NOAA Technical Memorandum NMFS-NE-137

Essential Fish Habitat Source Document:

Windowpane, *Scophthalmus aquosus*, 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:

Windowpane, *Scophthalmus aquosus*, 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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NORTHEAST FISHERIES SCIENCE CENTER

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INTRODUCTION

The windowpane, *Scophthalmus aquosus*, is an eurythemal, euryhaline, and fast-growing fish with a thin body (Figure 1). It inhabits estuaries, near-shore waters, and the continental shelf in the northwest Atlantic. Windowpane is not a target of the commercial fishing industry, but is mainly caught as bycatch in bottom trawl fisheries. It is managed by the New England Fishery Management Council under the Multispecies Fishery Management Plan (NEFMC 1993). This Essential Fish Habitat source document provides information on the life history and habitat characteristics of windowpane.

LIFE HISTORY

The windowpane is a left-eyed flounder with a thin body and nearly round outline. It occurs from the Gulf of Saint Lawrence to Florida (Scott and Scott 1988), but is most abundant from Georges Bank to Chesapeake Bay (Figures 2 and 3; Bigelow and Schroeder 1953; Dery and Livingstone 1982; Chang 1990). Windowpane generally inhabit shallow waters (< 110 m) with sand to sand/silt or mud substrates; they are most abundant from depths of 1-2 m (Warfel and Merriman 1944) to depths < 56 m (Thorpe 1991). They occur in most of the bays and estuaries south of Cape Cod, including Chesapeake Bay (Hildebrand and Schroeder 1928), Delaware Bay (de Sylva *et al.* 1962), Sandy Hook Bay (Wilk and Silverman 1976), Raritan Bay (Wilk *et al*. 1996), Long Island Sound (Moore 1947; Gottschall *et al*., in review), and Narragansett Bay (Jefferies and Johnson 1973). North of Cape Cod, windowpane inhabit nearshore waters, but their occurrence in estuaries is not well documented. Table 1 presents a qualitative summary of the distribution and relative abundance of windowpane life history stages in estuaries from Maine to Virginia (Jury *et al*. 1994; Stone *et al*. 1994).

EGGS

The eggs are buoyant and spherical, with a diameter of 0.9-1.4 mm), and a single oil globule 0.2-0.3 mm in diameter (Wheatland 1956). At a typical spawning temperature of 11^{o}C, hatching occurs in eight days (Miller *et al*. 1991).

LARVAE

At hatching, windowpane larvae are approximately 2 mm long (Fahay 1983; Able and Fahay 1998). Flexion begins at about 5.5 mm TL (Fahay 1983); eye transformation during metamorphosis begins at about 6.5 mm TL (Colton and Marak 1969; Fahay 1983). The body is darkly pigmented over most of its length. As development proceeds, the body becomes deeper and more laterally compressed. Fin ray formation is complete at about 11.5 mm TL. Details of larval development are provided by Moore (1947).

JUVENILES

The body is oval and wider (60-70% SL) than in other left-eyed flounders. The body and fins are heavily pigmented in larger young-of-the-year; smaller individuals are characterized by broad alternating dark and light bands. The mouth is large, extending to the eye or beyond and the lateral line is arched over the pectoral fin (Figure 1; Able and Fahay 1998). The growth patterns of young juveniles in estuaries and on the shelf vary with the timing of spawning. Fish spawned in the spring grow quickly and reach sizes of 11-19 cm TL by September, about four months after spawning. By the following spring, most fish of this cohort are larger than 16 cm TL. Fish spawned in the autumn are 4-7 cm TL in December and reach 18-21 cm TL by the following October (Morse and Able 1995; Able and Fahay 1998).

ADULTS

Windowpane attain a maximum total length of about 46 cm (Scott and Scott 1988). Few age and growth studies of windowpane have been conducted (Moore 1947; Shelton 1979; Thorpe, 1991). It is a fast growing species and spring and summer is the period of greatest growth (Moore 1947).

REPRODUCTION

Gonadal development indices (Wilk *et al.* 1990) and egg and larval distributions (Colton and St. Onge 1974; Smith *et al.* 1975; Colton *et al*. 1979; Morse *et al.* 1987) indicate that spawning occurs throughout most of the year. Spawning begins in February or March in inner shelf waters, peaks in the Middle Atlantic Bight in May, and extends onto Georges Bank during the summer (Able and Fahay 1998). Spawning also occurs in the southern portion of the Middle Atlantic Bight in the autumn (Smith *et al*. 1975). There is a split spawning season in the central Middle Atlantic Bight with peaks in the spring and autumn (Morse and Able 1995; Able and Fahay 1998). Evidence for a split spawning season is available for Virginia and North Carolina (Smith *et al.* 1975), for Long Island Sound, New York (Wheatland 1956), and for Great South Bay, New York (Dugay *et al.* 1989; Monteleone 1992). Gonad development indicated that split spawning off New Jersey and New York peaks in May and in September (Wilk *et al.* 1990). However, neither

Perlmutter (1939) nor Smith *et al.* (1975) found evidence for a split spawning season in Long Island Sound or in oceanic waters north of Virginia. Colton and St. Onge (1974) collected larvae on Georges Bank from July to November but found no indication of a split spawning season.

Some spawning may occur in the high salinity portions of estuaries in the Middle Atlantic Bight, including Great South Bay, New York (Monteleone 1992), Sandy Hook Bay, New Jersey (Croker 1965), inside Hereford Inlet, New Jersey (Allen *et al.* 1978), and in the coastal habitats of the Carolinas (Wenner and Sedberry 1989). Windowpane spawn in the evening or at night (Ferraro 1980) on or near bottom at temperatures ranging from 6-21^{o}C (Bigelow and Schroeder 1953; Wheatland 1956; Smith *et al.* 1975). Most spawning (70%) was found at bottom water temperatures between 8.5-13.5^{o}C; spawning stopped off Virginia and North Carolina when water temperatures exceeded 15^{o}C (Smith *et al.* 1975).

Sexual maturity occurs at 3-4 years of age when about 50% of females that are 22 cm TL are sexually mature. Females grow larger and faster than males after sexual maturity (O'Brien *et al.* 1993).

FOOD HABITS

Juvenile and adult windowpane feed exclusively on mysid shrimps in Johns Bay, Maine (Hacunda 1981). Stomach content data collected during Northeast Fisheries Science Center (NEFSC) bottom trawl surveys indicate windowpane feed on small crustaceans (e.g., mysids and decapod shrimp) and various fish larvae including hakes and tomcod, as well as their own species (Langton and Bowman 1981; Figure 4).

PREDATION

Spiny dogfish, thorny skate, goosefish, Atlantic cod, black sea bass, weakfish and summer flounder are major predator of windowpane, primarily juveniles.

MIGRATION

Juveniles that settle in shallow inshore waters move to deeper offshore waters as they grow (Klein-MacPhee, in prep.). Juveniles and adults may migrate to nearshore or estuarine habitats in the southern Middle Atlantic Bight in the autumn (Figures 2 and 3), however, juveniles are probably not adequately sampled by standard Northeast Fisheries Science Center trawl gear (Morse and Able 1995). Juveniles inhabiting Georges Bank (< 60 m) undergo seasonal movements to deeper waters along the southern flank of the Bank occur during late autumn, as bottom temperatures drop, and overwintering occurs in deeper areas until late spring (Figure 2).

STOCK STRUCTURE

Fish stocks are generally defined as having a fixed spawning ground, a definite spawning season, and a consistent migratory or movement pattern. Nonetheless, spawning in windowpane occurs throughout most of the year (April-December) and is closely linked to bottom temperature (Colton and St. Onge 1974; Smith *et al*. 1975; Colton *et al*. 1979; Morse *et al*. 1987). Thus, stock structure of windowpane could not clearly be identified. However, the species is managed as two stocks: a northern stock, Gulf of Maine-Georges Bank region, and a southern stock, southern New England-Middle Atlantic Bight region.

HABITAT CHARACTERISTICS

The habitat characteristics and preferences of windowpane are summarized in Table 2. The methods used to collect the fishery-independent survey data used in this characterization are summarized in Reid *et al*. (1999).

EGGS

Windowpane eggs were collected at integrated water column temperatures of 5-20^{o}C. Most eggs were collected at 4-16^{o}C in spring (March-May), 10-16^{o}C in summer (June-August) and 14-20^{o}C in autumn (September-November) in depths < 70 m (Figure 5).

LARVAE

Larvae settle to the bottom at approximately 10 mm TL (Bigelow and Schroeder 1953). However, individuals collected on Georges Bank may be planktonic up to 20 mm (Morse and Able 1995). Based on collections from southern New Jersey, it appears that settlement of spring-spawned individuals occurs in estuaries and on the shelf, while settlement of autumn-spawned individuals occurs primarily on the shelf. Larvae are found throughout the polyhaline portion of estuaries in the spring, but primarily on the shelf in the autumn (Morse and Able 1995).

The maximum abundance of small larvae (< 5 mm TL) occurred from 15-19^{o}C in areas south of Georges Bank and at 14-15^{o}C on Georges Bank. Windowpane larvae were collected during the NEFSC Marine Resources Monitoring, Assessment and Prediction (MARMAP) ichthyoplankton survey at integrated water column temperatures of 5-20^{o}C, but mostly at 3-14^{o}C in spring, 10-17^{o}C in summer, and 13-19^{o}C in autumn in water < 70 m deep (Figure 6).

JUVENILES

Juveniles were collected on the continental shelf throughout the year during NEFSC bottom trawl surveys (Figure 2) at a wide range of bottom temperatures (3-25°C) and depths (5-125 m). Juveniles were most abundant at bottom temperatures of 4-7°C in spring and 14-16°C in autumn at depths < 50 m (Figure 7).

Juveniles inhabiting Massachusetts inshore waters (Figure 8) were most abundant at 5-12°C in spring and 12-19°C in autumn, and at depths < 20 m (Figure 9).

Windowpane were common in the Rhode Island bottom trawl survey in Narragansett Bay; juveniles were caught throughout the bay in all seasons with no indication of seasonal differences. Juveniles were captured at most bottom depths but showed a preference for depths < 30 m in warmer bottom water temperature periods (9-25°C), and depths > 30 m in colder water temperatures (1-8°C). They occurred at a wide range of bottom water temperatures: winter (1-8°C), spring (1-15°C), summer (13-25°C), and autumn (10-21°C).

