NOAA Technical Memorandum NMFS-NE-149

Essential Fish Habitat Source Document:

Scup, *Stenotomus chrysops*, 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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Scup, *Stenotomus chrysops*, 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

Scup (*Stenotomus chrysops* Linnaeus 1766) (Figure 1), is a temperate species that occurs primarily from Massachusetts to South Carolina, although it has been reported as far north as the Bay of Fundy and Sable Island Bank, Canada (Bigelow and Schroeder 1953; Fritz 1965; Scott and Scott 1988) and as far south as Florida (Morse 1978; Manooch 1984).

The 'southern porgy' (*S. aculeatus*) is referred to in a number of South Atlantic Bight studies and reviews (e.g., Morse 1978; Powles and Barans 1980; Sedberry and Van Dolah 1984), but is not considered a separate species by the American Fisheries Society (Robins *et al.* 1991) leading to some taxonomic confusion (T. Munroe, National Systematics Laboratory, Smithsonian Institution, Washington, DC, personal communication). For example, Miller and Richards (1980) list *S. chrysops* and *S. aculeatus* as reef dwellers in the South Atlantic Bight.

Although there can be some mixing of the Middle and South Atlantic Bight scup populations off North Carolina, the Middle Atlantic Bight population is treated separately here, because only this population appears to make extensive seasonal migrations and few fish tagged off New England or New York have been caught south of Cape Hatteras (Nesbit and Neville 1935; Finkelstein 1971). Scup in the Middle Atlantic Bight population are commonly found during the summer in larger estuaries and in coastal waters; during the winter, they occur along the outer continental shelf to about 200 m (656 ft) and occasionally deeper. Beebe and Tee-Van (1933) reported that scup were introduced to Bermuda, but the status of that introduction is unknown and probably unsuccessful (B. Collette, National Systematics Laboratory, Smithsonian Institution, Washington, DC, personal communication). Archeological evidence suggests scup have been common in southern New England waters for several thousand years and were used as food by native Americans (Waters 1967).

The scup population in the Middle Atlantic Bight spawns along the inner continental shelf off southern New England from May through August with a peak in June to July. Larvae occur in coastal waters during the warmer seasons, feed upon small zooplankton, and are prey to a variety of planktivores, including medusae, crustaceans and fish. Larvae settle to the seafloor in coastal and estuarine waters when they are about 25 mm total length (TL), but this event is poorly documented. During the summer and early fall, juveniles and adults are common in most larger estuaries and coastal areas in open and structured habitats where they feed on a variety of small benthic invertebrates. Scup begin to mature at 2 years of age (Finkelstein 1969b) at about 15.5 cm fork length (FL) (O'Brien *et al.* 1993). Most fish are mature at 3 years and at 21 cm FL (Gabriel 1998). In the last century, scup ≥ 45 cm FL were reported (Baird 1873) living to about 20 years and weighing about 2 kg (Bigelow and Schroeder 1953). Currently, the population in the Middle Atlantic Bight is composed primarily of fish ≤ 7 years and ≤ 33 cm FL (Northeast Fisheries Science Center 1997). Since the 1930s, there has been a significant decline in the average size of scup; small scup have slightly different habitat and prey requirements than larger scup (Smith and Norcross 1968).

LIFE HISTORY

The life history of scup is typical of most demersal fishes, with pelagic eggs and larvae, and a gradual transition to the demersal adult stage. As a temperate species, scup is at the northern limits of its range in the northeastern United States and migrates south in the winter to warmer waters south of New Jersey.

EGGS

Scup eggs are small, 0.8-1.0 mm in diameter, and buoyant (Kuntz and Radcliffe 1918; Wheatland 1956). They require two to three days (40-75 hrs) to hatch depending on temperature (Griswold and McKenney 1984). Little else is known of this ephemeral stage.

LARVAE

The newly hatched larvae are about 2.0 mm TL, pelagic, and depend on their yolk for about three days until they are about 2.8 mm TL (Bigelow and Schroeder 1953) when active feeding begins. After reaching 15-30 mm TL in early July, the larvae become demersal in shoal waters (Lux and Nichy 1971; Johnson 1978; MAFMC 1996; Able and Fahay 1998). Griswold and McKenney (1984) considered the larvae as juveniles when they grow to about 18-19 mm TL. There is no information available on habitat use or requirements during this transition period.

JUVENILES

Able and Fahay (1998) noted that the smallest, young-of-the-year (YOY) individuals appeared in estuaries in June. In southern New England, juvenile scup grew to 5 to 10 cm FL by November (Bigelow and Schroeder 1953; Gottschall *et al.*, in review). Returning juveniles in the spring were about 10-13 cm FL (Michelman 1988; Able and Fahay 1998). Growth of YOY scup is considered relatively slow (Able and Fahay 1998). Michelman (1988) estimated daily growth of juveniles to be 0.84% of its dry wt/day using a length frequency method and 0.93% of its dry wt/day using a bioenergetics method. The growth production rates were between 0.15 and 0.40 g of its dry wt/m^2 with a growth efficiency of about 24%. Growth rates and curves for juvenile scup were reported in several studies, see MAFMC (1996).

ADULTS

Adult scup are common residents in the Middle Atlantic Bight from spring to fall and are generally found in schools on a variety of habitats, from open sandy bottom to structured habitats such as mussel beds, reefs or rough bottom. Smaller-sized adult scup are common in larger bays and estuaries but larger sizes tend to be in deeper waters. Schools are reported to be size-structured (Morse 1978). Scup mature at about 2 years of age and 50% of both sexes are reported to be mature when they achieve a length of 15.5 cm FL (O'Brien *et al.* 1993). Examining growth of male and female scup from the New York Bight (the continental shelf bounded by southern Long Island and the New Jersey coast), Wilk *et al.* (1978) found no significant difference in the length-weight relationships between sexes within the 113-361 mm FL range. The relationship for a larger sample of unsexed fish, 27-380 mm FL, was log W = log (-5.022) + 3.169 log FL, where W is weight in grams and fork length (FL) is in mm; similar relationships have been reported in MAFMC (1996). Growth in length is curvilinear between 10-38 cm FL corresponding to ages of about 1 to 13 years; growth is relatively rapid at 10-15 cm FL and declines with increasing size (Penttila *et al.* 1989).

Scup are members of an offshore-wintering guild of fishes whose movements, habitats, and food habits generally coincide (Musick and Mercer 1977; Colvocoresses and Musick 1984; Austen *et al.* 1994; Brown *et al.* 1996). This guild includes summer flounder (*Paralichthys dentatus*), black sea bass (*Centropristis striata*), northern searobin (*Prionotus carolinus*), and smooth dogfish (*Mustelus canis*) (Gabriel 1992; Shepherd and Terceiro 1994). Although biological interactions among guild members can occur, slight differences exist in their environmental tolerances and habitat preferences (Neville and Talbot 1964).

REPRODUCTION

The mean fecundity of scup, 17.5-23.0 cm FL, is about 7,000 (±4,860 SD) eggs per female (Gray 1990). Scup spawn once a year beginning in the spring during the inshore migration (Kendall 1973) when water temperatures are >10°C. In eastern Long Island bays (New York) and Raritan Bay (New York-New Jersey), spawning occurs in May and June (Breder 1922; Finkelstein 1969a). Along coastal Rhode Island, spawning peaks in June (O'Brien *et al.* 1993) and extends to August at temperatures of about 24°C (Herman 1963). In southern Massachusetts, spawning fish occur in shoal waters < 10 m deep until late June, when they move into deeper waters (MAFMC 1996). Most spawning occurs in southern New England from Massachusetts Bay south to the New York Bight, including eastern Long Island Sound, Peconic and Gardiners Bays, and Raritan Bay (Goode 1884; Kuntz and Radcliffe 1918; Breder 1922; Nichols and Breder 1927; Permutter 1939; Bigelow and Schroeder 1953; Wheatland 1956; Richards 1959; Finkelstein 1969a; Sisson 1974; Morse 1978; Clayton *et al.* 1978).

Able and Fahay (1998) noted that there has been no reported evidence of spawning in Block Island Sound (Rhode Island), Great South Bay (New York), the Hudson River estuary, and Great Bay (New Jersey). Although Breder (1922) reported ripe scup in the Hudson-Raritan estuary, more recent studies do not report the collection of scup eggs or larvae (Croker 1965; Berg and Levinton 1985). Esser's (1982) note on scup spawning in the estuary was not referenced and is probably based on Breder (1922).

Spawning has not been reported south of New Jersey (Morse 1982); e.g., off Chesapeake Bay (Hildebrand and Schroeder 1928; Pearson 1932). However, Berrien and Sibunka (1999) found eggs in this area between 1978 and 1987, although they were not abundant or widespread. Although scup are common in the spring off Maryland and Virginia, Eklund and Targett (1990) did not observe spawning over hard-bottom reef habitat. The scup they observed appeared to be migrants since few remained as summer residents in the study area.

Ferraro (1980) suggested that scup spawn in the morning in Peconic Bay, Long Island, unlike most fish that generally spawn in the evening or at night. Scup usually spawn over weedy or sandy areas and fertilization is external with no parental care (Morse 1978). Scup appear to refrain from feeding during spawning (Baird 1873; Bigelow and Schroeder 1953; Morse 1978).

Spawning can fail in some years, e.g., 1958 (Edwards *et al.* 1962), even though, based on landings data, spawning stocks are near peak abundance (MAFMC 1996). The relationship of this apparent spawning failure to environmental or habitat variables is unknown. Scup spawning coincides temporally with that of several other fish, including weakfish (*Cynoscion regalis*), tautog (*Tautoga onitis*), and northern searobin (Morse 1978).

FOOD HABITS

Although food habits data for scup larvae are not available, rearing experiments suggest that the larvae feed on small zooplankton (Griswold and McKenney 1984).

In Long Island Sound, juvenile scup feed during the day, principally on polychaetes (e.g., maldanids, nephthids, nereids, and flabelligerids), epibenthic amphipods and other small crustaceans, mollusks, and fish eggs and larvae (Bowman *et al.* 1987). Copepods and mysids are important to post-larvae and early juveniles, while bivalve mollusks are more commonly eaten by larger fish (Richards 1963b; Bowman *et al.* 1987; Michelman 1988). Allen *et al.* (1978) reported amphipods, polychaetes, copepods, and other small crustaceans were eaten by a small sample of juvenile scup in southern New Jersey, which is consistent with Northeast Fisheries Science Center (NEFSC) data [Figure 2; see Reid *et al.* (1999) for a discussion of NEFSC food habitats data]. Michelman (1988) reported that scup only eat when they are in a school and the relative importance of major prey taxa varies seasonally. Baird (1873) reported prey were "rooted out of the sand or mud." Juvenile and adult scup near an artificial reef in lower Delaware Bay ate a mix of hard-surface epifauna and sand bottom infaunal prey, including amphipods (caprellids and others), razor clams (*Ensis directus*), hydroids, blue mussels (*Mytilus edulis*), anemones, and mysids (F. Steimle, unpublished data). In Raritan Bay, scup 9-12 cm FL ate a variety of benthic infaunal and epifaunal invertebrates including polychaetes, copepods, small mollusks, and hydroids; dietary composition varied among areas within the bay (Steimle *et al*., in review). Michelman (1988) estimated that juvenile scup in Narragansett Bay (Rhode Island) consumed 0.6-1.7 g dry wt/m^2 of benthic prey between June 1 and September 30. The daily food ration of juvenile scup was 3.49-3.99% of dry body weight (depending on method used), or about 5% of their body weight per day.

Adult scup are also benthic feeders and forage on a variety of prey, including small crustaceans (including zooplankton), polychaetes, mollusks, small squid, vegetable detritus, insect larvae, hydroids, sand dollars, and small fish (Goode 1884; Nichols and Breder 1927; Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953; Oviatt and Nixon 1973; Maurer and Bowman 1975; Morse 1978; Sedberry 1983; Figure 2). As scup grow, their diets include larger prey. Bowman *et al.* (1976) found that polychaetes were more important in the diets of scup off southern New England and anthozoans were more important in the Middle Atlantic Bight. Sedberry (1983) reported that during the fall migration off New Jersey scup fed mainly on amphipods, polychaetes, and to a lesser extent on decapod crustaceans, copepods, snails, and other small invertebrates. Adults also prey on small benthic invertebrates, although feeding and growth appear to be reduced during the winter.

At times and in certain areas, scup diets overlap those of red hake (*Urophycis chuss*) and, depending on scup size, those of silver hake (*Merluccius bilinearis*) and Gulf Stream flounder (*Citharichthys arctifrons*) (Sedberry 1983). Langton (1982) found that although the diets of scup overlapped those of several other demersal species, there was little prey overlap with cod (*Gadus morhua*) or silver hake off New England, even though they have similar benthic diets. Jeffries and Terceiro (1985) hypothesized that an expanding scup population in Narragansett Bay seemed to replace the winter flounder (*Pseudopleuronectes americanus*) because both species have similar diets; if abundance of winter flounder were reduced, more prey could be available for benthic-feeding species such as scup. This dietary similarity was also found in a recent fish food habit study in Hudson-Raritan Bay (Steimle *et al*., in review).

During inshore residency, scup gradually accumulate food reserves from the spring into the fall. The mean caloric content increases from 24.2 kj/g ash-free dry weight of whole scup in the spring to 28.1 kj/g ash-free dry weight in the fall (Steimle and Terranova 1985). This stored energy can support the extra demands of migration, reduced feeding in winter, and gonadal development. Feeding may be minimal during the winter because there is so little growth (Bigelow and Schroeder 1953).

PREDATION AND MORTALITY

Larvae are probably preyed on by a variety of planktivores, including medusae, crustaceans, and fishes. Small or juvenile scup are heavily preyed on by bluefish (*Pomatomus saltatrix)*, Atlantic halibut (*Hippoglossus hippoglossus*), cod, various sharks, striped bass (*Morone saxitilus*), weakfish, goosefish (*Lophius americanus*), silver hake, and other coastal fish predators (Baird 1873; Smith 1898; Jensen and Fritz 1960; Schaefer 1970; Morse 1978; Sedberry 1983). Baird (1873) reported that cod ate large numbers of small scup on Nantucket Shoals in late November. Wading and diving shorebirds are also potential predators during the summer.

The NEFSC bottom trawl survey data on food habits lists the following species as predators of scup: dusky shark (*Carcharhinus obscurus*), sandbar shark (*C. plumbeus*), smooth dogfish, spiny dogfish (*Squalus acanthias*), Atlantic sharpnose shark (*Rhizoprionodon terraenovae*), Atlantic angel shark (*Squatina dumeril*), Atlantic torpedo (*Torpedo nobiliana*), bluntnose stingray (*Dasyatis say*), silver hake, bluefish, summer flounder, black sea bass, weakfish, northern stargazer (*Astroscopus guttatus*), goosefish, inshore lizardfish (*Synodus foetens*), and king mackerel (*Scomberomorus cavalla*).

Another potential source of mortality is disease. Disease can be initiated by direct epidermal exposure or through feeding on contaminated prey. Scup had fin rot in the degraded inner New York Bight and Hudson-Raritan estuary (Mahoney *et al.* 1975). Benthic invertebrate prey commonly eaten in the New York Bight were contaminated with several toxic heavy metals (Steimle *et al.* 1994).

MIGRATION

As inshore water temperatures decline to < 8-9^{o}C in the winter, scup leave inshore waters and move to warmer waters on the outer continental shelf south of the Hudson Canyon off New Jersey and along the coast from south of Long Island to North Carolina in depths ranging from 75-185 m (Morse 1978; Bowman *et al.* 1987). Juveniles follow adults to wintering areas on the mid to outer continental shelf south of Long Island, although some remain in larger and deeper estuaries during warmer winters. During migration, scup move south along the coast (within the 18 m isobath) and offshore (Hamer 1970) as coastal bottom water temperature declines below 10^{o}C. Phoel (1985) reported that scup migrated south of Cape Hatteras to about Cape Fear (North Carolina) in the winter and spring (he assumed one species and no population mixing).

With rising water temperatures in the spring, scup return inshore. Larger fish arrive first followed by schools of subadults, which have been reported to appear off southern New England slightly later (Sisson 1974). The fish reach Chesapeake Bay by April (Hildebrand and Schroeder 1928) and southern New England by early May (Baird 1873; Perlmutter 1939; Neville and Talbot 1964; Finkelstein 1971). It has been suggested that the population moves in schools of similarly-sized individuals during migration and perhaps at other times as well (Baird 1873; Hildebrand and Schroeder 1928; Neville and Talbot 1964; Sisson 1974; Morse 1978). Fish that arrive inshore early can be caught in pockets of residual cold water and can become inactive or dormant (Kessler 1966).

