DAR25-RD22

NOAA Technical Memorandum NMFS-NE-200

Essential Fish Habitat Source Document:

Black sea bass, *Centropristis striata*, 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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NOAA Technical Memorandum NMFS-NE-200

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

Essential Fish Habitat Source Document:

Black Sea Bass, *Centropristis striata*, Life History and Habitat Characteristics

Second Edition

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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.

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 black sea bass (*Centropristis striata* Linnaeus 1758) (Figure 1) is a warm temperate serranid that ranges from southern Nova Scotia and the Bay of Fundy (Scott 1988) to southern Florida (Bowen and Avise 1990) and into the Gulf of Mexico. Fish have been reported on the Grand Banks of Canada (Brown *et al.* 1996), but are uncommon in cooler waters north of Cape Cod (Scattergood 1952; DeWitt *et al.* 1981). Black sea bass are typically found on the continental shelf in complex habitats such as reefs and shipwrecks, but young of the year (YOY) fish also occur in large numbers in structurally complex estuarine habitats.

LIFE HISTORY

EGGS

Black sea bass eggs are pelagic and the length of the incubation period is inversely temperature dependent (Able and Fahay 1998).

Berrien and Sibunka (1999) showed that in the Mid-Atlantic Bight, areas with high average egg densities were generally located on the continental shelf in the vicinity of large estuaries including Chesapeake Bay, the Delaware River, and the Hudson River. Eggs are collected off Cape Hatteras as early as January but these may be reproductive products transported by the Gulf Stream from spawning areas to the south (Mercer 1978).

Black sea bass eggs also occur infrequently in large bays. They have been reported in Buzzards Bay, MA (Stone *et al*. 1994), with the highest egg concentrations between May and October, but eggs were also collected in January and April. Eggs are rare in Long Island Sound (Merrimann and Sclar 1952; Wheatland 1956; Richards 1959), and absent in Narragansett Bay Rhode Island (Bourne and Govoni 1988) and Delaware Bay (Wang and Kernehan 1979).

LARVAE

Larvae hatch from eggs at 1.5-2.1 mm TL and settle as early juveniles at 10-16 mm TL (Kendall 1972; Fahay 1983; Able *et al.* 1995). Kendall (1972) however, suggested that fish may delay settlement until they reach 25 mm TL.

Gelatinous zooplankton may be important predators of larvae (Arai 1988).

JUVENILES

In the Mid-Atlantic Bight, juveniles migrate in the fall from nearshore summer habitats to over wintering habitats on the outer continental shelf south of Long Island, NY. During warmer winters, juveniles may successfully over winter in deeper waters of lower Chesapeake Bay (MAFMC 1996; Chesapeake Bay Program 1996). The fall offshore migration of juveniles in most of the Mid-Atlantic Bight probably allows fish to avoid temperatures below the lower lethal limit (~2°C, see Habitat Characteristics section) (Hales and Able 2001). However, juveniles in the Gulf of Mexico also disappear in the fall from inshore collections in the lower reaches of Florida west coast estuaries where they are abundant, and appear to over winter in offshore areas (Reid 1954; Joseph and Yerger 1956; Springer and Woodburn 1960; Hastings 1972).

The growth of juvenile black sea bass has been measured in situ by Able and Hales (1997) who used mark recapture techniques in the lower reach of a southern New Jersey estuary to show that growth rates of age-0 and age-1 fish from spring through fall averaged ~ 0.45 mm d (SE=0.04). Juvenile growth was higher during the summer (July-September; 0.74 mm d, SE= 0.05) than during the spring (March-June; 0.29 mm d, SE=0.04) and fall (October-December; 0.39 mm d). Growth estimates for age 1+ fish derived from length frequencies of fish in the same region, but in a different study, were similar (average=0.77 mm/day) (Able *et al.* 1995). In the Hereford Estuary, New Jersey early juveniles ~ 20 mm SL are collected in July but leave the estuary in the fall at sizes > 40 mm TL (Allen *et al.* 1978). Age-1 fish enter this estuary at 60 mm TL but migrate in the fall at ~ 100 mm TL. In eastern Virginia bays juveniles are reported to be ~ 30 mm TL in April but reach 100-182 mm TL by the end of the growing season in November (Schwartz 1961). Juvenile black sea bass appear to allocate metabolic energy toward rapid growth from settlement to ~ 49 mm SL, but then show reduced growth as they begin to store energy as lipid at larger sizes (Guida, NOAA Fisheries, NEFSC, James J. Howard Marine Sciences Laboratory, Highlands, NJ, pers. comm.). Guida (pers. comm.) speculated that this pattern represented a two-phase metabolic program that allows young fish to reduce size dependent predation mortality during and immediately following settlement while allowing for the storage of fats necessary for over wintering survival by larger individuals which are less vulnerable to predators.

In the Mid-Atlantic Bight juveniles form annuli in otoliths in May or June which appears to be the beginning of the growing season for fish after their first winter (Dery and Mayo 1988). Annulus formation occurs earlier in the South Atlantic Bight (April and May) (Cupka *et al.* 1973; Mercer 1978; Waltz *et al.* 1979; Link 1980; Wenner *et al.* 1986).

ADULTS

Black sea bass are strongly associated with structurally complex habitats. Habitats used by adults include rocky reefs, cobble and rock fields, stone coral patches, exposed stiff clay, and mussel beds. In the South Atlantic Bight adult black sea bass are associated with hard or live bottom sponge coral habitat (Struhsaker 1969; Powles and Barans 1980; Grimes *et al.* 1982; Wenner 1983; Chester *et al.* 1984; Sedberry and Van Dolah 1984; Parker and Ross 1986). In the Gulf of Mexico, limestone and coral reefs and other low relief structures are important habitats, but black sea bass are rarely found off deeper ledges (> 25 m) inhabited by larger serranids (Topp 1963; Godcharles 1970; Bortone 1977). In Long Island Sound, adults are generally associated with structurally complex habitats embedded within areas of sandy rather than muddy substratum (Richards 1963b). Black sea bass are usually observed by divers hovering near or above shelters and retreat into them if threatened. Fish appear to remain near complex structures during the day, but may move to adjacent soft-bottom to feed at dawn and dusk (Steimle and Figley 1996). Once black sea bass find suitable summer habitat, they show strong habitat fidelity, and in the Mid-Atlantic Bight, remain until the fall migration (Briggs 1979).

In the Mid-Atlantic Bight adult black sea bass migrate from nearshore continental shelf habitats to outer shelf over wintering areas, south of New Jersey, as bottom temperatures decline in the fall (Musick and Mercer 1977). Offshore migration begins as bottom water temperatures approach 7^{o}C (Nesbit and Neville 1935; June and Reintjes 1957; Colvocoresses and Musick 1984; Chang 1990; Shepherd and Terceiro 1994). Larger fish appear to migrate earlier than smaller fish (Kendall 1977). Tag returns from fish tagged in Nantucket Sound (Massachusetts) suggest that fish migrate south to the outer shelf near Block Canyon (south of Rhode Island) and then move southwest along the outer shelf toward Norfolk Canyon off Virginia (Kolek 1990).

Fish in South Atlantic Bight and Gulf of Mexico appear to be non-migratory and attached to specific reefs throughout the year (Beaumariage 1964; Beaumariage and Wittich 1966; Moe 1966). Most fish using nearshore artificial reef and wreck habitats (< 20 m deep) support commercial and recreational fisheries during the winter (Chee 1977; Mercer 1989; Adams 1993). Sedberry *et al*. (1998) showed that 95% of black sea bass tagged and at large for more than one month in Gray's Reef National Marine Sanctuary were recaptured in the vicinity of the sanctuary. However some fish moved large distances as one individual was recaptured off St. Augustine (Florida), 167 km from Gray's reef. Musick and Mercer (1977) suggested that some adult black sea bass in the Gulf of Mexico may migrate, but tagging studies performed in the northeastern Gulf of Mexico suggest that adult fish become site attached once established on a specific reef (Topp 1963; Beaumariage 1964; Beaumariage and Wittich 1966; Moe 1966).

In the Mid-Atlantic Bight, adult black sea bass move from over wintering habitats on the outer continental shelf to inshore areas as waters warm in the spring. The inshore migration appears to begin in April as temperatures warm to > 7°C (Nesbit and Neville 1935; June and Reintjes 1957; Colvocoresses and Musick 1984; Chang 1990; Shepherd and Terceiro 1994). Primary summer habitats for adults are located on the nearshore continental shelf at depths < 60 m and fish may use complex habitats in the lower reaches of large estuaries which are relatively shallow (~ 5 m).

Adult black sea bass growth appears to vary with latitude. Growth was nearly twice as high for fish collected in Massachusetts than for fish in New York and Virginia (Dery and Mayo 1988; Kolek 1990; Caruso 1995). A similar latitudinal trend was suggested by Mercer (1978) and Wenner *et al.* (1986) who showed fish from the Mid-Atlantic Bight were larger at age and grew faster than fish from the South Atlantic Bight. Adults show linear growth up to age 6 (Wenner *et al.* 1986).

Several studies have suggested that growth rates are sex dependent in adult black sea bass, with females growing more rapidly than males (Lavenda 1949; Mercer 1978; Wilk *et al*. 1978). However, Alexander (1981) used otolith analyses of year 1 and older fish from New York to suggest that males grow faster than females. Shepherd and Idoine (1993) suggested growth was sex dependent for all stages including transitional individuals. However, the sex dependent and geographic differences in growth may be related to site specific differences in exploitation rates, gear selectivity, and other sampling biases (Mercer 1978; Wenner *et al.* 1986).

REPRODUCTION

Black sea bass are protogynous hermaphrodites, with fish changing sex from female to male as they increase in age and size. Age of sexual transition varies with latitude with females maturing and undergoing sexual transition at greater ages in northern latitudes (McGovern *et al*. 2002). Fish in the Mid-Atlantic Bight begin to mature at age 1 (8-17 cm TL) and 50% are mature at 2-3 yrs and ~19 cm SL (O'Brien *et al.* 1993). The majority of fish less < 19 cm are females, while larger fish are transitional individuals or males (Mercer 1978). Detailed studies of sexual development and transition have been performed with individuals collected in the South Atlantic Bight and Gulf of Mexico, where the patterns are similar (Mercer 1978; Link 1980; Wenner *et al.* 1986; Hood *et al.* 1994). In the South Atlantic Bight, frequency of occurrence for transitional fish is highest at ages 2-5 yrs (Waltz *et al.* 1979; Wenner *et al.* 1986). Fish older than 4-5 yrs and > 210 mm TL are primarily males (Hood *et al*. 1994). Maximum age and size of black sea bass are 7 yrs and 330 mm TL, respectively. The age and size of fish undergoing sexual transition has decreased as a result of increasing fishing pressure (Alexander 1981; Shapiro 1987). The frequency of large mature males also declined. A mark-recapture study of black sea bass in Gray's Reef National Marine Sanctuary, Georgia also showed that size distributions of fish decreased overtime as a result of fishing pressure in the South Atlantic Bight (Sedberry *et al*. 1998). Reproductive potential in black sea bass may be limited by the availability of large males (Shepherd and Idoine 1993). Reproductive output varies with the abundance of large males for other serranids that show strong spawning hierarchies and paired spawning (McGovern *et al*. 1998). However, black sea bass reproductive behavior has not been studied and the participation of non-dominant males in spawning could reduce the possibility that reproductive potential is depressed by the rarity of large dominant males (Shepherd and Idoine 1993).

Fecundity is related to body size and age. Female fish 2-5 years of age in the Mid-Atlantic Bight release between 191,000 and 369,500 eggs (Mercer 1978). In the South Atlantic Bight fecundity ranges from 17,000 for age-2 females (108 mm SL) to 1,050,000 for age 2-3 fish (438 mm SL) (Wenner *et al.* 1986). Frequency of occurrence for individuals in sexual transition may be highest just before spawning.

Primary spawning habitats appear to be located in the nearshore continental shelf at depths of 20-50 m (Breder 1932; Kendall 1972; Musick and Mercer 1977; Wilk and Brown 1980; Eklund and Targett 1990; Berrien and Sibunka 1999). Gravid females are common on the continental shelf and generally not found in estuaries (Allen *et al.* 1978). Fish may spawn on sand bottoms broken by ledges and move to structurally complex habitats in deeper water after spawning (Kolek 1990; MAFMC 1996). Kolek (1990) showed that some tagged black sea bass return to the spawning grounds in Nantucket Sound and suggested that the animals may home to spawning grounds. The population Kolek (1990) studied appeared to spawn earlier and in shallower water than reported for other populations in the Mid-Atlantic Bight (Kendall 1977).

In the Mid-Atlantic Bight, black sea bass spawn from April through October (Able and Fahay 1998; Reiss and McConaugha 1999). Spawning occurs earlier in the year at southern latitudes. In the South Atlantic Bight, spawning occurs from January through June with a peak from March through May (Mercer 1989). Spawning may also occur from September-October (Wenner *et al.* 1986). Fish in the Gulf of Mexico spawn from December through April (Hood *et al*. 1994).

STOCK STRUCTURE

The black sea bass population is currently managed as three separate stocks: Mid-Atlantic, South Atlantic, and Gulf of Mexico. The geographic dividing line for the Mid- and South Atlantic stocks is located at Cape Hatteras, North Carolina. The South Atlantic stock extends to Cape Kennedy, Florida (Ginsburg 1952; Mercer 1978; Shepherd 1991; Klein-MacPhee 2002), while the Gulf of Mexico stock ranges from Cape Kennedy to Texas (Bowen and Avise 1990). Ginsburg (1952) considered fish in the Atlantic and Gulf of Mexico to be separate species (*C. striata* and *C. melana*, respectively) based on meristic characteristics. Miller (1959) analyzed morphometric and meristic data from a larger number of specimens and concluded that the difference between populations warranted only subspecific designations: *C. striata striata* and *C. striata melana*. Miller's subspecific classification has been supported by analyses of osteological differences, allozyme and plasma protein variation, and mtDNA variation (Bortone 1977; Chapman 1977; Bowen and Avise 1990).

Recently, black sea bass year class strength has been strong in the Mid-Atlantic Bight (Atlantic States Marine Fisheries Commission 2004). The 2002 year-class was strong; the fourth highest since 1968; and the 2003 year-class appear to show moderate strength. However, South Atlantic Bight black sea bass stock appears to be declining (Harris and Sedberry 2004). Virtual population analyses (Vaughan *et al.* 1995, 1998) show the South Atlantic Bight stock population decreased from about 4 million individuals during 1979 to about 2.2 million in 1986. This trend was followed by an increase to over 3 million in 1988 and 1989 before the population decreased to 1.4 million in 1995 (Vaughan *et al.* 1995, 1998). Estimates of total mortality ranged from 1.00 in 1979 to 1.76 in 1982 (McGovern *et al*. 2002). In the Gulf of Mexico, black sea bass are federally managed but the status of the stock is unknown, which is why the Florida Fish and Wildlife Conservation Commission is proposing to regulate fishing practices (Florida Fish and Wildlife Conservation Commission 2004).

FOOD HABITS

Following the completion of the yolk sac stage (~ 2-d), larvae starve after three days if not exposed to appropriate prey (microalgae and zooplankton) (Tucker 1989).

Food habits data collected during Northeast Fisheries Science Center (NEFSC) bottom trawl surveys [see Link and Almeida (2000) for methodology] reveal that decapods were the dominant prey item for all size classes of black sea bass (Figure 2). Juveniles, which are diurnal, visual predators, prey on benthic and epibenthic crustaceans (isopods, amphipods, small crabs, sand shrimp, copepods, mysids) and small fish (Richards 1963a; Kimmel 1973; Allen *et al.* 1978; Link 1980; Werme 1981; Hood *et al.* 1994), and their diets appear to change with body size. Bowman *et al*. (2000), using the same NEFSC food habits database, but only for the years 1977-1980, found that crustaceans dominated the diet for all size classes of juvenile black sea bass (Table 1). Amphipods were among the more important crustacean prey for the smallest juveniles (1-5 cm), and although decapods dominated the diet of fish 11-20 cm, the euphausiid, *Meganyctiphanes norvegica*, was also an important prey item for that size class. Among the important decapod prey for juveniles were *Cancer irroratus* and *Crangon septemspinosa*. Crustaceans are also dominant prey for juveniles in New Jersey coastal and estuarine areas, but fish > 110-180 mm SL incorporate fish prey (anchovy and silversides *Menidia* sp.) in their diets (Allen *et al.* 1978). Large juveniles in New Jersey estuaries also feed on lady (*Ovalipes* sp.), blue and xanthid crabs, as well as caridean shrimp (Festa 1979). In lower Chesapeake Bay eelgrass beds, fish 140-165 mm TL consume juvenile blue crabs (*Callinectes sapidus*) and pipefish (*Syngnathus* sp.), as well as isopods, caprellid amphipods, and shrimp (Orth and Heck 1980). Kimmel (1973) reported a dietary shift in juveniles sampled in Magothy Bay, VA. Fish 30-90 mm SL consumed mysids (55%) and amphipods (15%), while juveniles 91-146 mm SL fed on larger brachyurian and xanthid crabs (35%) as well as mysids (19%), and polychaetes (14%). In nearshore continental shelf habitats in the South Atlantic Bight, amphipods, isopods and decapods are also important prey for juveniles 50-100 mm SL while larger individuals also consume more decapods and small fishes (Sedberry 1988).

Adult black sea bass are generalist carnivores that feed on a variety of infaunal and epibenthic invertebrates, especially crustaceans (including juvenile American lobster *Homarus americanus*, crabs, and shrimp) small fish, and squid (Bigelow and Schroeder 1953; Miller 1959; Richards 1963a; Mack and Bowman 1983; Hood *et al.* 1994; Steimle and Figley 1996). The Bowman *et al*. (2000) study showed that while crustaceans continue to be important diet items for the adults, fish also become more significant (Table 1), particularly for the largest black sea bass (> 40 cm), where sand lance (*Ammodytes dubius*) and scup (*Stenotomus chrysops*) were prominent. Sheepshead minnow (*Cyprinodon variegates*) was a major diet item for adults 36-40 cm. Decapods, and in particular, the crab *Cancer irroratus*, was the major crustacean prey. Squids are notable diet items for black sea bass 21-25 cm.

Regionally, in the Mid-Atlantic Bight, the winter diet of adult black sea bass is poorly known, although Bowman *et al*. (2000) showed that crustaceans, especially decapods, dominated the diet in that region. Other important prey in over wintering habitats may include echinoderms [e.g., sand dollars (*Echinarachnius parma*) and sea stars], mollusks [e.g., razor clams (*Ensis directus*)], and polychaetes; average benthic biomasses are 50-75 g/m^2 wet weight (Wigley and Theroux 1981; Steimle 1990). Squid (*Loligo* sp. and *Illex* sp.) and butterfish are also available during the winter. Species co-occurring with sea bass in over wintering habitats, including scup (*Stenotomus chrysops*), may be competitors for food (Austen *et al*. 1994.) Bowman *et al*. (2000) also showed that crustaceans, and again, especially decapods, dominated the diet in southern New England, Georges Bank, and inshore north of Cape Hatteras. In the South Atlantic Bight, black sea bass diets do not vary with season (Sedberry 1988). Fish, as well as epibenthic reef organisms (amphipods, stomatopods, shrimp, decapods) are dominant prey (Sedberry 1988; Bowman *et al*. 2000). Diets of fish in the Gulf of Mexico are similar to those of the South Atlantic Bight population (Miller 1959; Cupka *et al.* 1973; Link 1980; Sedberry 1988; Hood *et al.* 1994).

CO-OCCURRING SPECIES

During the summer, adult black sea bass in the Mid-Atlantic Bight share complex coastal habitats with other fishes including tautog (*Tautoga onitis*), spotted hake (*Urophycis regia*), red hake (*U. chuss*), conger eel (*Conger oceanicus*), ocean pout (*Macrozoarces americanus*), pinfish (*Lagodon rhomboides*), northern sea robin (*Prionotus carolinus*), and transients such as gray triggerfish (*Balistes capriscus*) (Chee 1977; Musick and Mercer 1977; Eklund and Targett 1991). Butterfish (*Peprilus triacanthus*), smooth dogfish (*Mustelus canis*), round herring (*Etrumeus teres*), and windowpane flounder (*Scophthalmus aquosus*) co-occur in samples with black sea bass in inshore trawl surveys (Phoel 1985; Gabriel 1992; Brown *et al.* 1996). Adult black sea bass in the South Atlantic Bight co-occur with southern porgy and scad (Powles and Barans 1980). Grouper, vermillion snapper, and red porgy occur on reef structures with black sea bass in the Gulf of Mexico (McGovern *et al.* 2002). Competition for food and shelter space with co-occurring species could affect habitat quality for black sea bass on specific reef structures.

Hartman and Brandt (1995) found black sea bass, presumably juveniles, in the summer diets of one year old weakfish (*Cynoscion regalis*) and other predators in Chesapeake Bay.

Resource species that co-occur with black sea bass in soft bottom over wintering habitats include scup, summer flounder, butterfish, squid, and American lobster (Chang 1990; Able and Kaiser 1994).

GEOGRAPHICAL DISTRIBUTION

EGGS

Black sea bass eggs were collected during the 1978-1987 NEFSC Marine Resources Monitoring, Assessment and Prediction (MARMAP) ichthyoplankton surveys mostly from New Jersey to Cape Hatteras (Figure 3). Eggs first appear in large numbers in June, with the highest mean monthly densities in July, August, and September, and the highest mean monthly density in August (6.63 eggs/10 m^2). Egg numbers decline sharply in October.

LARVAE

During the NEFSC MARMAP surveys, peak months for larval abundance in the Mid-Atlantic were from July-September, with the highest mean monthly density in August (3.36 larvae/10 m^2) (Figure 4). Larvae first appear near Cape Hatteras and occur farther north as the year progresses. A few larvae occur in the Mid Atlantic Bight in November (Kendall 1972; Able *et al.* 1995). Infrequent collections of larvae in deeper water (> 200 m) water may be the result of the cross shelf transport from near shore spawning areas and away from high quality settlement habitats.

Larvae have been reported in high salinity coastal areas of southern New England in August and September (Stone *et al*. 1994). Black sea bass in the near shore coastal larval assemblage were collected within 48 km in the New York Bight during the summer months (Cowen 1993). Larvae are abundant on the inner shelf outside Chesapeake Bay but not in association with estuarine plume water (Reiss and McConaugha 1999). Larvae may be more abundant in subsurface than in surface plankton tows in June near the mouth of Chesapeake Bay (Pearson 1941). Larval black sea bass also occur in surf zone plankton collections from northern New Jersey (Burlas *et al.* 2001).

While black sea bass larvae are collected close to shore on the continental shelf, they rarely occur within estuaries. Larvae are not reported in Delaware Bay (Wang and Kernehan 1979), Great Bay, NJ (Able and Fahay 1998), or the Hudson-Raritan Estuary (Croker 1965; Dovel 1981). Few larvae are collected in Cape Cod Bay (Scherer 1984), Narragansett Bay (Herman 1962; Bourne and Govoni 1988), and other southern New England estuaries (Stone *et al*. 1994). Both eggs and larvae have not been collected in Mystic River estuary (Connecticut) (Pearcy and Richards 1962). Black sea bass larvae occurred in the Indian River estuary (Delaware) during one of three survey years (Pacheco and Grant 1965) but were absent in a subsequent two-year survey of the estuary (Scotton 1970; Derickson and Price 1973; Klein-MacPhee 2002). Able *et al.* (1995) speculated that most larvae settle in near shore continental shelf habitats and then move into estuarine nurseries where post-settlement stage juveniles can be abundant.

JUVENILES

Because black sea bass are generally associated with structurally complex habitats and steep depth gradients, patterns of habitat specific distribution are not well described using standard trawl surveys. Black sea bass also use a variety of man-made habitats including artificial reefs, shipwrecks, bridge abutments, piers, pilings, jetties, groins, submerged pipes and culverts, navigation aids, anchorages, rip-rap barriers, fish and lobster traps, and rough bottom along the sides of navigation channels. The NEFSC and state trawl surveys avoid excessively rough bottom, shipwrecks, and reefs, or use roller gear, and thus under-sample fish that use structurally complex habitats. Furthermore these surveys avoid sampling in shallow coastal habitats where black sea bass may be abundant during juvenile life history stages. Thus habitat specific patterns of distribution derived from trawl survey data should be viewed with caution.

The distributions and abundances of juvenile black sea bass collected during NEFSC bottom trawl surveys from the Gulf of Maine to Cape Hatteras are shown in Figure 5. Note that winter and summer distributions are presented as presence data only. In winter they occurred mostly offshore on the shelf in the Mid-Atlantic and southern New England between the 50-200 m isobaths. In the spring the highest numbers are found off Chesapeake Bay and Cape Hatteras near the 200 m isobath, small numbers also occur inshore. In summer, the few juveniles that were present were found mostly nearshore from Delaware Bay to Cape Hatteras. In the fall, the highest numbers were found nearshore in southern New England around Buzzards Bay, Rhode Island Sound, and the tip of Long Island, as well as at the mouth of the Hudson-Raritan estuary; high numbers were also found in the nearshore Mid-Atlantic from Delaware Bay to Cape Hatteras (Figure 5).

Recently settled juveniles have been reported near the mouths of large estuaries from North Carolina to southern Cape Cod, and occasionally into the southern Gulf of Maine. At many locations, juvenile recruitment shows strong inter-annual variability (Adams 1993; Able *et al.* 1995) which may indicate that meteorological forcing and other "stochastic" factors strongly affect the transport and recruitment of larvae to specific settlement habitats.

Juveniles appear to be most abundant in oceanic waters and polyhaline regions of many estuaries, but can occur at salinities as low as 8 ppt. Juveniles can be relatively common in estuaries south of Cape Cod, and are found in estuaries such as Narragansett Bay, Long Island Sound, the Hudson-Raritan estuary, Great Bay (NJ), Delaware Bay, Chesapeake Bay and tributaries, as well as many estuaries farther south (Bean 1902; Sherwood and Edwards 1902; Mansueti 1955; Richards 1963a, b; Kimmel 1973; Allen *et al.* 1978; Chesapeake Bay Program 1996; Wilk *et al*. 1997; Able and Fahay 1998; Geer 2002; Gottschall *et al.* 2000).

The distributions and abundances of juveniles in Massachusetts coastal waters, based upon the spring and fall 1978-2003 Massachusetts inshore trawl surveys, are shown in Figure 6. Small numbers were found mostly in Buzzards Bay and around Martha's Vineyard in the spring, in contrast to the fall, where very high numbers were found in the Bay and south of Cape Cod; a large catch was found on the eastern tip of Martha's Vineyard.

The seasonal distributions and abundances of juveniles in Narragansett Bay from 1990-1996, based on the Rhode Island bottom trawl surveys, are shown in Figure 7. They were not very common in the Bay; the largest mean catch (1.3 individuals/tow) occurred in summer in Mount Hope Bay.

The distributions and abundances of both juvenile and adult black sea bass in Long Island Sound from April to November 1984-1994, based on the Connecticut Fisheries Division bottom trawl surveys (Gottschall *et al*. 2000), are shown in Figures 8, 9, and 10. The size range of black sea bass captured in the survey ranged from 5-57 cm (Figure 8), with the majority of juveniles captured in October and November (84% and 57% respectively), many of which were YOY (< 10 cm) (Gottschall *et al*. 2000). Most black sea bass taken from May through August were adults. The following description of their distributions relative to depth and bottom type is taken from Gottschall *et al*. (2000).

During May and June, when black sea bass were most commonly encountered (about 13.6% occurrence), they were mostly captured on the Mattituck Sill and along the Connecticut side of the Sound from Norwalk to Guilford (Figure 9). In contrast, during the summer, sea bass were found almost exclusively among sand wave formations on the Mattituck Sill in depths between 18-27 m. During the fall, they were once again more dispersed; however, during September they were taken only in depths < 27 m, whereas in October and November abundance was highest in depths > 27 m (Figure 10C) (Gottschall *et al*. 2000).

Surveys of the Hudson-Raritan estuary (1992-1997) show that juveniles were found from spring through fall, and the highest numbers were concentrated mainly around the center of Raritan Bay in summer and fall (Figure 11).

The Virginia Institute of Marine Science (VIMS) trawl surveys from 1988-1999 of Chesapeake Bay and its tributaries showed that black sea bass was common in the lower Bay and James River, although they were rarely captured in large numbers (Geer 2002). The trawl survey caught 4,907 juveniles and 1,832 adults, with a size range from 2.0-35.4 cm (mean = 10.9 cm). Juveniles were common throughout the Bay and lower portions of the James and York Rivers during spring and summer (April to July) (Figures 12 and 13). Small juveniles (> 7.0 cm) first recruited to the gear in August, so Geer (2002) considered this month to be the beginning of the biological year. Juveniles migrated offshore in the winter and returned to the Bay the following spring at a maximum length of 11 cm. By July it was assumed that YOY fish are a maximum of 17.5 cm (Geer 2002).

The VIMS 1994-1999 beach seine surveys of Chesapeake Bay showed that juvenile black sea bass was uncommon, with only 98 fish captured, ranging in size from 2.2-15.3 cm (mean = 7.4 cm) (Geer 2002). The catch peaked during May (Figure 14), primarily along the ocean sites (Figure 15).

ADULTS

The distributions and abundances of adult black sea bass collected during NEFSC bottom trawl surveys are shown in Figure 16. Note again that winter and summer distributions are presented as presence data only. In winter they were found offshore near the 200 m isobath from southern New England to Cape Hatteras. High numbers were also found along the 200 m isobath in spring, with comparatively small numbers scattered along the Mid-Atlantic coast. In summer, the adults were found mostly closer to shore from the Delmarva peninsula to Cape Hatteras, In the fall, relatively small numbers were found along the coast of southern New England and Mid-Atlantic, but occurred farther offshore towards the Delmarva peninsula and Cape Hatteras; some higher numbers were found near the 200 m isobath off Virginia.

During the spring 1978-2003 Massachusetts inshore trawl surveys (Figure 17), adults were mostly found south of Cape Cod, around the islands, and in Buzzards Bay, with the highest numbers near Nantucket Island and south of the Cape in Nantucket Sound. Distributions were similar in the fall, with the highest numbers occurring in Nantucket Sound and in Buzzards Bay.