The bottom trawl survey in the Hudson-Raritan estuary showed that juveniles were fairly evenly distributed throughout the estuary, but they were most abundant in the deeper channels in winter and summer (Figure 10; Wilk *et al.* 1996). For all seasons combined, juveniles were collected at bottom temperatures of 0-24°C, at depths < 25 m with salinities of 15-33 ppt, and dissolved oxygen (DO) levels of 2-13 mg/l (Figure 11; Wilk *et al.* 1996). Juvenile windowpane were most abundant at bottom water temperatures of 5-23°C, at depths of 7-17 m, at salinities of 22-30 ppt, and DO levels of 7-11 mg/l (Figure 11; Wilk *et al.* 1996).

ADULTS

The windowpane is a year-round resident off southern New Jersey and probably in the Gulf of Maine (Klein-MacPhee, in prep.). Adult windowpane tolerate a wide range of temperatures (0-26.8°C) and temperature may control the northern extent of the species as well as its local abundance (Moore 1947). In the Northeast Fisheries Science Center bottom trawl survey (Figure 3), adults were caught at bottom temperatures of 4-8°C and depths < 75 m in spring and at 12-18°C and depths < 50 m in autumn (Figure 7).

Data from the Massachusetts inshore trawl survey (Figure 8) indicated that most adults were caught south of Cape Cod during spring at bottom temperatures of 9-13°C and at depths < 15 m. In autumn, adults were more widely distributed and were caught at bottom temperatures of 9-19°C and depths < 30 m (Figure 9).

Adults were caught throughout Narragansett Bay in all seasons with no apparent seasonal shift in abundance. Adults preferred deeper waters (> 30 m) in cold bottom water temperature periods (1-8°C) and remained in a shallow water (< 30 m) in the warmer bottom water temperature periods (9-23°C).

The bottom trawl survey in Long Island Sound found that juvenile and adult windowpane were most abundant in spring (April-June) (Figure 12; Gottschall *et al.*, in review). In spring, they were caught at bottom temperatures of 3-18°C, at salinities of 21-31 ppt, and at depths < 60 m. The distribution pattern in autumn (September-November) was similar to the pattern in spring, but abundance was reduced (Figure 12). In autumn, windowpane adults were caught at bottom temperatures of 8-23°C, at salinities of 18-32 ppt, and at depths < 50 m (Gottschall *et al.*, in review).

Adults were fairly evenly distributed throughout the Hudson-Raritan estuary, but they were more abundant in deeper channels in the summer (Figure 10; Wilk *et al.* 1996). For all seasons combined, adults were collected at bottom temperatures of 0-24°C, at depths < 25 m, at salinities of 15-33 ppt, and DO levels of 2-13 mg/l (Figure 11; Wilk *et al.* 1996).

Adult windowpane occur primarily on sand substrates off southern New England and the Middle Atlantic Bight, but are frequently caught on mud grounds in the Gulf of Maine (Langton *et al*. 1994). Adults are euryhaline; they occur at salinities of 5.5-36.0 ppt (Tagatz 1967). Windowpane are sensitive to hypoxic conditions; few were collected where DO concentrations were < 3 mg/l, presumably because they avoid such conditions (Howell and Simpson 1994).

Adult windowpane may travel along the coast for considerable distances; in one case, they moved 129 km in three months (Moore 1947). These movements may play an important role in the intermingling of local populations (Klein-MacPhee, in prep.).

In a species association study using NEFSC groundfish survey bottom trawl data, windowpane commonly occurred with yellowtail flounder (*Limanda ferruginea*), ocean pout (*Macrozoarces americanus*), and little skate (*Raja erinacea*) during spring (Colvocoresses and Musick 1984). In autumn, windowpane were more widely distributed across the shelf and occurred with yellowtail flounder, little skate, northern searobin (*Prionotus carolinus*), and spiny dogfish (*Squalus acanthias*).

GEOGRAPHICAL DISTRIBUTION

The windowpane is distributed from the Gulf of St. Lawrence to Cape Hatteras, North Carolina, but it is most common south of Nova Scotia (Figure 13). The largest catches occur on Georges Bank.

EGGS

Windowpane eggs have been collected in several studies (Colton and St. Onge 1974; Smith *et al.* 1975; Colton *et al.* 1979; Morse *et al.* 1987; Berrien and Sibunka 1999). Windowpane egg distributions from NEFSC MARMAP ichthyoplankton surveys are summarized in Figure 14. Eggs were collected at 16% of the stations sampled; primarily at depths < 40 m between Georges Bank and Cape Hatteras. Eggs densities were generally low in the Gulf of Maine. Eggs were collected in nearshore shelf waters in the Middle Atlantic Bight from February to November. Egg densities peaked in May and October. Eggs were present on Georges Bank from April through October and density peaked during July-August.

LARVAE

The spatial distribution of windowpane larvae collected in NEFSC MARMAP ichthyoplankton surveys is summarized in Figure 15. More than 99% of the larvae collected were 2-10 mm TL. Peak densities of recently-spawned larvae (2-4 mm TL) occurred in the southern Middle Atlantic Bight in May and November, and on Georges Bank in July-October (Morse and Able 1995; Figure 15). The larval distribution mirrors that of the eggs in space and time.

JUVENILES

The spatial pattern of abundance for juvenile windowpane on the continental shelf in the Middle Atlantic Bight is similar to the spatial pattern for larvae (Morse and Able 1995). Juveniles occur nearshore in the Middle Atlantic Bight (< 40 m) and off southern New England (< 50 m) throughout the year (Figure 2). On Georges Bank, the spatial distribution of densities of juveniles differs between spring and autumn (Wigley and Gabriel 1991), and adults migration is similar to juveniles. Spatial distribution of juveniles in the Gulf of Maine shows low densities in nearshore areas in spring and autumn.

In the Hudson-Raritan estuary, juveniles were fairly evenly distributed throughout the estuary, but juveniles were most abundant in the deeper channels in winter and summer (Figure 10; Wilk *et al.* 1996).

ADULTS

The spatial distribution of adults on the continental shelf (Figure 3) is similar to the distribution of juveniles (Figure 2). Adults may migrate to nearshore or estuarine habitats in the southern Middle Atlantic Bight during spring through autumn. Adults on Georges Bank also show seasonal movements to deeper waters from late autumn through spring similar to juveniles. Adults in the Gulf of Maine use nearshore waters during the spring and autumn. The spring aggregation of adult windowpane in Nantucket Sound and on Nantucket Shoals is evident in the Massachusetts trawl survey (Figure 8). This aggregation suggests spawning or feeding activities; however, there is no supporting information on the densities of eggs, larvae, or prey organisms.

STATUS OF THE STOCKS

The NEFSC autumn bottom trawl survey has been used to estimate the relative abundance and biomass of windowpane (Hendrickson 1998). The abundance index for the Gulf of Maine-Georges Bank region generally increased from the mid-1960s to a peak in 1984 and then declined (Figure 16). The abundance index for the southern New England-Middle Atlantic Bight region declined sharply from 1963 to 1975 and has remained relatively low since then (Figure 16).

The windowpane is managed by the New England Fishery Management Council under the Multispecies Fishery Management Plan (NEFMC 1993). This plan defines overfishing for windowpane when the 3-year moving average of the autumn stock abundance index falls below the lowest quartile of the time series. Accordingly, windowpane stock in the Gulf of Maine-Georges Bank is considered to be fully exploited (Hendrickson 1998) while southern New England-Middle Atlantic Bight stock is overfished (National Marine Fisheries Service 1997; Hendrickson 1998).

The distributions of windowpane were compared between a period of high abundance (1984-1988) and a period of low abundance (1992-1996) based on the autumn Northeast Fisheries Science Center bottom trawl survey (Figure 17). The spatial extent of adults and juveniles was similar between the two periods.

RESEARCH NEEDS

- Studies to determine if the windowpane population is a unit stock or multiple stocks (e.g., genetics, otolith, cohort analysis).
- Windowpane spawning times and locations, and spawning habitat requirements (e.g., high salinity).
- Studies (tagging, more efficient gear to catch younger fish) to determine seasonal use of estuaries (residency during colder months) and nearshore waters.
- Habitat requirements for windowpane eggs, larvae, and juveniles.
- Growth rate studies.

ACKNOWLEDGMENTS

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Table 1. Summary of the distribution and abundance of windowpane in North Atlantic and Mid-Atlantic estuaries based on Jury *et al.* (1994) and Stone *et al.* (1994).

