NOAA Technical Memorandum NMFS-NE-145

Essential Fish Habitat Source Document:

Butterfish, *Peprilus triacanthus*, 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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Essential Fish Habitat Source Document:

Butterfish, *Peprilus triacanthus*, 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

Butterfish, *Peprilus triacanthus* (Figure 1), range from Newfoundland and the Gulf of St. Lawrence to the Atlantic and Gulf coasts of Florida (Figure 2), but they are most abundant from the Gulf of Maine to Cape Hatteras (Bigelow and Schroeder 1953; Haedrich 1967; Horn 1970a; Powell *et al*. 1972; Cooley 1978; Scott and Scott 1988; Brodziak 1995; Klein-MacPhee, in review). Butterfish are fast-growing, short-lived, pelagic fishes that form loose schools, often near the surface (Schreiber 1973; Dery 1988; Brodziak 1995). They winter near the edge of the continental shelf in the Middle Atlantic Bight and migrate inshore in the spring into southern New England and Gulf of Maine waters. During the summer, butterfish occur over the entire mid-Atlantic shelf from sheltered bays and estuaries out to about 200 m. In late fall, butterfish move southward and offshore in response to falling water temperatures (Fritz 1965; Horn 1970a; Schreiber 1973; Waring 1975; Azarovitz *et al*. 1980; Klein-MacPhee, in review).

LIFE HISTORY

Butterfish are short-lived and grow rapidly; few individuals live beyond 3 years and most are sexually mature at 1-2 years of age. The maximum age reported is 3+ years (DuPaul and McEachran 1973; Waring 1975; Kawahara 1977a) and 6 years (Draganik and Zukowski 1966). Butterfish are eurythermal (4.4-21.6ºC; Fritz 1965; Schaefer 1967; Horn 1970a) and euryhaline (5-32 ppt; Musick 1972).

EGGS

Butterfish eggs are buoyant, transparent, and spherical (0.68-0.82 mm diameter; Wheatland 1956; Colton and Marak 1969; Martin and Drewry 1978; Elliott and Jiminez 1981). The incubation period is about 48 hrs at 18ºC; 50% of eggs hatched at 72 hrs at about 15ºC (Martin and Drewry 1978; Colton and Honey 1963). Eggs have been collected between 12.8-22.5ºC and 78-100% seawater (Martin and Drewry 1978). At hatching, butterfish are 1.68-1.75 mm; yolk absorption is complete by 2.48-2.64 mm (Colton and Honey 1963; Colton and Marak 1969).

LARVAE

Butterfish larvae range from 2.6 to 16 mm standard length (SL) (Martin and Drewry 1978). By 6 mm they have the thin, deep body that is characteristic of adults and by 15-16 mm they have a forked tail (Horn 1970a; Ditty and Truesdale 1983). At 10-15 mm, larvae are more nektonic than planktonic (Martin and Drewry 1978) and are caught in neuston nets (Powles and Stender 1976; Lux and Wheeler 1992). They begin to associate with jellyfish, *Sargassum*, and other flotsam at this size (Mansueti 1963; Haedrich 1967; Horn 1970b; Thomas and Milstein 1973; Lippson and Lippson 1984). Larvae may undertake diel vertical migrations; more butterfish larvae were collected between 0-4 m at night than during the day (Kendall and Naplin 1981). Metamorphosis is gradual as the larvae progressively assume juvenile characters (Able and Fahay 1998). Rotunno (1992) reported growth rates of 0.227 mm/day for fish 6.0-28.0 mm SL based on otolith analyses.

JUVENILES

Juvenile butterfish range from 16 mm to about 120 mm SL (Martin and Drewry 1978). During their first year, they grow to 76-127 mm, or about half their adult size (Hildebrand and Schroeder 1928; Klein-MacPhee, in review). Early-spawned individuals are 76-102 mm in the fall; late-spawned individuals are 51-76 mm in the fall and 76-127 mm the following spring (Martin and Drewry 1978). Young butterfish (< 30 mm) often live in the shelter of large jellyfishes during their first summer. Although this commensal association is not essential, it is a source of food and provides young butterfish some protection from their predators (Mansueti 1963; Horn 1970b, 1975).

ADULTS

Adult butterfish range from about 120 mm to 305 mm SL (Hildebrand and Schroeder 1928) with an average length of 150-230 mm (Klein-MacPhee, in review). The median length at maturity (L_{50}) for butterfish collected on the northeast shelf (1986-1989) was 12.0 cm total length (TL) for females and 11.4 cm TL for males (O'Brien *et al*. 1993), which corresponds to an age of about 1 year (Horn 1970a; DuPaul and McEachran 1973). In Chesapeake Bay, butterfish begin to mature during their second summer (age 1) and most individuals are mature by their third summer (DuPaul and McEachran 1973). In the New York Bight, ripe females 124-242 mm FL were collected in 3-145 m of water from May through August; less than 5% of the ripe females were collected in the Hudson-Raritan estuary (Wilk *et al.* 1990). At 2+ years of age, butterfish are about 17 cm and at 3+, they are about 19 cm (Waring and Murawski 1982).

REPRODUCTION

Butterfish are broadcast spawners (Horn 1970a) and spawn primarily in the evening or at night (Ferraro 1980;

Kendall and Naplin 1981), but no direct observations have been made (Klein-MacPhee, in review). Butterfish may spawn in the upper part of the water column during the evening; more eggs were collected between 0-4 m at night in the Middle Atlantic Bight than during the day (Kendall and Naplin 1981).

Butterfish are usually reported to spawn offshore (e.g., Wang and Kernehan 1979). Butterfish may spawn a few miles out to sea off Woods Hole, MA and return inshore when they are spent (Klein-MacPhee, in review). However, eggs and larvae have been collected in coastal waters and most estuaries in the northern part of the Middle Atlantic Bight (Hildebrand and Schroeder 1928; Herman 1963; Martin and Drewry 1978; Lux and Wheeler 1992; Able and Fahay 1998). Early stage eggs have been collected in Narragansett Bay and Salem Harbor (Herman 1963; Bourne and Govoni 1988; Elliott and Jiminez 1981), Raritan Bay, NJ (Croker 1965), and in the lower portions of Chesapeake Bay (Lippson and Moran 1974), but not in Delaware Bay (Wang and Kernehan 1979).

Water temperatures appear to regulate butterfish reproduction as spawning dates are progressively later in the year in the northern part of its range (Murawski *et al.* 1978; Rotunno and Cowen 1997; Able and Fahay 1998). Spawning may occur year round in the South Atlantic Bight with a peak in spring (Fahay 1975; Able and Fahay 1998). Spawning probably does not occur below 15ºC (Colton 1972).

Butterfish begin spawning in Chesapeake Bay as early as late May with a peak in activity in June and July (Hildebrand and Schroeder 1928; Pearson 1941). Spawning in the Middle Atlantic Bight occurs from May through October (Smith *et al.* 1980); the gonad weight of fish > 15 cm increases in March and April, reaches its maximum during June and July, and decreases in the fall (Kawahara 1977b). In Long Island Sound, spawning occurs from June through late August with a peak in late July; the principal spawning areas are in the eastern part of the sound (Perlmutter 1939). In Narragansett Bay, butterfish eggs are found from June to August (Herman 1963). In Massachusetts Bay, butterfish spawn from June to August (Bigelow and Schroeder 1953). In the Gulf of Maine, spawning begins in May-June, peaks in July, and ends in August (Bigelow and Schroeder 1953; Smith *et al.* 1980). On the Scotian Shelf, spawning occurs from July to October (Markle and Frost 1985).

The spawning period may be more protracted in the Middle Atlantic Bight than previously thought. Rotunno (1992) and Rotunno and Cowen (1997) estimated spawning times from a birthdate analysis of otoliths from butterfish up to about 50 mm SL collected in the Middle Atlantic and South Atlantic bights. Spawning began in February and continued through at least late July. It began in the south and progressed northward over time, which is consistent with the temporal and spatial distribution of larvae, and suggests that butterfish spawn as they migrate north and inshore on their annual migration in association with seasonal warming of waters on the northeast shelf.

FOOD HABITS

Butterfish feed mainly on planktonic prey including thaliaceans (primarily Larvacea and Hemimyaria), mollusks (primarily squids), crustaceans (copepods, amphipods, and decapods), coelenterates (primarily hydrozoans), polychaetes (primarily Tomopteridae and Goniadidae), small fishes, and ctenophores (Fritz 1965; Leim and Scott 1966; Haedrich 1967; Horn 1970a, b; Schreiber 1973; Mauer and Bowman 1975; Oviatt and Kremer 1977; Tibbets 1977; Murawski *et al.* 1978; Bowman and Michaels 1984; Klein-MacPhee, in review).

The food habits of butterfish collected during the northeast shelf during Northeast Fisheries Science Center (NEFSC) bottom trawl surveys [see Reid *et al.* (1999) for details] were similar to diets reported in the literature (Figure 3). The stomach contents were dominated by unidentifiable animal remains. Arthropods dominated the identifiable items, followed by urochordates (thaliaceans and larvaceans), unidentified plankton, annelids (probably polychaetes), chaetognaths (arrowworms), mollusks (probably squids), cnidarians (coelenterates, probably jellyfish), and fishes.

PREDATION

Butterfish are preyed on by many species including haddock, silver hake, goosefish, weakfish, bluefish, swordfish, sharks (hammerhead), and longfin inshore squid (Bigelow and Schroeder 1953; Scott and Tibbo 1968; Horn 1970a; Maurer and Bowman 1975; Tibbets 1977; Stillwell and Kohler 1985; Brodziak 1995; Klein-MacPhee, in review).

MIGRATION

North of Cape Hatteras, butterfish have a seasonal inshore-offshore north-south migration in response to changing water temperatures. There is a limited seasonal inshore-offshore migration south of Cape Hatteras (Caldwell 1961; Fritz 1965; Horn 1970a; Klein-MacPhee, in review). During the summer, butterfish move north and inshore to feed on planktonic fish, squid, crustaceans, and jellyfish, and to reproduce. They remain near the surface at depths of 22-55 m and often come close inshore; schools are frequently seen on shallow flats and in sheltered bays and estuaries (Bigelow and Schroeder 1953; Klein-MacPhee, in review).

Butterfish are common in the lower Chesapeake Bay from March through November (Geer and Austin 1997;

Murdy *et al*. 1997). They occur in Great Bay, NJ and nearby coastal waters from June through November (Able and Fahay 1998) and in the surf zone off Long Island from June through October (Schaefer 1967). They appear off Rhode Island by the last half of April and off Woods Hole, MA by mid-May, although they are not abundant there until June. Butterfish appear on Georges Bank in early June, but are not abundant until late June or early July. They occur in the Gulf of Maine from late June-early July through the fall (Bigelow and Schroeder 1953; Overholtz and Tyler 1985; Klein-MacPhee, in review). They are found in New Hampshire waters from July to October with a peak in abundance in September (MAFMC 1995). Butterfish are common along the coast of Maine and, in some years, they are common along the coast of Nova Scotia bordering the Gulf of Maine (Bigelow and Schroeder 1953).

During the winter, the stock moves south and offshore. Butterfish are found near the bottom over sand, mud, and rock bottoms. They have been caught to about 200 m deep in the northwest Atlantic (Bigelow and Schroeder 1953; Klein-MacPhee, in review) and over 350 m in the South Atlantic Bight (Barans and Burrell 1976). Butterfish are absent from nearshore waters off New Jersey from January through late April (Milstein 1974; Milstein and Hamer 1976). South of Delaware Bay, the winter offshore movement is not so extensive and some individuals move south in shallow water (Waring and Murawski 1982).

STOCK STRUCTURE

Butterfish range from Newfoundland to Florida and are considered a unit stock (Brodziak 1995; Klein-MacPhee, in review). There may be two stocks south of Cape Hatteras that are isolated by depth, although the shallow stock (< 20 m) may be a *Peprilus triacanthus*-*Peprilus burti* hybrid (Caldwell 1961; Horn 1970a; Klein-MacPhee, in review) or *P. burti*, a Gulf of Mexico species (Pershbacher *et al*. 1979).

HABITAT CHARACTERISTICS

Butterfish are pelagic fishes that form loose schools, often near the surface (Schreiber 1973; Dery 1988; Brodziak 1995). They winter near the edge of the continental shelf in the Middle Atlantic Bight and migrate inshore in the spring into southern New England and Gulf of Maine waters. During the summer, butterfish occur over the entire Mid-Atlantic shelf from sheltered bays and estuaries out to about 200 m. In late fall, butterfish move southward and offshore in response to falling water temperatures (Fritz 1965; Horn 1970a; Schreiber 1973; Waring 1975; Azarovitz *et al*. 1980; Klein-MacPhee, in review).

Table 1 summarizes the environmental conditions where butterfish eggs, larvae, juveniles, and adults have been collected based on a literature survey and analyses of several fishery-independent databases [see Reid *et al.* (1999) for survey methods and location maps].

EGGS AND LARVAE

Butterfish eggs and larvae are pelagic and occur from the outer continental shelf to the lower, high salinity parts of estuaries in Middle Atlantic Bight. Eggs have been collected between 12-23ºC and larvae have been collected between 4-28ºC; eggs and larvae occur at salinities that range from estuarine to full strength seawater (Table 1). Larvae may undertake diel vertical migrations (Kendall and Naplin 1981). Larger larvae (10-15 mm) are more nektonic than planktonic; larger larvae and pelagic juveniles (< 30 mm) often associate with jellyfish, *Sargassum*, and other flotsam (Mansueti 1963; Haedrich 1967; Horn 1970b; Thomas and Milstein 1973; Lippson and Lippson 1984).

Eggs were collected during the NEFSC Marine Resources Monitoring, Assessment and Prediction program (MARMAP) ichthyoplankton survey at water temperatures ranging from 6º to 26ºC; most eggs were collected between 11-17ºC (Figure 4). Eggs were collected in surface waters (upper 200 m or within 5 m of bottom where station depths were < 200 m) in depths ranging from 10 to 1250 m (Figure 4). Most eggs were collected in water depths < 200 m.

Larvae were collected during the MARMAP ichthyoplankton survey at water temperatures ranging from 7-26ºC; most larvae were collected at 9-19ºC (Figure 5). Larvae were collected in surface waters in depths ranging from 10 to 1750 m; most larvae were collected in water depths < 120 m (Figure 5).

Eggs and larvae are common in the high salinity zones of some estuaries in southern New England and the Middle Atlantic Bight and in the mixing zone in Chesapeake Bay (Table 2a).

JUVENILES AND ADULTS

Juvenile and adult butterfish are pelagic fishes that form loose schools, often near the surface (Schreiber 1973; Dery 1988; Brodziak 1995). They are eurythermal (4.4-21.6ºC) and euryhaline (5-32 ppt) and are frequently found over sand, mud, and mixed substrates (Table 1). In Long Island Sound, butterfish were collected less frequently at low dissolved oxygen levels (2.0-2.9ml/l) (Howell and Simpson 1994).

During the summer, butterfish occur inshore where they remain near the surface; schools are frequently seen on shallow flats and in sheltered bays, estuaries, and the surf zone (Bigelow and Schroeder 1953; Leim and Scott

1966; Schaefer 1967; Klein-MacPhee, in review). Smaller juveniles often aggregate under floating objects including the bells of coelenterates (Pearson 1941; Bigelow and Schroeder 1953; Mansueti 1963; Haedrich 1967; Horn 1970b, 1975; Lippson and Moran 1974; Milstein 1974; Scott and Scott 1988). Larger juveniles are pelagic schooling fishes that may congregate near the bottom during the day and disperse upwards at night (Waring 1975).

Juvenile and adult butterfish are common to abundant in the high salinity and mixing zones of estuaries from Massachusetts Bay to the mid-Atlantic; they are rare to uncommon in the high salinity and mixing zones of estuaries in the central and northern Gulf of Maine and in the South Atlantic Bight (Tables 2a, b). In the Gulf of Maine and Middle Atlantic Bight, butterfish move offshore during the winter; fish are found near the bottom over sand, mud, and rock substrates (Bigelow and Schroeder 1953; Klein-MacPhee, in review). The offshore migration is not as pronounced south of Delaware Bay where winter water temperatures are warmer (Waring and Murawski 1982). In the South Atlantic Bight, butterfish are present throughout most of the year in nearshore waters (Keiser 1976).

In the NEFSC bottom trawl survey (1963-1997), juvenile and adult butterfish were collected on the continental shelf from 10 m of water nearshore out to about 360 m of water offshore; most juveniles and adults were collected in water depths < 180 m (Figure 6). Adults were distributed somewhat deeper than juveniles in all seasons. Bottom-water temperatures where juveniles and adults were captured ranged from 3º to 28ºC; most fish were collected between 7-20ºC (Figure 6). Modal water temperatures during spring and fall surveys were 10-14ºC for juveniles and adults.

In the Massachusetts trawl survey (1978-1996), juvenile and adult butterfish were collected at depths ranging from 5 to 80 m; most juveniles were collected between 10-35 m and most adults between 10-50 m (Figure 7). Bottom water temperatures ranged from 9-15ºC in the spring and 7-22ºC in the fall (Figure 7). Adults were caught deeper than juveniles in the fall when water temperatures were lower.

In the Rhode Island Narragansett Bay/Coastal trawl survey, juvenile and adult butterfish were collected at depths between 10-120 ft (3-37 m); most juveniles and adults were collected between 30-110 ft (10-34 m). Bottom water temperatures for juveniles and adults at the time of collection ranged from 9-24ºC in the summer and fall and 5-15ºC in the winter and spring.

In the Connecticut Long Island Sound trawl survey, juvenile and adult butterfish were collected at depths between 6-60 m; most fish were collected between 10-30 m. Bottom water temperatures for juveniles and adults at the time of collection ranged from 7-18ºC in the spring and 8-23ºC in the fall; most fish were captured at 9-15ºC in the spring and 16-21ºC in the fall. Bottom water salinities at the time of collection ranged from 18-32 ppt; most fish were captured at 26-29 ppt.

