NOAA Technical Memorandum NMFS-NE-143

Essential Fish Habitat Source Document:

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

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

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

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Editorial Notes on Issues 122-152 in the *NOAA Technical Memorandum NMFS-NE* Series

Editorial Production

For Issues 122-152, staff of the Northeast Fisheries Science Center's (NEFSC's) Ecosystems Processes Division have largely assumed the role of staff of the NEFSC's Editorial Office for technical and copy editing, type composition, and page layout. Other than the four covers (inside and outside, front and back) and first two preliminary pages, all preprinting editorial production has been performed by, and all credit for such production rightfully belongs to, the authors and acknowledgees of each issue, as well as those noted below in "Special Acknowledgments."

Special Acknowledgments

David B. Packer, Sara J. Griesbach, and Luca M. Cargnelli coordinated virtually all aspects of the preprinting editorial production, as well as performed virtually all technical and copy editing, type composition, and page layout, of Issues 122-152. Rande R. Cross, Claire L. Steimle, and Judy D. Berrien conducted the literature searching, citation checking, and bibliographic styling for Issues 122-152. Joseph J. Vitaliano produced all of the food habits figures in Issues 122-152.

Internet Availability

Issues 122-152 are being copublished, *i.e.*, both as paper copies and as web postings. All web postings are, or will soon be, available at: *www.nefsc.nmfs.gov/nefsc/habitat/efh*. Also, all web postings will be in "PDF" format.

Information Updating

By federal regulation, all information specific to Issues 122-152 must be updated at least every five years. All official updates will appear in the web postings. Paper copies will be reissued only when and if new information associated with Issues 122-152 is significant enough to warrant a reprinting of a given issue. All updated and/or reprinted issues will retain the original issue number, but bear a "Revised (Month Year)" label.

Species Names

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

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

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

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

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

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

FOREWORD

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

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

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

NMFS Strategic Plan for Fisheries Research (February 1998)

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

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

The Northeast Fisheries Science Center compiled the available information on the distribution, abundance, and habitat requirements for each of the species managed by the New England and Mid-Atlantic Fishery Management Councils. That information is presented in this series of 30 EFH species reports (plus one consolidated methods report). The EFH species reports comprise a survey of the important literature as well as original analyses of fishery-independent data sets from NMFS and several coastal states. The species reports are also the source for the current EFH designations by the New England and Mid-Atlantic Fishery Management Councils, and have understandably begun to be referred to as the "EFH source documents."

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

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

A historical note: the EFH species reports effectively recommence a series of reports published by the NMFS Sandy Hook (New Jersey) Laboratory (now formally known as the James J. Howard Marine Sciences Laboratory) from 1977 to 1982. These reports, which were formally labeled as *Sandy Hook Laboratory Technical Series Reports,* but informally known as "Sandy Hook Bluebooks," summarized biological and fisheries data for 18 economically important species. The fact that the bluebooks continue to be used two decades after their publication persuaded us to make their successors – the 30 EFH source documents – available to the public through publication in the *NOAA Technical Memorandum NMFS-NE* series.

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

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ECOSYSTEMS PROCESSES DIVISION
NORTHEAST FISHERIES SCIENCE CENTER

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INTRODUCTION

The black sea bass (*Centropristis striata* Linnaeus 1758) (Figure 1), is a warm temperate species that is usually associated with structured habitats, such as reefs and shipwrecks, on the continental shelf. It occurs from southern Nova Scotia and the Bay of Fundy (Scott and Scott 1988) to southern Florida (Bowen and Avise 1990) and into the Gulf of Mexico (Figure 2). The summer migrant fish assemblage, with which the black sea bass is associated, has been reported from scattered sites on the Grand Banks of Canada (Brown *et al.* 1996); however, it is uncommon or occurs irregularly in the cool waters north of Cape Cod (Scattergood 1952; DeWitt *et al.* 1981; Short 1992). According to Beebe and Tee-Van (1933), black sea bass were introduced to Bermuda, however this was unsuccessful (B. Collette, National Systematics Laboratory, Smithsonian Institution, Washington, DC, personal communication).

The species exists as three populations or stocks – northern, southern, and Gulf of Mexico. The northern stock, that occurs north of Cape Hatteras, is the focus of this review. The life histories and habitats of the southern and Gulf of Mexico populations are covered in the South Atlantic Fishery Management Council Snapper Grouper Fishery Management Plan.

The eggs and larvae are generally collected from late spring to late summer from mid-shelf into coastal waters. Larvae are believed to settle in coastal waters and move into estuarine or sheltered coastal nursery areas as early juveniles. This can be a two-step process involving nearshore accumulation and estuarine passage (Boehlert and Mundy 1988). During warmer months, juveniles are found in estuaries and coastal areas, often near shelter, between North Carolina and Massachusetts. Adults are found slightly deeper than juveniles and summer in coastal areas, usually near structured habitat, from the Middle Atlantic Bight into the Gulf of Maine. Temperature, not the availability of structured habitat, appears to limit black sea bass distribution north of Cape Cod. In the Middle Atlantic Bight, black sea bass are usually the most common fish on structured habitats, especially south of New Jersey where the abundance of cunner (*Tautogolabrus adspersus*) declines. These structured habitats include shellfish (oyster and mussel) beds, rocky areas, shipwrecks, and artificial reefs (Verrill 1873; Bigelow and Schroeder 1953; Musick and Mercer 1977; Steimle and Figley 1996).

As coastal waters cool below 14^{o}C in the fall, the Middle Atlantic Bight population begins to migrate south and offshore to wintering areas in deeper waters between central New Jersey and North Carolina. As bottom waters warm above about 7^{o}C in the spring, the population migrates inshore into coastal areas and bays in southern New England and the Middle Atlantic Bight. The southern population of black sea bass is not known to make an extensive migration, but may move away from shallow coastal areas during cold winters, especially in the Carolinas. Larger fish are commonly found in deeper waters and usually associated with rough bottom (Smith 1907; Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953).

Black sea bass usually mature as a female and with increasing size, change sex to male. In the Middle Atlantic Bight, they grow to over 60 cm TL, weigh over 3.5 kg, and live up to 20 years; the largest and oldest fish are almost always males (Bigelow and Schroeder 1953).

LIFE HISTORY

EGGS

The northern population spawns buoyant, pelagic eggs on the continental shelf from spring through fall (Able and Fahay 1998; Reiss and McConaugha 1999). Spawning begins in the spring in the southern part of their range (North Carolina and Virginia) and progresses north into southern New England waters from summer through fall. In the Middle Atlantic Bight, the incubation period of the eggs is five days (approximately 120 hrs) at 15^{o}C (Kendall 1972). Able and Fahay (1998) give an incubation period of 35-75 hrs depending on water temperature. Little else is known of this stage.

LARVAE

Larvae are 1.5-2.1 mm SL at hatching (Fahay 1983). The duration of the pelagic larval stage is unknown. Tucker (1989) reported that larval black sea bass can grow for two days before their yolk is exhausted and will die within three days thereafter if they can not acquire enough planktonic food. Cowen *et al.* (1993) classified black sea bass larvae in a New York Bight (bounded by Long Island and New Jersey coasts) mid-summer assemblage, which usually included cusk-eel (*Ophidion* sp.). Larvae settle and become demersal in coastal areas at 10-16 mm TL (Able and Fahay 1998). However, Kendall (1972) reported that settlement might be delayed until 25 mm TL. Allen *et al.* (1978) found 15-17 mm black sea bass larvae (transition to juveniles) in epibenthic sled collections off the oceanic side of the Cape May peninsula (New Jersey) in late July. Larval black sea bass were collected by plankton nets in the surf zone during June-July 1995-1996 off northern New Jersey (D. Clark, U.S. Army Corps Engineers, Vicksburg, MS, personal communication).

JUVENILES (< 19 CM TL)

Most juvenile settlement does not occur in estuaries, but in coastal areas. Recently settled juveniles then find their way to estuarine nurseries. Adams (1993) reported a "major settlement" of juvenile black sea bass (< 3.0 cm) in August 1992 near an artificial reef about 15 km off the Virginia-North Carolina border. He did not observe a large settlement in 1991. The fish were observed by diving and occurred singly and in small groups near shelter on the artificial reef or in depressions containing shell fragments in the surrounding sand. The transport mechanism and fish behavior that move these early juveniles into estuaries are unknown (Able and Fahay 1998).

Young-of-the-year (YOY) black sea bass enter Middle Atlantic Bight estuaries from July to September (Able *et al.* 1995b; Able and Hales 1997). This occurs earliest in the south. Kimmel (1973) collected 30-146 mm juveniles in Magothy Bay, Virginia as early as March; they occur later elsewhere in Chesapeake Bay (Chesapeake Bay Program 1996). Richards (1963a, b) did not find them in central Long Island Sound until September and October; this was confirmed by more recent surveys (1992-1997) of the Sound, (Gottschall *et al.*, in review). Older juveniles return to estuaries in late spring and early summer, and may follow the migration routes of adults into coastal waters. Bean (1902) reported that juveniles were "very common" in Great South Bay (New York) and Great Egg Harbor Bay (New Jersey). Sherwood and Edwards (1902) noted that, at that time, black sea bass were decreasing in abundance in Vineyard Sound (Massachusetts).

The seasonal recruitment of YOY black sea bass to estuaries is temporally and spatially variable. Juvenile black sea bass were collected in relatively high abundance (1.2-5.5 per tow) from trawls in Raritan Bay (New Jersey) during late summer 1997 (D. McMillan, NMFS, NEFSC, James J. Howard Marine Sciences Laboratory, Highlands, NJ, unpublished data), but they were rarely collected in surveys during the previous five years. Based on trap collections, juvenile black sea bass were a dominant species within and near shoreline pilings in New York Harbor in late summer 1993 (Able *et al.* 1995b). Black sea bass were rare in the Arthur Kill, a tributary to the Hudson-Raritan estuary (Howells and Brundage 1977) and in Raritan and Sandy Hook Bays (Breder 1922; Wilk *et al.* 1996). They were not collected in Newark Bay in the early 1990s (Wilk *et al.* 1997). Black sea bass are rare in Barnegat Bay (New Jersey) (Marcellus 1972; Vouglitois 1983; Tatham *et al.* 1984). However, Allen *et al.* (1978) reported that Hereford Estuary (New Jersey), about 60 km south, was an important black sea bass nursery area during several years of monitoring; they also reported significant fluctuations in annual abundance.

Juvenile black sea bass grow relatively fast in estuaries during the summer. Schwartz (1961) found 30-37 mm TL juveniles in east shore bays of Virginia as early as April; they grew to 98-182 mm by November. Able and Fahay (1998) noted that YOY grow to 100 mm by the fall. Able and Hales (1997) reported mean growth rates of 0.45 mm/day from spring to fall, with a peak rate 0.74 mm/day in the summer, for age 0+ and 1+ juveniles in coastal southern New Jersey. In a previous study, age 1+ fish grew an average of 0.77 mm/day (Able *et al.* 1995a). In contrast, Allen *et al.* (1978) reported that postlarvae (early juveniles) that enter the Hereford Estuary in July at about 18 mm leave at > 40 mm TL in the fall; they also reported that 1 year old fish arrive in this estuary at about 60 mm and leave at about 100 mm TL.

Kim (1987) found that juvenile growth in the laboratory was affected by food type, consumption rates, and fish size. Juvenile growth was increased 4-5 times on an enriched artificial diet. Laboratory studies indicated that temporary hypoxic conditions in estuaries in the summer could inhibit the growth of young-of-the-year fish (Hales and Able 1995). Growth of juveniles was clearly evident in otoliths and showed annulus formation in May or June (Dery and Mayo 1988).

ADULTS (≥ 19 CM TL)

Growth is sexually dimorphic in mature black sea bass; females grow faster but reach a lower maximum size (Lavenda 1949; Mercer 1978; Wilk *et al.* 1978). Shepherd and Idoine (1993) suggest that the species can have three sex-related growth rates: female, male, and transitional. Males grew faster than females off New York based on otolith annuli analyses of year 1 and older fish (Alexander 1981). Black sea bass from Massachusetts had growth rates almost double those reported for New York and Virginia, but different growth estimators were used (Dery and Mayo 1988; Kolek 1990; Caruso 1995). Fish from the Middle Atlantic Bight were larger at age and grew faster than fish from the South Atlantic Bight (Mercer 1978; Wenner *et al.* 1986). Growth is linear to about age 6, then slows; the Middle Atlantic Bight population is larger at age than the South Atlantic Bight population (Wenner *et al.* 1986).

During warm months, black sea bass share the coastal habitat with several other species, including tautog (*Tautoga onitis*), spotted hake (*Urophycis regia*), red hake (*U. chuss*), conger eel (*Conger oceanicus*), ocean pout (*Macrozoarces americanus*), pinfish (*Lagodon rhomboides*), northern searobin (*Prionotus carolinus*), and transients such as gray triggerfish (*Balistes capriscus*) (Chee 1977; Musick and Mercer 1977; Eklund and Targett 1991). Inshore trawl surveys included butterfish (*Peprilus triacanthus*), smooth dogfish (*Mustelus canis*), round herring (*Etrumeus teres*), and windowpane (*Scophthalmus aquosus*) in the summer group containing black sea bass (Phoel 1985; Gabriel 1992; Brown *et al.* 1996). North of Maryland, cunner is a dominant member of the reef ichthyofauna. In estuaries, black sea bass co-occur on oyster shell plantings with summer flounder (*Paralichthys dentatus*), spot (*Leiostomus xanthurus*), oyster toadfish (*Opsanus tau*), and other species (Arve 1960).

REPRODUCTION

Like most of the Serranidae, the black sea bass is a protogynous hermaphrodite; most fish mature as females and change to males with additional growth (Lavenda 1949). In the Middle Atlantic Bight, individuals begin to mature at age

1 (8-17 cm TL) and 50% are mature at about 19 cm SL and 2-3 years of age (O'Brien *et al.* 1993). The majority of fish in this size group are females (Mercer 1978). The average size of transformation from female to male occurs at 23.9-33.7 cm TL (Chesapeake Bay Program 1996). In the South Atlantic Bight, Cupka *et al.* (1973) reported that both sexes mature at smaller sizes (14-18 cm SL). Wenner *et al.* (1986) and Alexander (1981) found mature fish at about 10-11 cm (age 1+) off South Carolina and New York; a majority of fish were mature at about 19 cm TL and at an age of about 2-3 years. Alexander (1981) reported a decrease in the age and size of sex change since the 1940s with fewer mature males in the New York population; he associated this decrease with increasing fishing pressure. Mercer (1978) reported that 2-5 year old females release between 191,000 and 369,500 eggs.

Based on collections of ripe fish and distributions of egg, black sea bass spawn primarily on the inner continental shelf between Chesapeake Bay and Montauk Pt., Long Island at depths of about 20-50 m (Breder 1932; Kendall 1972, 1977; Musick and Mercer 1977; Wilk *et al.* 1990; Eklund and Targett 1990; Berrien and Sibunka 1999). Spawning has been reported as far north as Buzzards Bay and Nantucket Sound, Massachusetts (Wilson 1891; Sherwood and Edwards 1902; Kolek 1990). Gravid females are not generally found in estuaries (Allen *et al.* 1978). Larvae have been collected in Cape Cod Bay, but these were probably stragglers swept from Buzzards Bay through the Cape Cod Canal and not the product of local spawning (MAFMC 1996).

Spawning in the Middle Atlantic Bight population occurs from May to July (Kendall 1972, 1977; Musick and Mercer 1977; Feigenbaum *et al.* 1989; Wilk *et al.* 1990; Eklund and Targett 1990) during inshore migrations, but can extend to October-November (Fahay 1983; Berrien and Sibunka 1999). Larval distributions presented in Able *et al.* (1995a) suggest spawning occurs earliest off Virginia and North Carolina (in the vicinity of the wintering grounds) and progresses northerly and inshore as inner shelf waters warm.

In Massachusetts coastal waters, spawning fish aggregate on sand bottoms broken by ledges; after spawning, the fish disperse to ledges and rocks in deeper water (Kolek 1990; MAFMC 1996). Kolek (1990) reported evidence from tagging studies of homing to spawning grounds. Some tagged adult black sea bass returned to the spawning grounds in northwestern Nantucket Sound where they were tagged. Kolek (1990) also reported this local spawning group spawned earlier and in shallower waters than generally reported by Kendall (1977).

The complex social hierarchy of reef fishes, such as black sea bass, during spawning implies that the number of males may be an important factor limiting reproductive potential (Shepherd and Idoine 1993). They noted that theoretical studies suggest that, to the degree that non-dominant males participate in spawning, the current relative abundance of males may not be limiting in the black sea bass population. Although nothing is known of the mating of this species, pairing is characteristic of the family (Breder and Rosen 1966).

FOOD HABITS

The diet of larval black sea bass are poorly known, but probably consists of zooplankton. Tucker (1989) reported that black sea bass larvae are capable of surviving and growing at lower prey densities, and resist prey abundance fluctuations better, than bay anchovy (*Anchoa mitchilli*) larvae.

Juvenile black sea bass are diurnal, visual predators and often prey on small benthic crustaceans (isopods, amphipods, small crabs, sand shrimp, copepods) and other epibenthic estuarine and coastal organisms, such as mysids and small fish (Richards 1963a; Kimmel 1973; Allen *et al.* 1978; Werme 1981; Figure 3). Kimmel (1973) found that polychaete worms were significant in the diet and reported a shift from mysids (55%) and amphipods (15%) at 3.0-9.0 cm SL to xanthid and other crabs (35%), mysids (19%), and polychaetes (14%) at 9.1-14.6 cm SL. Orth and Heck (1980) reported that sub-adults (14.0-16.5 cm TL) feed in eelgrass beds in lower Chesapeake Bay; their prey included juvenile blue crabs (*Callinectes sapidus*), eelgrass (*Zostera marina*) fragments, isopods, caprellid amphipods, shrimp, and pipefish (*Syngnathus* sp.). Festa (1979) reported lady (*Ovalipes* sp.), blue, and mud (xanthid) crabs, and caridean shrimp as major diet items in a small sample of fish from a central New Jersey estuary. Allen *et al.* (1978) reported an increase in the occurrence of anchovies, silversides (*Menidia* sp.), and plant detritus in the diets of 11-18 cm black sea bass from southern New Jersey coastal and estuarine areas; crustaceans were the most common prey.