STOCK STRUCTURE

Although the Middle Atlantic Bight population was once considered to be two stocks, i.e., southern New England and New Jersey (Edwards *et al.* 1962; Neville and Talbot 1964; Hamer 1970; Morse 1978). More recent analysis found that the evidence for this segregation was weak. Pierce (1981) suggested that the apparent segregation of two stocks in the Middle Atlantic Bight could be an artifact of the temporary location of separate winter water masses containing temperatures acceptable to scup; in most years this water mass separation is lacking or less influential. Scup is presently considered a single stock in the Middle Atlantic Bight (Pierce 1981; Mayo 1982).

HABITAT CHARACTERISTICS

Scup are a temperate, demersal species that use several benthic habitats from open water to structured areas for feeding and possibly for shelter (Table 1). Their distribution changes seasonally as fish migrate from estuaries to the edge of the continental shelf as water temperatures decline in the winter and return from the edge of the continental shelf to inshore areas as water temperatures rise in the spring. Some reports on scup habitat use and distribution may be biased by the type of collection gear used and the habitats in which they can be deployed effectively. For example, most surveys use towed nets that are appropriate for open bottom but not for rough, structured habitats that scup are known to use such as mussel beds, rock rubble, or reefs.

EGGS

Scup eggs are commonly found in larger bodies of coastal waters such as bays and sounds in and near southern New England during spring and summer. Lebida (1969) reported eggs were relatively abundant in Buzzards Bay (Massachusetts) from May through June at water temperatures of 8.5^{o} to 23.7^{o}C, which is similar to their distribution in Connecticut and Rhode Island estuaries (Herman 1963). Eggs hatched in about 70-75 hrs at 18^{o}C and 40-54 hrs at 21-22^{o}C (Griswold and McKenney 1984); they may not develop normally at temperatures below 10^{o}C (Bigelow and Schroeder 1953).

Few scup eggs were collected in the NEFSC Marine Resources Monitoring, Assessment and Prediction (MARMAP) ichthyoplankton survey [see Reid *et al.* (1999) for survey methods]. The few survey tows that collected eggs were made during May-August when integrated water column temperatures were between 11^{o} and 23^{o}C (Figure 3). Their occurrence at 23^{o}C probably represents eggs collected off Maryland-Virginia during the summer. Most eggs were collected in generally < 50 m (Figure 3).

LARVAE

Larval scup are pelagic and occur in coastal waters during warmer months. Larvae were collected in the more saline parts of Long Island Sound and eastern Long Island bays, Narragansett Bay, Buzzards Bay, Vineyard Sound, and Cape Cod Bay from May through September at water temperatures of 14-22^{o}C; the greatest densities occurred at 15-20^{o}C (Fish 1925; Wheatland 1956; Pearcy and Richards 1962; Herman 1963; Scherer 1984; MAFMC 1996). Herman (1963) found larvae when water temperatures were 20.0-23.5^{o}C. The optimum for rearing larvae in the laboratory is 18^{o}C (Lawrence 1979). The NEFSC MARMAP larval data indicate a peak in abundance at 17^{o}C at depths < 50 m (Figure 4).

JUVENILES

During warmer months, juvenile scup live inshore in a variety of coastal habitats and can dominate the overall fish population in most larger estuarine areas during that period. In Rhode Island, YOY scup have been collected in intertidal and subtidal habitats, over sand, silty-sand, shell, mud, mussel beds and eelgrass (*Zosteria marina*) (Baird 1873). Although Gottschall *et al.* (in review) noted that 1 year old scup were found on various types of sediment during warmer months in Long Island Sound, Richards (1963a) reported collecting more juvenile scup in a sandy habitat 9 m deep than at a 17 m deep muddy area of the sound. Scup were also collected in the smaller coastal bays of Delaware (Derickson and Price 1973). However, scup were not common in shoreline seine or throw-trap surveys in vegetated and unvegetated habitats in Chesapeake Bay, Long Island Sound, or New Jersey estuaries (Greeley 1939; Warfel and Merriman 1944; Briggs and O'Connor 1971; Himchak 1982; Weinstein and Brooks 1983; Sogard 1989; Sogard and Able 1991).

While little is known about the specific habitats occupied in winter when juvenile scup reside offshore, their winter-spring distributions indicate that they occur in habitats ranging from relatively flat, open, sandy-silty bottoms to the head of submarine canyons, and other areas with topographical relief and varying sediments (Wigley and Theroux 1981).

The presence of structure can be important to scup. Gray (1990) and Auster *et al.* (1991, 1995) noted that juveniles use biogenic depressions in the sediments off southern New England in the fall; the size of the depression was directly related to the size of the fish. Juveniles can use biogenic depressions, sand wave troughs, and possibly mollusk shell fields for shelter in winter. Their poor growth during colder months (Bigelow and Schroeder 1953) suggests inactivity and possibly an increased need for shelter.

Juvenile scup have been collected at water temperatures ranging from 5-27^{o}C [Figures 5-8; see Reid *et al.* (1999) for survey methods]. This is slightly below the thermal maximum of 30.2-35.6^{o}C (depending on acclimation) reported by Everich and Gonzalez (1977). The modes of highest relative abundance shift from about 10^{o}C in the spring to peaks at 16^{o}C and 22^{o}C from summer to fall, except in Narragansett Bay (Figure 8) and Long Island Sound where the bimodality was unclear. In Long Island Sound, where juveniles dominate the population, they were collected at bottom temperatures of 7-18^{o}C in the spring and 15-22^{o}C in the fall at salinities of 25-31 ppt. Subadults, which usually follow the migrations of adults south during the fall, have been killed by sudden cold spells in shallow New England bays (Baird 1873; Sherwood and Edwards 1902; Morse 1978). However, from 1971 to 1975, juveniles over-wintered in Long Island Sound (Thomson *et al.* 1978). In the Hudson-Raritan estuary, juveniles were collected at temperatures ranging from 9^{o} to 26^{o}C, at salinities ranging from 18 to 33 ppt, and dissolved oxygen (DO) levels > 4 mg/l (Figure 6).

From summer through fall, YOY and age 1+ scup were found in many tidal bays, sounds, and coastal areas primarily north of Maryland at depths within the 38 m (< 125 ft) contour (Morse 1978; Figures 6-8). In Raritan Bay, juvenile scup were most commonly collected at depths between about 5 and 12 m (15 to 35 ft) (Figure 6).

ADULTS

Adult habitats are similar to those used by juveniles, including soft, sandy bottoms, on or near structures, such as rocky ledges, wrecks, artificial reefs, and mussel beds in euryhaline areas (Briggs 1975a; Eklund 1988; MAFMC 1996). In Long Island Sound, scup exhibit a strong preference for mixed sand and mud sediments (Gottschall *et al.*, in review), which are probably rich in small benthic prey (Reid *et al.* 1979). Similar to juveniles, the specific habitats used by adult scup during the winter or during migration are not known. The areas in which they have been found can include a variety of habitat types that differ in sediment composition, availability of food, and structure or relief (Wigley and Theroux 1981; Steimle 1990).

Adult scup also occurred at bottom water temperatures of 6-27^{o}C (Figures 5-8). Their winter distribution appears to be mostly limited by the 7^{o}C isotherm, their lower preferred limit (Neville and Talbot 1964). Magnuson *et al.* (1981) reported that scup may aggregate north of transient Gulf Stream frontal boundaries off Cape Hatteras, at least in the fall when the temperature differential was about 8^{o}C (25.6^{o} vs. 17.1^{o}C). However, there are taxonomic uncertainties about the species of *Stenotomus* involved.

Although scup are considered a demersal species, they have been observed at the water surface (Bigelow and Schroeder 1953). Off Massachusetts (Figure 7) and in Narragansett Bay (Figure 8), most adults were collected in spring through fall at depths < 30 m (100 ft). In New Jersey, they were reported to aggregate within the 20 m depth coastal zone as they began their offshore southerly movements (MAFMC 1996).

Adult scup in the Hudson-Raritan estuary were collected at salinities ranging primarily from 20 to 31 ppt (Figure 6), which is consistent with salinity associations in Long Island Sound (Gottschall *et al.*, in review). Similar to juveniles in the Hudson-Raritan estuary, most adults were collected at DO levels ≥ 4mg/l (Figure 6).

GEOGRAPHICAL DISTRIBUTION

Scup is a temperate species and north of Cape Hatteras the population is restricted to water temperatures above 6^{o}C (Figure 9). Postlarval scup migrate to stay within acceptable thermal limits as bottom water temperatures in the northeast decline in winter.

EGGS

Scup eggs have been collected primarily in coastal waters off southern New England where abundance can range up to 1000 eggs/10 m^2 of sea surface (Berrien and Sibunka 1999) but samples containing > 100 eggs/10 m^2 were rare during the NEFSC MARMAP survey (Figure 10) when stock abundance was relatively low (MAFMC 1996). Eggs were collected primarily during June and July from inshore waters off southern New England; few eggs were collected on the continental shelf from May to August (Berrien and Sibunka 1999). Patchy occurrences were recorded from mid-shelf in the Chesapeake Bight from May through August (Figure 10).

Since the NEFSC MARMAP surveys did not sample waters < 10 m and excluded most coastal bays, it is probable that eggs are more abundant and widely distributed in nearshore areas. Wheatland (1956) reported that in eastern Long Island Sound and nearby bays, eggs were variably abundant from year to year from May to August with peaks in June and July. According to Stone *et al.* (1994), scup eggs were common or abundant in the saline parts of coastal bays from southern Cape Cod to Long Island Sound, eastern Long Island, and the Hudson-Raritan estuary. In contrast, Merriman and Sclar (1952) did not find eggs in Block Island Sound, along the south shore of Long Island, or in coastal waters or bays to the south. Interestingly, Able and Fahay (1998) note that there has not been a verified collection of scup eggs within southern New England estuaries since Sisson (1974).

North of Cape Cod, scup eggs have been recorded in southern Cape Cod Bay from June to August (1974-1976), possibly transported from Buzzards Bay through the Cape Cod Canal (Scherer 1984). There have been other reports of eggs in Massachusetts Bay suggesting that spawning occurs there (MAFMC 1996).

LARVAE

Larval distribution is also limited and even more conjectural than for eggs. Although Kendall (1973) noted the offshore occurrence of larvae from Virginia to Cape Cod and in estuaries from Delaware Bay to Buzzards Bay, the NEFSC MARMAP surveys collected < 5 larvae/tow, mostly inshore (about 30 m) off Rhode Island in July (Figure 11). However, larvae can be more abundant in shallow, nearshore waters since Stone *et al.* (1994) reported them in the same areas as eggs; i.e., from southern Cape Cod to Long Island Sound and in the Hudson-Raritan estuary.

Despite these reports, Able and Fahay (1998) noted that like the eggs there has been no verified collection of scup larvae in southern New England estuaries since Sisson (1974). Cowen *et al.* (1993) did not collect scup larvae in coastal or shelf waters of the New York Bight during July and August 1988, nor were they common in bays or estuaries south of Long Island (Pearson 1932; Massman *et al.* 1961; de Sylva *et al.* 1962; Dovel 1967, 1981; Scotton 1970; Pacheco and Grant 1973; Himchak 1982; Morse 1982; Olney 1983; Berg and Levinton 1985; Monteleone 1992; Stone *et al.* 1994) or in the surf zone (D. Clark, U.S. Army Corps Engineers, Vicksburg, MS, personal communication). This is surprising since some of these areas; e.g., Delaware Bay, are important juvenile nurseries (de Sylva *et al.* 1962).

Clayton *et al.* (1978) reported the occurrence of larvae in Rocky Point in northwestern Cape Cod Bay, which, as with eggs, could have been transported through the Cape Cod Canal from Buzzards Bay (Scherer 1984). Based on the presence of eggs and larvae, there is a possibility that scup can spawn in Massachusetts Bay (MAFMC 1996).

JUVENILES

In contrast with the conflicting reports and uncertainty in the spatial extent and abundance of scup eggs and larvae, juveniles have been collected inshore and offshore from New England to the Chesapeake Bay area. In fact, the saline areas of Narragansett Bay, Long Island Sound, Raritan Bay, and Delaware Bay are important nursery areas (Richards 1963a; Abbe 1967; Oviatt and Nixon 1973; Werme *et al.* 1983; Michelman 1988; Gray 1990; MAFMC 1996; Wilk *et al.* 1997; Gottschall *et al.*, in review).

Reports of the coastal occurrence of juvenile scup date back to the last century. Smith (1894) reported that they were abundant from Hyannis, Massachusetts to Barnegat, New Jersey in 1891 and Moore (1894) indicated they were common only as far south as New Jersey. More recent reports indicate that during warmer months, juvenile scup were common from the intertidal zone to about 30 m in more saline (> 15 ppt) portions of bays and estuaries and along the inner continental shelf of the Middle Atlantic Bight from about May to November (Smith 1898; Breder 1922; Kendall 1973; Werme *et al.* 1983; Bowman *et al.* 1987; Szedlmayer and Able 1996; Gottschall *et al.*, in review).

The changes in seasonal distribution are reflected in the results of the NEFSC bottom trawl surveys in which juveniles occurred offshore in winter and spring, inshore in summer, and were concentrated in near-coastal waters through fall (Figure 12). Young-of-the-year fish are locally abundant north of Cape Cod (Clayton *et al.* 1978), especially in the fall (Lux and Kelly 1982). However, this is not reflected in the Massachusetts trawl survey that indicated higher concentrations south of the Cape in spring and fall (Figure 13). Juveniles were common in Narragansett Bay (Figure 14) and Long Island Sound (Figure 16) in summer and fall. Zawacki and Briggs (1976) routinely seined juveniles on the north shore of

Long Island from July through October. Gottschall *et al.* (in review) reported that YOY scup (approximately 4 cm FL) were first collected in Long Island Sound in August and became numerically dominant in the catch by September; 1 year old juveniles were collected in April. However, other surveys of Long Island estuaries or surf zones did not support these findings (Schaefer 1967; Briggs 1975b).

The occurrence of juveniles in coastal bays and estuaries south of Long Island is temporally and spatially variable. In Raritan Bay, juveniles were abundant in spring and summer; a few were collected in the fall and were not collected in winter (Figure 17). While juveniles occur in the larger bays; e.g., Raritan and Delaware Bays (de Sylva *et al.* 1962; Werme *et al.* 1983), they seldom occur in smaller coastal lagoons such as Barnegat Bay (New Jersey), tributaries of the Hudson-Raritan estuary, or the ocean surf zone (Marcellus 1972; Howells and Brundage III 1977; Vouglitois 1983; Wilk *et al.* 1997; D. Clark, personal communication).

Varying numbers have been collected in New Jersey estuaries south of Barnegat Bay; i.e. within Hereford Inlet (Allen *et al.* 1978). Although formerly relatively abundant, juvenile scup have not occurred in large numbers in vegetated sites in lower Chesapeake Bay (Orth and Heck 1980; MAFMC 1996). However, in fall they are still collected in relatively large numbers by the NEFSC trawl surveys at the mouth of the bay (Figure 12). While juveniles do not occur to any great extent in seaside bays of Maryland and Virginia (Arve 1960; Schwartz 1961, 1964), Richards and Castagna (1970) did find them in their survey of Virginia's seaside bays.

The NEFSC groundfish surveys (1963-1997) mostly post-date the last period of high scup abundance, approximately 1950-1965 (Northeast Fisheries Science Center 1997). The NEFSC bottom trawl survey results for 1963-1964 (not shown) indicated that juveniles were widespread and distribution was similar to the present. The only apparent change in this general coastal distribution pattern was in the late 1960s (during the period of relatively low abundance) when the largest collections of juveniles were clustered off southern New England, Virginia, and North Carolina. This distribution pattern raised the question of whether there were two stocks in the Middle Atlantic Bight (Hamer 1970).

ADULTS

Adults have been reported as far north as the Bay of Fundy, southern Nova Scotia, and Sable Island Bank (east of Nova Scotia) as summer visitors (Scott and Scott 1988) and at least as far south as Cape Hatteras. As part of a temperate, migrant guild, scup have even been collected occasionally on the southern Grand Banks (Brown *et al.* 1996).