In the Hudson-Raritan trawl survey, juvenile and adult butterfish were collected at depths ranging from 10-75 ft (3-23 m) (Figure 8). Bottom water temperatures ranged from 8-26ºC, salinities ranged from 19-32 ppt, and dissolved oxygen ranged from 3-10 mg/l (Figure 8).

GEOGRAPHICAL DISTRIBUTION

Butterfish range from Newfoundland and the Gulf of St. Lawrence to the Atlantic and Gulf coasts of Florida (Figure 2), but they are most abundant from the Gulf of Maine to Cape Hatteras (Haedrich 1967; Horn 1970a; Powell *et al*. 1972; Cooley 1978; Scott and Scott 1988; Brodziak 1995; Klein-MacPhee, in review). Butterfish spend the winter near the edge of the continental shelf in the Middle Atlantic Bight and migrate inshore in spring to waters off southern New England and into the Gulf of Maine. During the summer, butterfish range from the Gulf of Maine to the South Atlantic Bight where they are found from sheltered bays and estuaries (Table 3) across the shelf to depths of 200 m and greater. In late fall, butterfish move southward and offshore in response to falling water temperatures (Fritz 1965; Horn 1970a; Schreiber 1973; Waring 1975; Azarovitz *et al*. 1980; Klein-MacPhee, in review). During the winter, they are largely absent from bays and estuaries in the Middle Atlantic Bight and Gulf of Maine (Table 3).

EGGS

Butterfish eggs have been reported in the Gulf of Maine, on Georges Bank, in the Middle Atlantic Bight, and off North Carolina (Smith *et al.* 1980; Rotunno 1992; MAFMC 1995; Rotunno and Cowen 1997). They have also been collected in Salem Harbor, MA and Narragansett Bay, RI (Herman 1963; Bourne and Govoni 1988; Elliott and Jiminez 1981), Block Island Sound (Merriman and Sclar 1952), Long Island Sound (Wheatland 1956), Peconic Bay, NY (Ferraro 1980), Raritan Bay, NJ (Croker 1965), and Chesapeake Bay (Lippson and Moran 1974).

During the MARMAP ichthyoplankton survey, butterfish eggs were collected from Cape Hatteras to the northern Gulf of Maine from April through September (Figure 9). Eggs first appeared in ichthyoplankton collections in April; by May, eggs were distributed along the edge of the continental shelf between Cape Hatteras and Georges Bank and inshore in the southern and middle Mid-Atlantic Bight. As water temperatures increased on the shelf, eggs were found progressively closer to the coast from south to north. Eggs were most abundant and most frequently encountered in July; they were most abundant in the Gulf of Maine in August. By September,

egg abundance declined dramatically; no eggs were collected from October to March.

In coastal bays and estuaries, butterfish eggs were recorded as far north as Penobscot Bay and as far south as Chesapeake Bay (Stone *et al.* 1994). Eggs were abundant in Narragansett Bay and common in Massachusetts Bay, Cape Cod Bay, Waquoit Bay, Buzzards Bay, Long Island Sound, Gardiners Bay, Great South Bay, and Chesapeake Bay (Table 2a).

LARVAE

Butterfish larvae have been reported from the New York Bight and Georges Bank (Smith *et al*. 1980; Wilk *et al*. 1990; Rotunno 1992; MAFMC 1995; Rotunno and Cowen 1997), in Buzzards Bay, MA (Lux and Wheeler 1992), Narragansett Bay, RI (Herman 1963; Bourne and Govoni 1988; Elliott and Jiminez 1981), Raritan Bay, NJ (Croker 1965), Great Bay, NJ (Able and Fahay 1998), Chesapeake Bay (Lippson and Moran 1974), and in the South Atlantic Bight as far south as Cape Kennedy, FL (Fahay 1975; Powles and Stender 1976; Rotunno 1992; Rotunno and Cowen 1997). Larvae were not abundant in the South Atlantic Bight (< 0.5% of total ichthyoplankton) and did not occur frequently (< 10% of stations in a survey of 73 coastal stations) (Fahay 1975).

During the MARMAP ichthyoplankton survey, butterfish larvae were collected from Cape Hatteras into the Gulf of Maine in every month except December (Figure 10). Larvae first appeared in ichthyoplankton collections in January. From January through April, larvae were collected primarily off Cape Hatteras. In May and June, larvae began to appear along the edge of the continental shelf between Cape Hatteras and Georges Bank and inshore in the southern portion of the Middle Atlantic Bight. As water temperatures increased on the shelf, larvae were found progressively closer to the coast from south to north. Larvae were most abundant and most frequently encountered in July and August across the continental shelf in the Middle Atlantic Bight northward to Georges Bank. The abundance of larvae declined sharply from September through November.

In the coastal bays and estuaries of New England and the mid-Atlantic, butterfish larvae were recorded as far north as Penobscot Bay and as far south as Chesapeake Bay (Stone *et al.* 1994). Larvae were common in Boston Harbor, Waquoit Bay, Buzzards Bay, Narragansett Bay, Long Island Sound, Gardiners Bay, Great South Bay, Great South Bay, and Chesapeake Bay (Table 2a).

JUVENILES

Juvenile butterfish occur from Nova Scotia to the Atlantic and Gulf coasts of Florida, but they are most abundant from the Gulf of Maine to Cape Hatteras (Bigelow and Schroeder 1953; Haedrich 1967; Horn 1970a; Powell *et al.* 1972; Cooley 1978; Scott and Scott 1988; Brodziak 1995; Klein-MacPhee, in review). They occur in the high salinity and mixed salinity zones of most estuaries from the Gulf of Maine to Florida (Table 2a) (Jury *et al.* 1994; Stone *et al.* 1994; Geer and Austin 1997; Murdy *et al*. 1997).

During the NEFSC Bottom trawl survey, juvenile butterfish were collected from the northern Gulf of Maine south to Cape Lookout, South Carolina (Figure 11). During the winter and spring, juveniles were collected along the outer continental shelf from southern New England to Cape Hatteras and along the coast near Cape Hatteras. During the summer, juvenile butterfish were collected near the coast throughout the Middle Atlantic Bight and on Georges Bank. During the fall, they were abundant across the shelf throughout the Middle Atlantic Bight and on Georges Bank.

Juvenile butterfish were collected in spring and fall by the Massachusetts Trawl Survey, but catches were 1-2 orders of magnitude greater in the fall (Figure 12). During the Southeast Area Monitoring and Assessment Program-South Atlantic (SEAMAP-SA) bottom trawl survey, juvenile butterfish were collected from Cape Lookout, South Carolina to Cape Kennedy, Florida (Figure 13). Catches were smallest during the winter and largest during the summer.

In the coastal bays and estuaries of New England and the mid-Atlantic, juvenile butterfish were recorded from Passamaquoddy Bay, Maine south to the James River in Virginia (Table 2a) (Stone *et al.* 1994). South of Cape Hatteras, juveniles occurred in bays and estuaries in South Carolina, Georgia, and Florida (Table 2a). Juveniles were abundant in Buzzards Bay, Narragansett Bay, and Long Island Sound, and common in most of the remaining bays and estuaries between Massachusetts Bay and Chesapeake Bay.

In Narragansett Bay, juvenile butterfish were collected in all seasons, but they were rare in winter and spring; they were most abundant in summer when they occurred throughout the bay (Figure 14). In Long Island Sound, butterfish appeared in May; abundance peaked in September-October and declined in November (Figure 15). Juveniles composed 17% of all butterfish caught in May, 91% in September-October, and 73% in November. Juveniles appear in surf zone off Long Island in July and are common from August through October (Schaefer 1967). In the Hudson-Raritan estuary, juveniles were caught in trawls from spring through fall (Figure 16).

ADULTS

Adult butterfish have been reported from Newfoundland to the Atlantic and Gulf coasts of Florida, but they are most abundant from the Gulf of Maine to Cape Hatteras (Bigelow and Schroeder 1953; Haedrich

1967; Horn 1970a; Powell *et al*. 1972; Cooley 1978; Scott and Scott 1988; Brodziak 1995; Klein-MacPhee, in review). They have been collected in high salinity and mixed salinity zones of most estuaries from the Gulf of Maine to Florida (Tables 2a, b) (Hildebrand and Schroeder 1928; DuPaul and McEachran 1973; Wilk and Silverman 1976b; Jury *et al.* 1994; Stone *et al.* 1994; Geer and Austin 1997; Murdy *et al*. 1997).

During the NEFSC bottom trawl survey, adult butterfish were collected from the northern Gulf of Maine south to below Cape Lookout, South Carolina (Figure 11). During the winter and spring, they were distributed along the outer continental shelf from southern New England to Cape Hatteras; they occurred along the coast from Cape Hatteras to Maryland. During the summer, adult butterfish were collected across the shelf throughout the Middle Atlantic Bight, on Georges Bank, and in the coastal Gulf of Maine. During the fall, they were abundant on the shelf throughout the Middle Atlantic Bight, on Georges Bank, and in Massachusetts Bay.

In the Massachusetts Trawl Survey, adult butterfish were collected in the spring primarily south of Cape Cod and in Buzzards Bay, and in the fall primarily in Buzzards Bay, Massachusetts Bay, and around Cape Ann (Figure 12). During the SEAMAP-SA bottom trawl survey, adult butterfish were collected from Cape Lookout, South Carolina to Cape Kennedy, Florida (Figure 13). The size of the catches was similar throughout the year. Butterfish are present in nearshore waters off South Carolina throughout most of the year (Keiser 1976).

In the coastal bays and estuaries of New England and the mid-Atlantic, adult butterfish were recorded from Passamaquoddy Bay in Maine south to the James River in Virginia (Jury *et al.* 1994; Stone *et al.* 1994). South of Cape Hatteras, adults occurred in bays and estuaries in South Carolina, Georgia, and Florida (Table 2a, b). Adults were abundant in Buzzards Bay, Narragansett Bay, and Long Island Sound, and common in most of the remaining bays and estuaries between Massachusetts Bay and Chesapeake Bay (Table 2b). Spawning adults were recorded from Massachusetts Bay south to the Chesapeake Bay, but were common only in Long Island Sound, Gardiners Bay, Great South Bay, and Chesapeake Bay (Table 2b).

In Narragansett Bay, adult butterfish were collected in all seasons, but they were rare in winter and spring; they were most abundant in summer when they occurred throughout the bay (Figure 14). In Long Island Sound, butterfish appeared in May; abundance peaked in September-October and declined in November (Figure 15; Wheatland 1956). Adults composed 83% of all butterfish caught in May, 9% in September-October, and 27% in November. Adults appear in the surf zone off Long Island in May and are common from June through October (Schaefer 1967). Butterfish were among the most abundant species in both of these Long Island surveys. In the Hudson-Raritan estuary, adults were caught from spring through fall (Figure 16).

STATUS OF THE STOCKS

A fishery for butterfish has existed since the late 1800s (Murawski and Waring 1979); from 1920 to 1962, the average annual landings in US waters were 3,000 mt (Waring 1975). In 1963, distant water fleets from Japan, Poland, and the USSR began targeting butterfish from late autumn through early spring when the fish were concentrated offshore (Murawski and Waring 1979; MAFMC 1995). Annual landings increased to a record 19,500 mt in 1973 (Figure 17) (Brodziak 1995). Restrictions were placed on the foreign fisheries and landings subsequently decreased to an average of 6,100 mt from 1977 to 1987. Directed foreign fishing was halted in 1987 and landings continued to decline to an average 2,500 mt in the domestic fishery from 1987 to 1992 (Brodziak 1995; MAFMC 1995). The domestic fishery targeted butterfish from late spring through fall in inshore areas (Murawski and Waring 1979). Butterfish landings totaled 4,500 mt in 1993 and came primarily from southern New England (79% in Rhode Island ports) and the New York Bight. These landings were 60% higher than landings in 1992 and were comparable with record domestic catches in 1987 (Brodziak 1995).

Butterfish biomass estimated from the Northeast Fisheries Science Center bottom trawl surveys has made several record lows and near record highs in the last decade (Figure 17). Despite seasonal increases in biomass and pre-recruit indices, butterfish stock size has decreased and commercial landings remain low (Northeast Fisheries Science Center 1994). Although the demand for butterfish has declined in recent years, the capacity for increased landings remains in an under-exploited fishery (Brodziak 1995). The butterfish stock is not overfished nor approaching an overfished condition (National Marine Fisheries Service 1997).

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Table 1. Summary of life history and habitat characteristics for butterfish, *Peprilus triacanthus.* *

Life Stage	Geographic Location	Habitat	Substrate	Temperature	Salinity
Eggs (0.68-0.82 mm diameter)	Cape Sable, Nova Scotia to Florida; in spring along edge of continental shelf from Georges Bank to Cape Hatteras; found progressively closer to coast from south to north as water temperatures increase. Commonly occur in the saline parts of bays and estuaries from MA to NY and Chesapeake Bay in spring and summer.	Surface waters from continental shelf into estuaries and bays; collected to about 60 m deep in shelf waters. Common in high salinity zone of estuaries and bays from MA through VA. MARMAP Survey: collected in surface waters in 10-1250 m of water.		Literature: 12.8-22.5ºC; MARMAP Survey: 6-26ºC; most eggs collected between 11-17ºC	Estuarine to full seawater; about 25-33 ppt
Larvae (2.6-16 mm SL)	Cape Sable, Nova Scotia to Cape Kennedy, FL; most abundant in central Middle Atlantic Bight in summer, but absent in the winter. Commonly occur in bays and estuaries from MA to NY and Chesapeake Bay in summer and fall.	Surface waters from continental shelf into estuaries and bays; collected to about 60 m deep in shelf waters; common in high salinity zone of estuaries and bays; may spend day deeper in the water column and migrate to the surface at night. MARMAP Survey: collected in surface waters in water 10-1750 m deep.		Literature: 4.4-27.9ºC. MARMAP Survey: 7-26ºC; most eggs collected between 9-19ºC	6.4-37.4 ppt
Juveniles (16 mm SL-120 mm FL)	Cape Sable, Nova Scotia to Florida; most abundant in Middle Atlantic Bight in summer and near the edge of continental shelf in winter. Commonly occur in bays and estuaries from MA to VA from spring through fall; less abundant in bays and estuaries in the Gulf of Maine and in the South Atlantic Bight.	From surface waters to depth on continental shelf; into coastal bays and estuaries; common in inshore areas, including the surf zone, and in high salinity and mixed salinity zones of bays and estuaries. NEFSC Trawl Survey: collected on continental shelf in 10-330 m of water; most collected in < 120 m	Larger individuals found over sandy and muddy substrates.	4.4-29.7ºC; survival reduced below 10ºC	3.0-37.4 ppt
Adults (> 120 mm FL)	Cape Sable, Nova Scotia to Florida; most abundant inshore in Middle Atlantic Bight in summer and near the edge of continental shelf in winter; most abundant north of Cape Cod in summer and fall; commonly occur in bays and estuaries from MA to VA from spring through fall; less abundant in bays and estuaries in the Gulf of Maine and in the South Atlantic Bight; do not migrate far offshore in South Atlantic Bight.	From surface waters to depths of 270-420 m on continental shelf; into coastal bays and estuaries; common in inshore areas, including the surf zone, and in high salinity and mixed salinity zones of bays and estuaries. NEFSC Trawl Survey: collected on continental shelf in 10-360 m of water; most collected in < 180 m.	Schools found over sandy, sandy-silt, and muddy substrates.	4.4-26.0ºC; survival reduced below 10ºC	3.8-33.0 ppt
Spawning Adults	At least the Gulf of Maine to the South Atlantic Bight (SAB); most abundant in Middle Atlantic Bight; in SAB between Cape Hatteras and Cape Kennedy. Common in Long Island Sound, some Long Island bays, and Chesapeake Bay in spring and summer. In NY Bight, caught from May-August.	Spawning occurs on continental shelf, inshore areas, and in bays and estuaries (rarely in bays and estuaries north of Cape Cod). Spawning adults common in Long Island Sound and bays and estuaries of Long Island. In NY Bight, caught between 3-145 m.		Spawning does not occur at < 15ºC	

Table 1. cont'd.

Life Stage	Dissolved Oxygen	Light	Currents	Prey	Predators	Notes
Eggs (0.68-0.82 mm diameter)						Incubation period 2-3 days. Salinity range based on 78-100% seawater (Martin and Drewry, 1978) assuming seawater at 33 ppt.
Larvae (2.6-16 mm SL)						More nektonic than planktonic by 10-15 mm.
Juveniles (16 mm SL-120 mm FL)	Hudson-Raritan Bay: 3-9 mg/l; most 5-8 mg/l	Larger juveniles are pelagic schoolers; may congregate near bottom during day and disperse upward at night.		Feed mainly on planktonic prey, including thaliaceans, squids, copepods, amphipods, decapods, coelenterates, polychaetes, small fishes, and ctenophores.	Preyed on by haddock, silver hake, bluefish, swordfish, weakfish, goosefish, sharks, and long-finned squid	Smaller juveniles may associate with floating objects including jellyfish and inanimate objects.
Adults (> 120 mm FL)	Abundance declines in Long Island Sound at 2.0-2.9 mg/l. Hudson-Raritan Bay: 3-10 mg/l; most 6-9 mg/l.			Feed mainly on planktonic prey, including thaliaceans, squids, copepods, amphipods, decapods, coelenterates, polychaetes, small fishes, and ctenophores.	Preyed on by haddock, silver hake, bluefish, swordfish, weakfish, goosefish, sharks, skates, and long-finned squid	Median size of sexual maturity 120 mm FL based on O'Brien *et al.* (1993).
Spawning Adults						Spawning occurs July-October on Scotian Shelf, May-August in Gulf of Maine, May-October in Middle Atlantic Bight (peak June-August), January-April off Cape Hatteras (peak in March), and year round in South Atlantic Bight (peak in spring).