Very few adults were found in Narragansett Bay; none were found in winter (Figure 18).

The distributions and abundances of both juvenile and adult black sea bass in Long Island Sound, based on Gottschall *et al*. (2000), were discussed previously.

Very few adults were found in the Hudson-Raritan estuary (Figure 19); those few that were present were found mostly around the middle of Raritan Bay. None were found in winter.

The VIMS trawl and beach seine surveys of Chesapeake Bay and tributaries show that adults were more common during the latter part of the summer and into the fall on the eastern side of the Bay (Figures 12 and 20) (Geer 2002).

HABITAT CHARACTERISTICS

EGGS

In the laboratory, the incubation period is 38 h at 23^{o}C (Hoff 1970) and approximately 120 hrs at a temperature of 15^{o}C (Kendall 1972). Eggs are sensitive to high salinity, low pH, high nitrite-nitrate concentrations, and temperature extremes.

During the MARMAP ichthyoplankton surveys, eggs were collected mostly between temperatures of about 10-25^{o}C (Figure 21). During July through September, the months of highest mean monthly densities, most of the eggs were found at increasing temperatures over the three months: for July, about 16-22^{o}C; for August, about 17-24^{o}C; and for September, about 17-21^{o}C. Their depth range over the period of the survey was between 10-375 m (Figure 21); however, overall they were found in relatively shallow depths. During July through September, the majority of eggs were found at 30 m.

LARVAE

Larval growth and development rates are inversely temperature dependant. In the laboratory, larval duration is 24 days at 18°C and 21 days at 22°C (Berlinsky *et al.* 2000). At 22°C, larvae grew from 3.5 ± 0.1 to 12.2 ± 0.6 mm in about 18 days, which was significantly faster than those cultured at 18°C (Berlinsky *et al.* 2000). Growth was significantly higher in greenwater (algae-water) than in cultures without greenwater.

During the MARMAP ichthyoplankton surveys, larvae were collected between temperatures of 11-26^{o}C (Figure 22). During July through September, the months of highest mean monthly densities, most larvae were found at about 15-19^{o}C in July, at 15-20^{o}C in August, and in 17-21^{o}C in September. During the survey period they were found over a depth range between 10 m to > 2000 m (Figure 22); however, as with the eggs, the majority were found in shallow depths. During July through September, most were found at 30-50 m.

JUVENILES

Structural complexity appears to be essential component of juvenile black sea bass habitat in offshore as well as inshore nurseries throughout the species range. In offshore areas, recently settled fish occur in accumulations of shell on sand substrata, complex microtopographies on exposed clay, on rocky reefs, and on wrecks (Able *et al.* 1995). Because eggs and larvae are largely absent in estuaries, Able *et al*. (1995) speculated that primary black sea bass settlement habitats were probably located along the near shore continental shelf in accumulations of the shells of bivalves, including Atlantic surf clams (*Spisula solidissima*). Large numbers of newly settled black sea bass were observed on sandy substrates with shell fragments adjacent to an artificial reef 15 km off the coast of Virginia-North Carolina (Adams 1993). Settlers were also observed on the reef. Within estuaries, young fish use shallow shellfish (oyster and mussel), sponge (including *Microciona prolifera*), amphipod (*Ampelisca abdita*), seagrass beds (especially *Ruppia* sp.), and cobble habitats as well as manmade structures such as wharves, pilings, wrecks, reefs, crab and conch pots (Bean 1888; Moore 1892; Sherwood and Edwards 1902; Hildebrand and Schroeder 1928; Arve 1960; Kendall 1972; Derickson and Price 1973; Musick and Mercer 1977; Clayton *et al.* 1978; Weinstein and Brooks 1983; Feigenbaum *et al.* 1989; Able *et al.* 1995). Early juveniles are rare on un-vegetated sandy intertidal flats and beaches (Allen *et al.* 1978) as well as deeper, muddy bottoms (Richards 1963b). Juveniles are primarily associated with shell bottom throughout the year in the lower reaches of a Georgia estuary (Dahlberg 1972).

Juvenile black sea bass display extremely high site fidelity. Recapture rates of tagged juveniles 34-111mm TL (N = ~ 700) ranged from 20% to 30%, and 99% of recaptured fish occurred within 30 m of a release site in a New Jersey estuary (Able and Hales 1997). Young fish may be territorial and defend structured habitat from con-specifics (Werme 1981; Able and Fahay 1998). Like many reef species, juvenile recruitment strength for black sea bass may be strongly affected by the availability of shelters that serve as predation refuges (Huntsman *et al.* 1983; Richards and Lindeman 1987). Arve (1960) attributed black sea bass stock declines in the late 1950s in Chincoteague Bay, MD to declines in oyster populations that provided important shelter habitat for juveniles. Oysters, once common but now effectively extinct in Raritan Bay, NY and NJ, were once important juvenile black sea bass habitat in that estuary (Nichols and Breder 1927).

In the Mid and South Atlantic Bights, black sea bass nursery habitats occur at depths < 50 m (Sedberry *et al*. 1998). Most nurseries are located at depths < 20 m (Sedberry *et al*. 1998). Juvenile depth distributions appear to increase with age and body size (Kendall 1977; Musick and Mercer 1977). Within estuaries, older juveniles use habitats < 10 m deep but the YOY are collected in shallower shoal habitats (1 m) (Musick and Mercer 1977). Older juveniles use deeper estuarine channels (Bean 1888; de Sylva *et al*. 1962; Richards and Castagna 1970; Zawacki 1976; Allen *et al.* 1978; Szedlmayer and Able 1996), jetties (Schwartz 1964), and bridge abutments (Allen *et al.* 1978).

Laboratory studies show that growth rates of juvenile black sea bass vary with temperature, salinity, dissolved oxygen and prey quality (Berlinsky *et al.* 2000). Several studies have shown that juveniles grow most rapidly at intermediate salinities. Fish exposed to a salinity of 20 ppt showed higher growth than those exposed to 10 and 32 ppt in the laboratory (Berlinskiy *et al.* 2000). Optimal salinities for the growth of fish appear to be similar in the South Atlantic Bight (Cotton *et al*. 2003). Osmoregulatory costs are reduced for fish at intermediate salinities. High growth at polyhaline salinities may indicate that habitat suitability is higher in the lower reaches of estuaries and shelf areas under estuarine influence, than offshore nurseries, but experimental comparisons of habitat suitability in estuarine and continental shelf nursery habitats has not been performed.

In the South Atlantic Bight, fish 20-140 mm SL are most abundant on reefs where salinities exceed 30 ppt, but have been collected in estuarine regions where salinities are as low as 9 ppt (Cupka *et al.* 1973). In the St. John's River, FL, young-of the year black sea bass (28-71 mm TL) are primarily associated with salinities ranging from 15-25 ppt (Tagatz 1967). However, larger juveniles can occur in estuarine reaches where salinities are as low as 8-13 ppt. Juveniles were generally most abundant in the lower reaches of a Georgia estuary where salinities are > 30 ppt (Dahlberg 1972).

Hales and Able (1995) showed that laboratory exposure to short term periods of low dissolved oxygen result in poor growth and significant mortality in age-0 and 1+ black sea bass. In their study fish did not grow and showed respiratory distress and reduced feeding when exposed to oxygen concentrations < 2 ppm. In contrast exposure to ~ 6 ppm produced significantly positive growth rates (0.3% d TL). Fifty percent mortality occurred after short-term exposure to ~1 ppm. The authors speculated that conditions producing episodes of hypoxia near continental shelf settlement habitats could depress juvenile recruitment in some areas.

In the laboratory, juvenile black sea bass showed 100% mortality when exposed to temperatures of 2-3°C in seawater pumped from a New Jersey estuary. Temperatures < 6°C resulted in increased shelter use and burial behavior and feeding decreased dramatically at values < 4°C (Able and Hales 1997). These data are consistent with early observations of juvenile mortality during episodic cold temperatures in shallow nursery areas in southern New England (Baird 1873). The fall migration of juvenile black sea bass from shallow estuarine and coastal nursery habitats to deeper offshore waters in the Mid-Atlantic Bight appears to be triggered by declining temperatures. Juveniles begin to move into deeper warmer offshore water as temperatures decline below 14°C, and few individuals are collected in shallow areas when temperatures fall below 6°C (Able and Fahay 1998; Klein-MacPhee 2002). In the Mid-Atlantic Bight, juveniles return to nearshore and estuarine habitats in the spring and are collected as early as March in the Chesapeake Bay region (Kimmel 1973).

Juveniles (20-140 mm SL) are collected at temperatures ranging from 6-30°C in the South Atlantic Bight (Cupka *et al.* 1973). In North Carolina, young-of the year (30-50 mm SL) are abundant along inshore jetties at temperatures 6-29°C (Link 1980; Schwartz *et al.* 1981). Young of the year fish (28-71 mm FL) are also collected in June and July at temperatures ranging from 26.6-27.4°C in the Saint John's River, Florida (Tagatz 1967). During the winter and spring, larger juveniles (91-176 mm FL) occur at temperatures between 11.0-17.4°C in the estuary.

The spring and fall distributions of juvenile black sea bass 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 23. In the spring, they were found over a temperature range of 4-18°C, with most spread between about 8-15°C and a peak in catch at 12°C. They were found at depths ranging from 1-400 m; there were peaks in the catch at 101-140 m. Their salinity range was between 28-36 ppt, with the majority spread between 33-35 ppt. In the fall, the juveniles were spread over a warmer temperature range than in the spring: 7-28°C, with the majority found at temperatures ≥ 15°C. They were also found at shallower depths than in the spring, with a range from 1 m to about 140 m, with most found between 11-40 m. Their salinity range was between 29-36 ppt, with the majority at 31-33 ppt.

The spring and autumn distributions of juvenile black sea bass in Massachusetts coastal waters relative to bottom water temperature and depth based on 1978-2003 Massachusetts inshore trawl surveys are shown in Figure 24. The few that were found in spring were found over a temperature range of 9-12°C and a depth range of 6-35 m. The much larger numbers that were found in the fall were found over a higher temperature range of about 10-22°C, with most between 17-21°C. Their depth range during that season was between 1-35 m, with the majority between 6-15 m.

The seasonal distributions of the few juveniles found in Narragansett Bay, relative to bottom water temperature and depth, based on 1990-1996 Rhode Island Narragansett Bay trawl surveys are shown in

Figure 25. In the spring they were found in 11ºC waters, in summer almost all were found at 24ºC, and in the fall they were found at a temperature range of 14-22ºC. Juvenile black sea bass were found at depths of 30-40 ft (9-12 m) in the spring, 10-30 ft (3-9 m) in the summer, and from 10 ft to about 70 ft (21 m) in the fall, with most found in that latter season at 30-40 ft.

The distributions and abundances of both juveniles and adults in Long Island Sound relative to depth were discussed previously, and can be seen, along with their relation to bottom type, in Figure 10 (Gottschall *et al*. 2000).

The distributions of juvenile black sea bass relative to bottom water temperature, dissolved oxygen, depth, and salinity based on 1992-1997 NEFSC Hudson-Raritan estuary trawl surveys are shown in Figure 26. Over the entire survey, juveniles were found in waters ranging from 3-23ºC, with higher percentages found at temperatures $\geq$ 15ºC. They were found in dissolved oxygen levels of 4-11 mg/l, with most between 5-7 mg/l. They were found over a depth range of 10-75 ft (3-23 m), most were found at relatively shallow depths from approximately 20-50 ft (6-15 m). Juveniles were found in salinities ranging from 20-33 ppt, with the majority found at 25-27 ppt.

The hydrographic preferences of juveniles in Chesapeake Bay and tributaries from the 1988-1999 VIMS trawl surveys are shown in Figure 27 (all years and months combined). According to Geer (2002), most juveniles were caught at dissolved oxygen levels of 5-8 mg/l, at temperatures > 16ºC, at salinities > 18 ppt, and at depths > 8 m, (Figure 27). The hydrographic preferences of juveniles caught in the 1994-1999 seine surveys are shown in Figure 28 (all years and months combined). Geer (2002) suggests that the majority were caught in slighter higher temperatures than that of the trawl survey, which may be due to sampling only during months where water temperatures are fairly warm. Most juveniles were also caught in higher salinity waters, with nearly 90% of the catch occurring in waters > 26 ppt (Figure 28). The majority of juveniles caught in the seine surveys were found at dissolved oxygen levels of both 3 mg/l and 6-7 mg/l, and at pH levels of 7.4-8.2.

ADULTS

As stated previously, black sea bass are strongly associated with structurally complex habitats, including rocky reefs, cobble and rock fields, stone coral patches, exposed stiff clay, and mussel beds (see the Life History section for further discussion).

Over wintering habitats in the Mid-Atlantic Bight appear to occur at depths between 60-150 m (range: 30-410 m) (Musick and Mercer 1977). Some fish may also over winter in deep water (> 80 m) off southern New England (Bigelow and Schroeder 1953; Chang 1990; Kolek 1990). Larger fish, that are generally male, occur in deeper water (Nesbit and Neville 1935; Musick and Mercer 1977; Able *et al*. 1995). Potential over wintering habitat may be defined by bottom water temperatures > 7.5°C (Neville and Talbot 1964; Colvocoresses and Musick 1984). The lowest bottom temperatures recorded in the depth range inhabited by adult black sea bass off South Carolina was 5.6°C (Walford and Wicklund 1968). Adult fish exposed to temperatures near 6°C become inactive and were often found resting in holes and crevices (Adams 1993). Schwartz (1964) showed that adult black sea bass stopped feeding when exposed to a temperature of 8°C (salinity = 15 ppt) and died when temperatures were reduced below 2°C. Fish may not over winter in South Atlantic Bight estuaries in the northern part of the region, except during warm winters. Adult sea bass burrow into soft sediments during particularly cold winters off the coast of North and South Carolina (Parker 1990). Winter association of black sea bass with soft substrata on the continental shelf in the Mid-Atlantic Bight (Wigley and Theroux 1981) could be related to winter burial.

In the South Atlantic Bight, black sea bass occur in habitats 10-120 m deep but are most abundant between 20-60 m and occur at temperatures below 29°C (Struhsaker 1969; Link 1980). In the Gulf of Mexico they occur at depths of 7.3-18.3 m, and are most abundant between Tampa and Apalachee Bay (Godcharles 1970; Powers *et al*. 2003). Larger fish are generally found in deeper habitats than smaller fish (Musick and Mercer 1977). Fish have been collected at relatively low salinities (range: 1-36 ppt) in North Carolina estuaries but are most frequent where values exceed 14 ppt (Link 1980). Salinity ranges for fish in Gulf of Mexico and South Atlantic Bight estuaries are similar (Springer and Woodburn 1960).

Adult black sea bass also appear to be vulnerable to low dissolved oxygen stress. Episodic hypoxia in the New York Bight has resulted in mortality for fish and benthic invertebrates, and avoidance on the nearshore continental shelf (Ogren and Chess 1969; Azarovitz *et al.* 1979; Steimle and Radosh 1979). During such events commercial fishermen and sport divers have reported the disappearance and mortality of black sea bass and other fishes from shipwrecks and artificial reefs near the New Jersey coast. These hypoxic conditions are produced by meteorologically driven upwelling events that are followed by early and strong water column stratification that result in an unusually large dinoflagellate blooms. The transport of nutrients from the Hudson River estuary to the nearshore continental shelf may also be important. The Asbury Park Press (NJ) newspaper reported black sea bass mortality in an area where dissolved oxygen concentrations fell below 2 ppm off the New Jersey coast in June of 1997, which followed coastal upwelling.

The spring and fall distributions of adult black sea bass relative to bottom water temperature, depth, and salinity based on 1963-2003 NEFSC bottom trawl surveys are shown in Figure 29. In the spring, they were found over a temperature range of about 3-21°C, with most at 9-12°C. Their depth range was 1-400 m with higher percentages concentrated between 61-140 m. They were found in a salinity range of 32-36 ppt, with the majority between 34-35 ppt. In the fall, adults were spread over a warmer temperature range of 8-28°C, with most spread between about 16-27°C. Their depth range was shallower than in the spring: from 1m to greater than 160 m, with the majority at 11-40 m. Their salinity range was between 30-36 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 30. In spring they were found over at temperature range of 3-17°C, with the majority at 10-14°C. Their depth range during the spring survey was from 1-65 m, with most between 6-25 m. The adults were found at warmer temperatures in the fall, being found over a range of approximately 8-22°C, with the majority between 16-21°C. Almost all were found between depths of 6-20 m.

The seasonal distributions of the few adults found in Narragansett Bay, relative to bottom water temperature and depth, are shown in Figure 31. In the spring they were mostly found in 13-14ºC waters, in summer they were found in a temperature range of 15-24ºC, with peaks at 91-20ºC, and in the fall the majority were at 19-20ºC. Adults were found mostly at a depth of 100 ft (30 m) in the spring, 20-80 ft (6-24 m) in the summer, and from 30-50 ft (9-15 m) and from 100-110 ft (30-34 m) in the fall.

The distributions and abundances of both juveniles and adults in Long Island Sound relative to depth were discussed previously, and can be seen, along with their relation to bottom type, in Figure 10 (Gottschall *et al.* 2000).

The distributions of the few adults found in the Hudson-Raritan estuary, relative to bottom water temperature, dissolved oxygen, depth, and salinity are shown in Figure 32. Over the entire survey, adults were found in a temperature range of 11-23ºC, in a depth range of about 15-65 ft (5-20 m), and were spread over a salinity range spread 20-33 ppt. The majority were found at a dissolved oxygen level of 7mg/l.

In Chesapeake Bay and its tributaries, adults had similar hydrographic preferences to the juveniles in the VIMS trawl surveys (Figure 33) (Geer 2002).

RESEARCH NEEDS

- Studies examining hydrographic mechanisms and larval behaviors controlling larval transport from adult spawning and settlement habitats, including effects of hydrographic processes on the spatial characteristics of settlement habitats and on inter-annual variation in local early juvenile recruitment
- Studies of the mechanisms determining successful migration from offshore settlement to estuarine nursery grounds.
- Comparative studies of the functional habitat quality of coastal ocean and estuarine nursery grounds.
- All aspects of reproductive biology and behavior including the spatial and environmental characteristics of primary spawning habitats, factors controlling sexual transition, and density dependent reproductive success.

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Table 1. Diet composition of black sea bass by fish length category. Data expressed as percentage of stomach content by weight. Squared brackets indicate major taxon subtotal; parentheses indicate minor taxon subtotal. Source: Bowman *et al*. (2000); from NEFSC groundfish surveys, 1977-1980.

Stomach Contents	Length Category (cm)									
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	>40	Total
MOLLUSCA	-	[0.5]	[2.4]	[6.7]	[20.4]	[9.2]	[2.5]	[10.5]	[6.7]	[10.2]
Bivalvia	-	(0.5)	(1.8)	(4.2)	(7.4)	(8.0)	(1.1)	(6.9)	(1.3)	(5.2)
Laevicardium sp.	-	-	-	1.7	2.2	6.6	-	-	-	2.6
Ensis directus	-	-	-	-	0.3	-	-	6.9	1.3	0.5
Bivalvia unid.	-	0.5	1.8	2.5	4.9	1.4	1.1	-	-	2.1
Cephalopoda	-	-	-	(1.0)	(12.1)	(0.6)	(0.5)	(3.3)	(2.3)	(3.8)
Loligo sp.	-	-	-	-	4.1	-	-	-	2.2	1.3
Cephalopoda unid.	-	-	-	1.0	8.0	0.6	0.5	3.3	0.1	2.5
Mollusca unid.	-	-	(0.6)	(1.5)	(0.9)	(0.6)	(0.9)	(0.3)	(3.1)	(1.2)
POLYCHAETA	-	[5.8]	[8.3]	[0.2]	[0.7]	[0.2]	[0.4]	[<0.1]	[9.6]	[1.9]
CRUSTACEA	[85.5]	[91.5]	[82.4]	[76.3]	[45.7]	[57.8]	[78.8]	[45.7]	[17.3]	[54.5]
Amphipoda	(43.6)	(19.9)	(0.3)	(<0.1)	(<0.1)	(<0.1)	(7.5)	-	-	(1.2)
Mysidacea	(3.2)	(4.2)	-	(1.1)	(<0.1)	(2.5)	(<0.1)	-	-	(0.9)
Euphausiacea	-	-	(33.8)	(34.2)	(7.3)	-	-	-	-	(6.3)
Meganyctiphanes norvegica	-	-	33.8	34.2	7.3	-	-	-	-	6.3
Decapoda	(35.5)	(44.2)	(46.9)	(40.3)	(38.2)	(54.9)	(70.2)	(45.7)	(17.3)	(45.6)
Dichelopandalus leptocerus	-	7.2	-	<0.1	-	-	-	-	-	<0.1
Crangon septemspinosa	14.5	19.4	0.1	<0.1	0.3	0.3	<0.1	-	0.1	0.2
Paguridae	-	1.9	6.4	2.4	5.8	3.8	0.9	-	2.0	3.4
Munida sp.	-	1.7	-	2.3	0.4	4.5	1.7	-	-	1.9
Cancer borealis	-	-	1.8	-	-	<0.1	7.6	-	-	1.2
Cancer irroratus	-	10.2	23.8	19.6	17.5	40.4	37.2	45.7	7.6	27.0
Ovalipes sp.	-	-	-	-	-	-	15.2	-	4.8	3.0
Decapoda unid.	21.0	3.8	14.8	16.0	14.2	5.9	7.6	-	2.8	8.9
Crustacea unid.	(3.2)	(23.2)	(1.4)	(0.7)	(0.2)	(0.4)	(1.1)	-	-	(0.5)
OSTEICHTHYES	-	[1.8]	[2.6]	[8.4]	[27.8]	[25.0]	[14.7]	[43.5]	[62.9]	[28.5]
Ophichthus cruentifer	-	-	-	-	-	-	-	-	0.3	0.1
Alepocephalidae	-	-	-	-	-	2.0	-	-	-	0.6
Clupea harengus	-	-	-	-	2.3	-	-	-	-	0.6
Anchoa hepsetus	-	-	-	6.8	17.2	-	-	-	9.5	6.4
Anchoa mitchilli	-	-	-	-	-	-	9.6	-	-	1.5
Engraulidae	-	-	-	-	3.7	-	-	-	-	0.9
Cyprinodon variegatus	-	-	-	-	-	-	-	30.4	-	1.3
Hippocampus sp.	-	-	-	-	-	-	1.9	-	-	0.3
Syngnathus fuscus	-	-	-	-	-	-	3.0	-	-	0.5
Myctophidae	-	-	-	-	-	12.8	-	-	-	3.6
Ophidiidae	-	-	-	-	-	2.1	-	-	-	0.6
Ammodytes dubius	-	-	-	-	-	-	-	-	20.6	3.0
Stenotomus chrysops	-	-	-	-	-	3.7	-	-	25.3	4.8
Scophthalmus aquosus	-	-	-	-	-	-	-	-	4.4	0.7
Osteichthyes larvae	-	-	-	-	<0.1	<0.1	-	-	-	<0.1
Osteichthyes unid.	-	1.8	2.6	1.6	4.6	4.4	0.2	13.1	2.8	3.6
ANIMAL REMAINS AND MISC.	[14.5]	[0.4]	[4.3]	[8.4]	[5.4]	[7.8]	[3.6]	[0.3]	[3.5]	[4.9]
Number sampled	9	82	69	142	188	103	49	16	22	680
Number empty	1	11	19	36	64	30	18	11	5	195
Mean stomach content (g)	0.007	0.023	0.223	0.581	0.975	2.033	2.314	1.912	4.983	1.097
Mean fish length (cm)	5	7	13	18	22	27	32	38	45	21

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

	Length Category (cm)									
Stomach Contents	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	>40	Total
MOLLUSCA	-	[0.5]	[2.4]	[6.7]	[20.4]	[9.2]	[2.5]	[10.5]	[6.7]	[10.2]
Bivalvia	-	(0.5)	(1.8)	(4.2)	(7.4)	(8.0)	(1.1)	(6.9)	(1.3)	(5.2)
Laevicardium sp.	-	-	-	1.7	2.2	6.6	-	-	-	2.6
Ensis directus	-	-	-	-	0.3	-	-	6.9	1.3	0.5
Bivalvia unid.	-	0.5	1.8	2.5	4.9	1.4	1.1	-	-	2.1
Cephalopoda	-	-	-	(1.0)	(12.1)	(0.6)	(0.5)	(3.3)	(2.3)	(3.8)
Loligo sp.	-	-	-	-	4.1	-	-	-	2.2	1.3
Cephalopoda unid.	-	-	-	1.0	8.0	0.6	0.5	3.3	0.1	2.5
Mollusca unid.	-	-	(0.6)	(1.5)	(0.9)	(0.6)	(0.9)	(0.3)	(3.1)	(1.2)
POLYCHAETA	-	[5.8]	[8.3]	[0.2]	[0.7]	[0.2]	[0.4]	[<0.1]	[9.6]	[1.9]
CRUSTACEA	[85.5]	[91.5]	[82.4]	[76.3]	[45.7]	[57.8]	[78.8]	[45.7]	[17.3]	[54.5]
Amphipoda	(43.6)	(19.9)	(0.3)	(<0.1)	(<0.1)	(<0.1)	(7.5)	-	-	(1.2)
Mysidacea	(3.2)	(4.2)	-	(1.1)	(<0.1)	(2.5)	(<0.1)	-	-	(0.9)
Euphausiacea	-	-	(33.8)	(34.2)	(7.3)	-	-	-	-	(6.3)
Meganyctiphanes norvegica	-	-	33.8	34.2	7.3	-	-	-	-	6.3
Decapoda	(35.5)	(44.2)	(46.9)	(40.3)	(38.2)	(54.9)	(70.2)	(45.7)	(17.3)	(45.6)
Dichelopandalus leptocerus	-	7.2	-	<0.1	-	-	-	-	-	<0.1
Crangon septemspinosa	14.5	19.4	0.1	<0.1	0.3	0.3	<0.1	-	0.1	0.2
Paguridae	-	1.9	6.4	2.4	5.8	3.8	0.9	-	2.0	3.4
Munida sp.	-	1.7	-	2.3	0.4	4.5	1.7	-	-	1.9
Cancer borealis	-	-	1.8	-	-	<0.1	7.6	-	-	1.2
Cancer irroratus	-	10.2	23.8	19.6	17.5	40.4	37.2	45.7	7.6	27.0
Ovalipes sp.	-	-	-	-	-	-	15.2	-	4.8	3.0
Decapoda unid.	21.0	3.8	14.8	16.0	14.2	5.9	7.6	-	2.8	8.9
Crustacea unid.	(3.2)	(23.2)	(1.4)	(0.7)	(0.2)	(0.4)	(1.1)	-	-	(0.5)
OSTEICHTHYES	-	[1.8]	[2.6]	[8.4]	[27.8]	[25.0]	[14.7]	[43.5]	[62.9]	[28.5]
Ophichthus cruentifer	-	-	-	-	-	-	-	-	0.3	0.1
Alepocephalidae	-	-	-	-	-	2.0	-	-	-	0.6
Clupea harengus	-	-	-	-	2.3	-	-	-	-	0.6
Anchoa hepsetus	-	-	-	6.8	17.2	-	-	-	9.5	6.4
Anchoa mitchilli	-	-	-	-	-	-	9.6	-	-	1.5
Engraulidae	-	-	-	-	3.7	-	-	-	-	0.9
Cyprinodon variegatus	-	-	-	-	-	-	-	30.4	-	1.3
Hippocampus sp.	-	-	-	-	-	-	1.9	-	-	0.3
Syngnathus fuscus	-	-	-	-	-	-	3.0	-	-	0.5
Myctophidae	-	-	-	-	-	12.8	-	-	-	3.6
Ophidiidae	-	-	-	-	-	2.1	-	-	-	0.6
Ammodytes dubius	-	-	-	-	-	-	-	-	20.6	3.0
Stenotomus chrysops	-	-	-	-	-	3.7	-	-	25.3	4.8
Scophthalmus aquosus	-	-	-	-	-	-	-	-	4.4	0.7
Osteichthyes larvae	-	-	-	-	<0.1	<0.1	-	-	-	<0.1
Osteichthyes unid.	-	1.8	2.6	1.6	4.6	4.4	0.2	13.1	2.8	3.6
ANIMAL REMAINS AND MISC.	[14.5]	[0.4]	[4.3]	[8.4]	[5.4]	[7.8]	[3.6]	[0.3]	[3.5]	[4.9]
Number sampled	9	82	69	142	188	103	49	16	22	680
Number empty	1	11	19	36	64	30	18	11	5	195
Mean stomach content (g)	0.007	0.023	0.223	0.581	0.975	2.033	2.314	1.912	4.983	1.097
Mean fish length (cm)	5	7	13	18	22	27	32	38	45	21

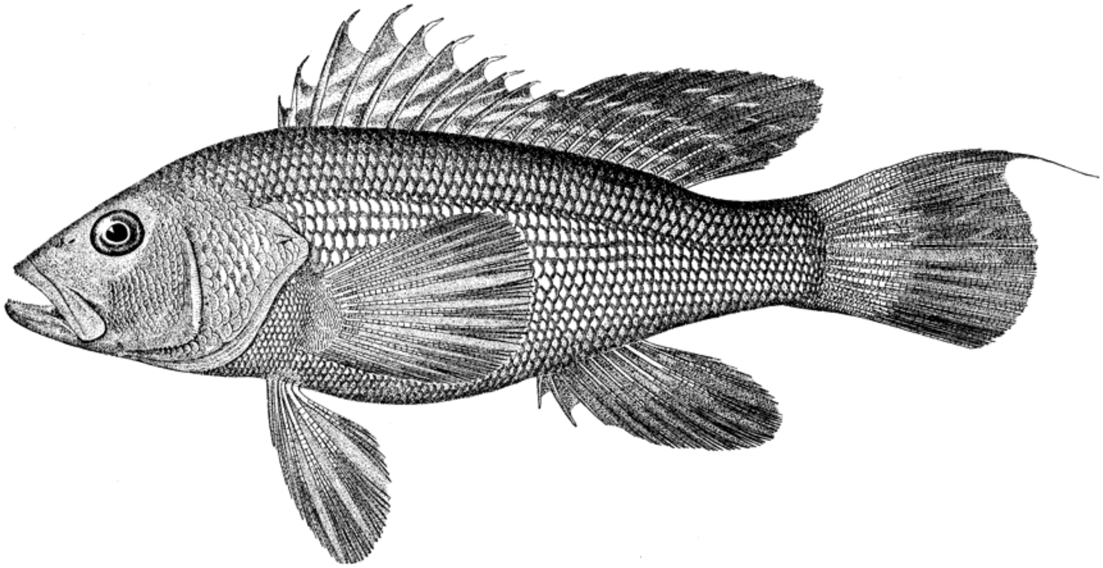

Figure 1. The black sea bass, *Centropristis striata* (from Goode 1884).