Scup occur primarily in the Middle Atlantic Bight. They migrate from offshore winter habitats into coastal waters from Chesapeake Bay to southern New England where they reside from spring to fall (Bigelow and Schroeder 1953; Richards 1963a; Scott and Scott 1988; Morse 1978; Chang 1990). These migration patterns are reflected in the results of the NEFSC bottom trawl surveys (Figure 12) and in the Massachusetts inshore survey (Figure 13). During warm months, larger scup occur in or near the mouths of larger bays, such as Narragansett Bay (Figures 14, 15) and Long Island Sound (Figure 16), and along the coast within the 38 m contour (Morse 1978).

Distribution and abundance of adult scup off New England is temperature dependent (Mayo 1982; Gabriel 1992). Smaller fish are found in more saline (> 15 ppt) shallow bays and parts of estuaries including the Hudson-Raritan estuary and Hereford Inlet (New Jersey) (Figures 6, 17; Allen *et al.* 1978; Morse 1978; Werme *et al.* 1983; Wilk *et al.* 1997). However, they may not be abundant in all bays; e.g., they have not been reported in Barnegat Bay (Marcellus 1972; Vouglitois 1983; Tatham *et al.* 1984), Maryland bays (MAFMC 1996), or in New York Harbor (Stoecker *et al.* 1992; Will and Houston 1992).

Adult scup usually arrive offshore in December and winter in deeper water from Nantucket Shoals to Cape Hatteras to depths of about 240 m (Figures 5 and 12; Pearson 1932; Neville and Talbot 1964; Morse 1978). Scup density and distribution during the winter are related to the location of the 7^{o}C bottom isotherm, their lower preferred limit (Neville and Talbot 1964). Nesbit and Neville (1935) indicated that this band of warmer, outer continental shelf water is influenced mainly by the Gulf Stream just off the shelf. During warm winters, scup can be found across most of the continental shelf south of New Jersey (Nesbit and Neville 1935). As coastal waters warm above the 7^{o}C threshold in spring, scup return inshore and to the north.

STATUS OF THE STOCKS

Commercial landings of scup in the Middle Atlantic Bight have declined substantially since peak landings in the 1950s and early 1960s; although there was a minor peak in landings in the early 1980s (Figure 18; Northeast Fisheries Science Center 1997). Recreational landings have also declined (MAFMC 1996).

Groundfish surveys by the NEFSC indicated cycles in abundance of scup of about 3-4 years and an overall decline since the 1950-1960s (Figure 18; Gabriel 1998). Currently, the stock is composed primarily of fish < 3 years old and the age distribution is truncated (MAFMC 1996). The abundance of scup eggs off southern New England has been low recently (Gray 1990; Able and Fahay 1998). According to Jeffries and Terceiro (1985), slightly warmer average summer temperatures (+1°C) in coastal waters off southern New England are related to an increase in scup abundance.

The Middle Atlantic Bight stock is currently considered overfished because the stock is near record low abundance levels and catches exceed F_{max} (Gabriel 1998; National Marine Fisheries Service 1997; Northeast Fisheries Science Center 1997).

RESEARCH NEEDS

- The taxonomic status of scup and "southern porgy" should be resolved.
- The degree of mixing between populations in the Middle Atlantic and South Atlantic Bights across Cape Hatteras should be determined.
- Better characterization of spawning sites and egg and larval habitats is needed.
- Offshore winter habitats in the Middle Atlantic Bight need to be identified and described.
- The relative importance of larger estuaries (e.g., Chesapeake, Delaware, and Raritan Bays, Long Island Sound) compared to smaller estuaries and inshore areas (e.g., Barnegat Bay, seaside bays from Maryland to Virginia) as primary nurseries should be examined.
- Determine whether the patchy, inconsistent occurrence of juveniles results from inadequate monitoring or highly variable recruitment.
- The habitat factors that result in the patchy distributions of juvenile and adult scup in space and time need to be identified.
- The role of natural and artificial structured habitats in the life history, productivity, and fishery management of scup should be determined.
- Research should be conducted on the trophic relationships of scup, including the factors that control the production and distribution of their prey (Kline 1997).
- The effects of altering the population age structure on habitat requirements should be examined.
- The effects of the winter trawl fishery in the southern Middle Atlantic Bight on spawning stock, juvenile survival, and habitat should be determined.
- Information is needed on the direct and indirect effects of degraded environments on feeding, growth, fecundity, survival, and distribution of scup; indirect effects should include food web alterations.
- The long-term, synergistic effects of combinations of environmental variables (e.g., pH and toxins) on survival, reproduction, and genetic changes should be investigated (Kline 1997).

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Table 1. Summary of life history and habitat characteristics for scup, *Stenotomus chrysops.* MAB = Middle Atlantic Bight, SNE = southern New England, GOM = Gulf of Maine.

Life Stage	Time of Year	Size and Growth	Geographic Location	Habitat	Substrate	Temperature
Eggs	May-Aug, south to north progression	0.8-1.0 mm	Coastal Virginia - SNE, southern GOM	Water column, < 30 m in depth	Buoyant in water column	11-23°C; most common 12-14°C
Larvae	May-Sept, south to north	Hatch at ~2.0 mm; stage lasts to ~15-30 mm	MAB and southern GOM, near shore; mostly SNE	Water column, < 20 m until juvenile transition	In water column until transition	14-22°C; peak densities at 15-20°C
YOY and older juveniles	May-Nov, south to north	YOY: 15-30 mm to 10 cm by Nov; juveniles: to 16 cm by end of 1+ yr	MAB-GOM; in estuaries spring to fall	Estuarine and coastal; from intertidal to about 38 m	Sand, mud, mussel, and eel grass beds	Greater than ~9-27°C; mostly 16-22°C
Winter juveniles	Nov-Apr/ May	~10-13 cm; growth rate reduced	Most move offshore and south of New Jersey to warmer, deeper waters; some overwinter in Long Island Sound	Mostly > 38 m depth; mid and outer continental shelf; sometime in deep estuaries	Poorly known, found over various sand substrates	Greater than ~7°C
Summer adults	Apr-Dec	> 15.5 cm FL	Coastal from Delaware to GOM	~2-38 m	Fine to silty-sand, mud, mussel beds, rock, artificial reefs, wrecks, and other structures	~7-25°C; can acclimate to 35.6°C
Winter adults	Jan-Mar	> 15.5 cm FL	Most move offshore and south of New Jersey to warmer, deeper waters.	Mostly 38-185 m depths; mid/outer continental shelf.	Poorly known, found over various sands.	> 7°C
Spawning adults	May-Aug, peak in June	> 15.5 cm FL; mature at about age 2	Inshore from Delaware Bay north to SNE; mostly in SNE	< 30 m, during inshore migration	Weedy to sandy	> 9-24°C

Table 1. cont'd.

Life Stage	Salinity	Prey	Predators	Notes
Eggs	> 15 ppt		Most planktivores where the eggs are found.	Eggs hatch in 70-75 hrs at 18°C, and in 40-54 hrs at 21°C
Larvae	> 15 ppt	Can use yolk for ~3 days; at ~2.8 mm feeding on zooplankton must begin	Most planktivores where the larvae are found.	Benthic settlement and juvenile transition occurs at ~15-30 mm FL
YOY and older juveniles	> 15 ppt	Small benthic invertebrates, fish eggs and larvae	Bluefish, cod, hake, summer flounder, weakfish, striped bass, and others	Diurnal schooling feeders. Most migrate to deeper/warmer waters to the south in winter
Winter juveniles	Mostly > 30 ppt, except in estuaries	Poorly known; possibly small benthic invertebrates, but feeding may be reduced	Cod during SNE migration	Migrate offshore as temperatures fall below 8-9°C and inshore and north as water warms to > 7°C; early arrivals can be affected by late cold spell
Summer adults	> 15 ppt	Benthic and near bottom invertebrates, and small fish	Sharks, stingrays, dogfish, bluefish, silver hake, black sea bass, and others	Usually found in schools of similarly sized individuals. Possibly tolerant or avoid hypoxic conditions
Winter adults	> 30 ppt	Poorly known, but feeding may be reduced	Sharks, stingrays, dogfish, bluefish, silver hake, black sea bass, and others	7°C isotherm greatly influences distribution
Spawning adults	> 15 ppt	Poorly known, but feeding may be reduced	Sharks, stingrays, dogfish, bluefish, silver hake, black sea bass, and others	Spawning is often in AM; fish may avoid hypoxic areas

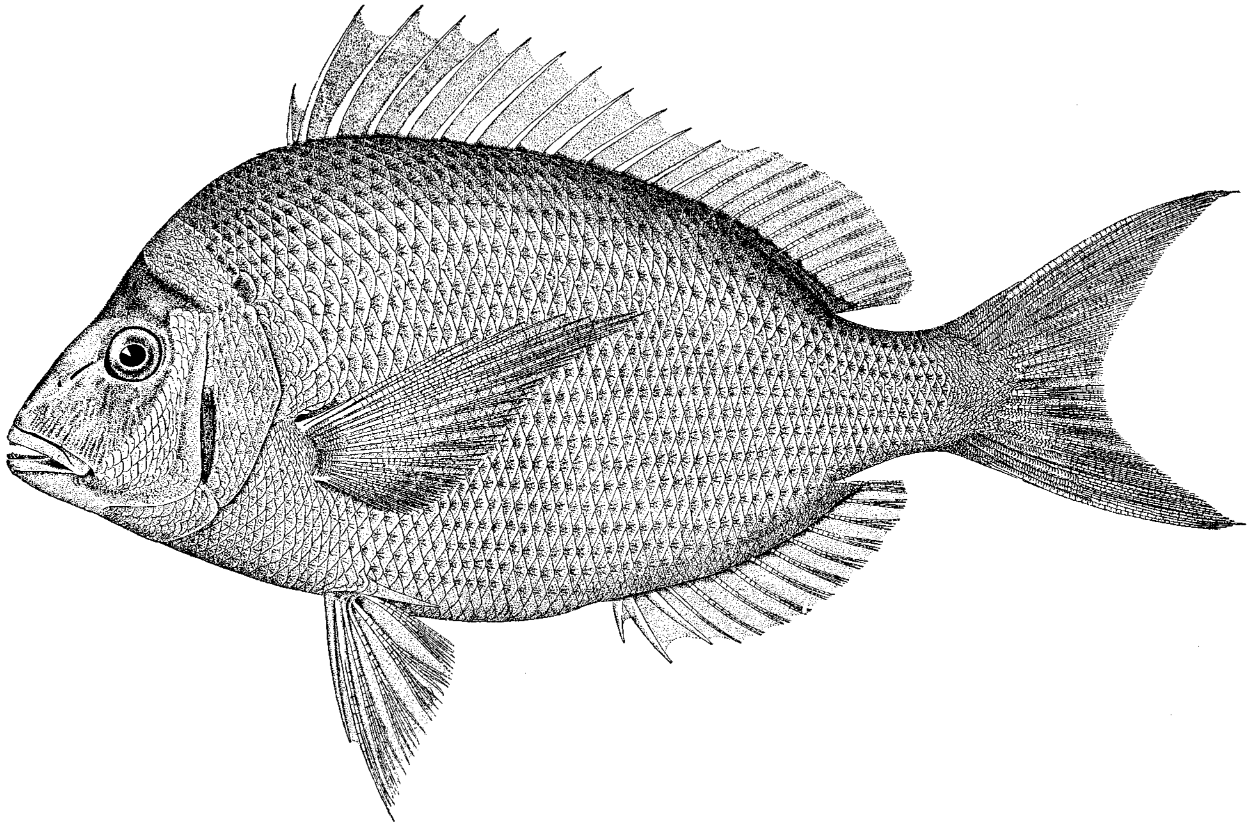


Figure 1. The scup, *Stenotomus chrysops* (from Goode 1884).

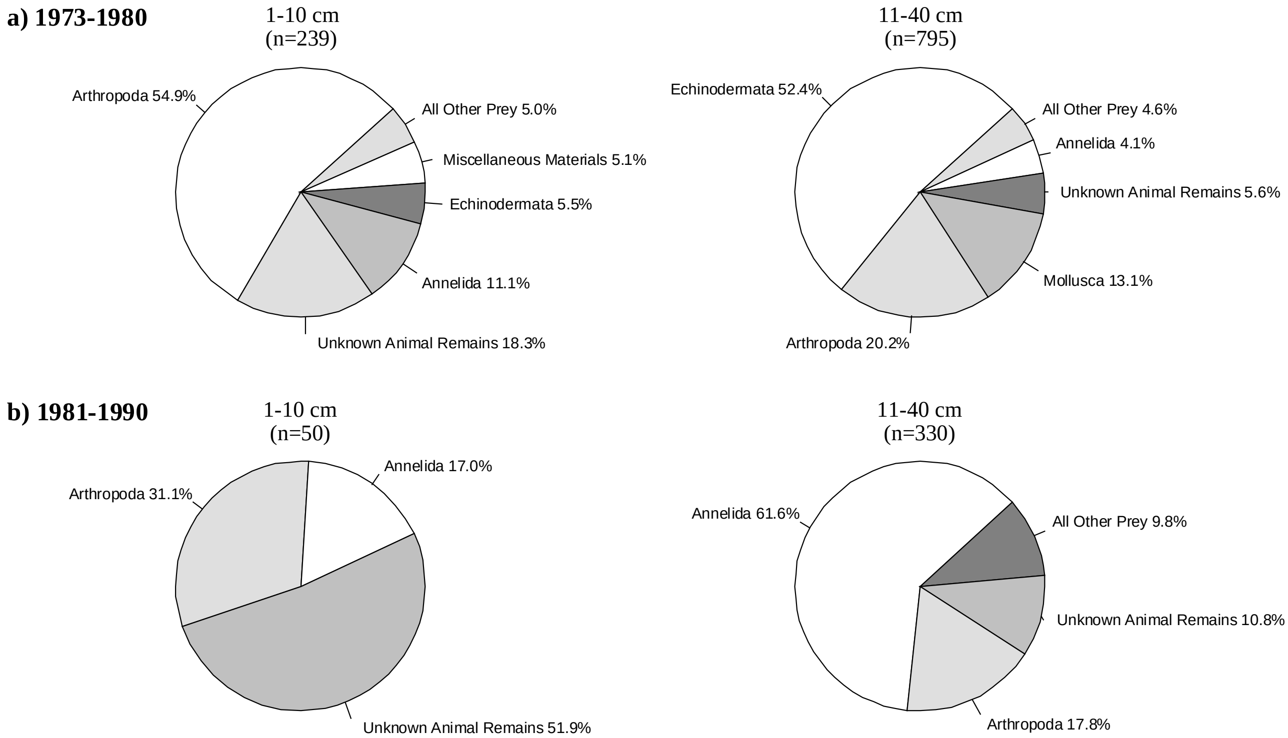


Figure 2. Abundance of the major items in the diet of juvenile (1-10 cm) and adult (11-40 cm) scup collected during NEFSC bottom trawl surveys from 1973-1980 and 1981-1990. Abundance in the 1973-1980 samples is defined by mean percent prey weights, and in the 1981-1990 samples as mean percent prey volume. The "Arthropoda" are almost entirely crustacea; see text for discussion of specific taxa involved. The category "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].

