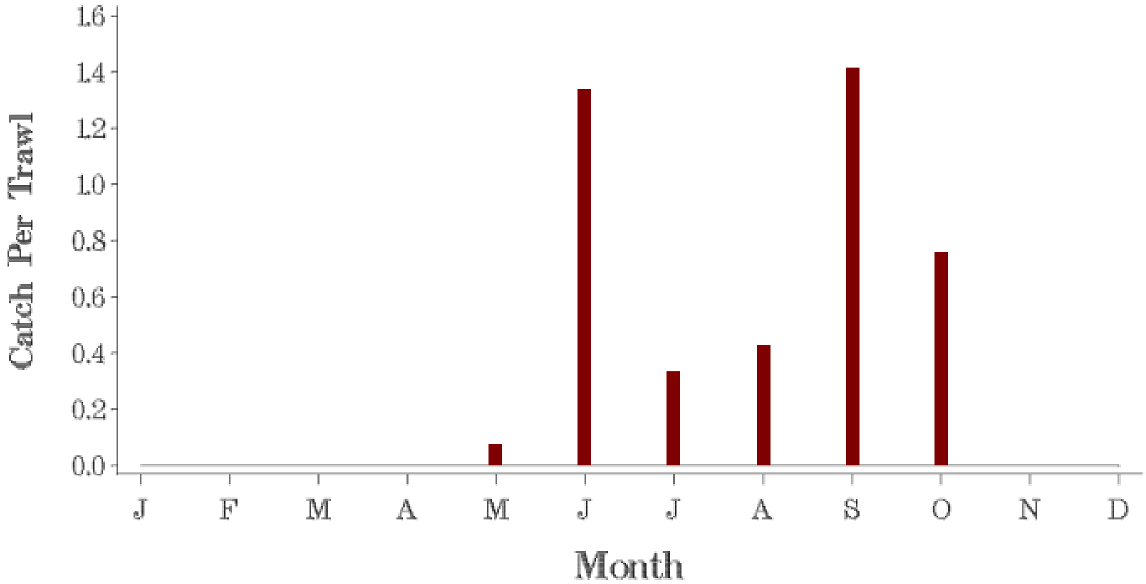


Figure 23. Catch per unit effort for total catch of juvenile bluefish in Chesapeake Bay, from the VIMS seine surveys, 1994-1999 (all years combined). Source: Geer (2002).

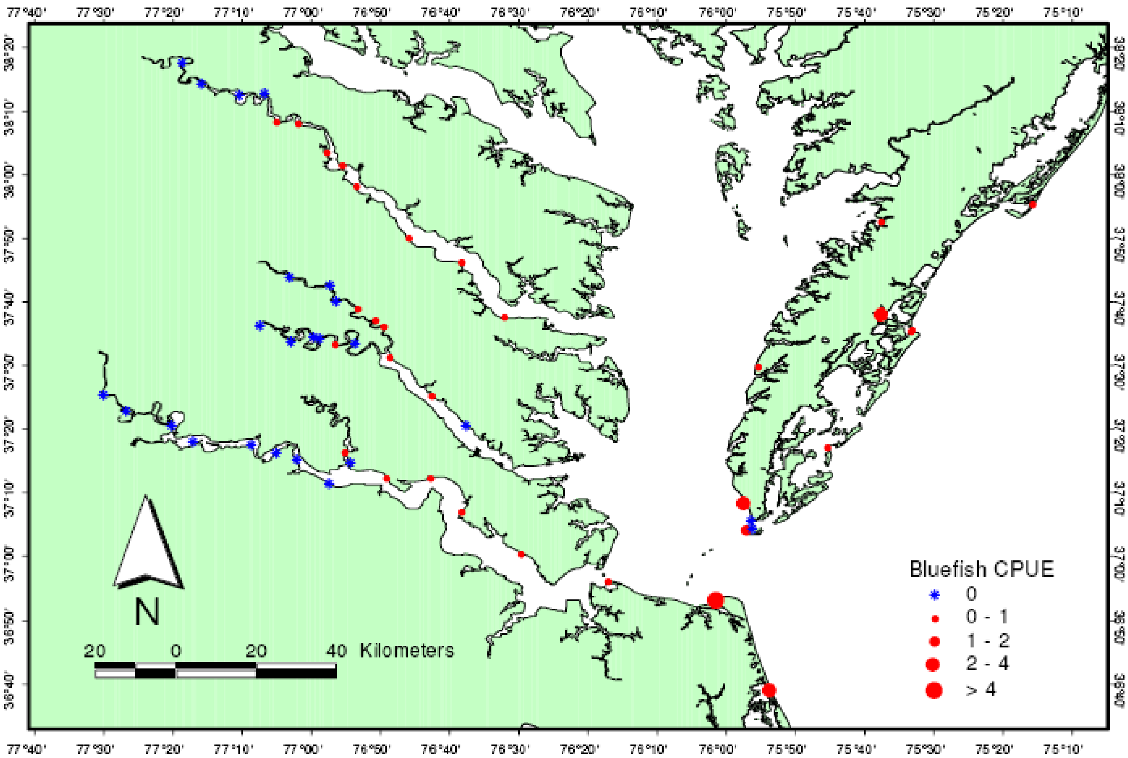


Figure 24. Juvenile bluefish catch per unit effort by site from the VIMS beach seine surveys, 1994-1999 (all years combined). Source: Geer (2002).

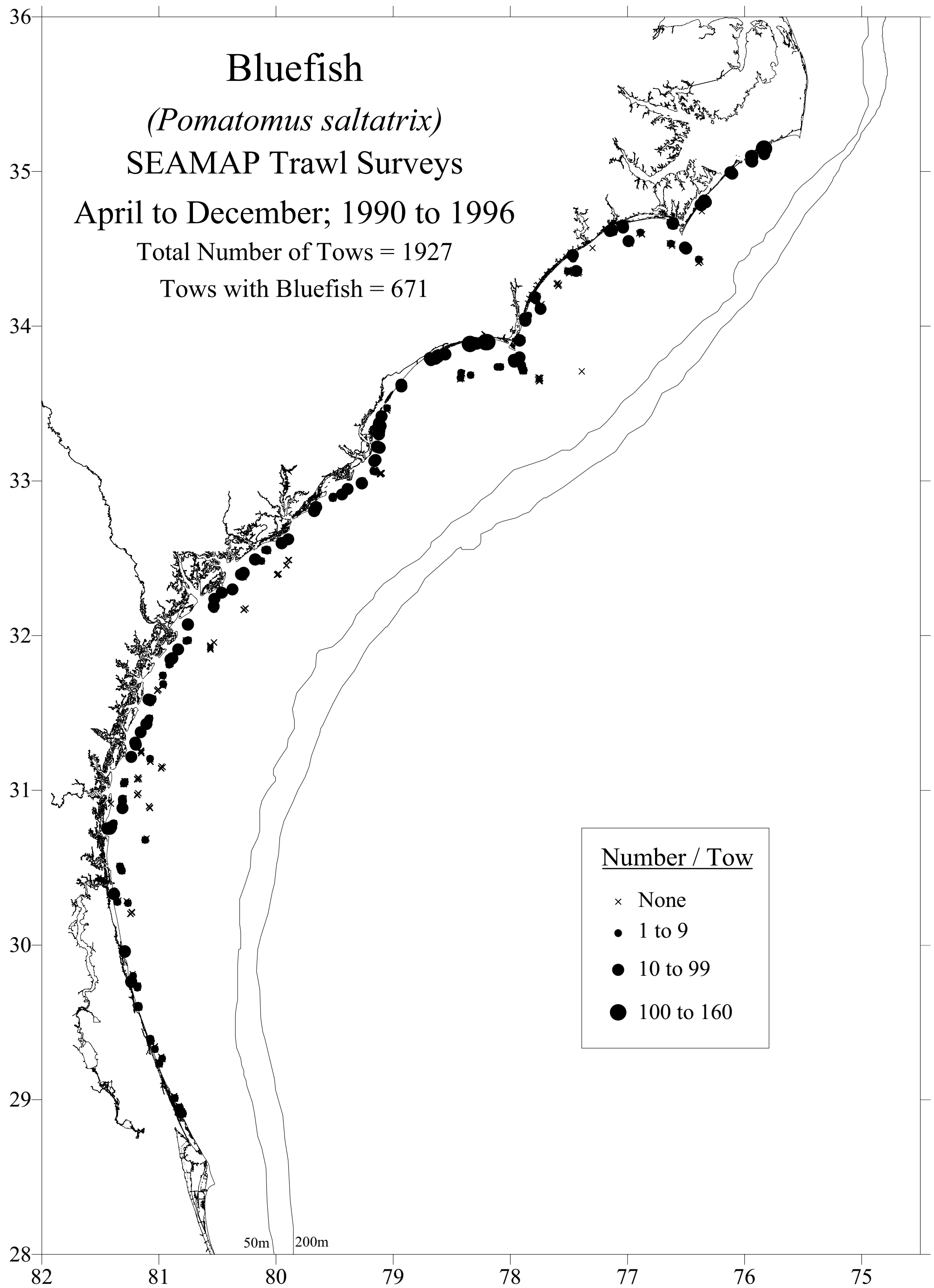


Figure 25. Distribution and abundance of bluefish in the South Atlantic Bight collected during SEAMAP bottom trawl surveys [1990-1996, all years combined; see Reid *et al.* (1999) for details].

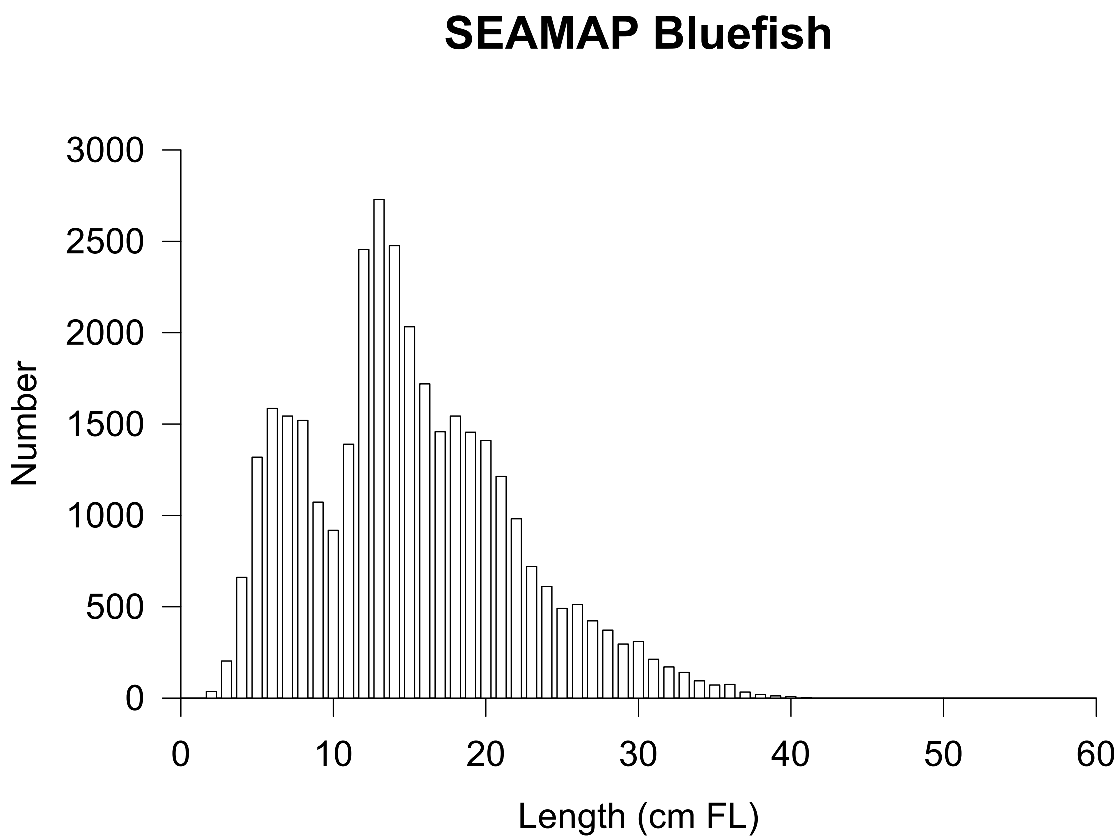


Figure 26. Length frequency distribution of bluefish in the South Atlantic Bight collected during SEAMAP bottom trawl surveys (1990-1996, all years combined).

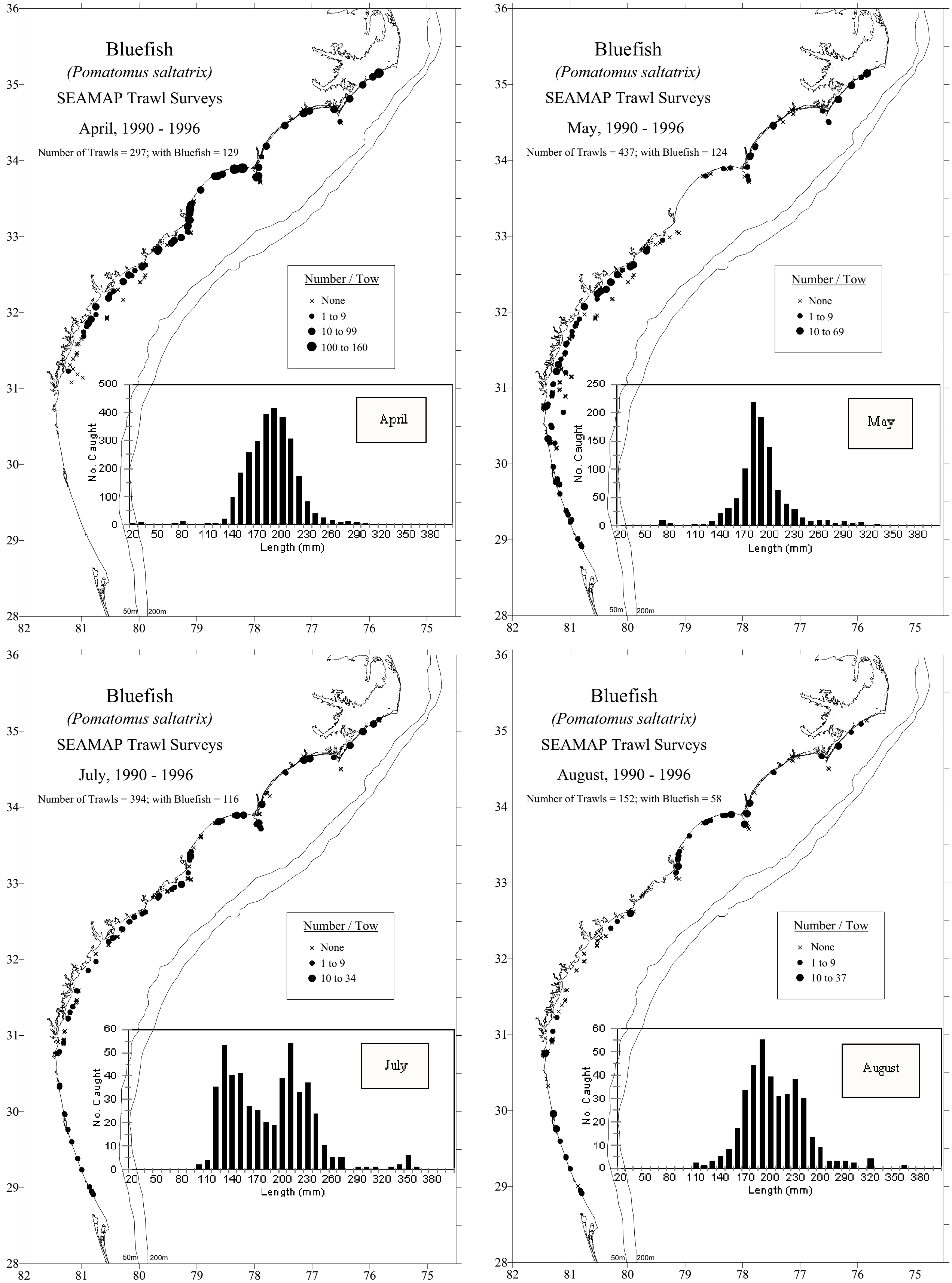
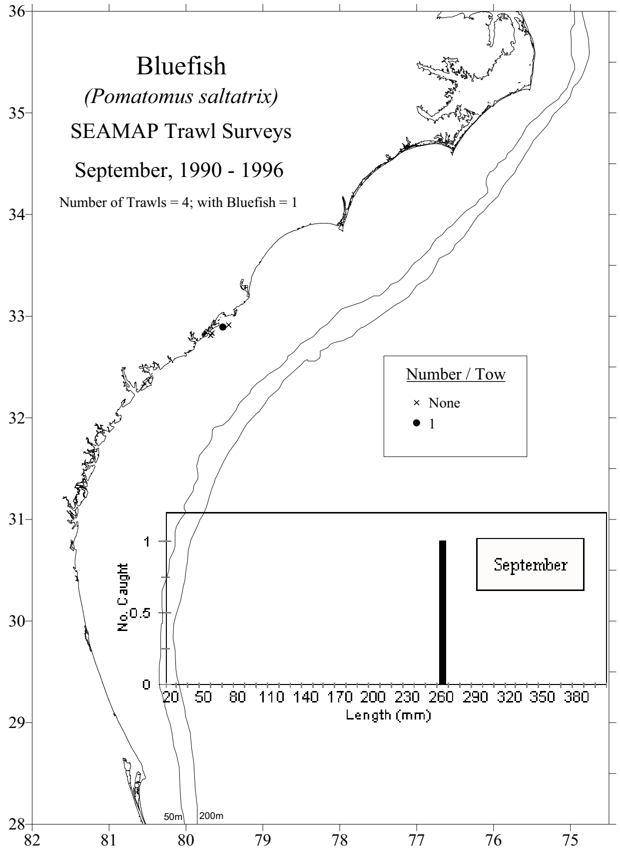
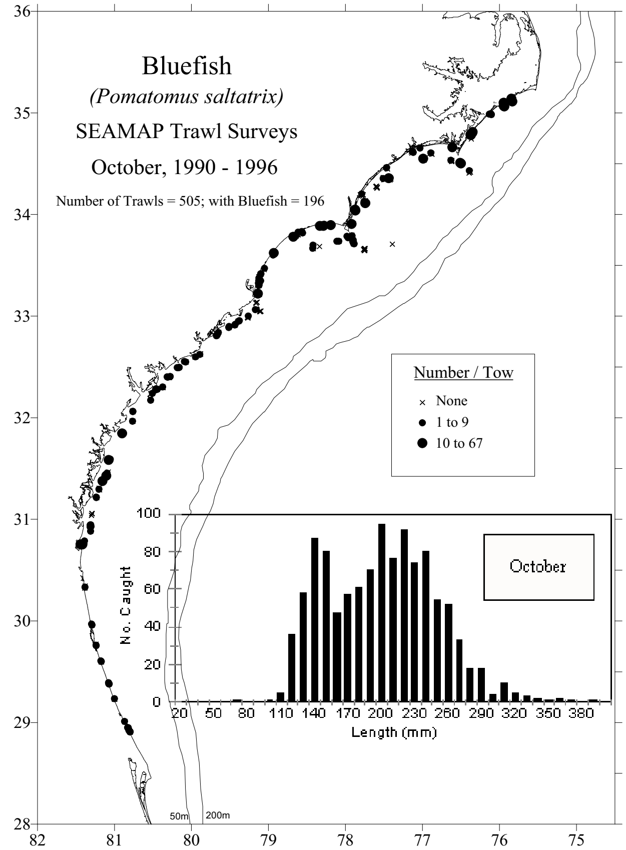


Figure 27. Monthly distribution, abundance, and length frequency distribution of bluefish in the South Atlantic Bight collected during SEAMAP bottom trawl surveys (1990-1996, all years combined).