During the summer, adult black sea bass feed on a variety of infaunal and epibenthic invertebrates [especially crustaceans, including juvenile American lobster (*Homarus americanus*)], small fish, and pelagic squid and baitfish (Bigelow and Schroeder 1953; Miller 1959; Richards 1963a; Mack and Bowman 1983; Steimle and Figley 1996; Figure 3). Feeding was heaviest after spawning (Hoff 1970).

The diets and feeding of the offshore wintering population are poorly known. The potential benthic invertebrate prey in the wintering area can be dominated by 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). Some co-wintering guild species, e.g. scup (*Stenotomus chrysops*) (Austen *et al.* 1994), may be competitors for habitat or food. Other guild species, such as butterfish and squid (*Loligo* sp. and *Illex* sp.), can be prey for adult black sea bass.

PREDATION AND MORTALITY

There are many potential predators on larval black sea bass. "Jellyfish" can be a significant source of larval mortality when they are abundant in the coastal zone (Arai 1988).

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. Summer flounder, smooth dogfish, and oyster toadfish are potential demersal predators of juvenile black sea bass, and juveniles in exposed areas can also be preyed upon by bluefish (*Pomatomus saltatrix*), striped bass (*Morone saxatilus*), weakfish, and other predators that use the water column, including diving birds. Steimle (unpublished data) found juvenile black sea bass in the stomachs of the following predators from Raritan Bay (New Jersey) during the summer 1997: clearnose skate (*Raja eglanteria*), northern and striped searobin (*Prionotus evolans*), summer flounder, and spot. Weakfish, bluefish, oyster toadfish, smooth dogfish, and fourspot flounder (*Paralichthys oblongus*) contained small, partially digested fish similar to juvenile black sea bass.

The Northeast Fisheries Science Center (NEFSC) food habits database lists the following species as predators of black sea bass: spiny dogfish (*Squalus acanthias*), Atlantic angel shark (*Squatina dumeril*), clearnose skate, little skate (*Raja erinacea*), spotted hake, summer flounder, windowpane, and goosefish (*Lophius americanus*). [See Reid *et al.* (1999) for food habits database methods.]

An extensive hypoxia/anoxia event in the New York Bight in the summer of 1976 resulted in fish mortalities, avoidance of the area by fish (including black sea bass), and extensive loss of benthic invertebrates (Azarovitz *et al.* 1979; Steimle and Radosh 1979). Commercial pot fishermen reported black sea bass mortality and sport divers reported the disappearance of black sea bass and other fish from shipwrecks and artificial reefs along the north-central New Jersey coast. The cause of the condition was the oxygen demand created by the decay of an unusually massive dinoflagellate bloom on the Middle Atlantic Bight continental shelf. This occurred during a period of unusual wind patterns and climate that caused early and strong water column stratification. Anthropogenic influences, such as nutrient exports from urban estuaries to offshore areas, were not confirmed or eliminated as causative factors. Earlier episodes of anoxia/hypoxia in the area caused mortalities or severe stress in fish (ocean pout and cunner) and shellfish (lobster and crabs), but not in black sea bass, tautog, or flounder (Ogren and Chess 1969). The June 25, 1997 Asbury Park Press (New Jersey) newspaper reported black sea bass as one of the fish observed dead in an hypoxic area off the New Jersey coast (dissolved oxygen < 2 ppm).

MIGRATION

Black sea bass belong to a group of warm temperate, migrating species that do not tolerate cold, inshore winter conditions; these include scup, summer flounder, northern searobin, spotted hake, butterfish, and smooth dogfish (Musick and Mercer 1977; Colvocoresses and Musick 1984). The composition of this group varies between spring, summer and fall (Phoel 1985).

The summer coastal population migrates in scattered aggregates in the fall by generally unknown routes from inshore areas across the continental shelf to outer shelf wintering areas south of New Jersey as bottom temperatures decline (Musick and Mercer 1977). Returns from adult fish tagged in Nantucket Sound (Massachusetts) suggest that the fish migrate directly south to the outer shelf near Block Canyon (south of Rhode Island), move southwest along this outer shelf zone to the vicinity of Norfolk Canyon (off Virginia), and return along the same route (Kolek 1990). Offshore migrations are stimulated in the fall as coastal bottom water temperatures approach 7^{o}C and the return inshore migration begins in the spring (about April) as inshore bottom water temperatures rise above 7°C (Nesbit and Neville 1935; June and Reintjes 1957; Colvocoresses and Musick 1984; Chang 1990; Shepherd and Terceiro 1994). Larger fish (a high proportion of which are males) begin migrating offshore sooner than smaller fish (Kendall 1977).

STOCK STRUCTURE

The black sea bass population from Cape Hatteras to Cape Kennedy (Florida) is considered a distinct population (Mercer 1978; Shepherd 1991; Collette and Klein-MacPhee, in prep.) and the Gulf of Mexico population is considered a distinct subspecies (*C. s. melanus*) (Link 1980; Bowen and Avise 1990). Subpopulations have not been identified within the northern population, although the evidence for a putative local population in Nantucket Sound suggested by Kolek (1990) bears further consideration.

HABITAT CHARACTERISTICS

Black sea bass is a warm temperate, demersal species that uses benthic habitats in open water to structured areas for feeding and shelter. Their distribution changes seasonally as fish migrate from coastal areas to the outer continental shelf while water temperatures decline in the fall and from the outer shelf to inshore areas as water temperatures rise in the spring. Information on the habitat use, characteristics, and preferences for the major life stages of the black sea bass population north of Cape Hatteras, North Carolina is summarized in Table 1.

EGGS

The habitat requirements of the planktonic stages of temperate reef fishes are thought to be little different from many tropical species. These requirements involve highly complex biological, physical, and chemical interactions such as predation, oceanographic processes, and food availability (Richards and Lindeman 1987).

Based on the NEFSC Marine Resources Monitoring, Assessment and Prediction (MARMAP) ichthyoplankton survey [see Reid *et al.* (1999) for details], black sea bass eggs were collected most frequently at average water column temperatures of 12-24^{o}C with a mode at about 15-18^{o}C, except in January and August-September when there was a secondary mode at 20-22^{o}C (Figure 4). The buoyant eggs were collected mostly in < 50 m water depths, but > 5% of the eggs were collected in waters > 240 m in May and October. This wide range undoubtedly reflects the relatively long spawning period, which begins in the spring and extends into the fall, and the seasonal migration of the adult population (from offshore to inshore).

Laboratory spawned *C. striata melanus* eggs and larvae are sensitive to high salinity, low pH, high nitrite-nitrate concentrations, and temperature extremes (Hoff 1970). Similar data are not known for *C. striata*, although comparable sensitivities can reasonably be expected.

LARVAE

Based on NEFSC MARMAP survey data, larvae were collected at average water column temperatures of 11-26^{o}C and were most abundant between 13-21^{o}C (Figure 5), which is a slightly wider range than found for eggs. Larvae were generally collected at depths of < 100 m, but several collections during May-July and October occurred over deeper (> 200 m) water. These deep water occurrences could reflect off-shelf transport effects of Gulf Stream gyres (or other oceanographic processes) and possibly reduce their opportunity to settle inshore and find their way into estuarine nurseries.

JUVENILES

The distribution and abundance data for reef fish based on towed nets probably do not represent all of the benthic habitats occupied. The NEFSC and state trawl surveys may avoid excessively rough bottom, shipwrecks, and reefs, or tow over them with roller gear that does not sample fish that seek shelter in holes. This potentially under estimates the association of fish like the black sea bass with rough bottom habitats and areas with steep depth gradients. The draft of survey vessels limits sampling in shallow waters and potentially underestimates the association with shallow, coastal habitats. The survey results presented herein are based on trawling and may bias the interpretation of habitat use by black sea bass.

Hydrographic data from the NEFSC groundfish surveys indicate that juvenile black sea bass occurred at bottom water temperatures > 5^{o}C and the largest catches occurred at 11-12^{o}C in the winter and spring (Figure 6). Juveniles were collected from about 20-240 m with a mode at 90-100 m. There were temperature modes at about 17^{o} and about 25^{o}C in the summer suggesting use of different habitats or geographic areas; most fish were collected in shallow (around 10-20 m) water. In the fall, the temperature distribution was wide (9-27°C) with a mode at about 14-15^{o}C; inshore waters < 50 m were preferred. [See Reid *et al.* (1999) for NEFSC survey methods.]

Hydrographic data from the Massachusetts spring and fall trawl surveys reflected warmer conditions in shallow coastal areas and were mostly consistent with the NEFSC data (Figure 7). In Narragansett Bay (Rhode Island), juveniles (3-13 cm TL) were rarely collected (average of 0.08 individuals/tow) and only from spring through fall at bottom temperatures of 11-22°C and depths < 24 m (80 ft) (Figure 8). In Long Island Sound during the fall, black sea bass (juveniles and adults) were collected at bottom temperatures of 14-19^{o}C, at depths of 5-50 m, and salinities of 23-32 ppt. In the Hudson-Raritan estuary, juveniles were collected at 6-23°C, around 10 m, at salinities > 20 ppt, and dissolved oxygen levels < 4 mg/L (ppm), although some fish were collected at 2 mg/L (Figure 9). [See Reid *et al.* (1999) for state survey methods.]

Data for juvenile black sea bass in smaller estuaries are scarce; available data are mostly estimates of extremes in tolerance or based on laboratory results (e.g., Hales and Able 1995; Able and Fahay 1998). Within smaller estuaries, natural coastal geological processes can alter the suitability of potential nursery habitat. For example, the natural opening and closing of inlets in barrier islands along the eastern shore of Virginia can change salinity and temperature regimes in lagoons, which changes the distribution of acceptable nursery habitat and juvenile fish, such as black sea bass (Schwartz 1961).

In many studies of reef fish, such as black sea bass, the availability of shelter limits successful postlarval and/or juvenile recruitment (Huntsman *et al.* 1982; Richards and Lindeman 1987). The estuarine nursery habitat of black sea bass is shallow, hard bottom with structure (refuge). These include shellfish (oyster and mussel), sponge, amphipod (*Ampelisca abdita*) tubes, and sea grass beds (especially *Ruppia* sp.), as well as wharves, pilings, wrecks, artificial reefs, crab and conch pots; and cobble and shoal grounds (southern New England to Cape Cod) at salinities > 8 ppt (Bean 1888; Moore 1892; Sherwood and Edwards 1902; Arve 1960; Hildebrand and Schroeder 1928; 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.* 1995a). They also occur at the mouths of salt marsh creeks (Werme 1981; Hales and Able 1994; Szedlmayer and Able 1996; Able and Hales 1997). Able *et al.* (1995a) reported little use of eelgrass in New Jersey. Juveniles were not common on open, unvegetated sandy intertidal flats or beaches (Allen *et al.* 1978), or deeper, muddy bottoms (Richards 1963b). Bean (1888) and Allen *et al.* (1978) reported that larger juveniles used deeper estuarine channels. In some urbanized areas, there were early reports of juvenile black sea bass using habitats that were formerly common but are now rare, such as oyster beds near Staten Island (Nichols and Breder 1927) and eelgrass beds in Gravesend Bay, Brooklyn (Bean 1902). Recent surveys in the Hudson-Raritan estuary collected YOY black sea bass usually only where beds of red beard sponge (*Microciona prolifera*) were common (Steimle, unpublished data).

In estuarine nurseries, YOY and older juveniles can use different habitats. Older juveniles tend to stay in shallower waters (< 10 m) (Musick and Mercer 1977), but not in the shallow shoals and marsh fringe favored by YOY. Older juveniles use channels (Bean 1888; de Sylva *et al.* 1962; Richards and Castagna 1970; Zawacki and Briggs 1976; Szedlmayer and Able 1996), jetties (Schwartz 1964), and bridge abutments (Allen *et al.* 1978). Werme (1981) reported that juvenile black sea bass (3.0-7.5 cm TL) occupied a sandy, saltmarsh creek in southern Massachusetts during August and September with juvenile tautog and winter flounder (*Pseudopleuronectes americanus*). There were differences in diets among these species that would limit competition.

Within structured nursery habitats, YOY black sea bass display high habitat fidelity; they move very little and may be territorial (Werme 1981; Able and Hales 1997). Able and Fahay (1998) observed YOY black sea bass defending a small shell used for shelter from others of its cohort.

There is a lack of information about winter habitats of YOY and yearling black sea bass (M. Dixon, NMFS, NEFSC, Milford Laboratory, Milford, CT, personal communication). Yearlings winter on the continental shelf and return to the estuaries the following spring (as early as March in Chesapeake and other bays); more specific winter habitat information is not available. Some individuals may spend the warmer months along the coast in accumulations of surf clam and ocean quahog shells, or in irregularities or holes in exposed clay (Able *et al.* 1995a). When temperatures drop below 14^{o}C, the juveniles gradually migrate to deeper and warmer water; few are collected below 6^{o}C (Able and Fahay 1998; Collette and Klein-MacPhee, in prep.). At temperatures below 6^{o}C in laboratory studies, juveniles bury in the sand; below 4^{o}C they cease feeding and mortality increases (Hales and Able 1995). Juveniles that overwinter in shallow estuaries in New Jersey can experience thermal stress and mortalities (Able and Hales 1997). A sudden cold spell resulted in mortalities in shallow nursery areas off southeastern New England (Baird 1873). In warmer winters, juveniles overwinter successfully in deeper waters of Chesapeake Bay (MAFMC 1996; Chesapeake Bay Program 1996). Able *et al.* (1995a) reported that windrows, patches, or beds of empty, hinged surf clam and ocean quahog shells may be important coastal habitat for juvenile and sub-adult black sea bass.

ADULTS

Adult black sea bass orient to structures, especially during their summer residency in coastal waters. Unlike juveniles, adults tend to enter only larger estuaries and are most abundant along the coast. Larger fish are found in deeper water than smaller fish. They occur on shipwrecks, rocky and artificial reefs, mussel beds, and other objects on the bottom. They are usually observed by divers hovering near or above these shelters and retreat into them if threatened. They remain near structures during the day, but can move away at dawn and dusk to feed on open bottom (Steimle and Figley 1996).

A characteristic of the northern population of black sea bass is their seasonal migration to southerly and offshore wintering grounds. In the Middle Atlantic Bight, black sea bass adults spend the winter on the middle to outer continental shelf between 30-240 m (with some as deep as 410 m, but most between 60-150 m) generally south of the Hudson Canyon off central New Jersey (Musick and Mercer 1977). Based on commercial catches, some fish spend the winter in deep water (> 80 m) off southern New England (Chang 1990; Kolek 1990; Bigelow and Schroeder 1953). Water mass movements on the continental shelf influence fish winter distribution. The distribution of bottom temperatures > 7.5°C may define the potential winter distribution of the species and its associates (Neville and Talbot 1964). Larger fish (mostly males) tend to occur in deeper water (Nesbit and Neville 1935; Musick and Mercer 1977; Able *et al.* 1995a). Off Virginia, artificial reefs and wrecks are populated with active resident adult black sea bass during most winters and support commercial and recreational fisheries (Chee 1977; Adams 1993). Adams (1993) observed that when bottom water temperatures were near 6^{o}C on inshore artificial reefs, adult fish became inactive and were often found resting in holes and crevices. Schwartz (1964) reported adult black sea bass in aquaria at 15 ppt salinity stopped feeding at water temperatures below 8^{o}C and died at temperatures below about 2^{o}C.

The offshore habitats occupied by adult black sea bass during the winter are poorly known. There are speculative and anecdotal reports that the northern population is associated with rough bottom during the winter (Pearson 1932; June and Reintjes 1957; Neville and Talbot 1964). The existence of significant amounts of rough bottom in wintering areas has not been confirmed. Wigley and Theroux (1981) characterized the wintering area as flat sandy-silt with occasional areas of relict and active sand waves of varying size, without hard bottom. There are reports of hard bottom (consolidated clay or rock) near the head of submarine canyons at the shelf edge and in a few other isolated places (Emory and Uchupi 1972; Stanley *et al.* 1972; Grimes *et al.* 1987). Scattered shipwrecks and man-made debris are also available as offshore wintering habitat. Shellfish beds (current and relict) and shallow pits on the mid to outer shelf (possibly created by large crabs, lobsters, or fish) could be used as sheltering habitat (Emory and Uchupi 1972; Folger *et al.* 1979; Shepard *et al.* 1986; Able *et al.* 1995a). Parker (1990) reports that black sea bass burrow into sediments during cold spells off the Carolinas. This behavior can explain how structure-associated black sea bass accommodate themselves during the winter on the relatively featureless offshore continental shelf of the Middle Atlantic Bight. However, burrowing in open, soft sediments may not protect them from trawls or the possible harm from suspended sediments (Churchill 1989). Several other resource species use the same habitat as black sea bass in the winter, including scup, summer flounder, butterfish, squid, and American lobster (Chang 1990; Able and Kaiser 1994).

During the warmer months, adult black sea bass are usually found inshore associated with structured habitats, including eelgrass, oyster, and mussel beds, rocky reefs, cobble and rock fields, stone coral patches, and exposed stiff clay. Man-made structures include 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. Towed nets do not adequately sample these habitats. Richards (1963a, b) and others reported that black sea bass in Long Island Sound are usually found in structured habitats within areas of sandy sediments and rarely in muddy areas. A continual supply of shipwrecks and anthropogenic debris, and state-supervised artificial reef programs, are increasing the quantity of habitat available to this and associated species.

For adult black sea bass, bottom temperatures about 6-7.5^{o}C or above are a critical factor in habitat use and distribution (Colvocoresses and Musick 1984). In the NEFSC groundfish survey, adults were most commonly collected at water temperatures of 9-12^{o}C in the winter and spring (Figure 6). The temperature distribution in the summer when black sea bass occurred in shallow (10-20 m) coastal areas was bimodal with peaks at about 10^{o}C and 25^{o}C (Figure 6). During the fall, adults were collected at 7-27^{o}C; most fish were collected at 13-21^{o}C with a secondary peak at about 25-27^{o}C; fish were collected mostly in relatively shallow water (< 50 m) (Figure 6).

In the spring Massachusetts surveys, black sea bass were collected at bottom temperatures between 6-17^{o}C and at depths < 35 m; most were in 11-14^{o}C and very shallow, around 5 m (Figure 7). In the fall Massachusetts surveys, they were collected at bottom temperatures between 14-23^{o}C and at depths between 5-25 m, most were at depths of < 15 m (Figure 7). In Narragansett Bay, adult black sea bass 21-41 cm TL were rarely caught in trawls (average catch of 0.036 individuals/tow). They were collected mainly in the summer and fall at bottom temperatures between 13-20^{o}C and at depths between 6-38 m (20-110 ft) (Figure 8). Adult black sea bass dominated spring catches in central Long Island Sound; a few were collected in the fall. Black sea bass were collected at bottom temperatures of 6-18^{o}C, from 7-47 m, and at salinities between 25-30 ppt. Black sea bass collected in the Hudson-Raritan estuary had similar temperature and depth ranges; adult black sea bass were collected at dissolved oxygen levels of > 5 mg/L (Figure 9).