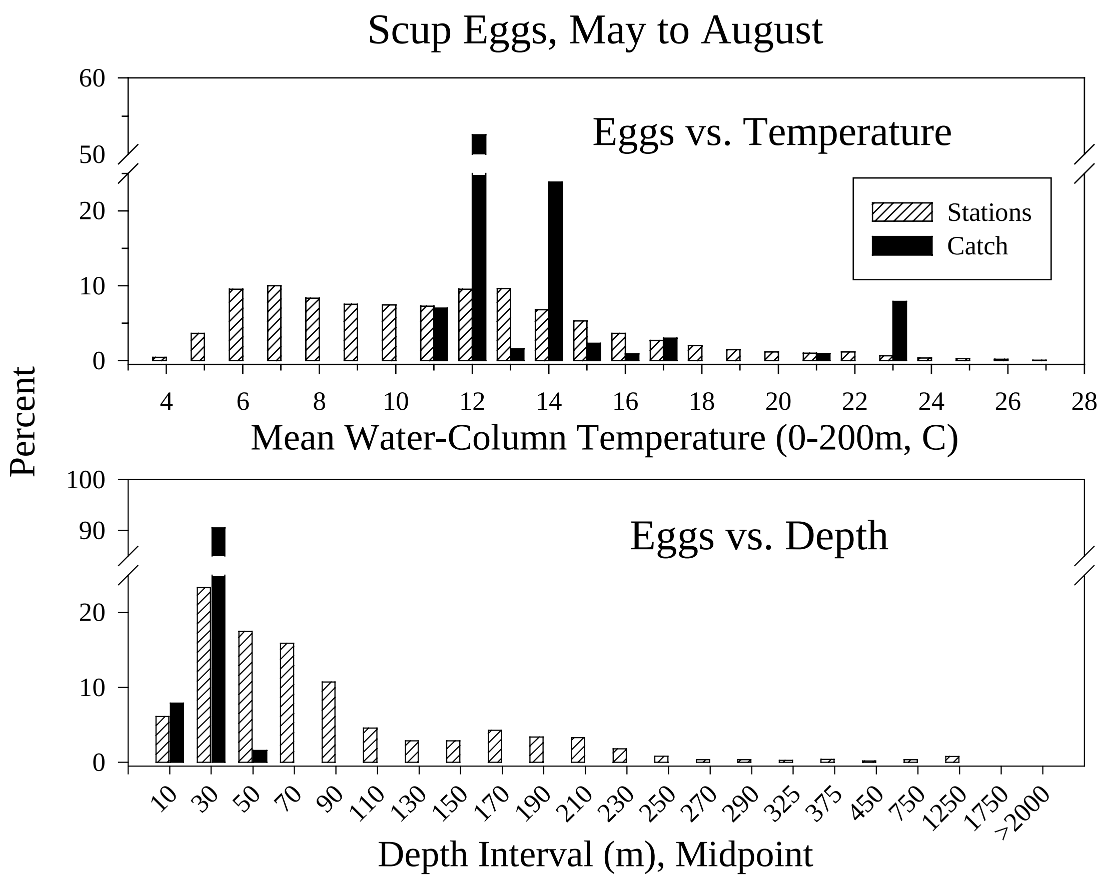


Figure 3. Abundance of scup eggs relative to water column temperature (to a maximum of 200 m) and bottom depth from NEFSC MARMAP ichthyoplankton surveys (May to August 1978-1987, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

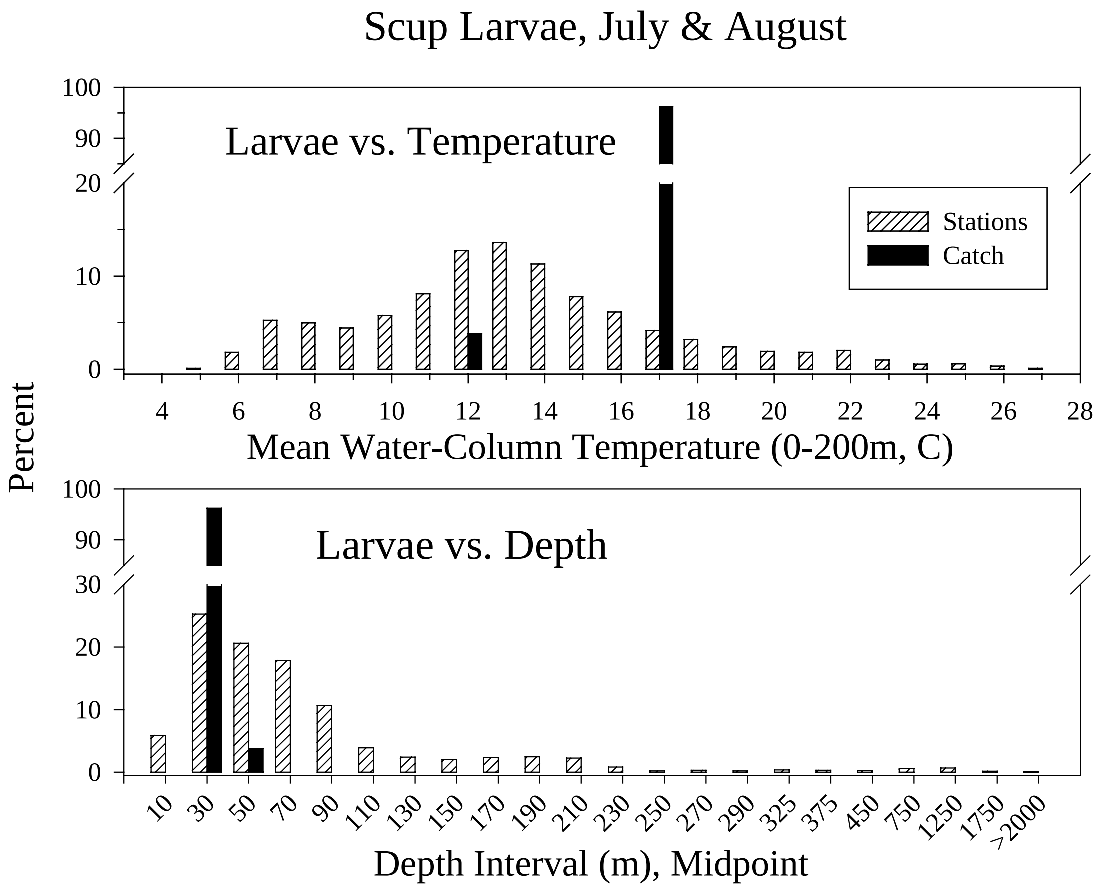


Figure 4. Abundance of scup larvae relative to water column temperature (to a maximum of 200 m) and bottom depth from NEFSC MARMAP ichthyoplankton surveys (July and August 1977-1987, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

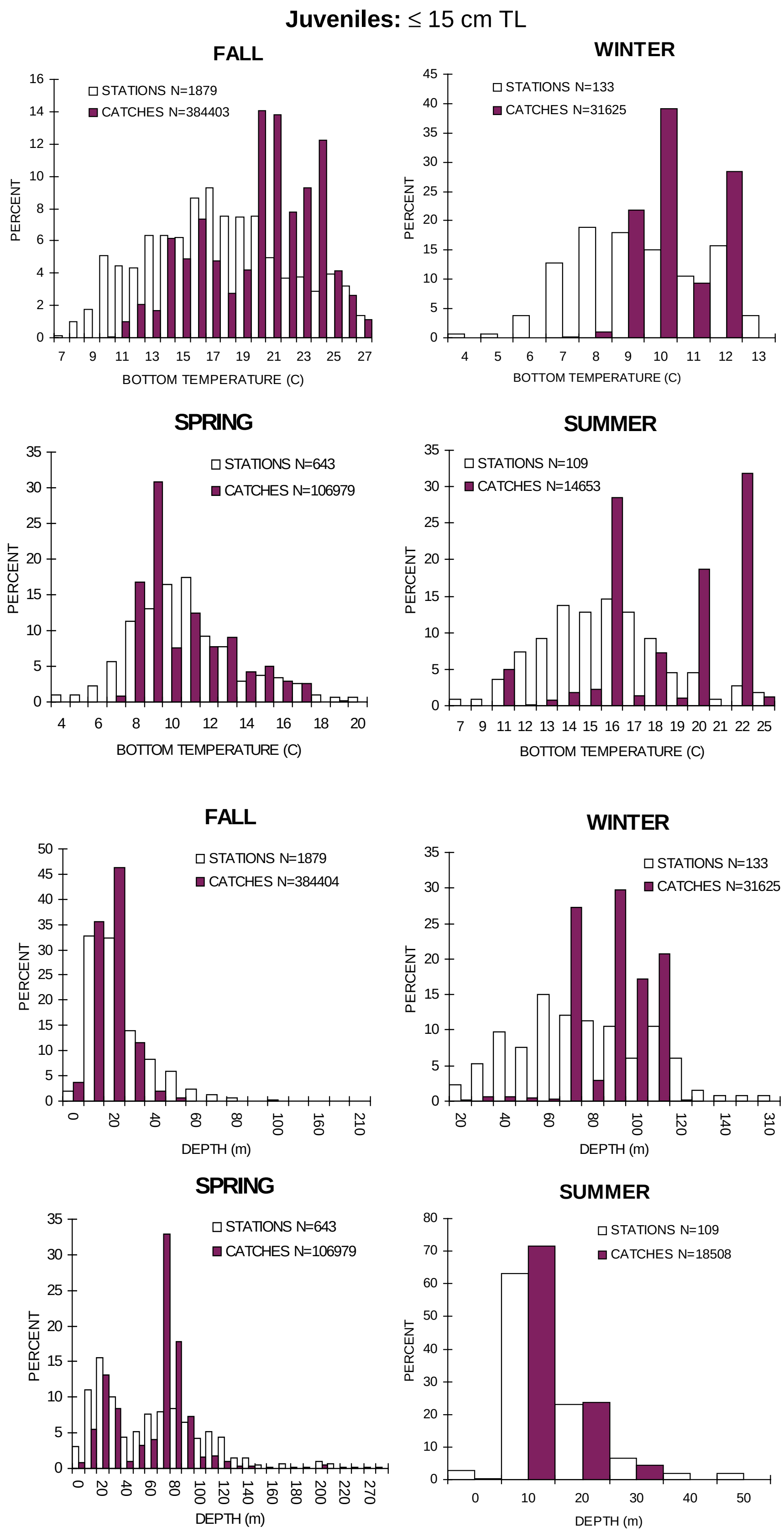


Figure 5. Seasonal abundance of juvenile and adult scup relative to bottom water temperature and depth based on NEFSC bottom trawl surveys (1963-1997, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

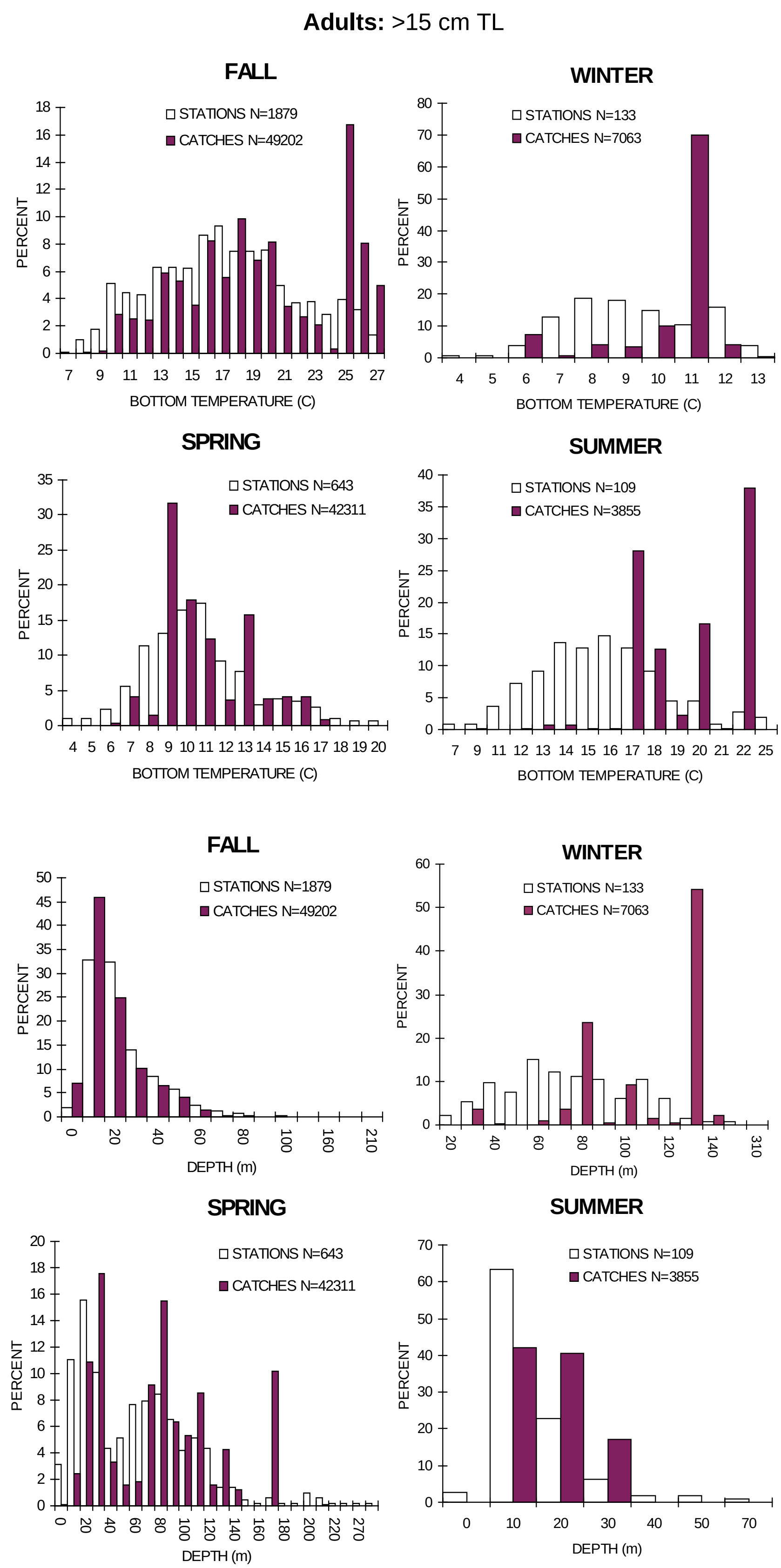


Figure 5. cont'd.

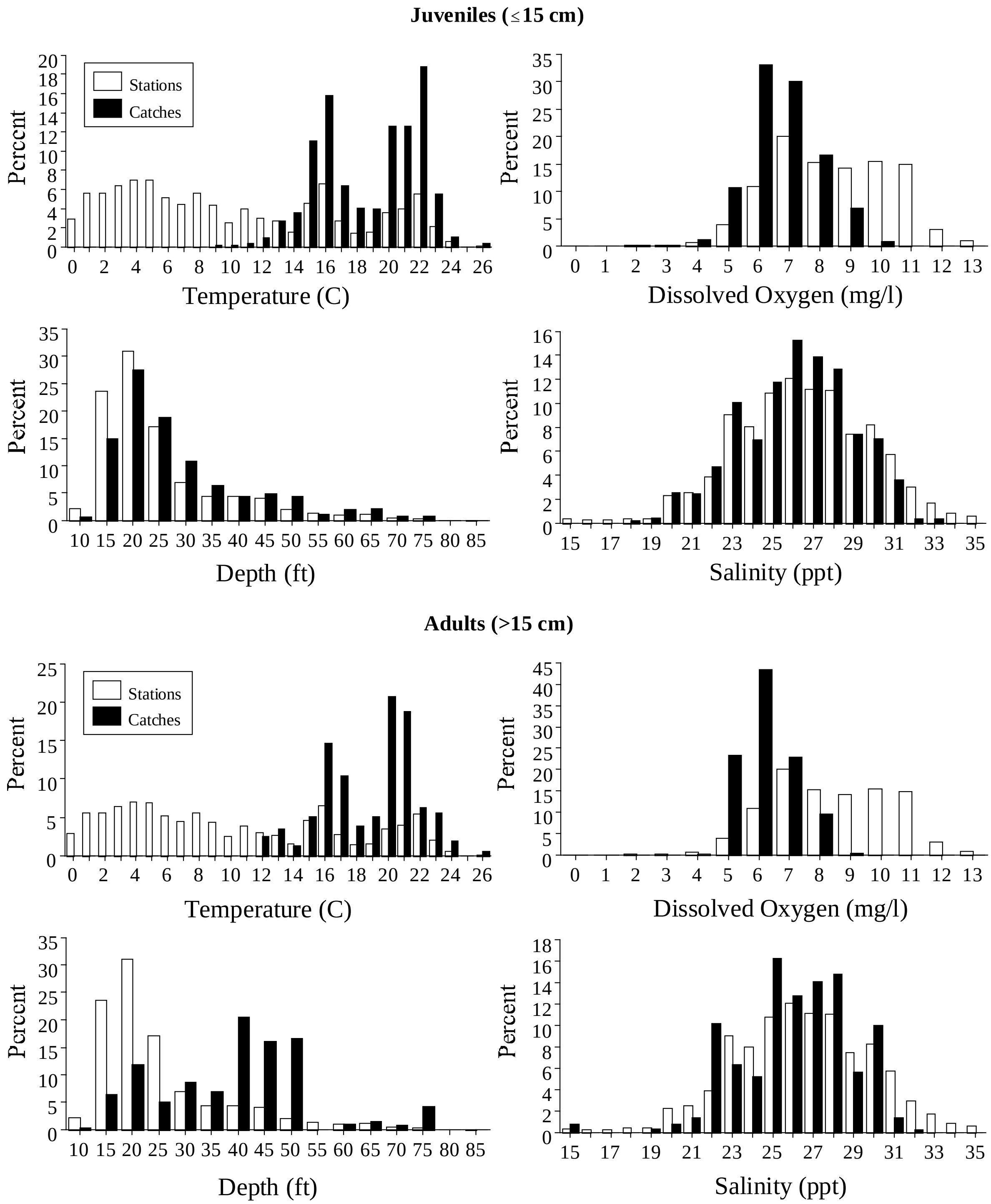


Figure 6. Abundance of juvenile and adult scup relative to bottom water temperature, depth, dissolved oxygen, and salinity based on Hudson-Raritan estuary trawl surveys (1992–1997, all years combined).