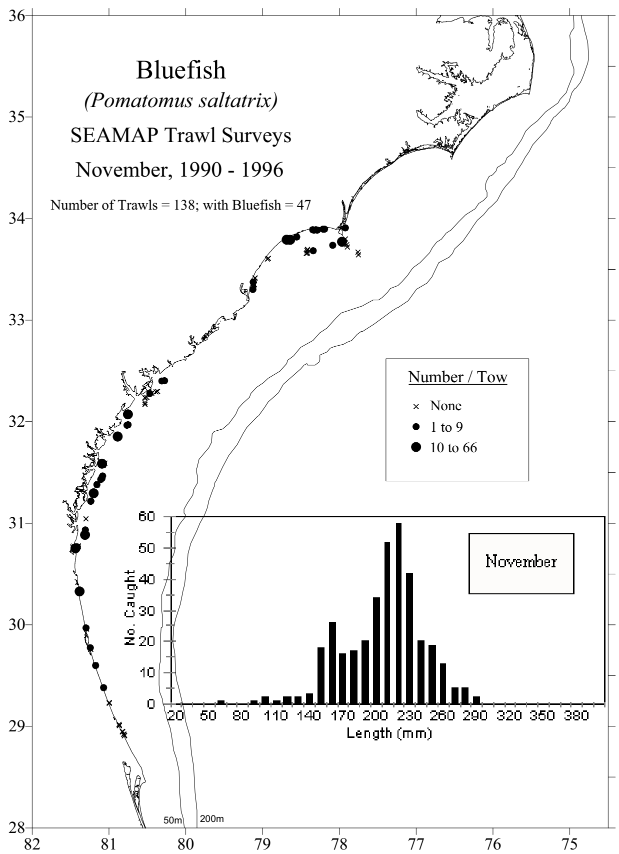


Figure 27. Continued.

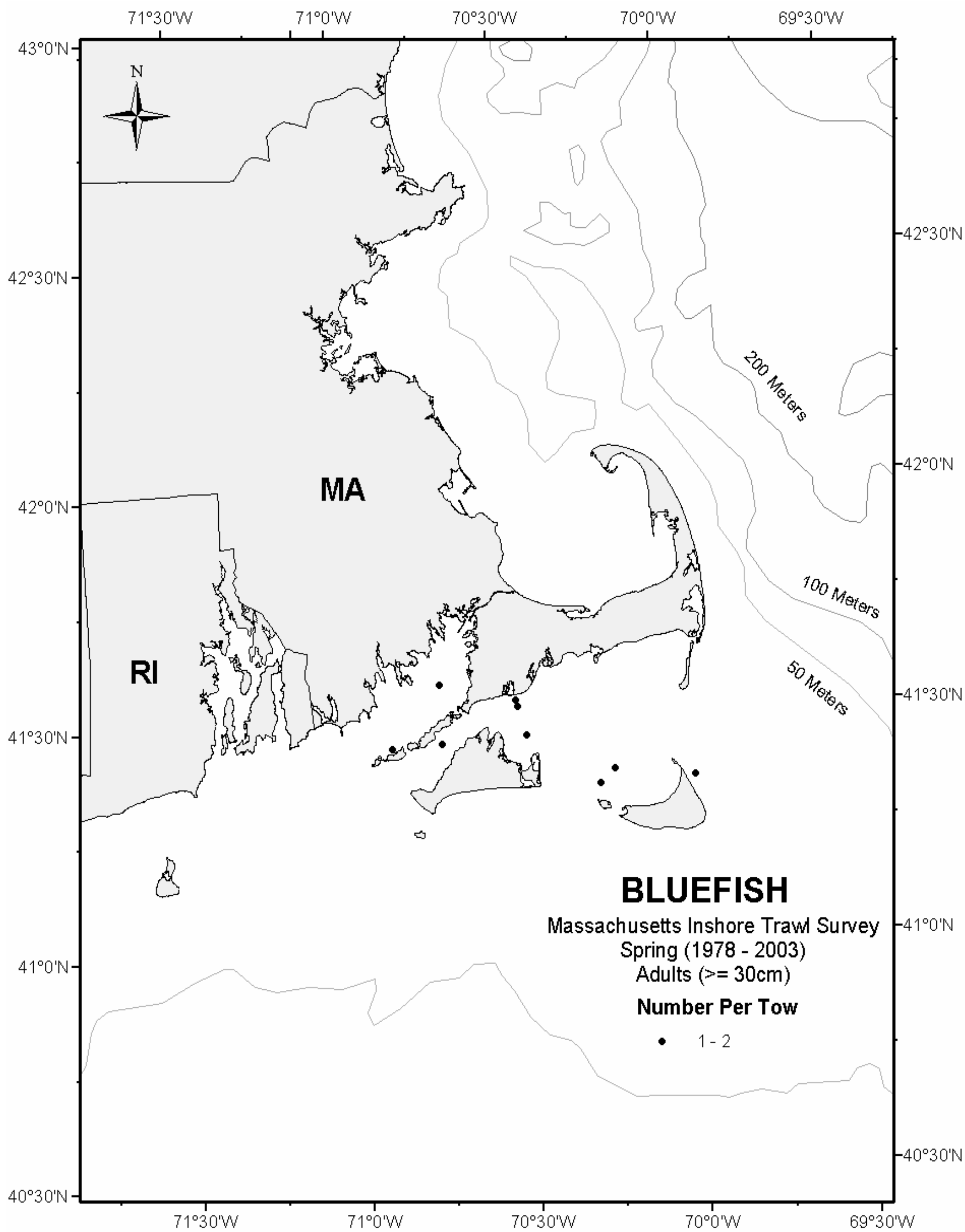


Figure 28. Distributions and abundances of adult bluefish in Massachusetts coastal waters collected during the spring and fall Massachusetts inshore trawl surveys (1978-2003, all years combined). Survey stations where adults were not found are not shown.

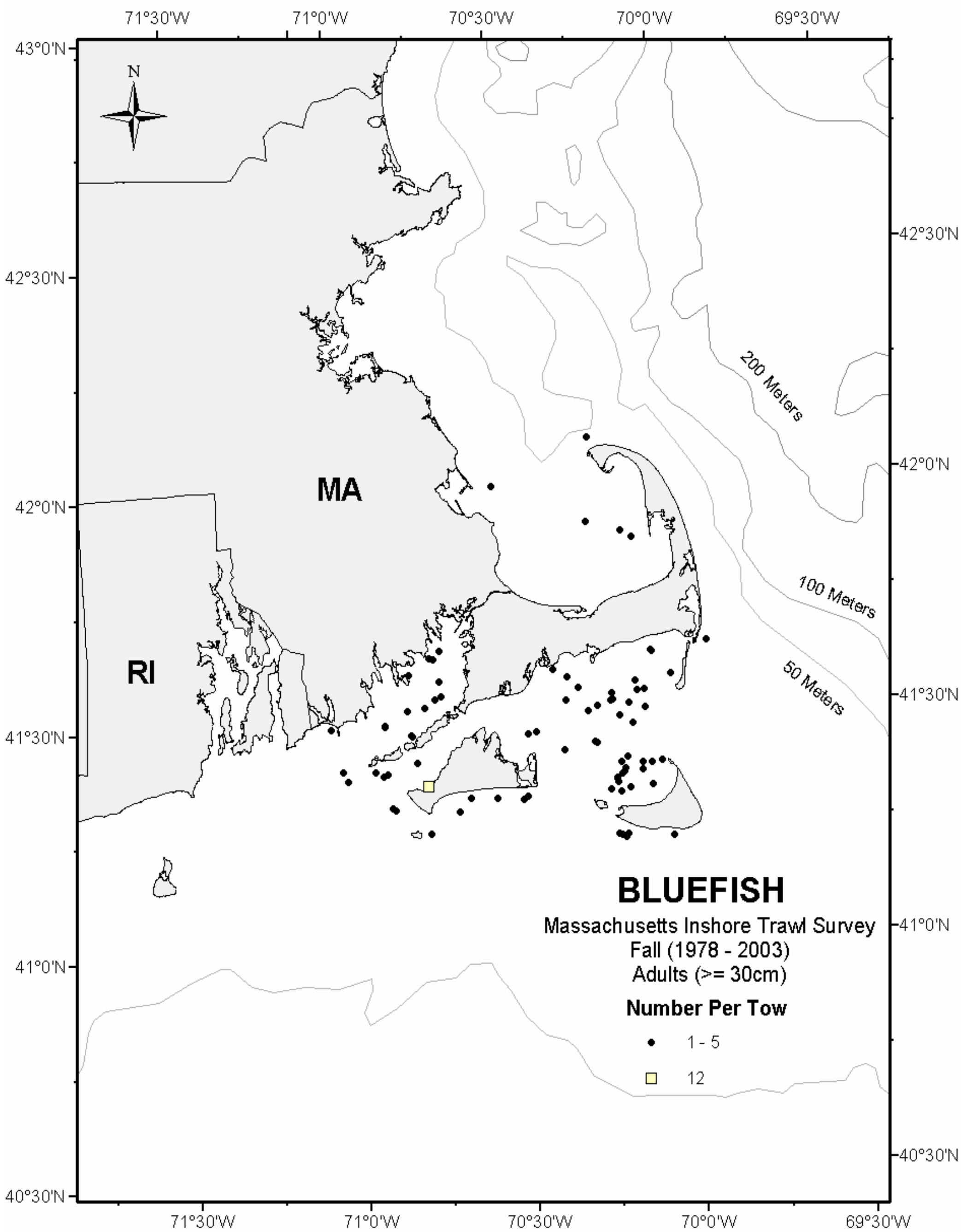


Figure 28. Continued.

Bluefish Adults (>= 35 cm)

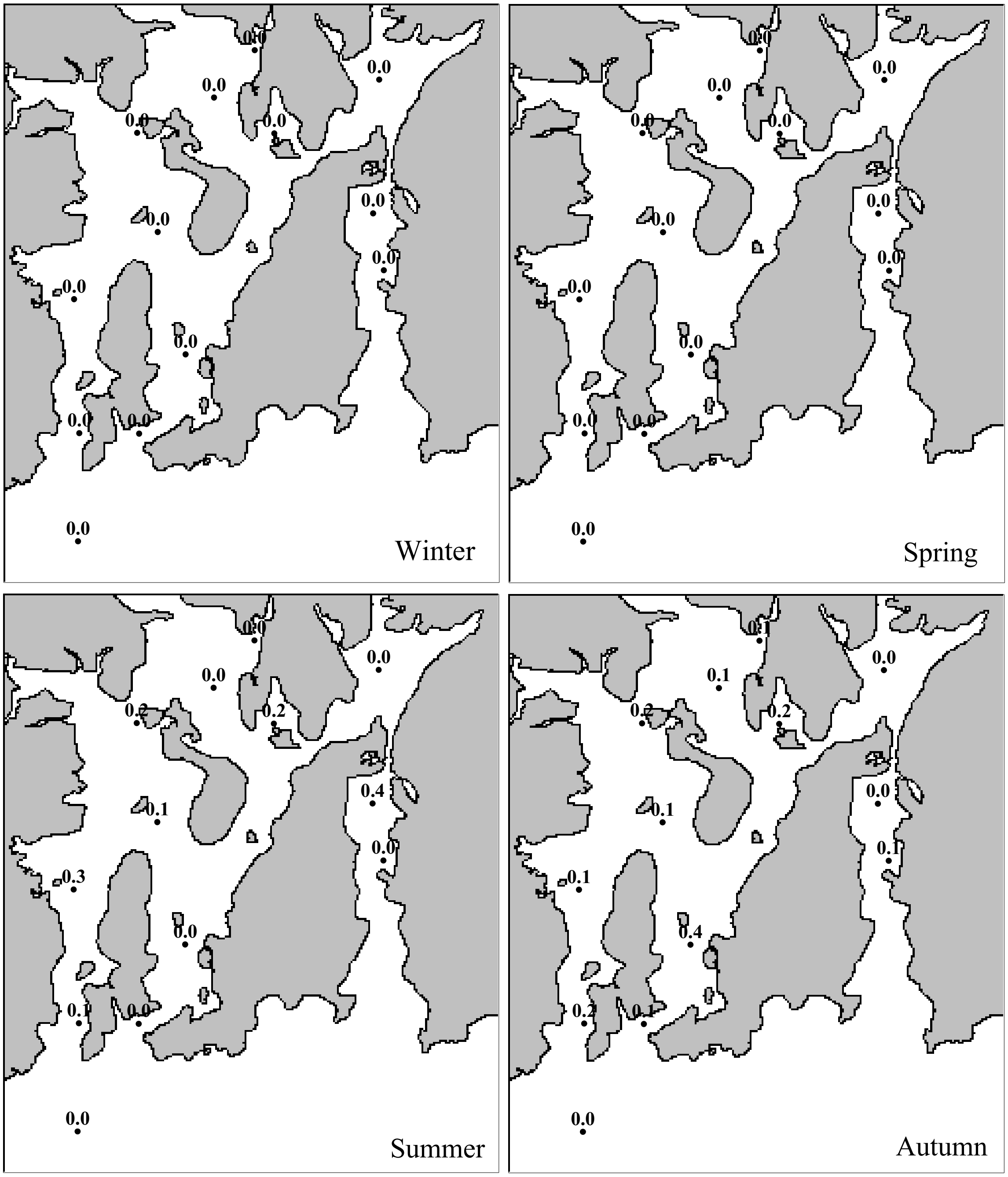


Figure 29. Distributions and abundances of adult bluefish collected in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid et al. (1999) for details].

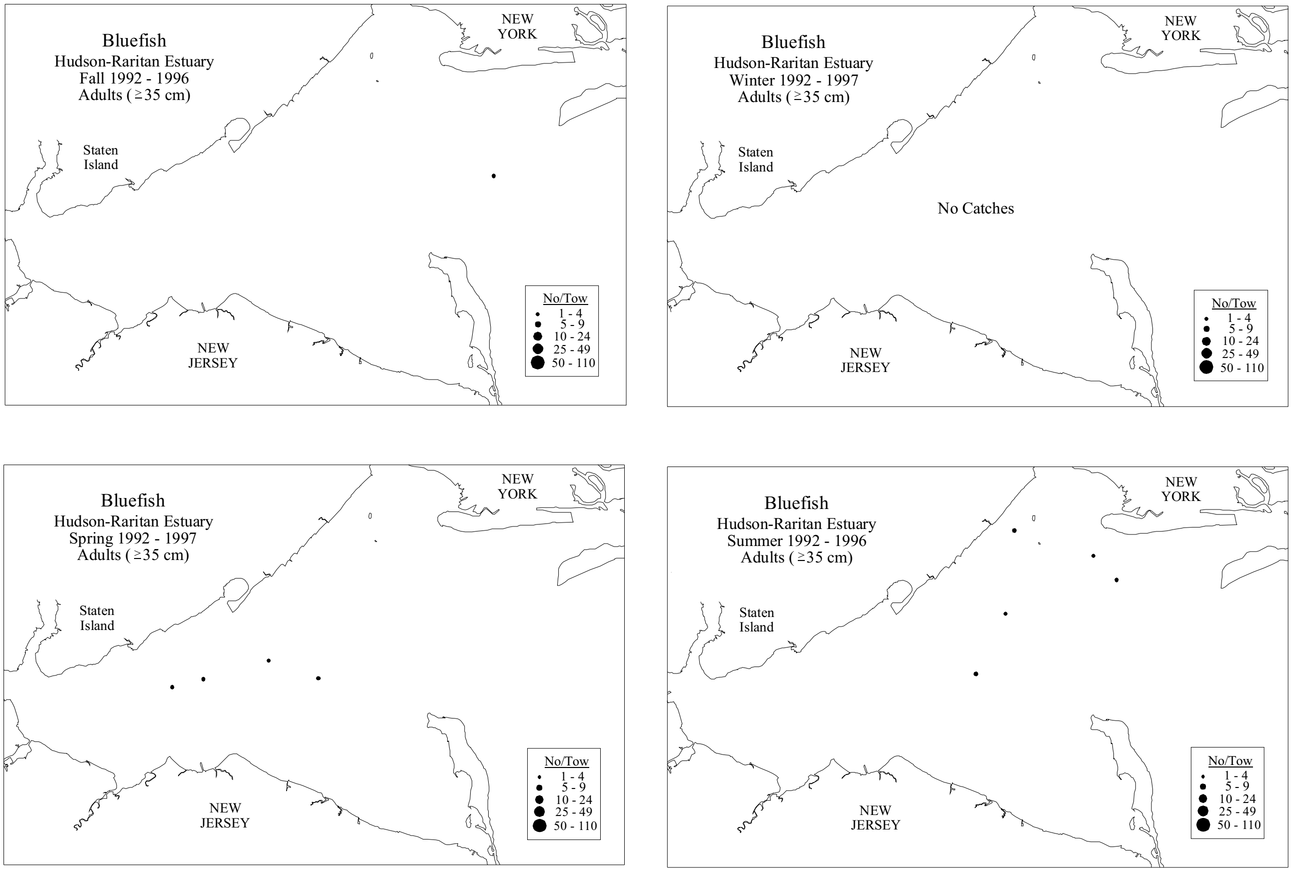


Figure 30. Seasonal distribution and abundance of adult bluefish in the Hudson-Raritan estuary collected during Hudson-Raritan estuary trawl surveys, 1992–1997 [see Reid *et al.* (1999) for details].