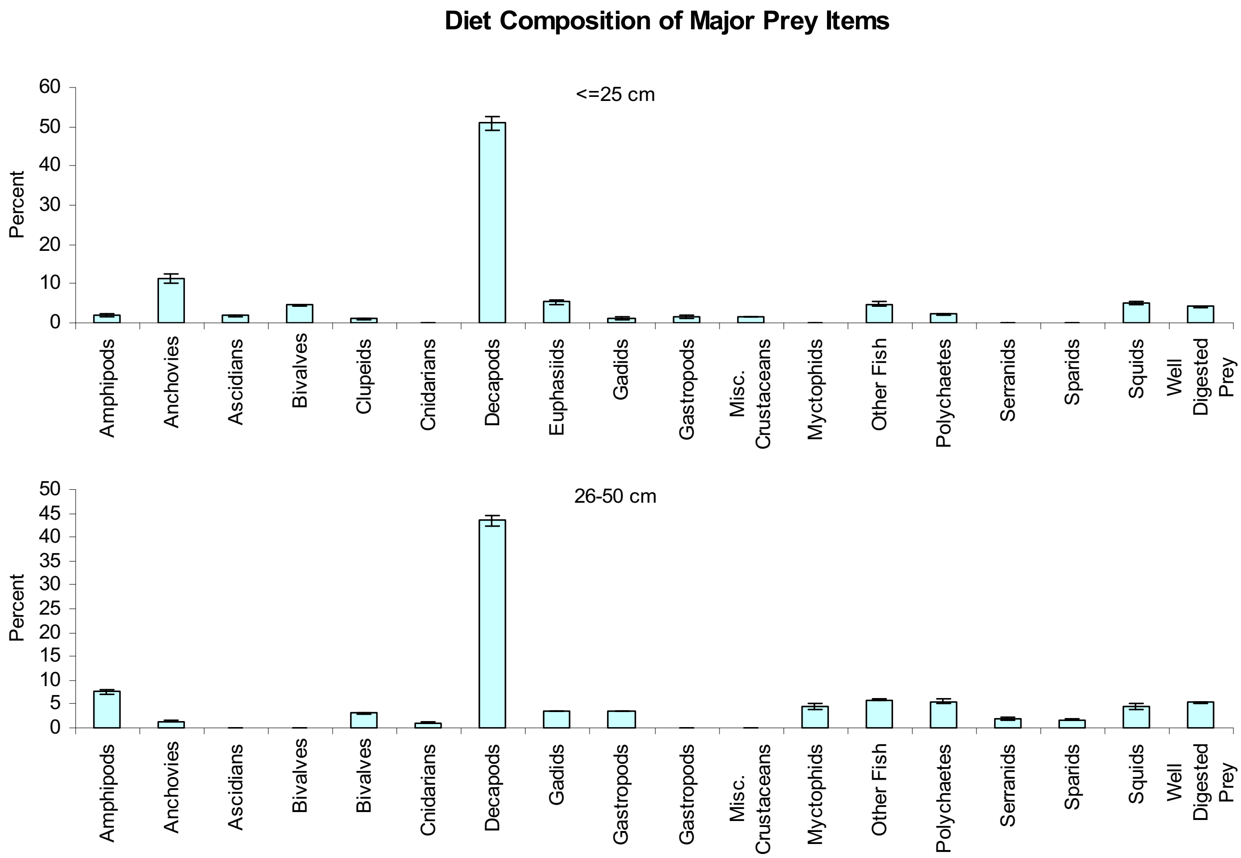

Figure 2. Percent by weight of the major prey items in the diet of two size categories of black sea bass. Specimens were collected during NEFSC bottom trawl surveys from 1973-2001 (all seasons). For details on NEFSC diet analysis, see Link and Almeida (2000).

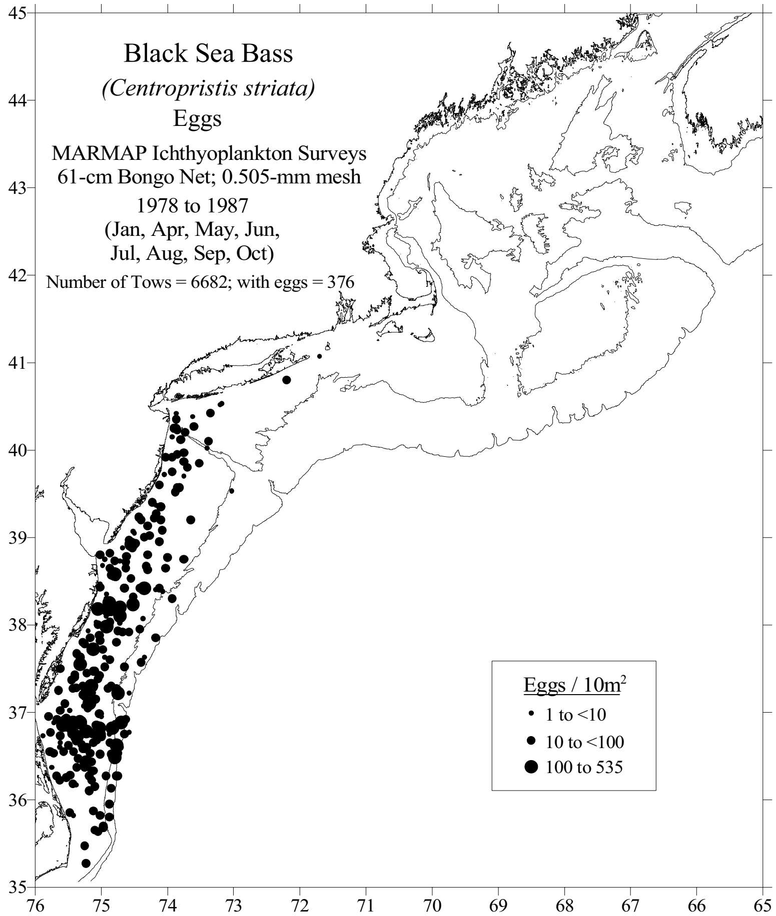

Figure 3. Distributions and abundances of black sea bass eggs collected during NEFSC MARMAP ichthyoplankton surveys, for all available months and years from 1978-1987 combined.

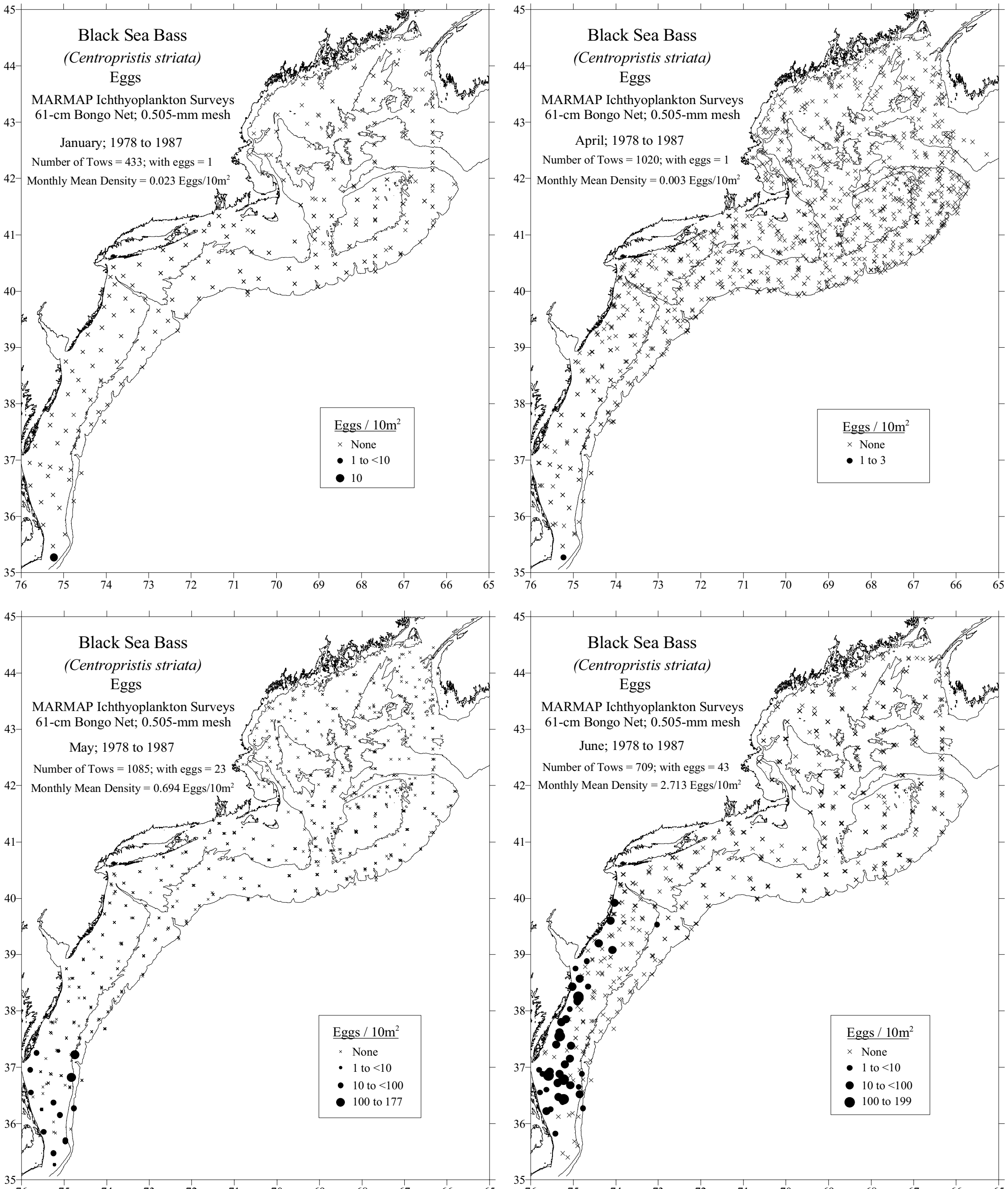

Figure 3. Cont'd.
From MARMAP ichthyoplankton surveys, January, April, May, and June, 1978-1987.

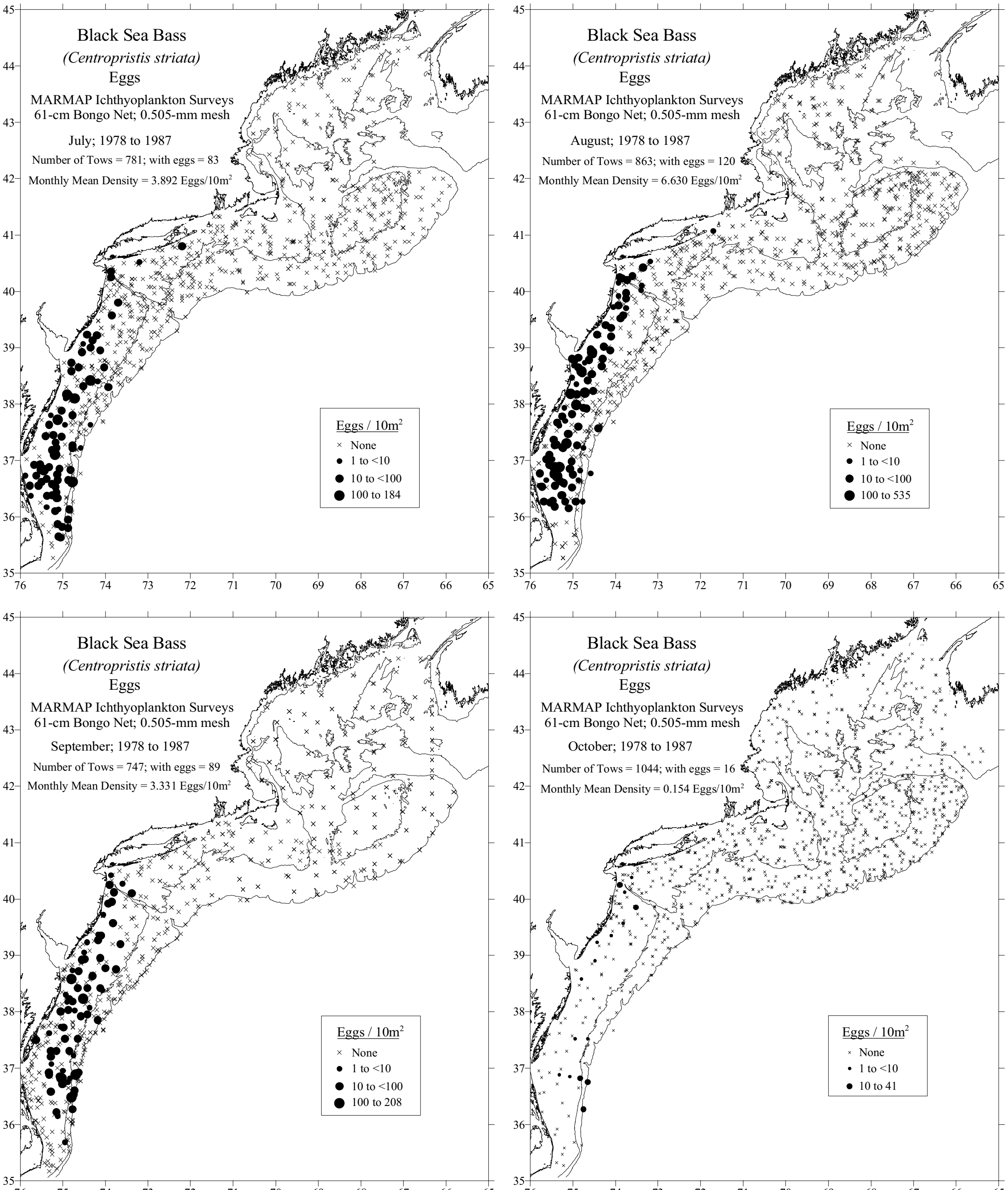

Figure 3. Cont'd.
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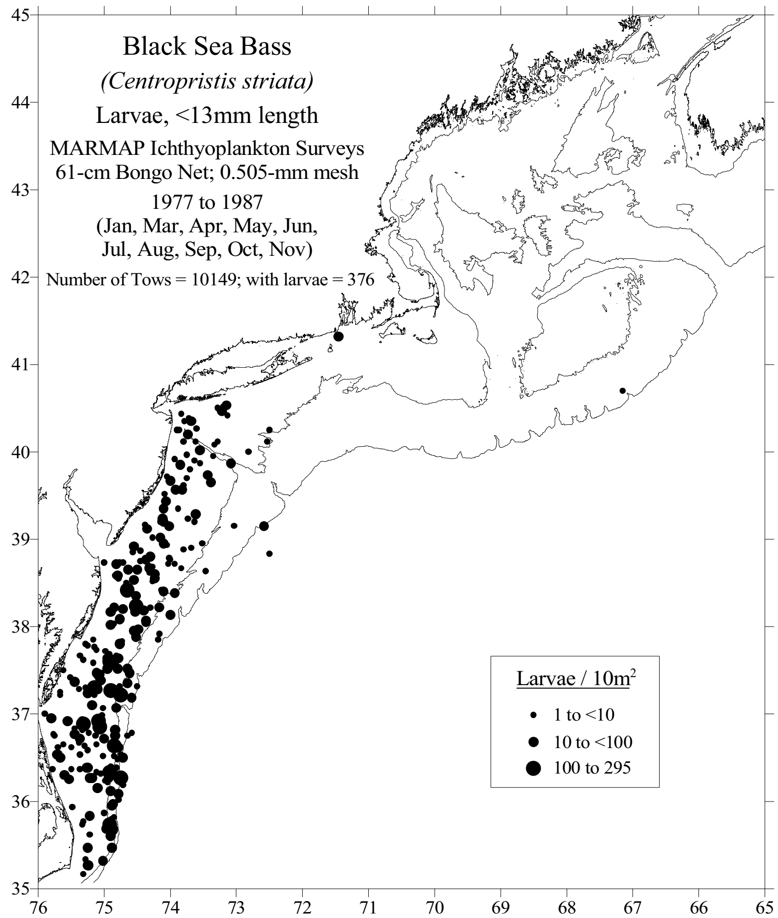
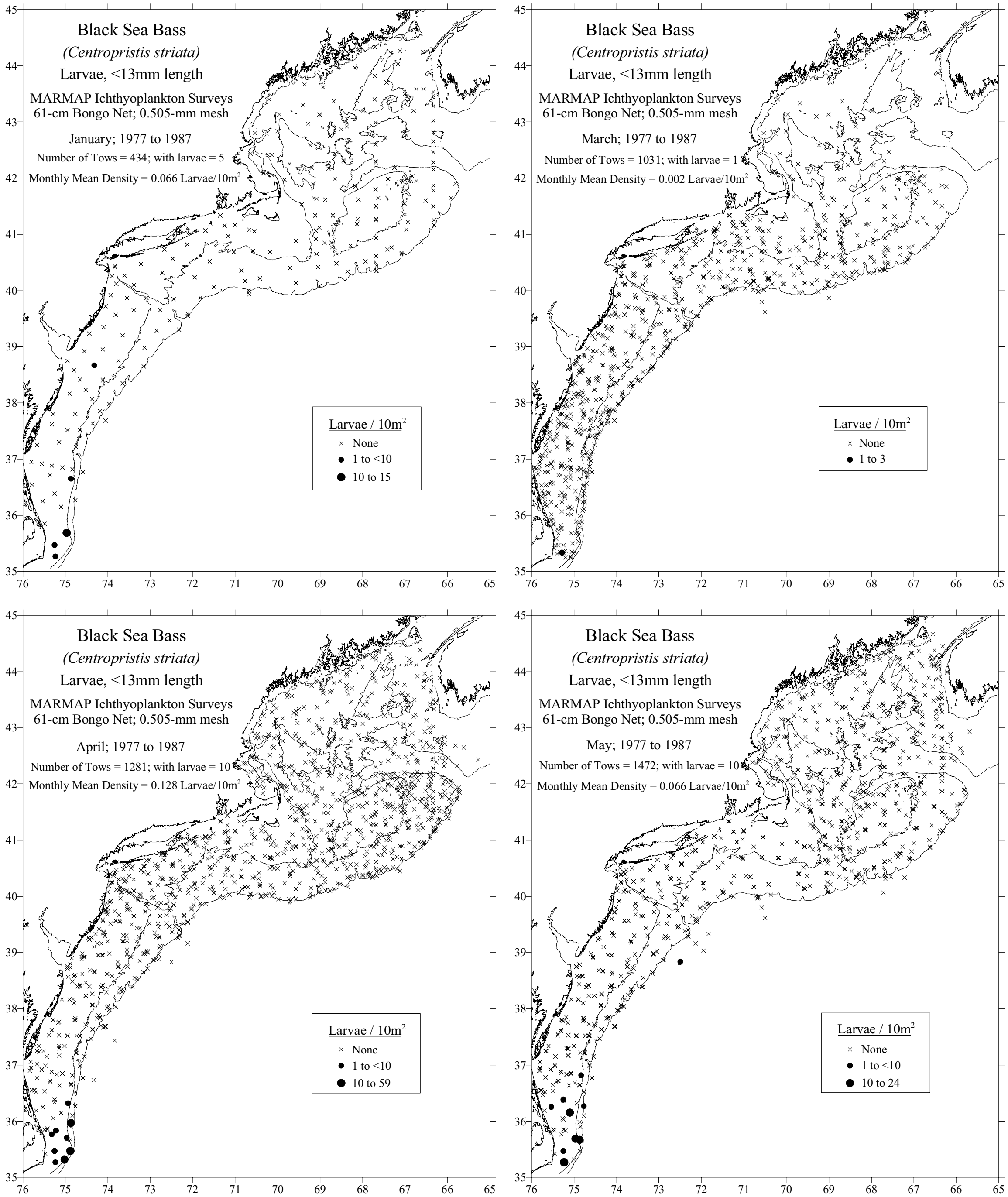


Figure 4. Distributions and abundances of black sea bass larvae collected during NEFSC MARMAP ichthyoplankton surveys, for all available months and years from 1977-1987 combined.



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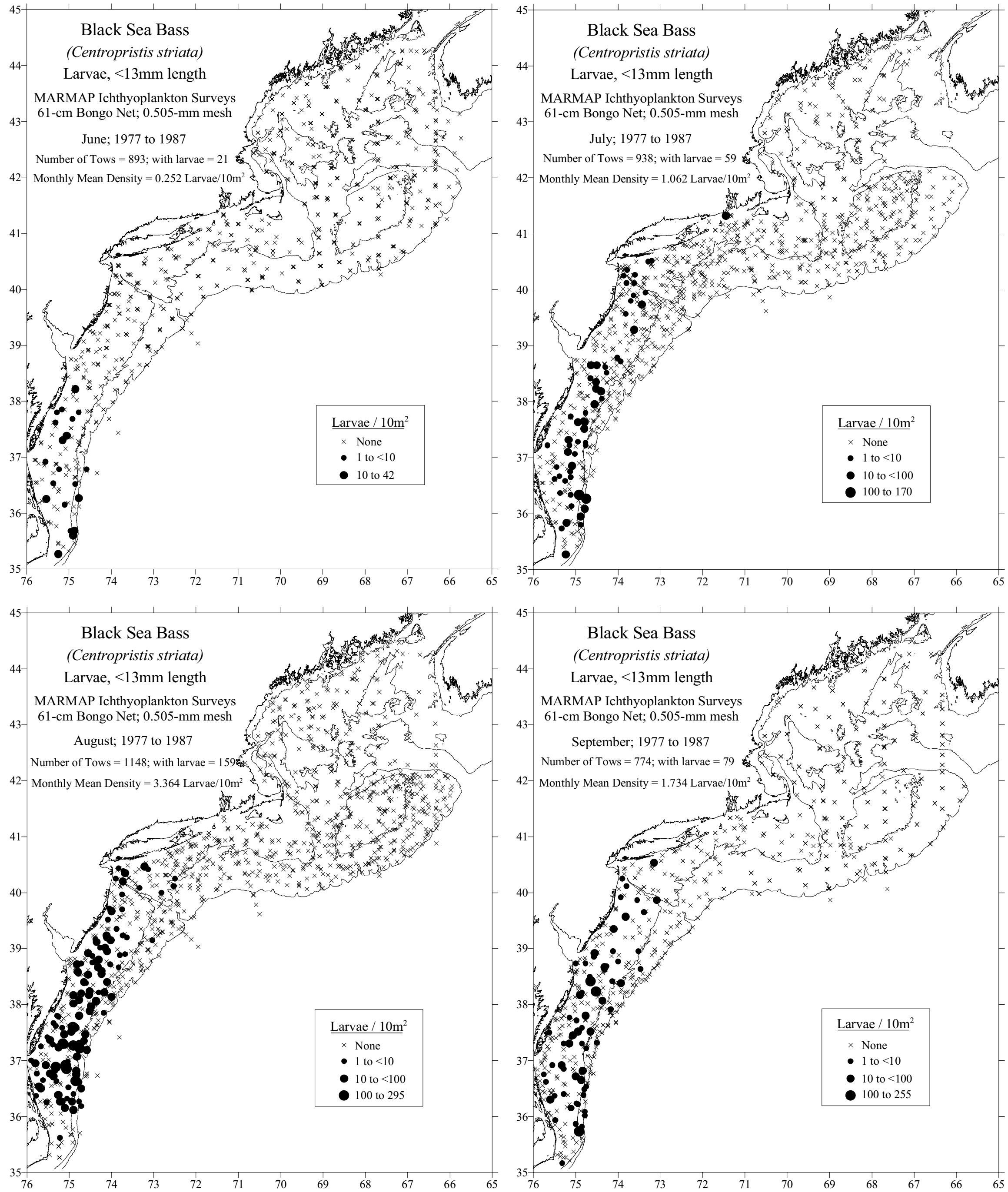

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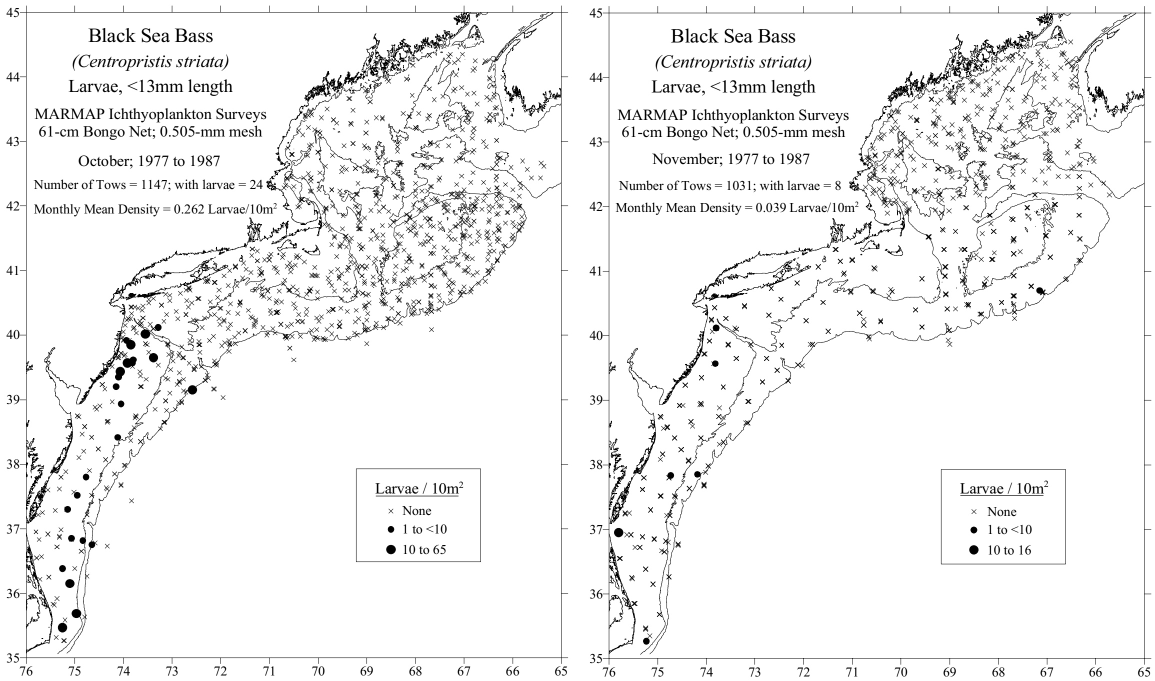

Figure 4. Cont'd.
From MARMAP ichthyoplankton surveys, October and November, 1977-1987.

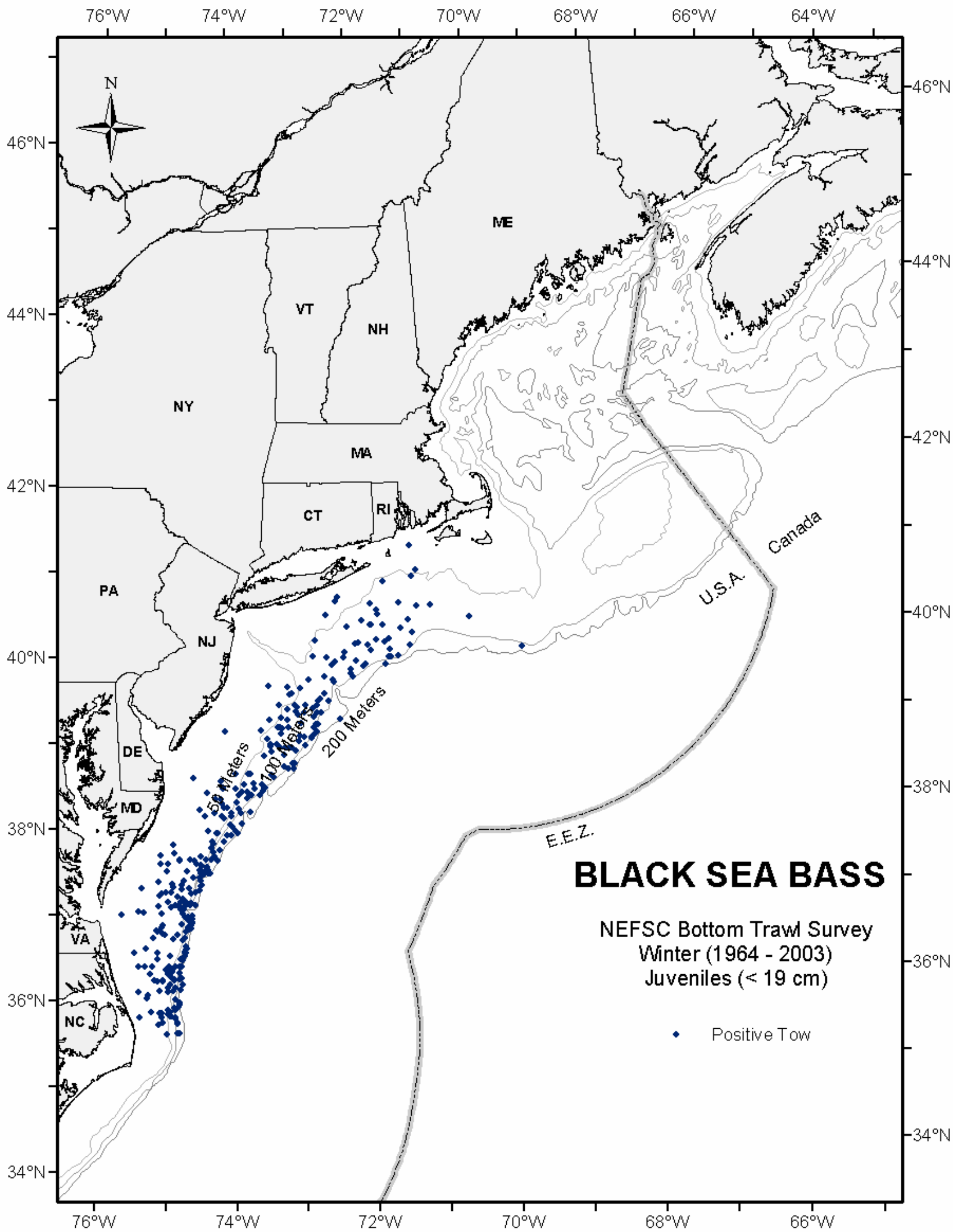

Figure 5. Seasonal distributions and abundances of juvenile black sea bass collected during NEFSC bottom trawl surveys, based on NEFSC winter bottom trawl surveys (1964-2003, all years combined). Distributions are displayed as presence only.