*In addition to the citations mentioned in the text, the following references were used to compile Table 1: Austin 1973, 1976; Berrien *et al*. 1978; Colton *et al*. 1979; Edwards *et al*. 1962; Lang 1974; Lessard 1974; Obenchain 1981; Wilk and Silverman 1976a; Wilk *et al*. 1977.

Table 2a. Relative abundance of eggs, larvae, and juvenile butterfish (*Peprilus triacanthus*) in New England and Mid-Atlantic estuaries by salinity zone [based on Estuarine Living Marine Resources (ELMR) data in Stone *et al.* 1994]. Salinity zone: T = tidal fresh, M = mixing zone, S = seawater, • = salinity zone not present. Relative abundance: H = highly abundant, A = abundant, C = common, R = rare, blank = not present, na = no data available.

	Eggs			Larvae			Juveniles		
	T	**M**	**S**	**T**	**M**	**S**	**T**	**M**	**S**
Passamaquoddy Bay		na	na		na	na		R	R
Englishman/Machias Bays								R	R
Narraguagus Bay								R	R
Blue Hill Bay								R	R
Penobscot Bay		R	R		R	R		R	R
Muscongus Bay								R	R
Damariscotta River								R	R
Sheepscot River								R	R
Kennebec/Androscoggin Rivers								R	R
Casco Bay								R	R
Saco Bay								R	R
Wells Harbor	•			•			•		
Great Bay		R	R		R	R		R	R
Merrimack River		R	•		R	•		R	•
Massachusetts Bay	•	•	C	•	•	R	•	•	C
Boston Harbor	•		C	•		C	•		R
Cape Cod Bay	•		C	•		R	•	C	C
Waquoit Bay		R	C		R	C		R	C
Buzzards Bay		R	C		R	C		C	H
Narragansett Bay		R	H		R	C		C	H
Long Island Sound			C			C	R	H	A
Connecticut River								C	
Gardiners Bay			C			C			C
Great South Bay, NY			C			C		R	C
Hudson River/Raritan Bay			R	R	C	R	R	C	C
Barnegat Bay, NJ						R		C	C
New Jersey Inland Bays						R		C	C

Table 2a cont'd.

	Eggs			Larvae			Juveniles		
	T	**M**	**S**	**T**	**M**	**S**	**T**	**M**	**S**
Delaware Bay			R			C		C	C
Delaware Inland Bays									C
Chincoteague Bay									
Chesapeake Bay Mainstream		C	C		C	C		C	C
Chester River									
Coptank River								R	
Patuxent River								R	
Potomac River								R	
Tangier/Pocomoke Sound								R	
Rappahannock River								R	
York River, VA								C	
James River, VA								C	
South Atlantic estuaries – see below									

Butterfish occur in estuaries between North Carolina and Florida, but this species was not included in the ELMR survey of the southeast estuaries (Nelson *et al.* 1991). Information on their occurrence in South Atlantic estuaries is presented below.

North Carolina

- Cape Fear River estuary: butterfish < 0.05% of all fishes caught (Schwartz *et al.* 1979)

South Carolina

- Winyah Bay estuary: butterfish (50-110 mm TL) collected in lower and middle estuary; < 1% of all fishes caught (Wenner *et al*. 1981)
- Charleston Harbor estuary system: occur in Charleston Harbor and lower reaches of Ashley, Cooper, and Wando rivers; < 0.05% of all fishes collected (Stender and Martore 1990)

Georgia

- Sapelo Sound: butterfish collected "occasionally" on ocean beaches and in the lower and middle reaches of estuary; did not occur at salinities < 19.5 ppt (Dahlberg 1972).

Florida

- Pensacola Bay: juveniles present in winter, spring, summer; rare to uncommon (Cooley 1978).
- Santa Rosa Sound: juveniles collected in winter, spring, summer; rare to uncommon (Cooley 1978).
- Escambia Bay: juveniles collected in winter, spring, fall; rare to uncommon (Cooley 1978).
- Butterfish recorded from ocean beaches on Atlantic and Gulf coasts (to Mississippi) and in Tampa Bay (Powell *et al*. 1972).

Table 2b. Relative abundance of spawning adult and adult butterfish (*Peprilus triacanthus*) in New England and Mid-Atlantic estuaries by salinity zone [based on Estuarine Living Marine Resources (ELMR) data in Stone *et al.* 1994]. Salinity zone: T = tidal fresh, M = mixing zone, S = seawater, • = salinity zone not present. Relative abundance: H = highly abundant, A = abundant, C = common, R = rare, blank = not present, na = no data available.

	Spawning Adults			**Adults**		
	T	**M**	**S**	**T**	**M**	**S**
Passamaquoddy Bay					R	R
Englishman/Machias Bays					R	R
Narraguagus Bay					R	R
Blue Hill Bay					R	R
Penobscot Bay					R	R
Muscongus Bay					R	R
Damariscotta River					R	R
Sheepscot River					R	R
Kennebec/Androscoggin Rivers					R	R
Casco Bay					R	R
Saco Bay					R	R
Wells Harbor	•			•		
Great Bay					R	R
Merrimack River	•			•	R	
Massachusetts Bay	•	•	R	•	•	C
Boston Harbor	•			•	R	R
Cape Cod Bay	•			•	C	C
Waquoit Bay	•		R	•	R	C
Buzzards Bay	•		R	•	C	H
Narragansett Bay			R		C	A
Long Island Sound			C		A	H
Connecticut River			•		C	•
Gardiners Bay	•		C	•	C	C
Great South Bay, NY	•		C	•	R	C
Hudson River/Raritan Bay					C	C
Barnegat Bay, NJ					R	R
New Jersey Inland Bays						R

Table 2b cont'd.

	Spawning Adults			Adults		
	T	**M**	**S**	**T**	**M**	**S**
Delaware Bay			R		R	C
Delaware Inland Bays	•			•		C
Chincoteague Bay	•	•		•	•	
Chesapeake Bay Mainstream		C	C		C	C
Chester River			•			•
Coptank River			•		R	•
Patuxent River			•		R	•
Potomac River			•		R	•
Tangier/Pocomoke Sound	•		•	•	R	•
Rappahannock River			•		R	•
York River, VA			•		C	•
James River, VA			•		C	•
South Atlantic estuaries[1]						

[1]See note at bottom of Table 2a.

Table 3. Abundance of butterfish eggs, larvae, juveniles, adults, and spawning adults in New England and Mid-Atlantic estuaries by month summarized across salinity zones [based on Estuarine Living Marine Resources (ELMR) data in Stone *et al.* 1994]. Maximum abundance: A = abundant, C = common, R = rare, blank = not present.

	Eggs		**Larvae**		**Juveniles**		**Adults**		**Spawning Adults**	
Estuary	months present	max. abun.	months present	max. abun.	months present	max. abun.	months present	max. abun.	months present	max. abun.
Passamaquoddy Bay	----------		----------		-----JJASO--	R	-----JJASO--	R	----------	
Englishman/Machias Bays	----------		----------		-----JJASO--	R	-----JJASO--	R	----------	
Narraguagus Bay	----------		----------		-----JJASO--	R	-----JJASO--	R	----------	
Blue Hill Bay	----------		----------		-----JJASO--	R	-----JJASO--	R	----------	
Penobscot Bay	------JAS---	R	------JAS---	R	-----JJASO--	R	-----JJASO--	R	----------	
Muscongus Bay	----------		----------		-----JJASO--	R	-----JJASO--	R	----------	
Damariscotta River	----------		----------		-----JJASO--	R	-----JJASO--	R	----------	
Sheepscot River	----------		----------		-----JJASO--	R	-----JJASO--	R	----------	
Kennebec/Androscoggin Rivers	----------		----------		-----JJASO--	R	-----JJASO--	R	----------	
Casco Bay	----------		----------		-----JJASO--	R	-----JJASO--	R	----------	
Saco Bay	----------		----------		-----JJASO--	R	-----JJASO--	R	----------	
Wells Harbor	----------		----------		----------		----------		----------	
Great Bay	-----JJAS---	R	-----JJAS---	R	-----JJASO--	R	-----JJASO--	R	----------	
Merrimack River	-----JJA----	R	-----JJA----	R	-----JJAS---	R	-----JJAS---	R	----------	
Massachusetts Bay	-----JJAS---	C	-----JJAS---	R	-----JJASO--	C	-----JJASO--	C	-----JJAS---	R
Boston Harbor	-----JJAS---	C	------JAS---	C	-----JJASO--	R	-----JJASO--	R	----------	
Cape Cod Bay	-----JJASO--	C	------JASO--	R	-----JJASO--	C	-----JJASO--	C	----------	
Waquoit Bay	----MJJA----	C	-----JJASO--	C	----MJJASO--	C	----MJJASO--	C	----MJJAS---	R
Buzzards Bay	----MJJAS---	C	-----JJASO--	C	---AMJJASOND	A	---AMJJASOND	A	-----JJAS---	R
Narragansett Bay	----MJJA----	A	-----JJASO--	C	---AMJJASOND	A	---AMJJASOND	A	----MJJA----	R
Gardiners Bay	----MJJ-----	C	----MJJ-----	C	----MJJASOND	C	----MJJASOND	C	----MJJ-----	C
Long Island Sound	-----JJAS---	C	-----JJASON-	C	----MJJASOND	A	----MJJASOND	A	-----JJAS---	C
Connecticut River	----------		----------		----MJJASOND	C	----MJJASOND	C	----------	
Great South Bay	----MJJ-----	C	----MJJA----	C	----MJJASOND	C	----MJJASOND	C	----MJJ-----	C
Hudson River/Raritan Bay	-----JJA----	R	----MJJASON-	C	---AMJJASON-	C	---AMJJASON-	C	----------	
Barnegat Bay	----------		-----JJA----	R	-----JJASO--	C	----MJJASO--	R	----------	
New Jersey Inland Bays	----------		-----JJA----	R	-----JJASO--	C	------JAS---	R	----------	
Delaware Bay	----MJJ-----	R	----MJJ-----	C	------JASOND	C	----MJJASO--	C	----MJJ-----	R
Delaware Inland Bays	----------		----------		----MJJASON-	C	----MJJASON-	C	----------	
Chincoteague Bay	----------		----------		----------		----------		----------	
Chesapeake Bay	----MJJ-----	C	-----JJA----	C	------JASO--	C	---AMJJASON-	C	----MJJ-----	C
Potomac River	----------		----------		-----JJASO--	R	----MJJASO--	R	----------	
Rappahannock River	----------		----------		------JASON-	R	---AMJJASON-	R	----------	
York River	----------		----------		------JASON-	C	---AMJJASON-	C	----------	
James River	----------		----------		------JASON-	C	---AMJJASON-	C	----------	
Patuxent River	----------		----------		------JAS---	R	-----JJAS---	R	----------	
Chester River	----------		----------		----------		----------		----------	
Choptank River	----------		----------		------JAS---	R	-----JJAS---	R	----------	
Tangier/Pocomoke Sound	----------		----------		------JASO--	R	----MJJASO--	R	----------	

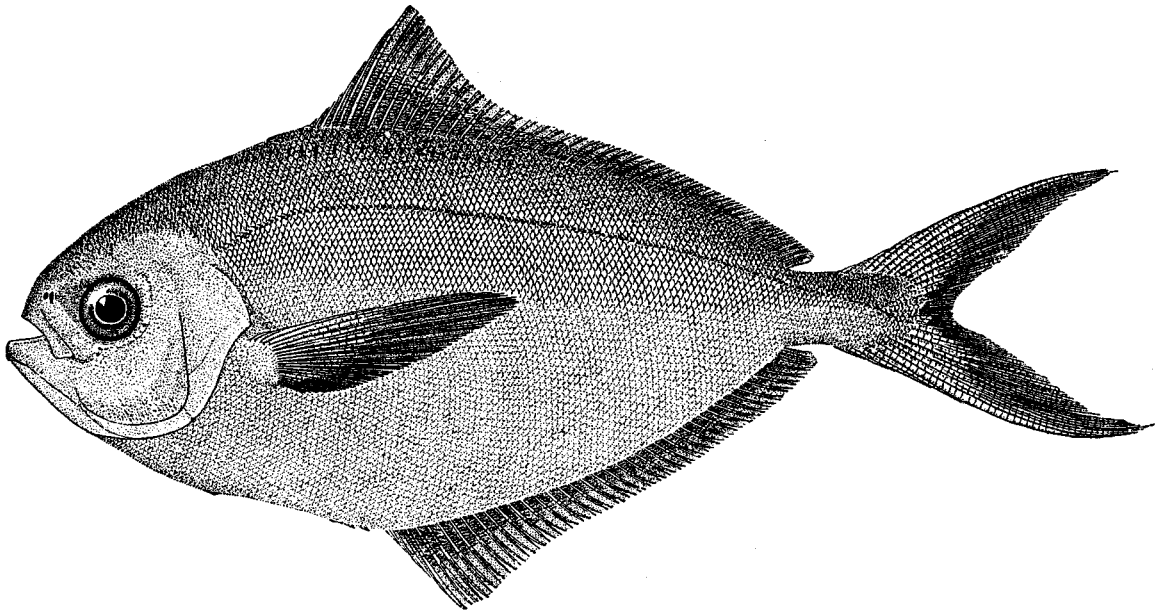


Figure 1. The adult butterfish, *Peprilus triacanthus* (from Goode 1884).

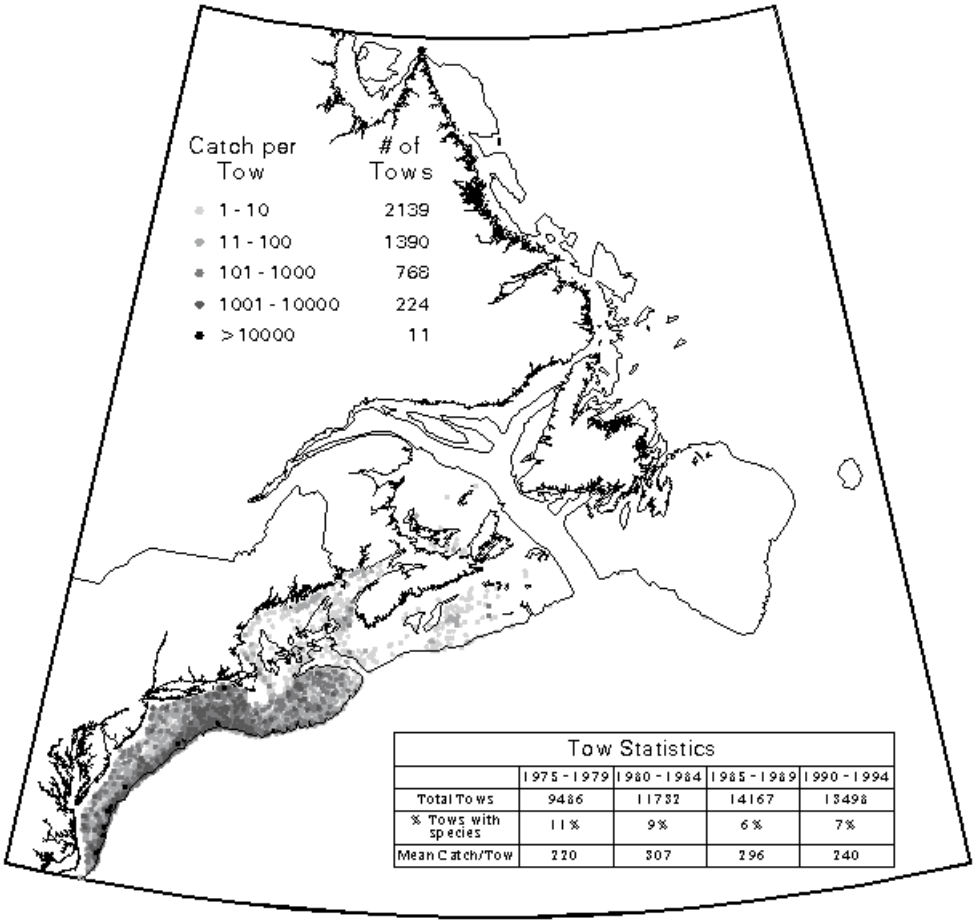


Figure 2. The distribution of butterfish from Newfoundland to Cape Hatteras. Data are from the U.S. NOAA/Canada DFO East Coast of North America Strategic Assessment Project (http://www-orca.nos.noaa.gov/projects/ecnasap/ecnasap_table1.html).