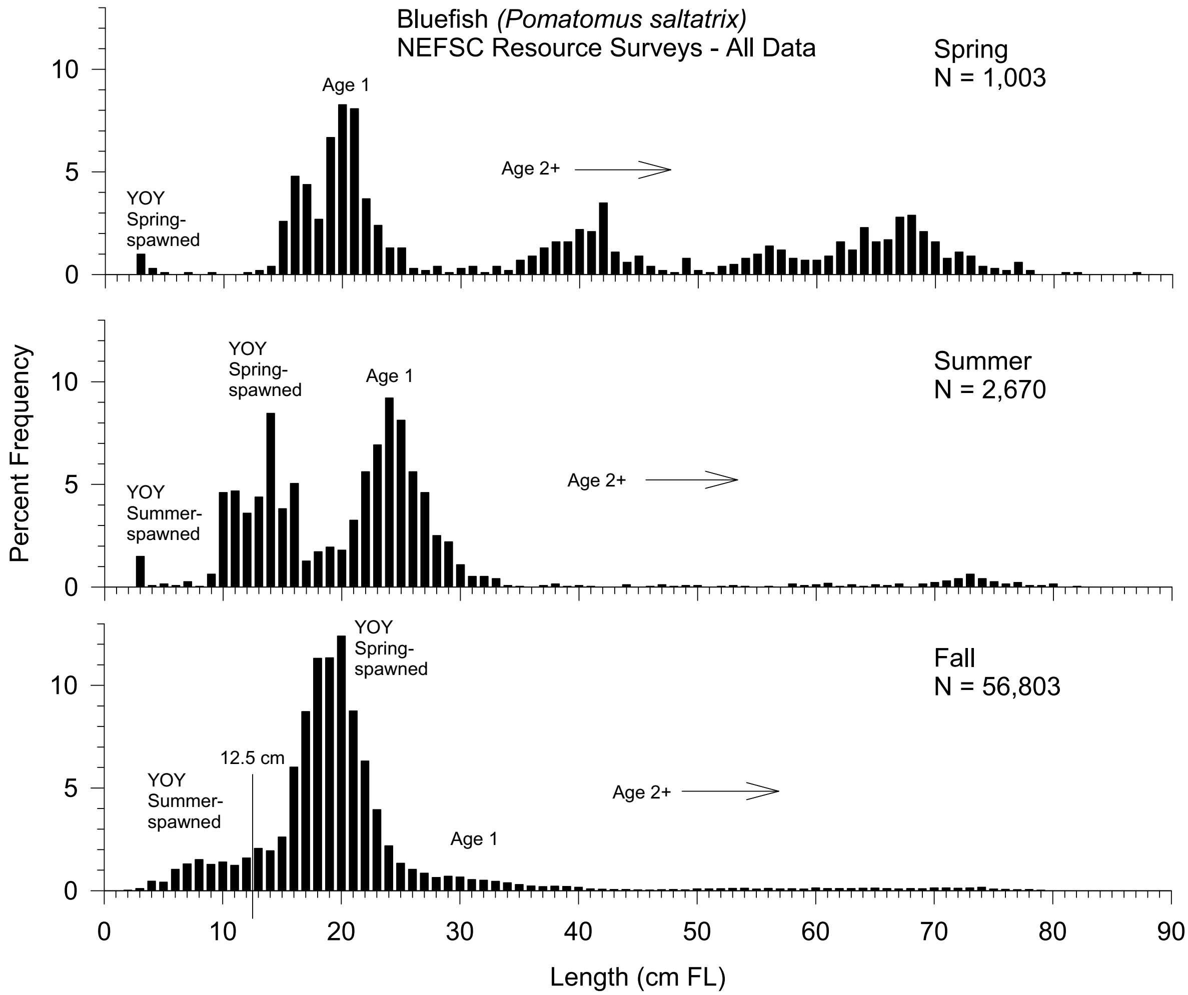


Figure 31. Seasonal length frequency distributions used to determine bluefish size and age cutoffs in NEFSC bottom trawl surveys.

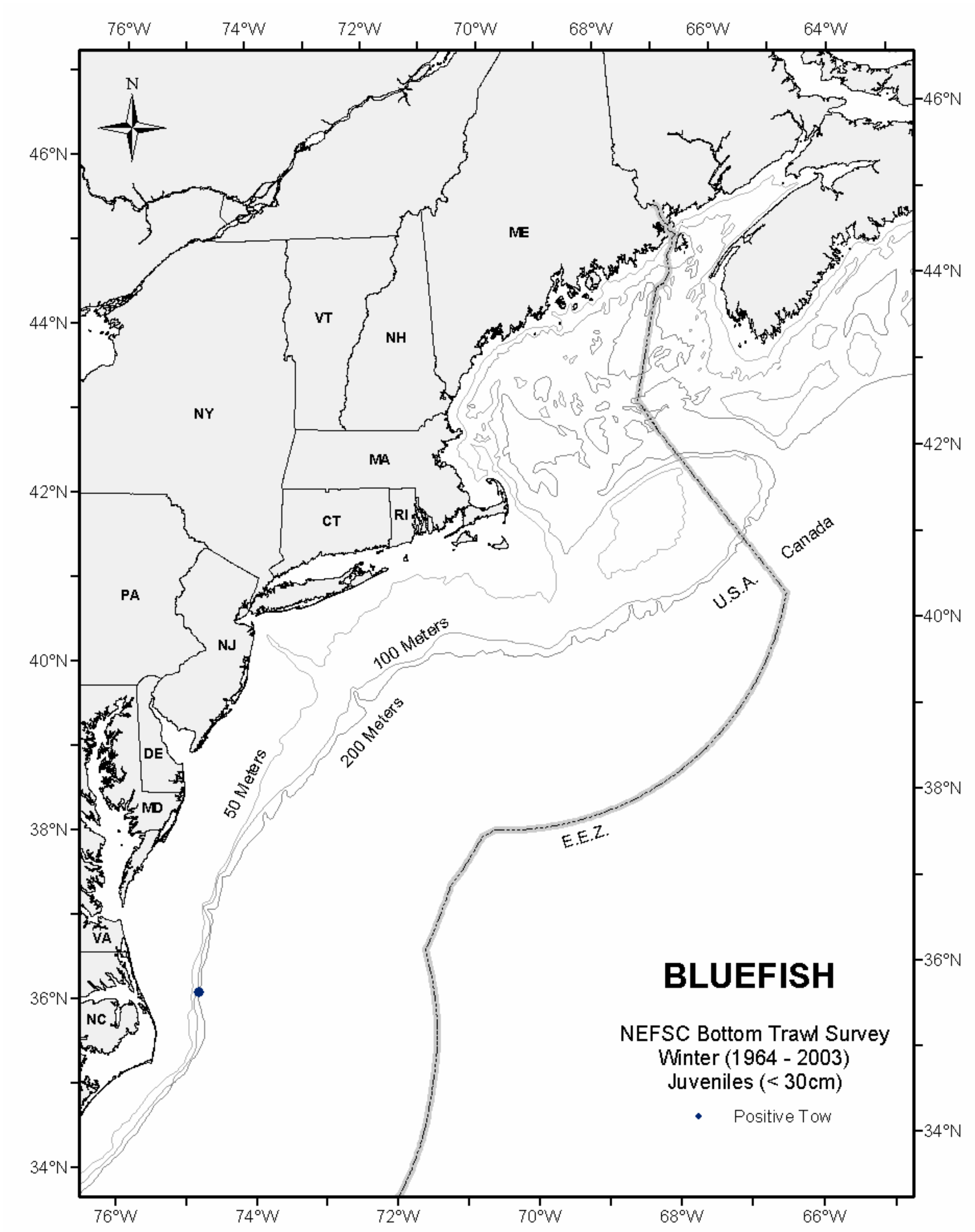


Figure 32. Distributions and abundances of juvenile and adult bluefish collected during winter NEFSC bottom trawl surveys (1964-2003, all years combined). Distributions are displayed as presence only.

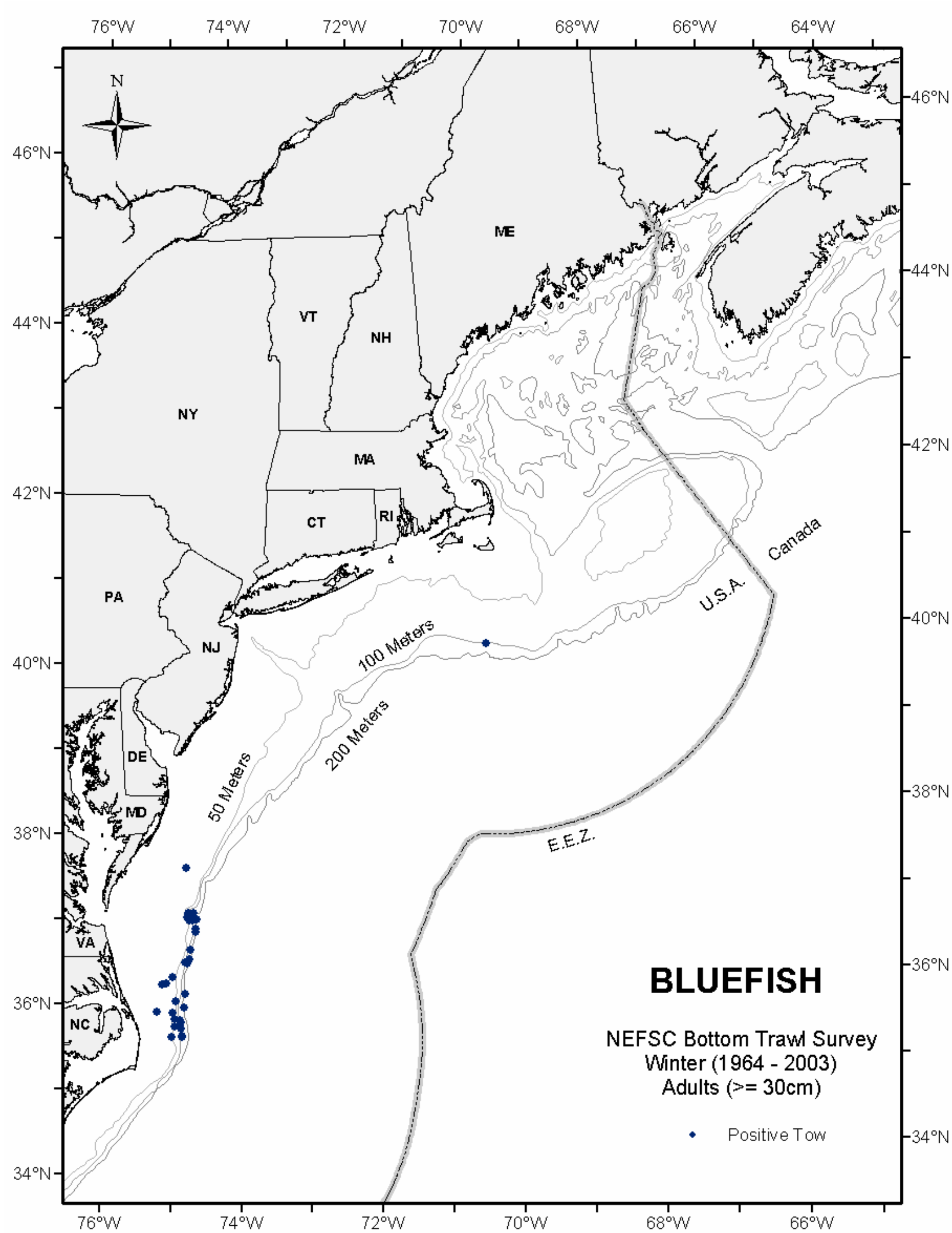


Figure 32. Continued.

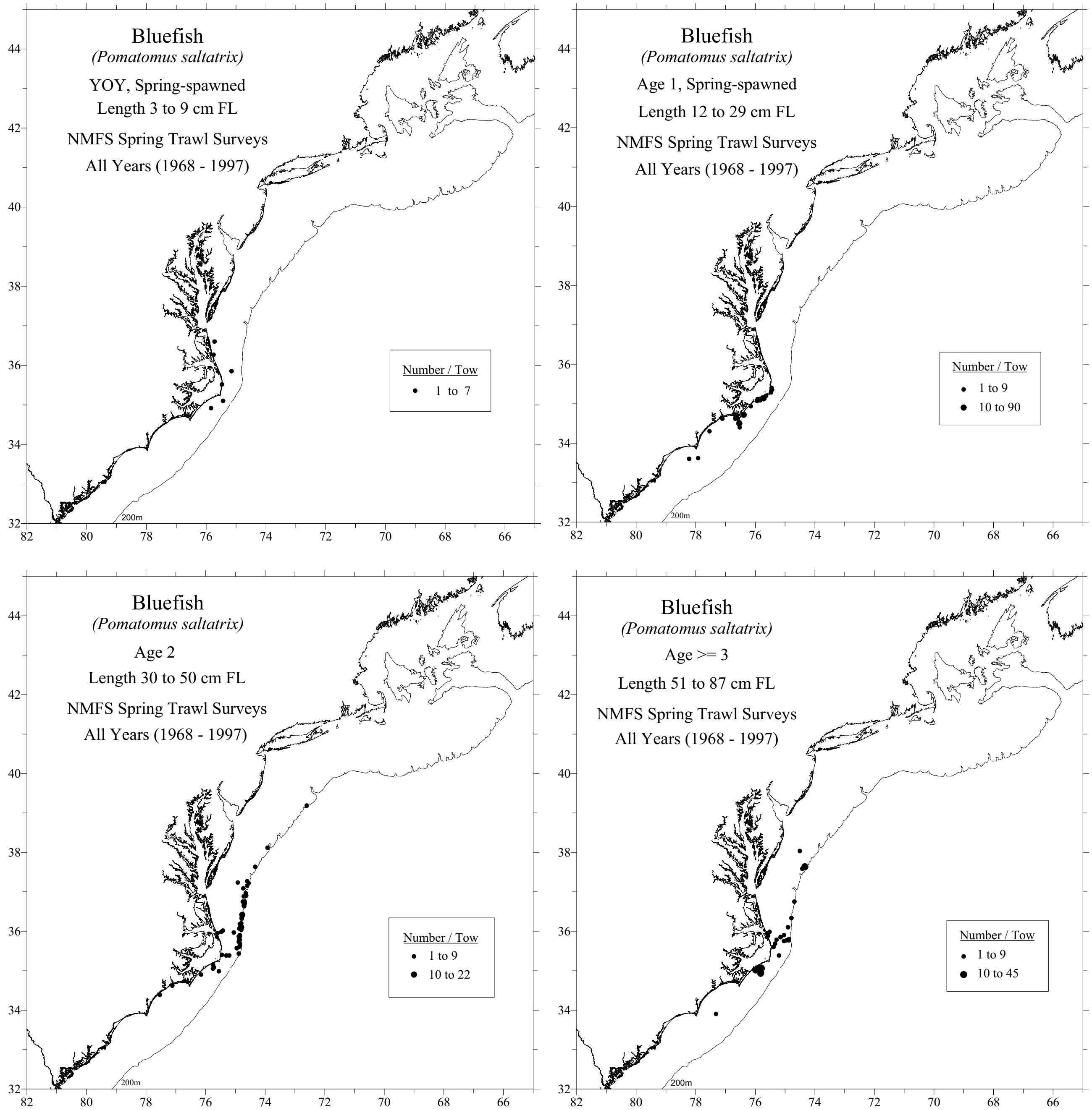


Figure 33. Distributions and abundances of four size classes of bluefish collected during spring NEFSC bottom trawl surveys (1968-1997, all years combined). Survey stations where bluefish were not found are not shown.