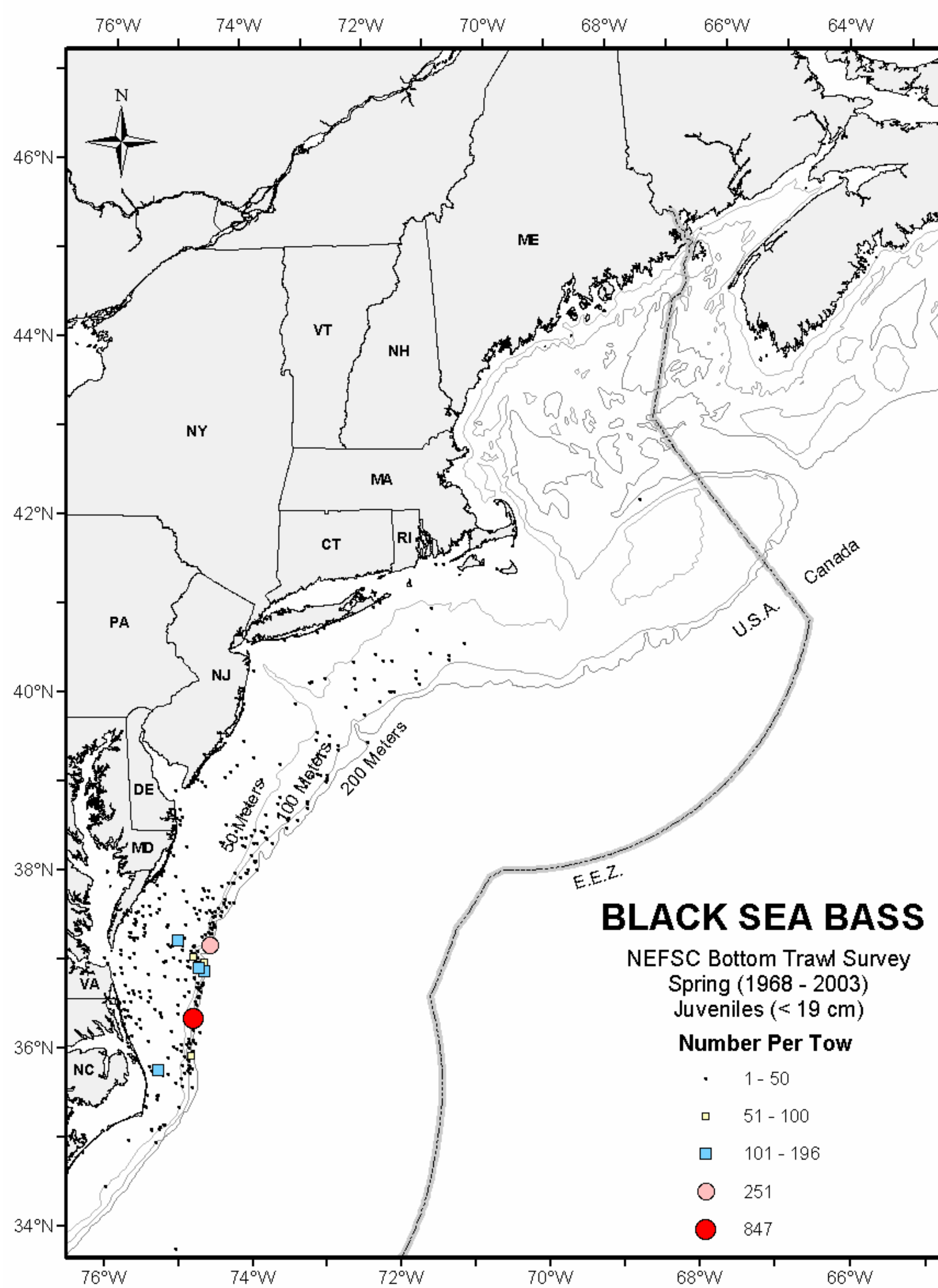

Figure 5. Cont'd.
Based on NEFSC spring bottom trawl surveys (1968-2003, all years combined). Survey stations where juveniles were not found are not shown.

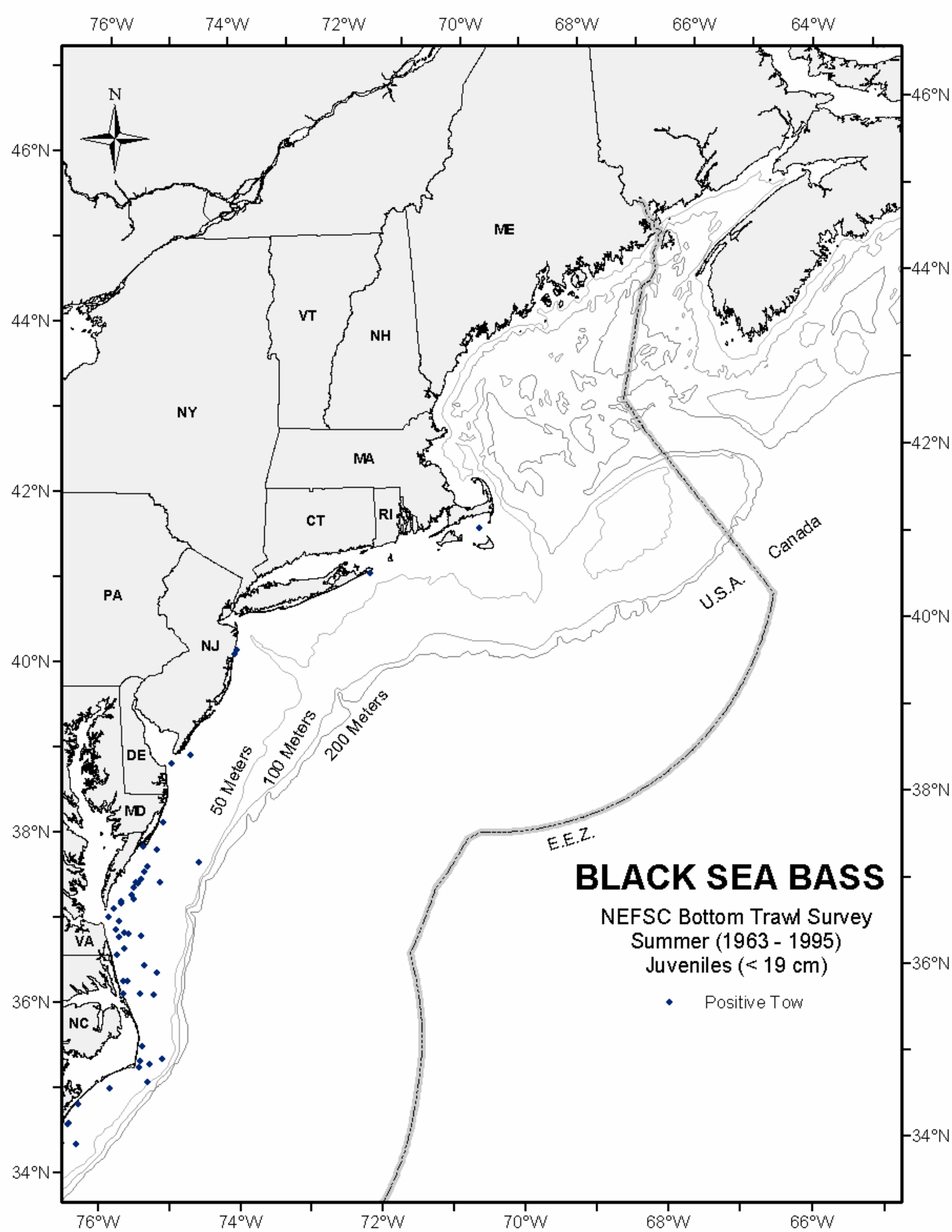

Figure 5. Cont'd.
Based on NEFSC summer bottom trawl surveys (1963-1995, all years combined). Distributions are displayed as presence only.

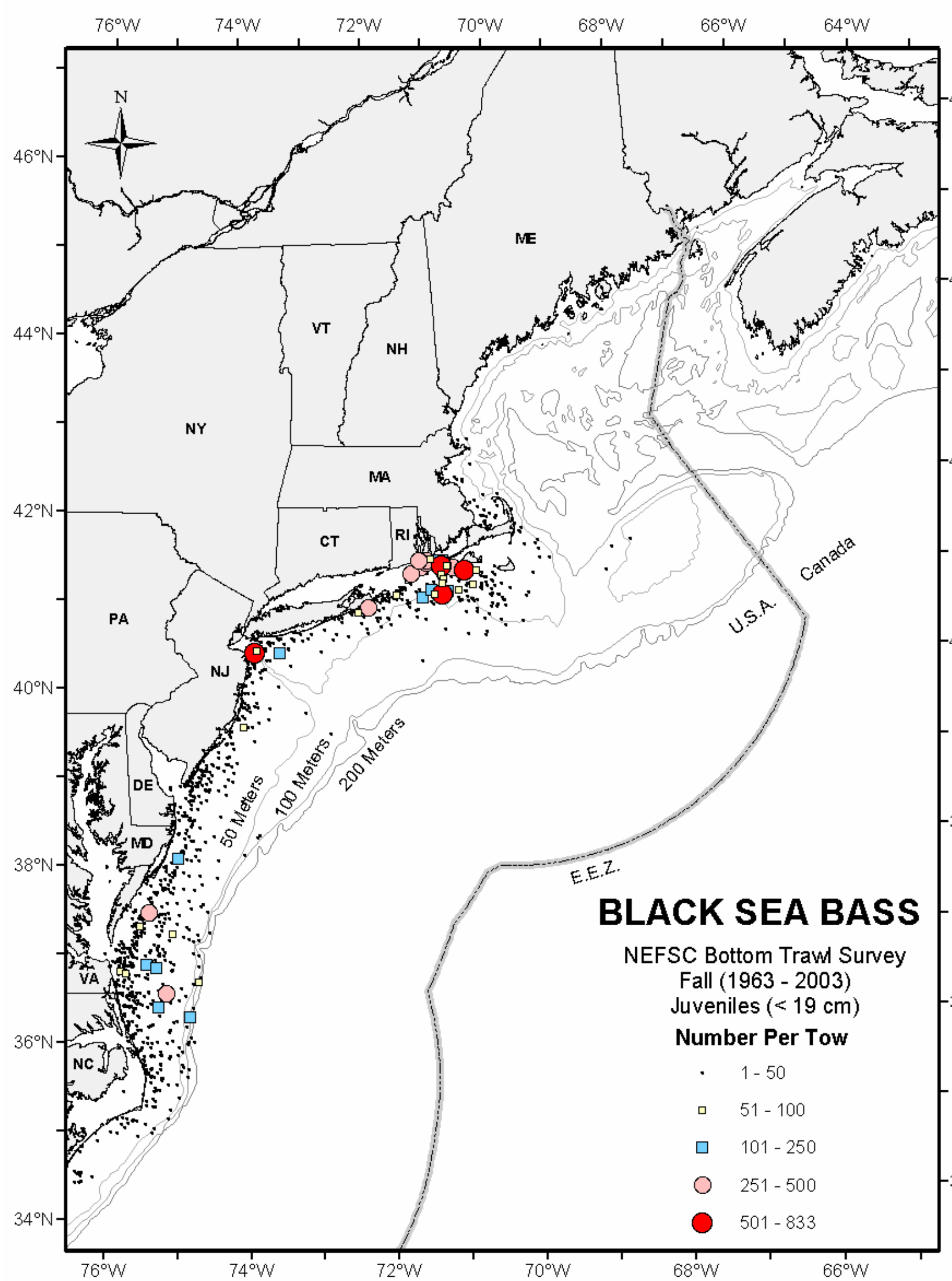

Figure 5. Cont'd.
Based on NEFSC fall bottom trawl surveys (1963-2003, all years combined). Survey stations where juveniles were not found are not shown.

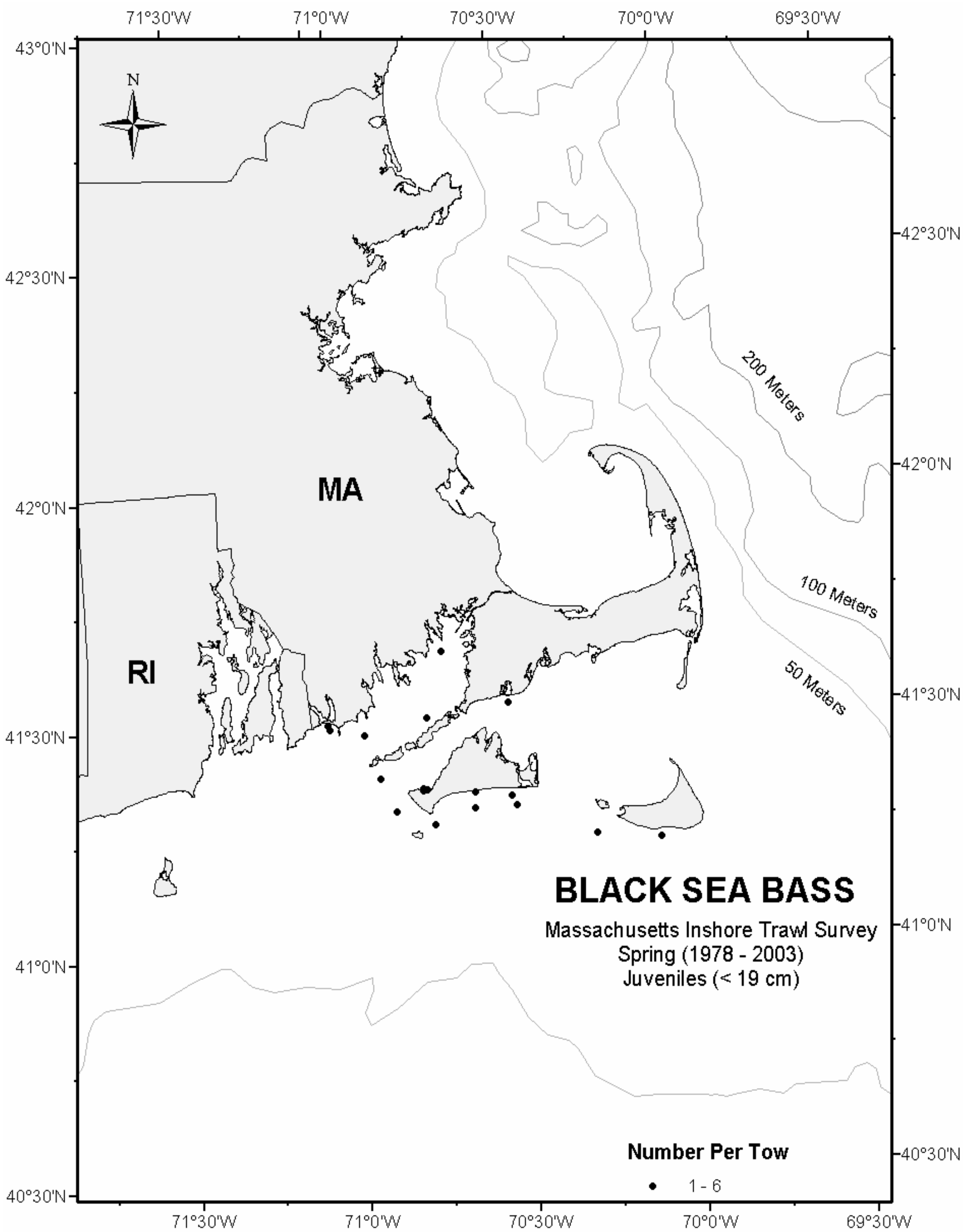

Figure 6. Seasonal distributions and abundances of juvenile black sea bass in Massachusetts coastal waters, based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where juveniles were not found are not shown.

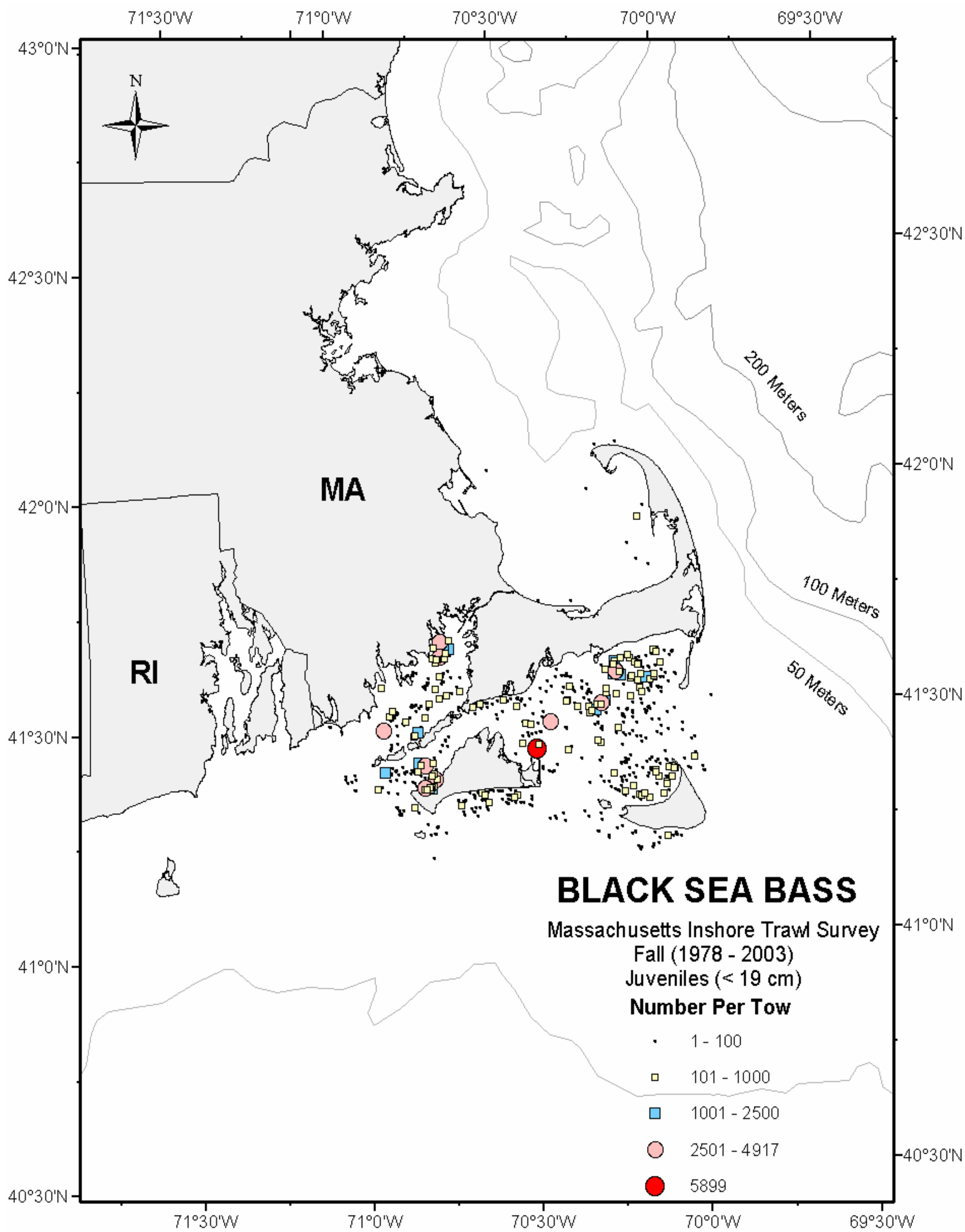

Figure 6. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where juveniles were not found are not shown.

Black Sea Bass Juveniles (< 19 cm)

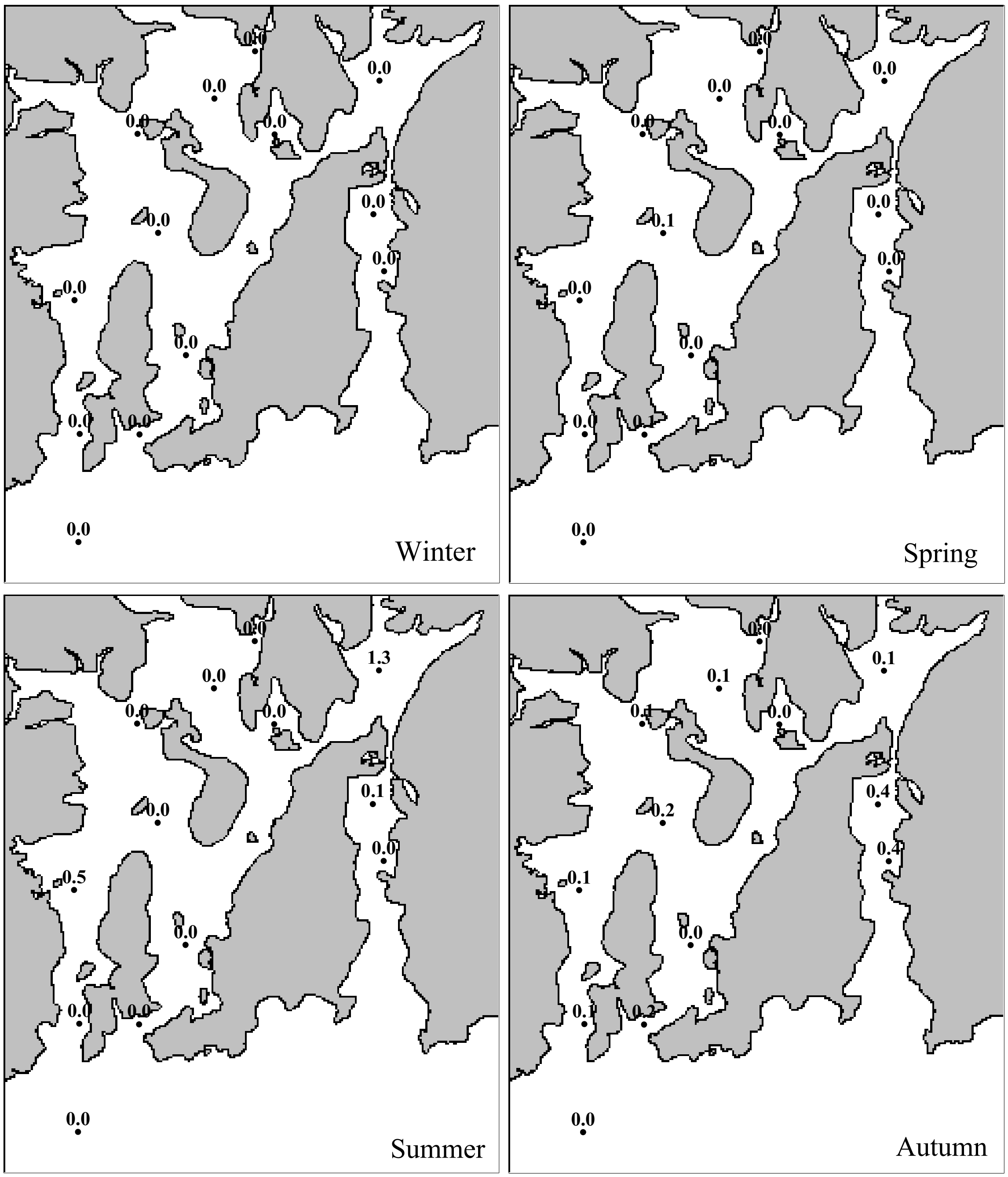

Figure 7. Seasonal distribution and abundance of juvenile black sea bass collected in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid *et al.* (1999) for details].

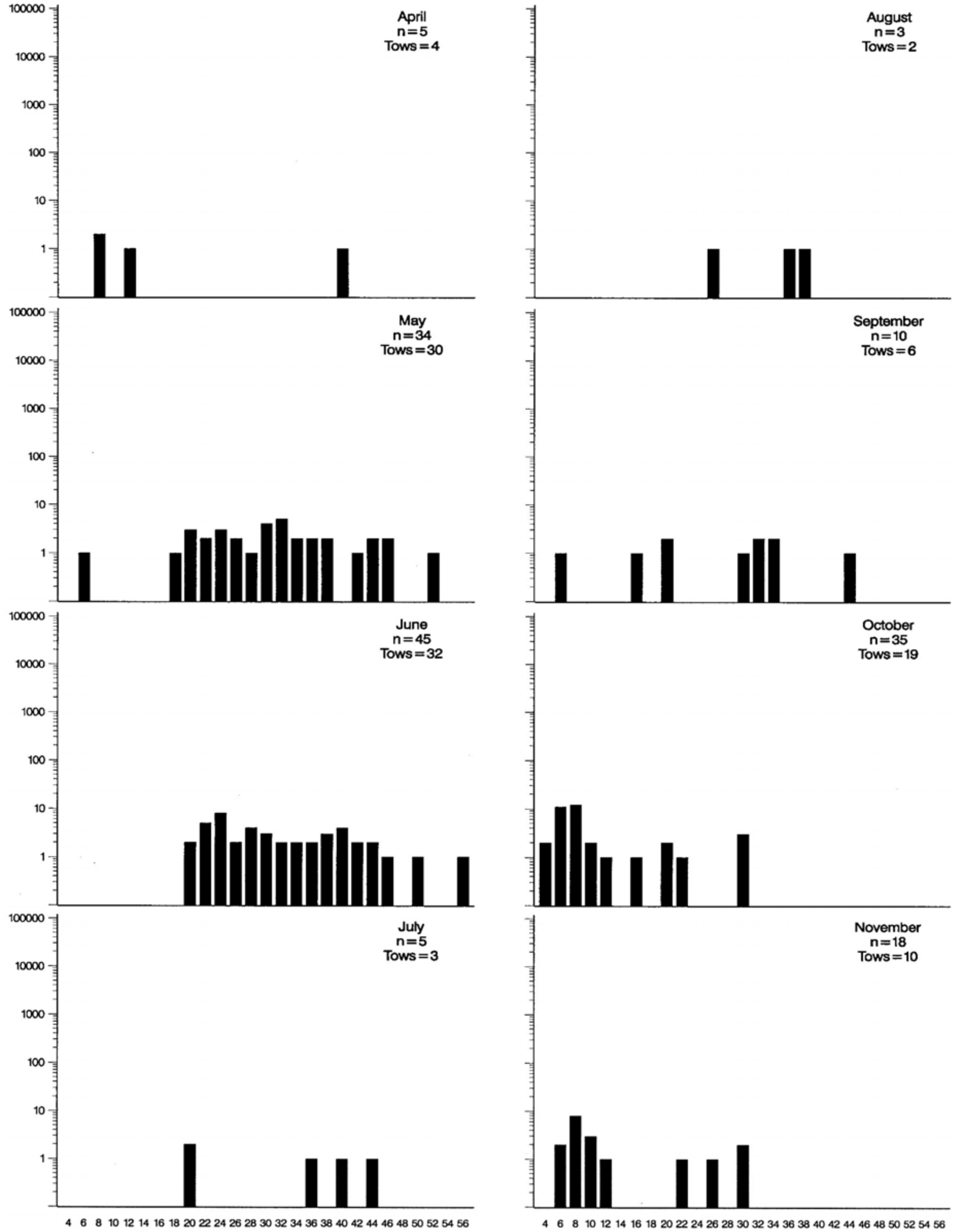

Figure 8. Monthly $\log_{10}$ length frequencies (cm) of juvenile and adult black sea bass collected in Long Island Sound, based on 155 fish taken in 106 tows during the finfish surveys of the Connecticut Fisheries Division between 1989-1994. Source: Gottschall *et al.* (2000).

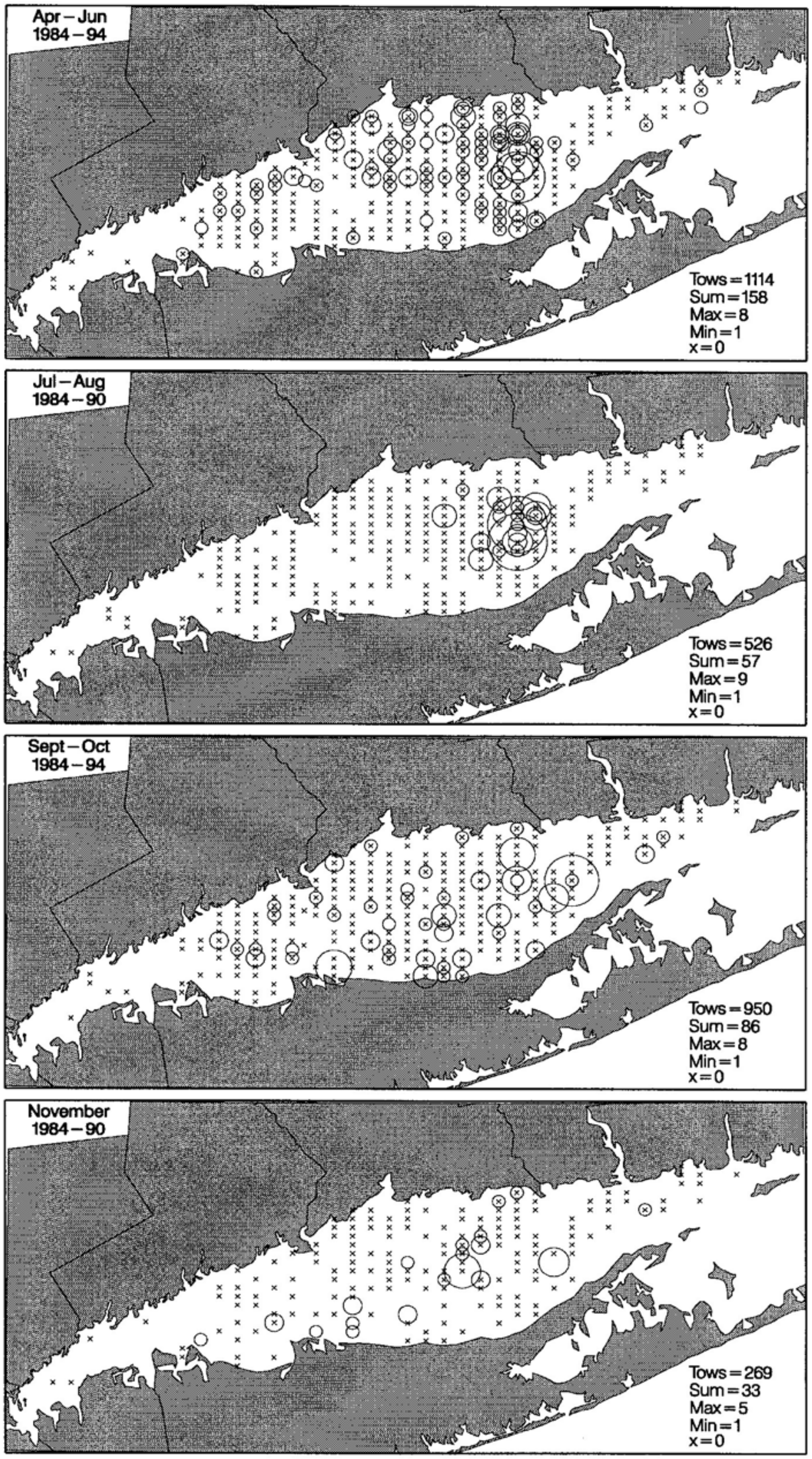

Figure 9. Distribution and abundances of juvenile and adult black sea bass in Long Island Sound, based on 334 fish taken in 2,859 tows during the finfish surveys of the Connecticut Fisheries Division, 1984-1994. The largest circle size represents a tow with a catch of nine black sea bass. Collections were made with a 14 m otter trawl at about 40 stations chosen by stratified random design. Source: Gottschall *et al.* (2000).