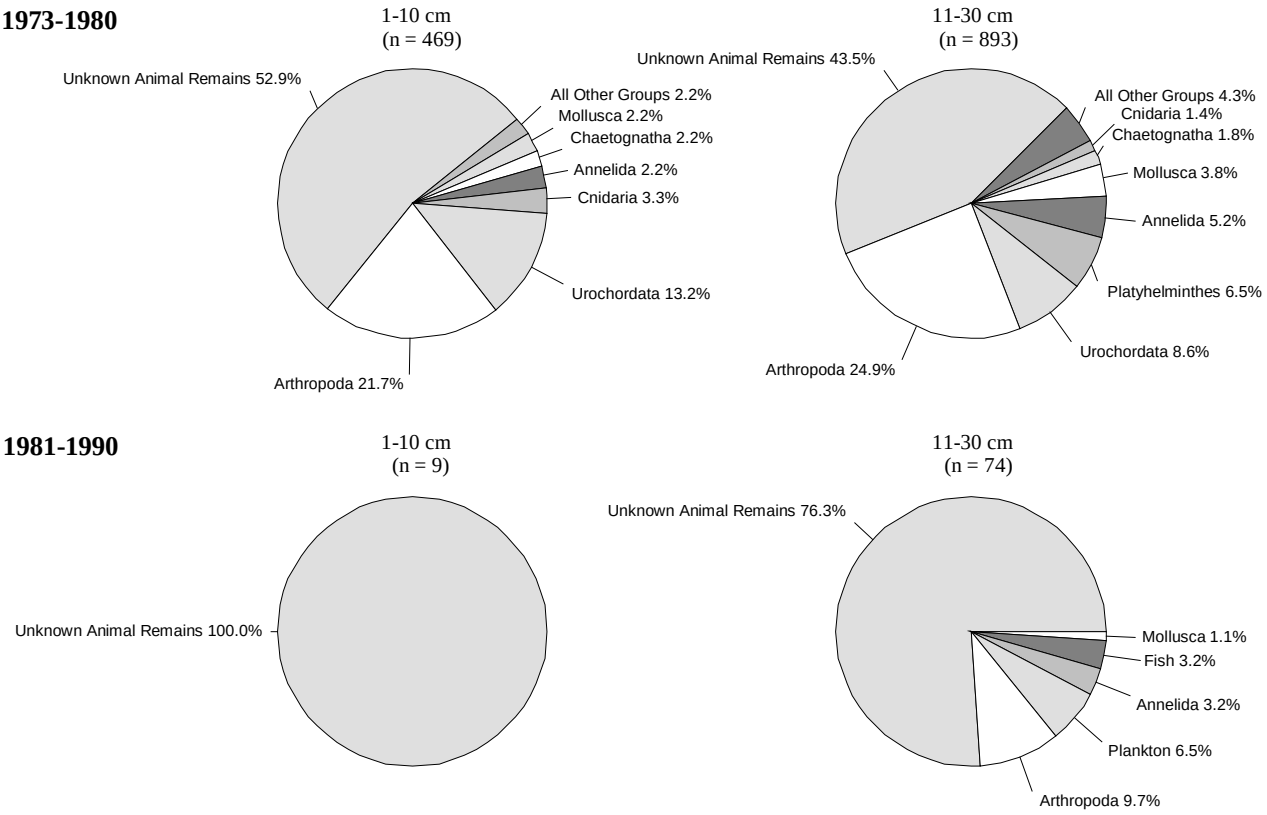


Figure 3. Abundance (percent occurrence) of the major prey items of butterfish collected during NEFSC bottom trawl surveys from 1973-1980 and 1981-1990. The 1-10 cm size range corresponds, at least roughly, to juveniles, and the 11-30 cm size class corresponds to adults. The category “animal remains” 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].

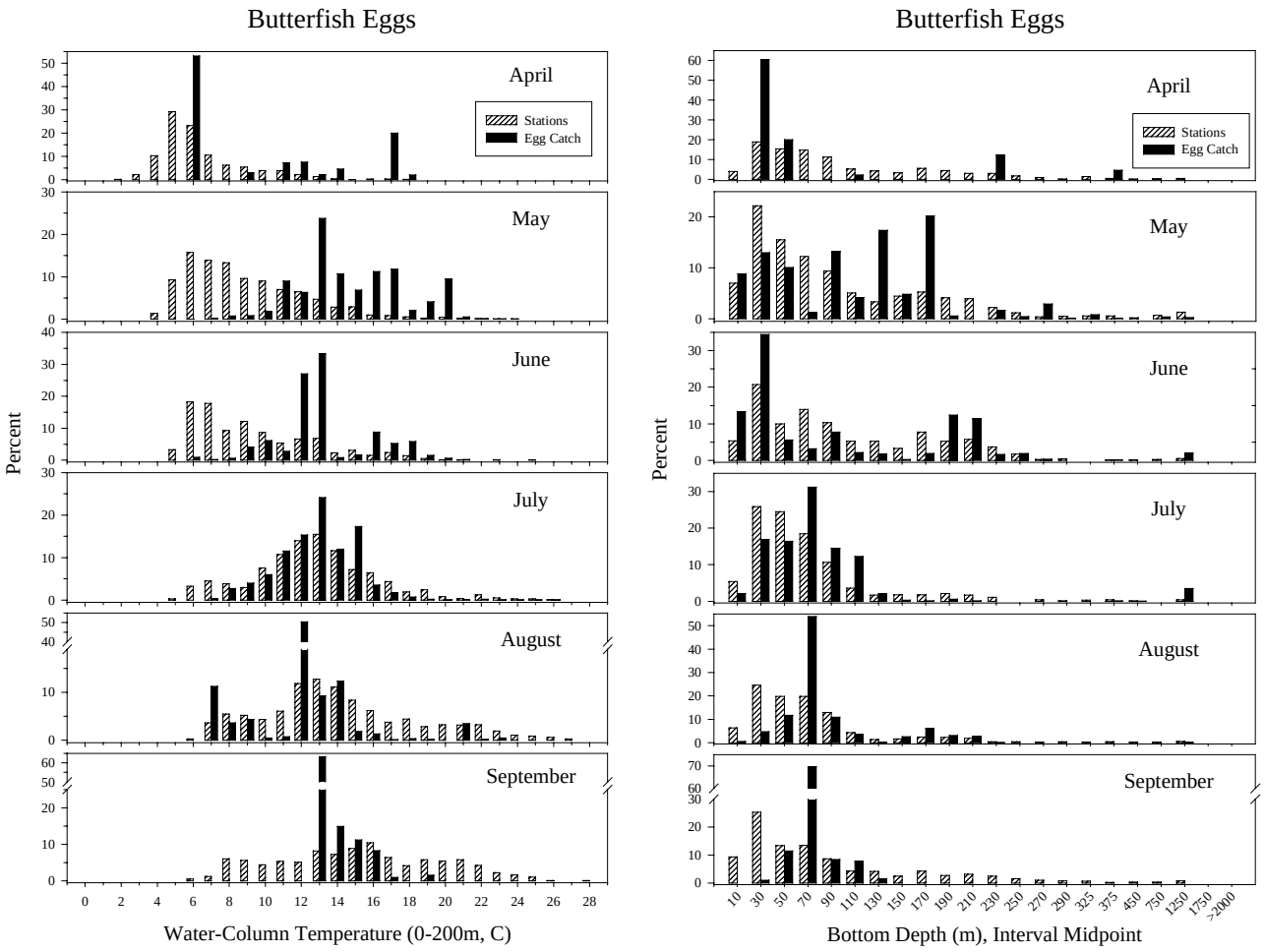


Figure 4. Abundance of butterfish eggs relative to water column temperature (to a maximum of 200 m) and bottom depth from NEFSC MARMAP ichthyoplankton surveys (1978-1987) by month for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion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

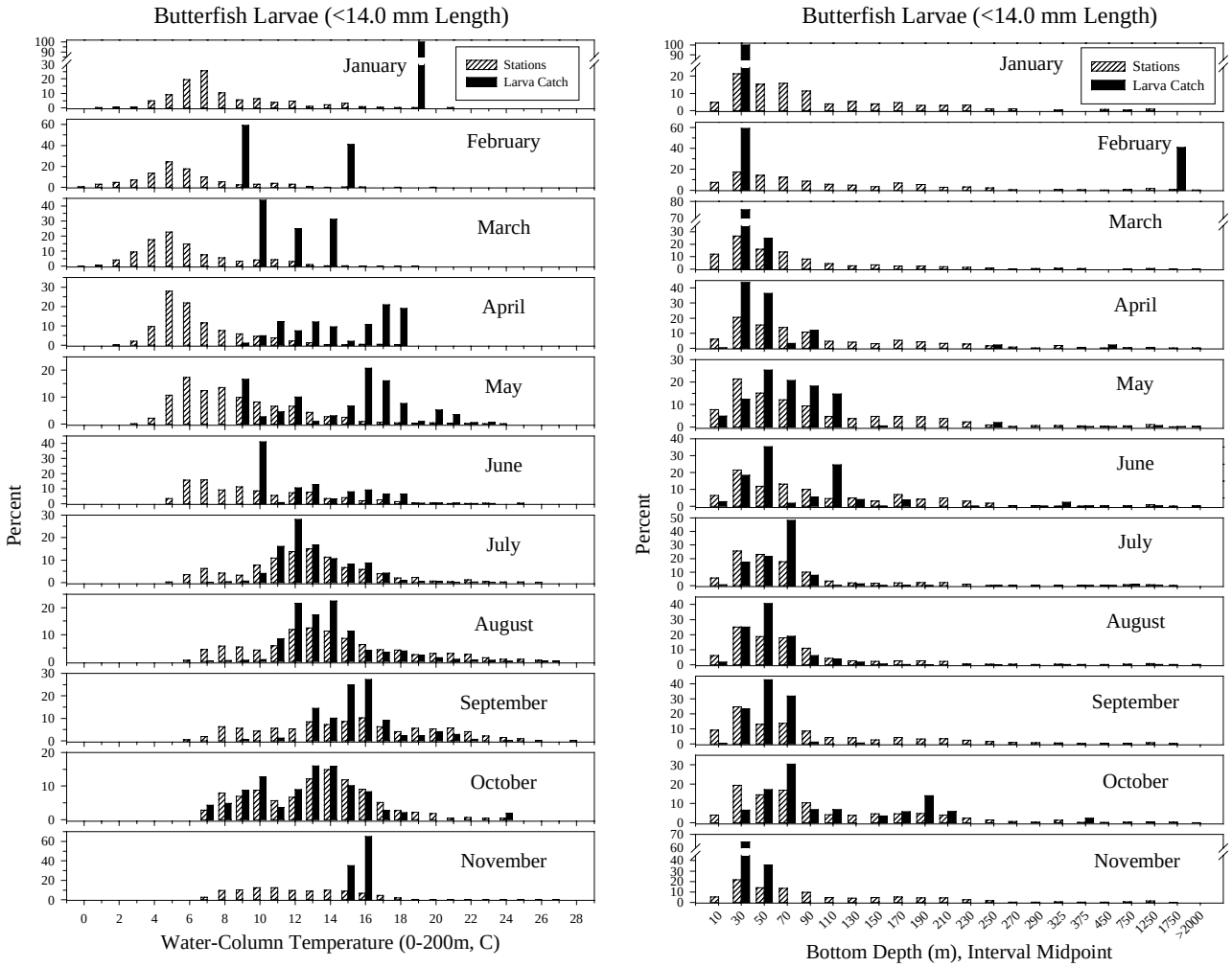


Figure 5. Abundance of butterfish larvae (< 14 mm) relative to water column temperature (to a maximum of 200 m) and bottom depth from NEFSC MARMAP ichthyoplankton surveys (1977-1987) by month for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

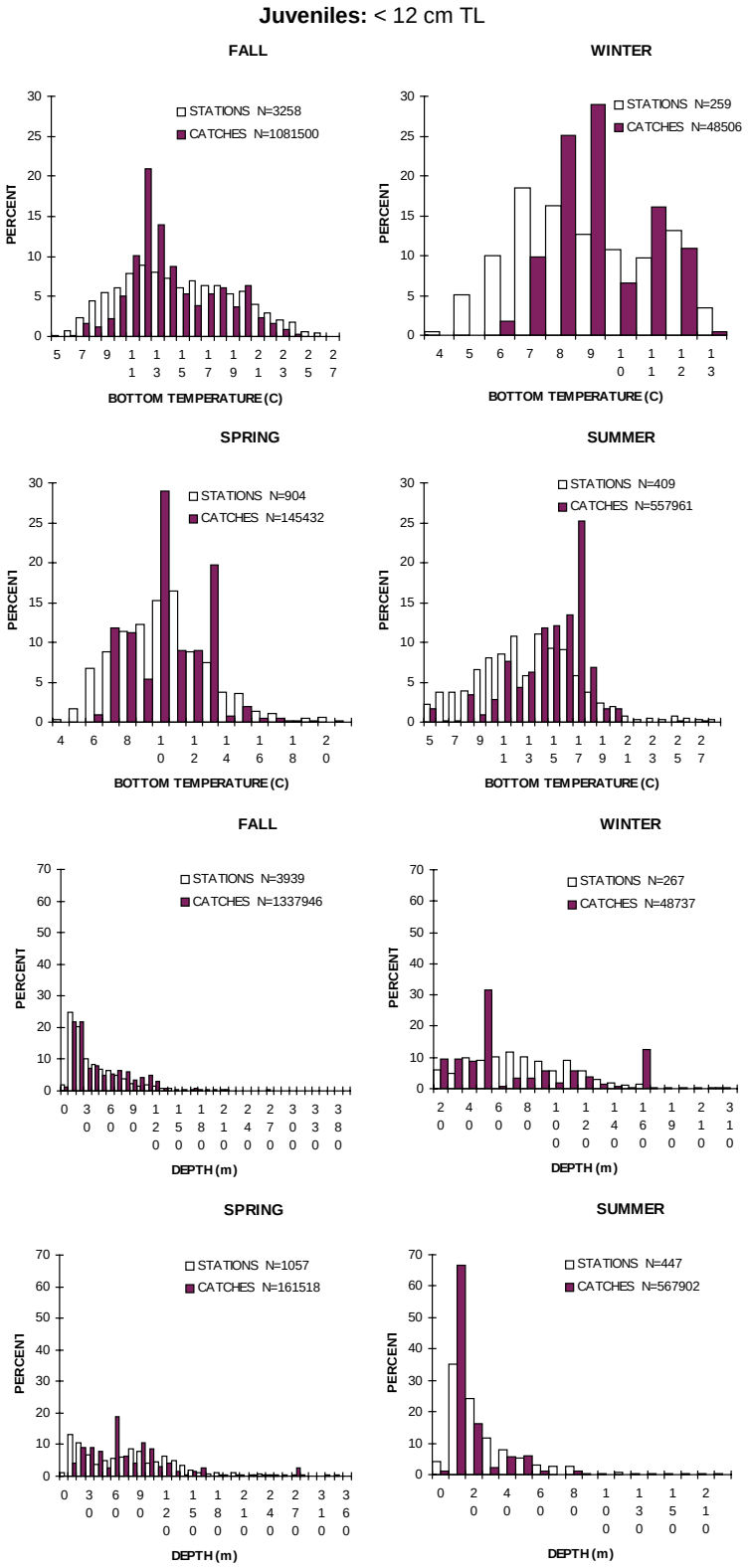


Figure 6. Abundance of juvenile (< 12 cm) and adult (≥ 12 cm) butterfish relative to bottom water temperature and depth based on NEFSC bottom trawl surveys (1963-1997) by season for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

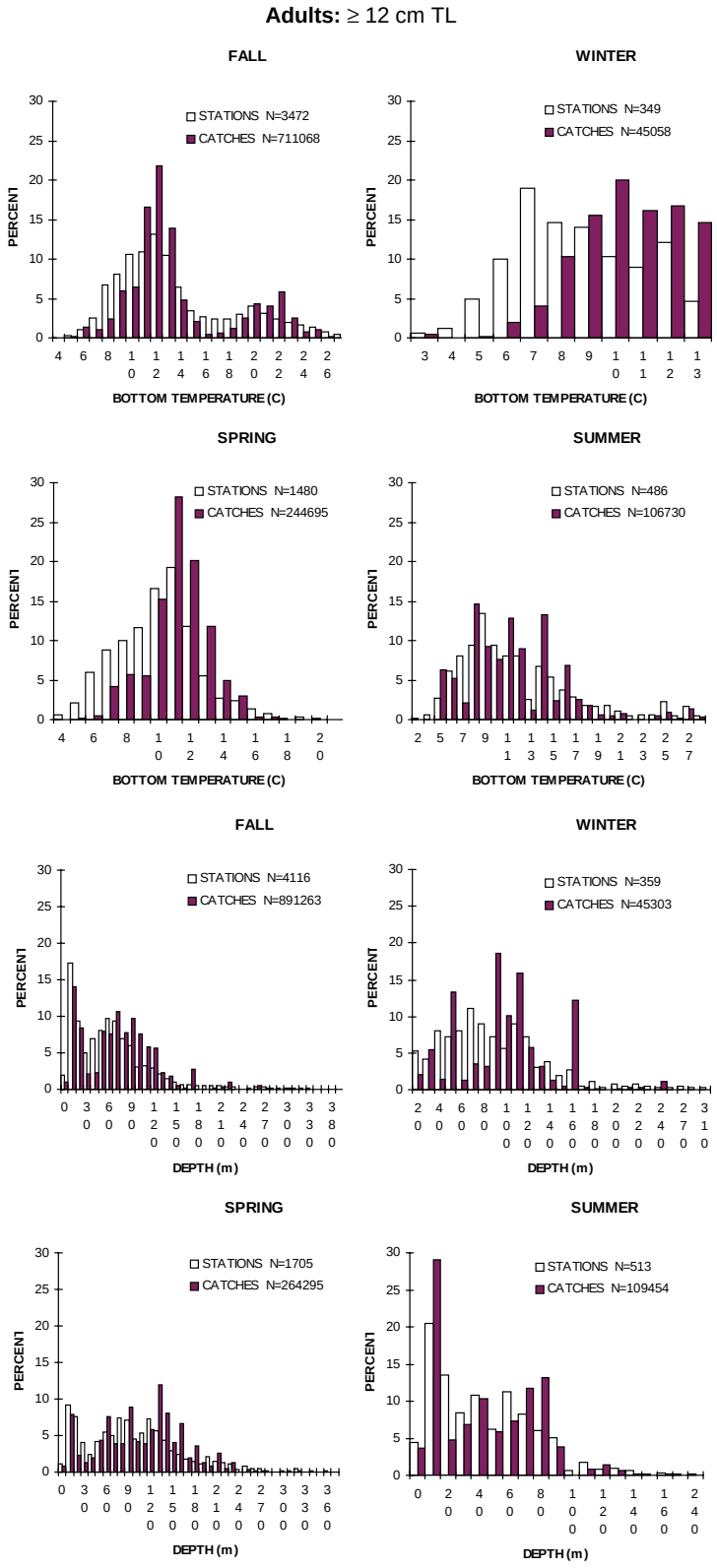


Figure 6. cont'd.