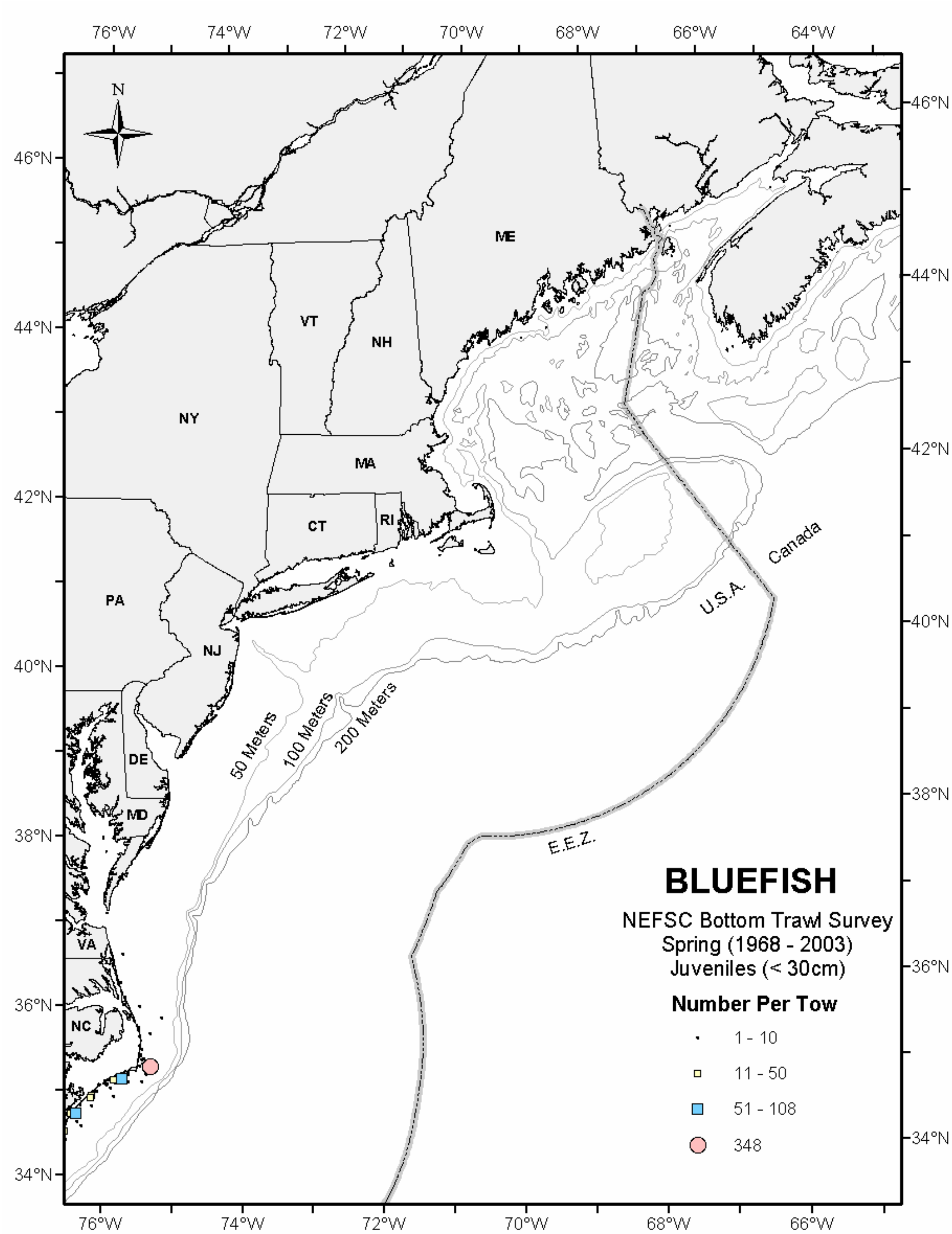


Figure 34. Distributions and abundances of juvenile and adult bluefish collected during spring NEFSC bottom trawl surveys (1968-2003, all years combined). Survey stations where bluefish were not found are not shown.

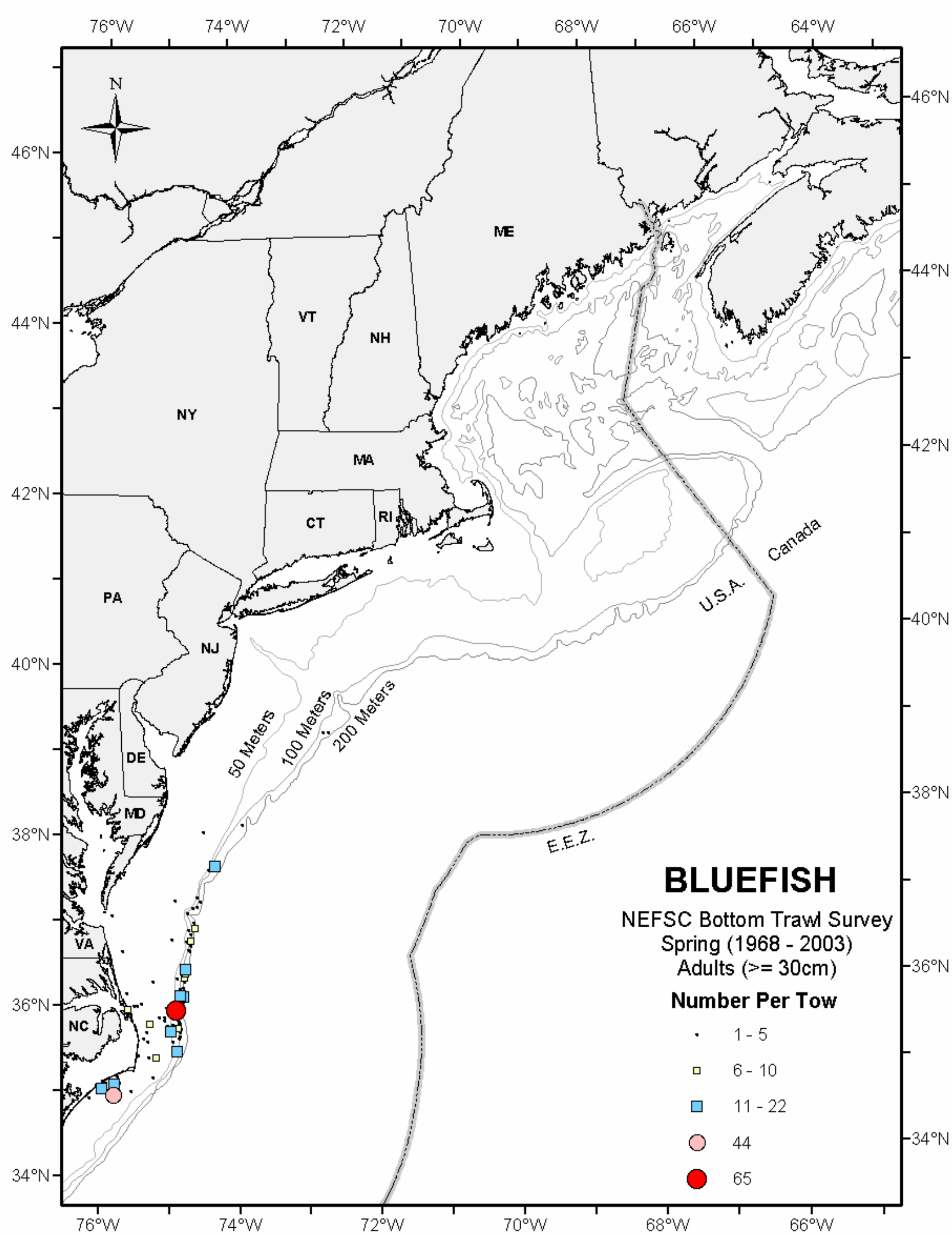


Figure 34. Continued.

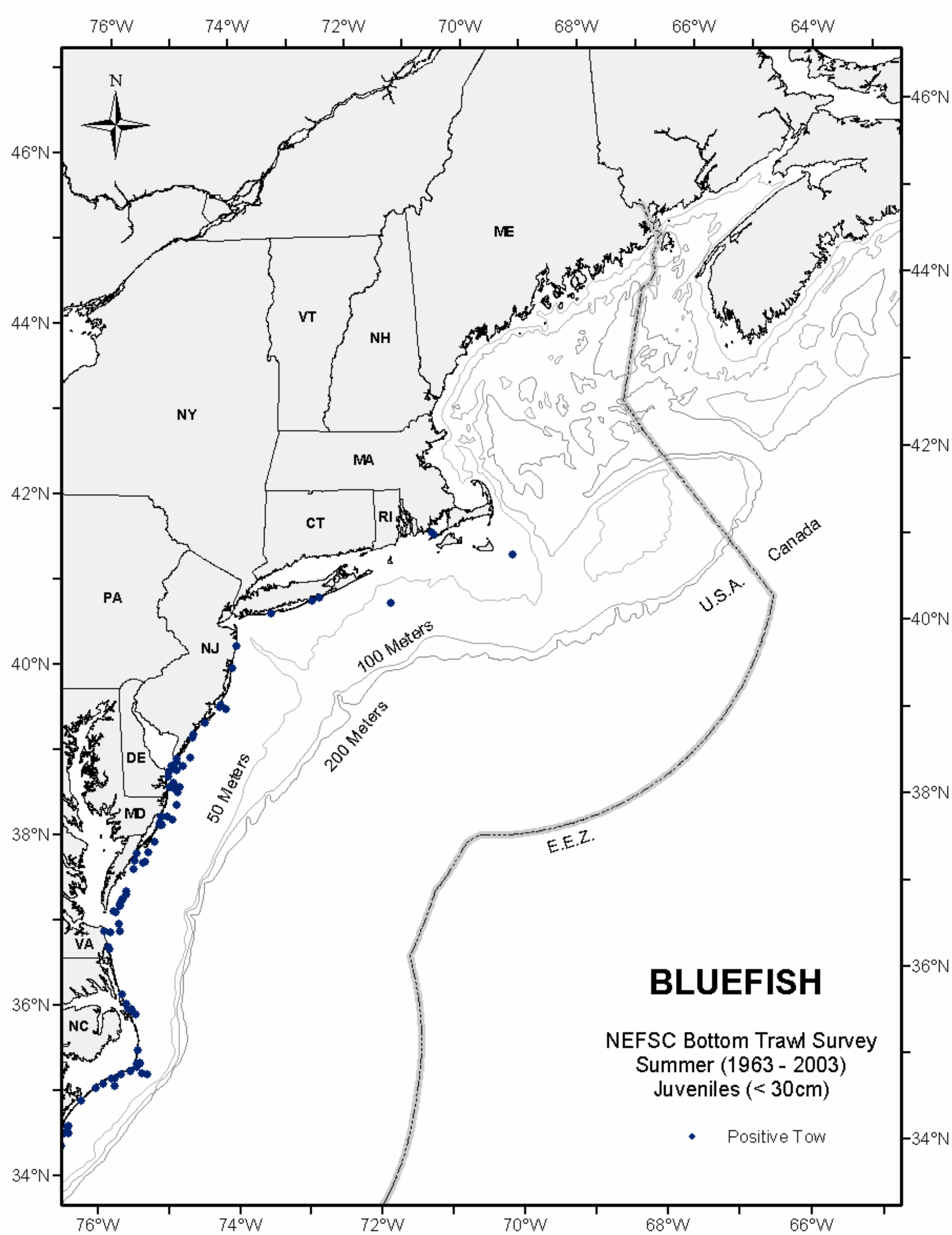


Figure 35. Distributions and abundances of juvenile and adult bluefish collected during summer NEFSC bottom trawl surveys (1963-2003, all years combined). Distributions are displayed as presence only.

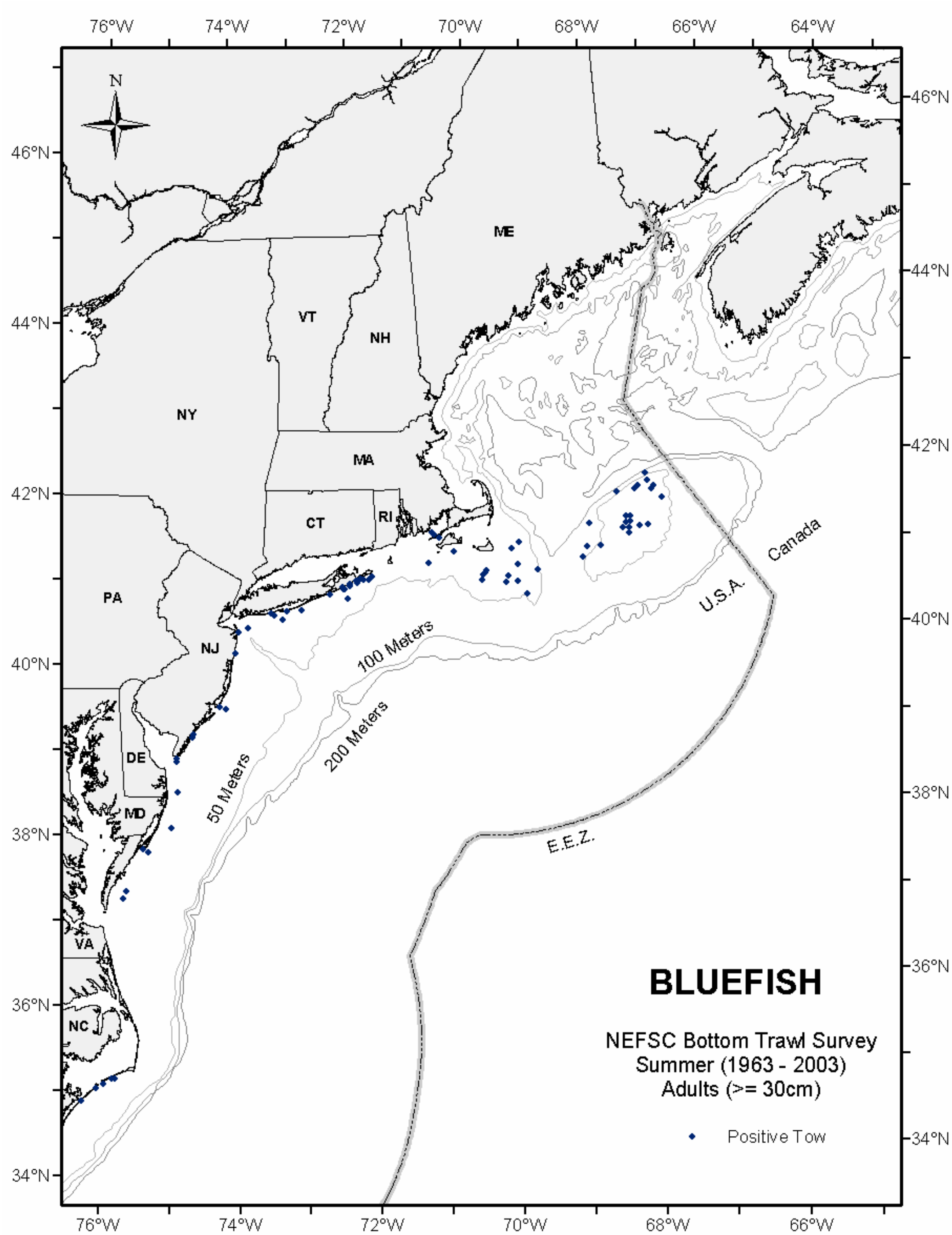


Figure 35. Continued.

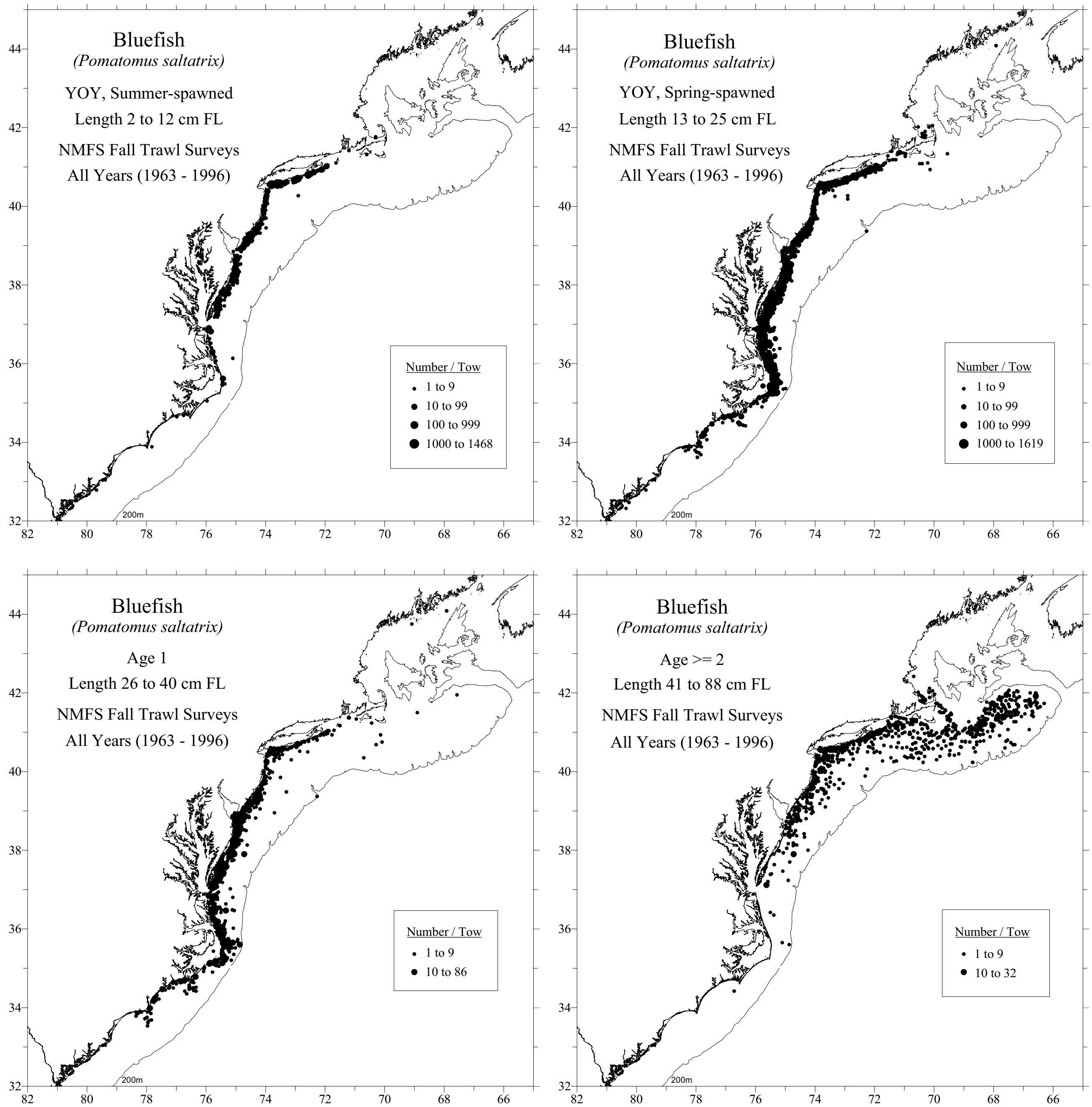


Figure 36. Distributions and abundances of four size classes of bluefish collected during fall NEFSC bottom trawl surveys (1963-1996, all years combined). Survey stations where bluefish were not found are not shown.