Estuary	**Adults**			**Spawning Adults**			**Juveniles**			**Larvae**			**Eggs**		
	T	M	S	T	M	S	T	M	S	T	M	S	T	M	S
Passamaquoddy Bay		**c**	**c**		**c**	**c**		**c**	**c**		**c**	**c**		**c**	**c**
Englishman/Machias Bays		c	c		c	c		c	c		c	c		c	c
Narragaugus Bay		c	c		c	c		c	c		c	c		c	c
Blue Hill Bay		c	c		c	c		c	c		c	c		c	c
Penobscot Bay		**c**	**a**		**c**	**a**		**c**	**a**		**c**	**a**		**c**	**a**
Muscongus Bay		c	c		c	c		**c**	**c**		c	c		c	c
Damariscotta Bay		**c**	**c**		**c**	**c**		**c**	**c**		**c**	**c**		**c**	**c**
Sheepscot Bay		**<u>c</u>**	**<u>c</u>**		**c**	**c**		**<u>c</u>**	**<u>c</u>**		**c**	**c**		**c**	**c**
Kennebec/Androscoggin Rivers		**c**	**c**		c	c		**c**	**c**		c	c		c	c
Casco Bay		c	c		c	c		c	c		c	c		c	c
Saco Bay		c	c		c	c		c	c		c	c		c	c
Wells Harbor	nz	c	c	nz	c	c	nz	c	c	nz	c	c	nz	c	c
Great Bay		**r**	**c**		**r**	**c**		**r**	**c**		**r**	**c**		**r**	**c**
Merrimack River		r	nz		r	nz		r	nz		r	nz		r	nz
Massachusetts Bay	**<u>nz</u>**	**<u>nz</u>**	**<u>c</u>**	**nz**	**nz**	**c**	**nz**	**nz**	**c**	**nz**	**nz**	**c**	**nz**	**nz**	**c**
Boston Harbor	nz	c	c	nz	c	c	**nz**	**c**	**c**	nz	c	c	nz	c	c
Cape Cod Bay	**<u>nz</u>**	**<u>a</u>**	**<u>a</u>**	**nz**	**c**	**c**	**<u>nz</u>**	**<u>a</u>**	**<u>a</u>**	**nz**	**c**	**c**	**nz**	**c**	**c**
Waquoit Bay	nz	c	c	nz	c	c	nz	c	c	nz	c	c	nz	c	c
Buzzards Bay	nz	a	a	nz	c	c	nz	a	a	nz	c	c	nz	c	c
Narragansett Bay	r	a	a		c	c	r	a	a		**c**	**c**		c	c
Long Island Sound	r	h	h		**h**	**h**	r	h	h		**c**	**c**		**h**	**h**
Connecticut River		h	nz		h	nz		h	nz		c	nz		h	nz
Gardiners Bay	nz	c	c	**nz**	**c**	**c**	nz	c	c	**nz**	**c**	**c**	**nz**	**c**	**c**
Great South Bay	nz	a	a	**nz**	**a**	**a**	nz	a	a	**nz**	**c**	**c**	**nz**	**a**	**a**
Hudson River/Raritan Bay	r	c	c		r	c	r	c	c	r	c	c	r	r	c
Barnegat Bay		**<u>h</u>**	**<u>h</u>**		**h**	**h**		**<u>h</u>**	**<u>h</u>**		**h**	**h**		**h**	**h**
New Jersey Inland Bays		**<u>h</u>**	**<u>h</u>**		**h**	**h**		**<u>h</u>**	**<u>h</u>**		**h**	**h**		**h**	**h**
Delaware Bay		a	a					**a**	**a**						
Delaware Inland Bays	**nz**	**c**	**c**	nz	c	c	**nz**	**c**	**c**	nz	c	c	nz	c	c
Chincoteague Bay	**<u>nz</u>**	**<u>nz</u>**	**<u>c</u>**	**nz**	**nz**		**<u>nz</u>**	**<u>nz</u>**	**<u>c</u>**	**nz**	**nz**		**nz**	**nz**	
Chesapeake Bay mainstream		**c**	**c**					**c**	**c**			**r**			
Chester River			**nz**			**<u>nz</u>**			**nz**			**<u>nz</u>**			**<u>nz</u>**
Choptank River			**nz**			**<u>nz</u>**			**nz**			**<u>nz</u>**			**<u>nz</u>**
Patuxent River			**nz**			**<u>nz</u>**			**nz**			**<u>nz</u>**			**<u>nz</u>**
Potomac River			**nz**			**<u>nz</u>**			**nz**			**<u>nz</u>**			**<u>nz</u>**
Tangier/Pocomoke Sounds	**nz**	**c**	**nz**	**<u>nz</u>**		**<u>nz</u>**	**nz**	**c**	**nz**	**<u>nz</u>**		**<u>nz</u>**	**<u>nz</u>**		**<u>nz</u>**
Rappahannock River			**nz**			**<u>nz</u>**			**nz**			**<u>nz</u>**			**<u>nz</u>**
York River			**nz**			**<u>nz</u>**		**<u>r</u>**	**<u>nz</u>**			**<u>nz</u>**			**<u>nz</u>**
James River		**r**	**nz**			**<u>nz</u>**		**r**	**nz**			**nz**			**<u>nz</u>**

<u>Relative Abundance</u>
h = highly abundant, a = abundant, c = common, r = rare, blank = not present, n = no data presented, * = no data available, nz = particular zone not present

<u>Data Reliability for Life Stages</u>
Highly Certain = Bold and Underlined Text
Moderately Certain = Bold Text
Reasonable Inference = Normal Text

<u>Tidal Zones</u>
T = Tidal Fresh 0.0-0.5 ppt
M= Mixing Zone 0.5-25 ppt
S = Seawater Zone > 25 ppt

Table 2. Summary of life history and habitat parameters for windowpane.

Life Stage	Size and Growth	Geographic Location	Time of Year	Habitat	Substrate	Temperature, Salinity and DO	Prey/Predators
Eggs [1]	0.9-1.4 mm	Middle Atlantic Bight	Feb-July Sept-Nov	Planktonic; less than 70 m	Not applicable	**Water column temp:** 6-14°C spring 10-16°C summer 14-20°C autumn	Eaten by adults of own and other species.
		Georges Bank	May-Oct				
Larvae [2]	2-10 mm	Middle Atlantic Bight	Feb-July Sept-Nov	Planktonic; less than 70 m	Not applicable	**Water column temp:** 3-14°C spring 10-17°C summer 13-19°C autumn	Prey on copepods and other zooplankton. Eaten by adults of own and other species.
		Georges Bank	May-Oct				
Juveniles [3]	< 22 cm TL	Gulf of Maine	June-Oct	Nearshore bays and estuaries; less than 50 m	Muddy sediment in the Gulf of Maine	**Bottom temp:** Offshore: 4-7°C in spring; 14-16°C in autumn	Prey on polychaetes and small crustaceans, especially mysids. Eaten by adults of own and other species (spiny dogfish, thorny skate, goosefish, cod).
		Georges Bank	June-Oct	Less than 50 m (summer/autumn); less than 75 m (winter/spring)	Fine sandy sediment in Georges Bank	Inshore off MA: 5-12°C in spring 1 2-19°C in autumn	
		Middle Atlantic Bight	May-July Oct-Nov	Nearshore bays and estuaries; less than 75 m	Fine sandy sediment in New England & Middle Atlantic Bight	Hudson-Raritan Bay 0-24°C (15-33 ppt - Salinity) (2-13 mg/l - DO)	
Adults [4]	≥ 22 cm TL	Gulf of Maine	Year-round	Nearshore bays and estuaries; less than 75 m	Muddy sediment in the Gulf of Maine	**Bottom temp:** Offshore: 4-8°C in spring 12-18°C in autumn	Prey on polychaetes, small crustaceans (mysids, decapod shrimp) various small fishes (hakes, tomcod). Eaten by adults of various fishes (spiny dogfish, thorny skate, goosefish, cod).
		Georges Bank		Less than 50 m (summer and autumn); less than 75 m (winter and spring)	Fine sandy sediment on Georges Bank	Inshore off MA 9-13°C in spring 9-19°C in autumn	
		Middle Atlantic Bight		Nearshore bays and estuaries; less than 75 m	Fine sandy sediment in New England and Middle Atlantic Bight	Hudson-Raritan Bay 0-24°C (15-33 ppt - Salinity) (2-13 mg/l - DO)	

[1] Colton and St. Onge (1974), Smith *et al.* (1975), Colton *et al.* (1979), Morse *et al.* (1987), Berrien and Sibunka (1999)
[2] Moore (1947), Colton and Marak (1969), Morse and Able (1995)
[3] Moore (1947), Thorpe (1991), Morse and Able (1995), Wilk *et al.* (1996), Able and Fahay (1998), Klein-MacPhee (in prep.)
[4] Colvocoresses and Musick (1984), Morse and Able (1995), Wilk *et al.* (1996), Able and Fahay (1998), Gottschall *et al.* (in review), Klein-MacPhee (in prep.)

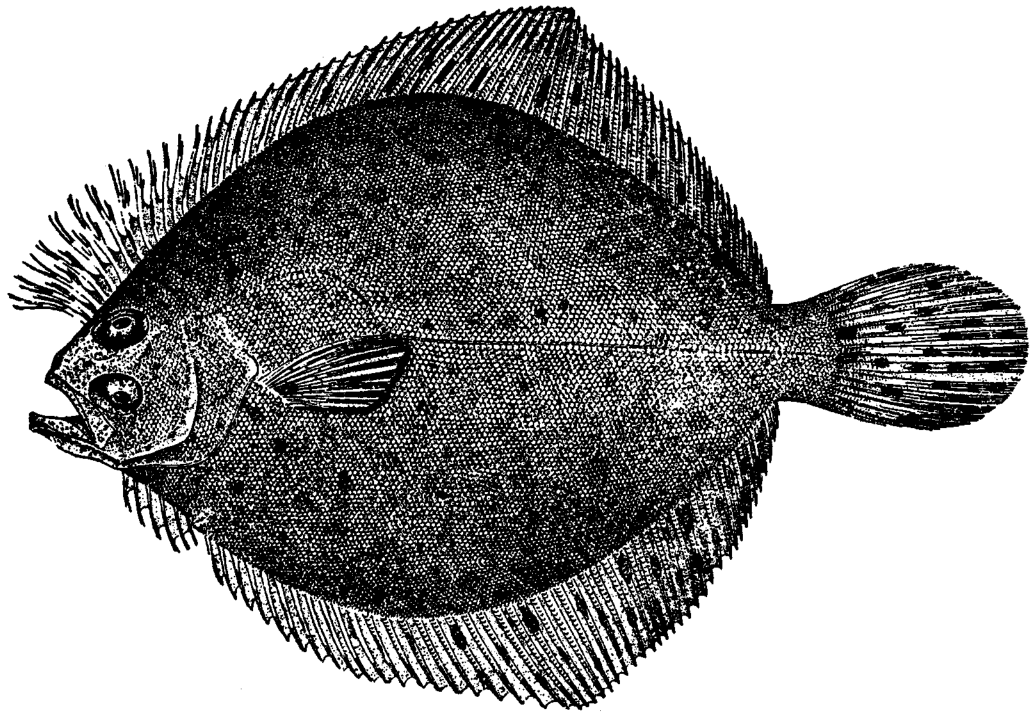

Figure 1. The windowpane, *Scophthalmus aquosus* (from Bigelow and Schroeder 1953).