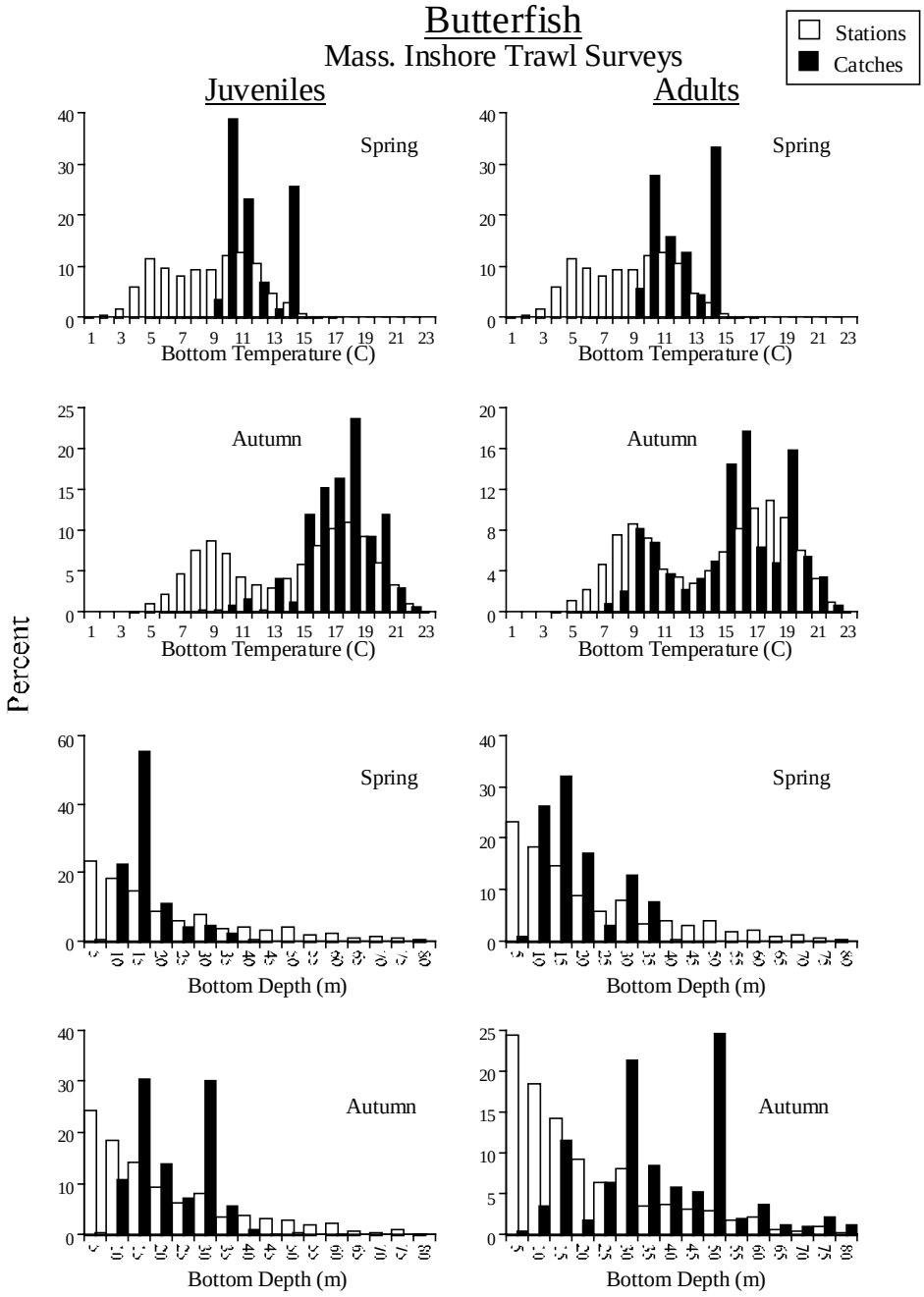


Figure 7. Abundance of juvenile and adult butterfish relative to bottom water temperature and depth based on Massachusetts inshore bottom trawl surveys (spring and autumn 1978-1996, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion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

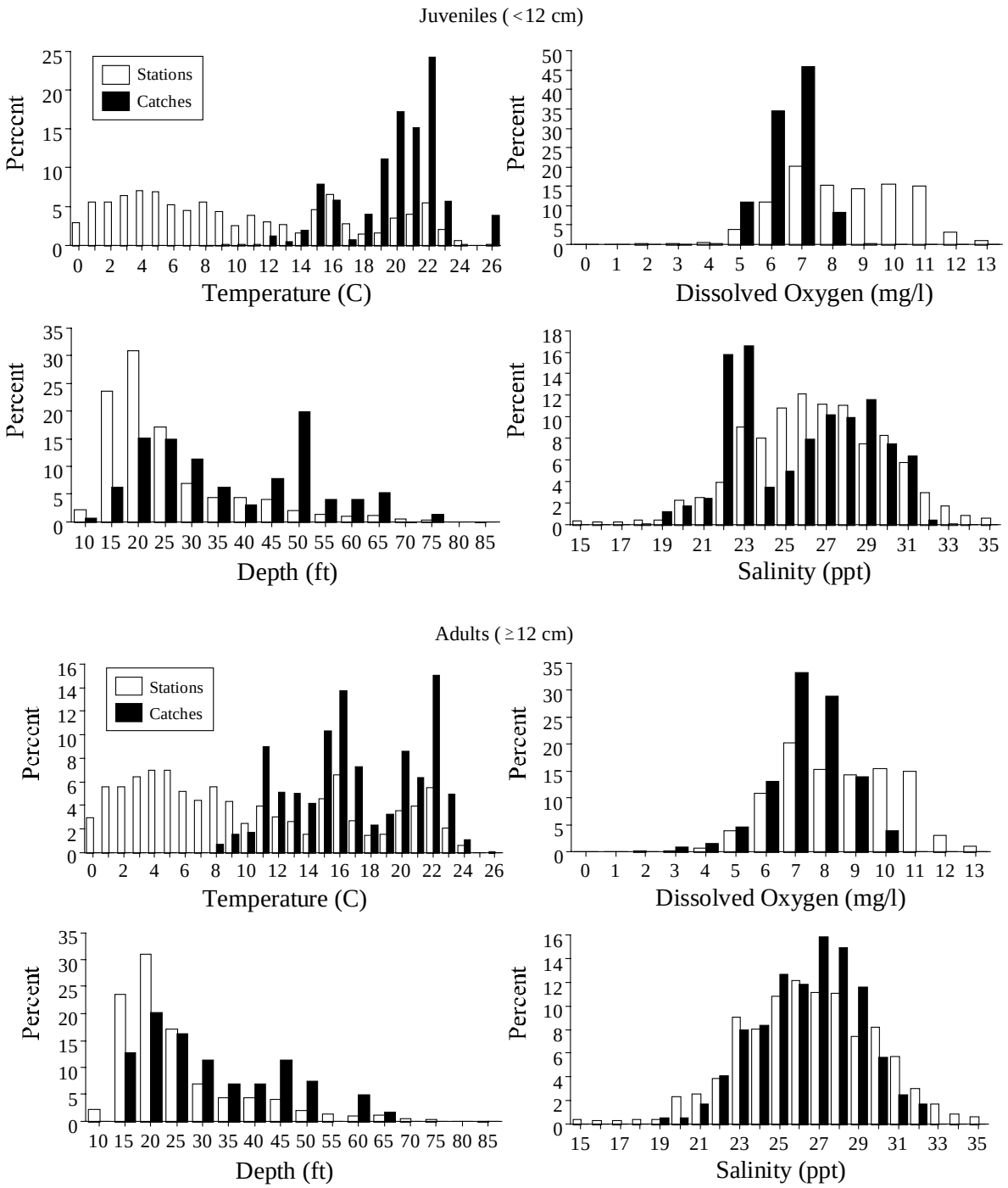


Figure 8. Abundance of juvenile and adult butterfish relative to bottom water temperature, depth, dissolved oxygen and salinity from Hudson-Raritan estuary trawl surveys (1992-1997) for all years combined.

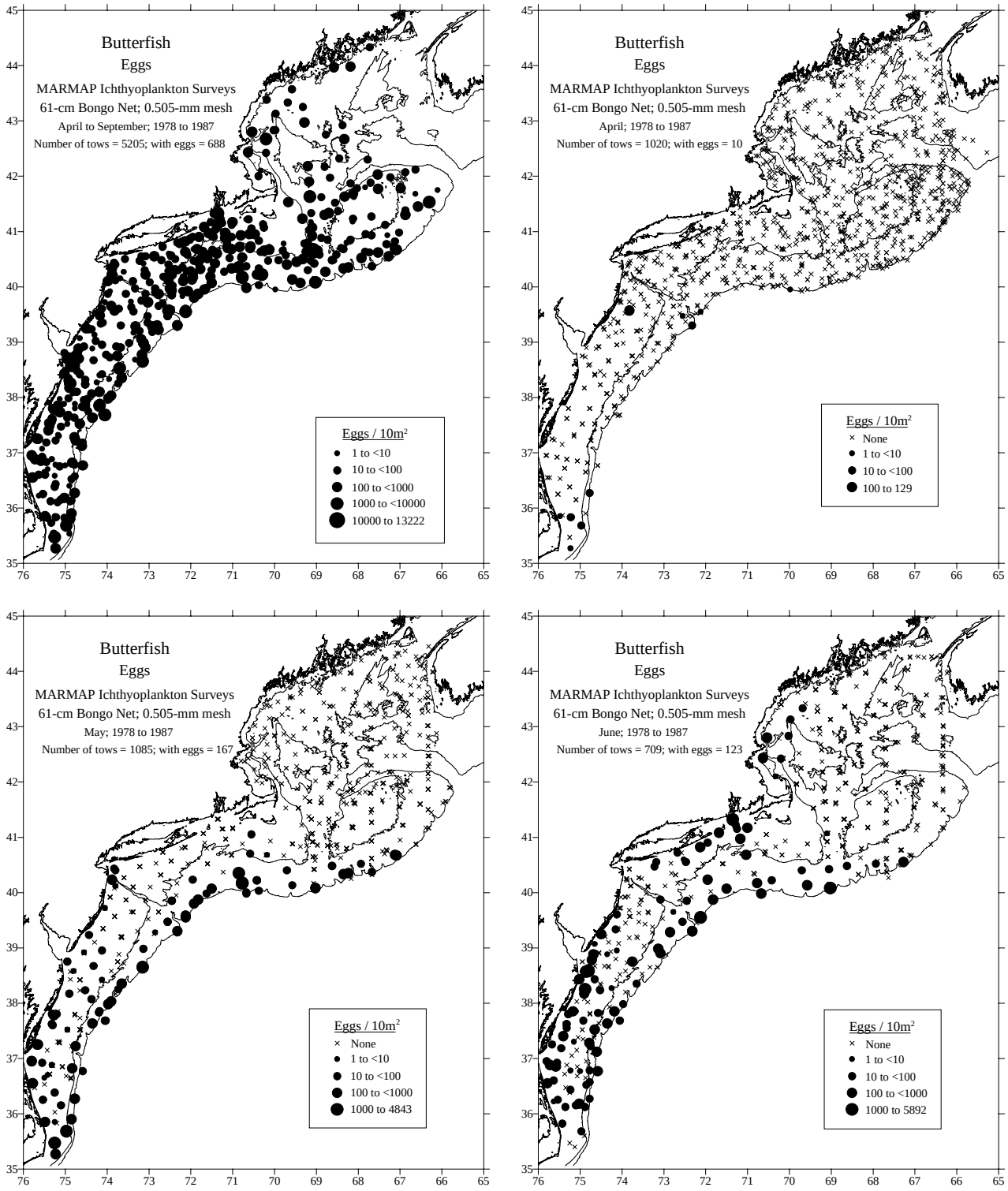
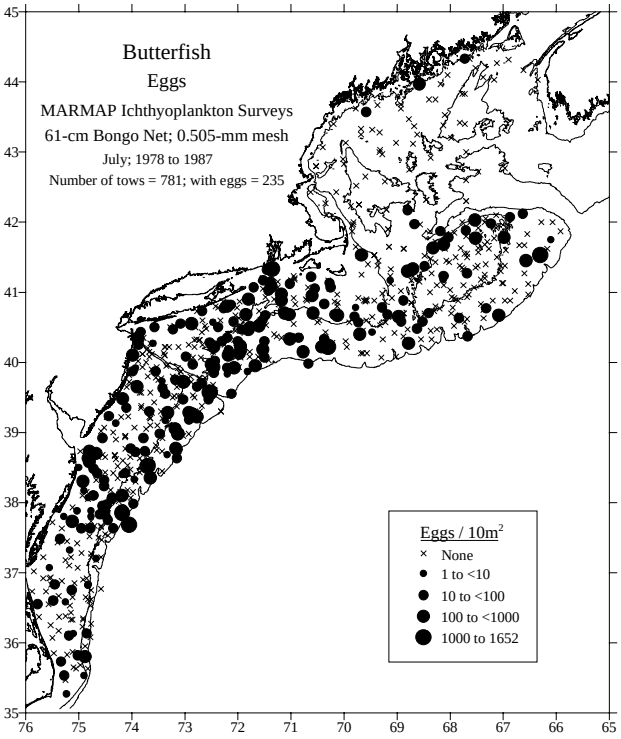
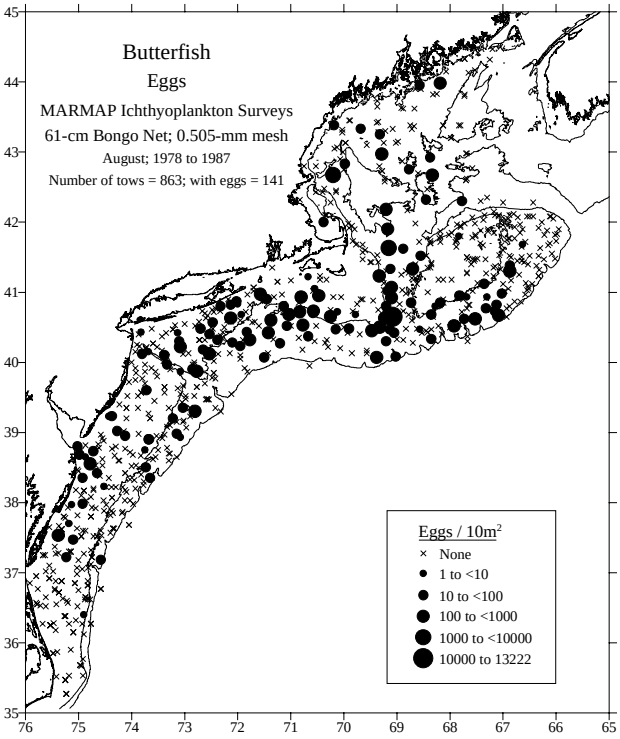


Figure 9. Distribution of butterfish eggs based on NEFSC MARMAP ichthyoplankton surveys from April to September, 1978-1987 [see Reid *et al.* (1999) for details].





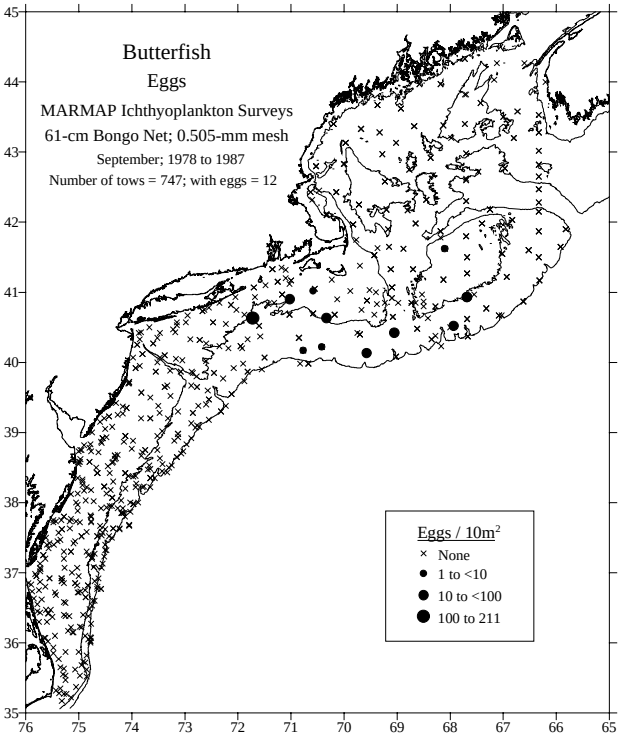


Figure 9. cont'd.