GEOGRAPHICAL DISTRIBUTION

EGGS

Black sea bass eggs were collected during NEFSC MARMAP surveys in the water column across most of the continental shelf from North Carolina to Delaware, and in the New York Bight (Figure 10; Berrien and Sibunka 1999), and have been reported in Buzzards Bay (Stone *et al.* 1994). The highest egg concentrations in Buzzards Bay occurred between May and October, although they were also collected in January and April (there were no surveys during February). Eggs were collected inconsistently in Long Island Sound (Merriman and Sclar 1952; Wheatland 1956; Richards 1959) and were not collected in Delaware Bay (Wang and Kernehan 1979) or Narragansett Bay (Bourne and Govoni 1988). Eggs collected as early as January and April off Cape Hatteras were probably the result of spawning in the South Atlantic Bight and transport north by the Gulf Stream, which flows close to the coast off Cape Hatteras (Mercer 1978).

LARVAE

During the NEFSC MARMAP surveys, larvae were collected from January to November from Cape Hatteras to southern New England (Figure 11). Larvae first appeared near Cape Hatteras and were collected progressively north and shoreward mostly from June through October; a few larvae were collected in November (Kendall 1972; Able *et al.* 1995a). According to Pearson (1941), black sea bass larvae were more commonly collected by plankton nets in subsurface tows than by surface tows in June-July 1929-1930 at the mouth of and in the lower Chesapeake Bay.

Larvae are rarely reported in estuaries. Pacheco and Grant (1965) found black sea bass larvae in the Indian River estuary (Delaware) in one of three survey years; a later two-year survey found none in this estuary (Scotton 1970; Derickson and Price 1973). Larvae were not reported in Delaware Bay (Wang and Kernehan 1979), Great Bay (New Jersey) (Able and Fahay 1998), or the Hudson-Raritan estuary (Croker 1965; Dovel 1981). Few larvae were 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). Neither eggs nor larvae were collected in Mystic River estuary (Connecticut) (Pearcy and Richards 1962). Larvae have been reported in high salinity coastal areas of southern New England in August and September (Stone *et al.* 1994; Collette and Klein-MacPhee, in prep.). Able *et al.* (1995a), discussing Kendall's (1972) note about the absence of larvae in many estuarine surveys, believe that larval settlement occurs in nearshore marine waters, but usually not in estuaries.

JUVENILES

Recently settled juveniles occur in high salinity areas of most estuaries from North Carolina to southern Cape Cod, and occasionally into the southern Gulf of Maine, during the warmer months. Juvenile black sea bass abundance varied seasonally in the NEFSC fall groundfish surveys (Figure 12). In recent winter surveys, they were collected mostly along the outer continental shelf south of Long Island. As the continental shelf water warms in the spring, they were collected inshore in the Chesapeake Bight. There were few summer surveys, but juveniles were collected in several coastal areas mostly south of New Jersey. However, during this season many juveniles inhabit estuaries or submerged coastal reefs, wrecks, and other structures that are outside of the NEFSC survey area or are poorly sampled by trawl. In the fall, juveniles were common along the coast from southern New England to Maryland, and across the shelf off Virginia-North Carolina; this probably reflects their migration out of shallow coastal areas as these waters cooled.

Only a few juvenile black sea bass were collected in the spring in Massachusetts trawl surveys (Figure 13). They were abundant in the fall south and west of Cape Cod and a few were collected in Cape Cod Bay (Figures 12, 13). In Narragansett Bay, juvenile black sea bass were uncommon but they occurred in most areas (Figure 14); the largest mean catch (1.3 individuals/tow) came from Mount Hope Bay during the summer. Juveniles and adults were widespread in the fall in Long Island Sound (Figure 15). In the Hudson-Raritan estuary, juvenile black sea bass were collected from spring through fall (Figure 16); they were more abundant in 1997 than in the other years of the survey (1992-1997). Mansueti (1955) reported that juvenile black sea bass were common in the lower Potomac River (Maryland-Virginia).

ADULTS

The geographic distribution of the northern population of adult black sea bass is similar to the distribution of juveniles, although adults tend to prefer deeper bays and coastal waters over estuaries. Briggs (1979) suggested that once black sea bass find suitable summer habitat in New York waters, they remain until the fall migration; adult habitat fidelity is consistent with juvenile behavior (Able and Hales 1997).

Black sea bass is normally considered a reef fish. In the warmer months, they are usually closely associated with sheltering habitat in estuarine and coastal waters, generally at depths < 40 m, but they have a wider distribution in the Chesapeake Bight (Figure 12). Bigelow and Schroeder (1953) and Collette and Hartel (1988) reported occurrences of black sea bass in Massachusetts Bay at the turn of the century and occasionally since then (e.g., Figure 13), but they are rarely caught off New Hampshire and largely absent off Maine and on Georges Bank (Figure 12). At one time, they were captured by gill net over rocky bottom in Maine (Ojeda and Dearborn 1989). Adults were relatively common in the spring in the Massachusetts trawl surveys (Figure 13). In Narragansett Bay adults were rare, but they were collected from a wide range of sites from spring to fall (Figure 14). In Long Island Sound, adults were most common in the spring survey in the central sound (Figure 15). Adult black sea bass were never common in the Hudson-Raritan estuary (Figure 16).

STATUS OF THE STOCKS

The black sea bass population in the Middle Atlantic Bight is presently overexploited (National Marine Fisheries Service 1997). Recent CPUE and survey indices have been moderate to low compared to levels in the mid-1970s (Figure 17) and before 1965. Juvenile recruitment was poor in 1992-1993 and above average in 1994 (Shepherd 1998; MAFMC 1996; Northeast Fisheries Science Center 1997). Spawning stock estimates suggest that the population has been relatively stable since 1984 (Northeast Fisheries Science Center 1997). There were no apparent differences in the distributions of juvenile and adult black sea bass between periods of high (1975-1979) and low (1990-1997) abundance (Northeast Fisheries Science Center, unpublished data). Arve (1960) attributed declining black sea bass catches in the late 1950s (compared to the relatively high levels of the early 1950s) to a decline in oyster beds.

RESEARCH NEEDS

More information is needed on the use of artificial reefs by black sea bass. The following ideas were discussed in several papers in *Fisheries* (American Fisheries Society, April 1997, Volume 22, Number 4), a special issue on artificial reef management.

- What mechanisms or processes enhance black sea bass production on reefs (e.g., reducing habitat limitation, enhancing larval settlement, alleviating post-settlement demographic bottlenecks, enhancing reef and near-reef food webs)?
- How can artificial reefs and habitats be designed to enhance survival and growth of juvenile and adult black sea bass?
- Are black sea bass habitat limited such that habitat restoration or enhancement is required?

More general research needs include:

- What habitats are used during the winter on the continental shelf in the Middle Atlantic Bight? Where do 1-2 year old juveniles spend the winter? Some may remain in estuaries while others may move to coastal or inner shelf shell beds (Able *et al.* 1995a; M. Dixon, personal communication).
- What are the winter diets of juveniles? Feeding may be reduced at low temperatures.

- Clam shell beds nearshore may provide important habitat at all times of the year, but little is known of distributions of dead shells or spatial and temporal trends in shell beds.
- Do young-of-the-year black sea bass that overwinter offshore return to their natal estuary the following spring (Able and Fahay 1998)?

Adams (1993) identified the following information needs:

- Tagging studies to track seasonal migration patterns and identify habitats.
- Dietary studies to evaluate the value of specific habitats.
- The relationship between habitat structural complexity, black sea bass abundance, and fish community composition.
- Suitable habitats for juvenile black sea bass in coastal areas.
- If black sea bass are territorial.
- Spawning areas, behaviors, and feeding during spawning.

The Chesapeake Bay Program (1996) Black Sea Bass Fishery Management Plan lists the following research needs:

- Seasonal distribution and migration studies to determine size distribution and sex ratios in various areas.
- Identify spawning areas, determine spawning production, and estimate optimum size for female maximum viable egg production.
- Quantify the diet and seasonal changes in the diet [i.e., seasonal importance of blue mussels (*Mytilus*) and other reef fauna].
- Determine the optimum size of submerged aquatic vegetation beds and oyster reefs necessary for nursery and refuge grounds for juveniles.
- Investigate the transport mechanism of newly settled juveniles from the coastal zone to estuarine nurseries (Able and Fahay 1998).

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Table 1. Summary of life history and habitat characteristics for black sea bass, *Centropristis striata*. (YOY = young-of-the-year; SNE = southern New England; MAB = Middle Atlantic Bight; GOM = Gulf of Maine).

Life Stage	Time of Year	Size and Growth	Geographic Location	Habitat	Substrate
Eggs	May-Oct; appear earlier in south and later in north	0.9-1.0 mm; incubation 2-5 days	Coastal MAB; rarely in estuaries	Upper water column, shore to > 200 m depth off Virginia	Buoyant in upper water column
Larvae	May-Nov; peak June-July; appear earlier in south and later in north	Hatch at ~2.1 mm; stage lasts to ~15 mm transition	MAB, near shore, mouths of some estuaries, but rarely in them	As for eggs, < 100 m until transition to juveniles	Upper water column until transition to juveniles
Juveniles YOY	April-Dec; most settle June-Nov	~10-16 mm to 100 mm TL by Nov	MAB into GOM, inshore and into estuaries mid-late summer	Estuarine - coastal; ~1-38 m; salt marsh edges & channels; high habitat fidelity	Rough bottom, shellfish, sponge, and eelgrass beds, nearshore shell patches, man-made objects
Juveniles Winter	Dec-April	~2-12 cm; growth rate reduced	MAB: Most move offshore and south of New Jersey to warmer, deeper waters	Mostly deeper than 38 m; may prefer 90-100 m; mid and outer continental shelf and Chesapeake Bay	Nearshore shell patches and other shelter on sandy bottoms
Adults Summer	April-Dec	> 19 cm FL; growth sexually dimorphic	Coastal: MAB into GOM	~2-38 m; larger fish stay in deeper waters	Mussel beds, rock, artificial reefs, wrecks and other structures
Adults Winter	Nov-March	> 19 cm FL	Most move offshore and south of New Jersey to warmer (> 6°C) waters.	30-240 m depths; mostly 60-150 m mid/outer continental shelf; otherwise poorly known	Poorly known, possibly available shelter on offshore silty sand (e.g., pits)
Spawning Adults	May-Oct, peak in June; begins in the south and progresses north	> 19 cm FL; mature at age 1+	Inshore MAB, south to north, during migration	~20-50 m	Over sand, sand with rock, and reefs

Table 1. cont'd.

Life Stage	Temperature	Salinity	Prey	Predators	Notes
Eggs	Sensitive to extremes	Sensitive to extremes		Most planktivores where the eggs are found	Lab studies suggest eggs sensitive to high nitrate-nitrite concentrations and low pH
Larvae	11-26°C, mostly 14-23°C; sensitive to extremes	30-35 ppt; sensitive to extremes	Use yolk reserves in a few days; feeding begins on zooplankton at ~6 mm	Most planktivores where the larvae are found	Benthic settlement and transition to juvenile occurs at ~10-16 mm FL, July to October
Juveniles YOY	6-30°C, prefer 17-25°C	8-38 ppt, prefer ~18-20 ppt	Small epibenthic invertebrates, especially crustaceans and mollusks	Sharks, dogfish, skates, hakes, searobins, summer flounder, and others	Most migrate to warmer offshore or more southerly waters in winter. Hypoxia can inhibit growth
Juveniles Winter	> 5°C; sudden drops < 4°C inshore can cause mortality	12-38 ppt, prefer > 18 ppt.	Small epibenthic invertebrates, fish, but feeding may be reduced	Sharks, dogfish, skates, hakes, searobins, summer flounder, and others	Migrate inshore and northerly as waters warm > 6°C; over-wintering juveniles return to coastal estuarine areas
Adults Summer	~6-28°C, mostly 13-21°C	> 20 ppt	Benthic and near-bottom invertebrates and small fish	Sharks, dogfish, skates, hakes, searobins, summer flounder, and others	Mortality and avoidance at dissolved oxygen levels < 2 ppm
Adults Winter	> 6°C, prefer 9-12°C	~30-35 ppt	Poorly known; benthic and near-bottom invertebrates, small fish, butterfish, and squid; feeding may be reduced	Sharks, dogfish, and others	The 6-7.5°C isothermal boundary greatly influences distribution; activity and survival reduced below this temperature
Spawning Adults	> 10°C, peak at ~ 18-20°C	> 15 ppt	Poorly known; benthic and near-bottom invertebrates, small fish, butterfish, and squid; feeding may be reduced	Sharks, dogfish, and others	Spawn in coastal bays but not in estuaries; mature mostly as females, most change sex to males with growth

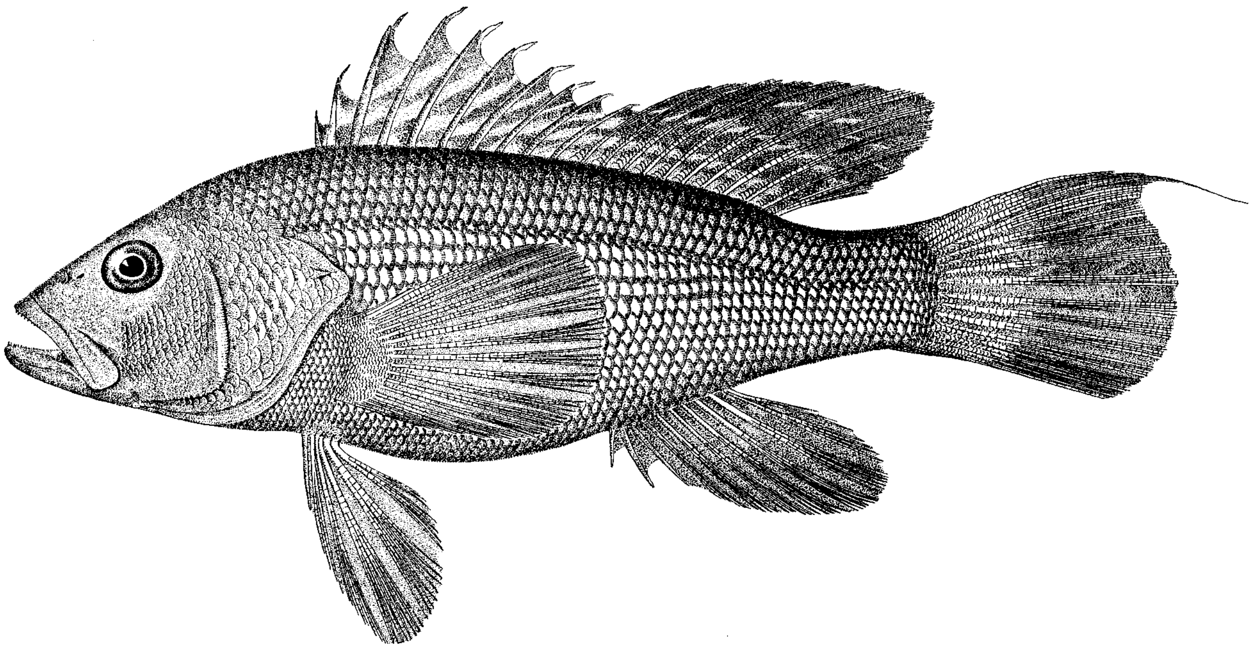


Figure 1. The black sea bass, *Centropristis striata* (from Goode 1884).

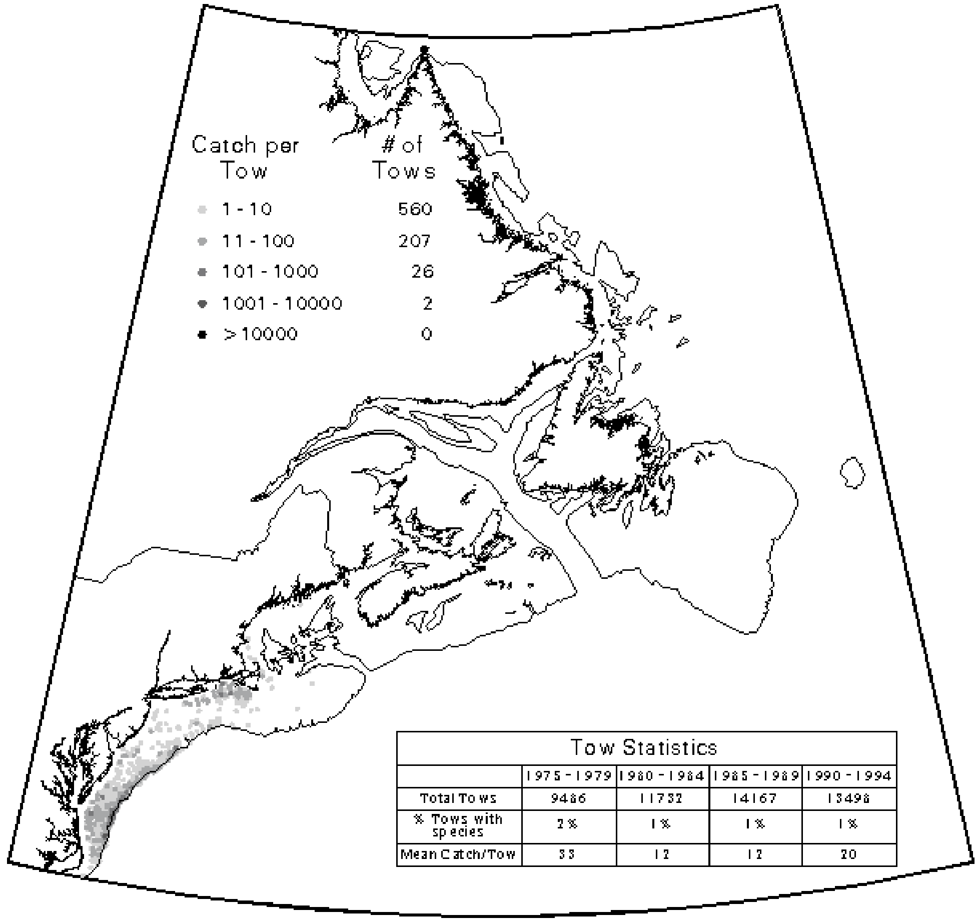


Figure 2. Distribution and abundance of black sea bass in the Northwest Atlantic during 1975-1994. Data are from the U.S. NOAA/Canada DFO East Coast of North America Strategic Assessment Project (http://www-orca.nos.noaa.gov/projects/ecnasap/ecnasap_table1.html).