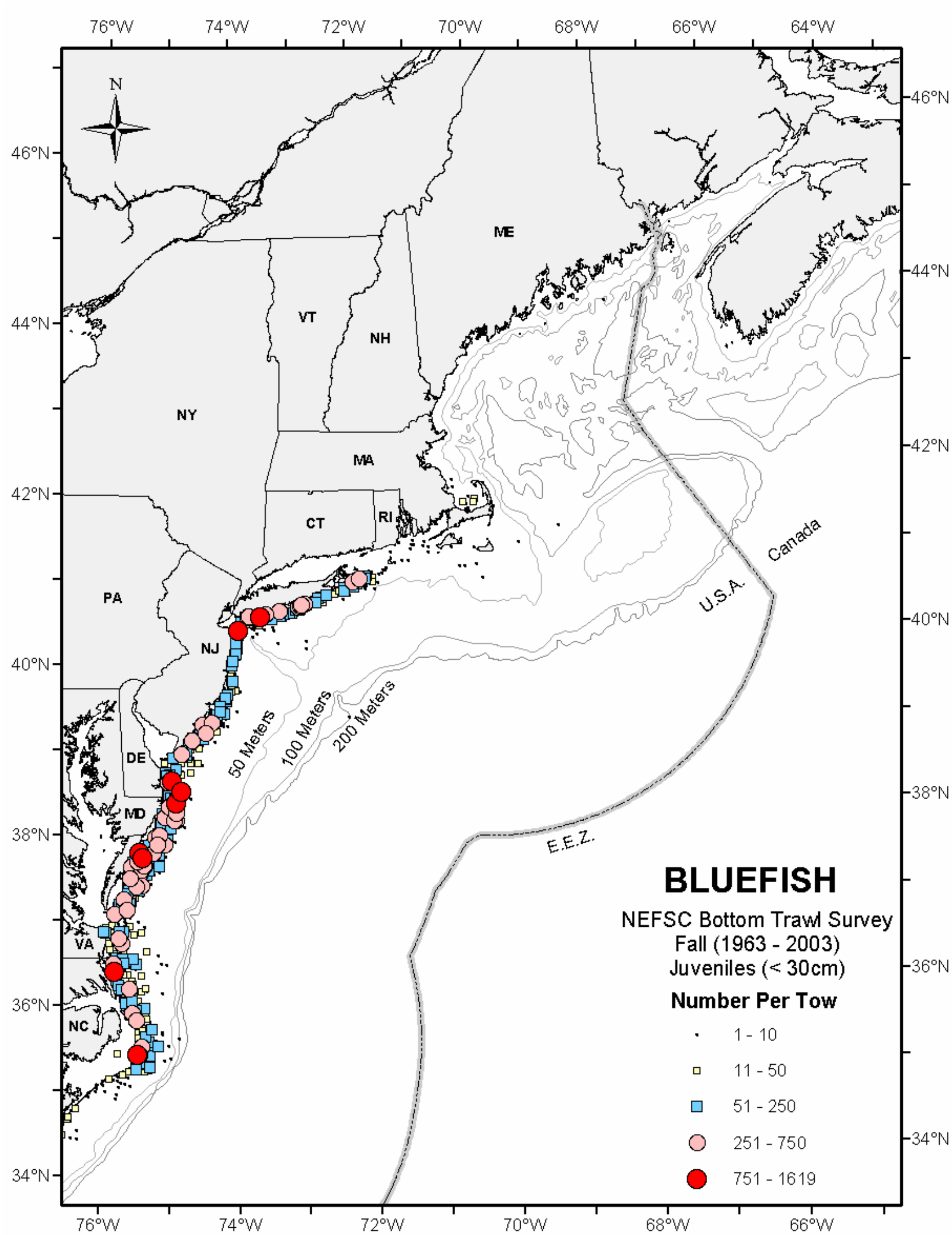


Figure 37. Distributions and abundances of juvenile and adult bluefish collected during fall NEFSC bottom trawl surveys (1963-2003, all years combined). Survey stations where bluefish were not found are not shown.

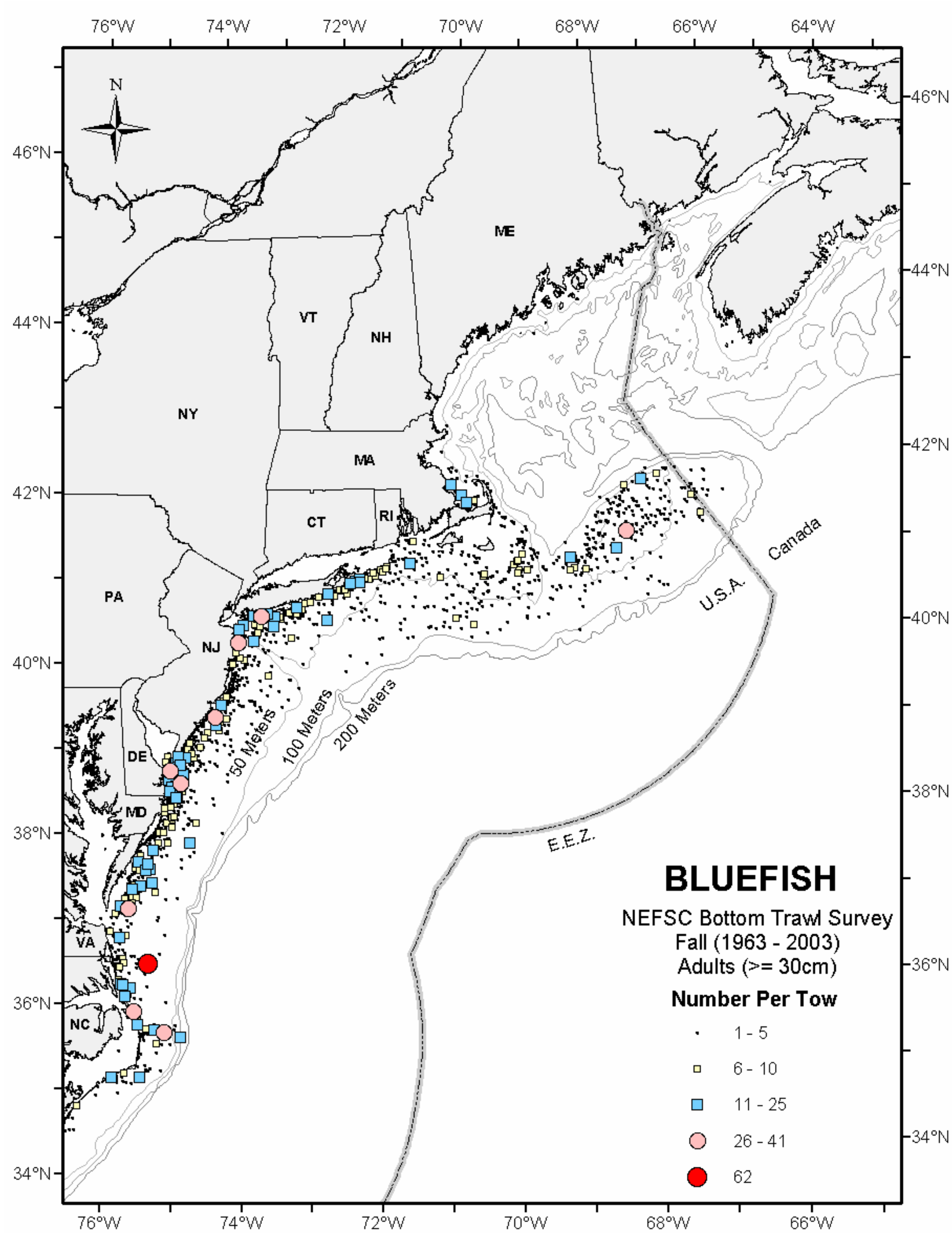


Figure 37. Continued.

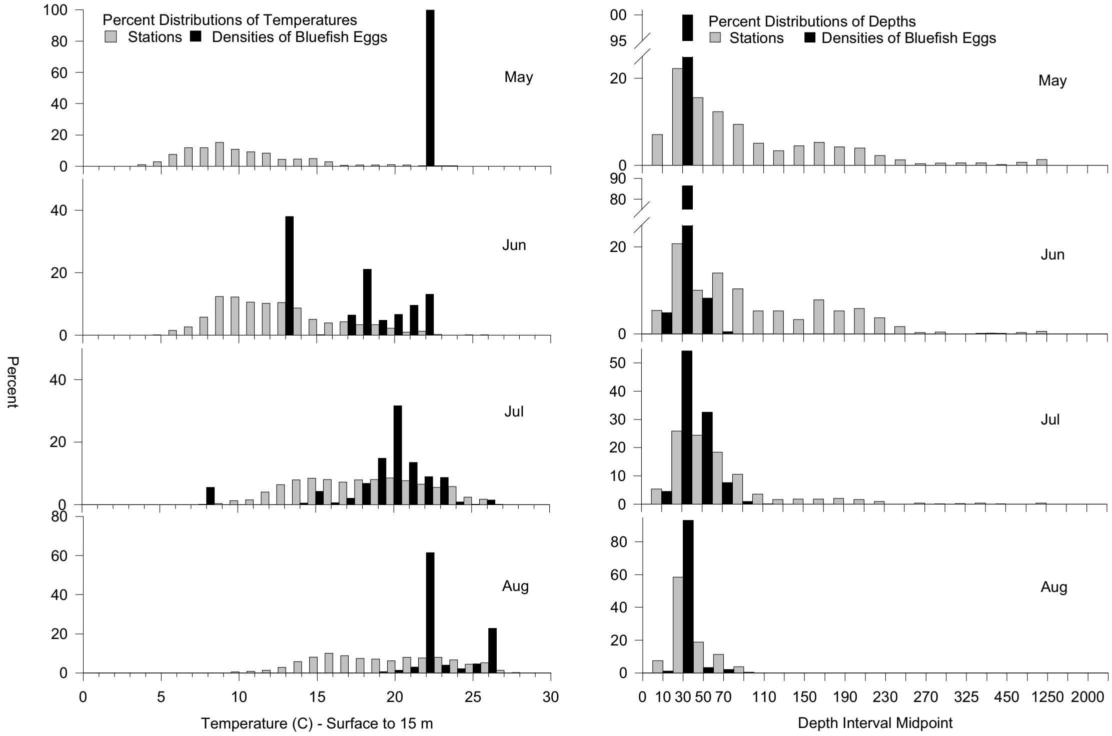


Figure 38. Distributions of bluefish eggs collected during NEFSC MARMAP ichthyoplankton surveys relative to near-surface water column temperature and depth, from May- August 1978-1987, all years combined. Open bars represent the proportion of all stations which were surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2). Note that the bottom depth interval changes with increasing depth.

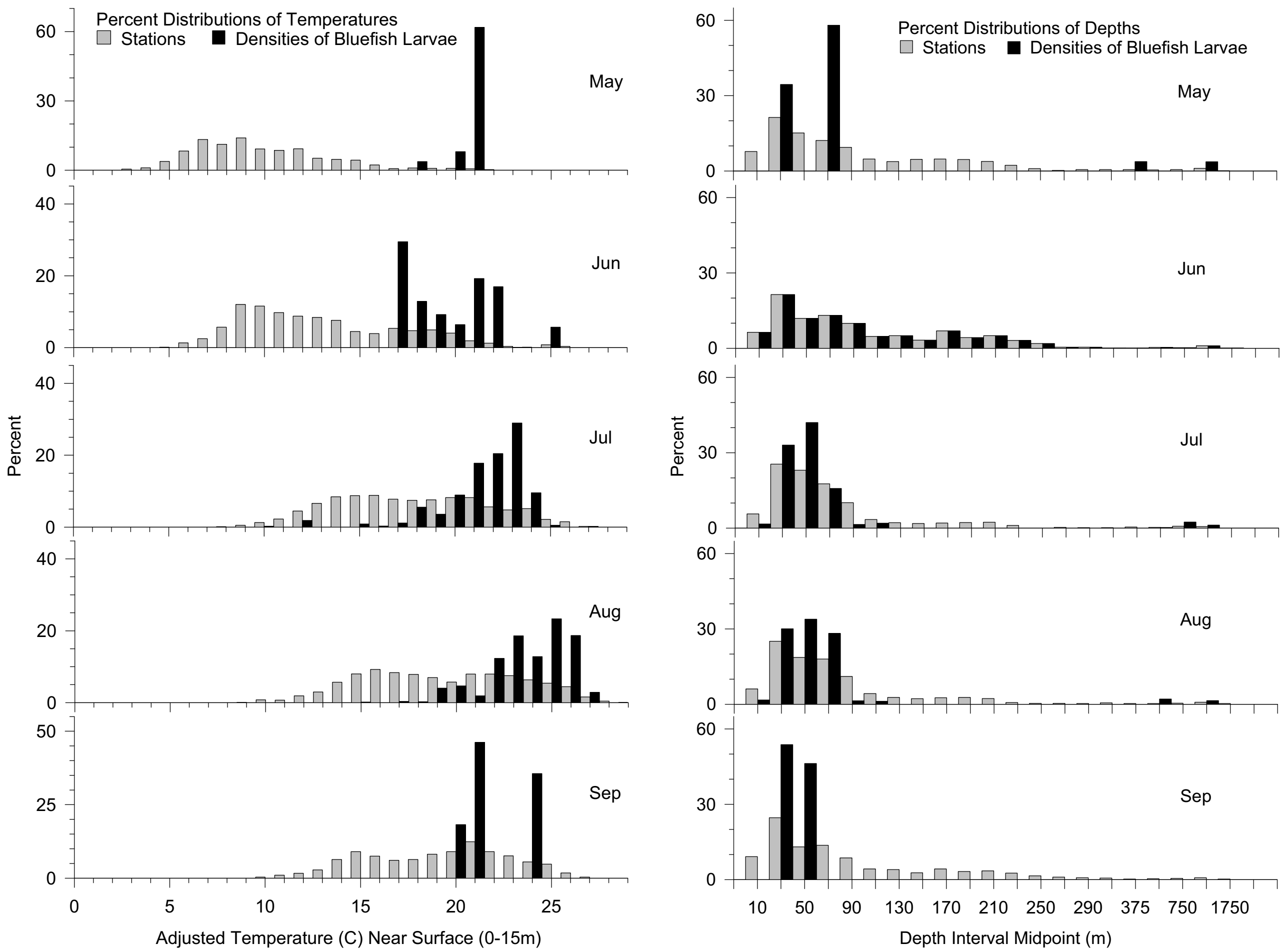


Figure 39. Distributions of bluefish larvae collected during NEFSC MARMAP ichthyoplankton surveys relative to near-surface water column temperature and depth, from May- September 1977-1987, all years combined. Open bars represent the proportion of all stations which were surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2). Note that the bottom depth interval changes with increasing depth.