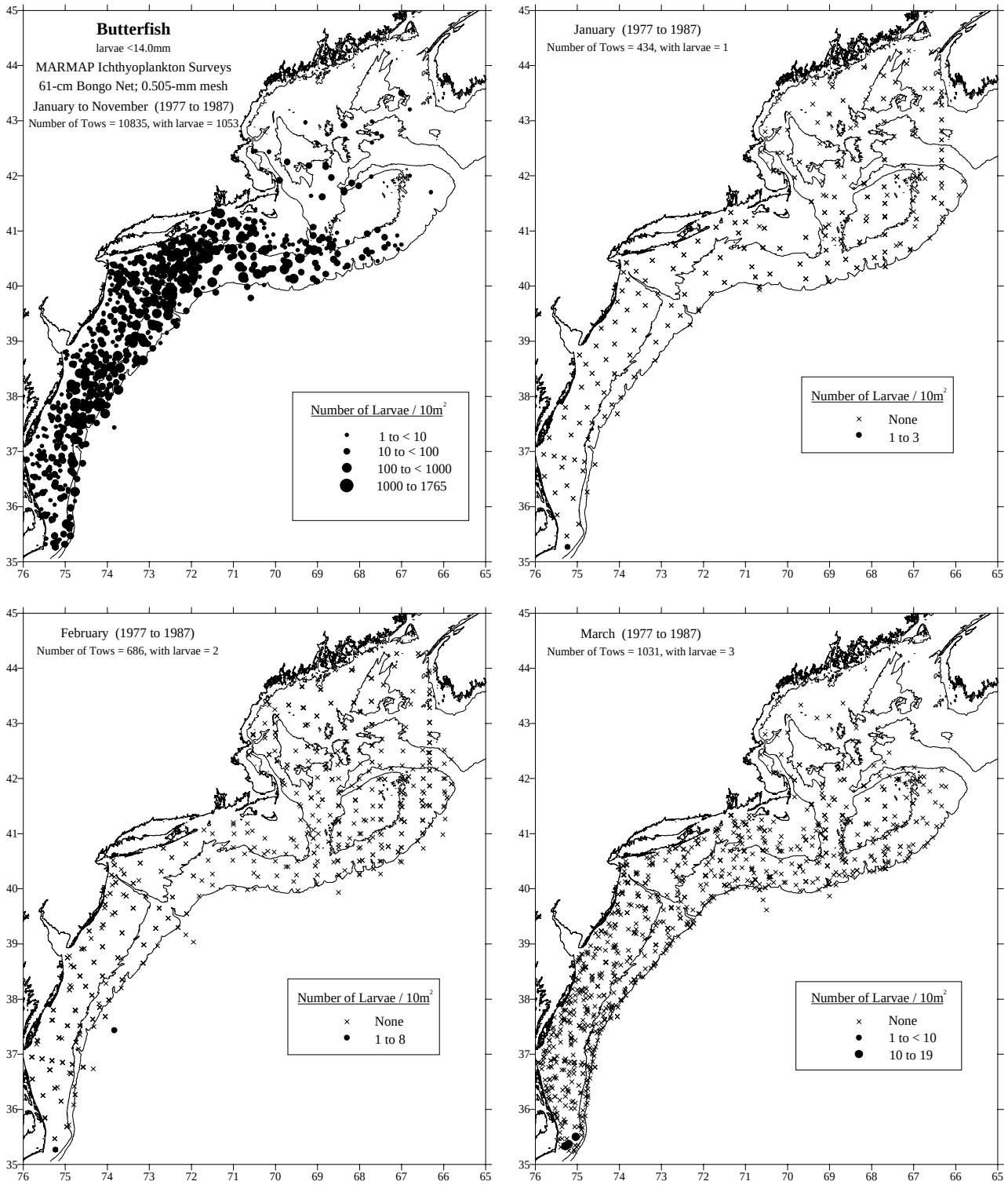
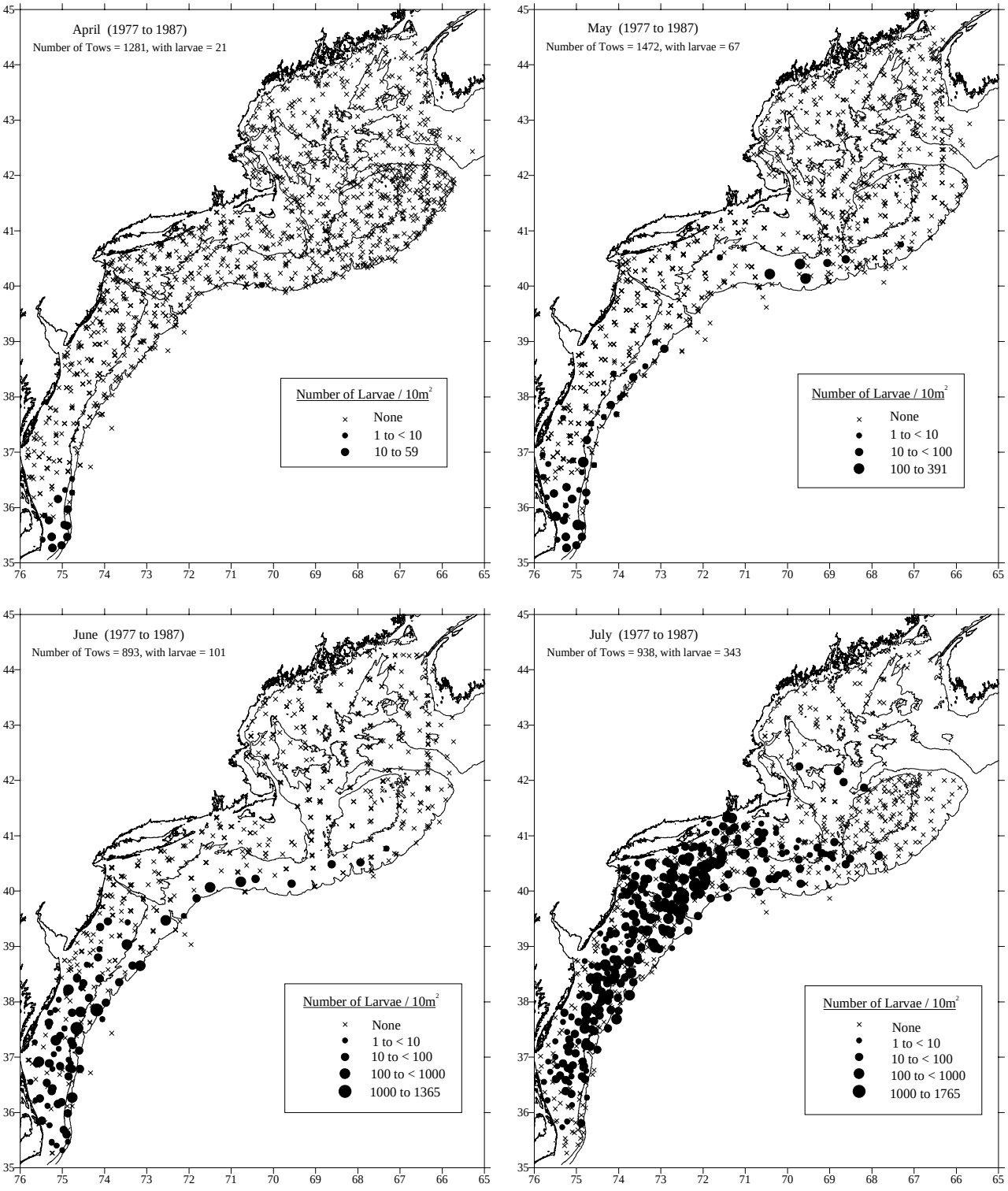


Figure 10. Distribution of butterfish larvae (< 14 mm) collected during NEFSC MARMAP ichthyoplankton surveys from January through November, 1977-1987 [see Reid *et al.* (1999) for details].



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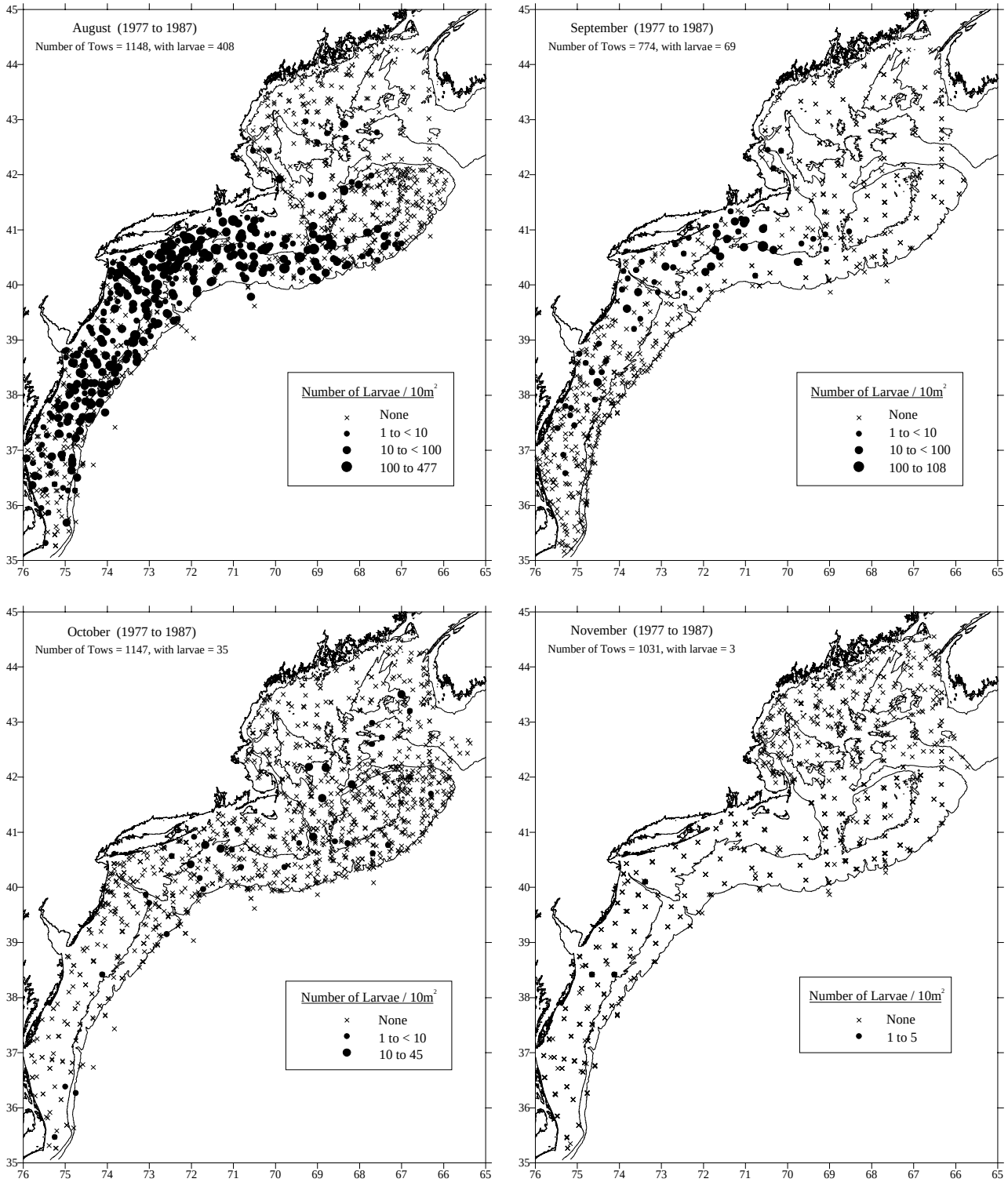


Figure 10. cont'd.

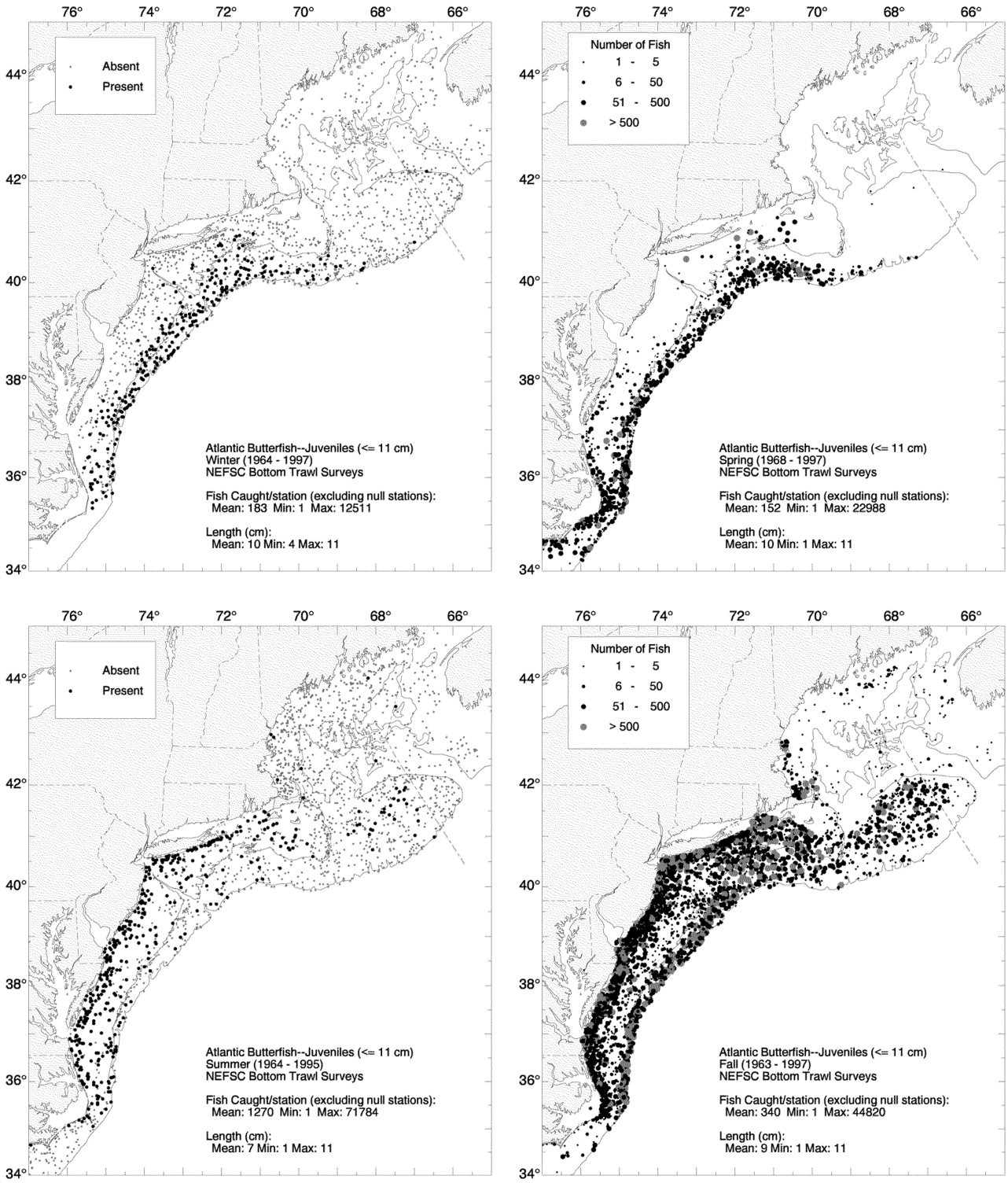


Figure 11. Distribution of juvenile and adult butterfish collected during NEFSC bottom trawl surveys during all seasons during 1963-1997. Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].

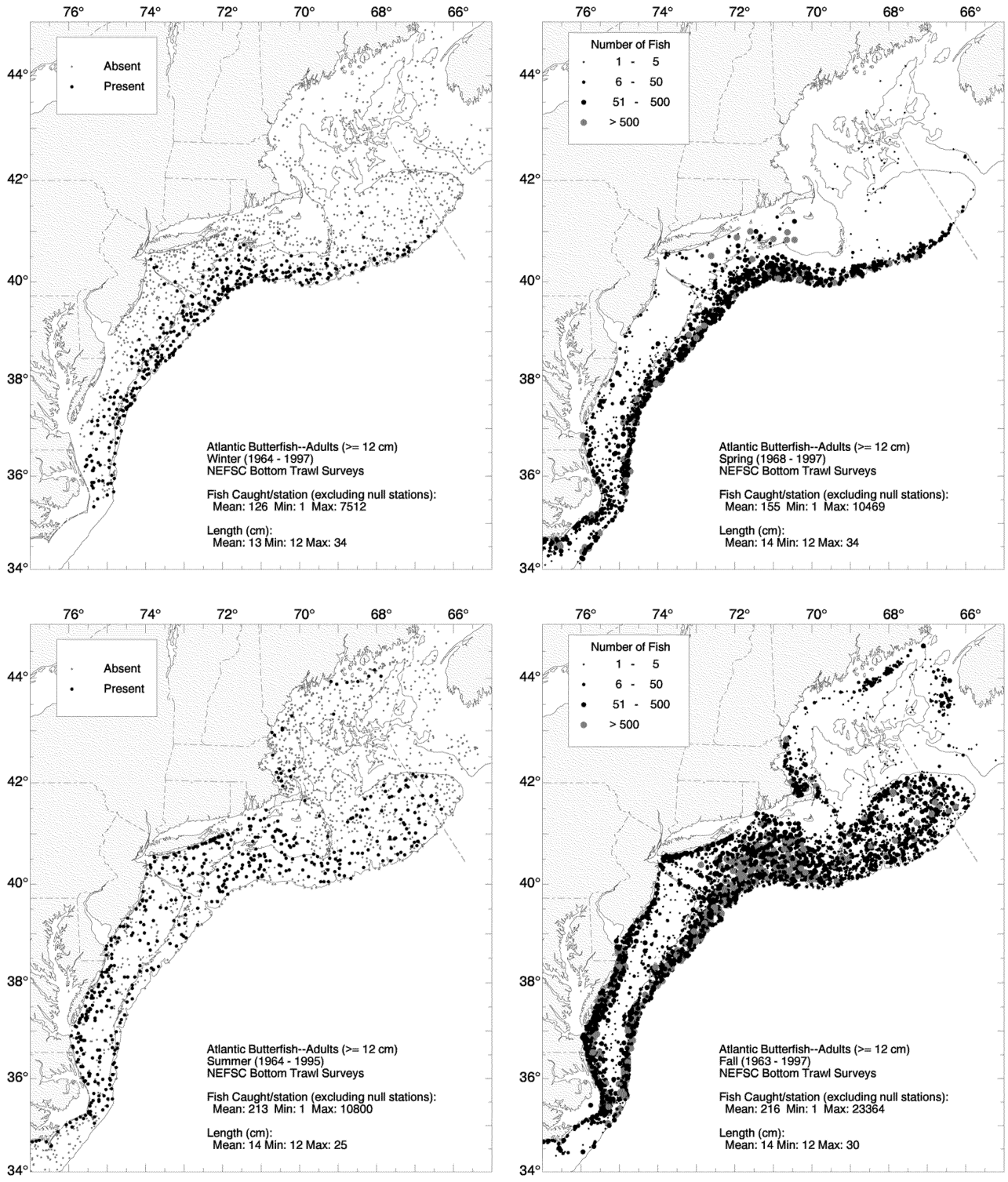


Figure 11. cont'd.