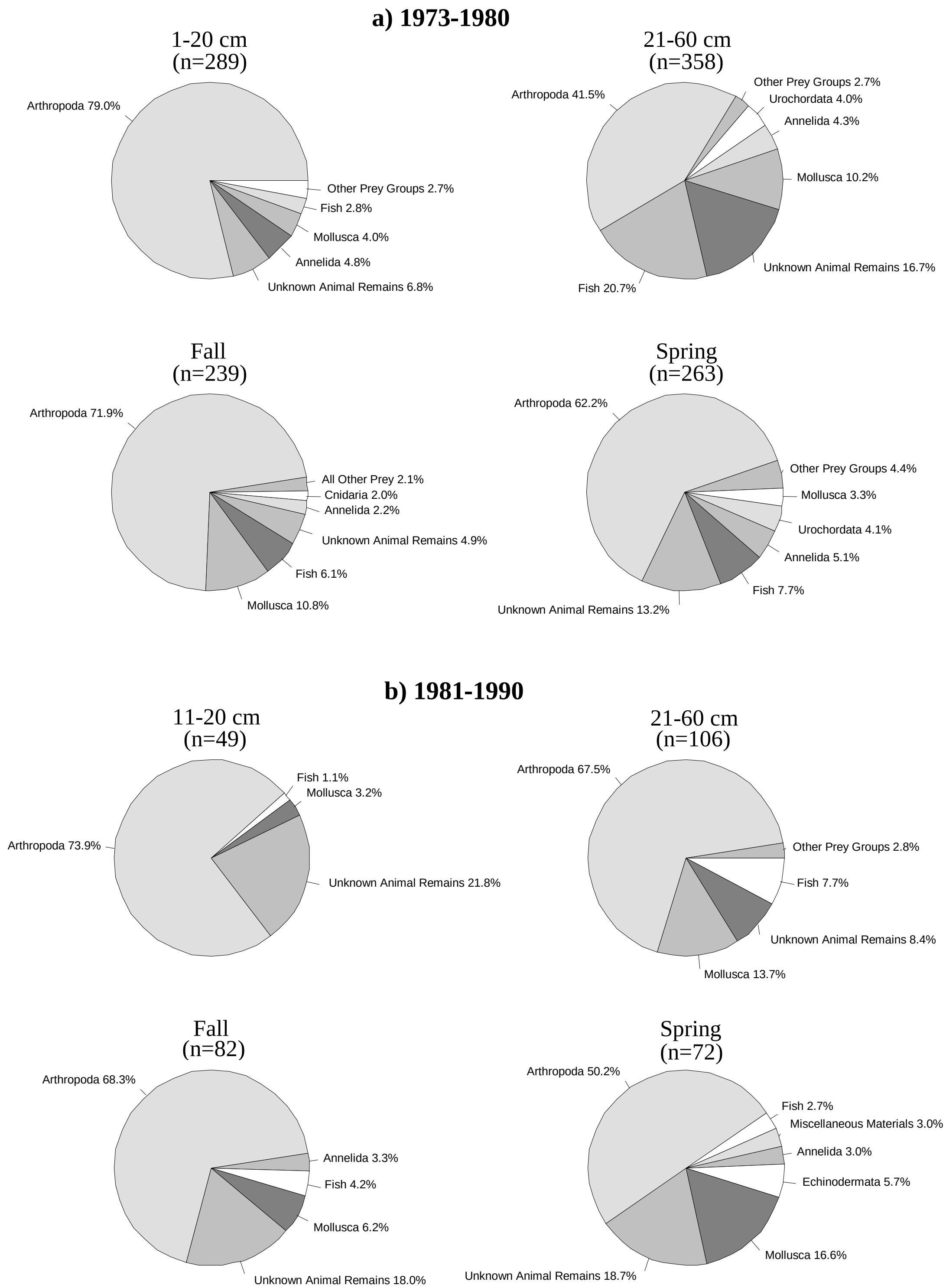


Figure 3. Abundance of the major prey items in the diets of juvenile (≤ 20 cm) and adult (> 20 cm) black sea bass collected during NEFSC bottom trawl surveys from 1973-1980 and 1981-1990. Abundance in the 1973-1980 samples is defined by mean percent prey weights, and in the 1981-1990 samples as mean percent prey volume. The category "unknown animal remains" refers to unidentifiable animal matter. Methods for sampling, processing, and analysis of samples differed between the time periods [see Reid *et al.* (1999) for details].

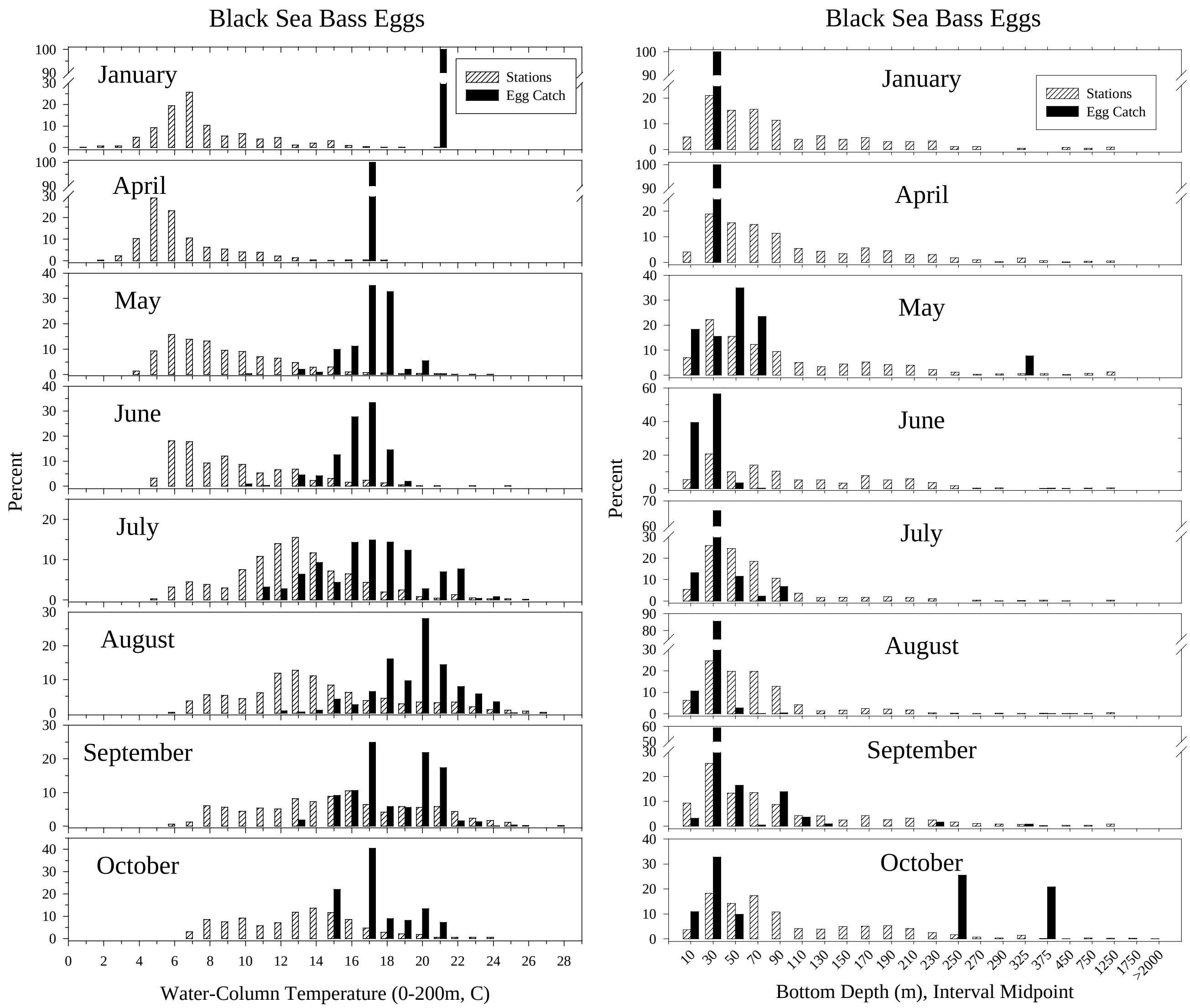


Figure 4. Abundance of black sea bass eggs relative to water column temperature (to a maximum of 200 m) and bottom depth from NEFSC MARMAP ichthyoplankton surveys (1978-1987) by month for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

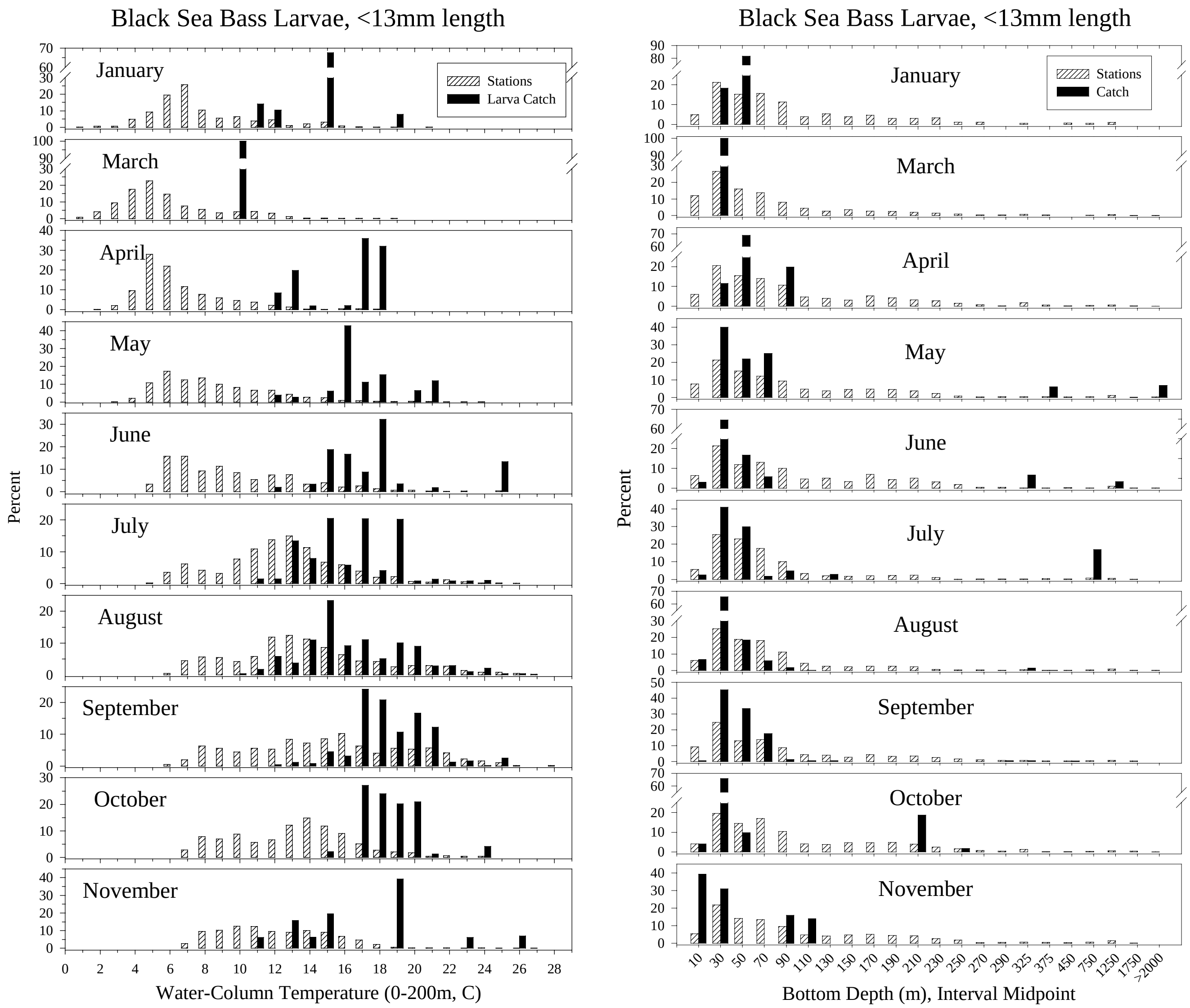


Figure 5. Abundance of black sea bass larvae relative to water column temperature (to a maximum of 200 m) and bottom depth from NEFSC MARMAP ichthyoplankton surveys (1977-1987) by month for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

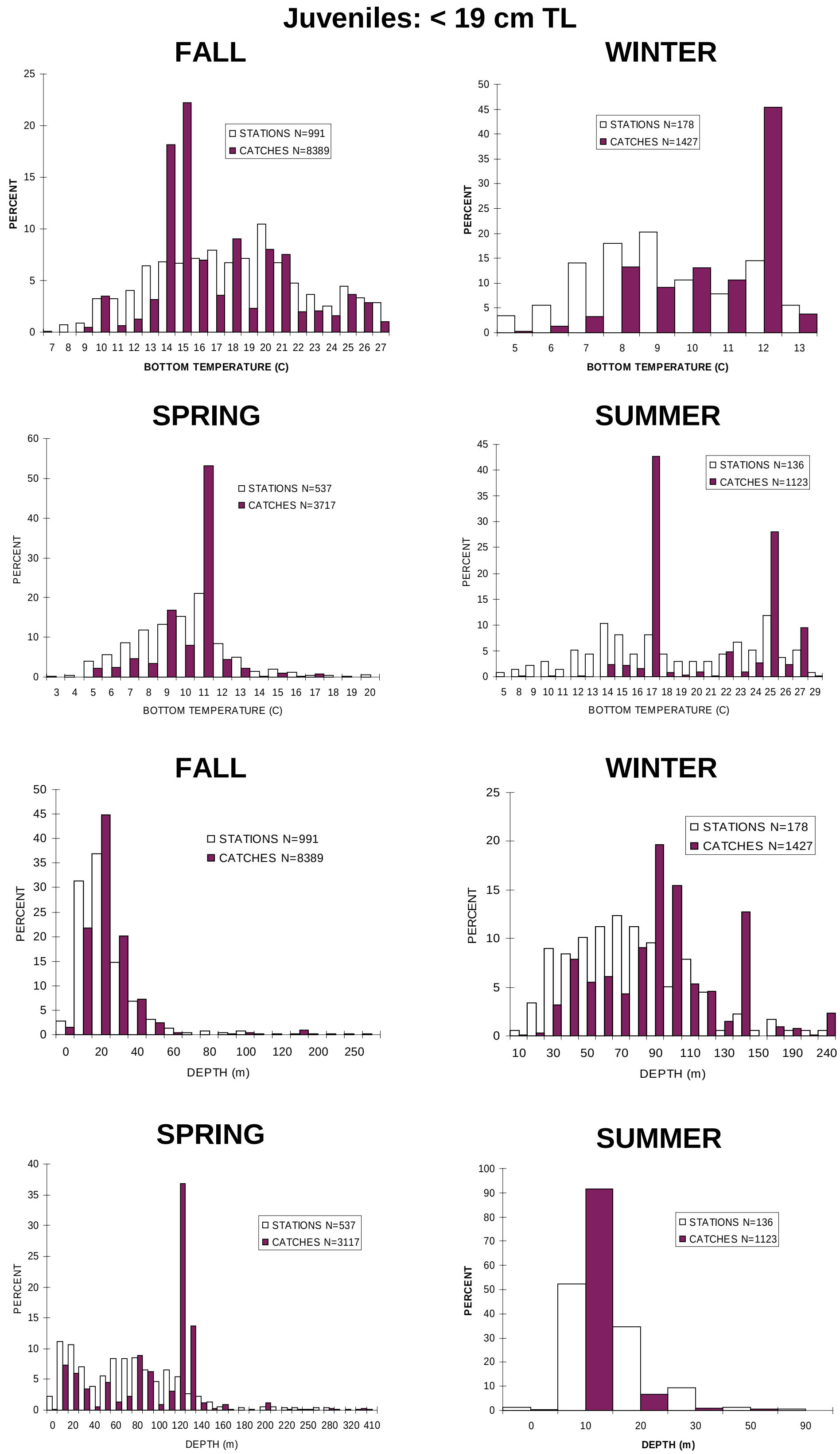


Figure 6. Seasonal abundance of juvenile (< 19 cm) and adult (≥ 20 cm) black sea bass relative to bottom water temperature and depth based on NEFSC bottom trawl surveys (1963-1997, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

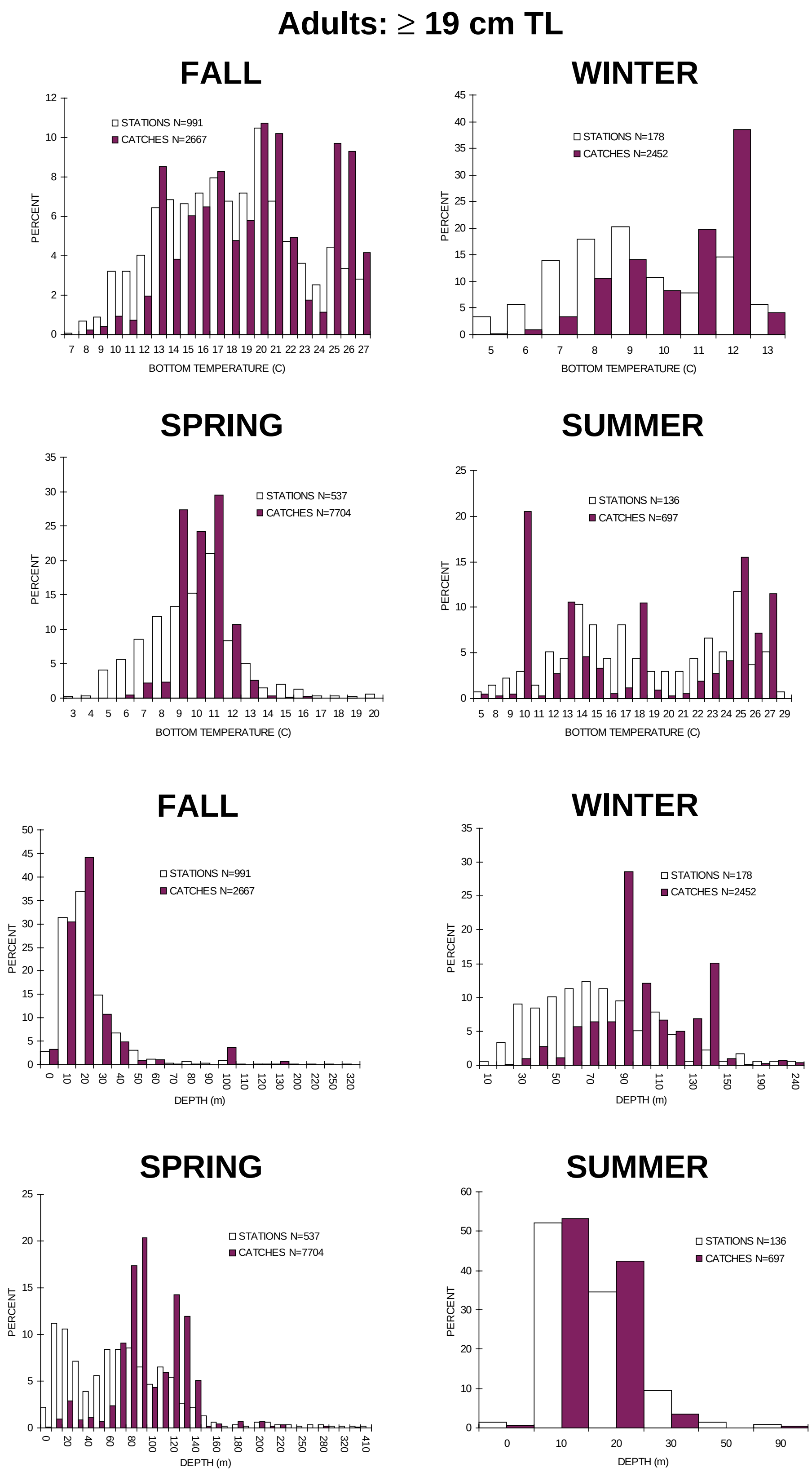


Figure 6. cont'd.