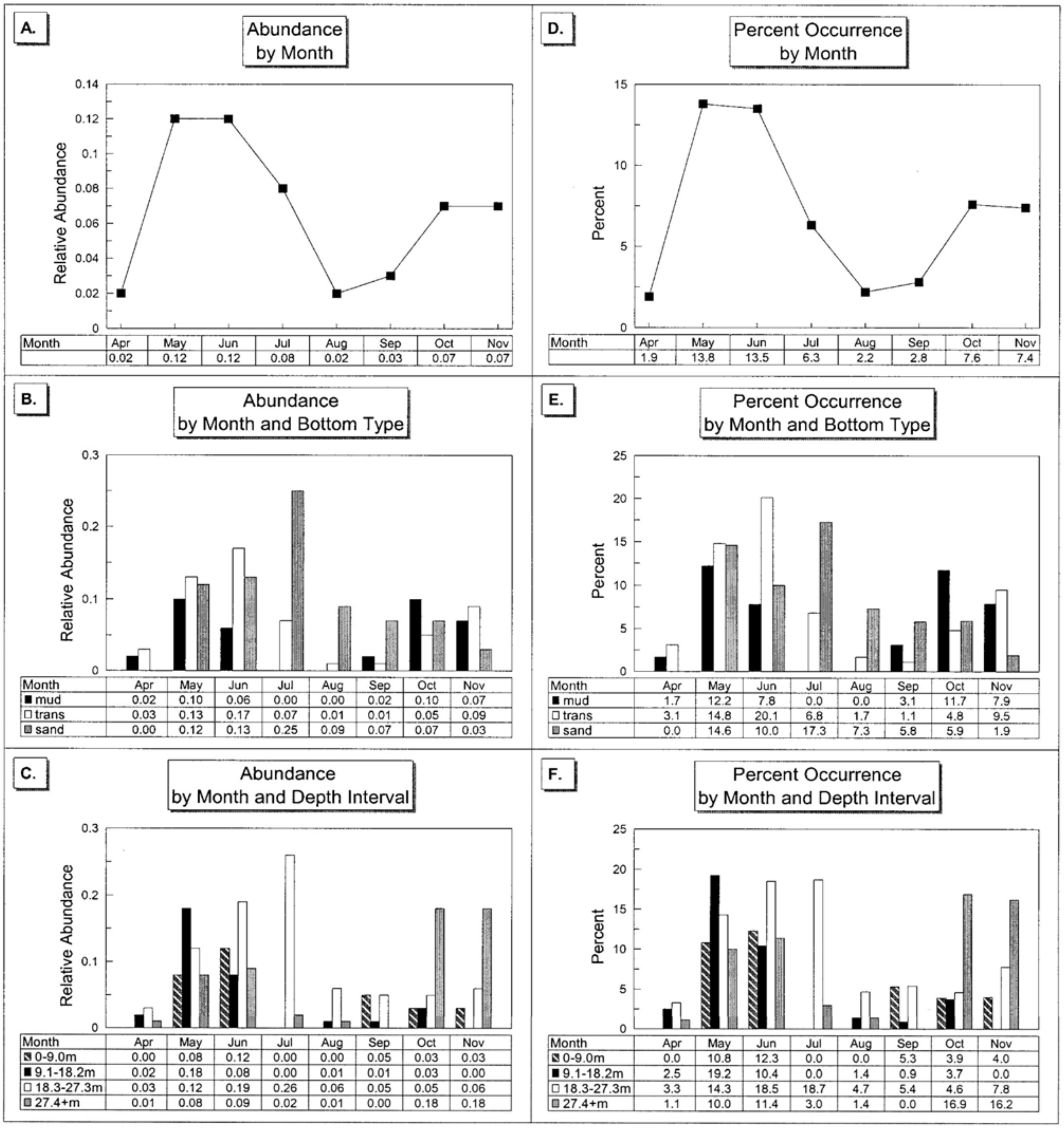

Figure 10. Relative abundance (geometric mean catch/tow) catch/tow and percent occurrence (proportion of samples in which at least one individual was observed) for juvenile and adult black sea bass in Long Island Sound, by month, month and bottom type, and month and depth interval. Source: Gottschall *et al.* (2000).

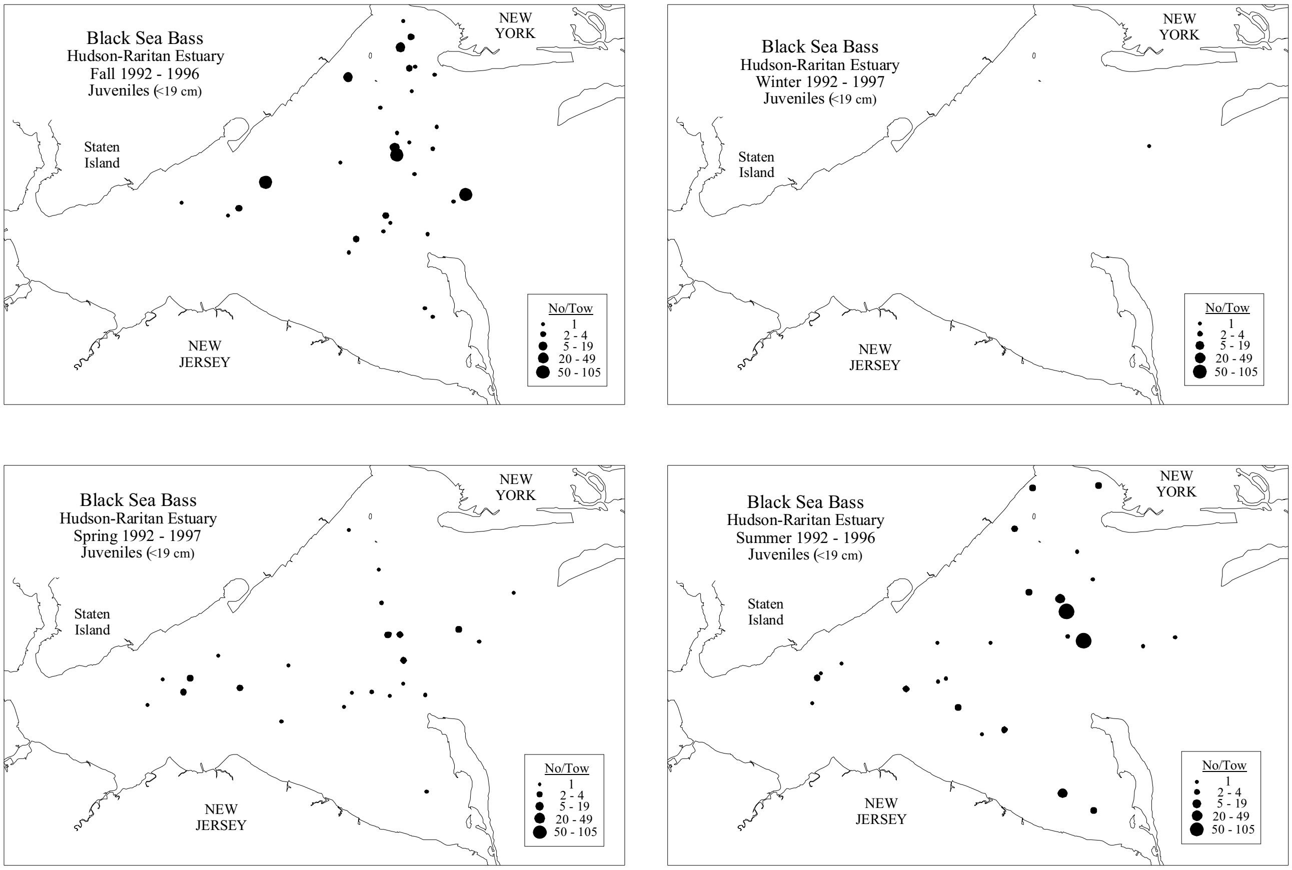

Figure 11. Seasonal distribution and abundance of juvenile black sea bass in the Hudson-Raritan estuary collected during Hudson-Raritan estuary trawl surveys, 1992–1997 [see Reid *et al.* (1999) for details].

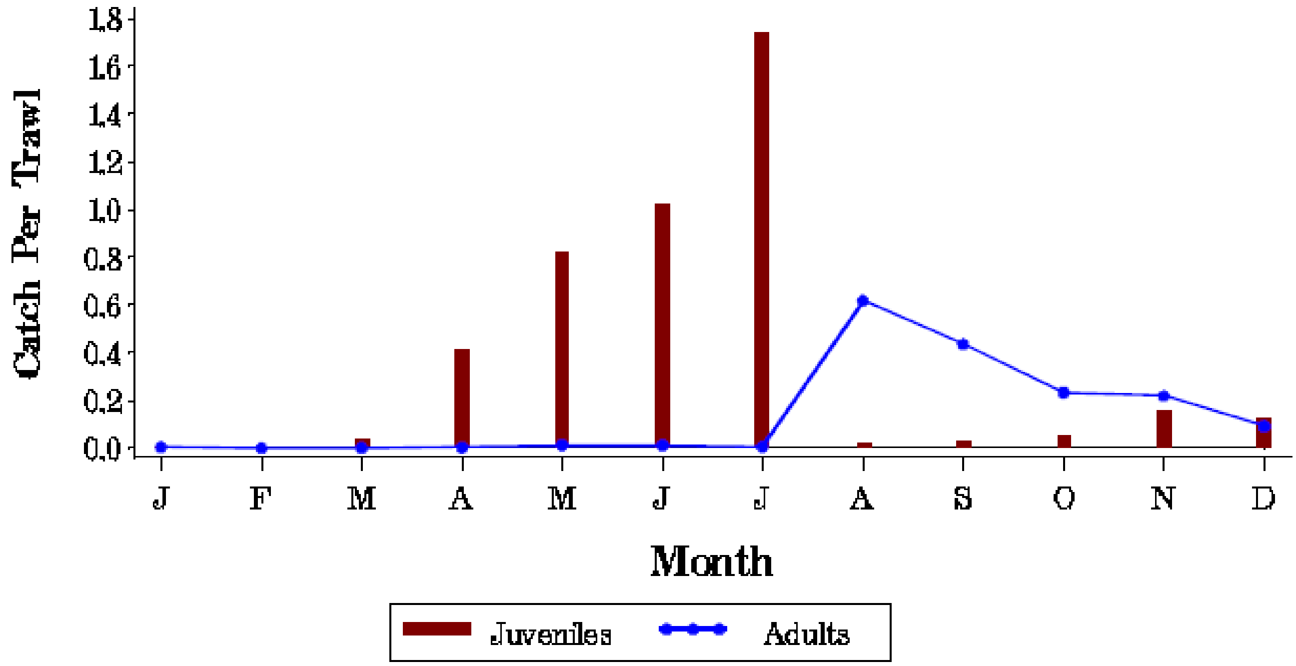

Figure 12. Catch per unit effort for total catch of juvenile and adult black sea bass in Chesapeake Bay and tributaries, from the Virginia Institute of Marine Science's (VIMS) trawl surveys, 1988-1999 (all years combined). Source: Geer (2002).

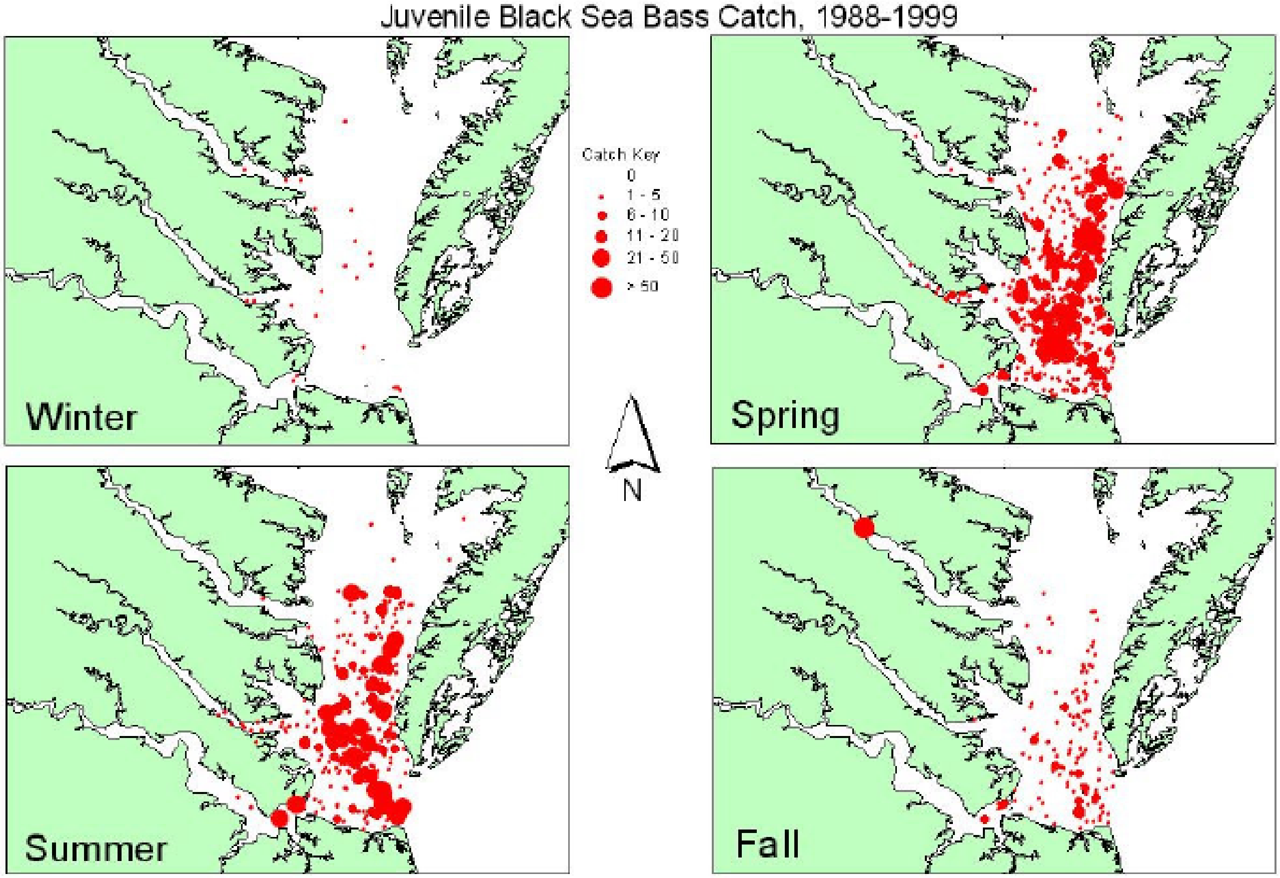

Figure 13. Seasonal distribution and abundance of juvenile black sea bass in Chesapeake Bay and tributaries, from the VIMS trawl surveys, 1988-1999 (all years combined). Monthly surveys were conducted using a random stratified design of the main stem of the Bay using a 9.1 m semi-balloon otter trawl with 38 mm mesh and 6.4 mm cod end with a tow duration of five minutes. Source: Geer (2002).

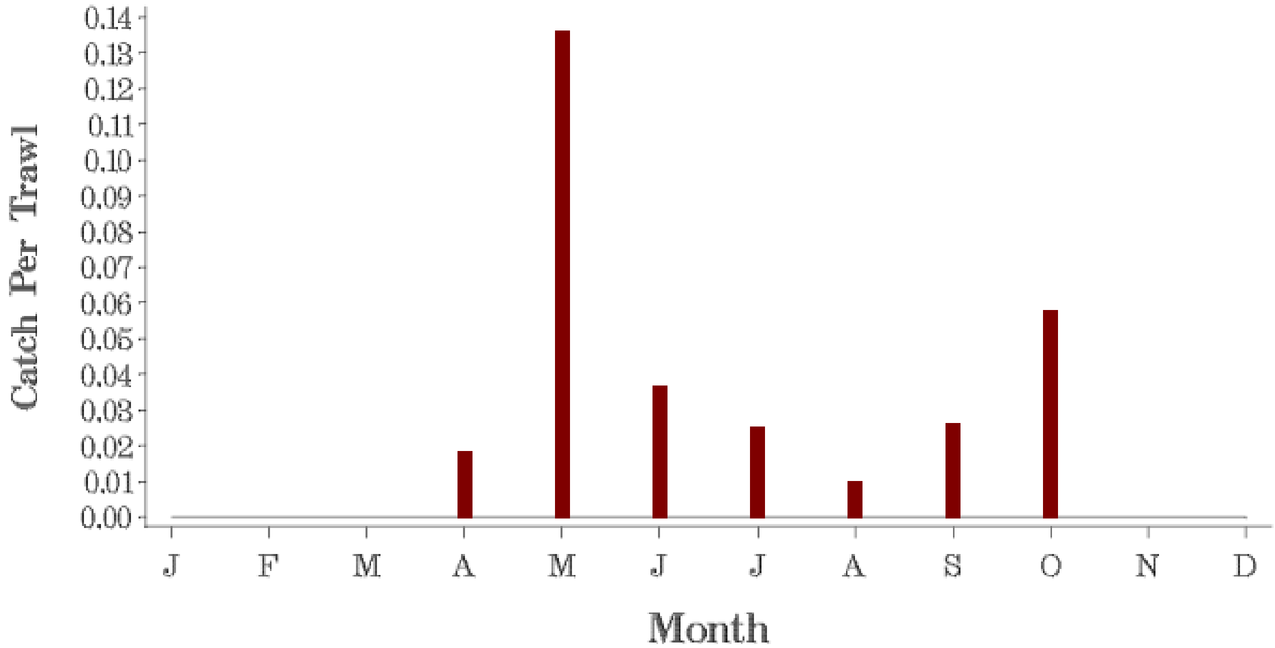

Figure 14. Catch per unit effort for total catch of juvenile black sea bass in Chesapeake Bay, from the VIMS seine surveys, 1994-1999 (all years combined). Source: Geer (2002).

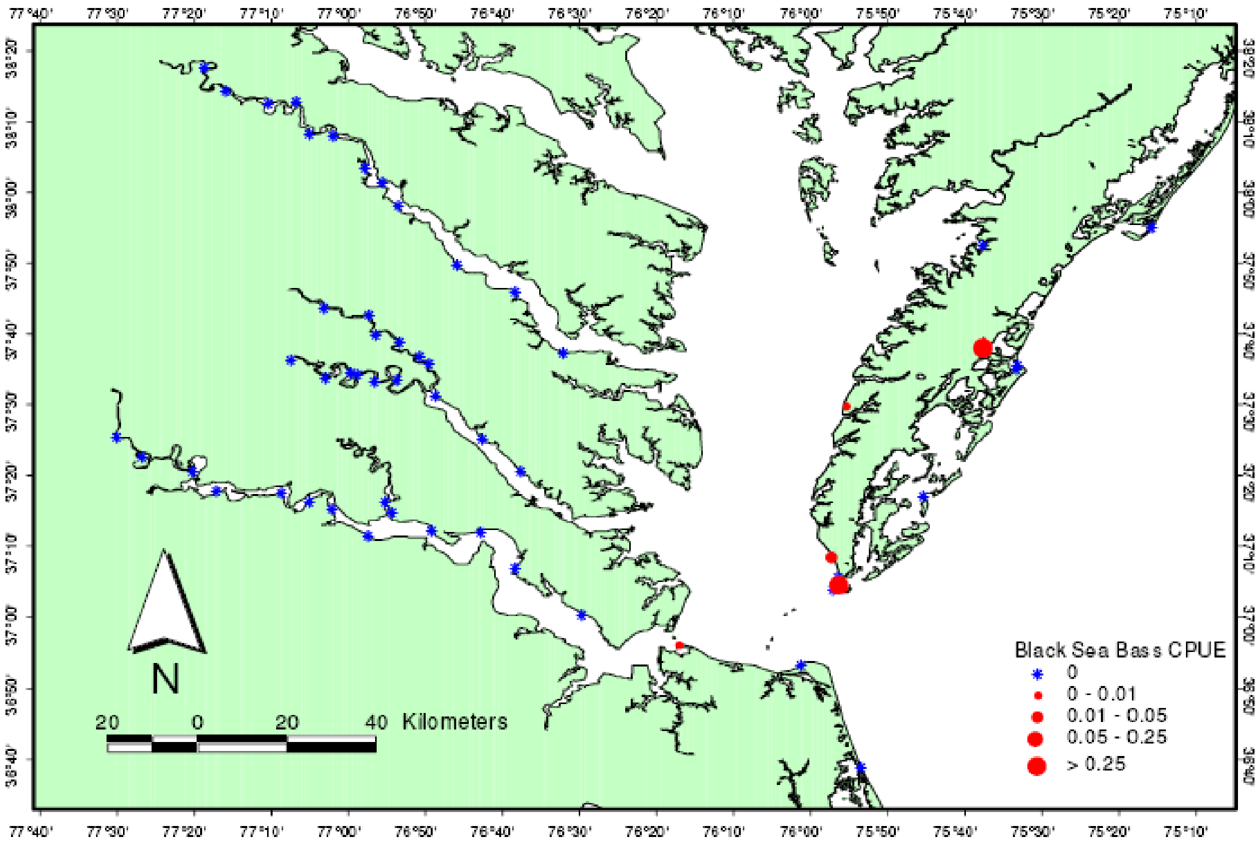

Figure 15. Juvenile black sea bass catch per unit effort by site from the VIMS beach seine surveys, 1994-1999 (all years combined). Source: Geer (2002).

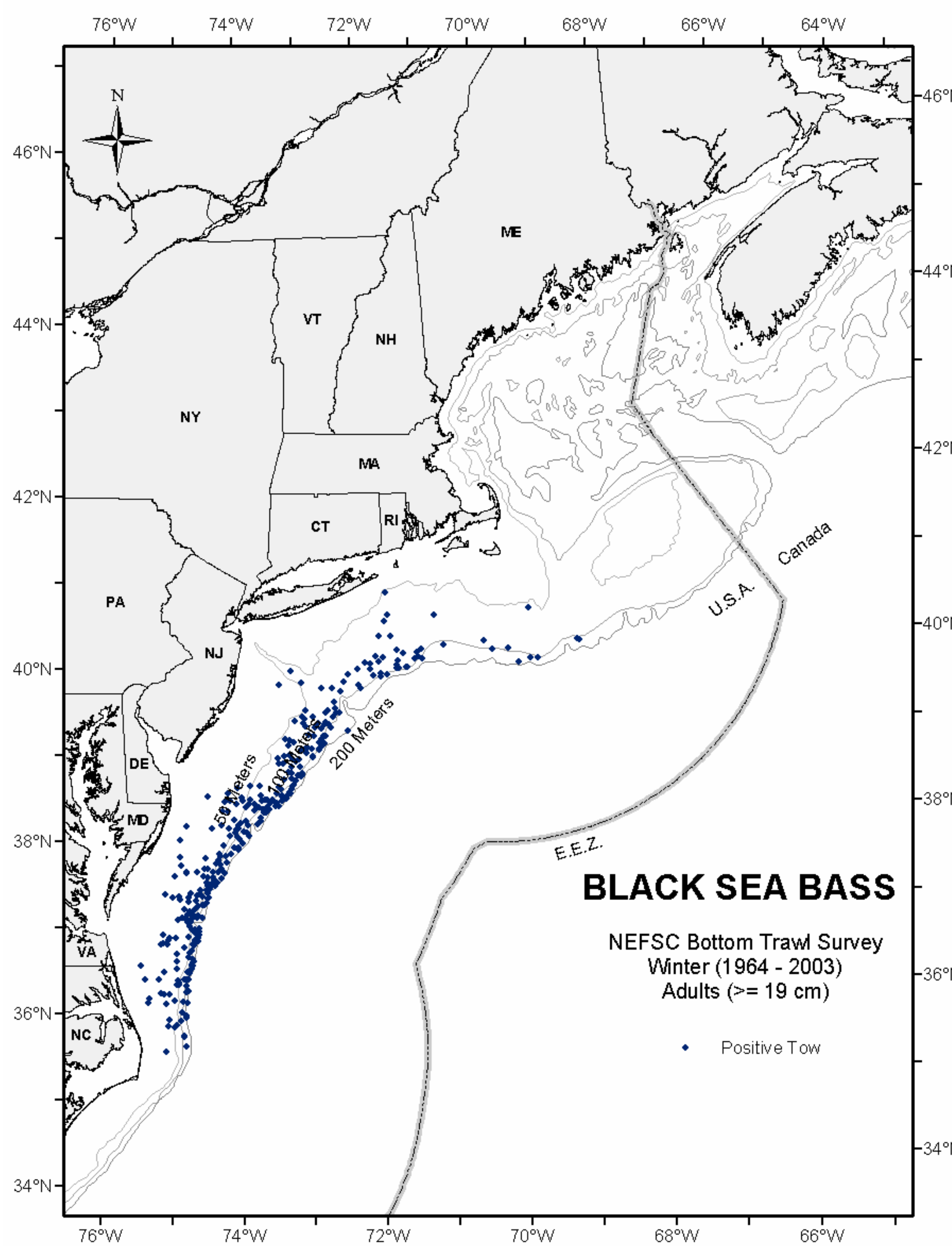

Figure 16. Seasonal distributions and abundances of adult black sea bass collected during NEFSC bottom trawl surveys, based on NEFSC winter bottom trawl surveys (1964-2003, all years combined). Distributions are displayed as presence only.

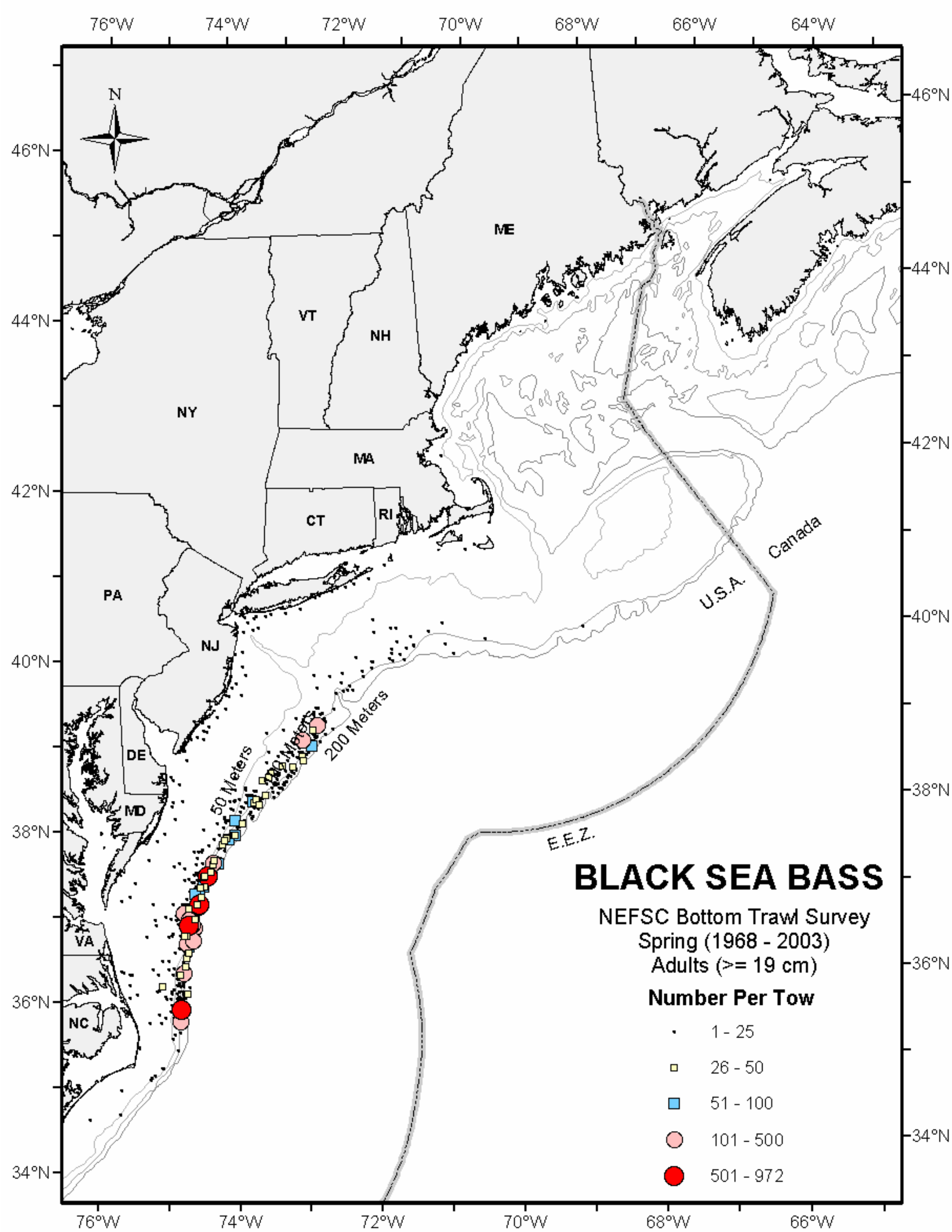

Figure 16. Cont'd.
Based on NEFSC spring bottom trawl surveys (1968-2003, all years combined). Survey stations where adults were not found are not shown.