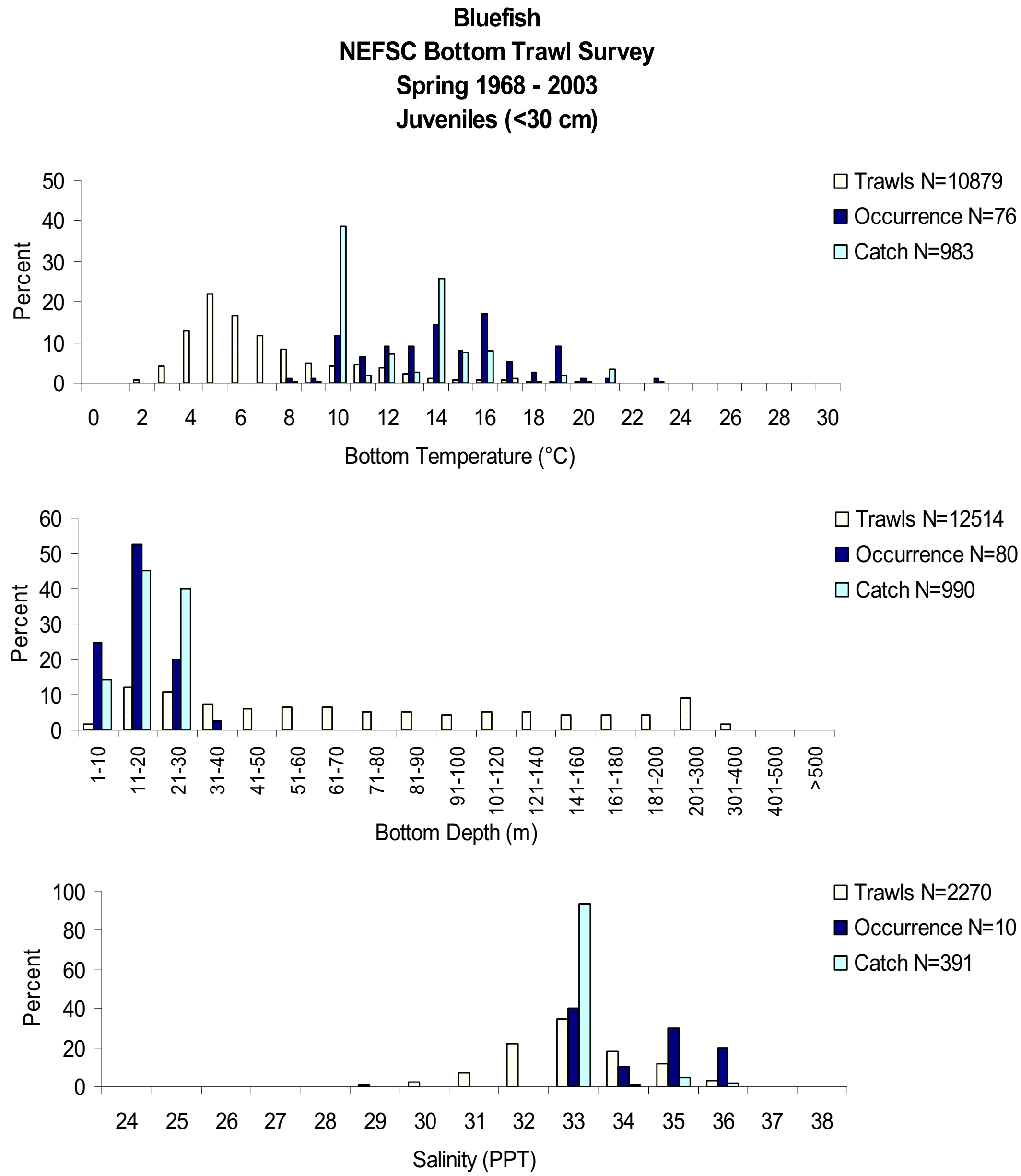


Figure 40. Distributions of juvenile bluefish and trawls from NEFSC bottom trawl surveys relative to bottom water temperature, depth, and salinity, based on NEFSC spring bottom trawl surveys (temperature and depth: 1968-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which bluefish occurred and medium bars show, within each interval, the percentage of the total number of bluefish caught. Note that the bottom depth interval changes with increasing depth.

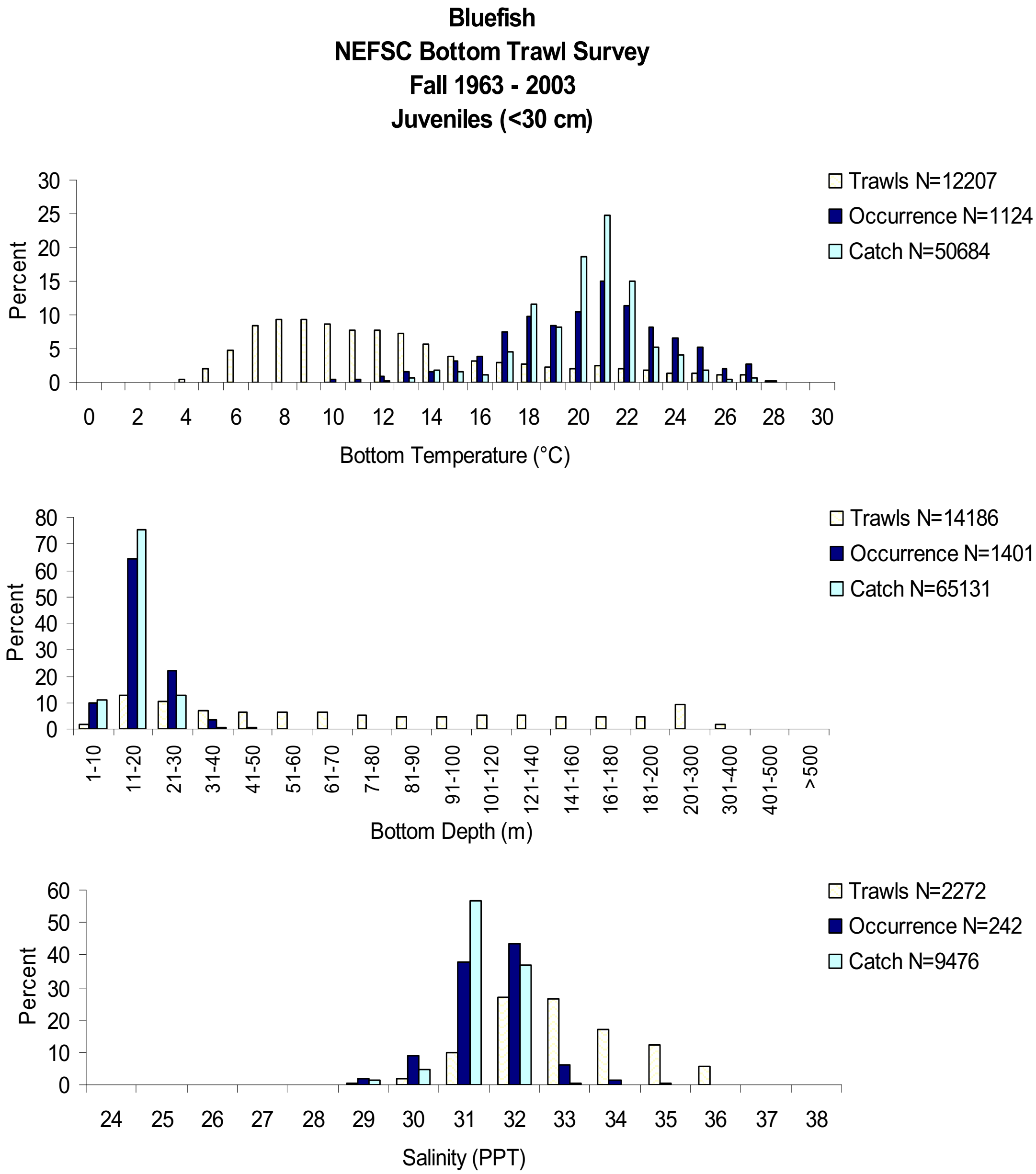


Figure 40. Continued.
Based on NEFSC fall bottom trawl surveys (temperature and depth: 1963-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which bluefish occurred and medium bars show, within each interval, the percentage of the total number of bluefish caught. Note that the bottom depth interval changes with increasing depth.

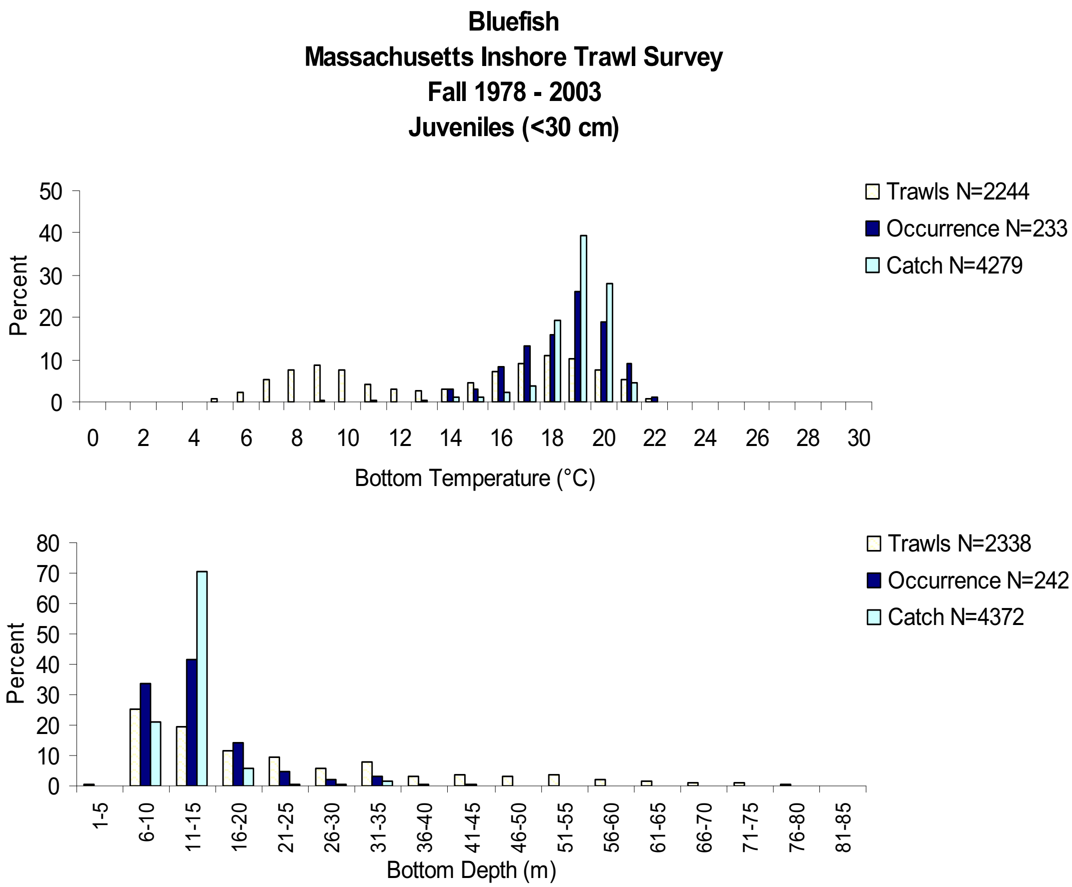


Figure 41. Distributions of juvenile bluefish and trawls in Massachusetts coastal waters relative to bottom water temperature and depth, based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which bluefish occurred and medium bars show, within each interval, the percentage of the total number of bluefish caught.

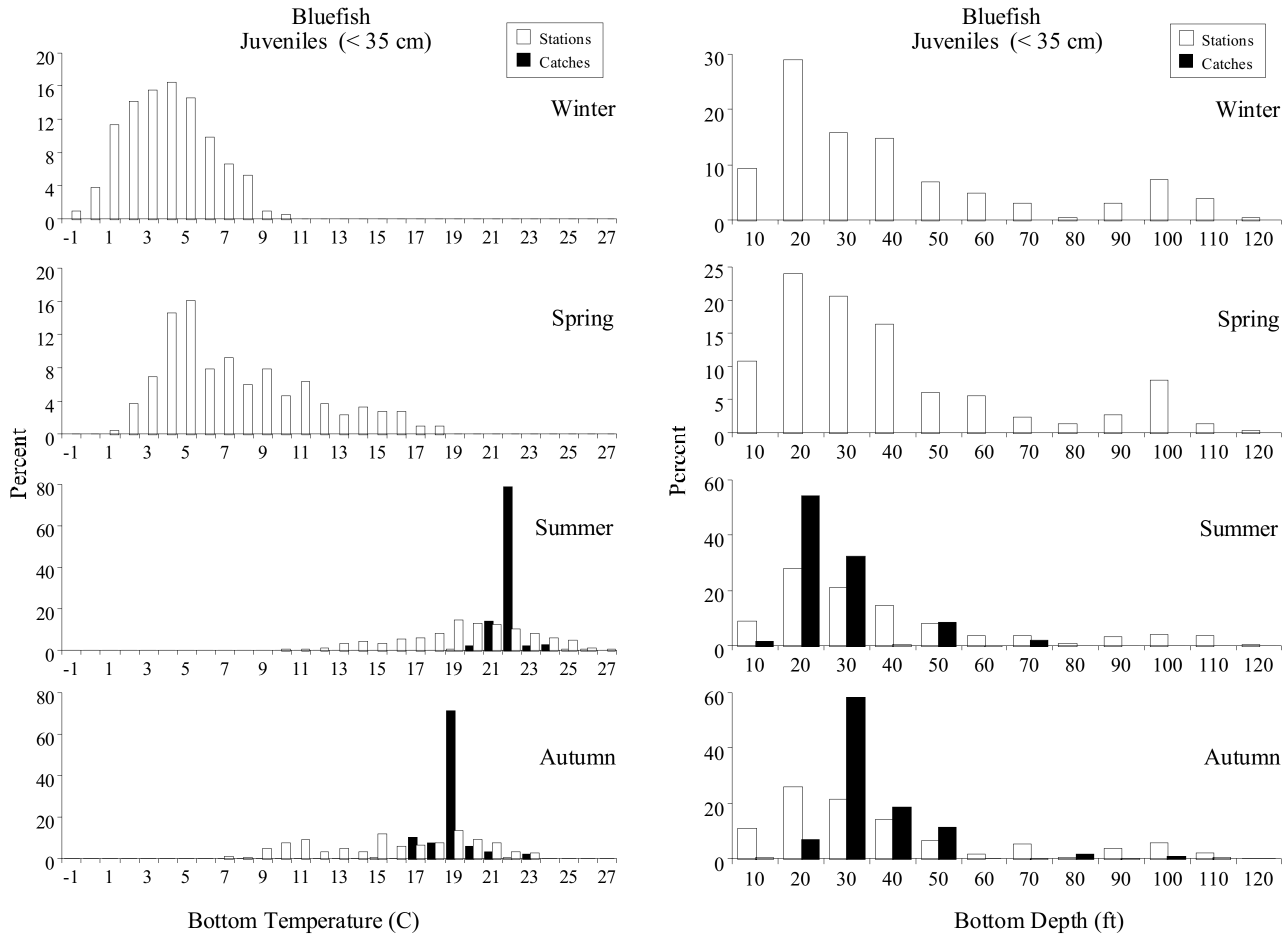


Figure 42. Seasonal distributions of juvenile bluefish and trawls relative to bottom water temperature and depth based on Rhode Island Narragansett Bay trawl surveys (1990-1996; all years combined). White bars give the distribution of all the trawls and black bars represent, within each interval, the percentage of the total number of juveniles caught.

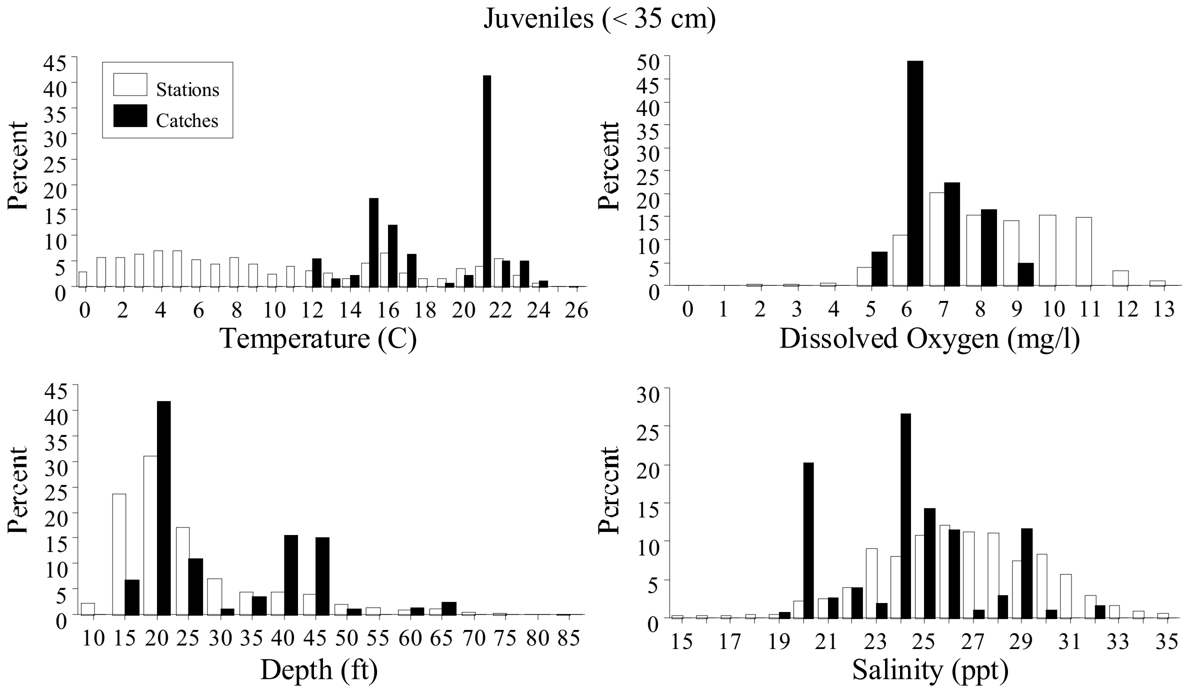


Figure 43. Distributions of juvenile bluefish relative to mean bottom water temperature, dissolved oxygen, depth, and salinity, based on Hudson-Raritan estuary trawl surveys (January 1992 - June 1997, all years combined). Open bars represent stations surveyed and closed bars represent fish collected.