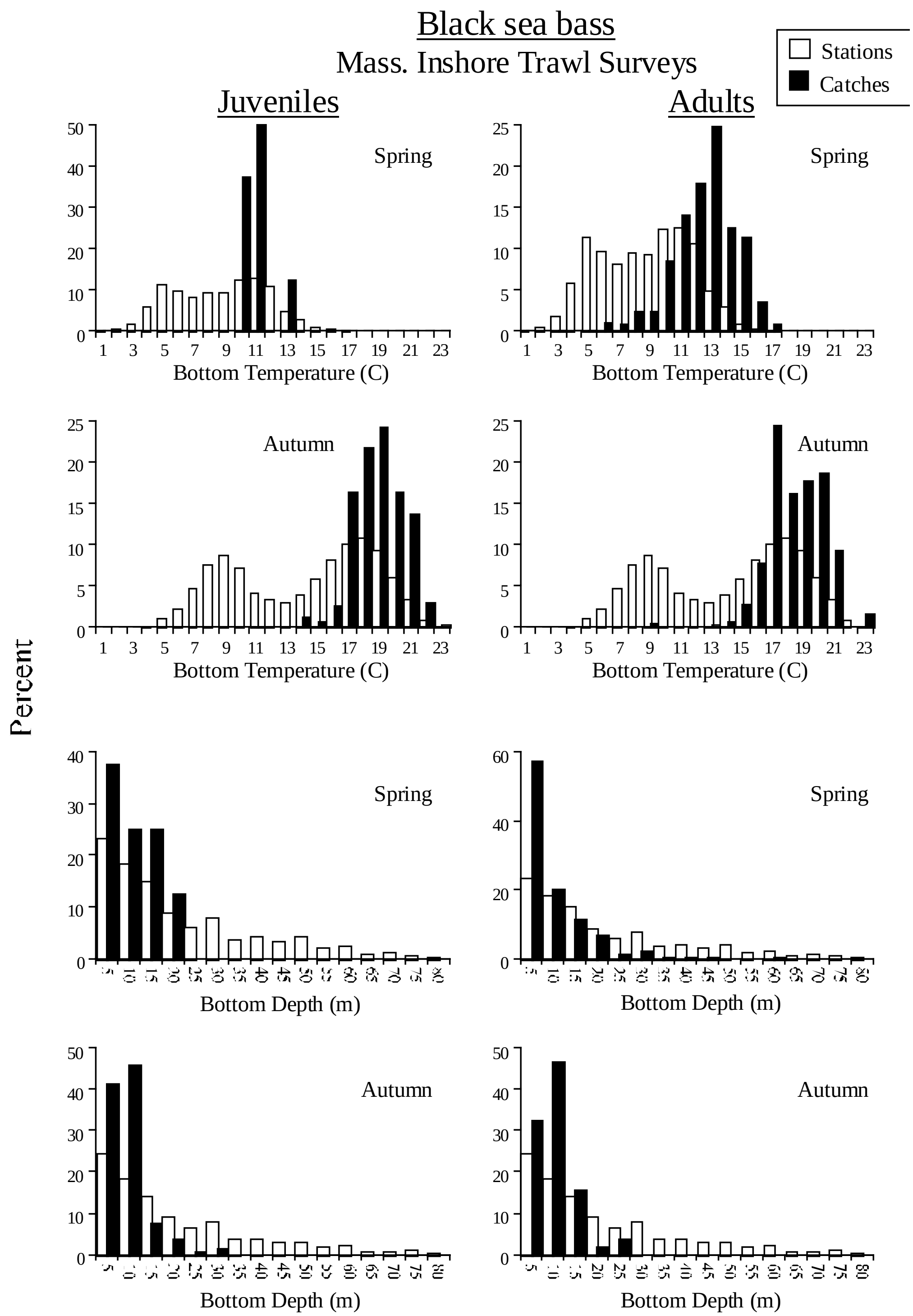


Figure 7. Abundance of juvenile and adult black sea bass relative to bottom water temperature and depth based on Massachusetts inshore bottom trawl surveys (spring and autumn 1978-1996, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

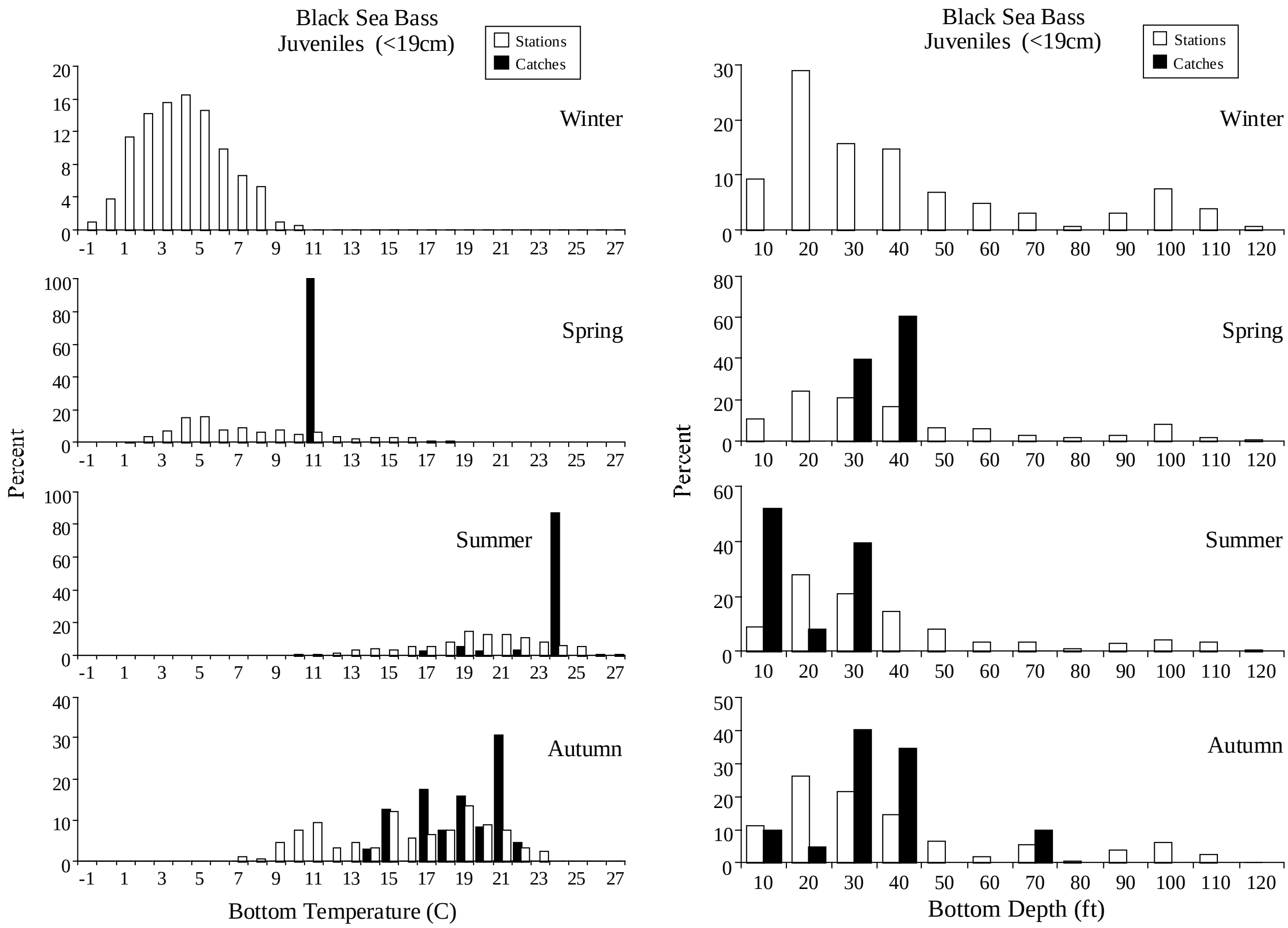
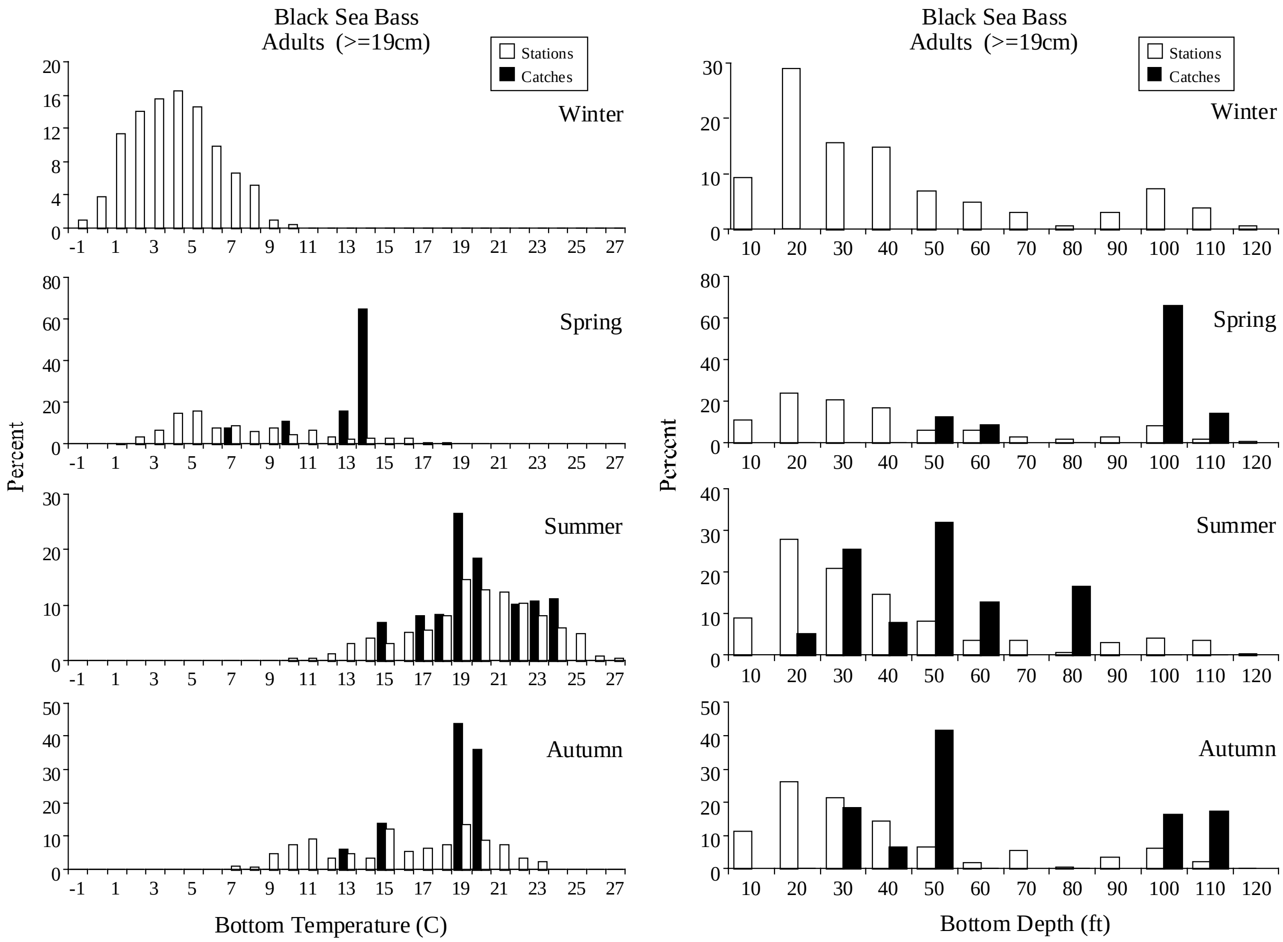


Figure 8. Seasonal abundance of juvenile and adult black sea bass relative to bottom water temperature and depth from Rhode Island Narragansett Bay trawl surveys, 1990-1996. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all catches.



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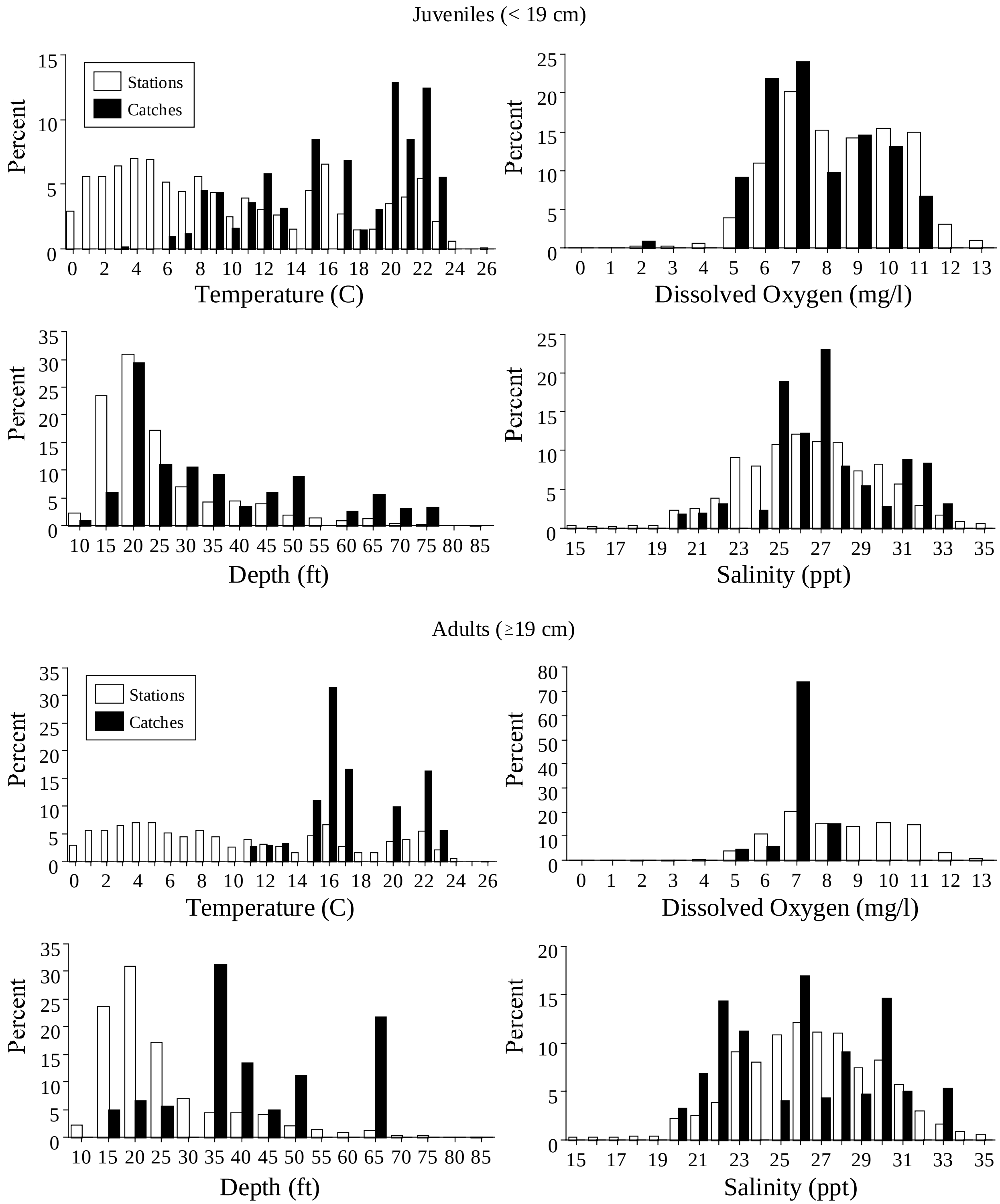


Figure 9. Abundance of juvenile and adult black sea bass relative to bottom water temperature, dissolved oxygen, depth, and salinity from Hudson-Raritan estuary trawl surveys (January 1992 - June 1997, all years combined).