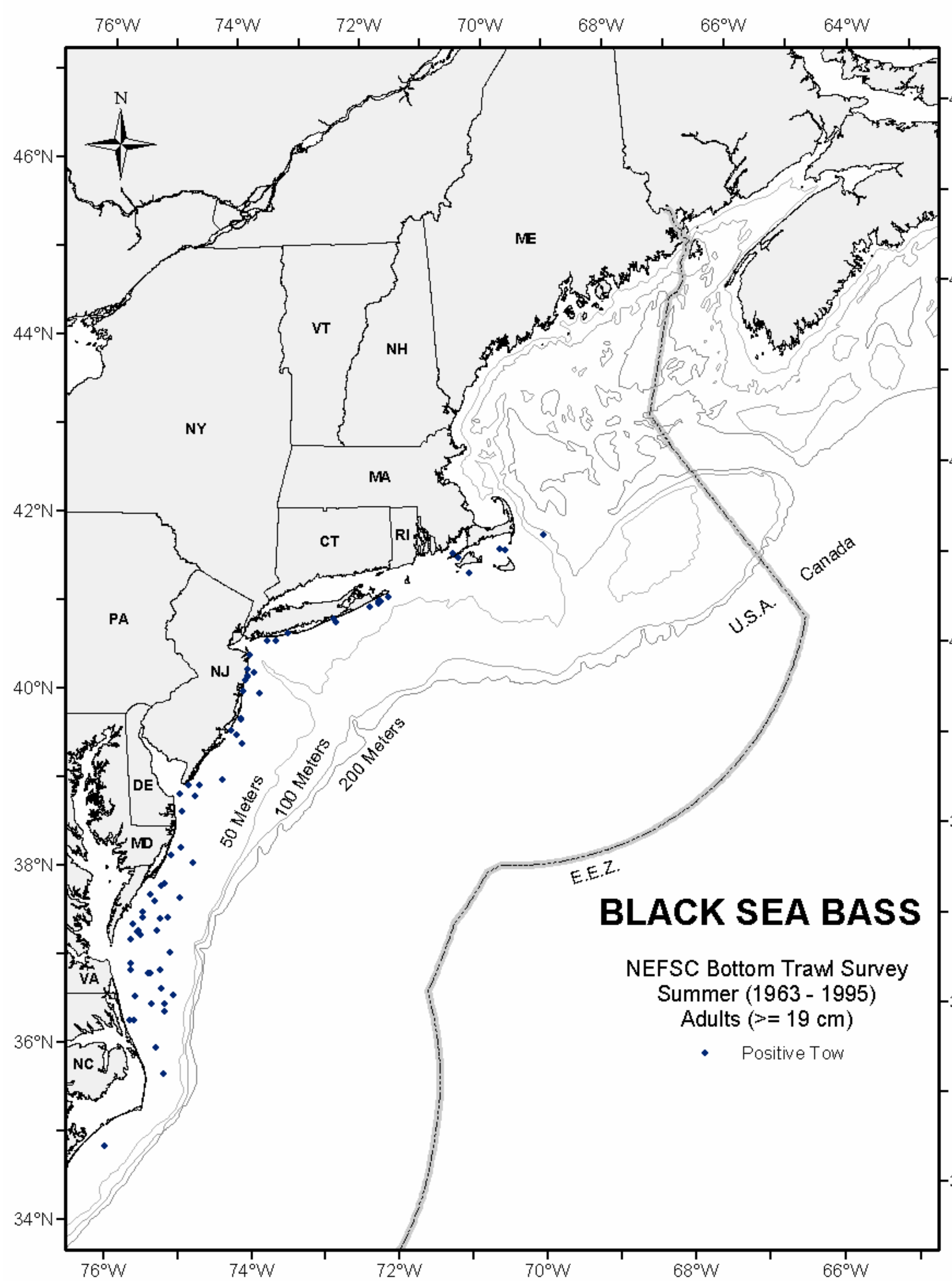

Figure 16. Cont'd.
Based on NEFSC summer bottom trawl surveys (1963-1995, all years combined). Distributions are displayed as presence only.

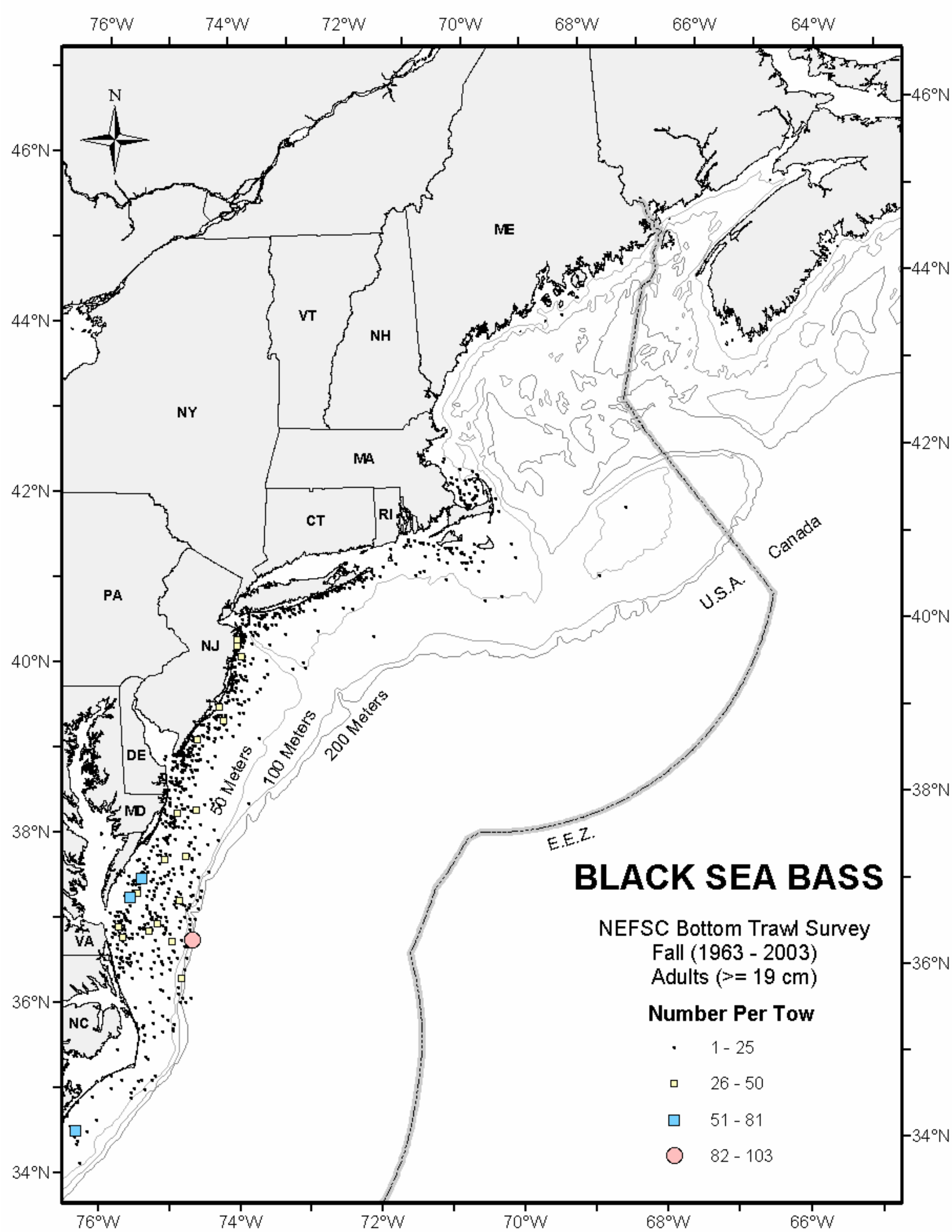

Figure 16. Cont'd.
Based on NEFSC fall bottom trawl surveys (1963-2003, all years combined). Survey stations where adults were not found are not shown.

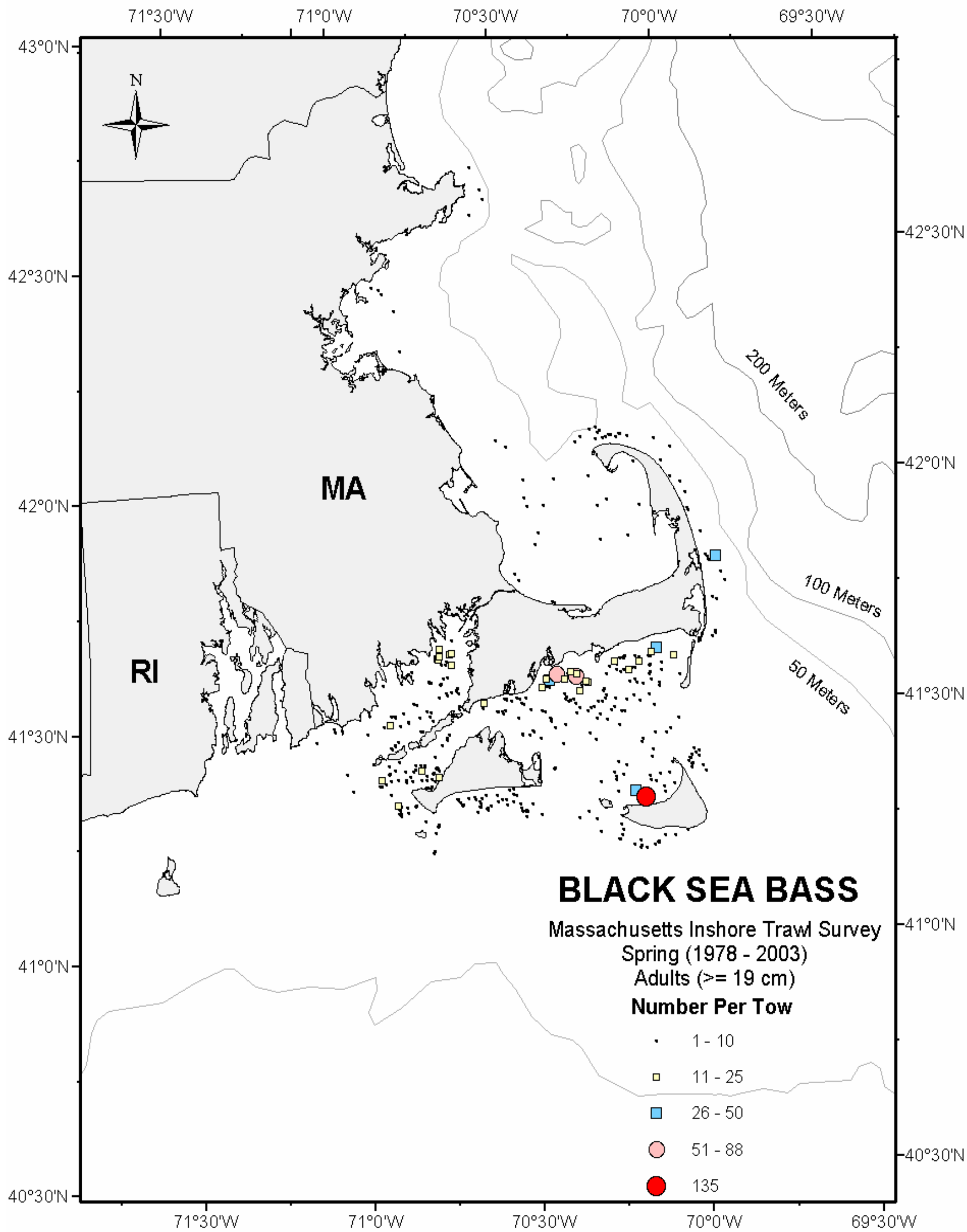

Figure 17. Seasonal distributions and abundances of adult black sea bass in Massachusetts coastal waters, based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where adults were not found are not shown.

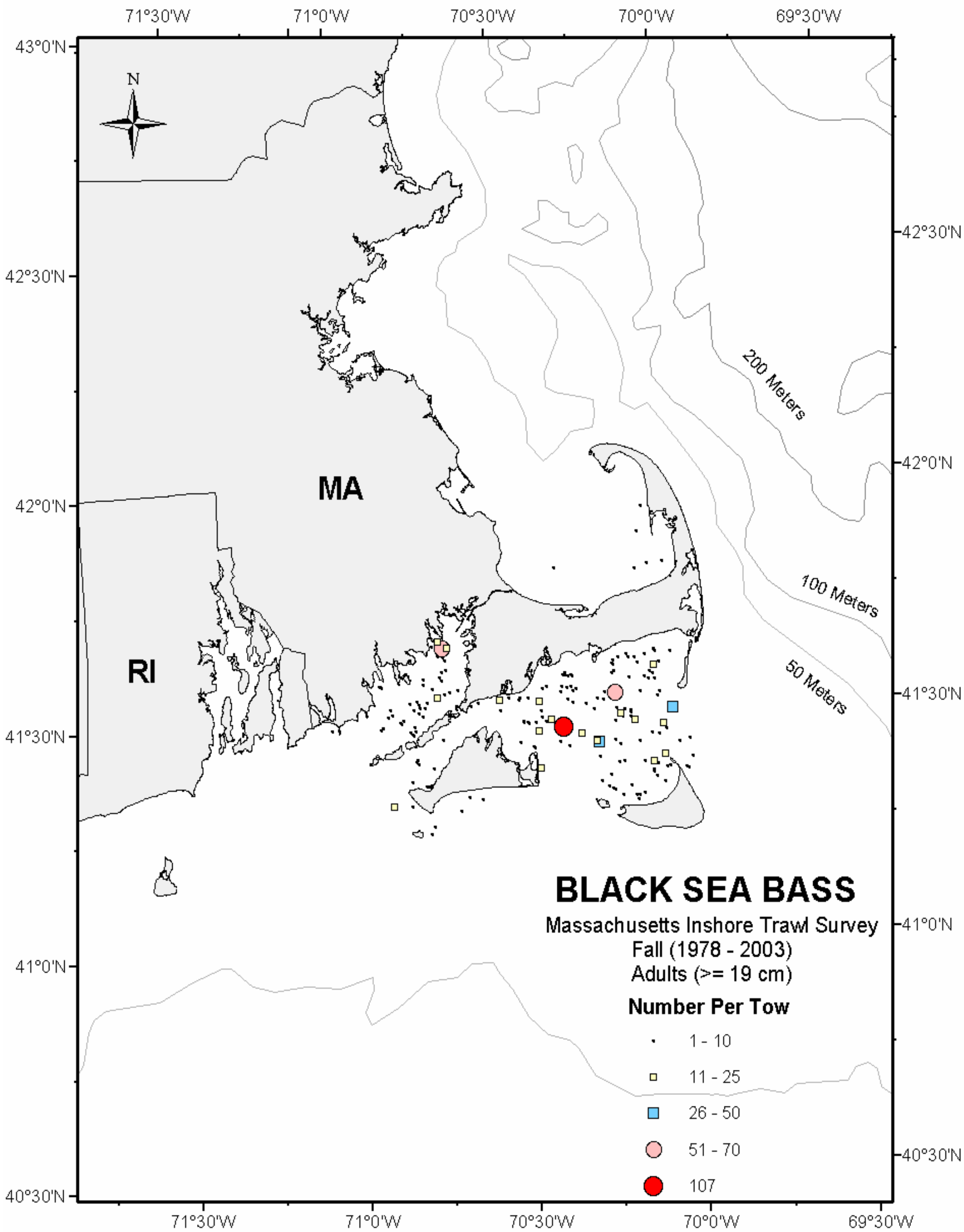

Figure 17. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where adults were not found are not shown.

Black Sea Bass Adults (>= 19 cm)

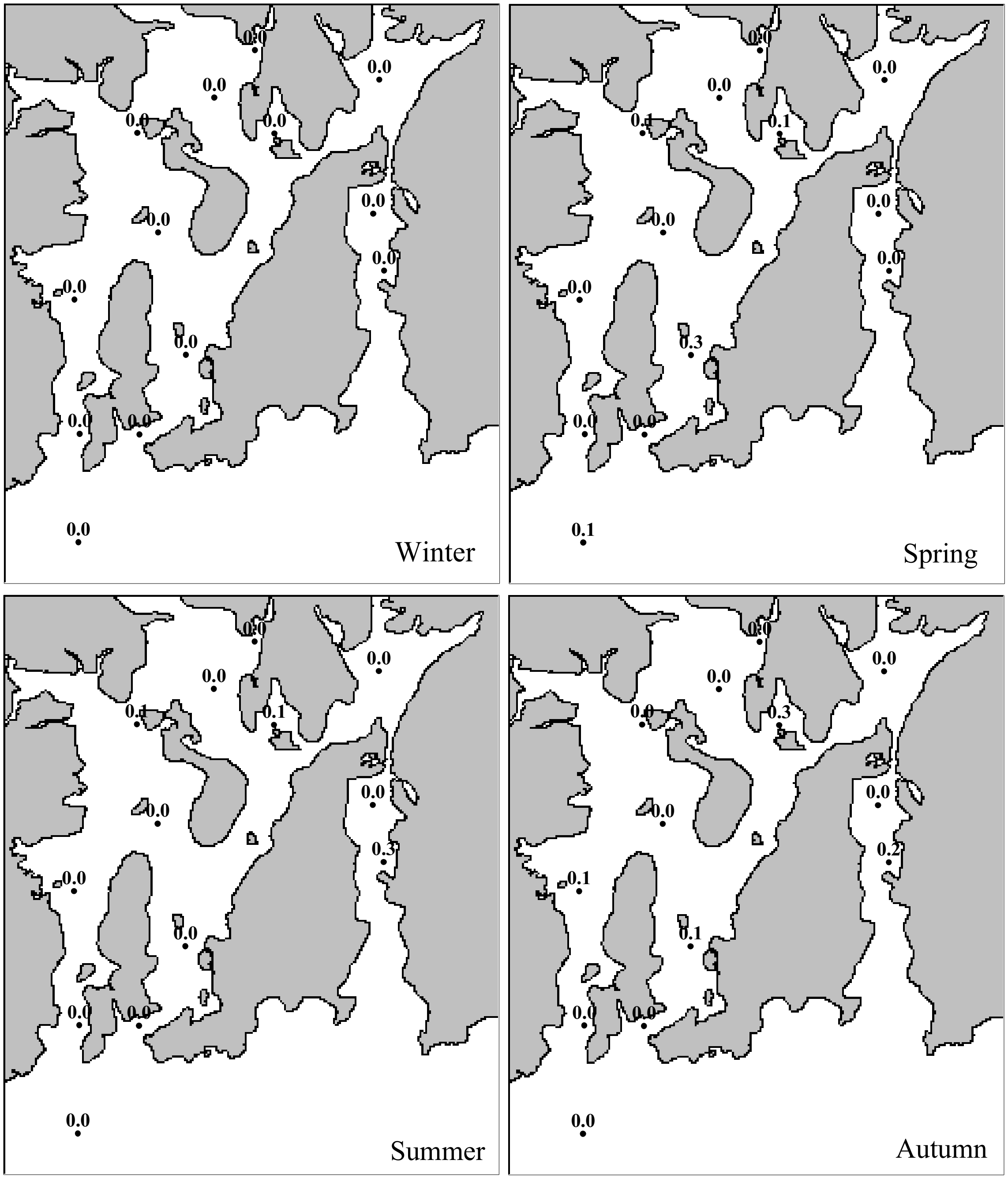

Figure 18. Seasonal distribution and abundance of adult black sea bass collected in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid *et al.* (1999) for details].

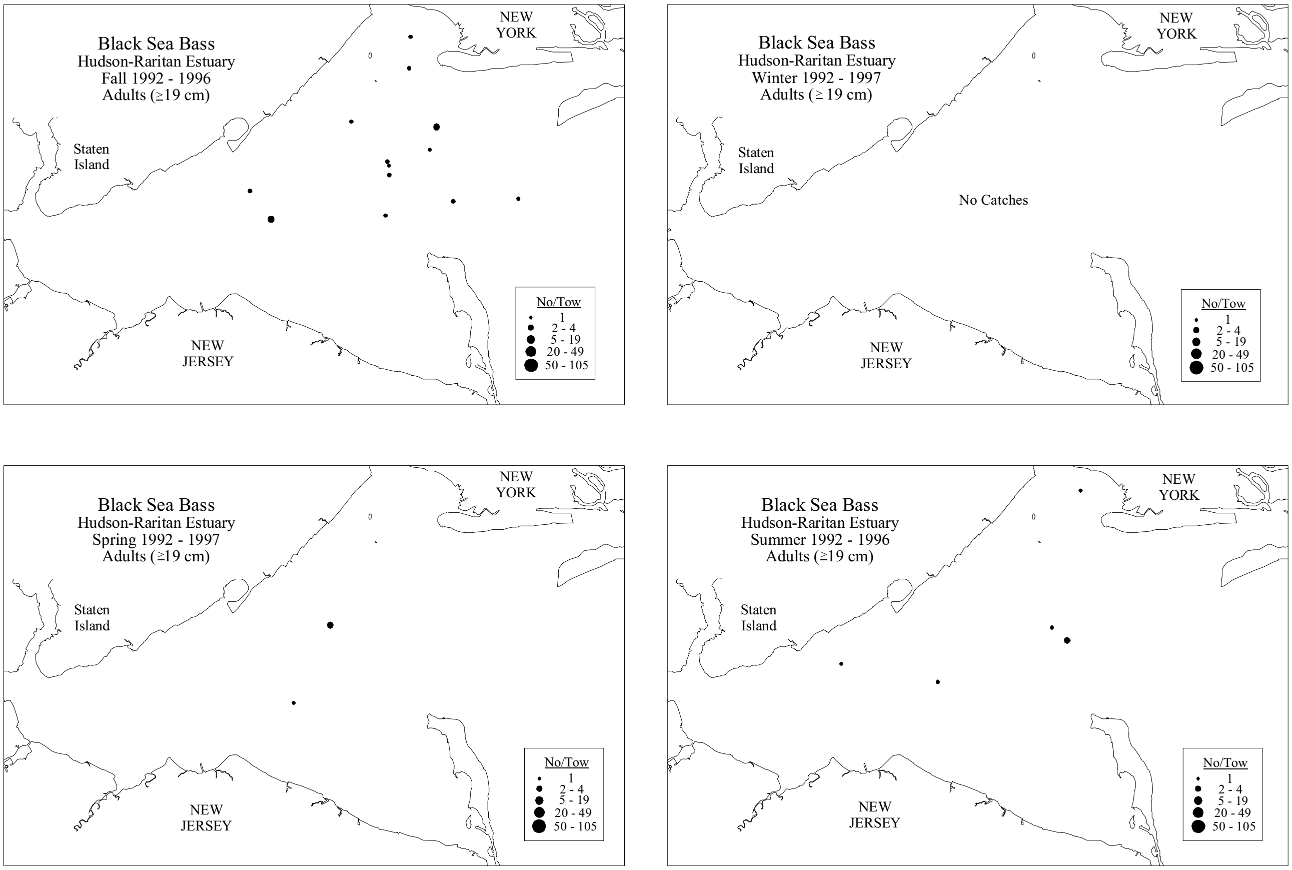

Figure 19. Seasonal distribution and abundance of adult black sea bass in the Hudson-Raritan estuary collected during Hudson-Raritan estuary trawl surveys, 1992–1997 [see Reid *et al.* (1999) for details].

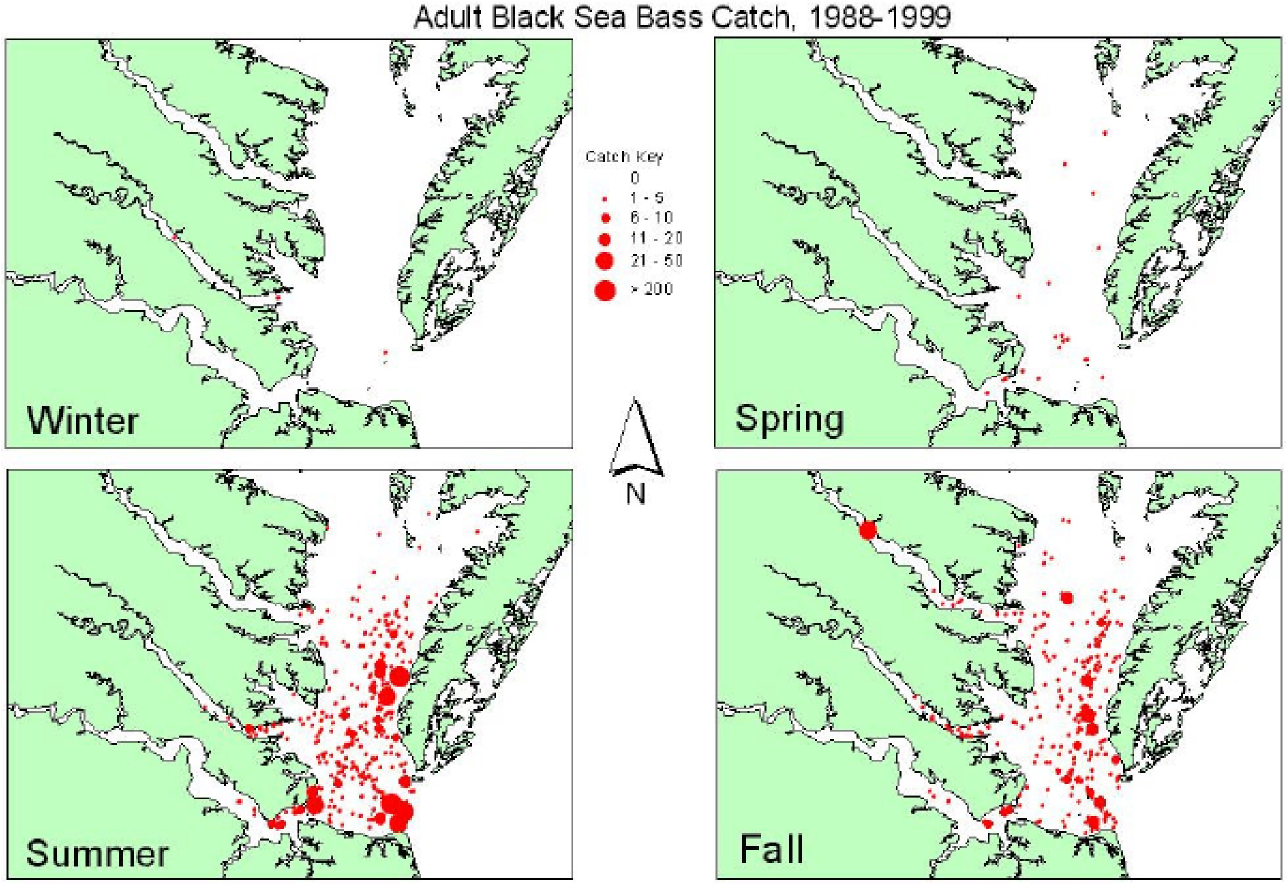

Figure 20. Seasonal distribution and abundance of adult black sea bass in Chesapeake Bay and tributaries, from the VIMS trawl surveys, 1988-1999 (all years combined). Source: Geer (2002).

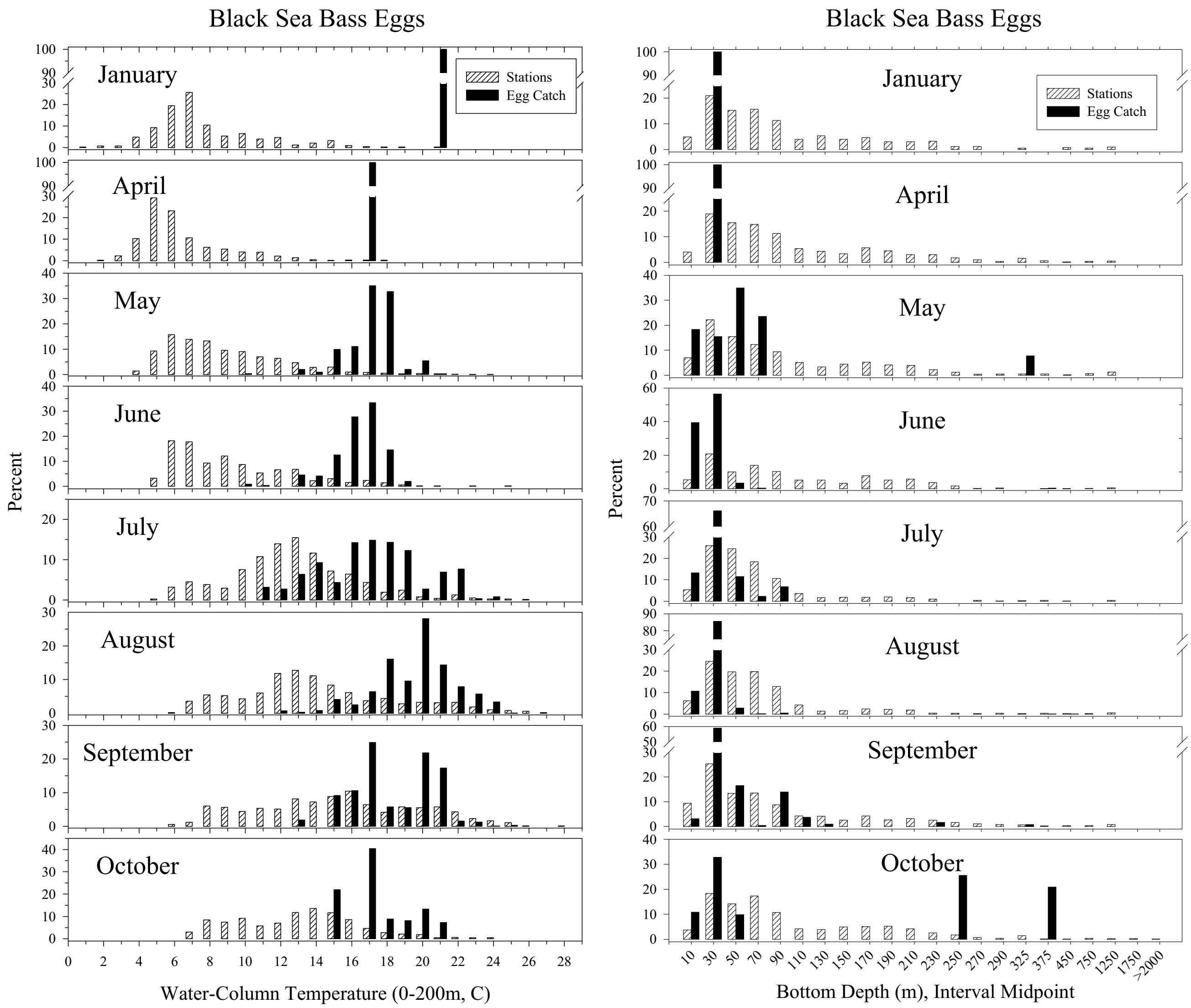

Figure 21. Distributions of black sea bass eggs collected during NEFSC MARMAP icthyoplankton surveys relative to water column temperature and bottom depth, for the years 1978-1987, by month for all years combined. Open bars represent the proportion of all stations which were surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2). Note that the bottom depth interval changes with increasing depth.