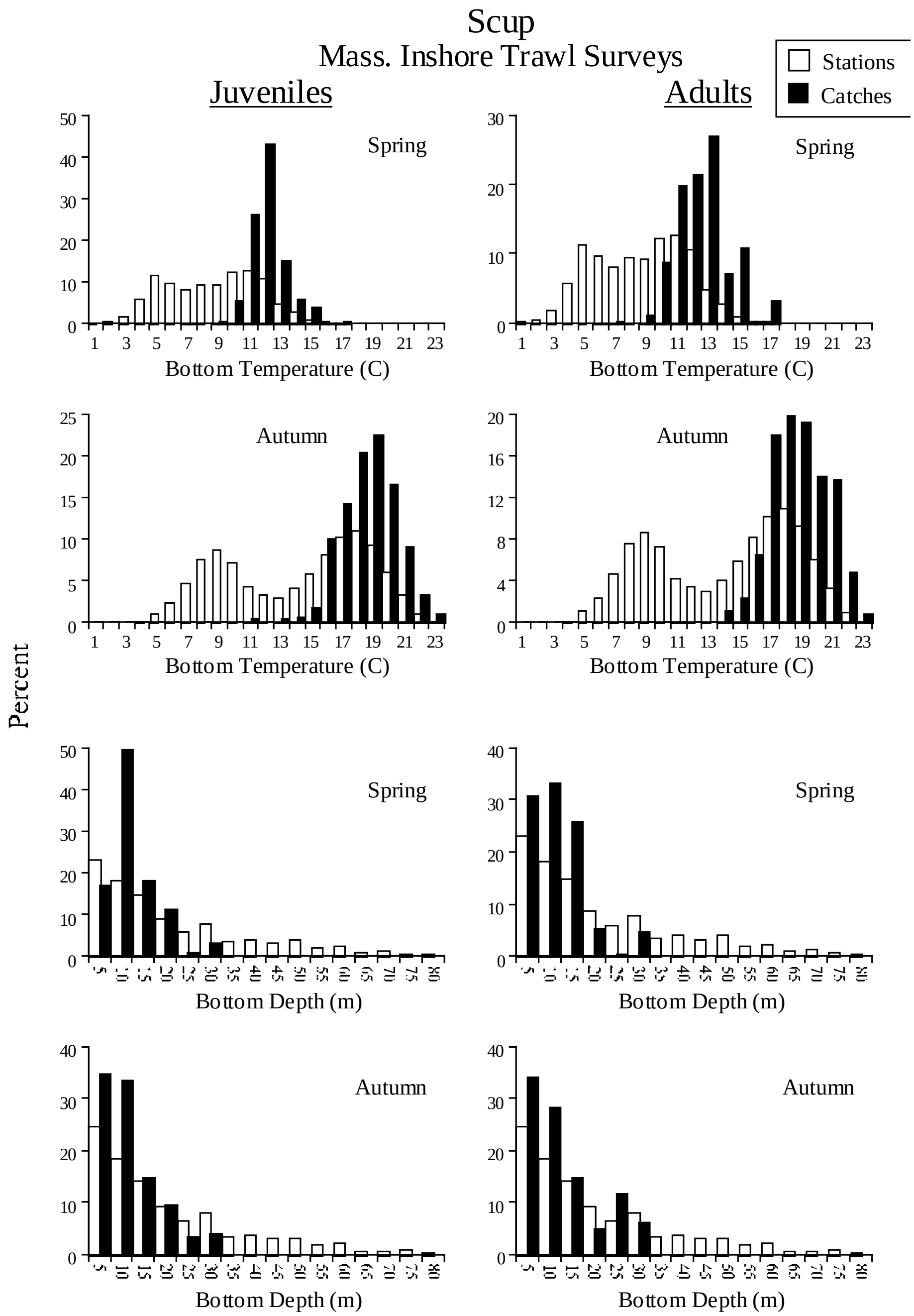


Figure 7. Abundance of juvenile and adult scup relative to bottom water temperature and depth based on Massachusetts inshore bottom trawl surveys (spring and autumn 1978-1996, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of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

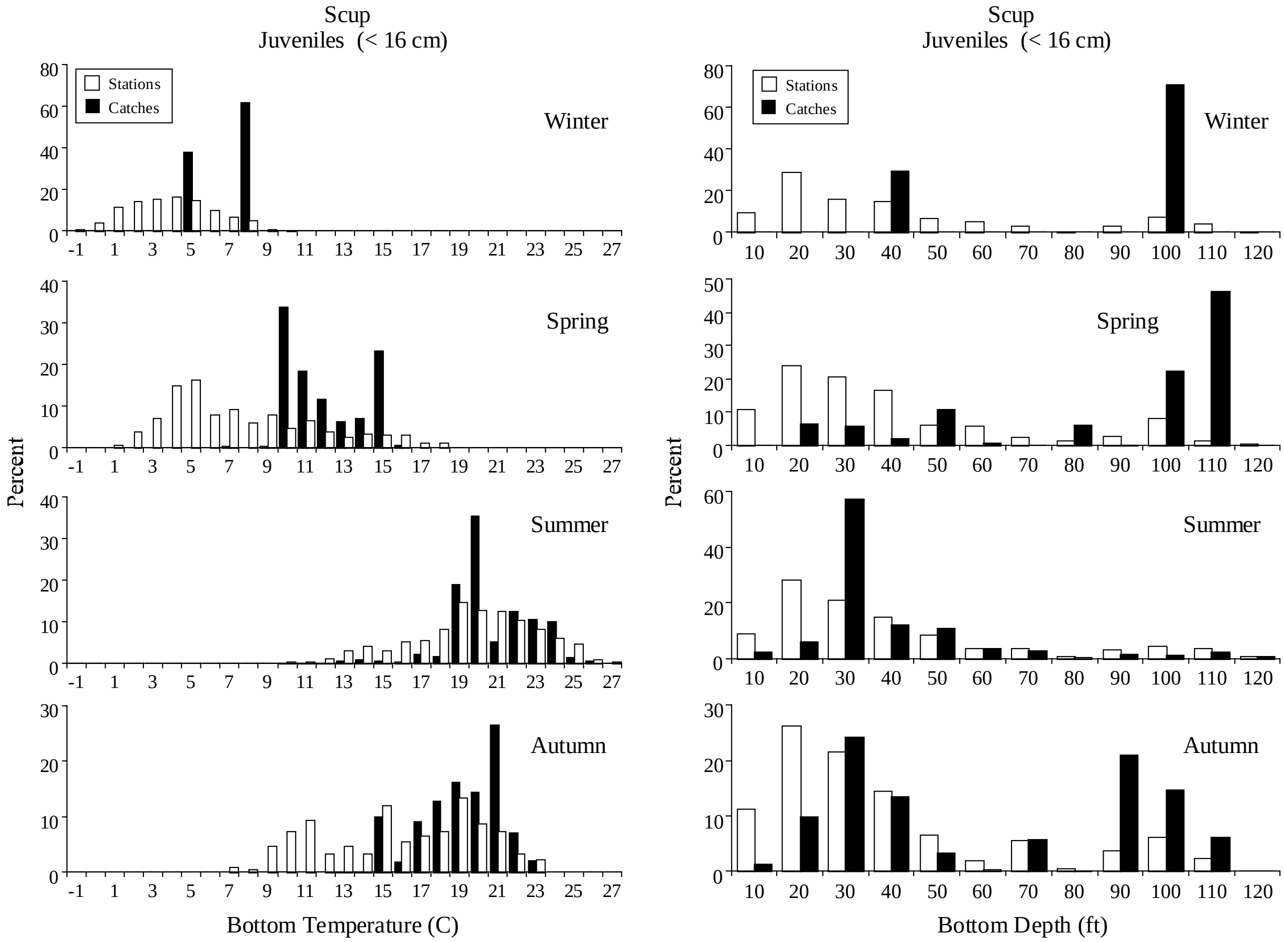
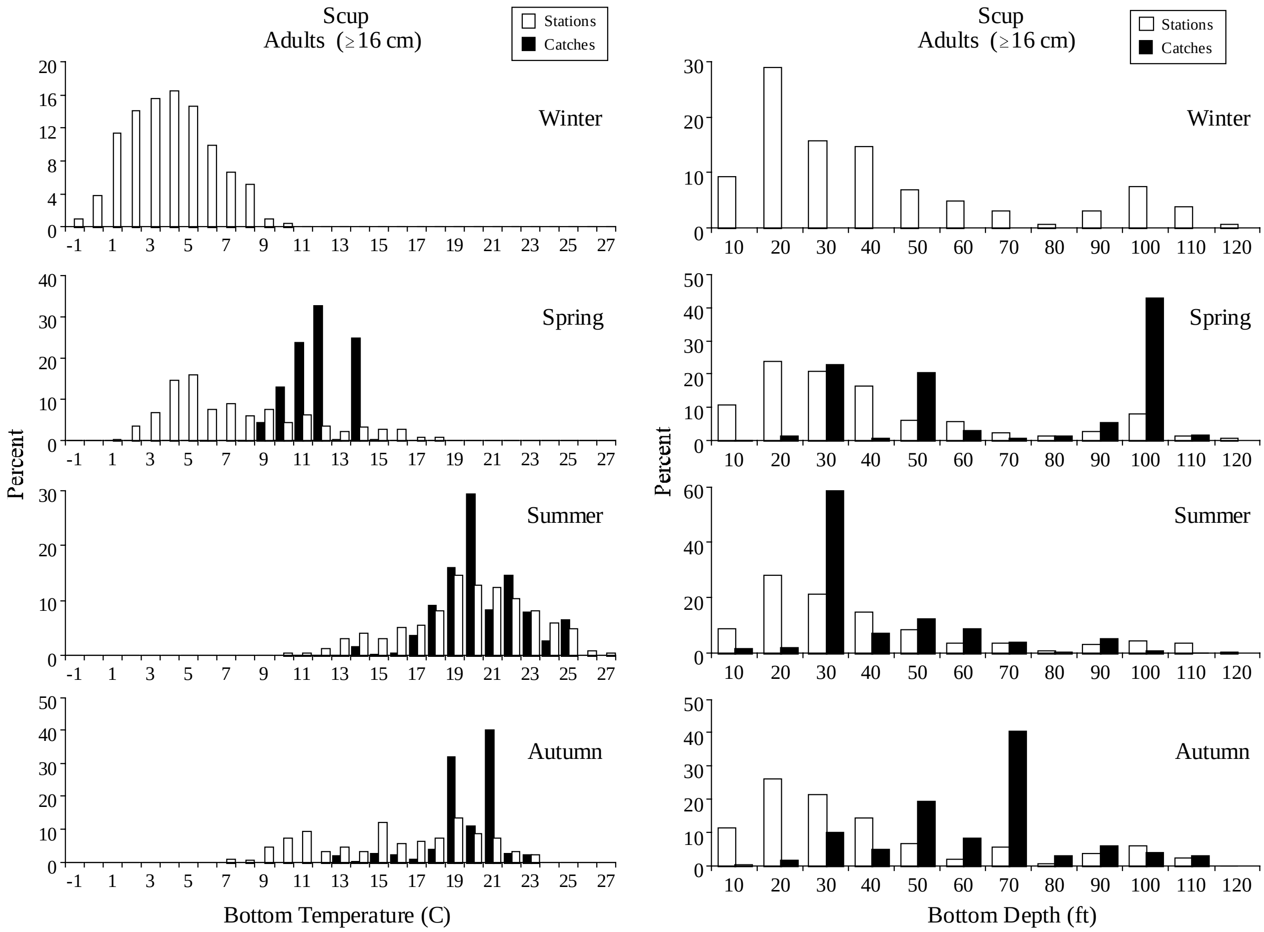


Figure 8. Seasonal abundance of juvenile and adult scup relative to mean bottom water temperature and bottom depth from Rhode Island Narragansett Bay trawl surveys, 1990-1996. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all catches.



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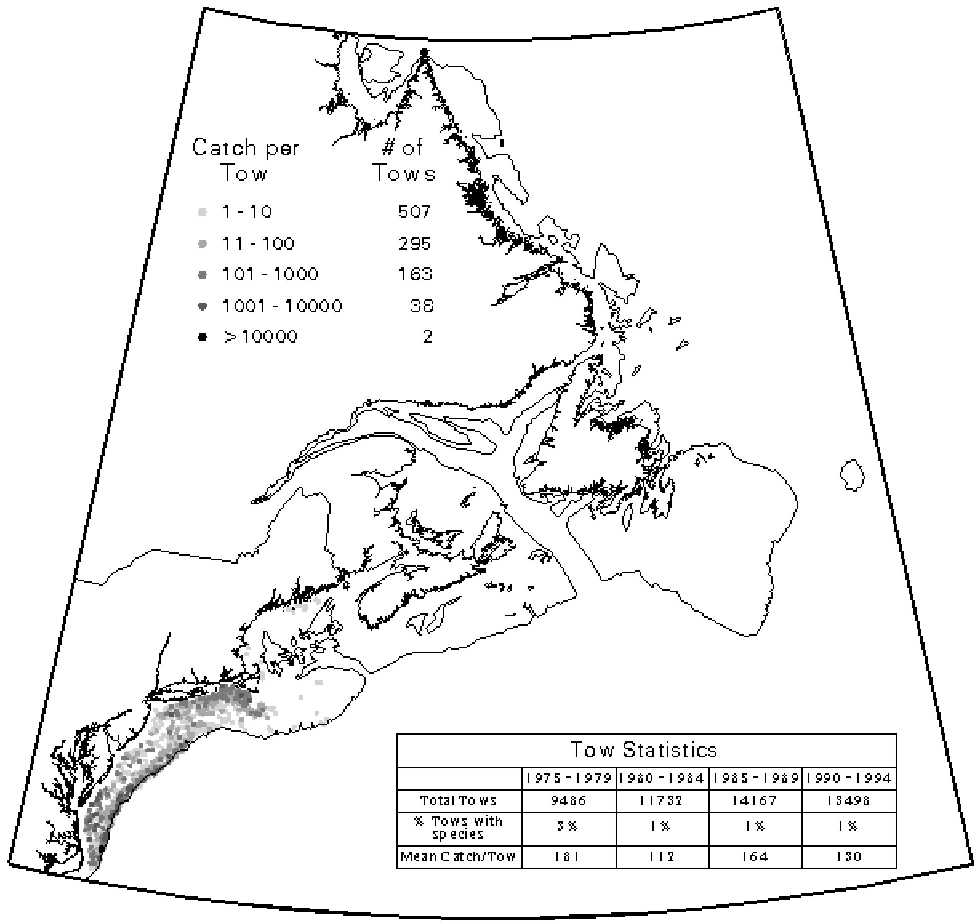


Tow Statistics

	1975 - 1979	1980 - 1984	1985 - 1989	1990 - 1994
Total Tows	9486	11732	14167	13498
% Tows with species	3 %	1 %	1 %	1 %
Mean Catch/Tow	181	112	164	130

Figure 9. The distribution of scup from Newfoundland to Cape Hatteras. 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).