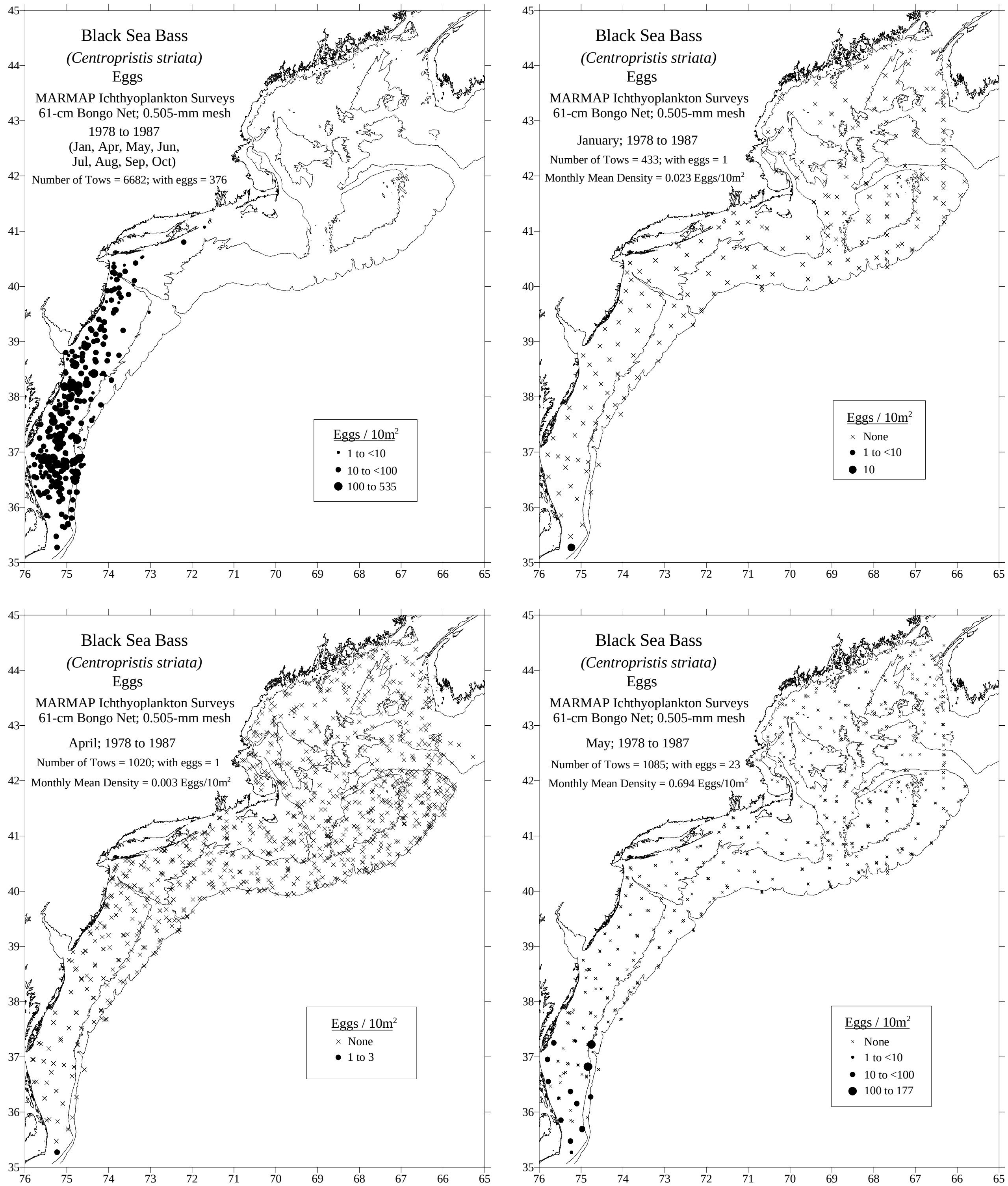
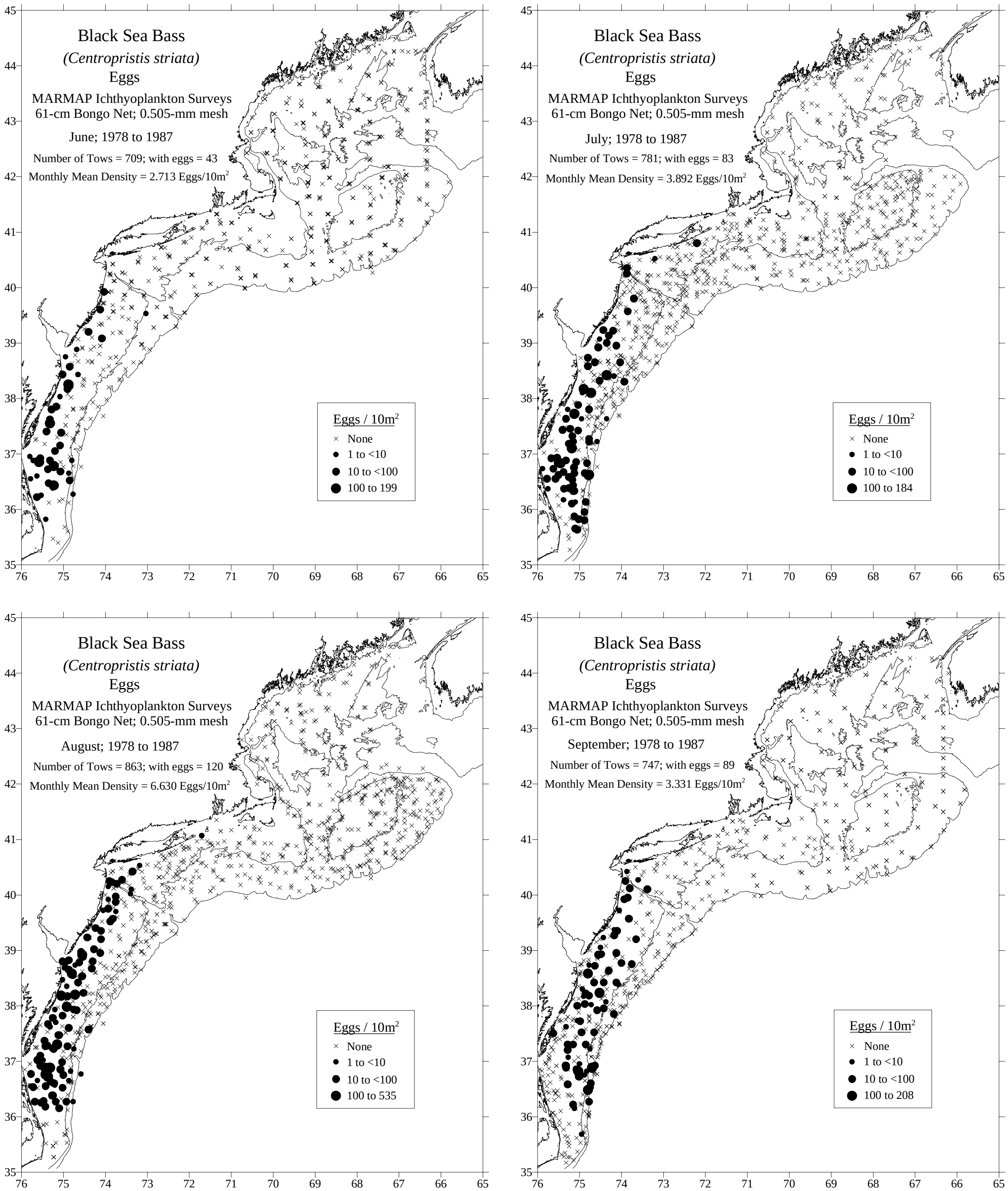


Figure 10. Distribution and abundance of black sea bass eggs collected during NEFSC MARMAP ichthyoplankton surveys, 1978-1987 [see Reid *et al.* (1999) for details]. The upper left figure is all months and all years combined, the remaining figures are individual months for all years combined.



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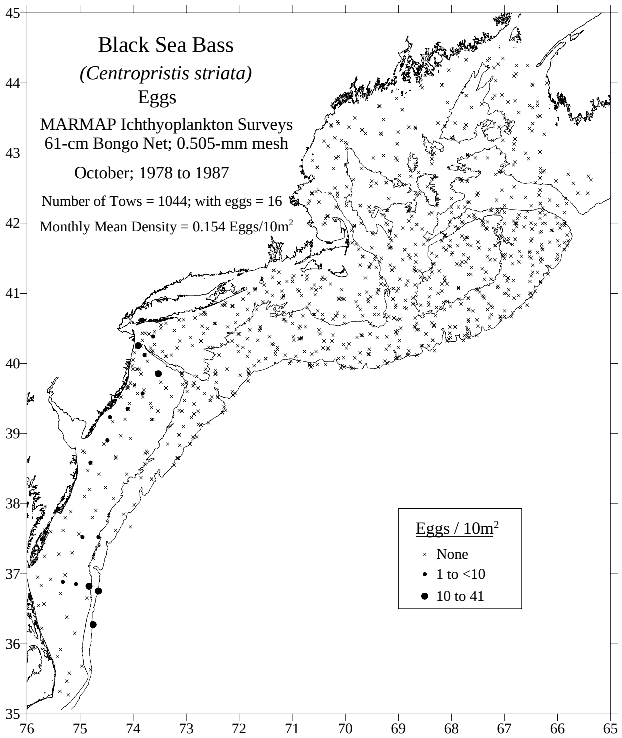

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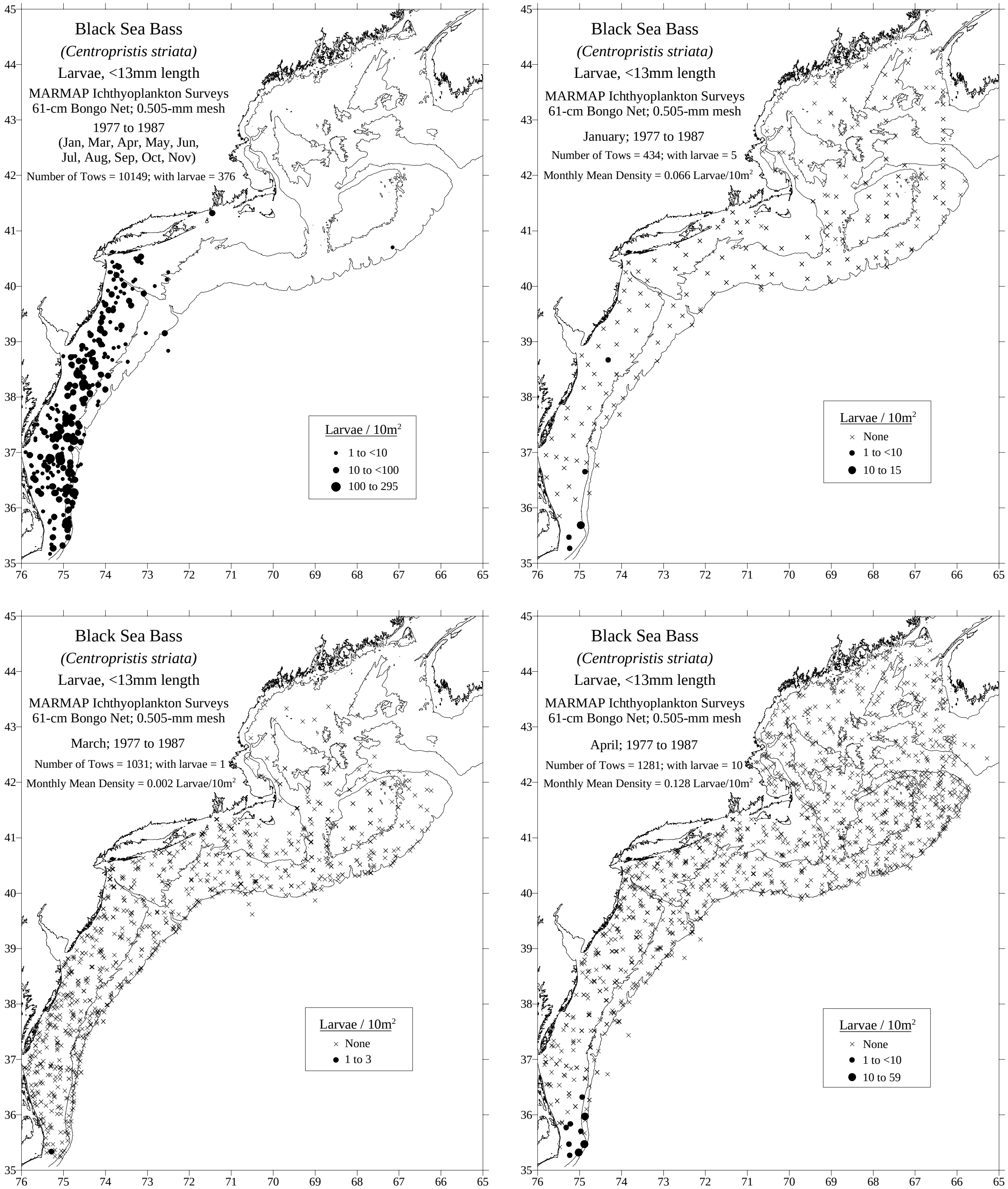
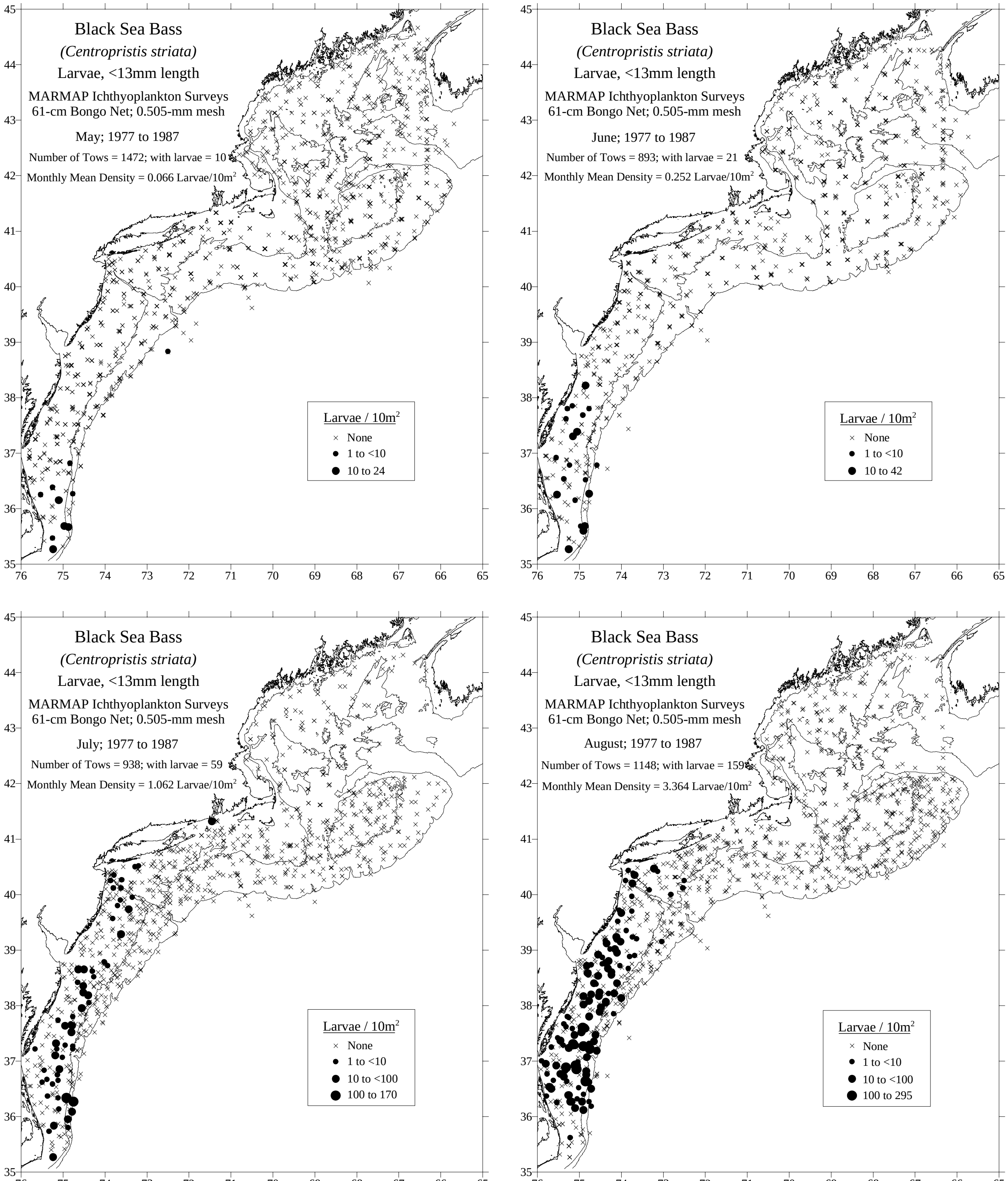


Figure 11. Distribution and abundance of black sea bass larvae (< 13 mm) collected during NEFSC MARMAP ichthyoplankton surveys, 1977-1987 [see Reid *et al.* (1999) for details]. The upper left figure is all months and all years combined, the remaining figures are individual months for all years combined.