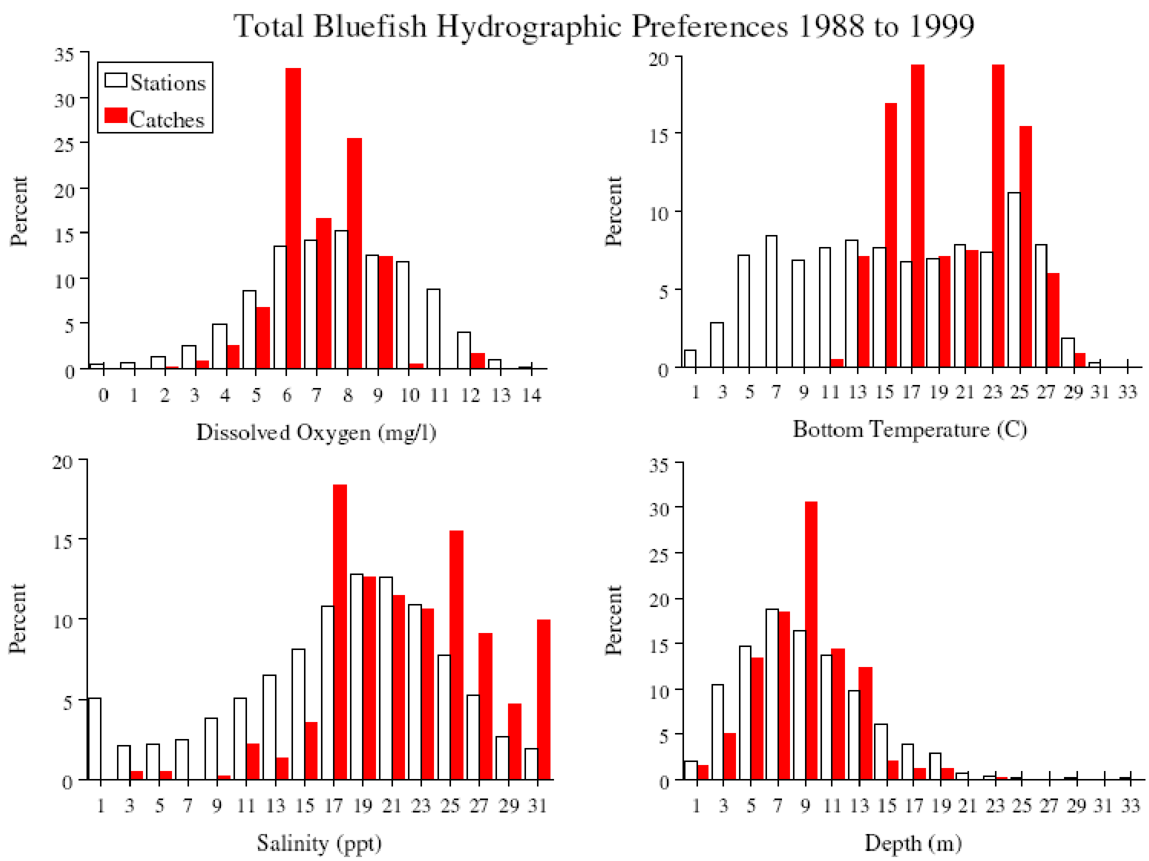


Figure 44. Hydrographic preferences for bluefish in Chesapeake Bay and tributaries, from the VIMS trawl surveys, 1988-1999 (all years combined). Source: Geer (2002).

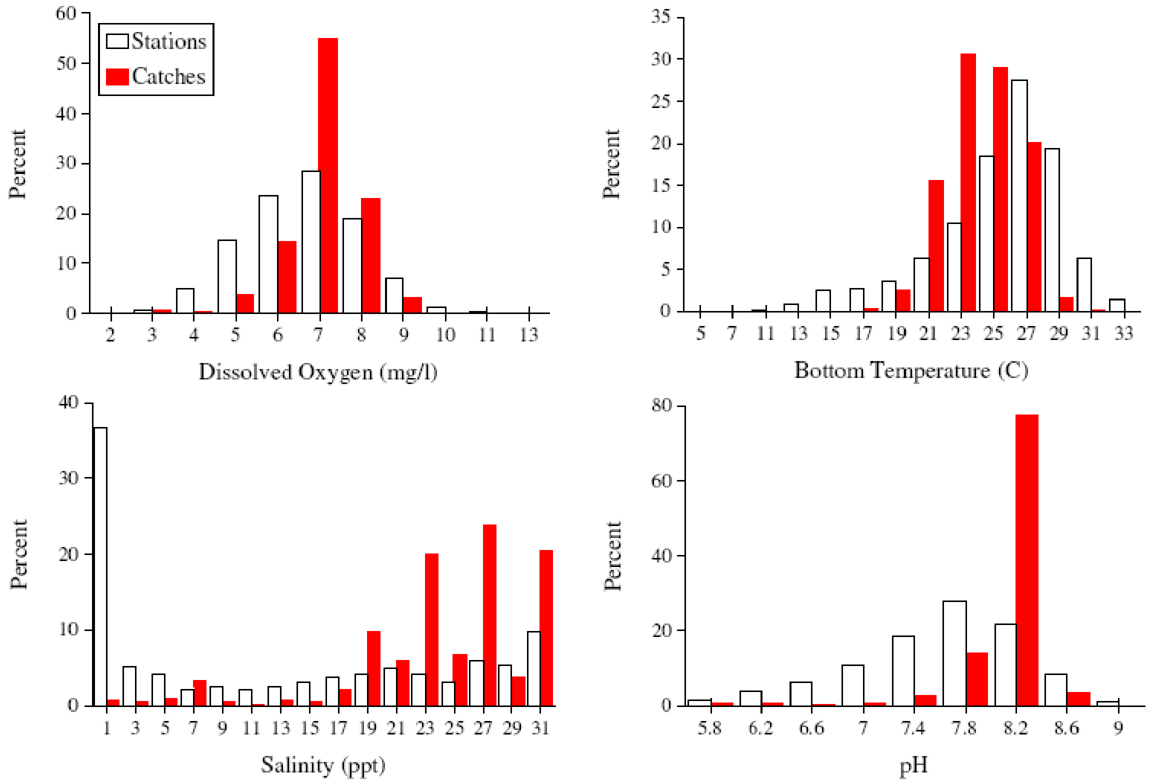


Figure 45. Hydrographic preferences for juvenile bluefish, from the VIMS seine surveys, 1994-1999 (all years combined). Source: Geer (2002).

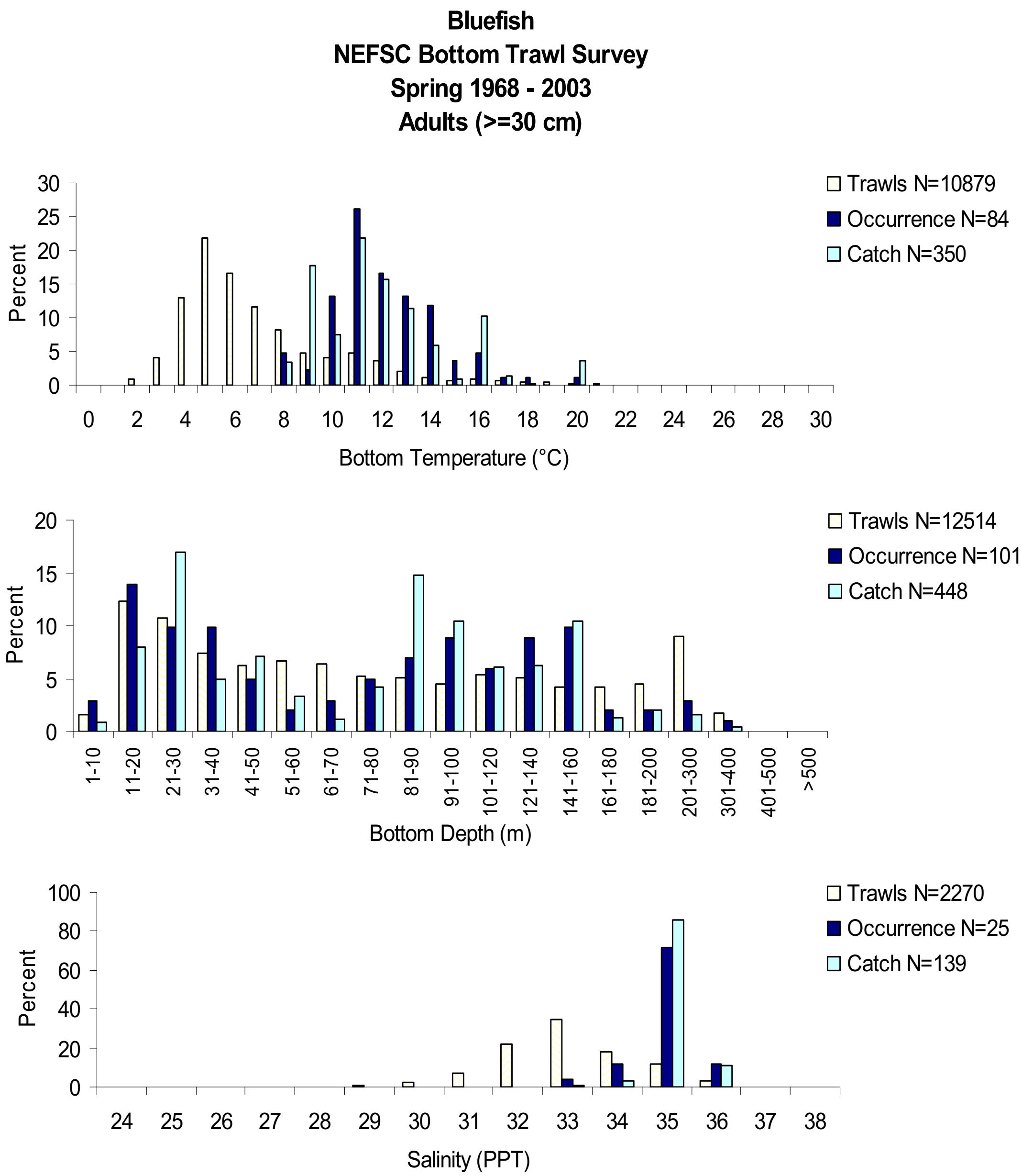


Figure 46. Distributions of adult bluefish and trawls from NEFSC bottom trawl surveys relative to bottom water temperature, depth, and salinity, based on NEFSC spring bottom trawl surveys (temperature and depth: 1968-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which bluefish occurred and medium bars show, within each interval, the percentage of the total number of bluefish caught. Note that the bottom depth interval changes with increasing depth.

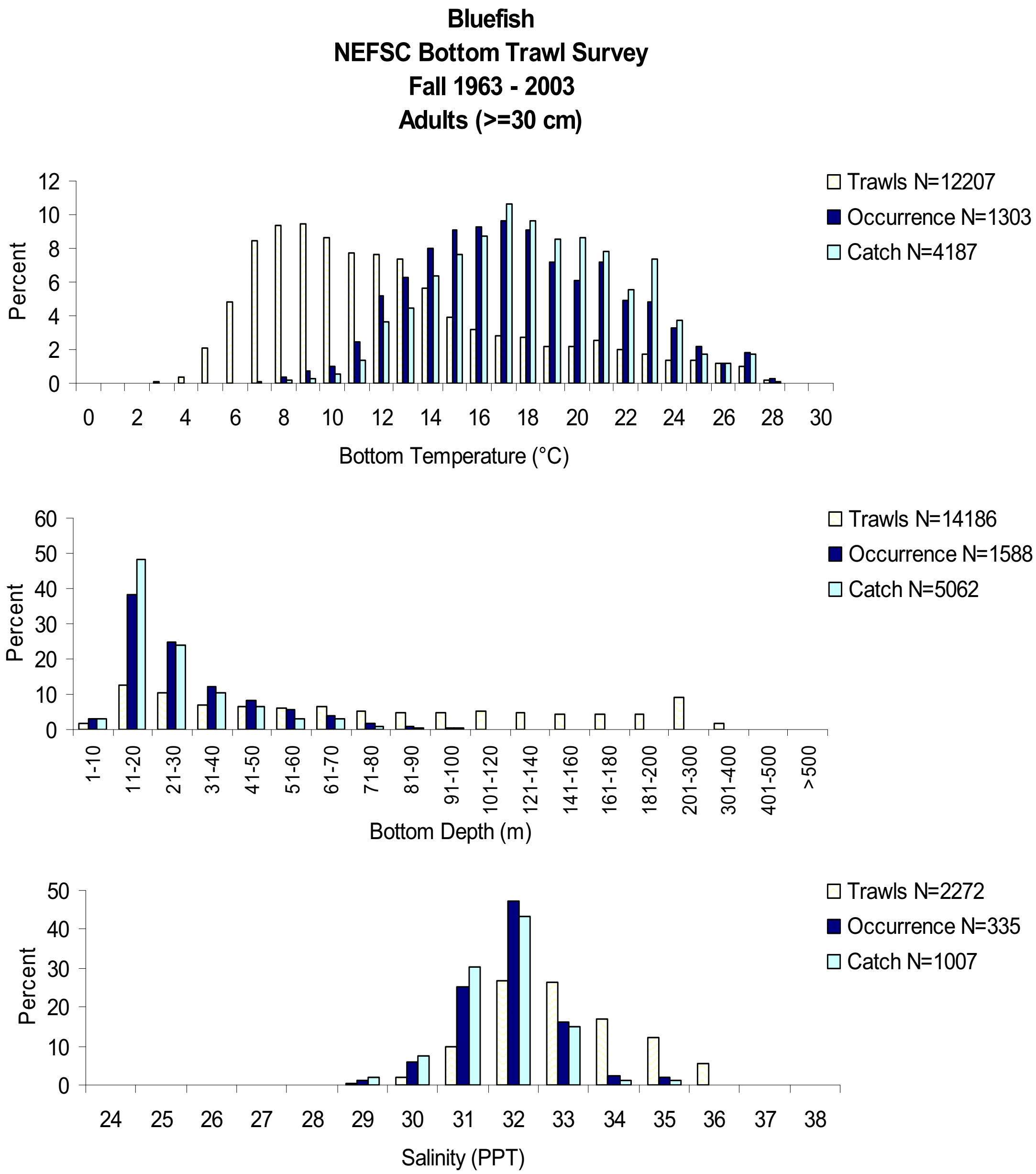


Figure 46. Continued.
Based on NEFSC fall bottom trawl surveys (temperature and depth: 1963-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which bluefish occurred and medium bars show, within each interval, the percentage of the total number of bluefish caught. Note that the bottom depth interval changes with increasing depth.

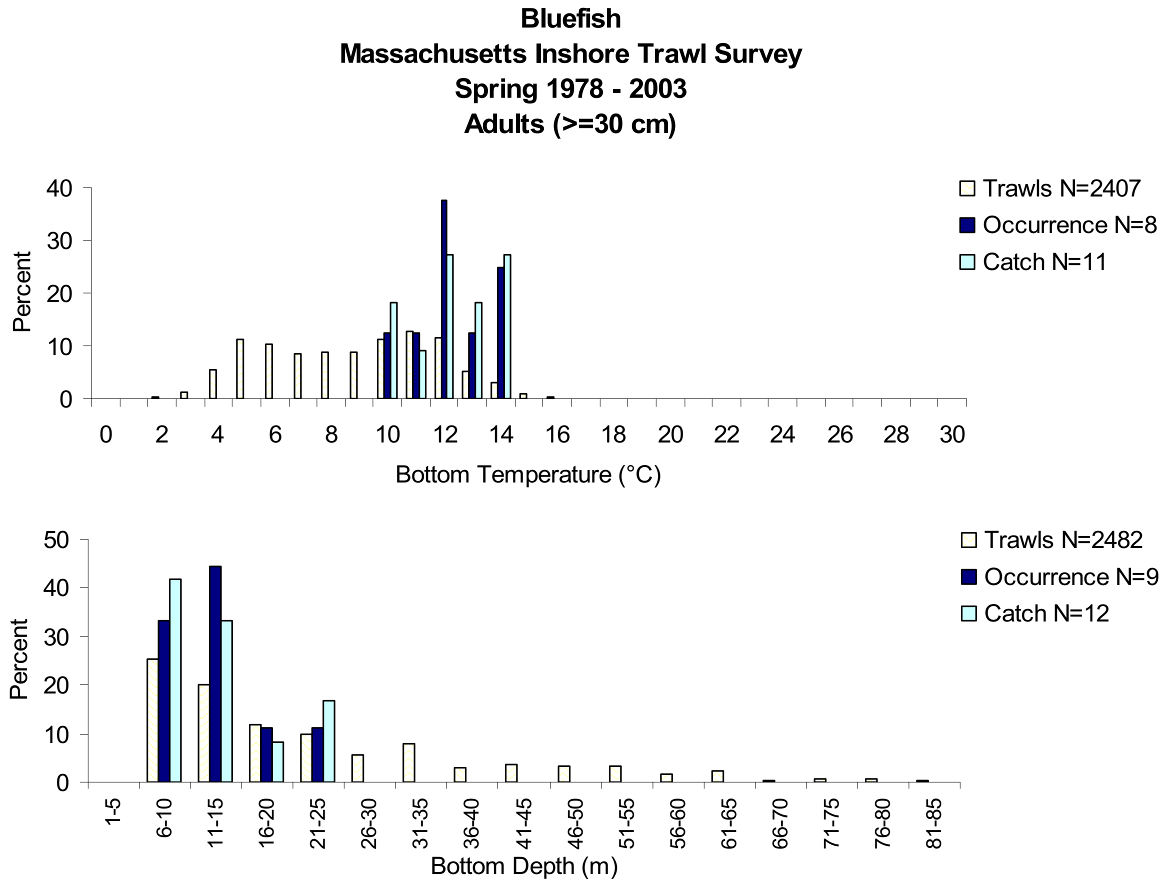


Figure 47. Distributions of adult bluefish and trawls in Massachusetts coastal waters relative to bottom water temperature and depth, based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which bluefish occurred and medium bars show, within each interval, the percentage of the total number of bluefish caught.