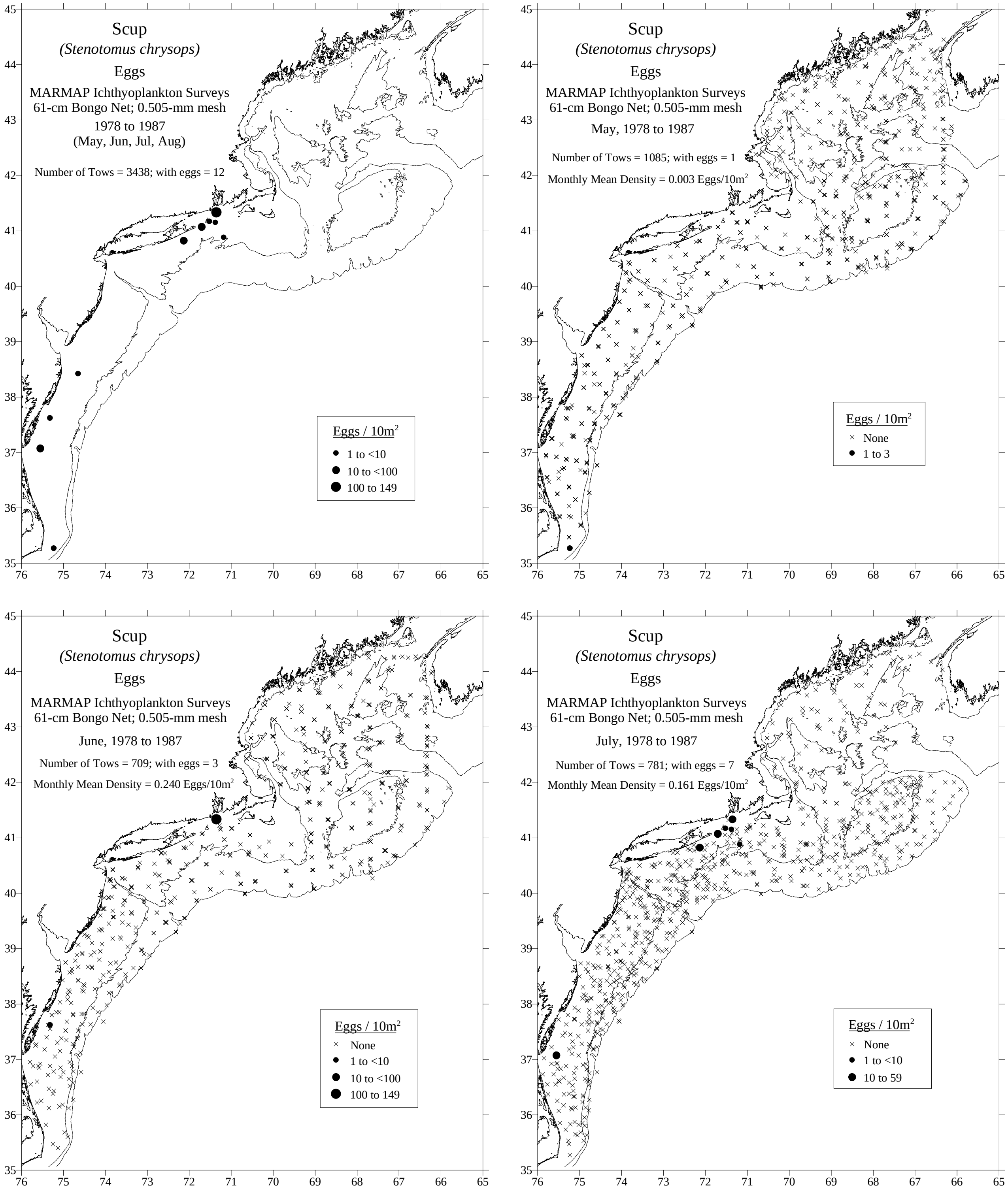


Figure 10. Distribution and abundance of scup eggs collected during NEFSC MARMAP ichthyoplankton surveys, 1978-1987 [see Reid *et al.* (1999) for details]. The upper left figure is a summary of all months and years; the remaining figures are by individual month (May, June, July and August) for all years combined.

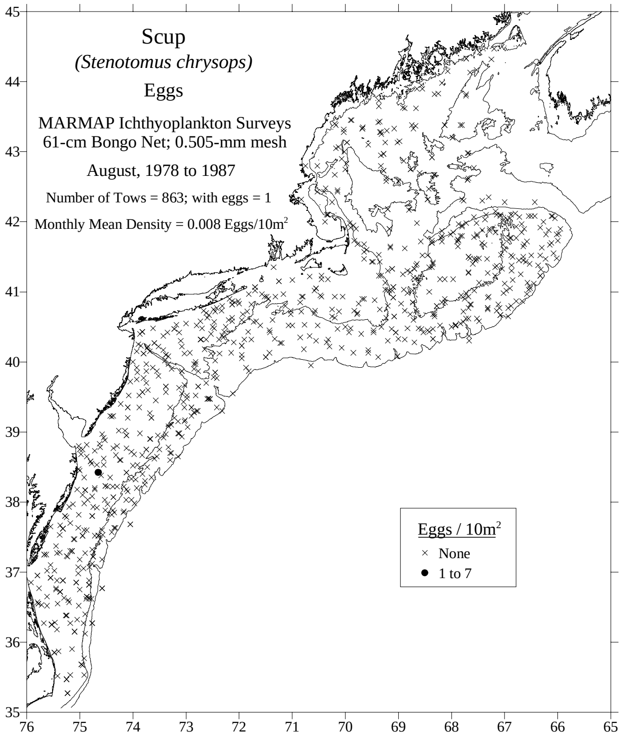


Figure 10. cont'd.

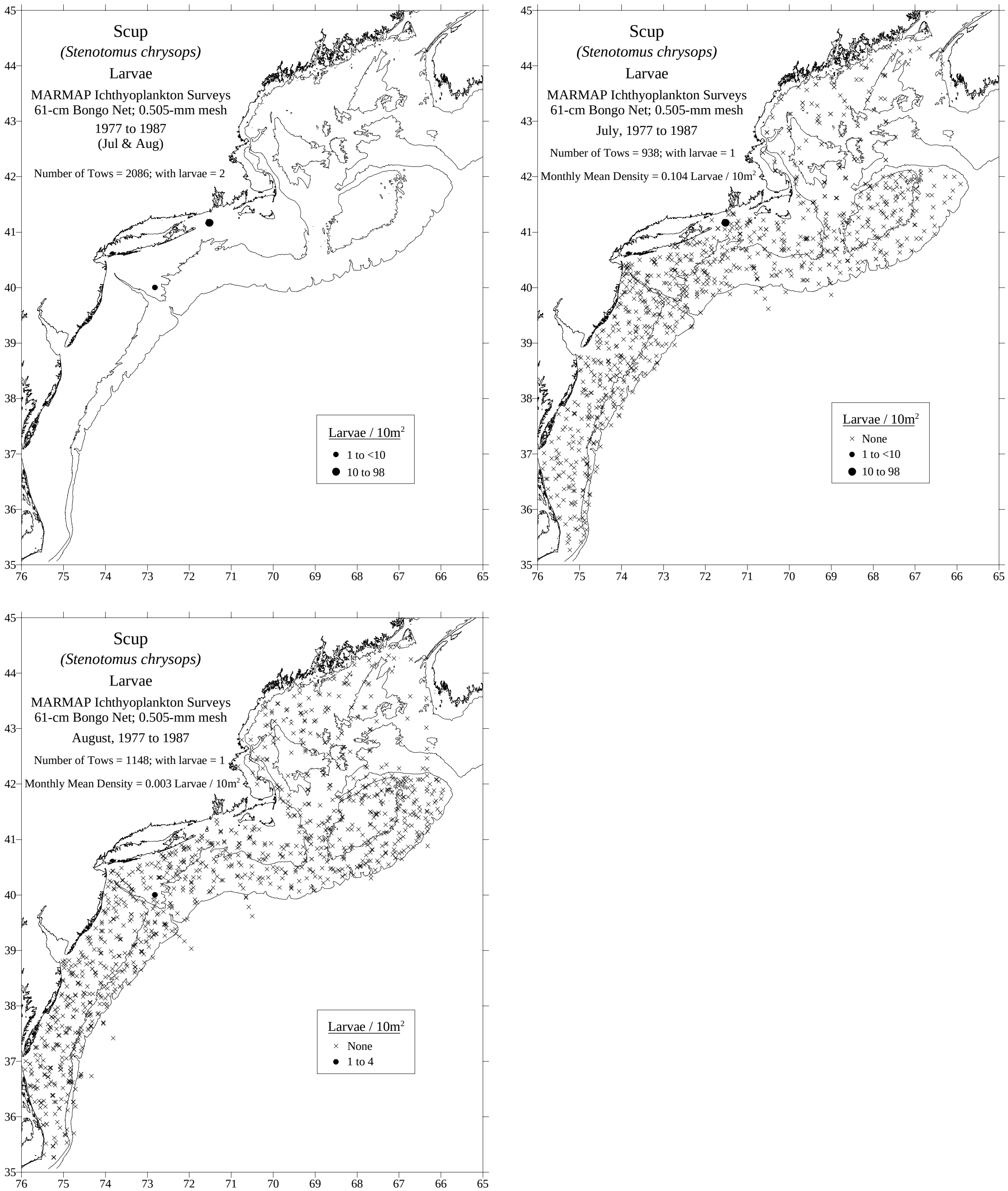


Figure 11. Distribution and abundance of scup larvae collected during NEFSC MARMAP ichthyoplankton surveys, 1977-1987 [see Reid *et al.* (1999) for details]. The upper left figure is a summary of all months and years; the remaining figures are by individual month (July and August) for all years combined.

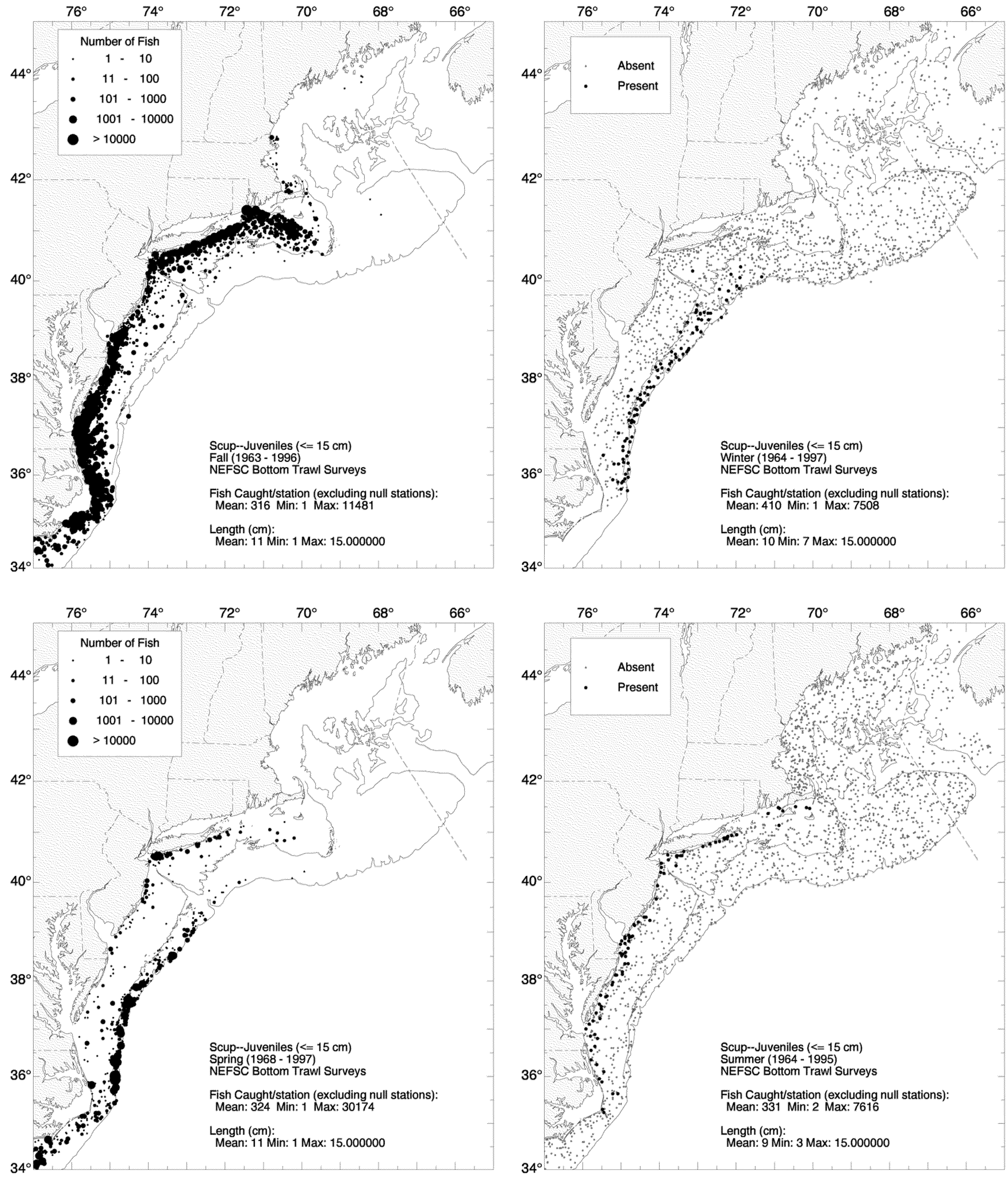


Figure 12. Distribution and abundance of juvenile and adult scup collected during NEFSC bottom trawl surveys (1963-1997, all years combined). Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999)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

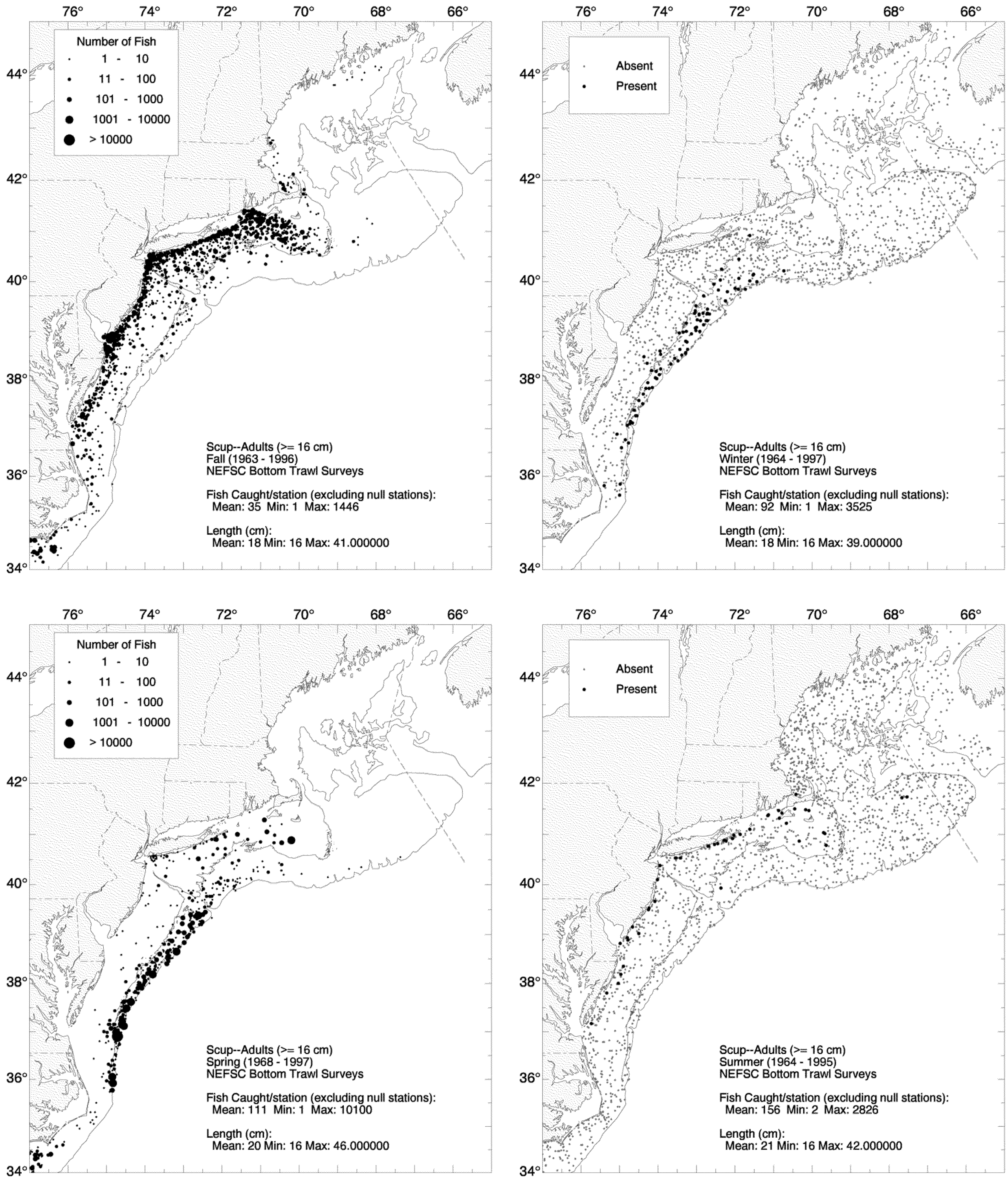


Figure 12. cont’d.