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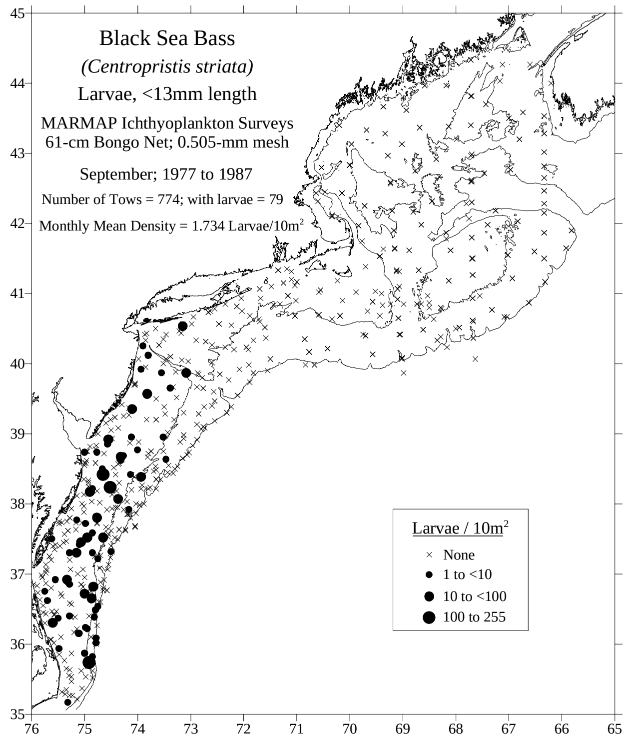

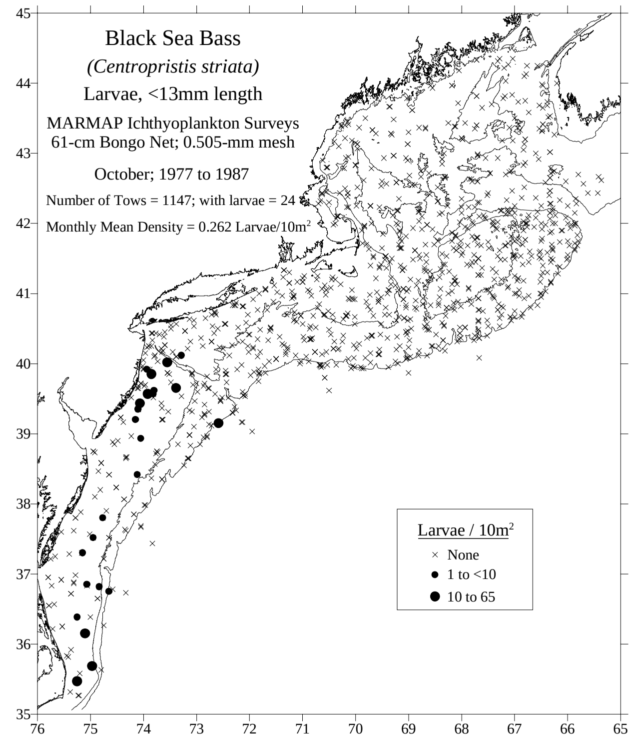

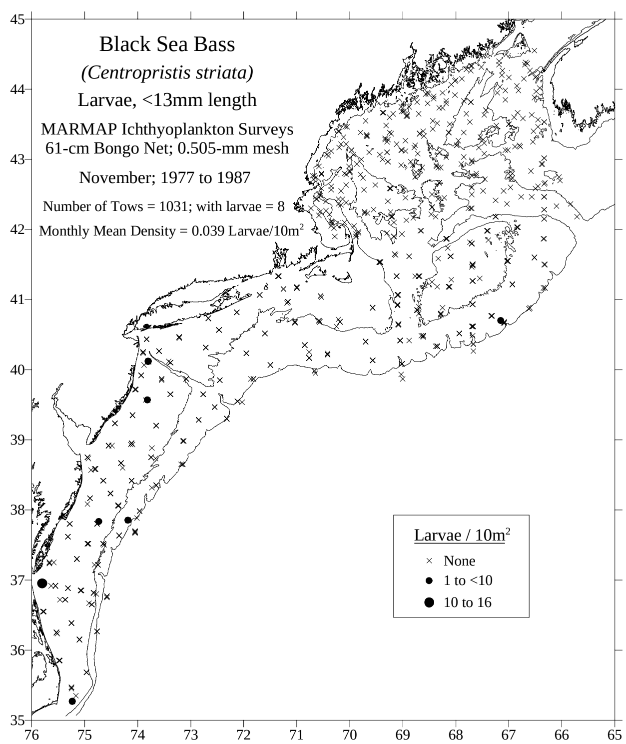

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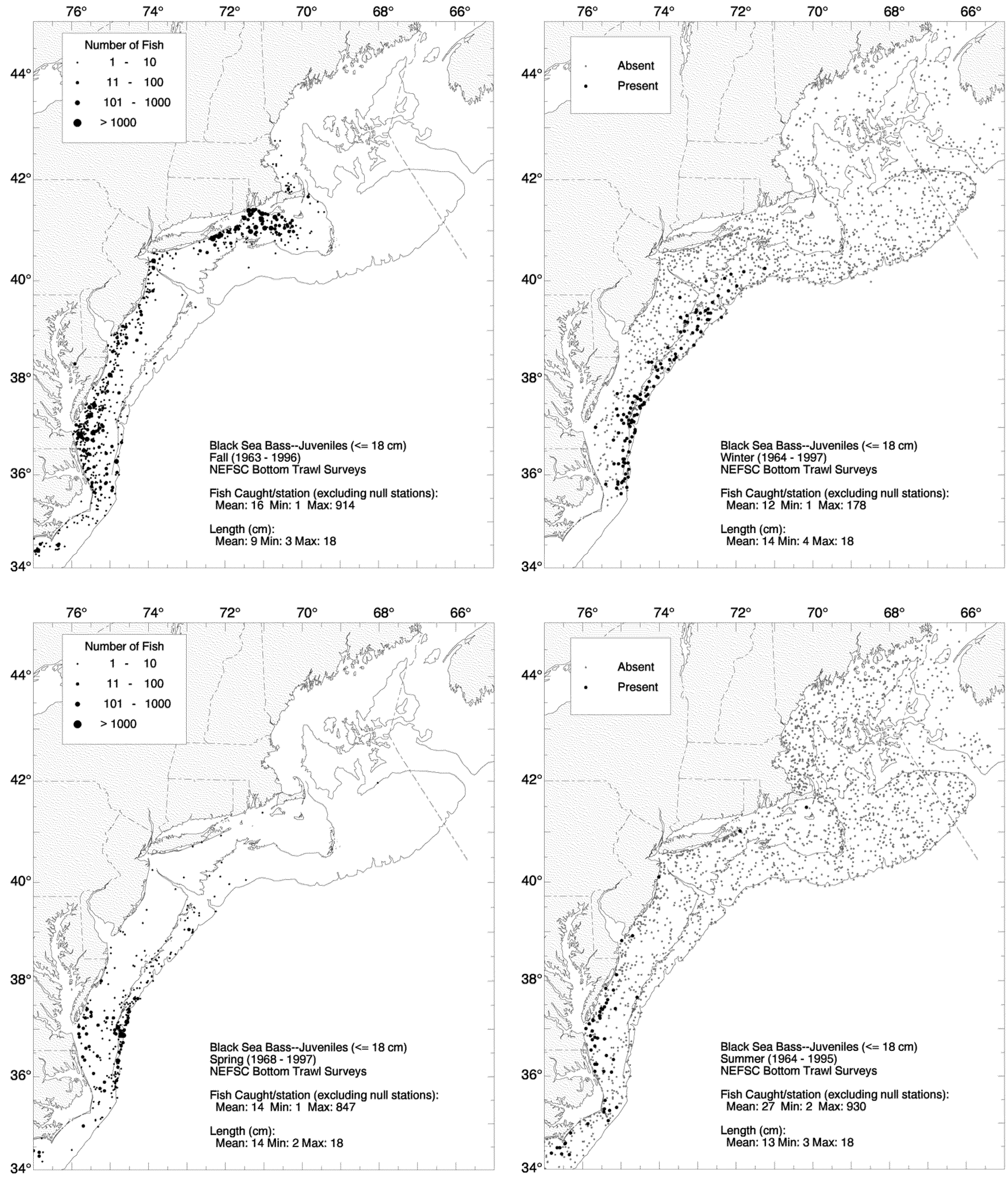
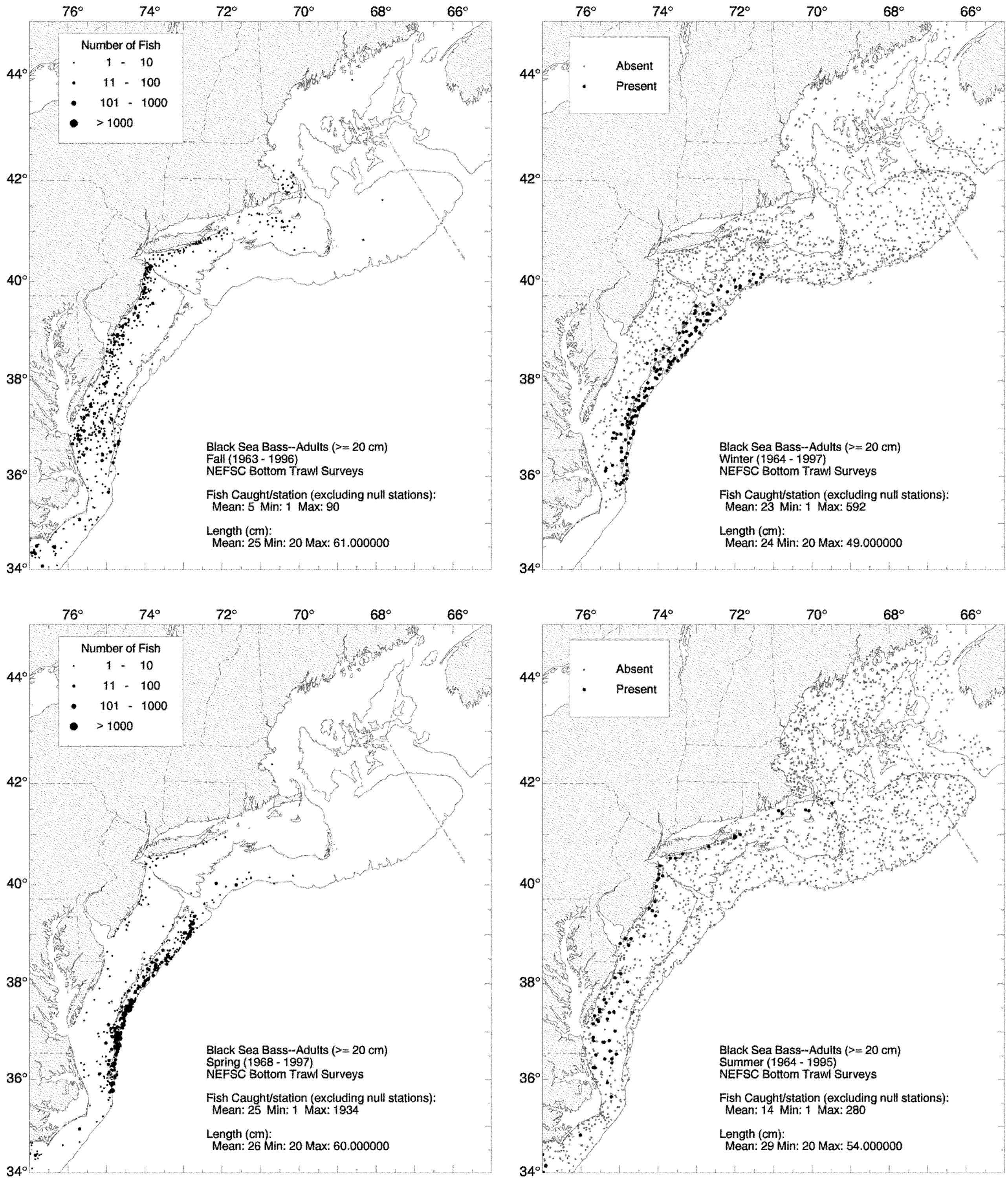


Figure 12. Seasonal distribution and abundance of juvenile and adult black sea bass collected during NEFSC bottom trawl surveys, 1963-1997 (all years combined). Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].



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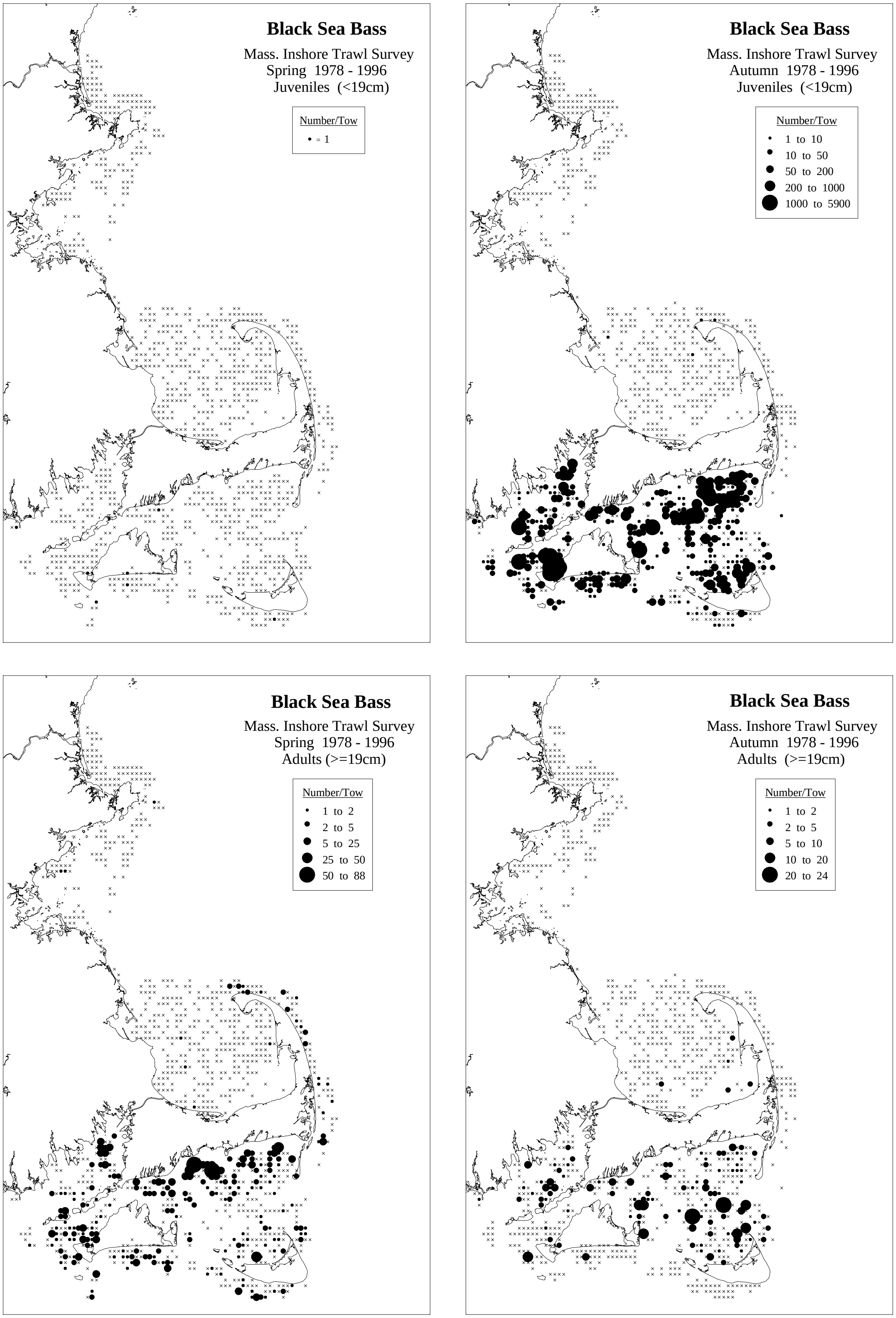


Figure 13. Distribution and abundance of juvenile and adult black sea bass collected in Massachusetts coastal waters during spring and autumn Massachusetts trawl surveys, 1978-1996 [see Reid *et al.* (1999) for details].

Black Sea Bass Juveniles (< 19 cm)

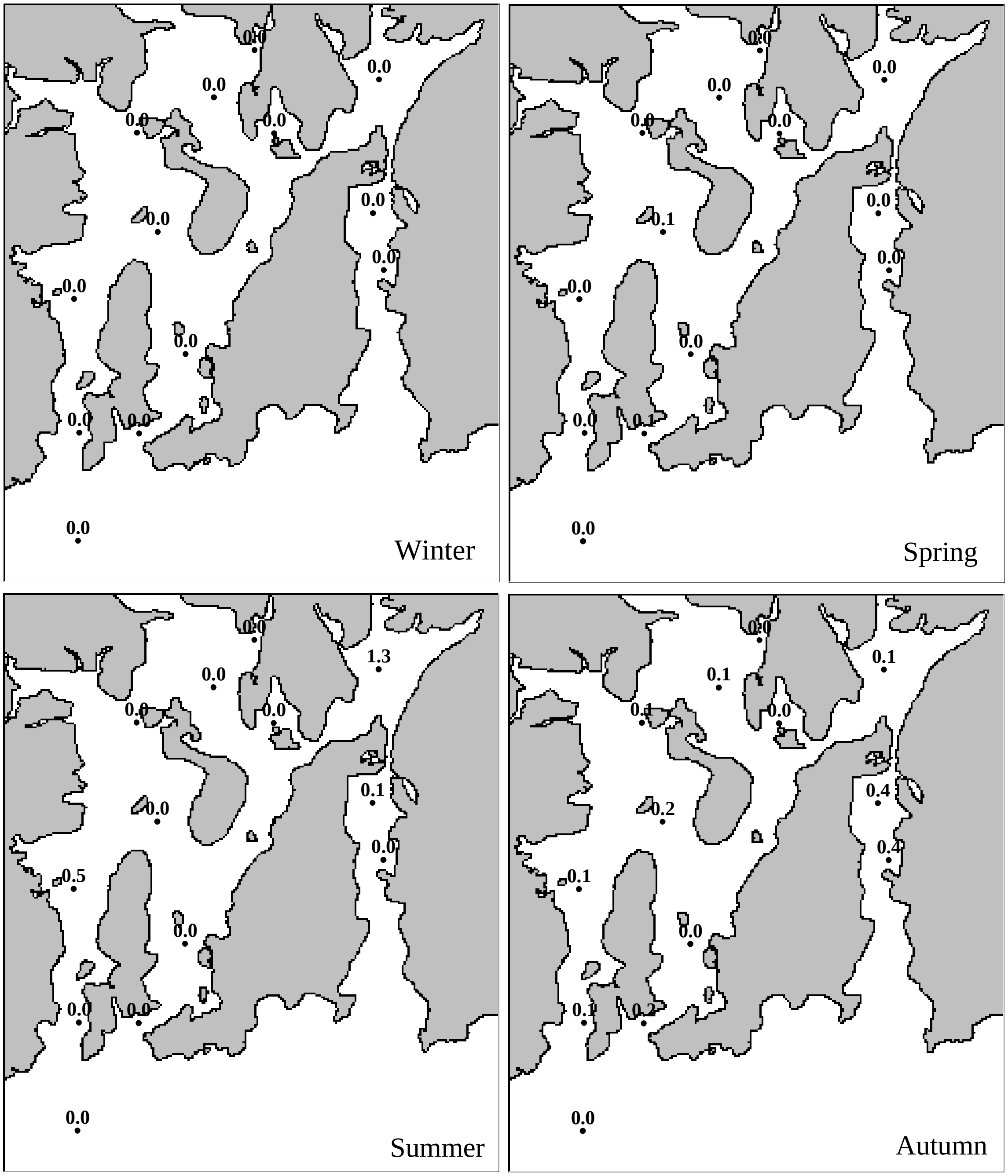
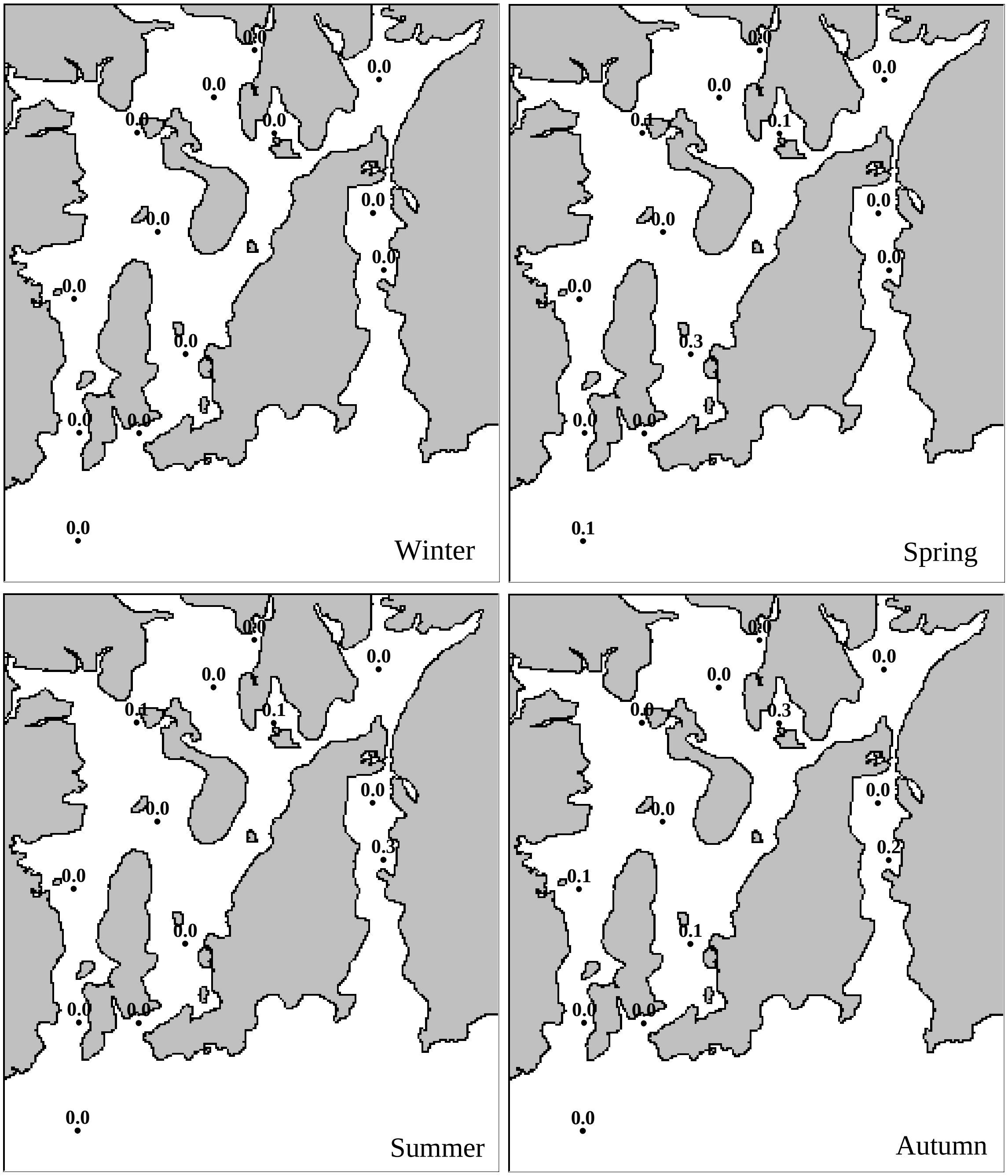