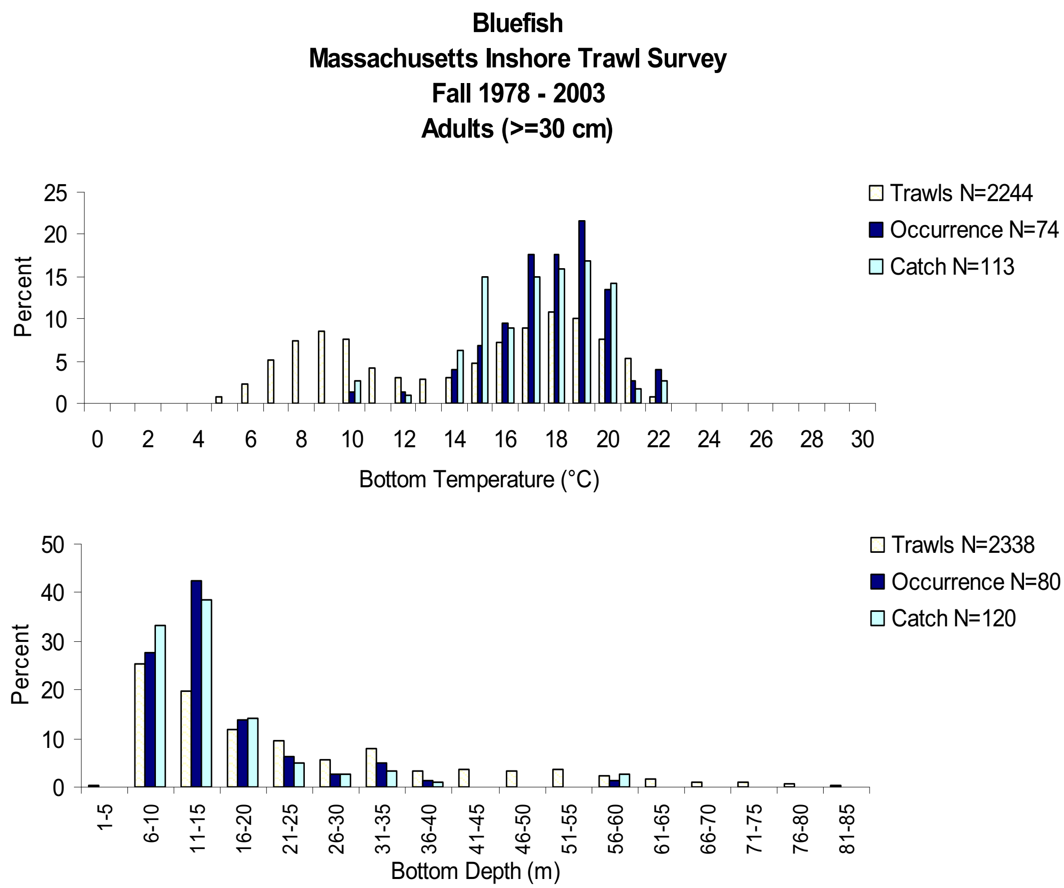


Figure 47. Continued.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which bluefish occurred and medium bars show, within each interval, the percentage of the total number of bluefish caught.

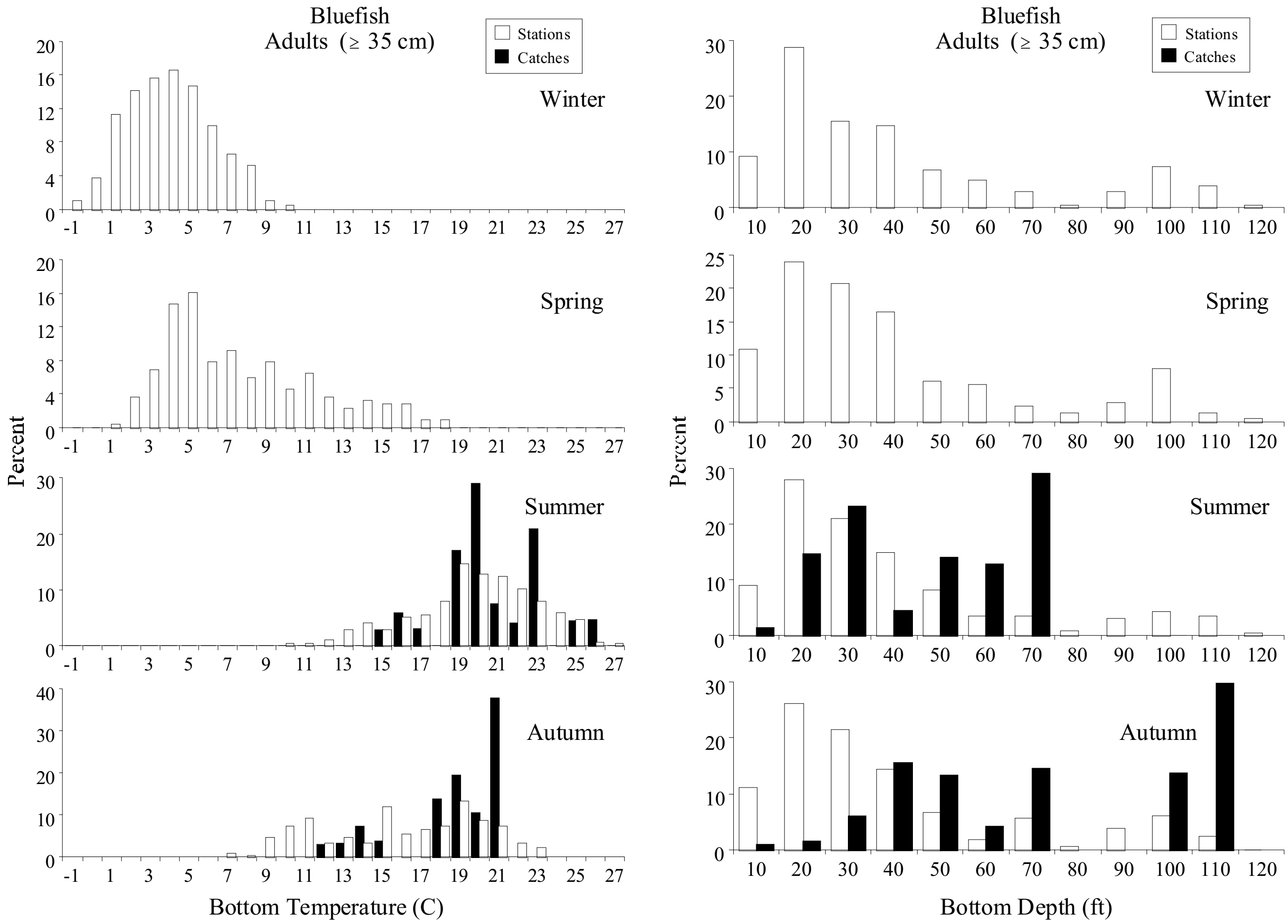


Figure 48. Seasonal distributions of adult bluefish and trawls relative to bottom water temperature and depth based on Rhode Island Narragansett Bay trawl surveys (1990-1996; all years combined). White bars give the distribution of all the trawls and black bars represent, within each interval, the percentage of the total number of adults caught.

Appendix 1. Bluefish habitat characteristics. MAB = Middle Atlantic Bight; SAB = South Atlantic Bight.

EGGS

Authors	Study Period and Area	Habitat (Spatial and Temporal)	Temperature	Salinity	Dissolved Oxygen	Currents	Light	Prey
Norcross *et al.* (1974)	1960-1962, Continental Shelf waters off Virginia.	Across shelf, from nearshore to shelf edge, but most in outer half of shelf. June through August, peak July.	22°C or more. (Minimum 18°C).	31 ppt or more. (Minimum 26.6 ppt).	---	Prevailing surface currents transport eggs south and offshore.	Peak spawning evening (1900-2100 hrs).	---
Berrien and Sibunka (1999)	1977-1987, Continental Shelf waters, Gulf of Maine to Cape Hatteras.	Occur southern New England to Cape Hatteras across entire shelf. Most in mid-shelf waters of MAB, especially off New Jersey and Delaware Bay. May-August.	---	---	---	---	---	---

Appendix 1. Continued.

LARVAE

Authors	Study Period and Area	Habitat (Spatial and Temporal)	Temperature	Salinity	Dissolved Oxygen	Currents	Light/Vertical Distribution	Prey
Norcross *et al.* (1974)	1960-1962, Continental Shelf waters off Virginia.	Surface waters, most near edge of shelf.	---	---	---	---	---	---
Kendall and Walford (1979)	1965-1967, Continental Shelf waters between Cape Cod and Palm Beach, Florida.	Late April: in and near Gulf Stream off Cape Hatteras; May: near edge of shelf off Carolinas; August: mid-shelf depths off New Jersey; September: few in New York Bight; October: concentration near shelf edge off Georgia.	C. Hatteras: 22.1-22.4°C; MAB: 18-26°C, SAB: 20-26°C.	MAB: 30-32 ppt, SAB: 35-38 ppt.	---	Larvae from spring spawn advected north via Gulf Stream.	---	---
Kendall and Naplin (1981)	July 1974, outer Continental Shelf off Delaware Bay.	Vertical distribution study. Most larvae within 4 m of surface.	Surface 23°C.	Surface 33 ppt.	---	---	Near surface at night; mostly at 4 m during daylight.	Mostly copepod life history stages. Guts full during day; empty during night.
Powles (1981)	1973-1976, Cape Fear, North Carolina to Cape Canaveral, Florida.	Peaked April-May; smallest near edge of shelf; larger closer to shore or advected north.	Smallest larvae > 24°C.	Smallest larvae > 35 ppt.	---	Ekman drift would impede inshore migration.	Predominately neustonic.	---
Collins and Stender (1987)	1973-1980, Cape Hatteras to Cape Canaveral, Florida.	Mostly in waters > 40 m, primarily in spring, secondarily in late summer.	---	---	---	Southerly counter-current retains larvae in SAB.	> 4 mm strongly associated with surface.	---
Hare and Cowen (1996); Hare *et al.* (2001)	March 1990, 1991; April 1989; June 1991; Water masses off Cape Hatteras.	Larvae occurred March through June; different sizes occurred in different water masses.	March: 20-25°C; April: 18-25°C; June: 21-25°C	March: 36+ ppt; April: 34.5-36.5 ppt; June: 31-36 ppt.	---	SW winds in MAB may facilitate cross-shelf transport of larvae.	---	---

Appendix 1. Continued.

PELAGIC-JUVENILES

Authors	Study Period and Area	Habitat (Spatial and Temporal)	Temperature	Salinity	Dissolved Oxygen	Currents	Light/Vertical Distribution	Prey
Fahay (1975)	Seasonal, May 1967-Feb. 1968. SAB Continental Shelf.	14 collected between North Carolina and Cape Canaveral, various depths between nearshore and shelf edge. All during May.	19.0-24.0°C	---	---	---	---	---
Kendall and Walford (1979)	1965-1972, East Coast U.S. (MAB and SAB Continental Shelf into Slope Sea).	April (late): many near Cape Hatteras; May: shelf in SAB, largest nearshore; June: MAB between shore and shelf/slope front; Fall: few between Delaware Bay and Cape Hatteras; Winter: few between St. Johns River and Cape Canaveral.	April-May: 22.1-24.0°C, Jun: 15.0-20.0°C (most > 18.0°C), Fall: 15.0-18.0°C, Winter: 13.0-15.0°C.	---	---	Migrate across shelf from shelf/slope front to shore as shelf waters warm.	All collected in near-surface samplers.	---
Powles (1981)	1973-1976; SAB Cape fear-Cape Canaveral.	Smallest collected near 180 m contour; larger near shore.	180 m contour: > 24.0°C.	180 m contour: > 35.0 ppt.	---	Weak association of size with proximity to coast. Most probably advected north.	Strongly associated with the surface.	---
Collins and Stender (1987)	1973-1980, SAB Cape Fear-Cape Canaveral.	Seaward of 40 m isobath, mostly spring, some fall occurrences.	---	---	---	Strong negative correlation of size and depth during spring, indicates shoreward movement with growth.	Strongly associated with the surface.	---
Hare and Cowen (1996)	1988, MAB shelf edge.	Cross shelf from Slope Sea to shore early to mid-June.	13.0-15.0°C.	---	---	Wind-driven flow may be important, but active swimming probably more important.	Surface oriented.	---

Appendix 1. Continued.

JUVENILES AND OLDER

Authors	Study Period and Area	Habitat (Spatial and Temporal)	Temperature	Salinity	Dissolved Oxygen	Currents/Tide	Substrate/ Vegetation	Light/ Diel	Prey
de Sylva *et al.* (1962)	1958-1960, Delaware Bay and River.	July and August, mostly in shore zone of lower estuary.	---	usually high, but as low as 3.0 ppt.	---	Surf zone, clear to turbid.	Sand.	---	Collected with small clupeids and anchovies.
Smith (1971)	1969-1970, four low-salinity creeks, upper Delaware Bay.	Six YOY occurred in two of the creeks, June and July.	24.5-30.0°C.	0-5.2 ppt.	4.5-7.3.	Ebb/flood.	Sand/gravel.	Day.	---
Milstein *et al.* (1977)	1972-1974, Great Bay, New Jersey.	Several distinct habitats studied; bluefish most abundant in mud-sand, high salinity sites; also sandy beaches.	---	---	---	Slow to moderate, swept by waves.	Mostly sand, some gravel, silt, clay; *Ulva lactuca*, *Spartina alterniflora*, *Fucus* (sometimes).	---	---
Pristas and Trent (1977)	1972, St. Andrews Bay, Florida.	Range of depths sampled with gill nets, 24 hrs. Bluefish most dense in shallowest zone (0.7-1.1 m).	11.4-27.0°C.	25.3-34.6 ppt.	---	---	> 80% sand; vegetation most dense in shallow zone.	Bluefish most abundant at night in shallowest zone.	---
Nyman and Conover (1988)	1985-1986, both shores of Long Island, New York.	Occur in embayments, between late May and October.	Arrive > 20°C; emigrate ca. 15°C.	---	---	---	---	---	---
Rountree and Able (1992a, b).	1988-1989, Great South Bay, New Jersey.	Occur in polyhaline subtidal marsh creeks during summer.	> 20.0°C.	23.0-30.0 ppt.	---	---	---	Day: tidal creeks Night: open bay.	*Menidia menidia.*
McBride *et al.* (1995)	Narragansett Bay, Rhode Island.	June-October, shallow beaches.	18.0-28.0°C.	25.0-34.0 ppt.	---	---	Cobble, gravel, shell, sand; *Ulva* and some *Zostera.*	Day sampling only.	---
Able *et al.* (1996)	Great Bay, New Jersey.	Most bluefish in subtidal creeks.	19.0-28.0°C.	25.0-33.0 ppt.	---	---	0.3-1.2 m depth; *Ulva lactuca.*	---	---

Appendix 1. Continued.

JUVENILES AND OLDER (CONTINUED)

Authors	Study Period and Area	Habitat (Spatial and Temporal)	Temperature	Salinity	Dissolved Oxygen	Currents/Tide	Substrate/ Vegetation	Light/ Diel	Prey
Buckel and Conover (1997)	1992-1993, Hudson River estuary.	Mid-channel and nearshore day-night occurrence and feeding study.	---	---	---	---	---	Most abundant nearshore during daylight; mid-channel at night and twilight.	Gut fullness highest twilight and day, usually low at night. Prey: striped bass, bay anchovy, clupeids.
Fahay *et al.* (1999)	1964-1997, Continental shelf MAB, south to Cape Fear, Cape Canaveral.	Inner shelf (over depths < 20 m) during summer and fall.	Most 18-22°C.	---	---	---	---	---	---
Harding and Mann (2001)	Chesapeake Bay 1997.	May to September. Oyster reefs, oyster bars, and sandy bottoms.	17°C to 28°C.	11 to 18 ppt.	---	No significant effect on abundance.	More abundant on oyster bars. More diverse diet on bars.	Most abundant in samples at night.	Clupeids, other teleosts, polychaetes and crustaceans.
Buckel and McKown (2002)	New York Bight embayments, 1997 and 1998.	May to November, embayments in western Long Island and Staten Island.	15°C to 26°C.	22 to 27 ppt.	---	---	---	---	Sand shrimp, mysids, *Menidia* spp., *Anchoa* spp., *Fundulus* spp. , amphipods.
Scharf *et al.* (2002)	Navesink River/Sandy Hook Bay.	Shallow estuaries May to October.	---	---	---	Low velocity currents.	Depositional habitat – high turbidity zones.	---	Primarily menhaden large niche overlap between predator and prey.
Fox *et al.* (2002)	Delaware Bay June – Nov 2001.	Marsh creeks in NJ.	---	Range from mesohaline to oligohaline.	---	---	---	---	Menhaden, *Fundulus* spp., *Menidia* spp.

Appendix 1. Continued.

JUVENILES AND OLDER (CONTINUED)

Authors	Study Period and Area	Habitat (Spatial and Temporal)	Temperature	Salinity	Dissolved Oxygen	Currents/Tide	Substrate/ Vegetation	Light/ Diel	Prey
Secor *et al.* (2002)	Chesapeake Bay and MD coastal bays.	Shoal habitats (< 2 m depth) and deeper offshore habitats (4-40 m depth). Concluded that shallow ocean habitat important for YOY in late summer – early fall.	---	---	---	---	---	---	*Menidia* spp. in July, *Anchoa* spp. in August.
Able *et al*. (2003)	Coastal NJ 1995-1998.	Sandy ocean beaches and Great Bay and Little Egg Harbor estuary.	7.7°C to 25.4°C.	27.1 to 33.4 ppt.	---	High wave energy on beaches and 1.4 m tidal range.	Sand.	---	Bay anchovy, *Menidia spp*., amphipods, decapods.

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