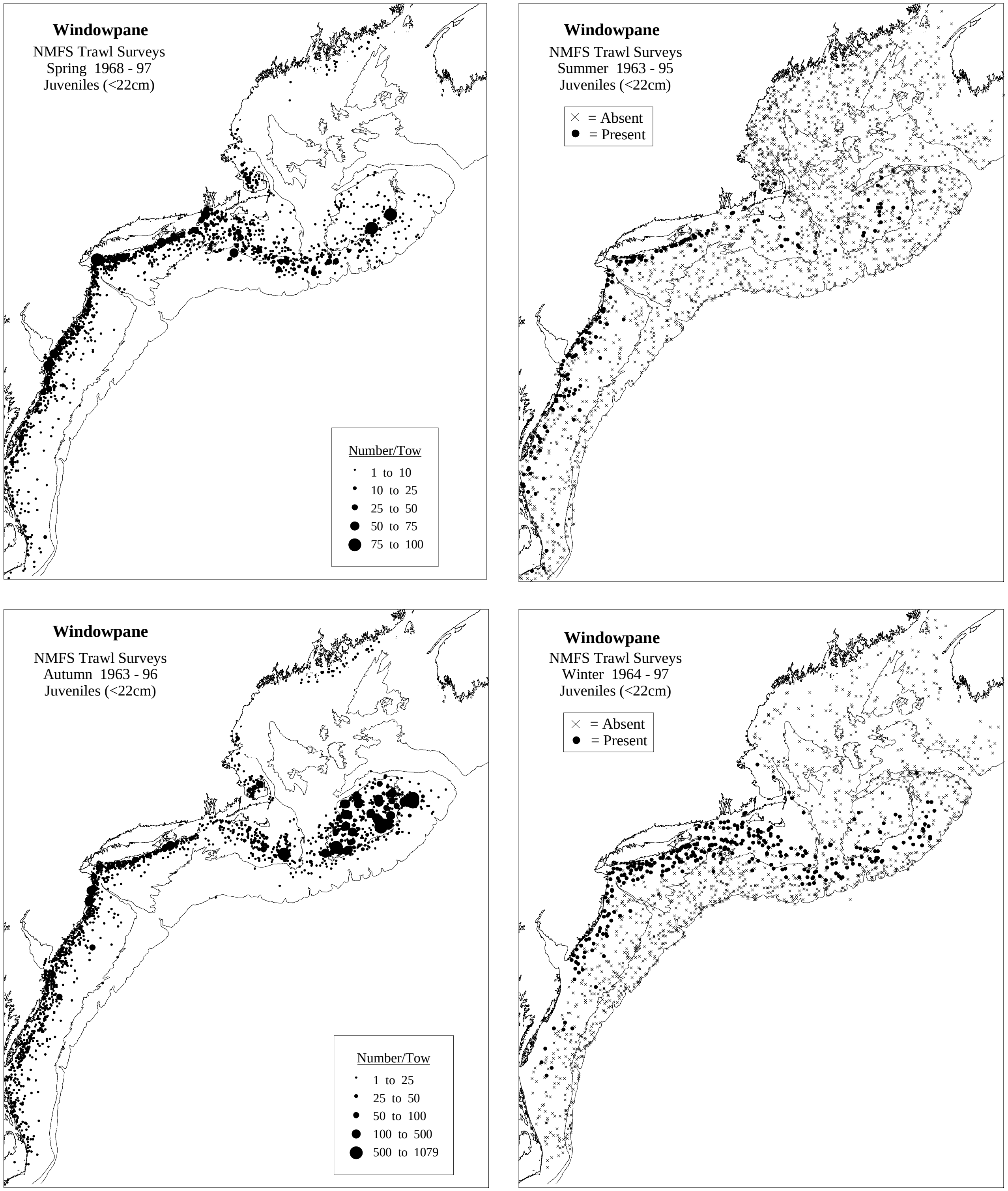

Figure 2. Distribution and relative abundance of juvenile windowpane (< 22 cm) from NEFSC bottom trawl surveys, spring (1968-1997), summer (1963-1995), autumn (1963-1996), and winter (1964-1997). Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].

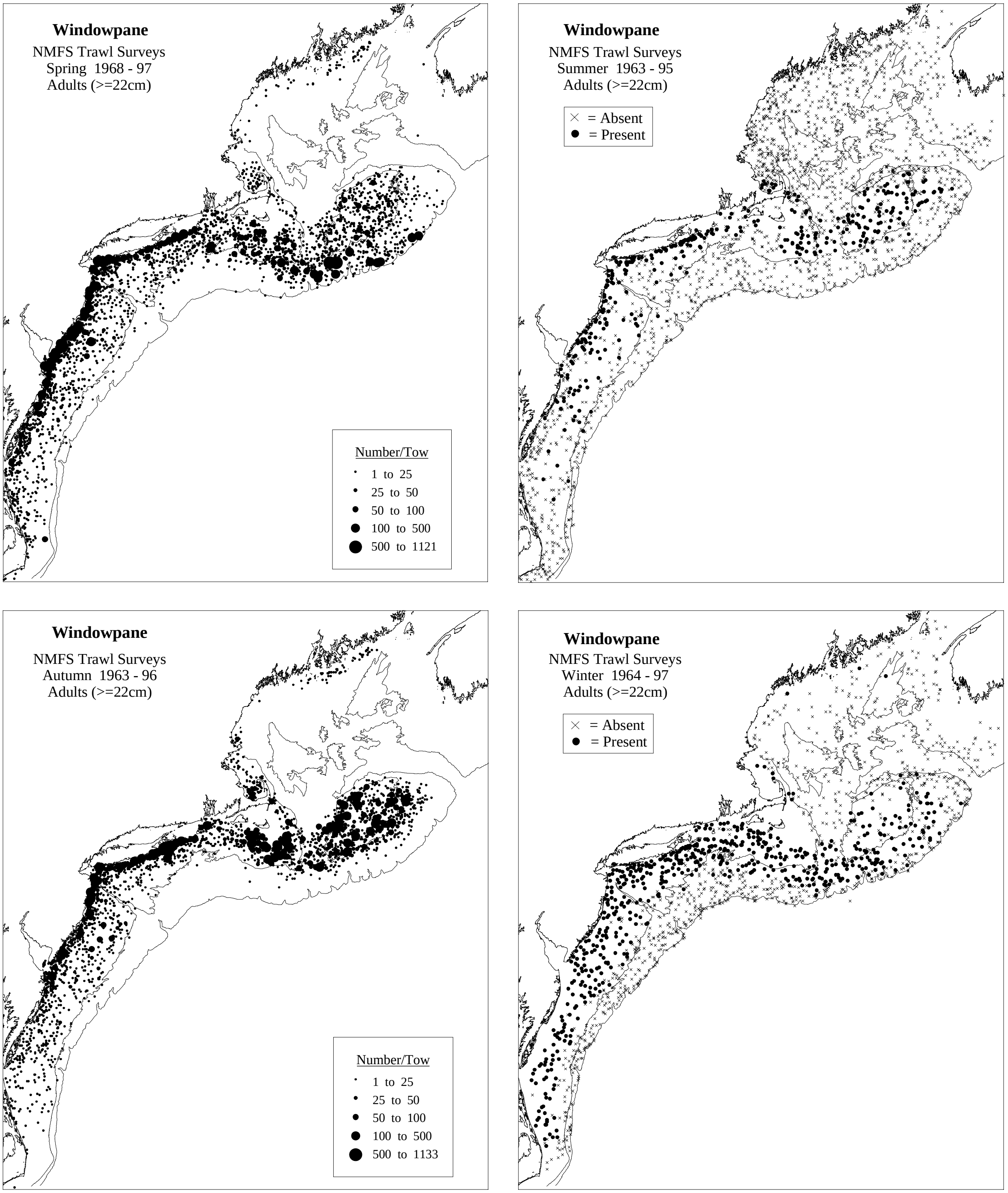

Figure 3. Distribution and relative abundance of adult windowpane (≥ 22 cm) from NEFSC bottom trawl surveys, spring (1968-1997), summer (1963-1995), autumn (1963-1996), and winter (1964-1997). Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].

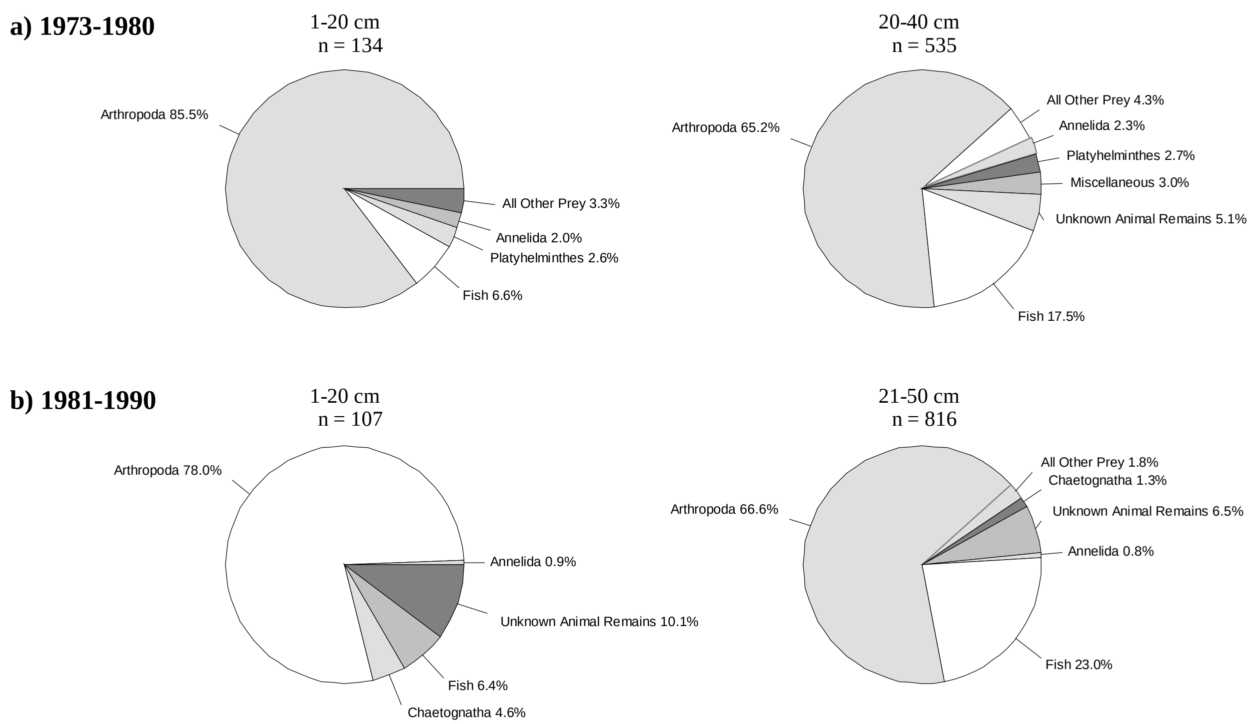

Figure 4. Abundance (percent occurrence) of the major types of prey identified in the stomachs of juvenile and adult windowpane collected during NEFSC bottom trawl surveys during 1973-1980 and 1981-1990. Note that the use of 20 cm as the segregation size between juvenile and adults differs from the actual size generally used (22 cm); this is an artifact of the diet database that summarizes results in 10 cm length intervals. 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].