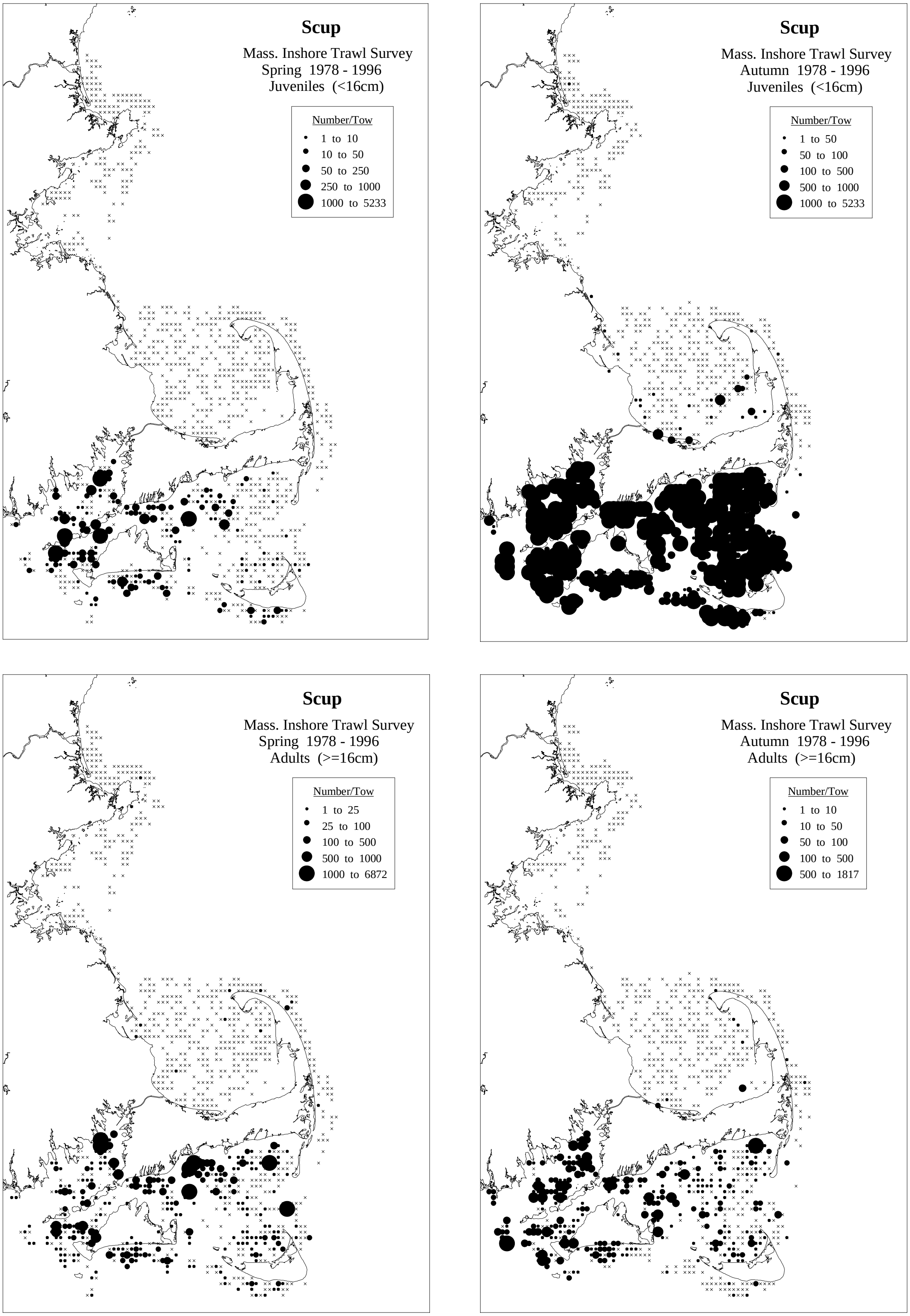


Figure 13. Distribution and abundance of juvenile and adult scup in Massachusetts coastal waters collected during spring and autumn Massachusetts inshore bottom trawl surveys, 1978-1996 [see Reid *et al.* (1999) for details].

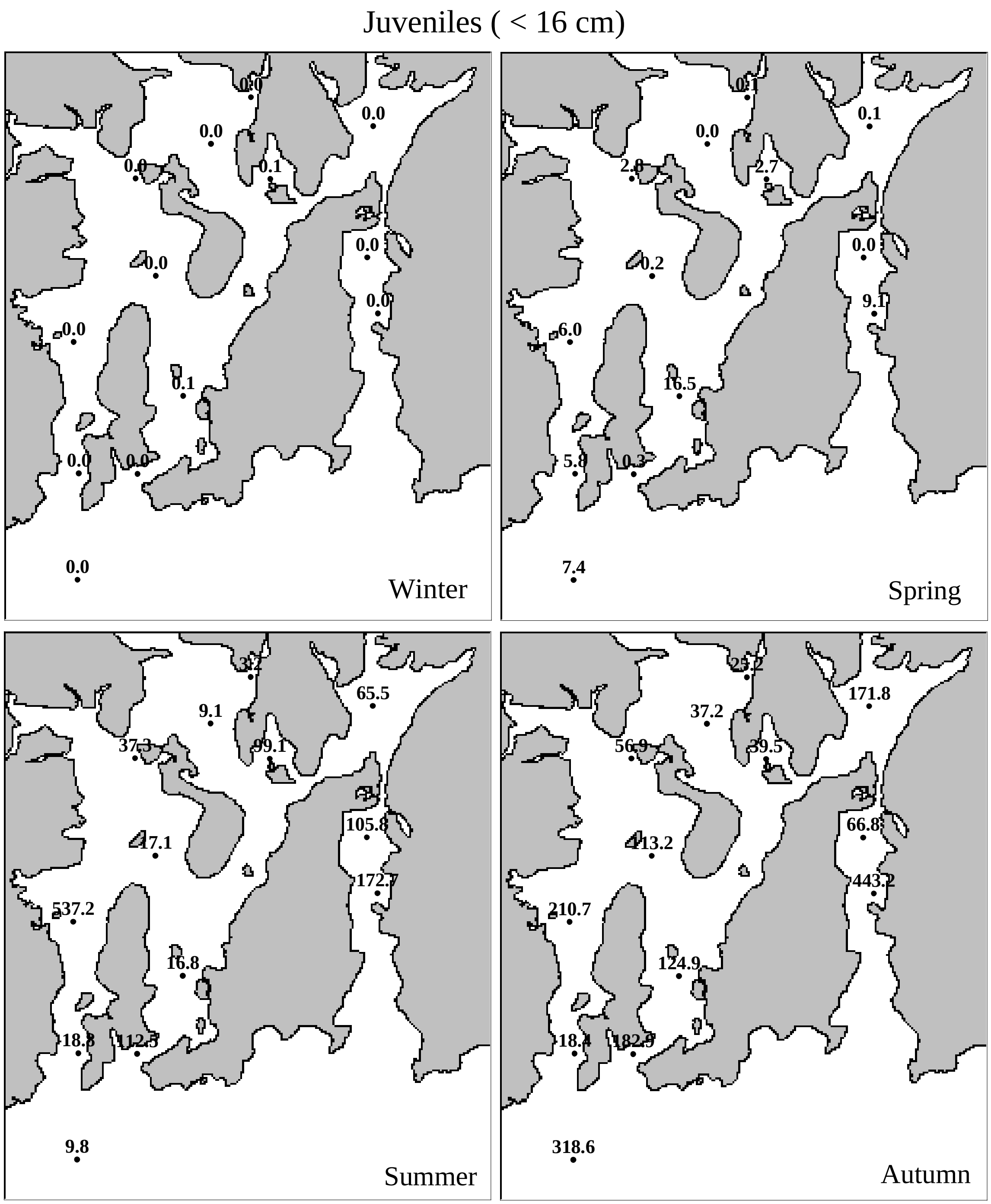


Figure 14. Seasonal distribution and abundance of juvenile and adult scup collected in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid *et al.* (1999) for details].

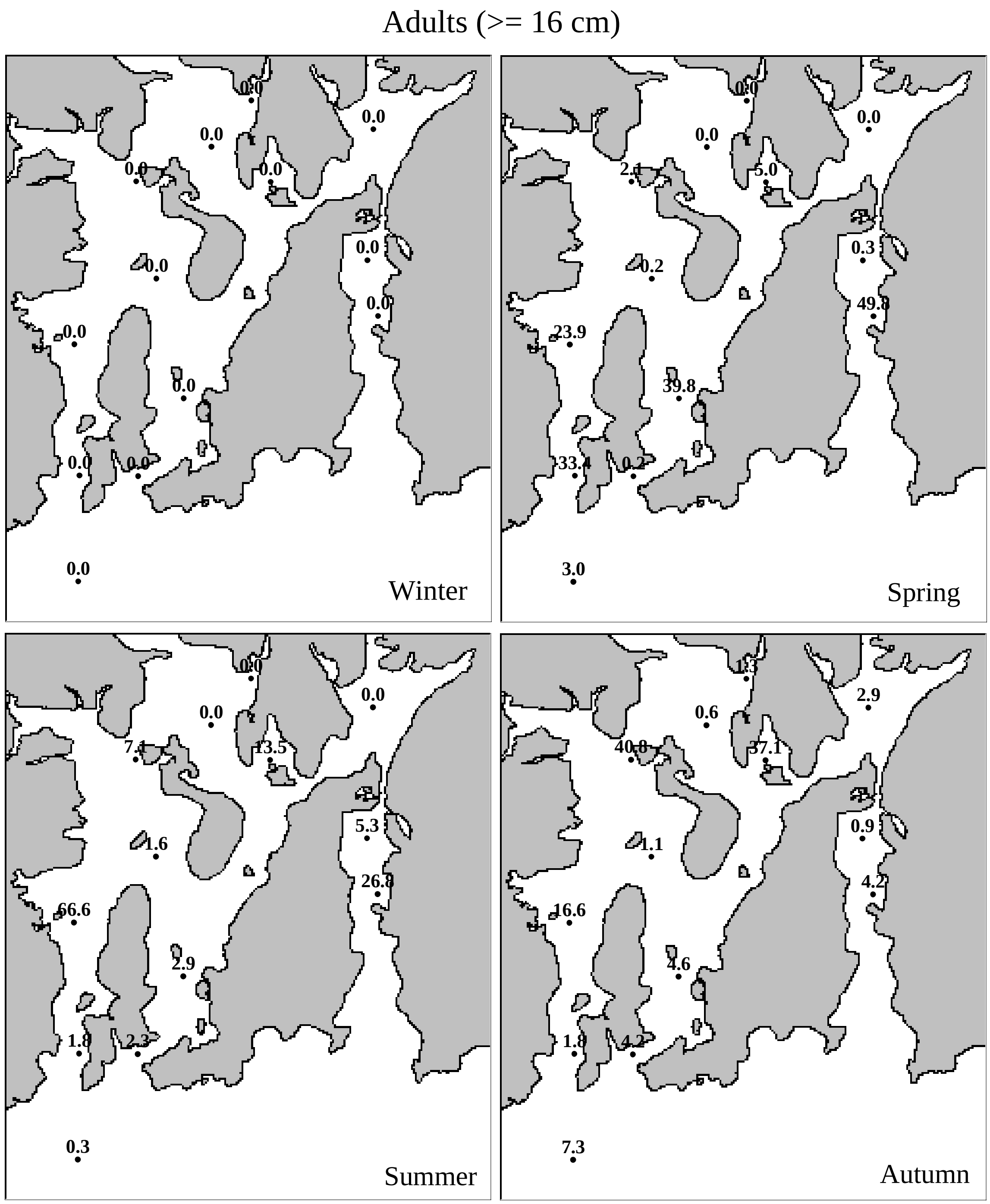


Figure 14. cont'd.

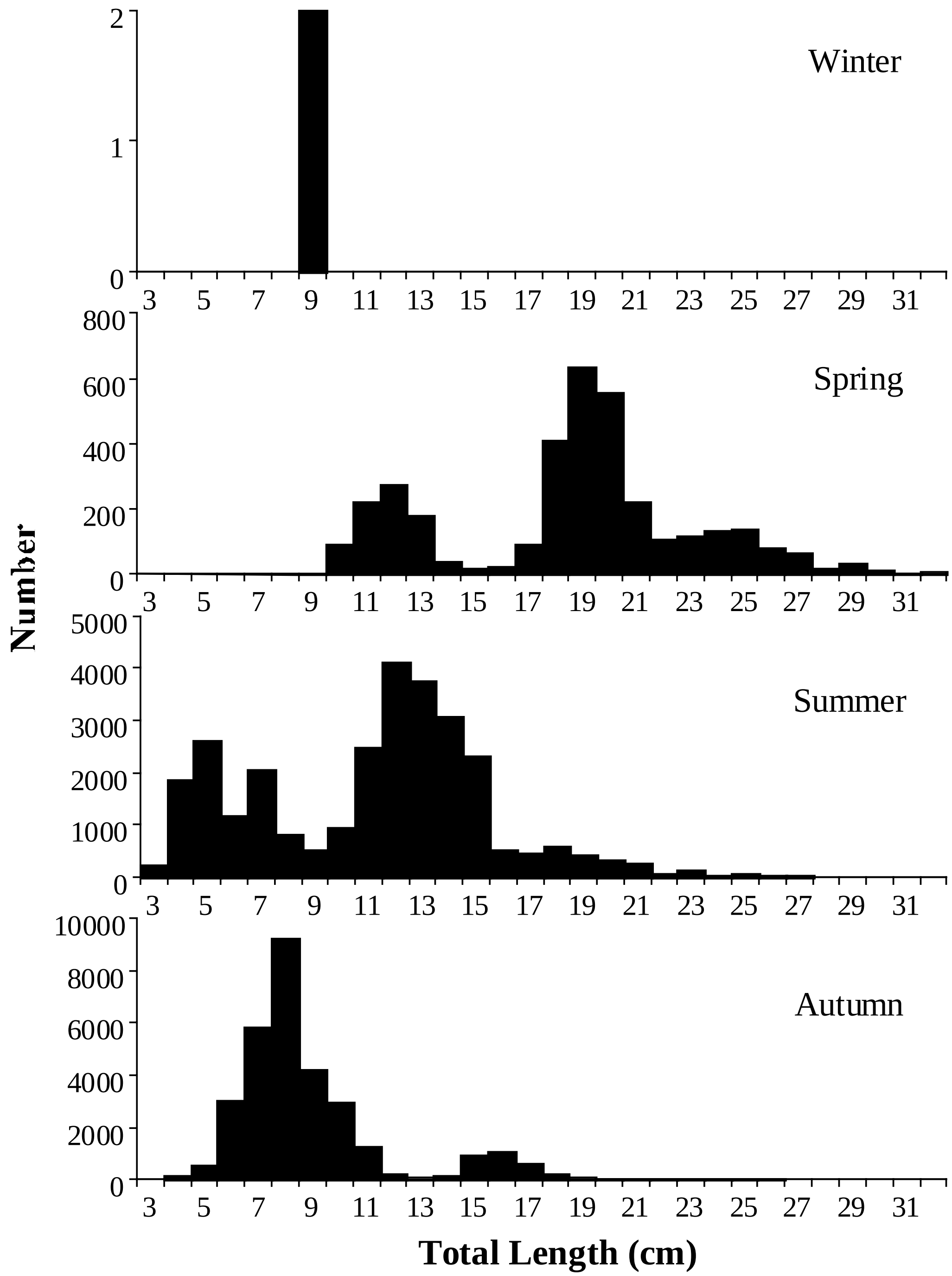
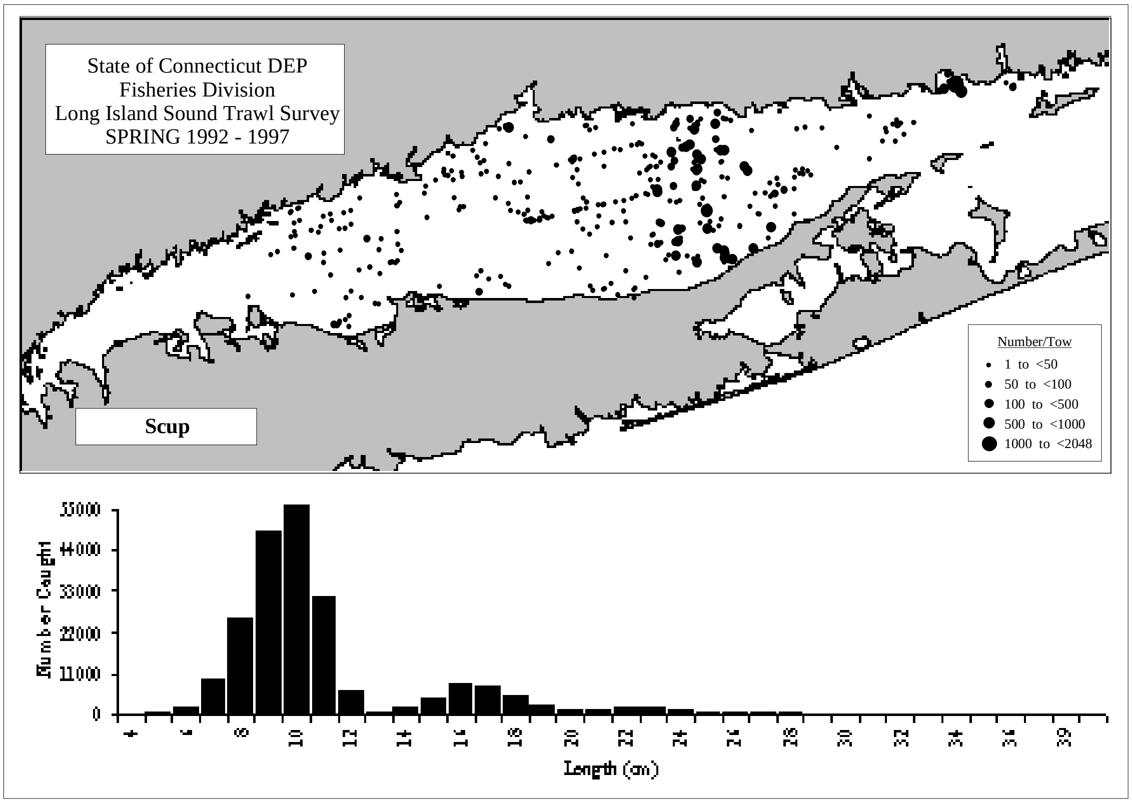