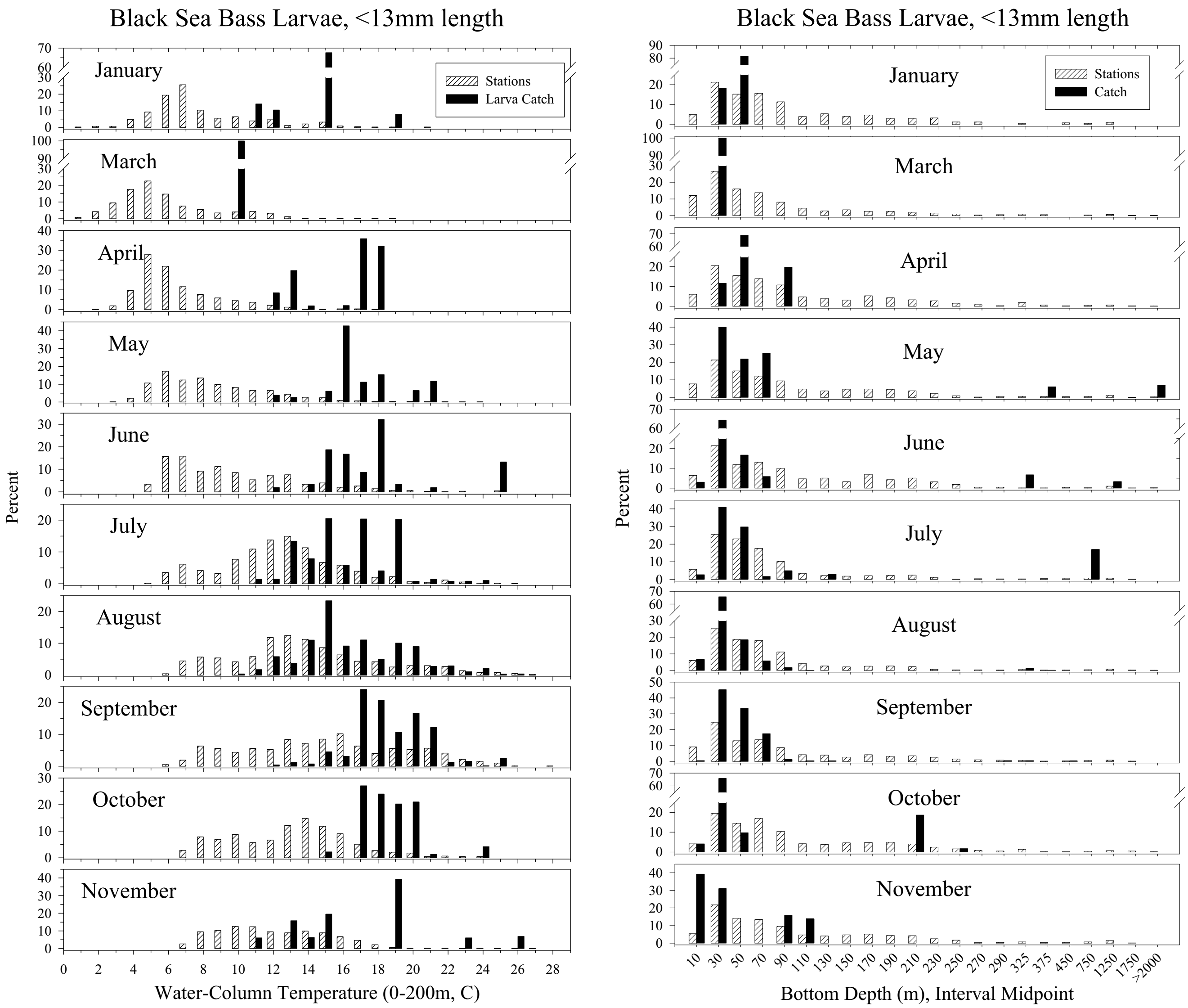

Figure 22. Distributions of black sea bass larvae collected during NEFSC MARMAP icthyoplankton surveys relative to water column temperature and bottom depth, for the years 1977-1987, by month for all years combined. Open bars represent the proportion of all stations which were surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2). Note that the bottom depth interval changes with increasing depth.

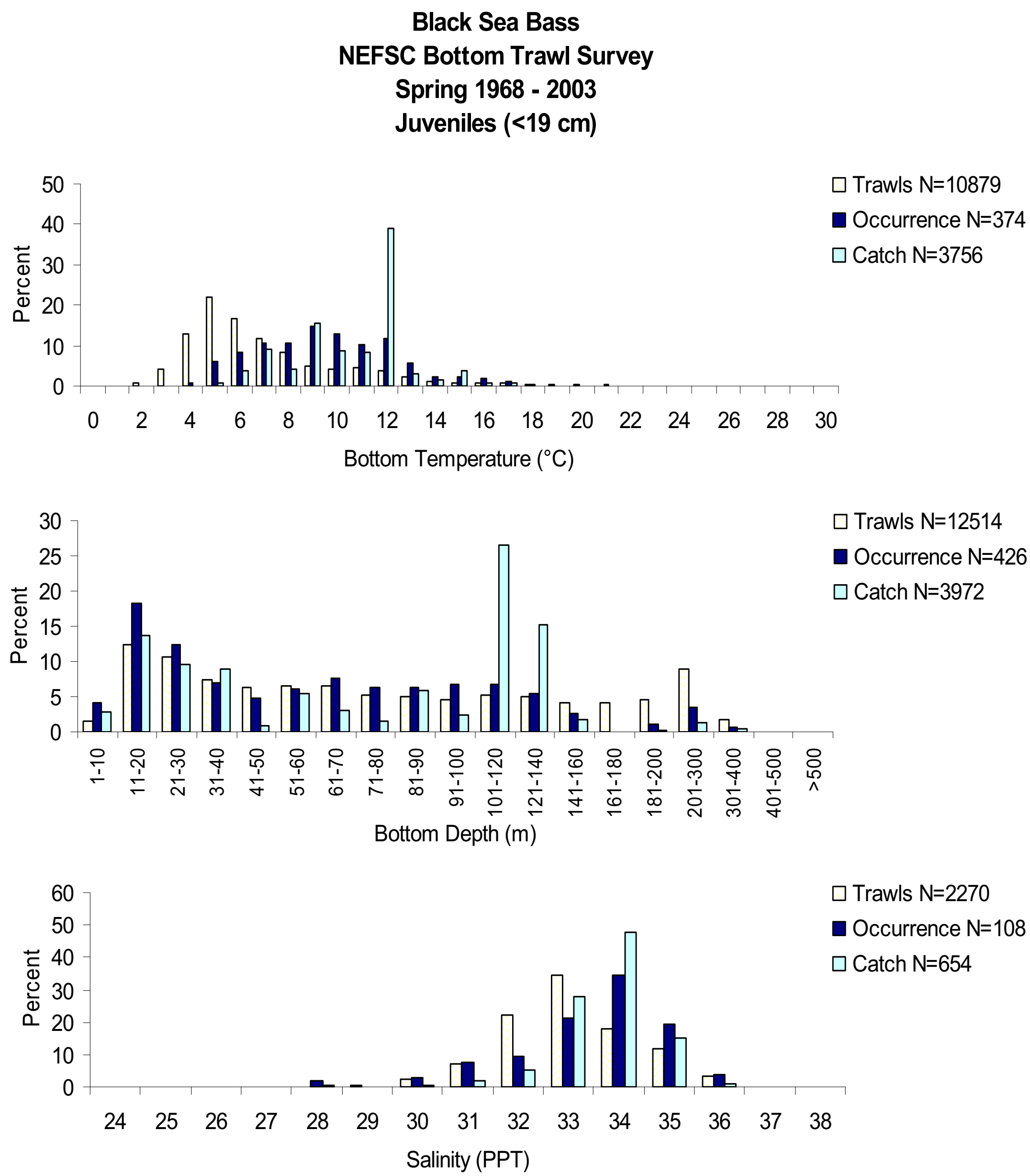

Figure 23. Distributions of juvenile black sea bass and trawls from NEFSC bottom trawl surveys relative to bottom water temperature, depth, and salinity, based on NEFSC spring bottom trawl surveys (temperature and depth: 1968-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which black sea bass occurred and medium bars show, within each interval, the percentage of the total number of black sea bass caught. Note that the bottom depth interval changes with increasing depth.

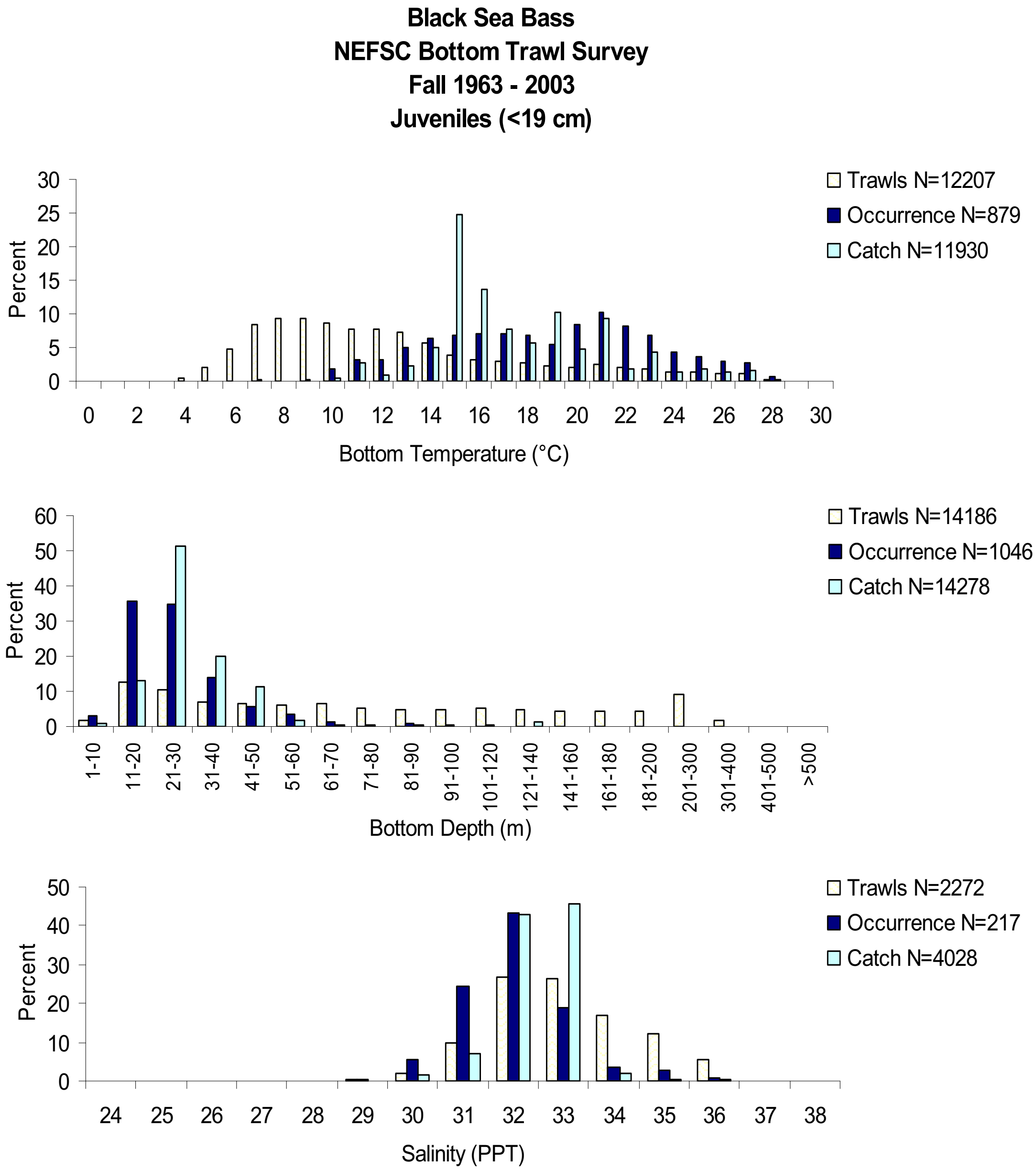

Figure 23. Cont'd.
Based on NEFSC fall bottom trawl surveys (temperature and depth: 1963-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which black sea bass occurred and medium bars show, within each interval, the percentage of the total number of black sea bass caught. Note that the bottom depth interval changes with increasing depth.

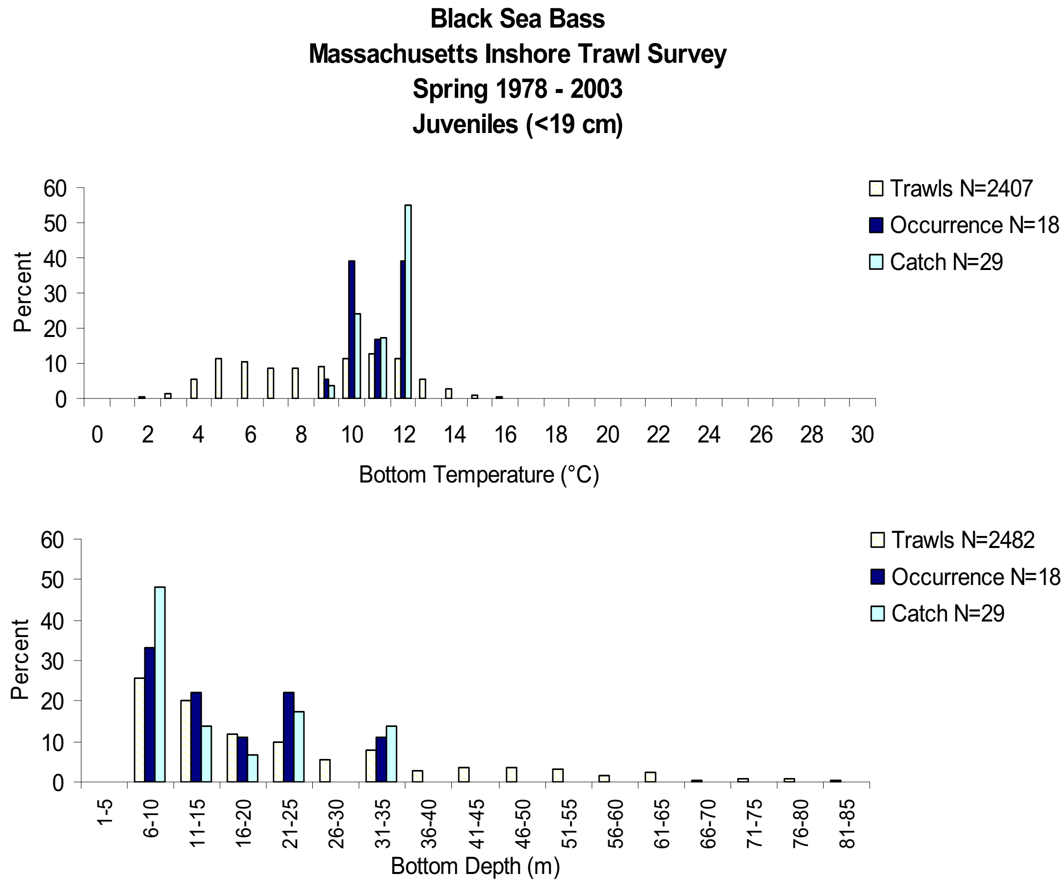

Figure 24. Distributions of juvenile black sea bass and trawls in Massachusetts coastal waters relative to bottom water temperature and depth, based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which black sea bass occurred and medium bars show, within each interval, the percentage of the total number of black sea bass caught.

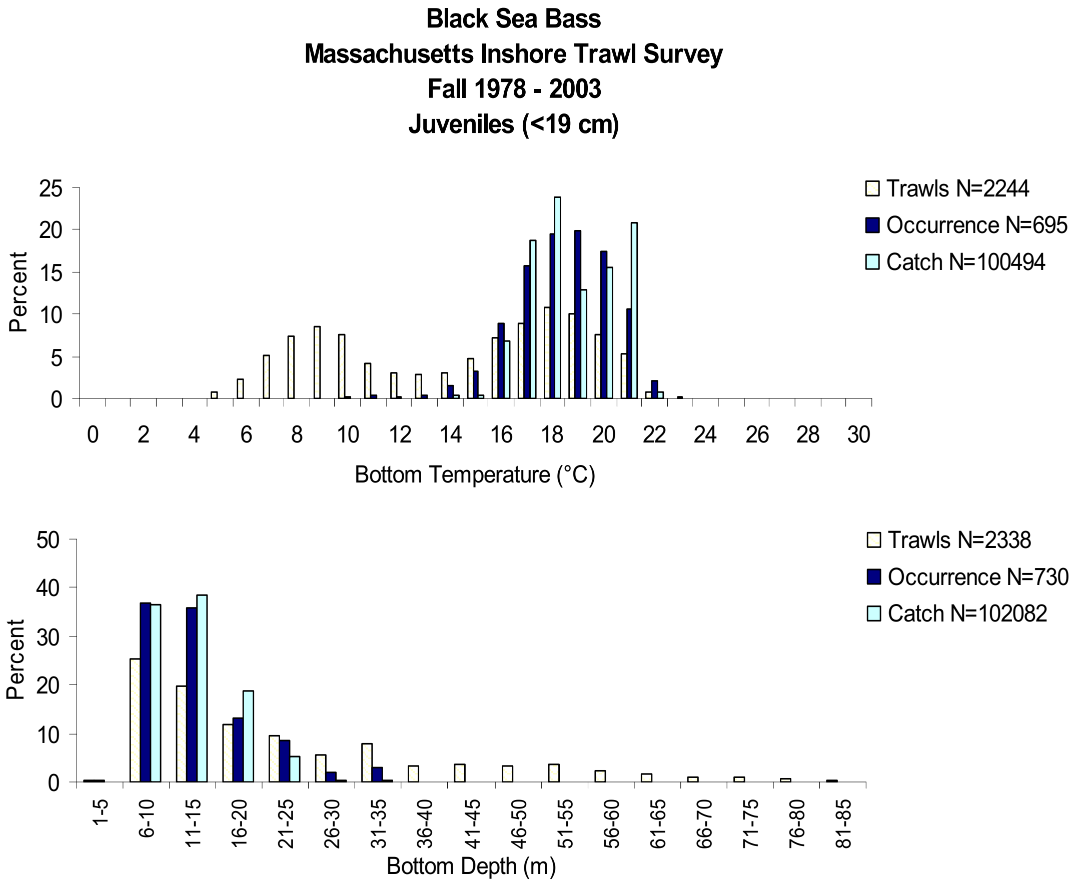

Figure 24. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which black sea bass occurred and medium bars show, within each interval, the percentage of the total number of black sea bass caught.

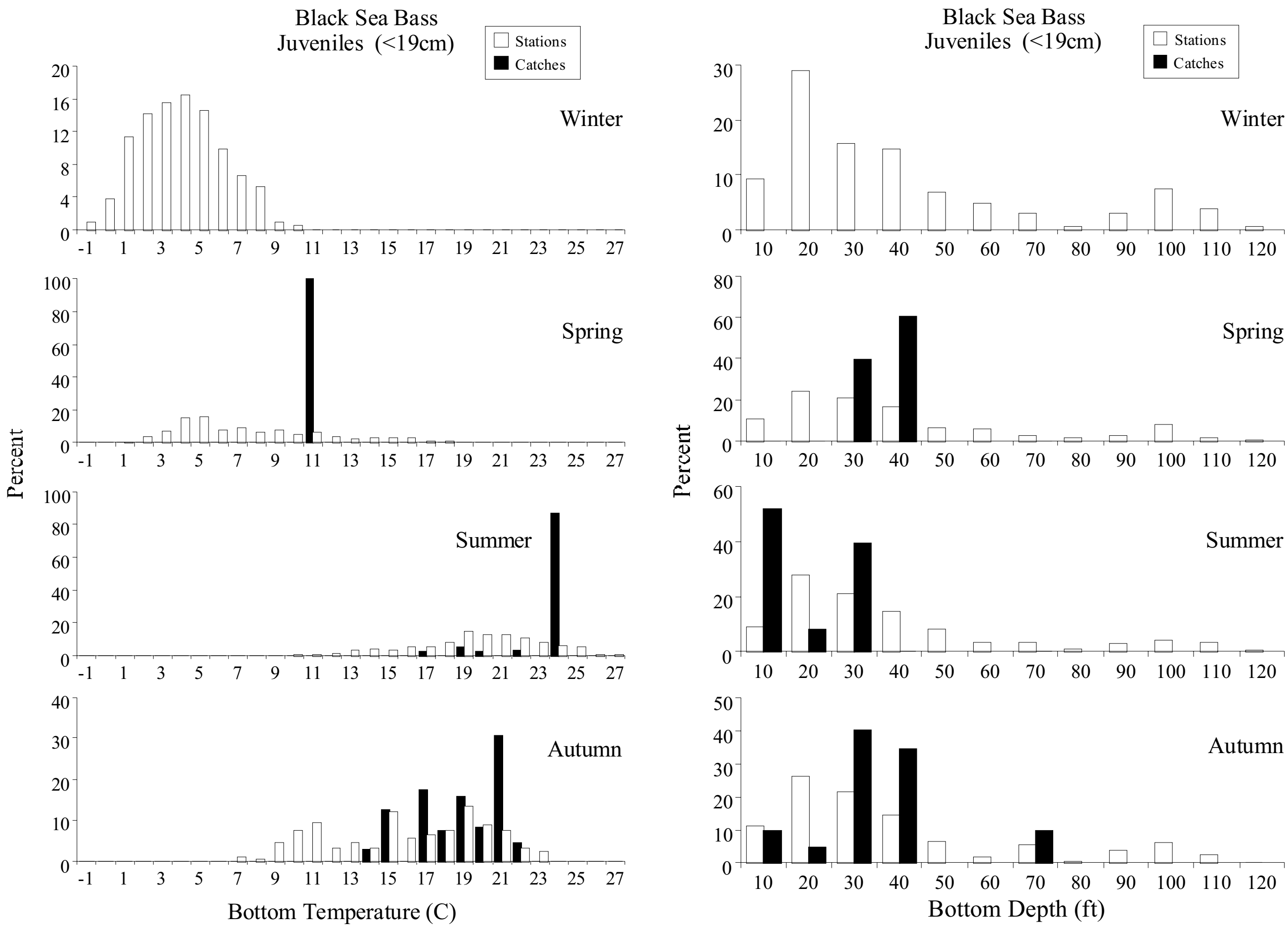

Figure 25. Seasonal distributions of juvenile black sea bass and trawls relative to bottom water temperature and depth, based on Rhode Island Narragansett Bay trawl surveys (1990-1996; all years combined). White bars give the distribution of all the trawls and black bars represent, within each interval, the percentage of the total number of juveniles caught.

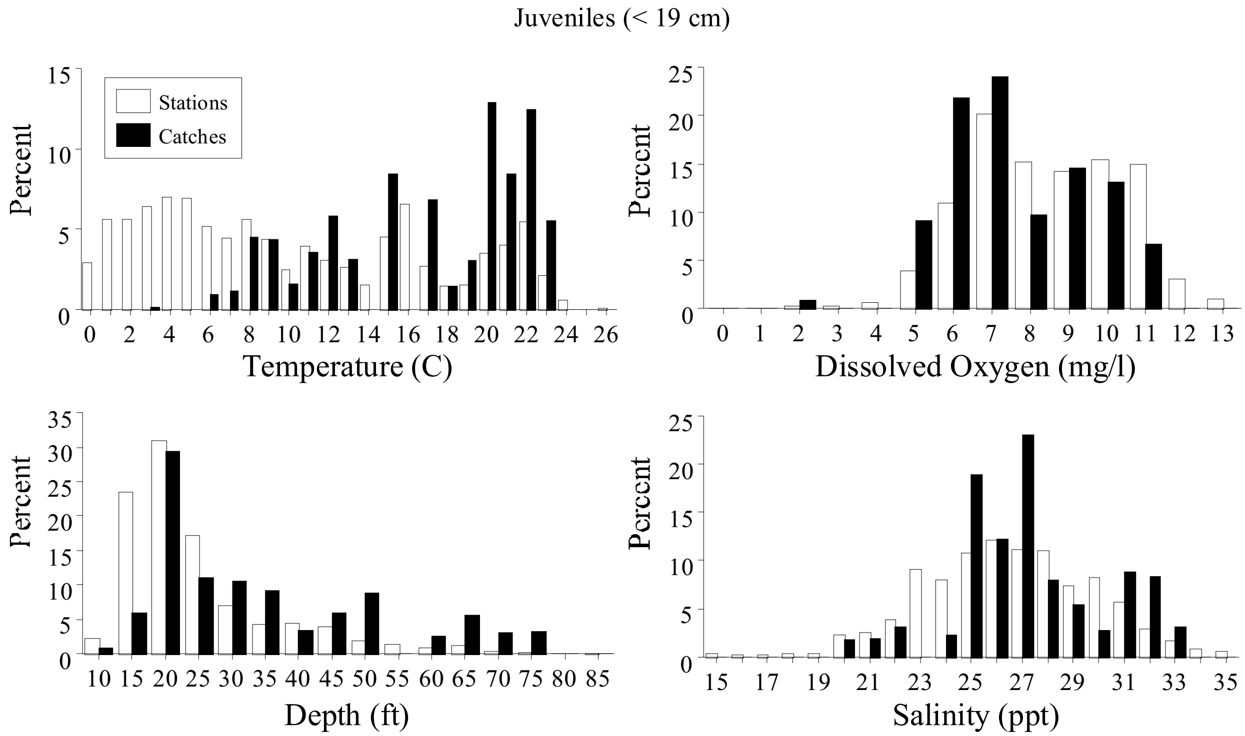

Figure 26. Distributions of juvenile black sea bass relative to mean bottom water temperature, dissolved oxygen, depth, and salinity, based on Hudson-Raritan estuary trawl surveys (January 1992 - June 1997, all years combined). Open bars represent stations surveyed and closed bars represent fish collected.

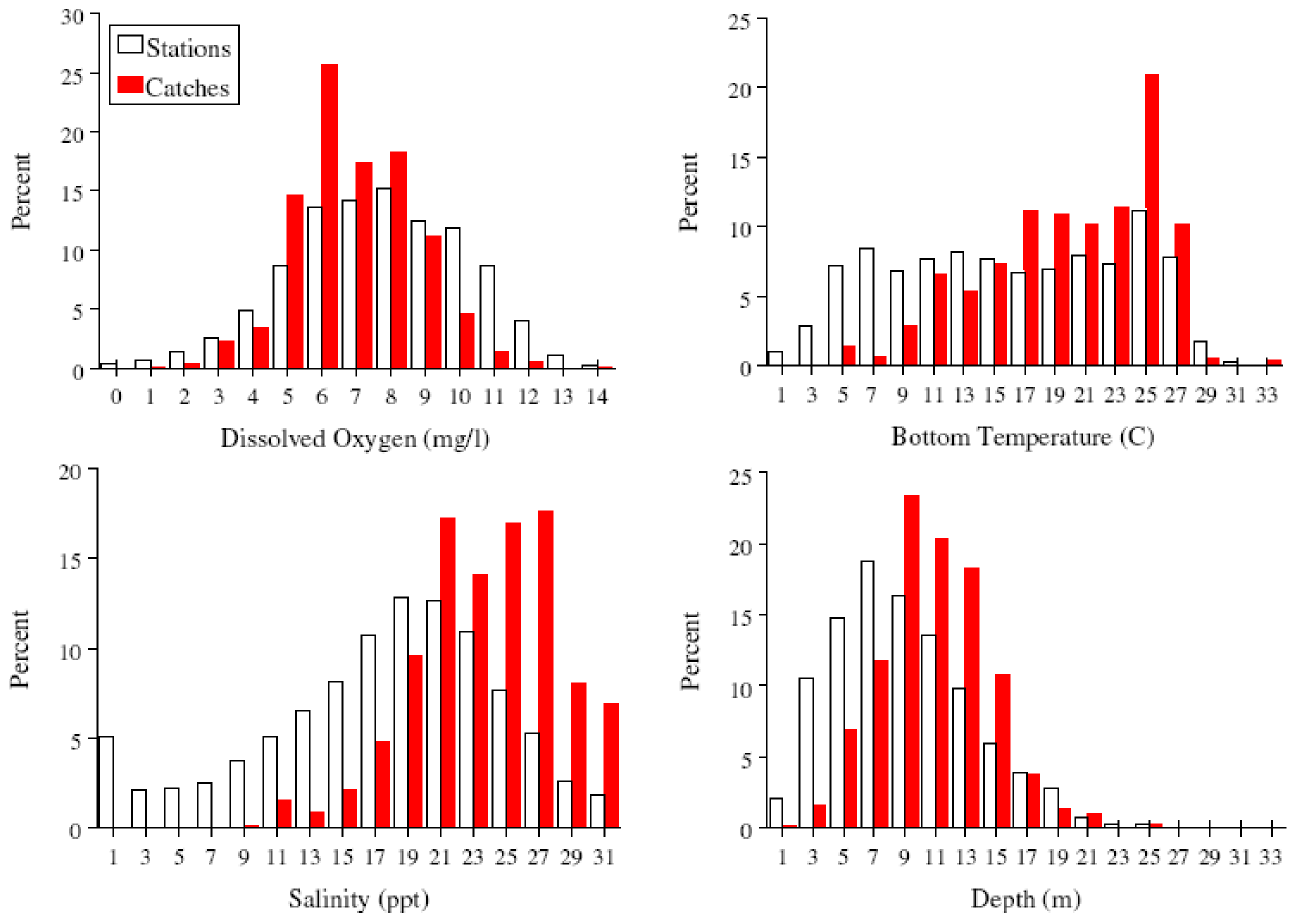

Figure 27. Hydrographic preferences for juvenile black sea bass in Chesapeake Bay and tributaries, from the VIMS trawl surveys, 1988-1999 (all years combined). Source: Geer (2002).