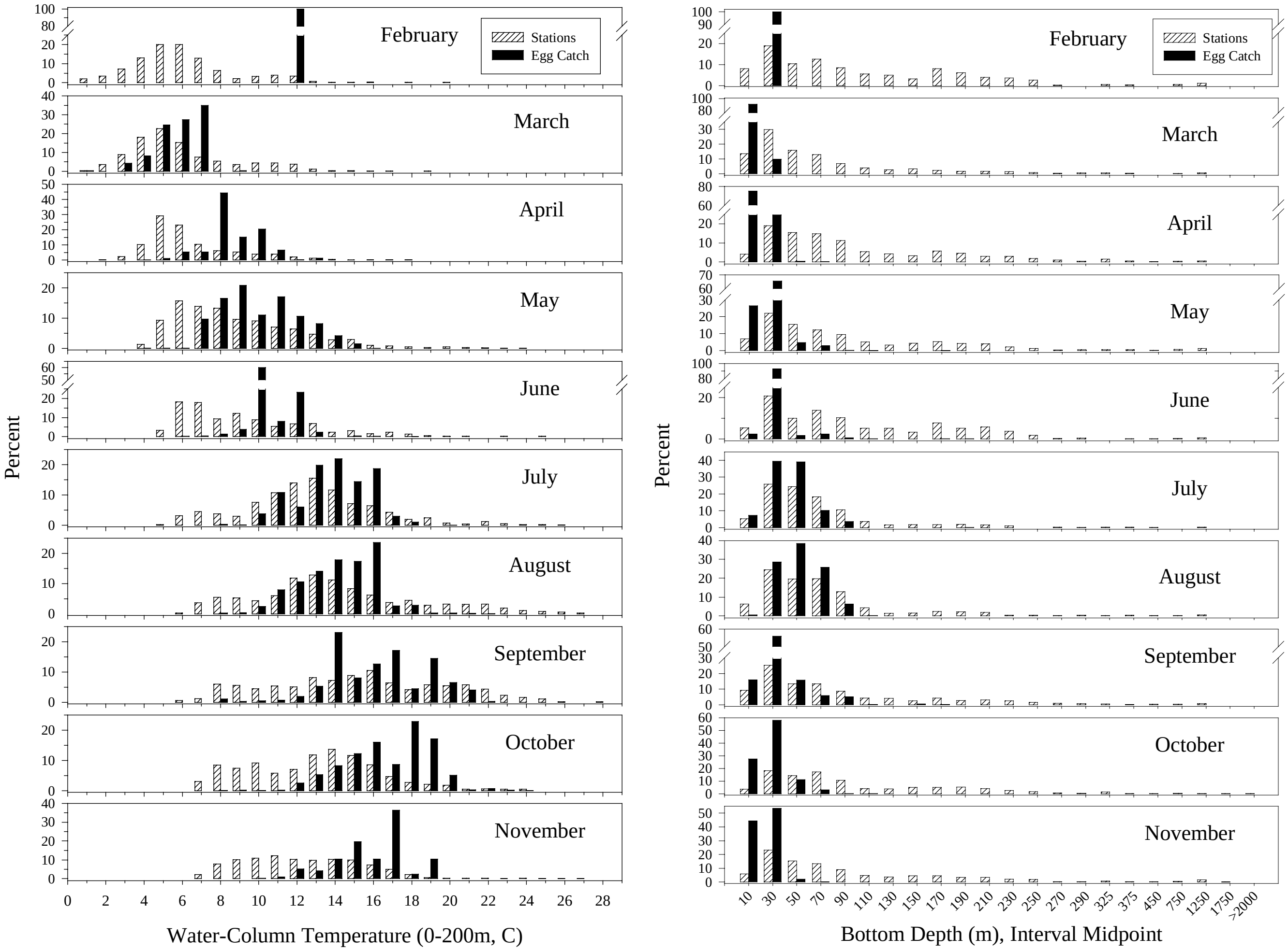

Figure 5. Percentage of windowpane eggs in relation to water column temperature (0-200 m, °C) and bottom depth (m) from NEFSC MARMAP ichthyoplankton surveys, February to November, 1978-1987 (all years combined). Open bars represent the proportion of all stations which were surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

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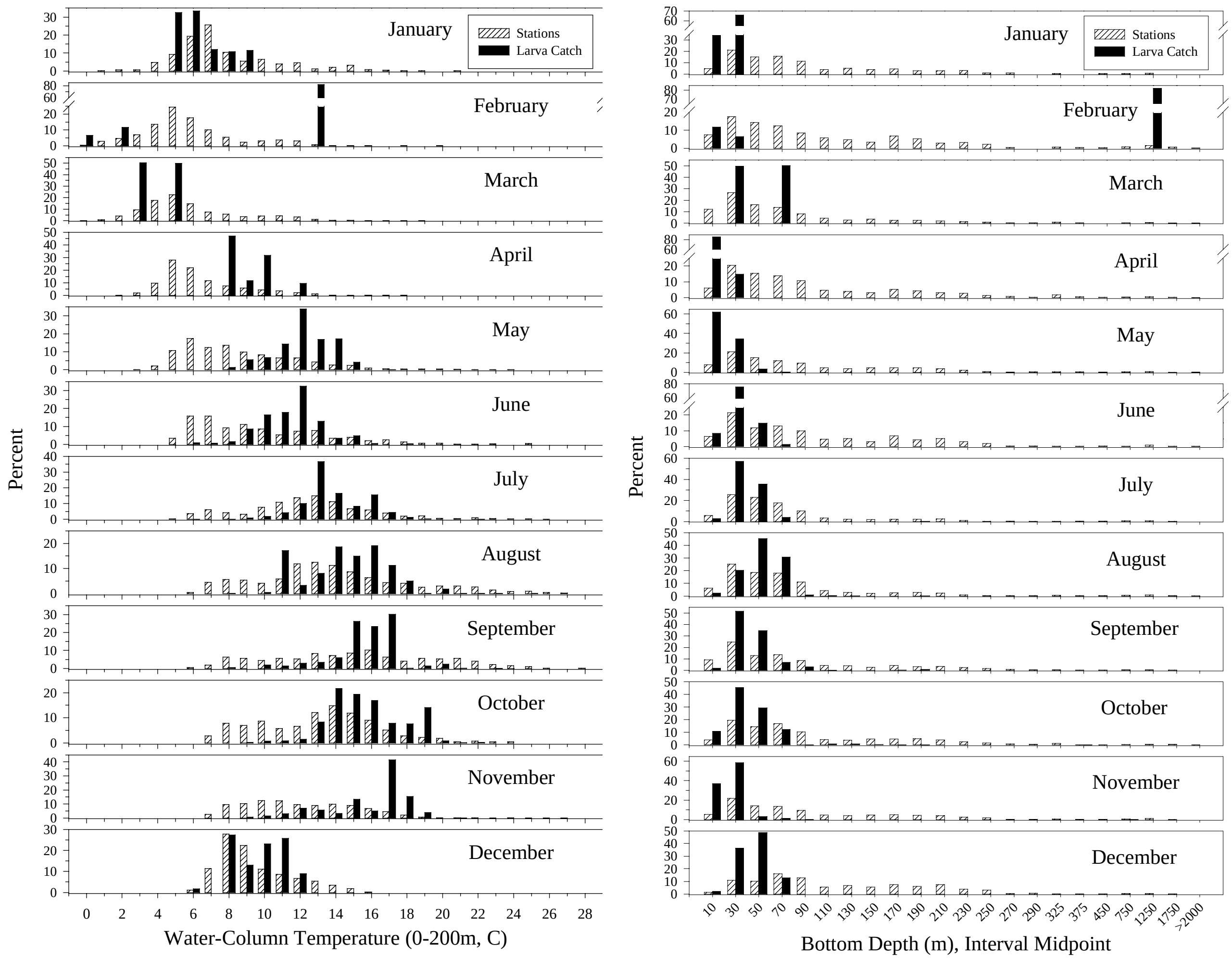


Figure 6. Percentage of windowpane larvae in relation to water column temperature (0-200 m, ^oC) and bottom depth (m) from NEFSC MARMAP ichthyoplankton surveys, January to December, 1977-1987 (all years combined). Open bars represent the proportion of all stations which were surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