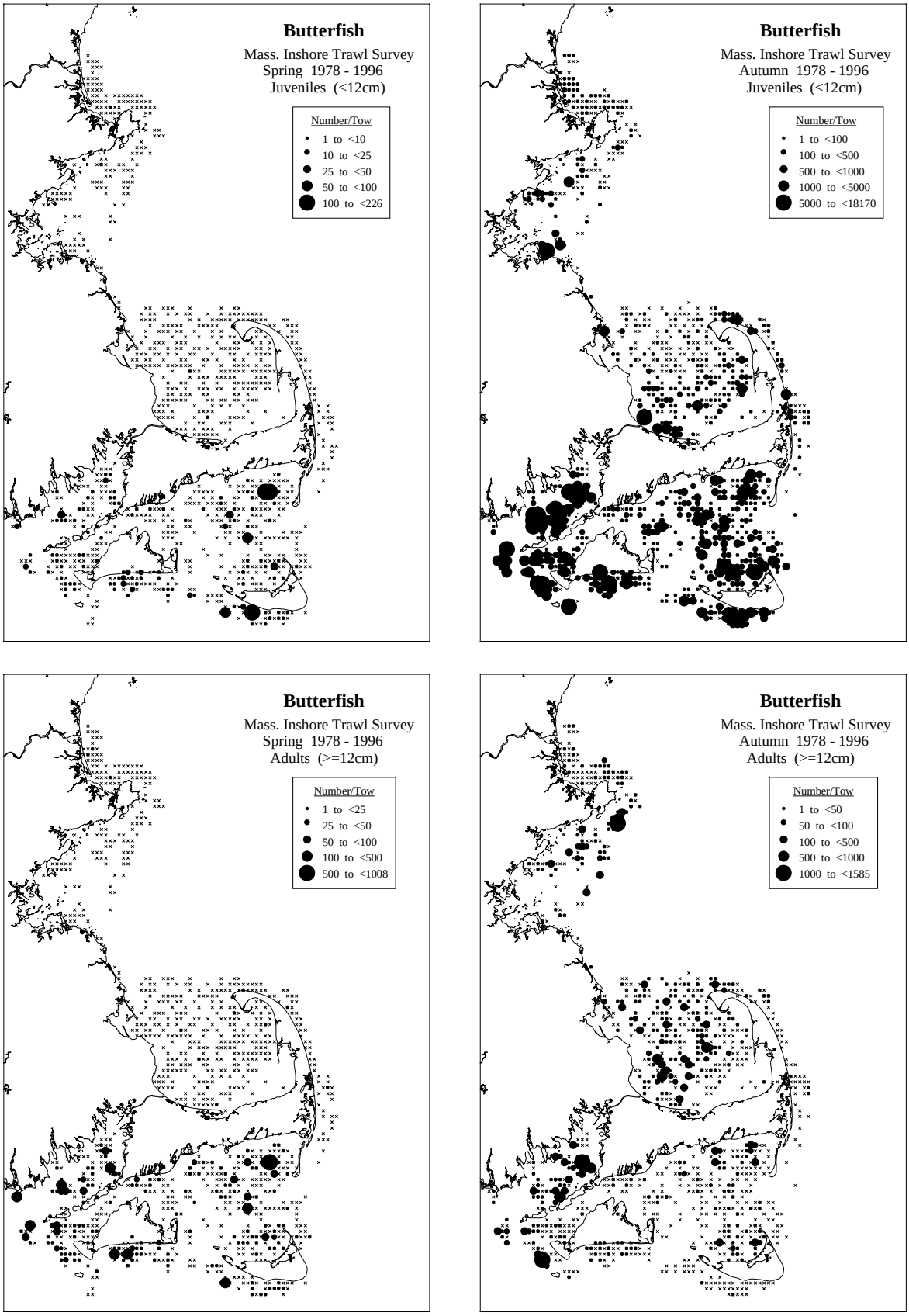


Figure 12. Distribution of juvenile and adult butterfish in Massachusetts coastal waters during spring and autumn Massachusetts trawl surveys, 1978-1996 [see Reid *et al.* (1999) for details].

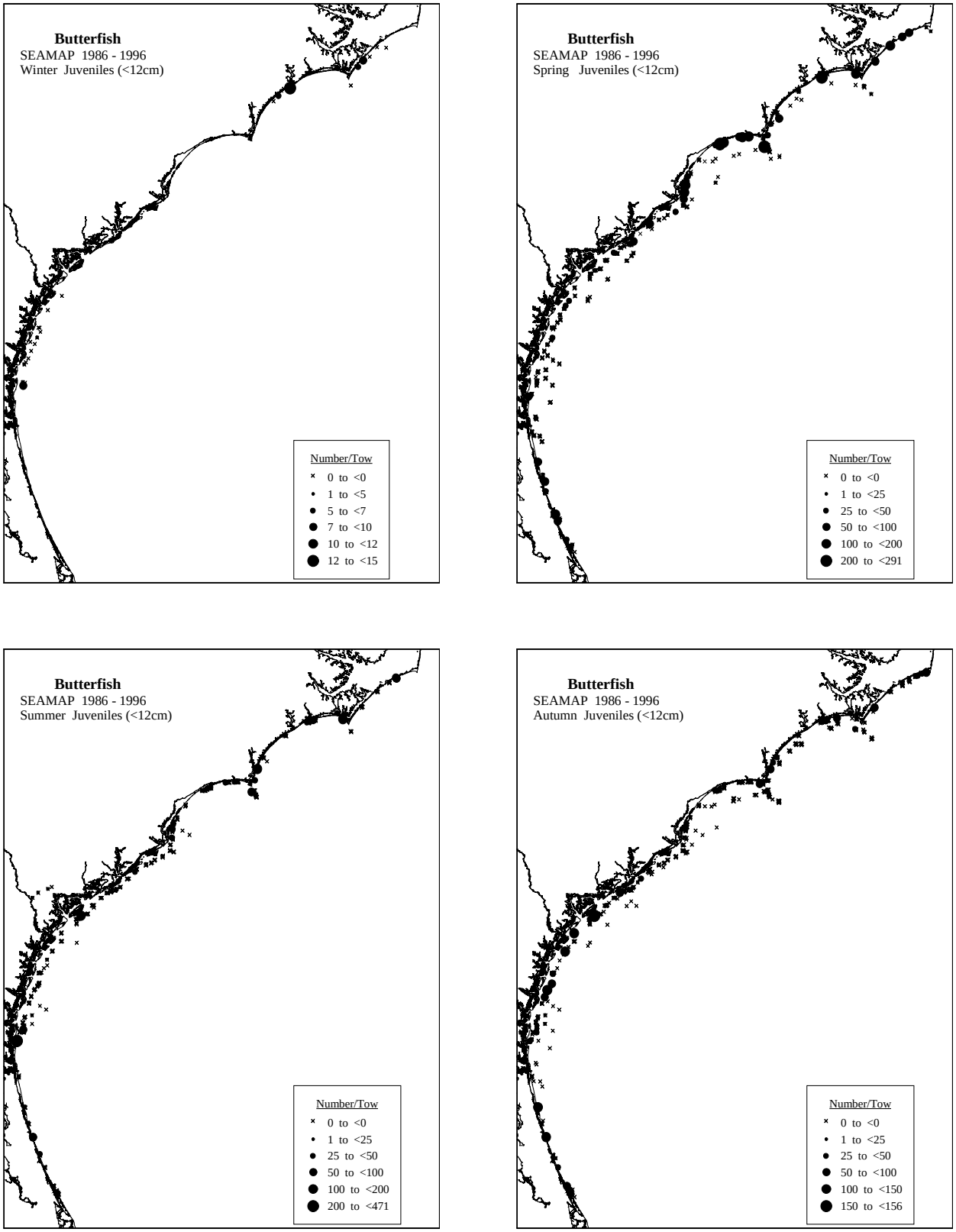
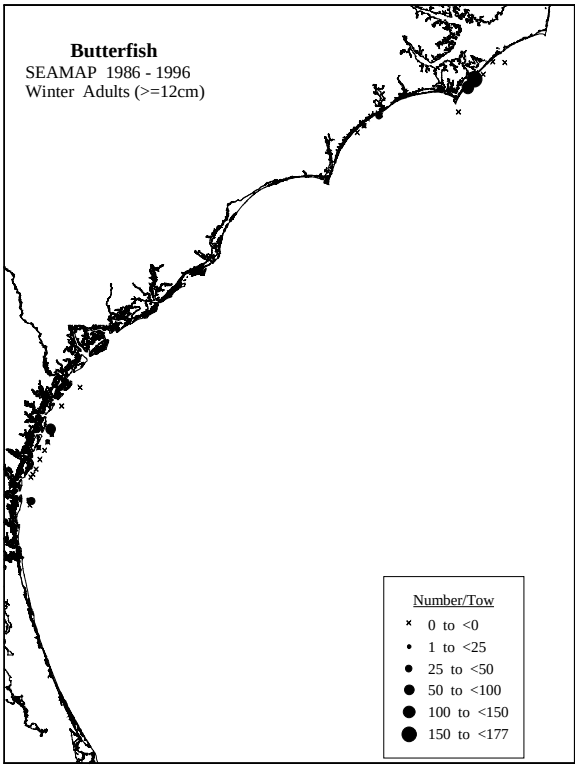
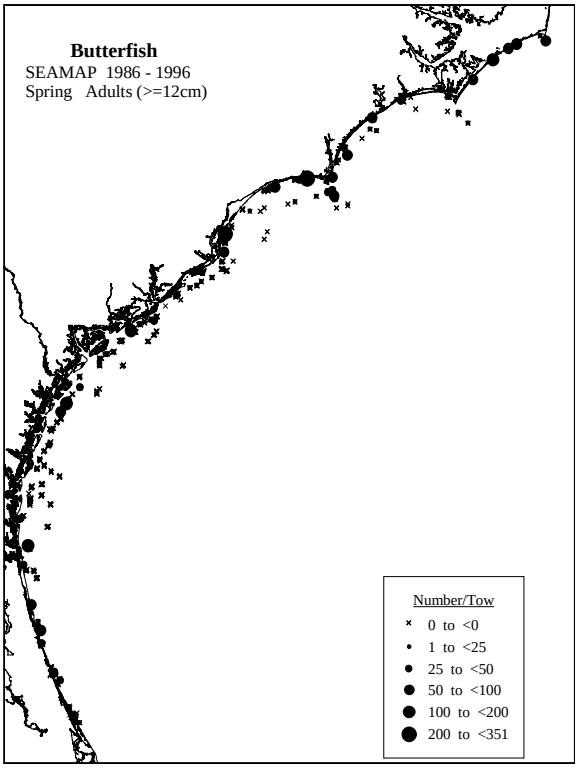
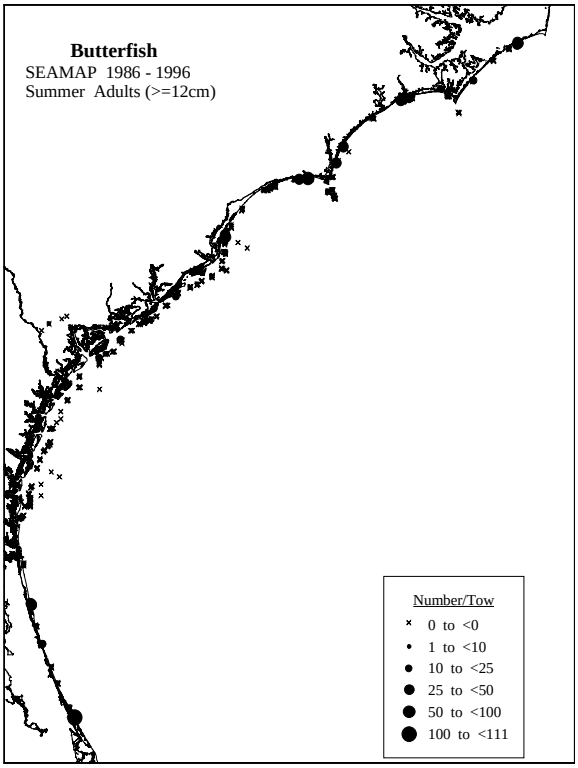
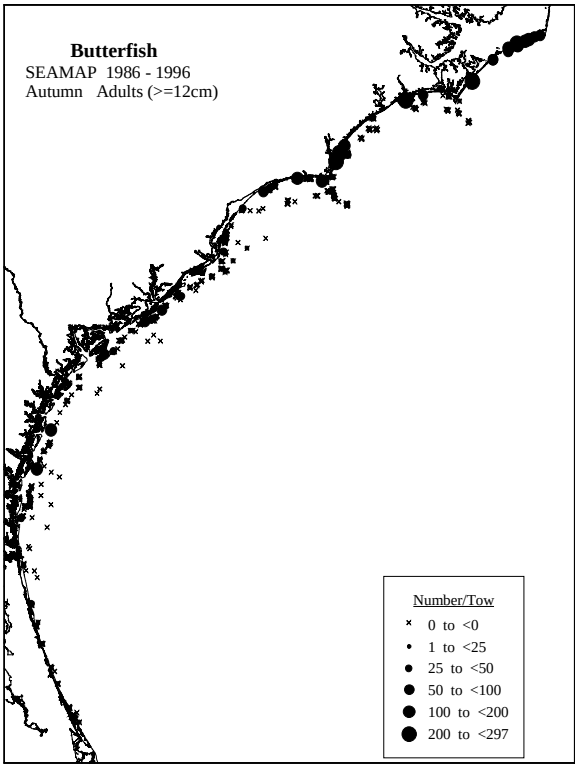


Figure 13. Distribution of juvenile and adult butterfish in the SEAMAP bottom trawl surveys in all seasons for all years combined (1986-1996).









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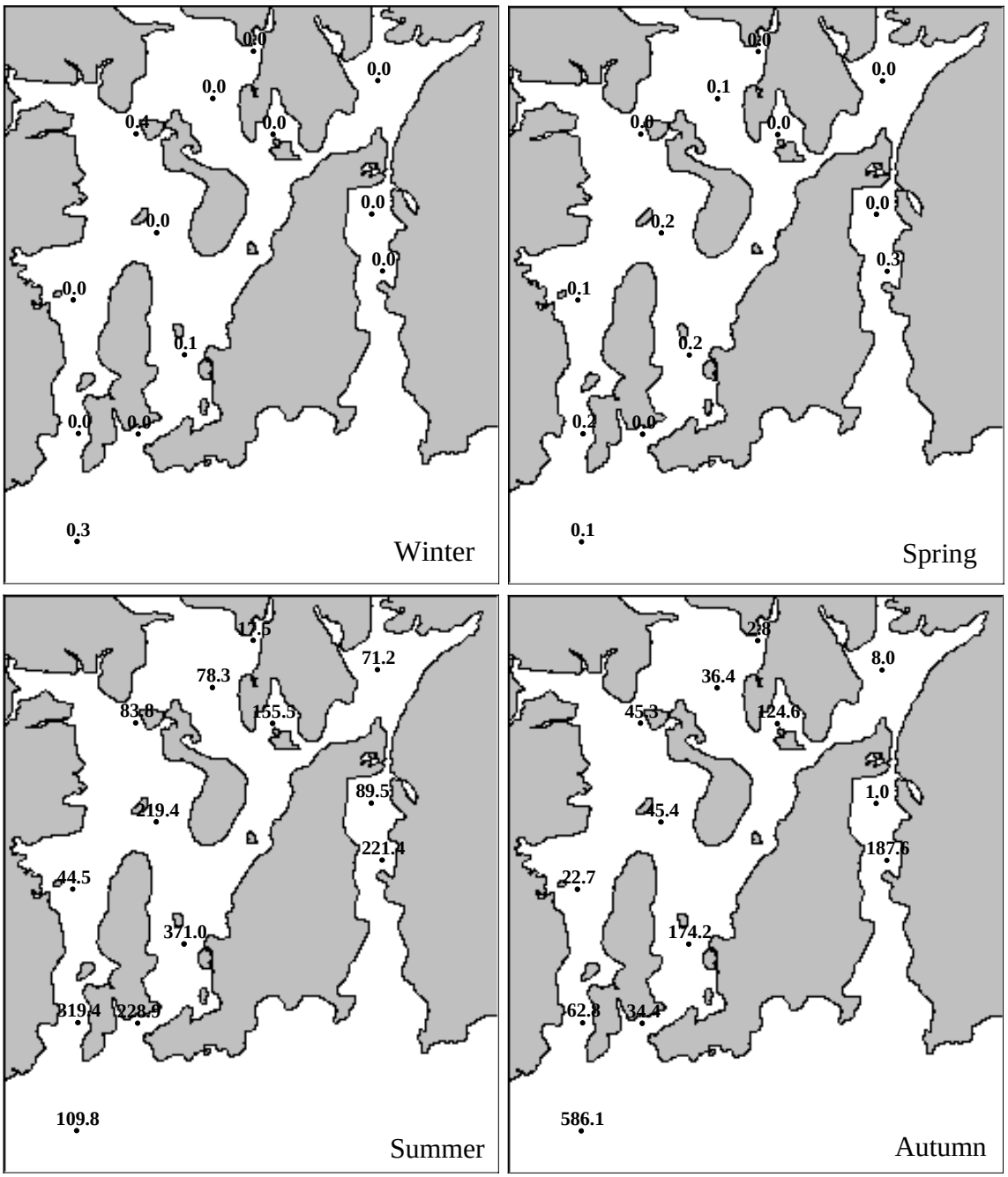
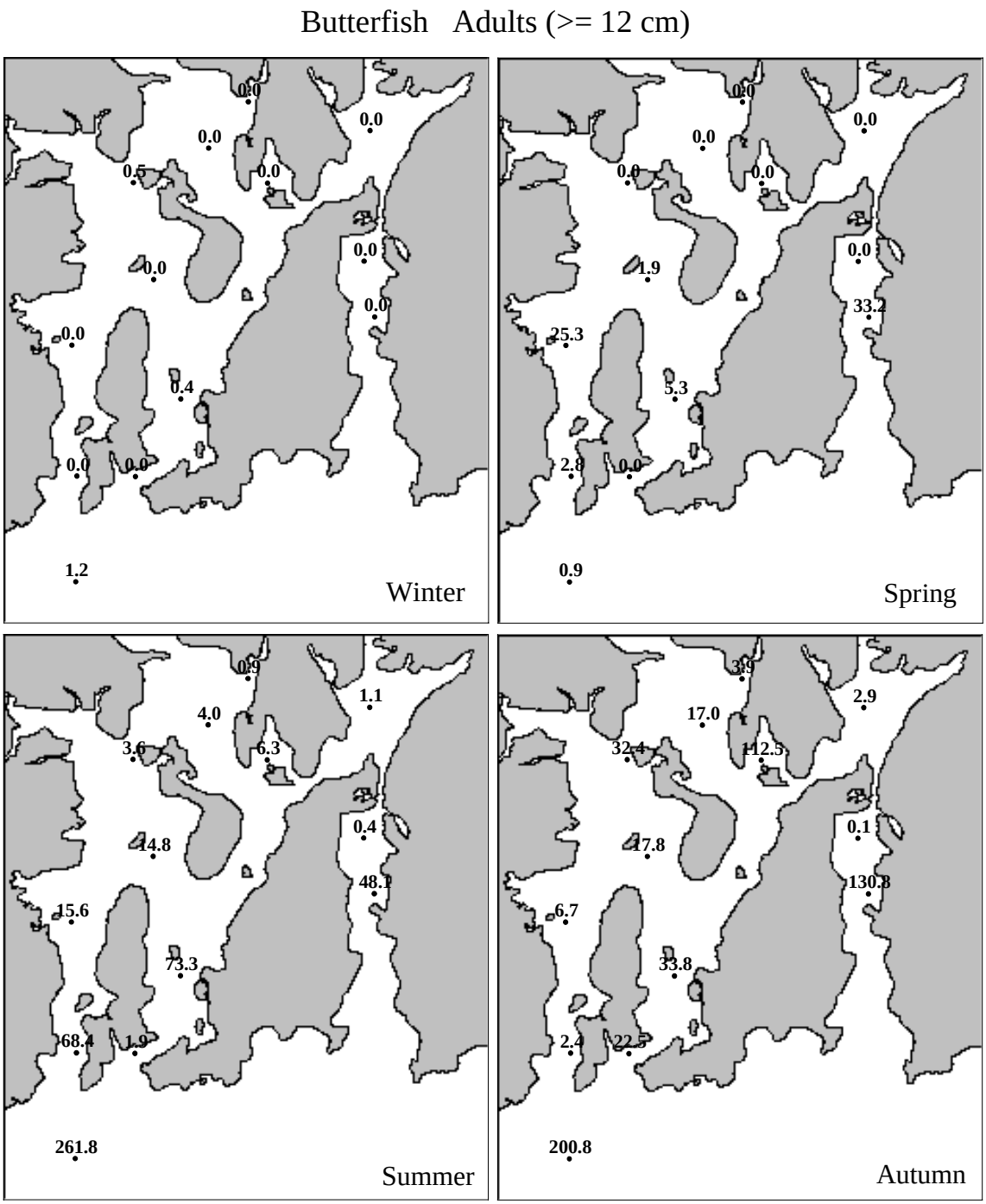