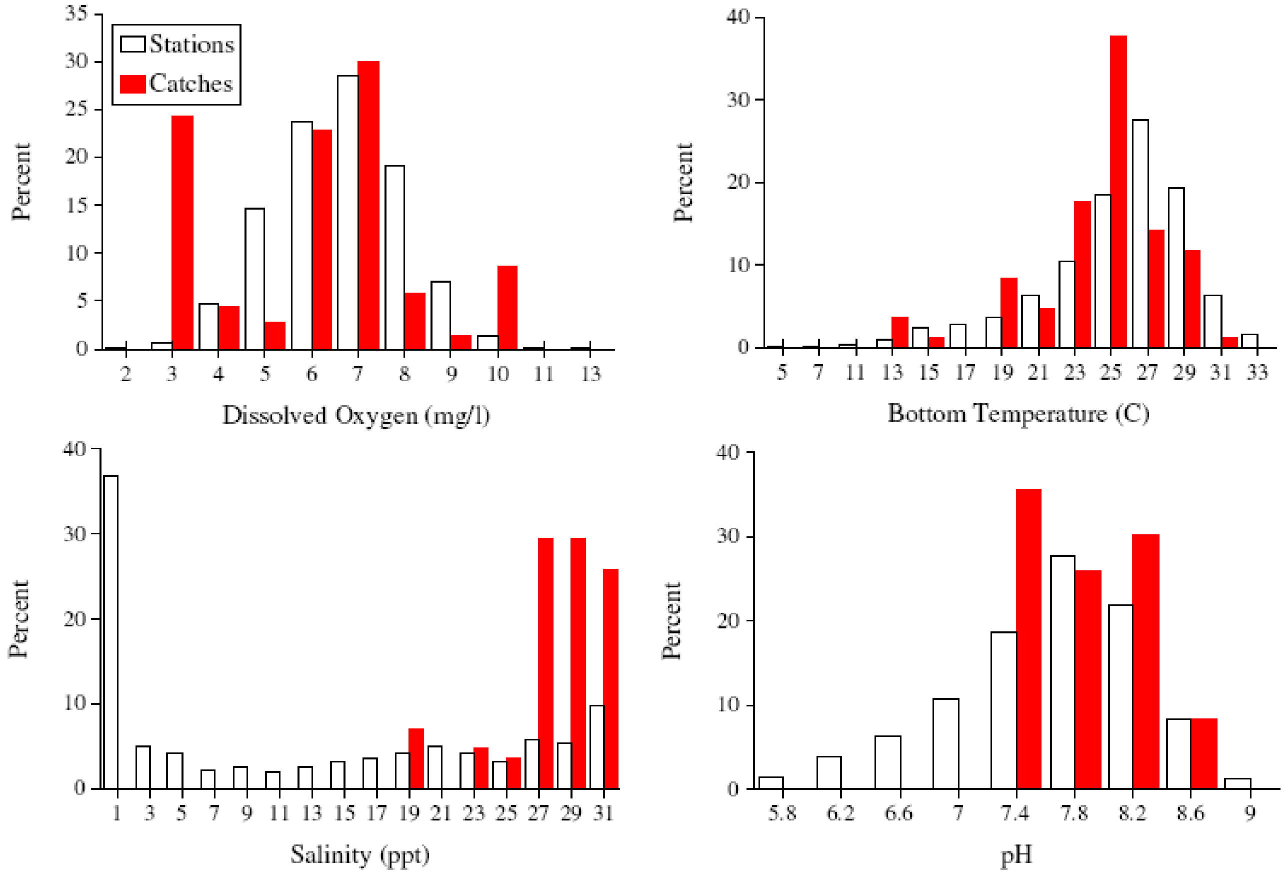

Figure 28. Hydrographic preferences for juvenile black sea bass, from the VIMS seine surveys, 1994-1999 (all years combined). Source: Geer (2002).

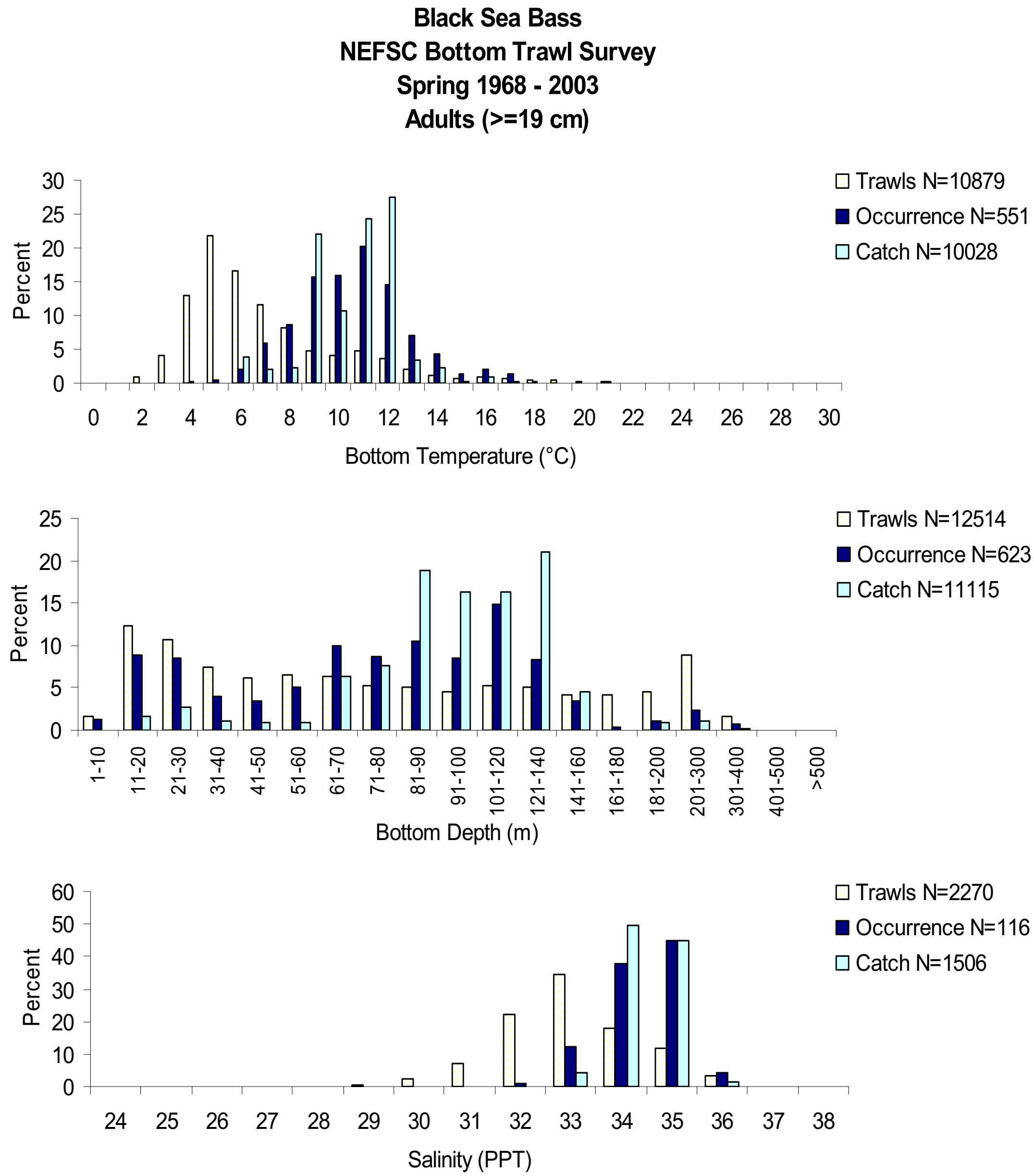

Figure 29. Distributions of adult black sea bass and trawls from NEFSC bottom trawl surveys relative to bottom water temperature, depth, and salinity, based on NEFSC spring bottom trawl surveys (temperature and depth: 1968-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which black sea bass occurred and medium bars show, within each interval, the percentage of the total number of black sea bass caught. Note that the bottom depth interval changes with increasing depth.

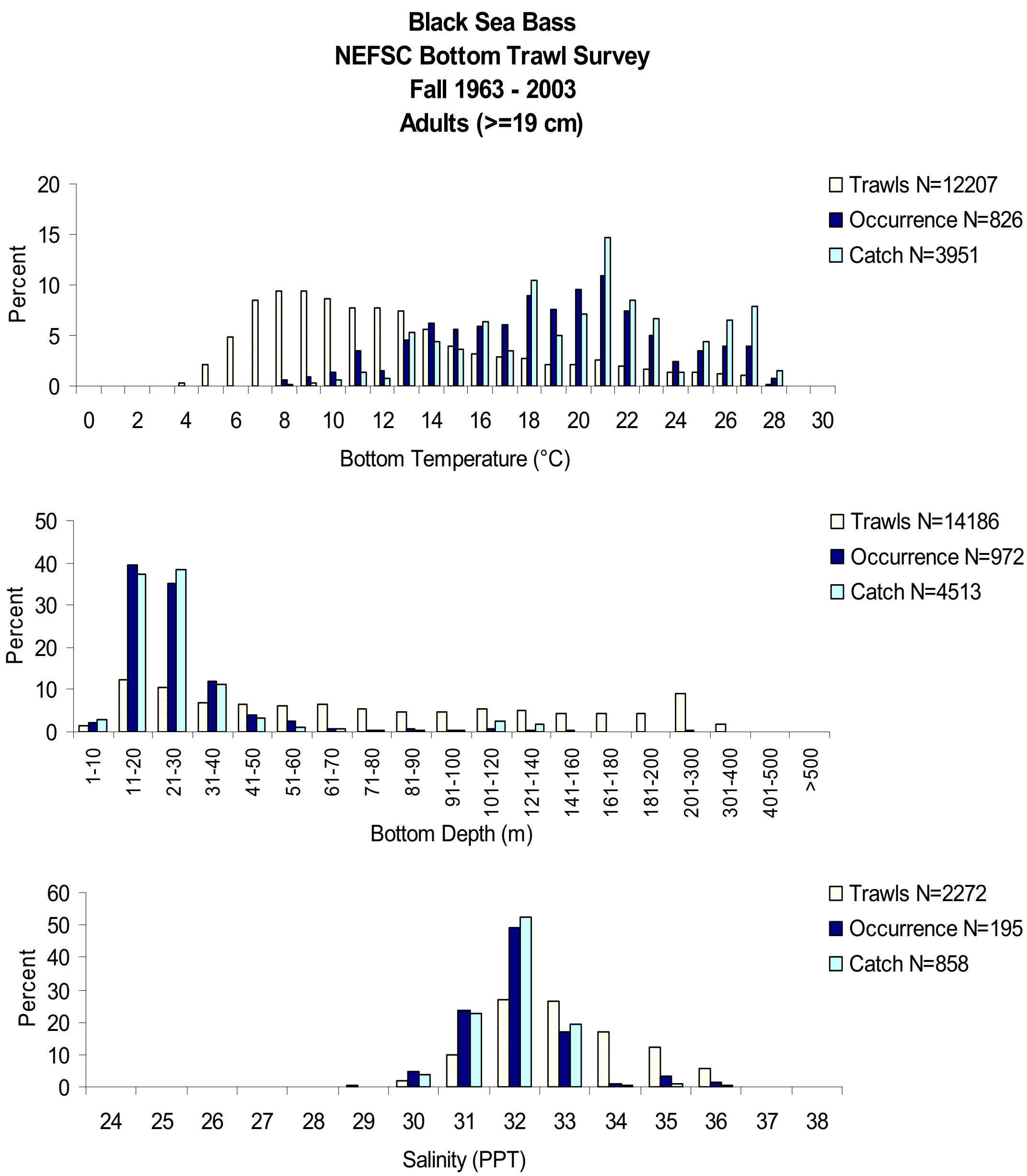

Figure 29. Cont'd.
Based on NEFSC fall bottom trawl surveys (temperature and depth: 1963-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which black sea bass occurred and medium bars show, within each interval, the percentage of the total number of black sea bass caught. Note that the bottom depth interval changes with increasing depth.

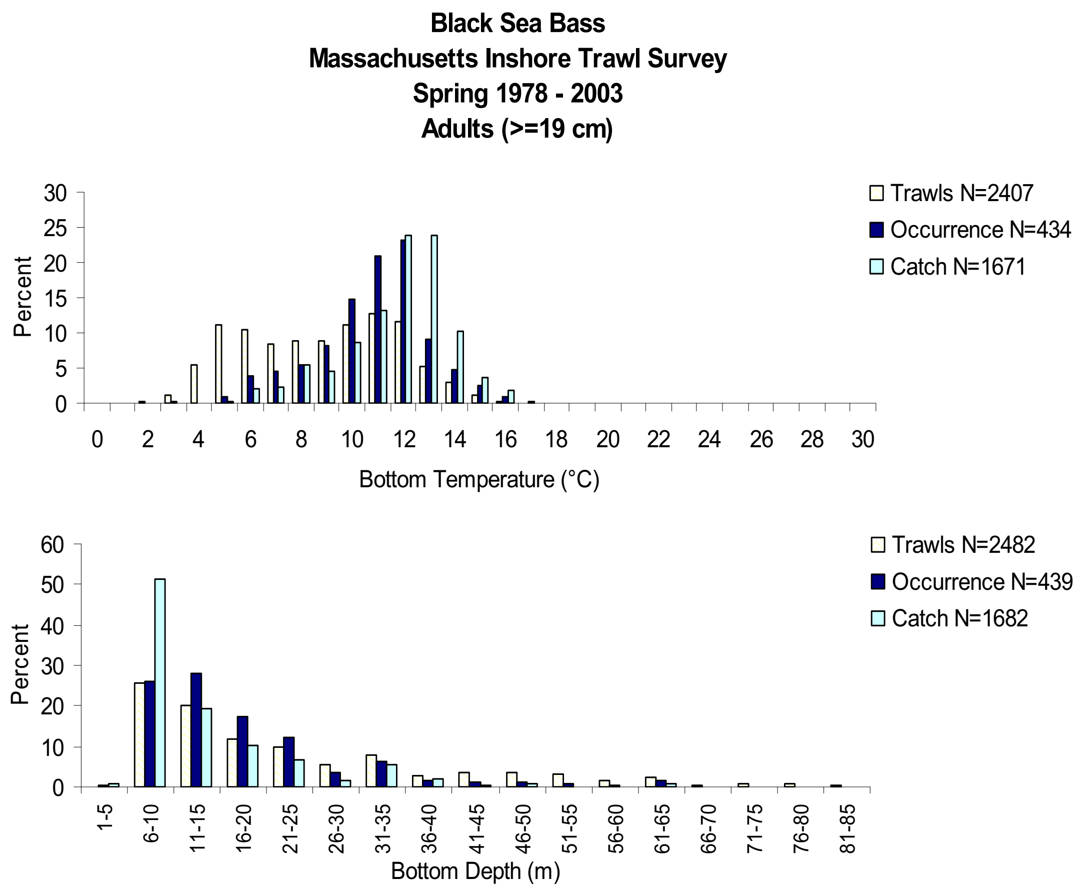

Figure 30. Distributions of adult black sea bass and trawls in Massachusetts coastal waters relative to bottom water temperature and depth, based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which black sea bass occurred and medium bars show, within each interval, the percentage of the total number of black sea bass caught.

Black Sea Bass
Massachusetts Inshore Trawl Survey
Fall 1978 - 2003
Adults (>=19 cm)

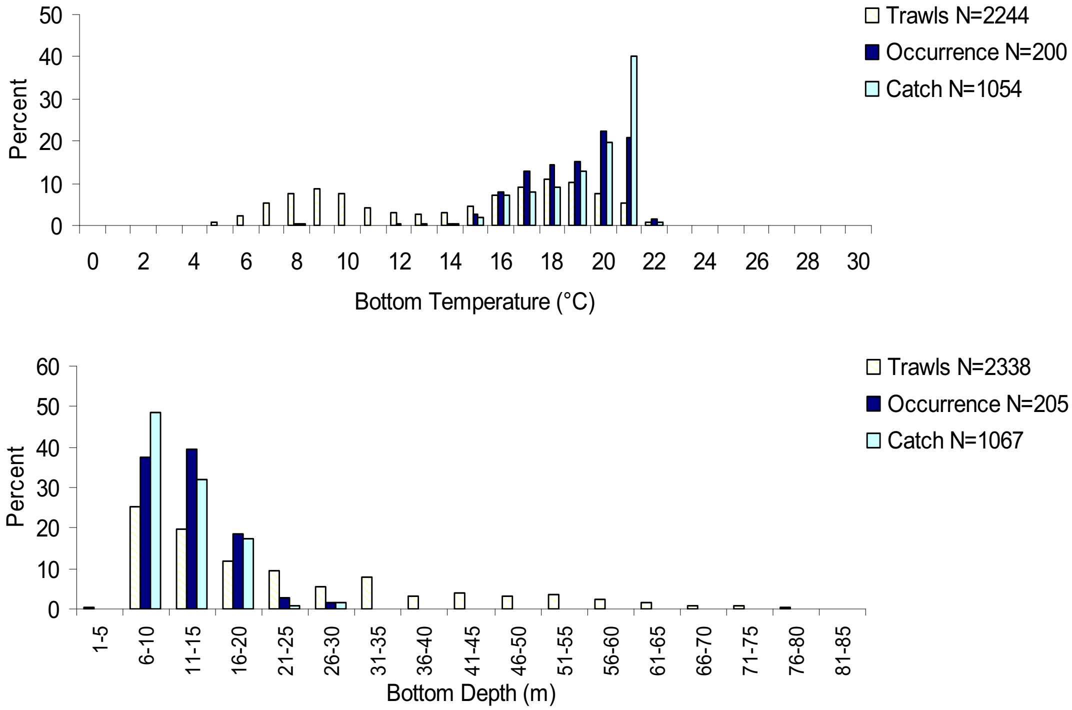

Figure 30. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which black sea bass occurred and medium bars show, within each interval, the percentage of the total number of black sea bass caught.

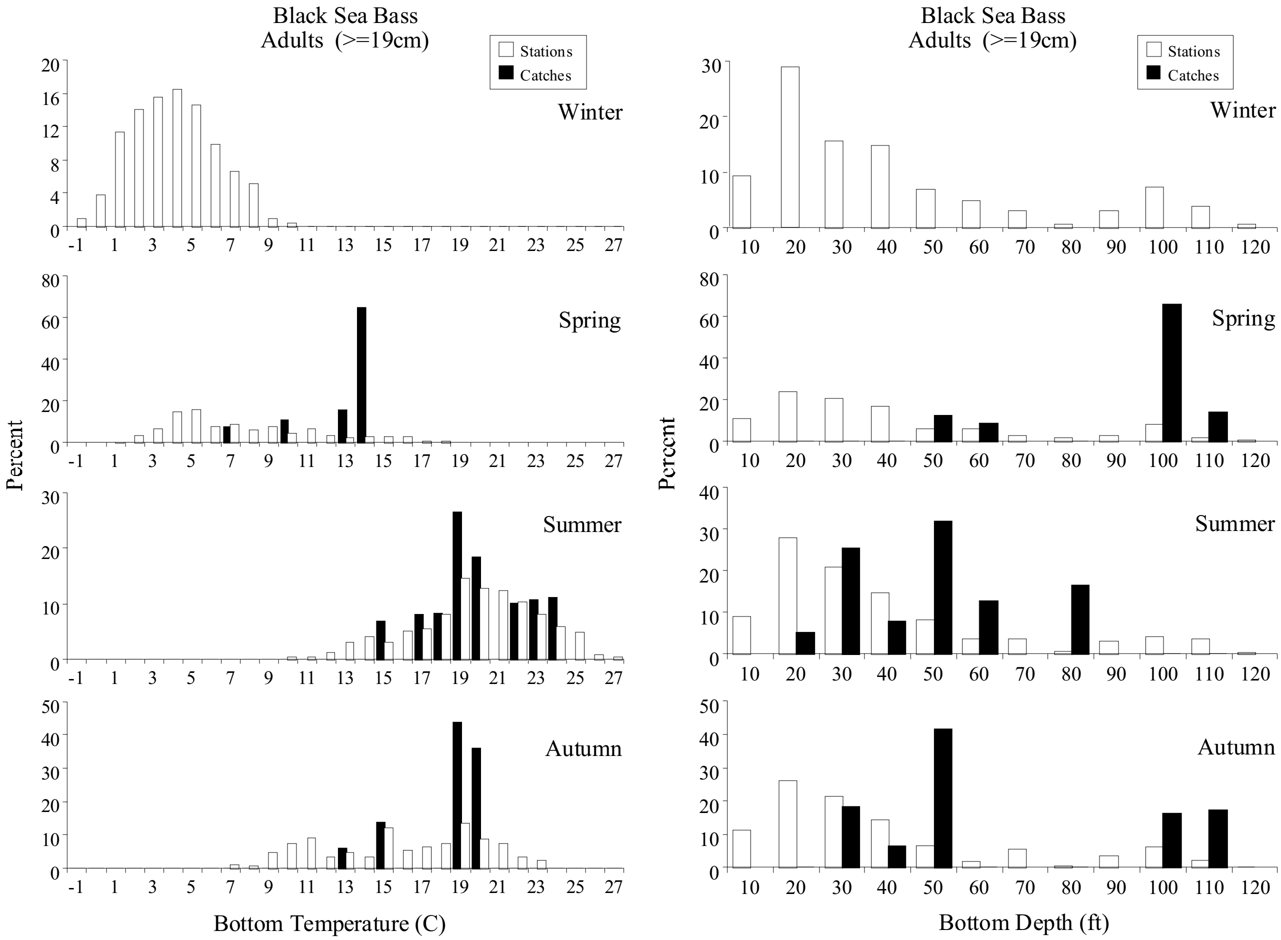

Figure 31. Seasonal distributions of adult black sea bass and trawls relative to bottom water temperature and depth, based on Rhode Island Narragansett Bay trawl surveys (1990-1996; all years combined). White bars give the distribution of all the trawls and black bars represent, within each interval, the percentage of the total number of adults caught.

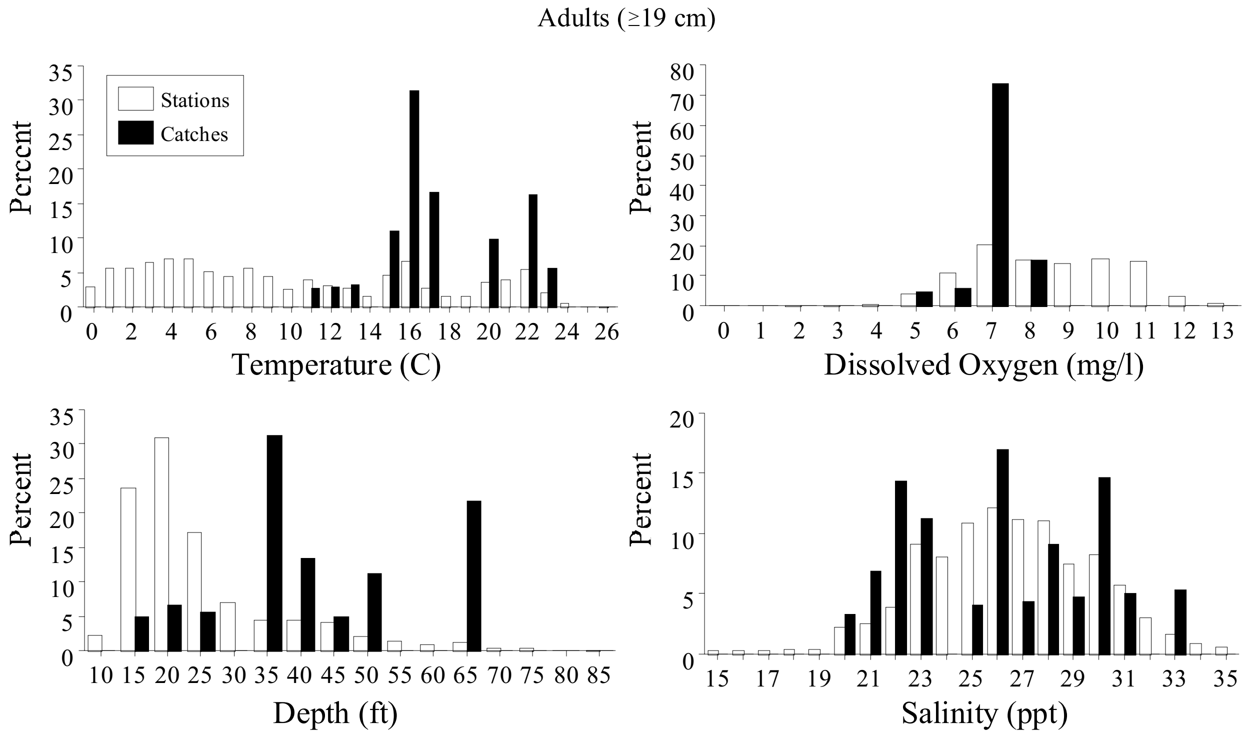

Figure 32. Distributions of adult black sea bass relative to mean bottom water temperature, dissolved oxygen, depth, and salinity, based on Hudson-Raritan estuary trawl surveys (January 1992 - June 1997, all years combined). Open bars represent stations surveyed and closed bars represent fish collected.

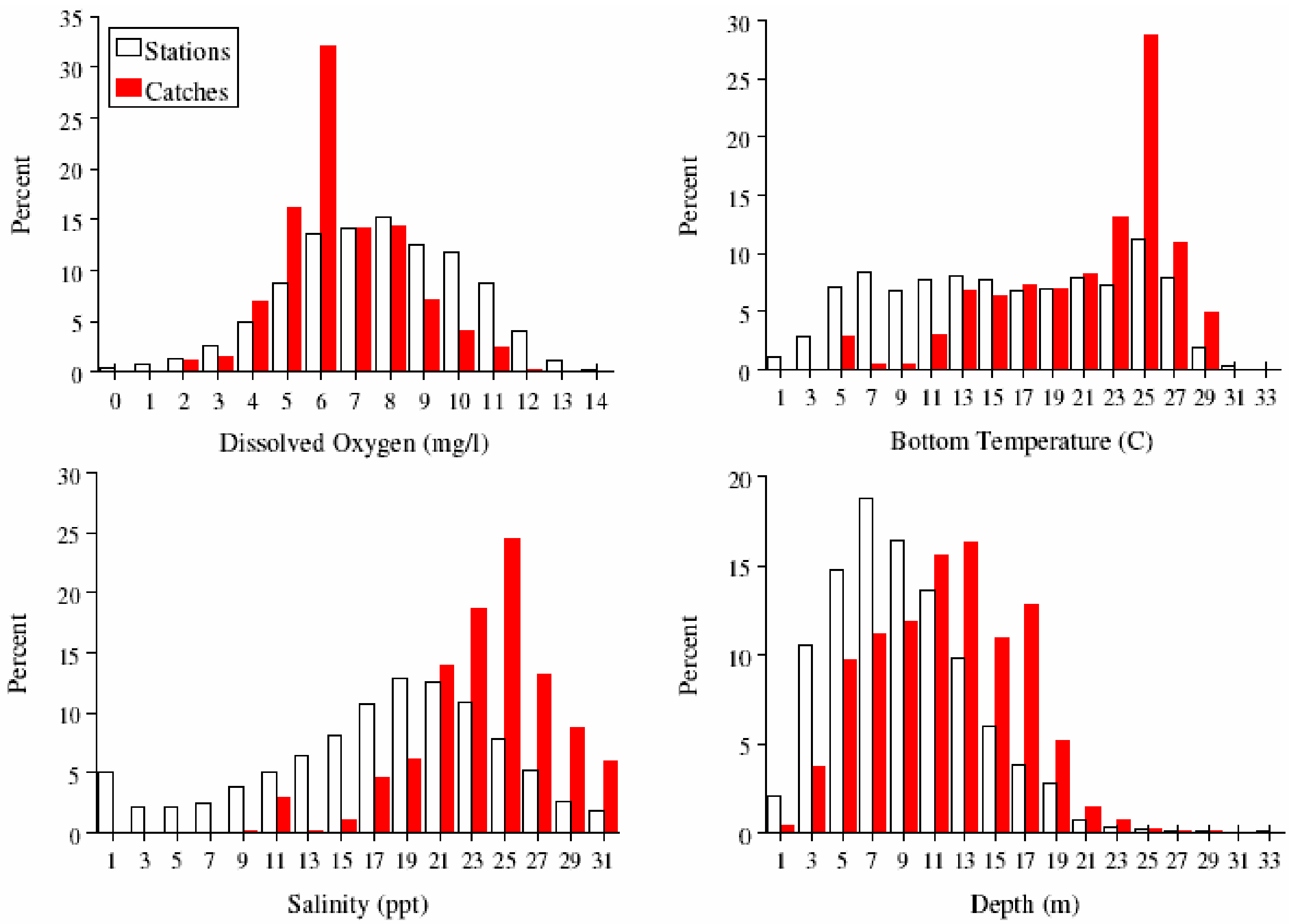

Figure 33. Hydrographic preferences for adult black sea bass in Chesapeake Bay and tributaries, from the VIMS trawl surveys, 1988-1999 (all years combined). Source: Geer (2002).

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Northeast Fisheries Science Center
Operations, Management & Information Division
Research Communications Branch
Editorial Office

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MEDIA MAIL

Publications and Reports of the Northeast Fisheries Science Center

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

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term field or lab studies of important species or habitats; synthesis reports for important species or habitats; annual reports of overall assessment or monitoring programs; manuals describing program-wide surveying or experimental techniques; literature surveys of important species or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

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

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

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