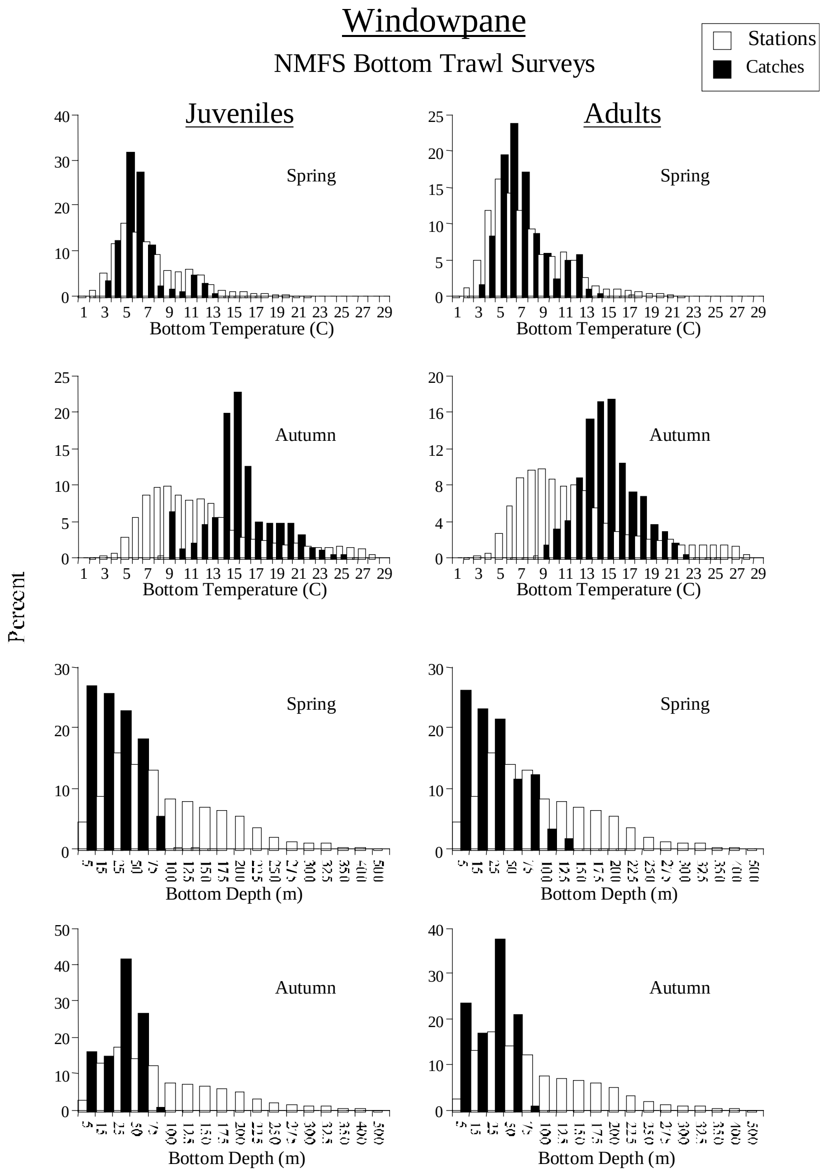


Figure 7. Percentage of juvenile and adult windowpane in relation to bottom water temperature and depth, based on spring (1968-1997) and autumn (1963-1996) NEFSC bottom trawl surveys (all years combined). Open bars represent the proportion of all stations which were surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

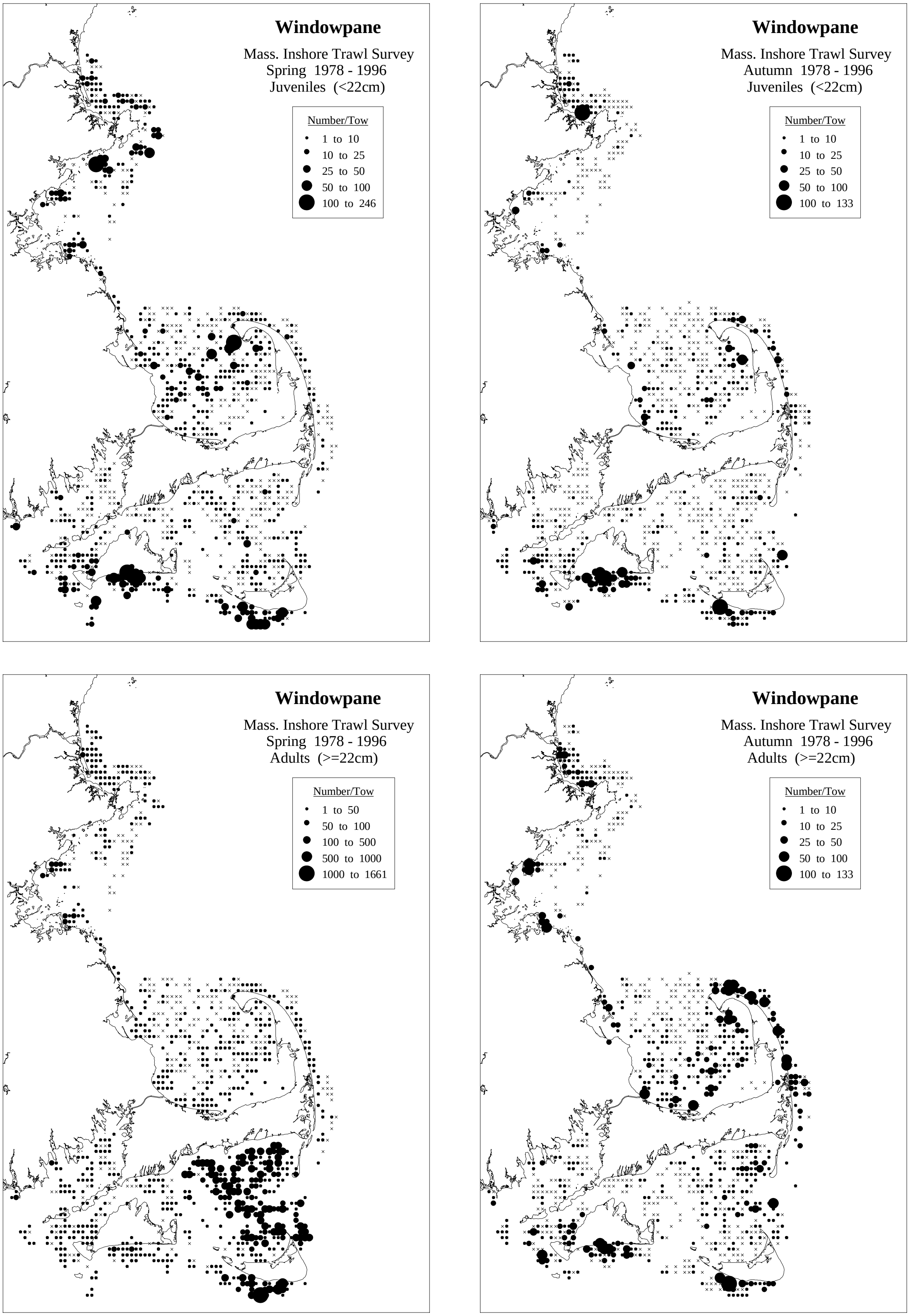


Figure 8. The distribution and relative abundance of juvenile and adult windowpane from Massachusetts inshore trawl surveys, spring and autumn 1978-1996 [see Reid *et al*. (1999) for details].

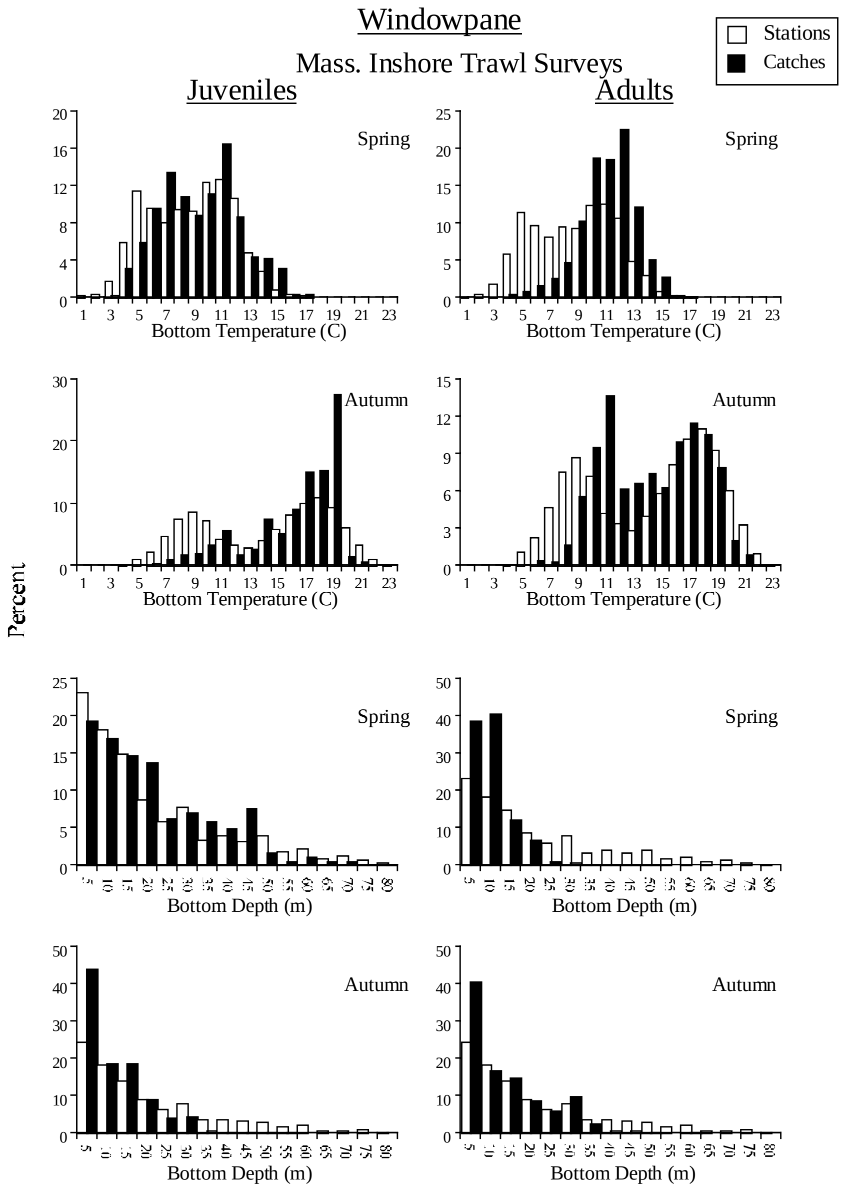


Figure 9. Percentage of juvenile and adult windowpane in relation to bottom water temperature and depth from the spring and autumn Massachusetts inshore bottom trawl surveys (spring and autumn 1978-1996) for all years combined. Open bars represent the proportion of all stations which were surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