Figure 14. Distribution and abundance of juvenile and adult black sea bass collected in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid *et al.* (1999) for details].

Black Sea Bass Adults (>= 19 cm)



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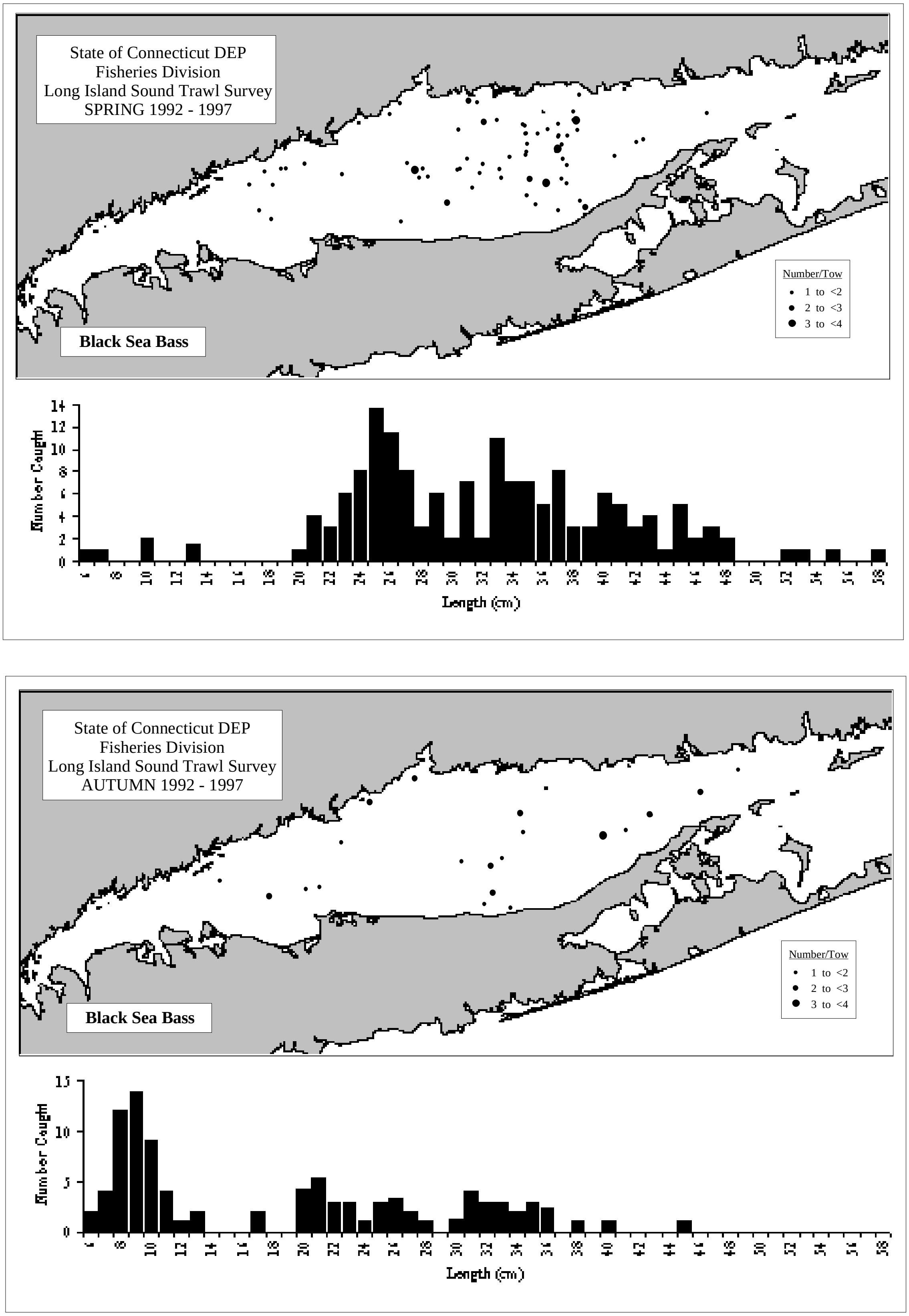


Figure 15. Distribution, abundance, and size frequency distribution of black sea bass collected in Long Island Sound during spring and autumn Connecticut bottom trawl surveys, 1992-1997 [see Reid *et al.* (1999) for details].

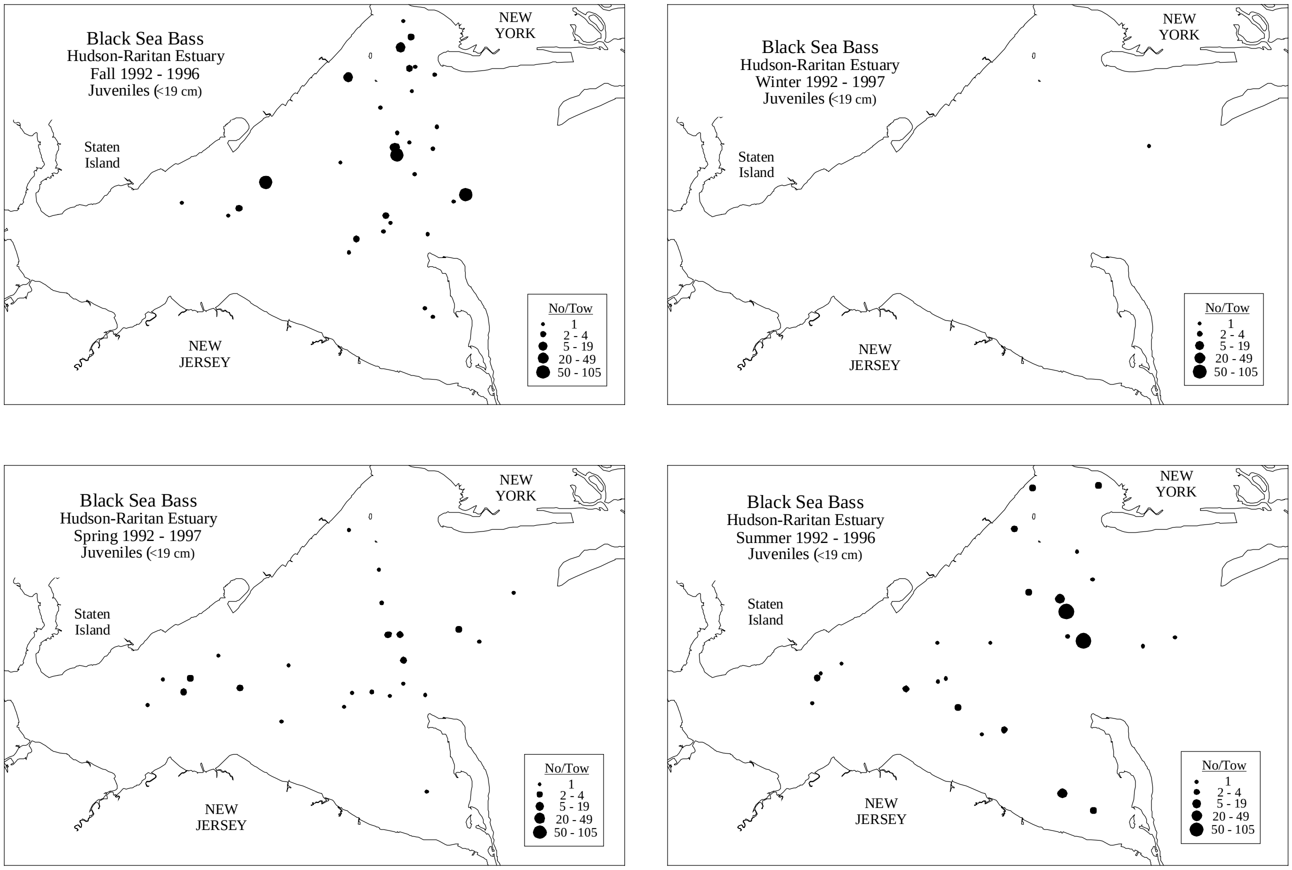
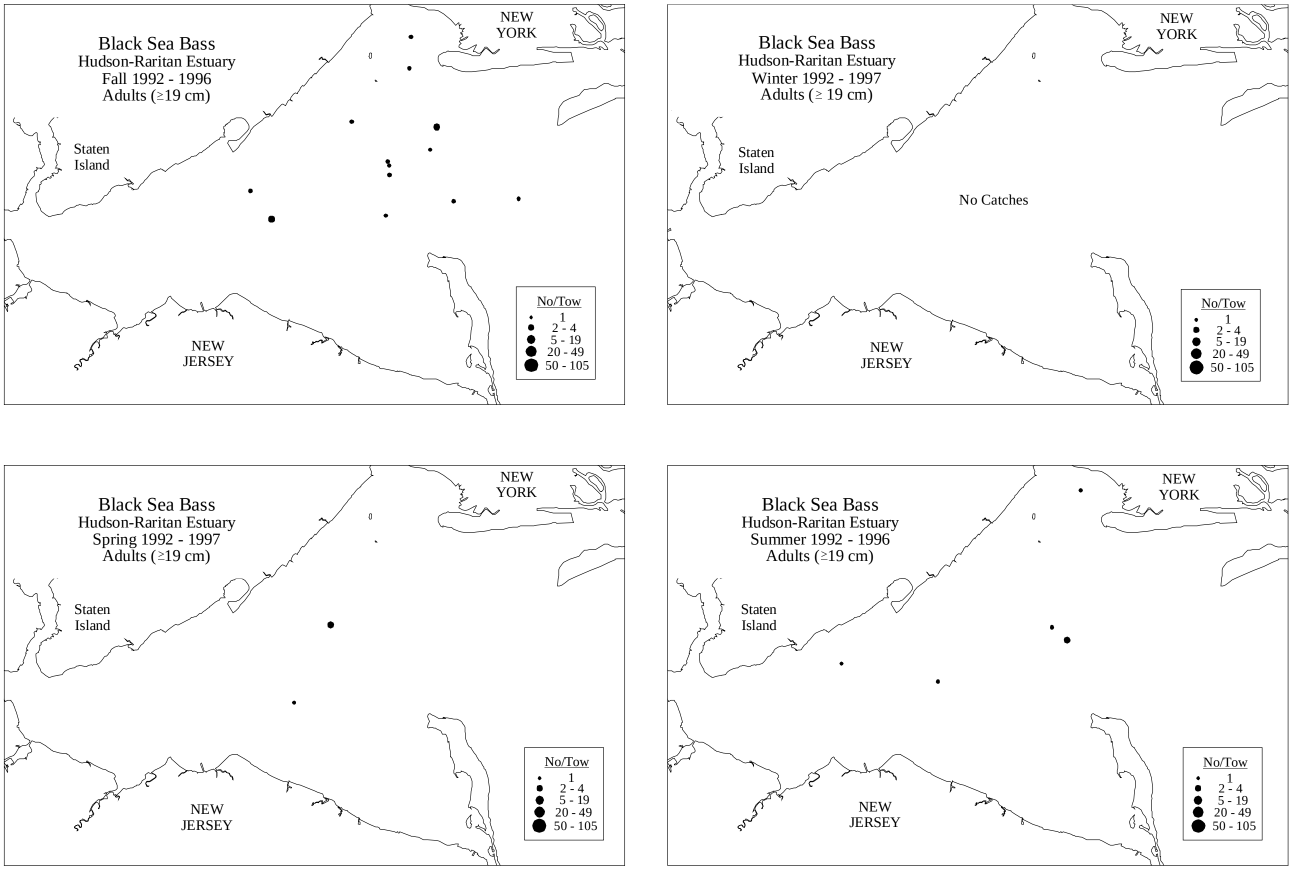


Figure 16. Seasonal distribution and abundance of juvenile and adult black sea bass in the Hudson-Raritan estuary collected during Hudson-Raritan estuary trawl surveys, 1992–1997 [see Reid *et al.* (1999) for details].



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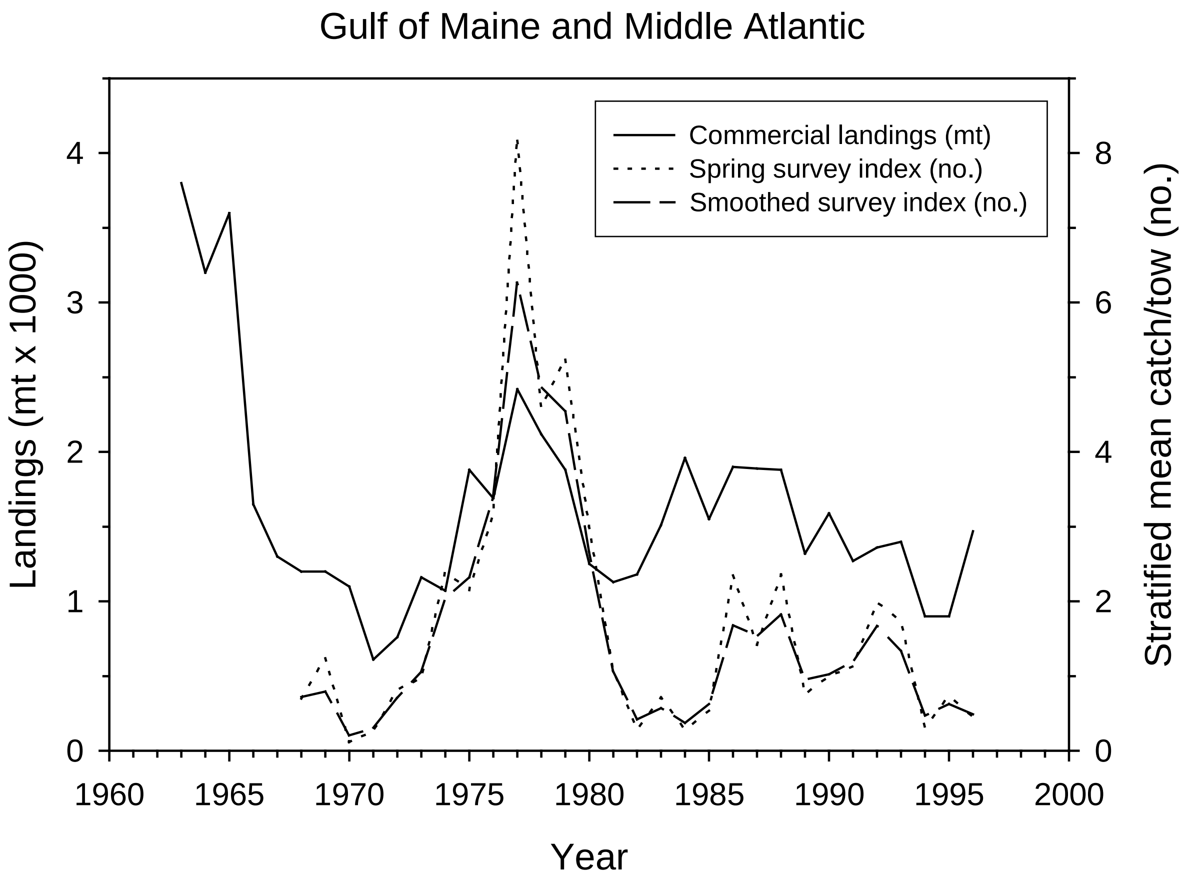

Figure 17. Commercial landings and NEFSC bottom trawl survey indices for black sea bass in the Gulf of Maine and Middle Atlantic Bight.

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