Figure 15. Size frequency distribution of scup collected in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys.



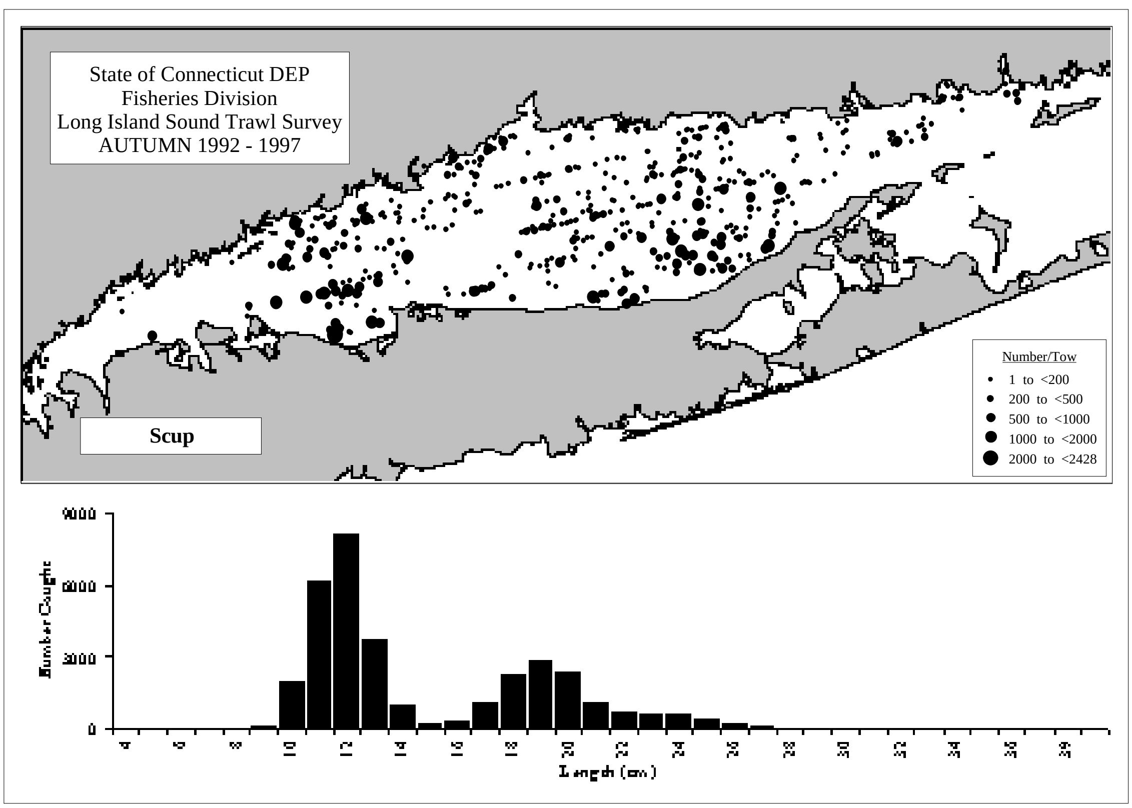


Figure 16. Distribution, abundance, and size frequency of scup in Long Island Sound in spring and autumn, from the Connecticut bottom trawl surveys, 1992-1997 [see Reid *et al.* (1999) for details].

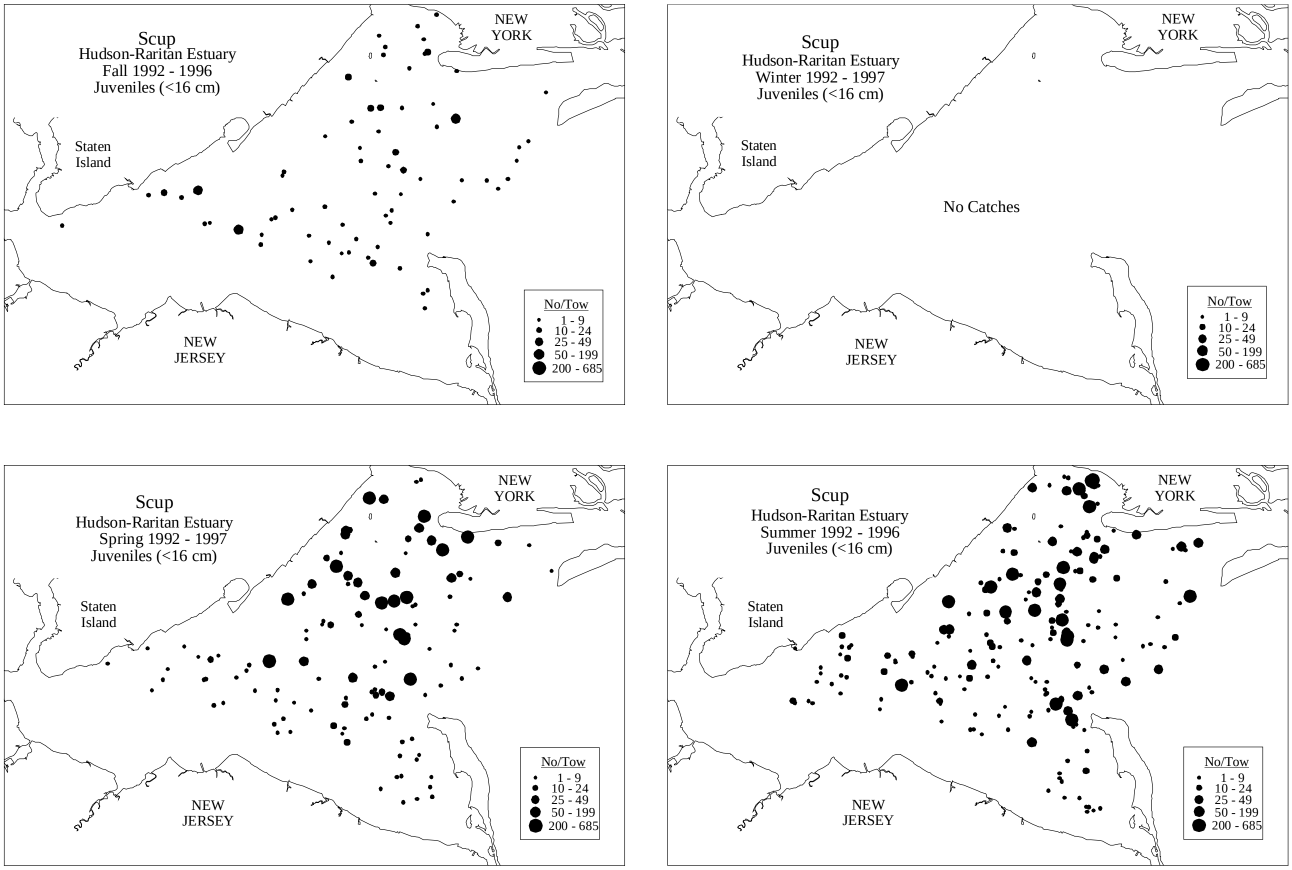


Figure 17. Seasonal distribution and abundance of juvenile and adult scup in the Hudson-Raritan estuary collected during Hudson-Raritan estuary trawl surveys, 1992–1997 [see Reid *et al.* (1999) for details].

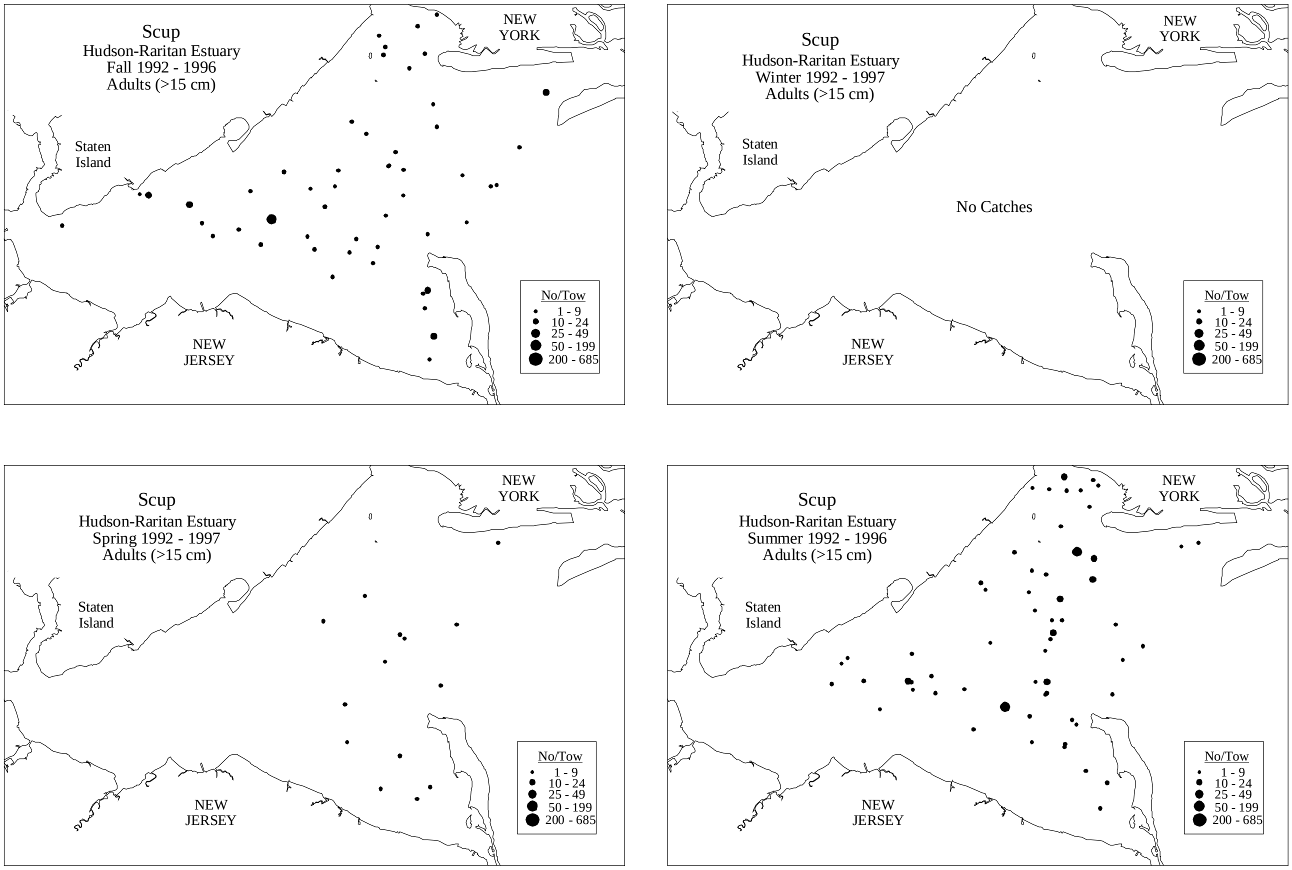


Figure 17. cont'd.

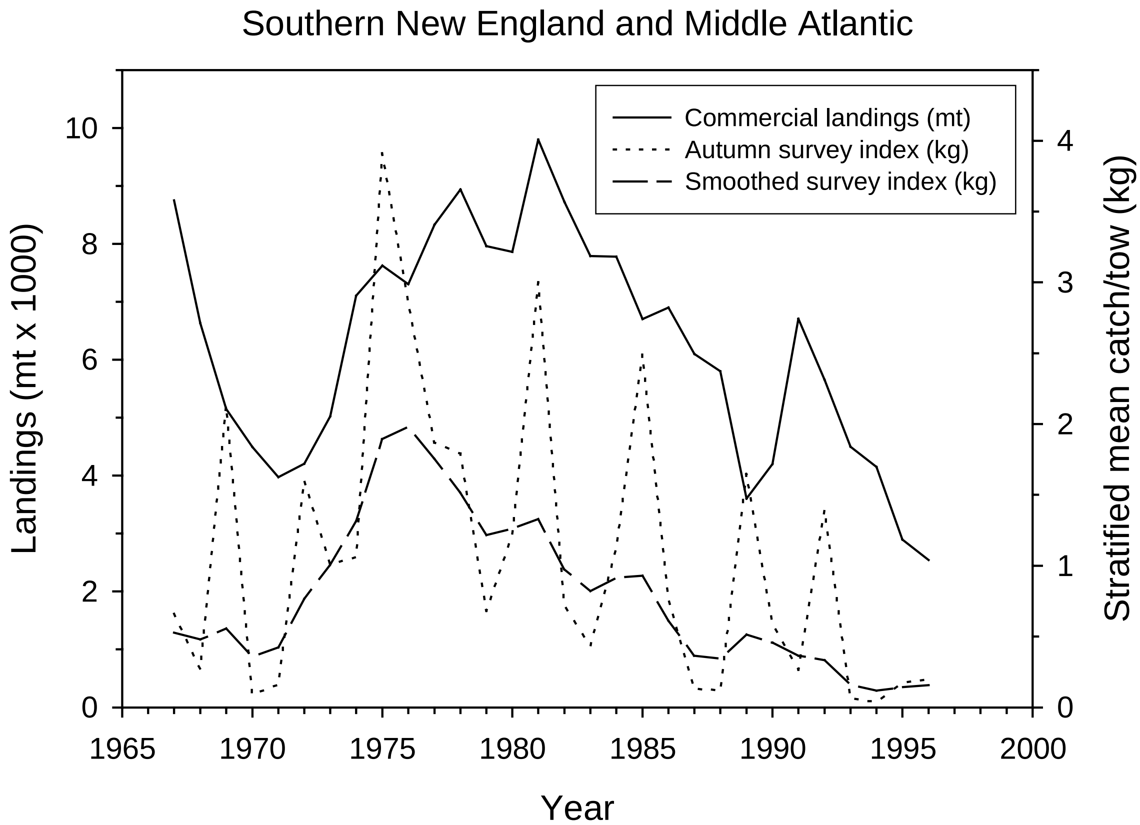


Figure 18. Commercial landings (metric tons, mt) and NEFSC bottom trawl survey indices (stratified mean catch per tow, kg) for scup in southern New England and the Middle Atlantic Bight.

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