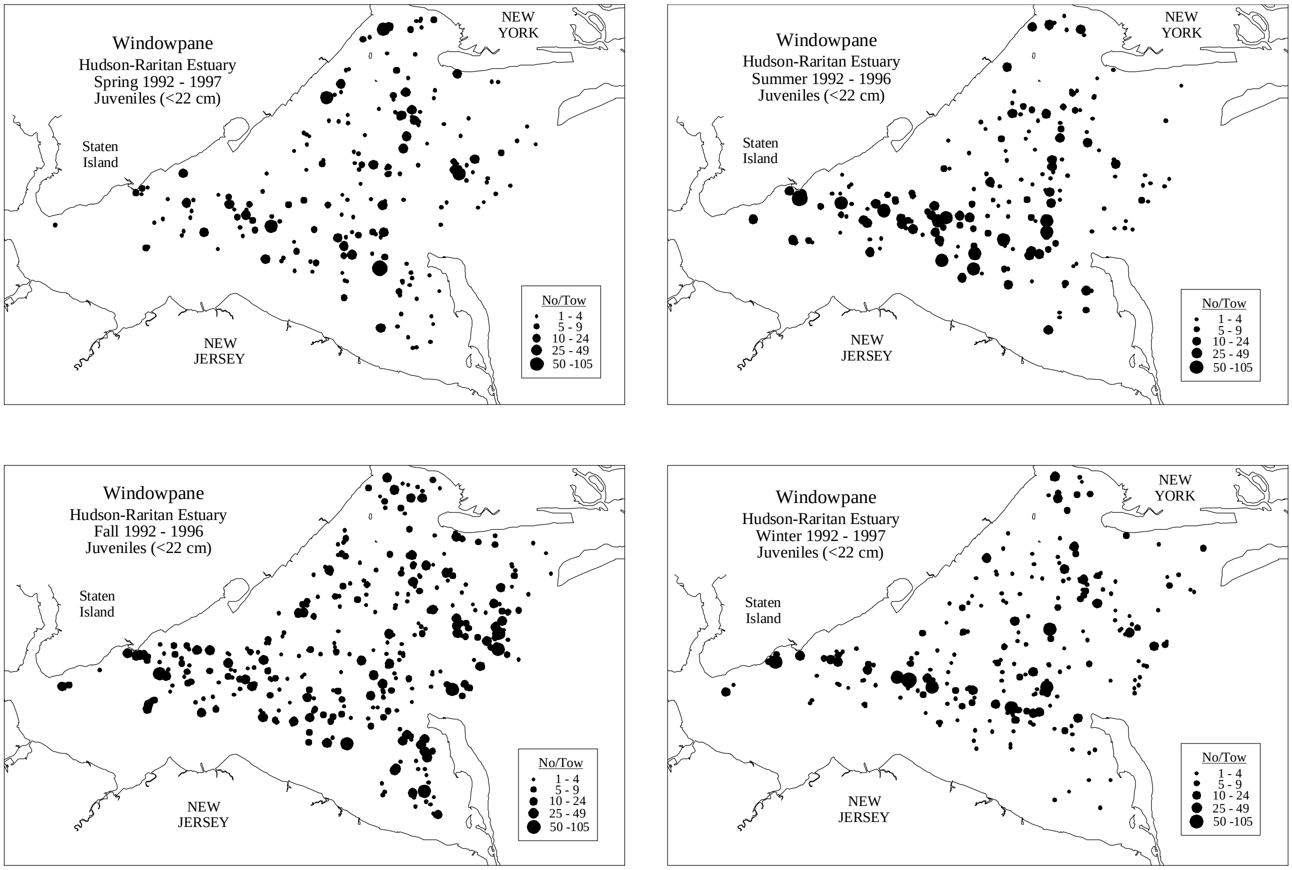


Figure 10. Distribution and relative abundance of juvenile (< 22 cm) and adult (> 21 cm) windowpane collected during spring, summer, autumn and winter in the Hudson-Raritan estuary from January 1992 to June 1997 [see Reid *et al.* (1999) for details].

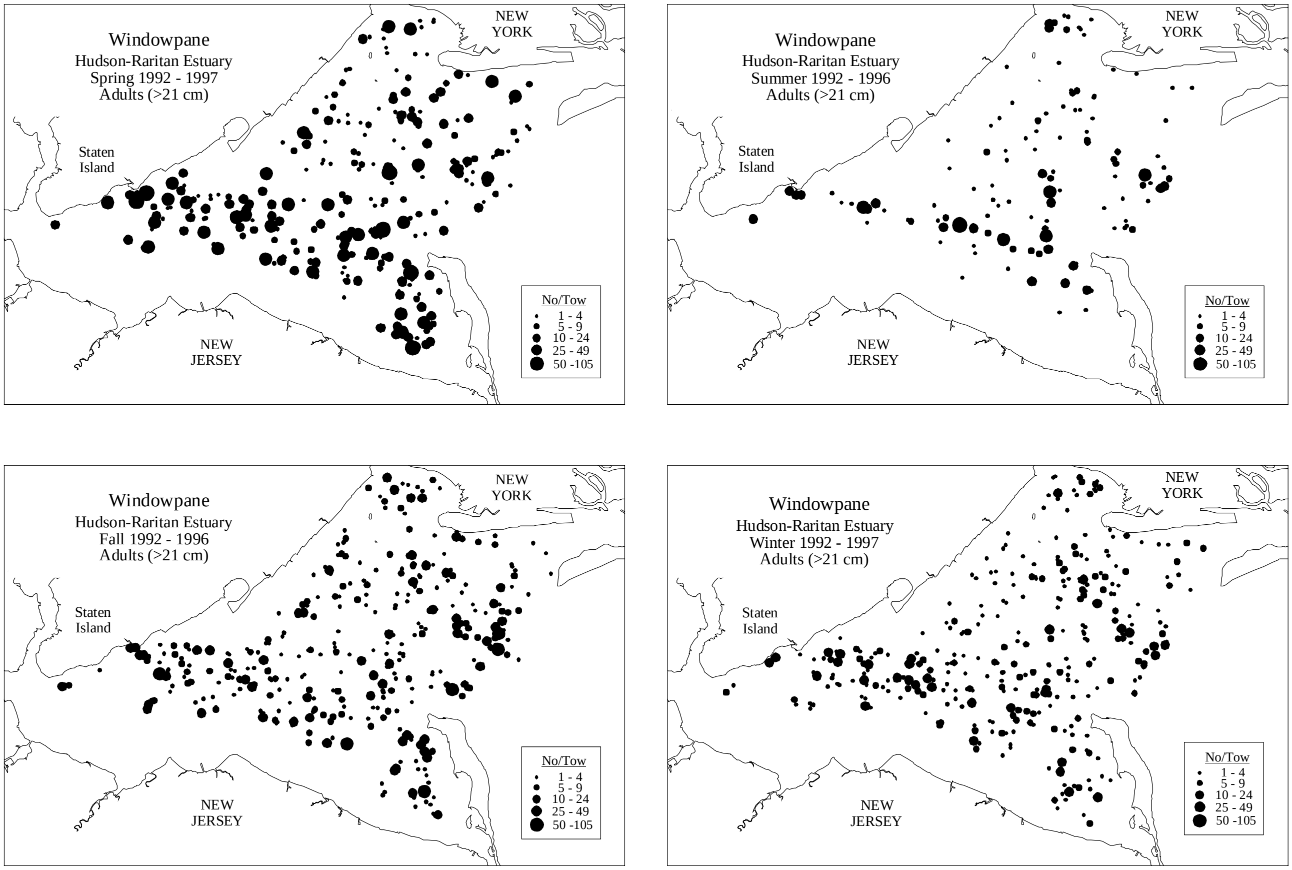


Figure 10. cont’d.