Figure 14. Distribution of juvenile and adult butterfish collected in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid *et al.* (1999) for details].



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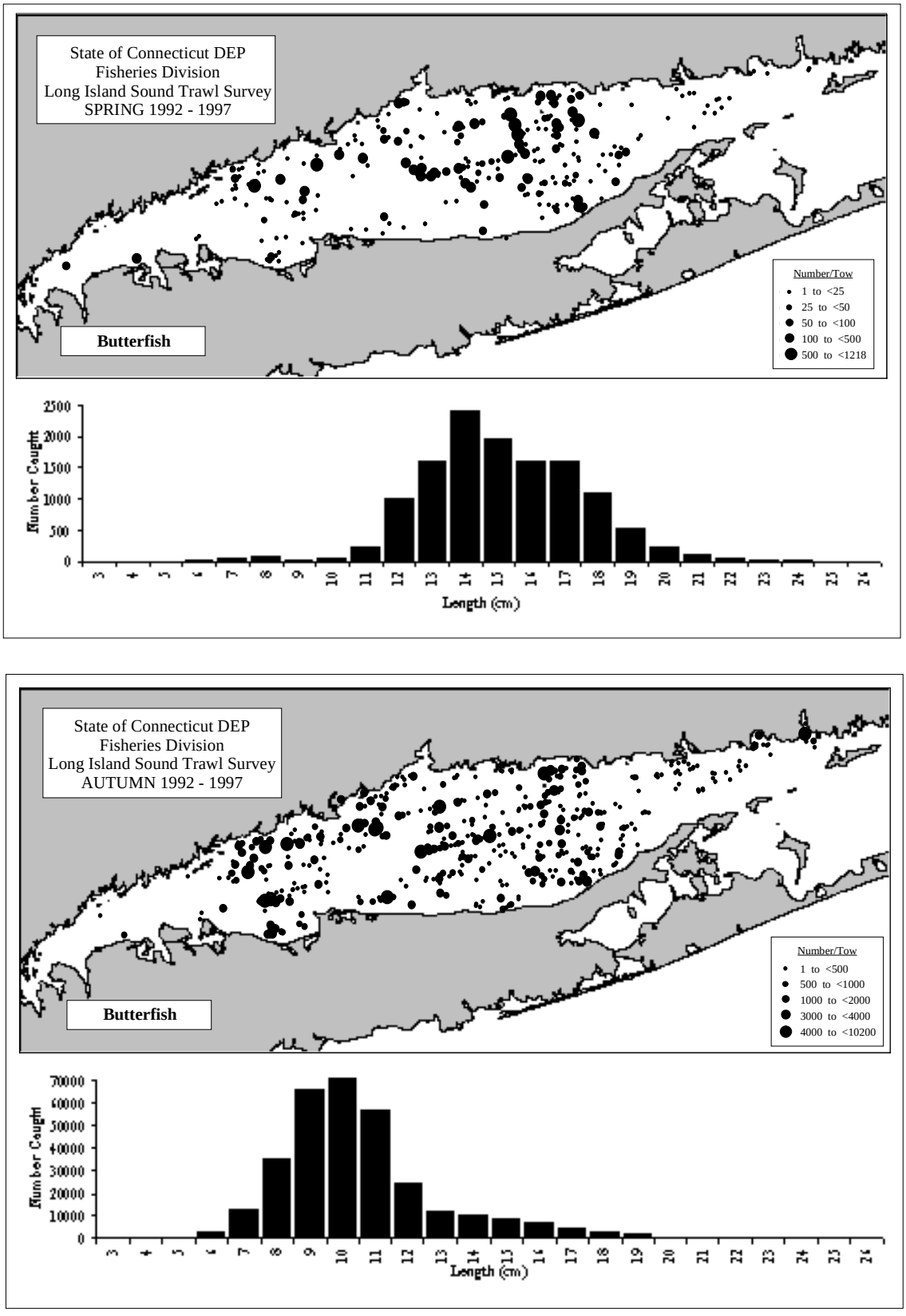


Figure 15. Distribution of juvenile and adult butterfish in Long Island Sound in spring and autumn, from the Connecticut bottom trawl surveys, 1992-1997 [see Reid *et al.* (1999) for details].

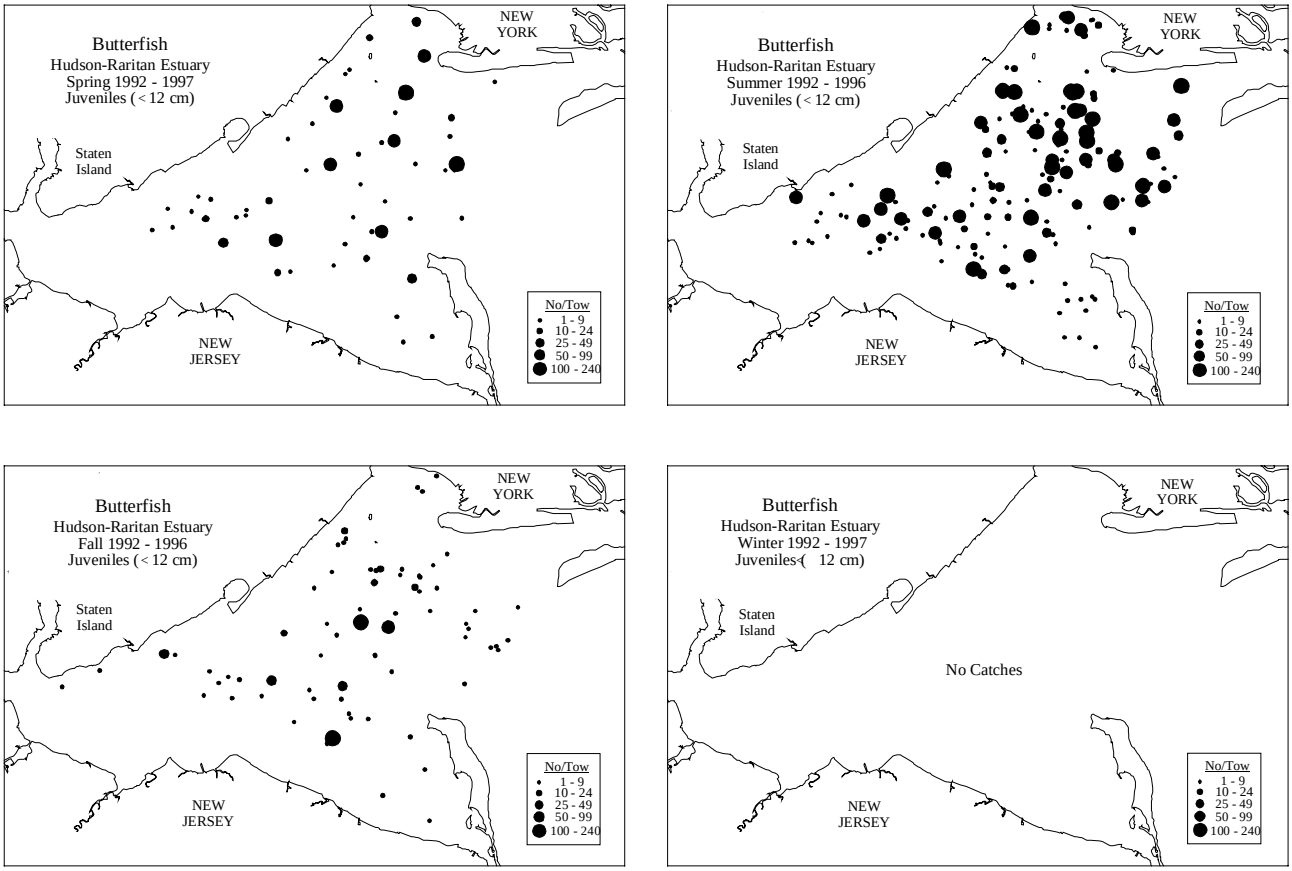
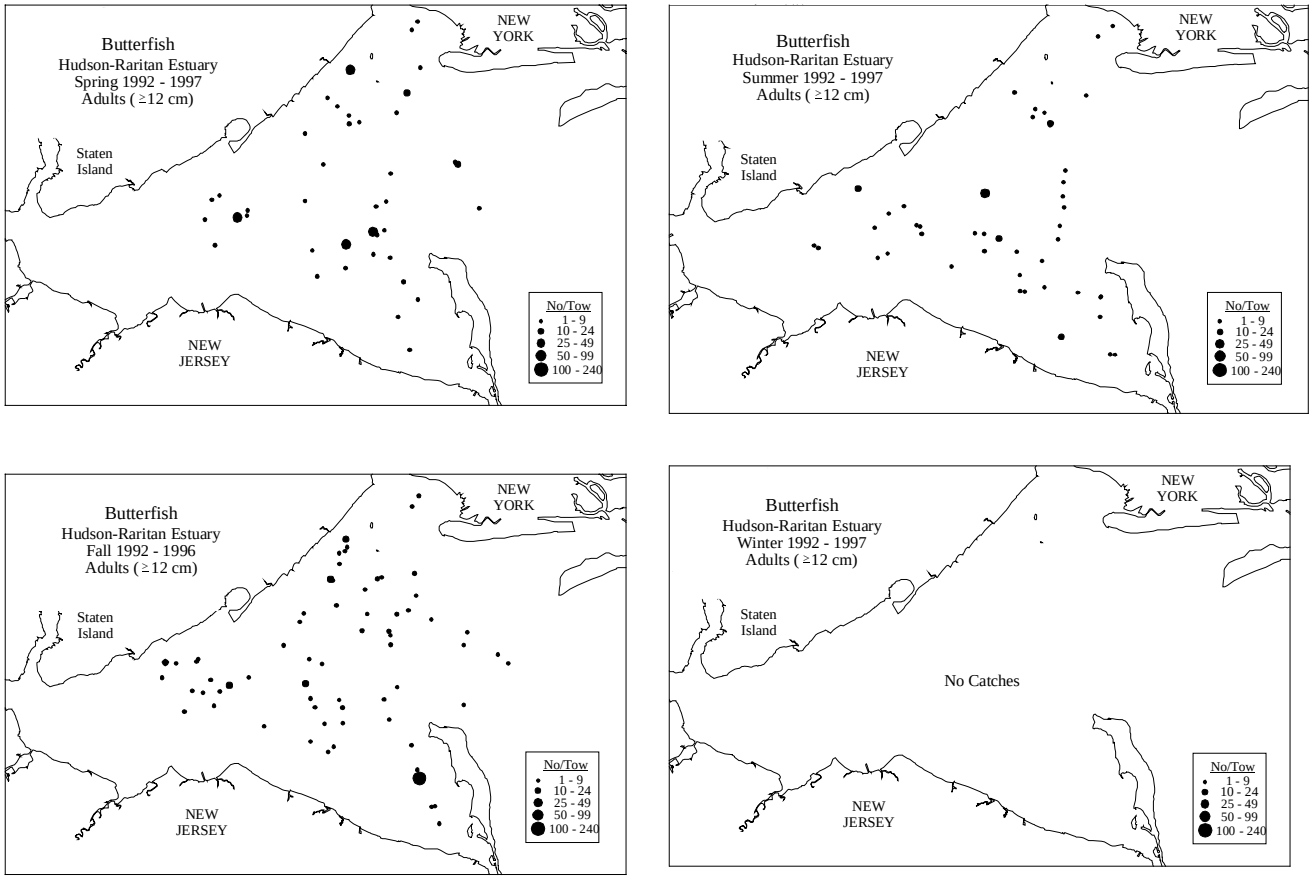


Figure 16. Distribution of juvenile and adult butterfish in the Hudson-Raritan estuary based on Hudson-Raritan trawl surveys, 1992-1997 [see Reid *et al.* (1999) for details].



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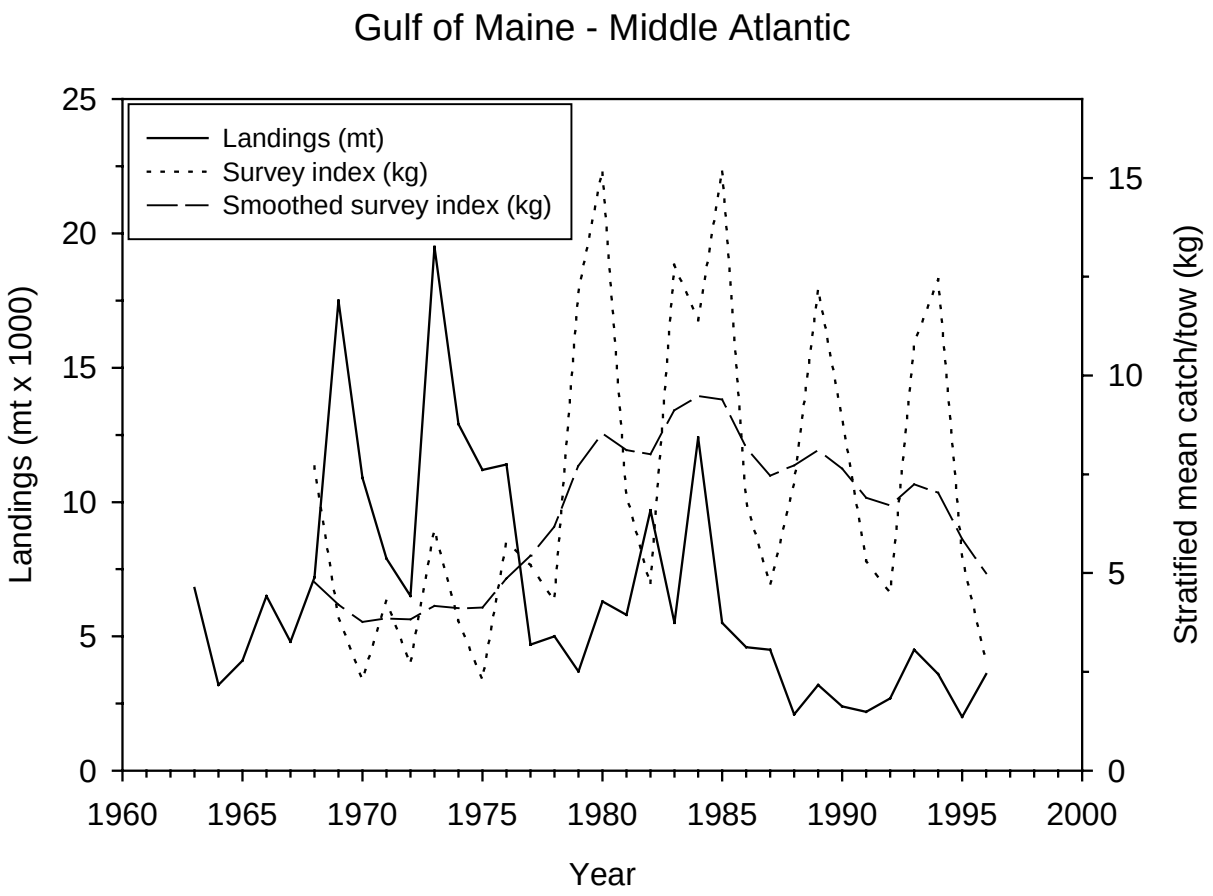

Figure 17. Commercial landings and abundance indices (from the NEFSC bottom trawl surveys) for butterfish from the Gulf of Maine to the Middle Atlantic.

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