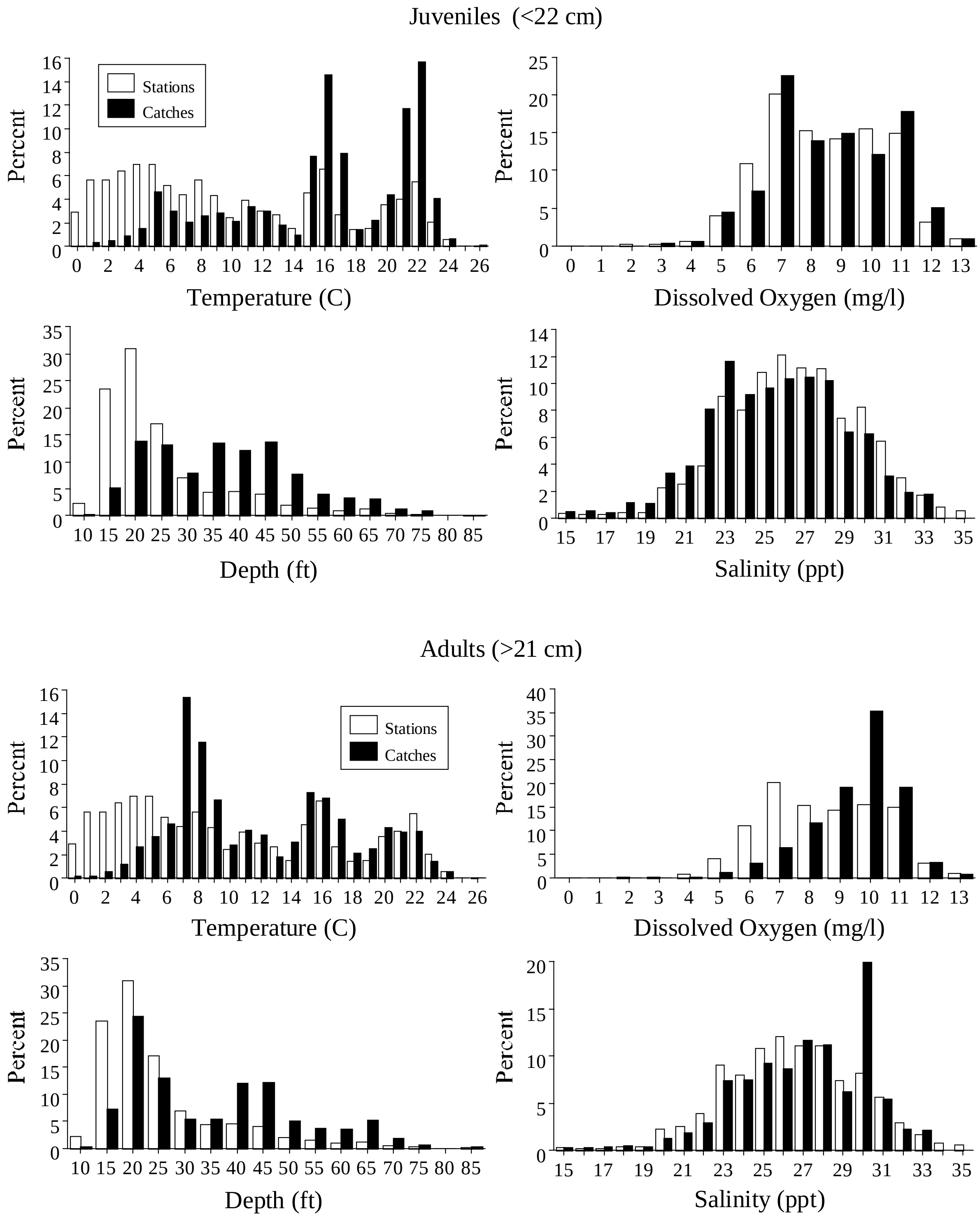
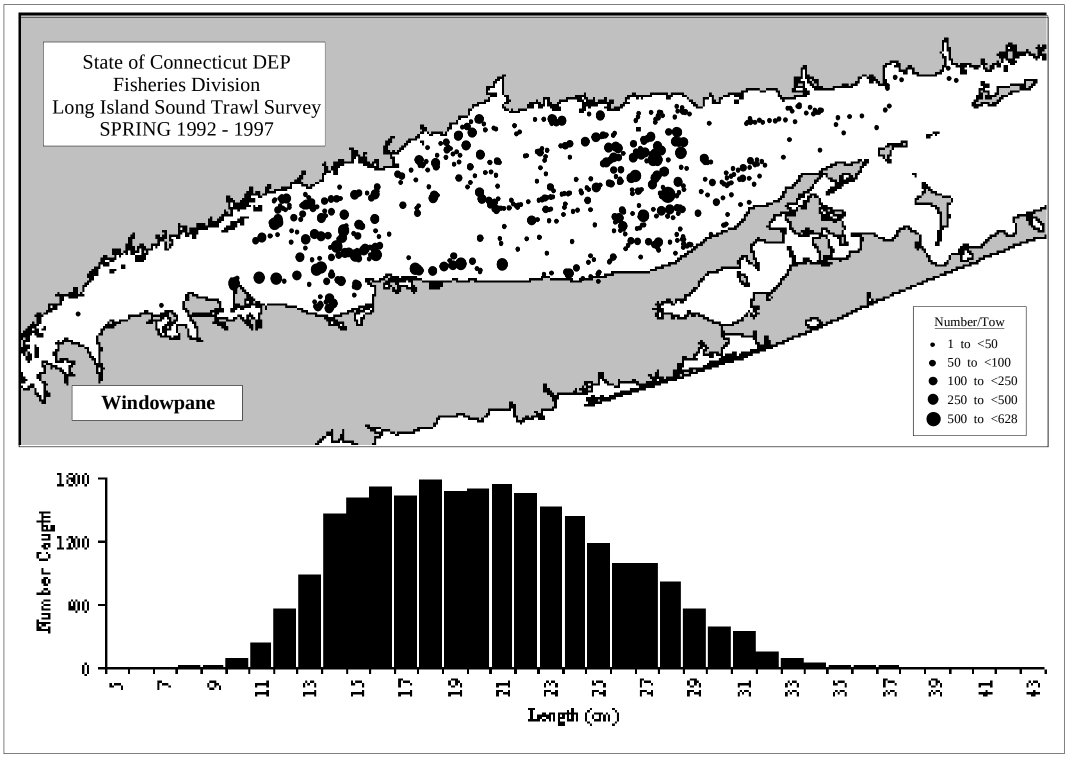


Figure 11. Percent frequency of juvenile and adult windowpane in relation to bottom water temperature, depth, dissolved oxygen, and salinity in the Hudson-Raritan estuary, January 1992 to June 1997 (all years combined).



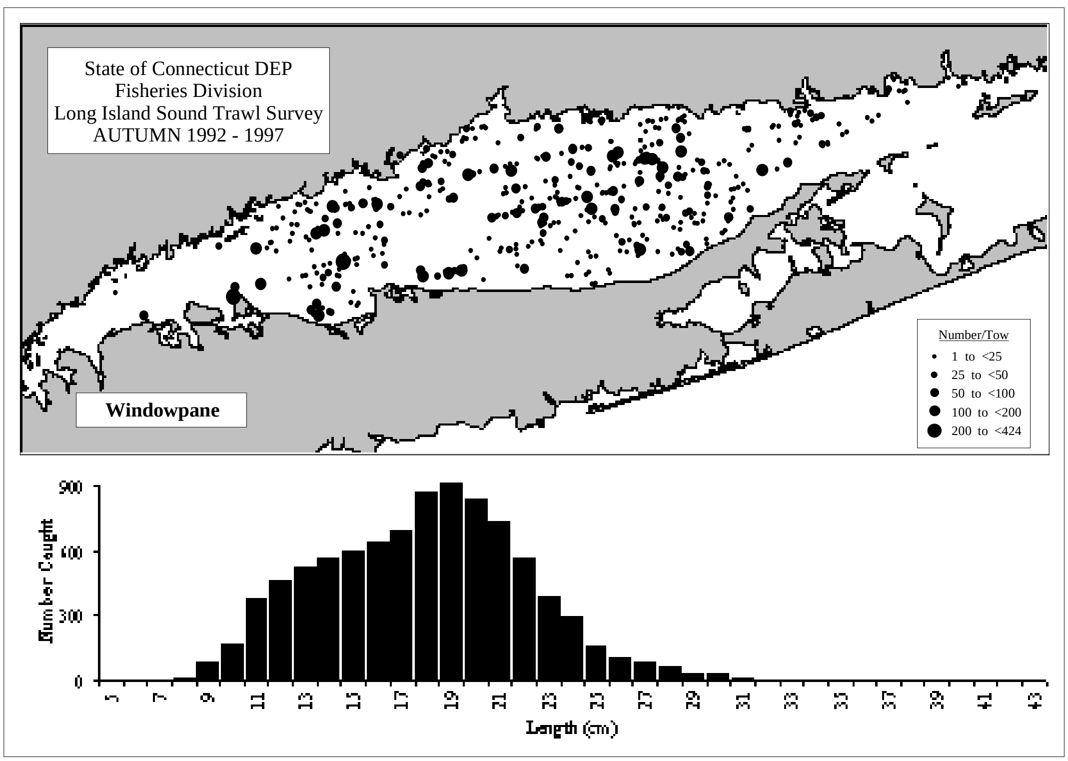
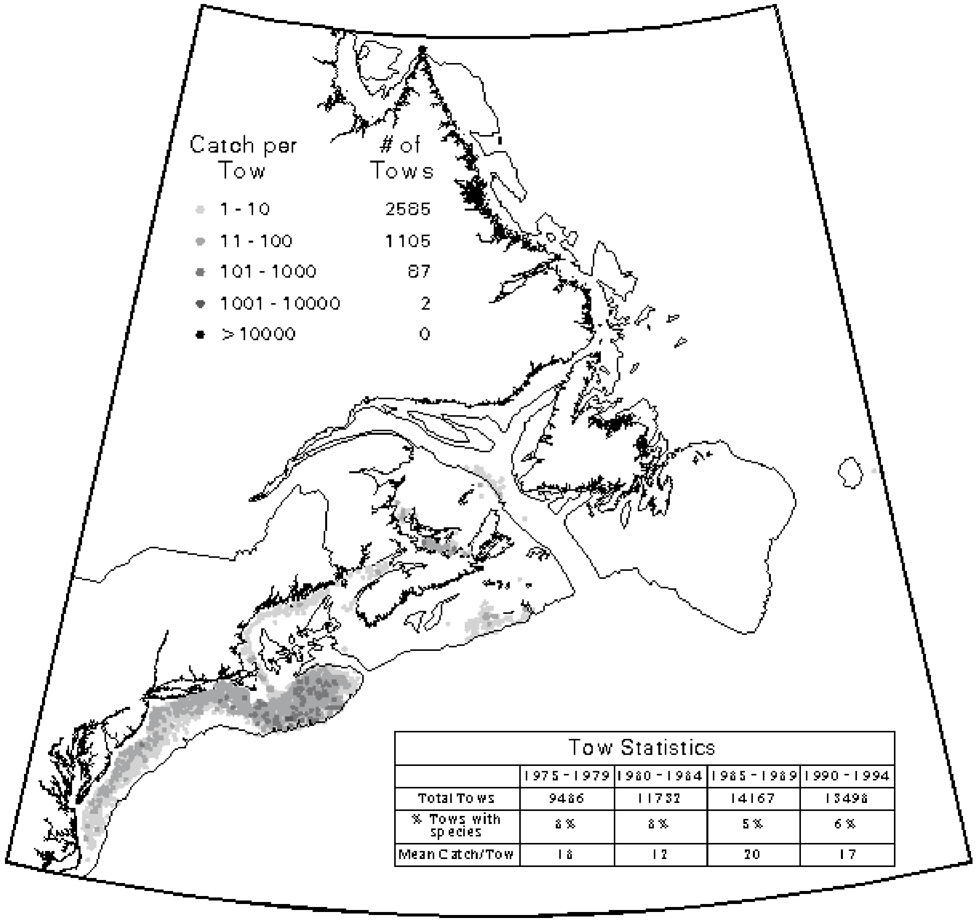


Figure 12. Abundance and length frequency distributions of windowpane in Long Island Sound during spring and autumn, from the Connecticut bottom trawl surveys, 1992-1997 [see Reid *et al.* (1999) for details].



	1975 - 1979	1980 - 1984	1985 - 1989	1990 - 1994
Total Tows	9486	11732	14167	13498
% Tows with species	8 %	8 %	5 %	6 %
Mean Catch/Tow	18	12	20	17

Figure 13. Distribution and abundance of windowpane from Newfoundland to Cape Hatteras during 1975-1994. Data are from the U.S. NOAA/Canada DFO East Coast of North America Strategic Assessment Project (http://www-orca.nos.noaa.gov/projects/ecnasap/ecnasap_table1.html).

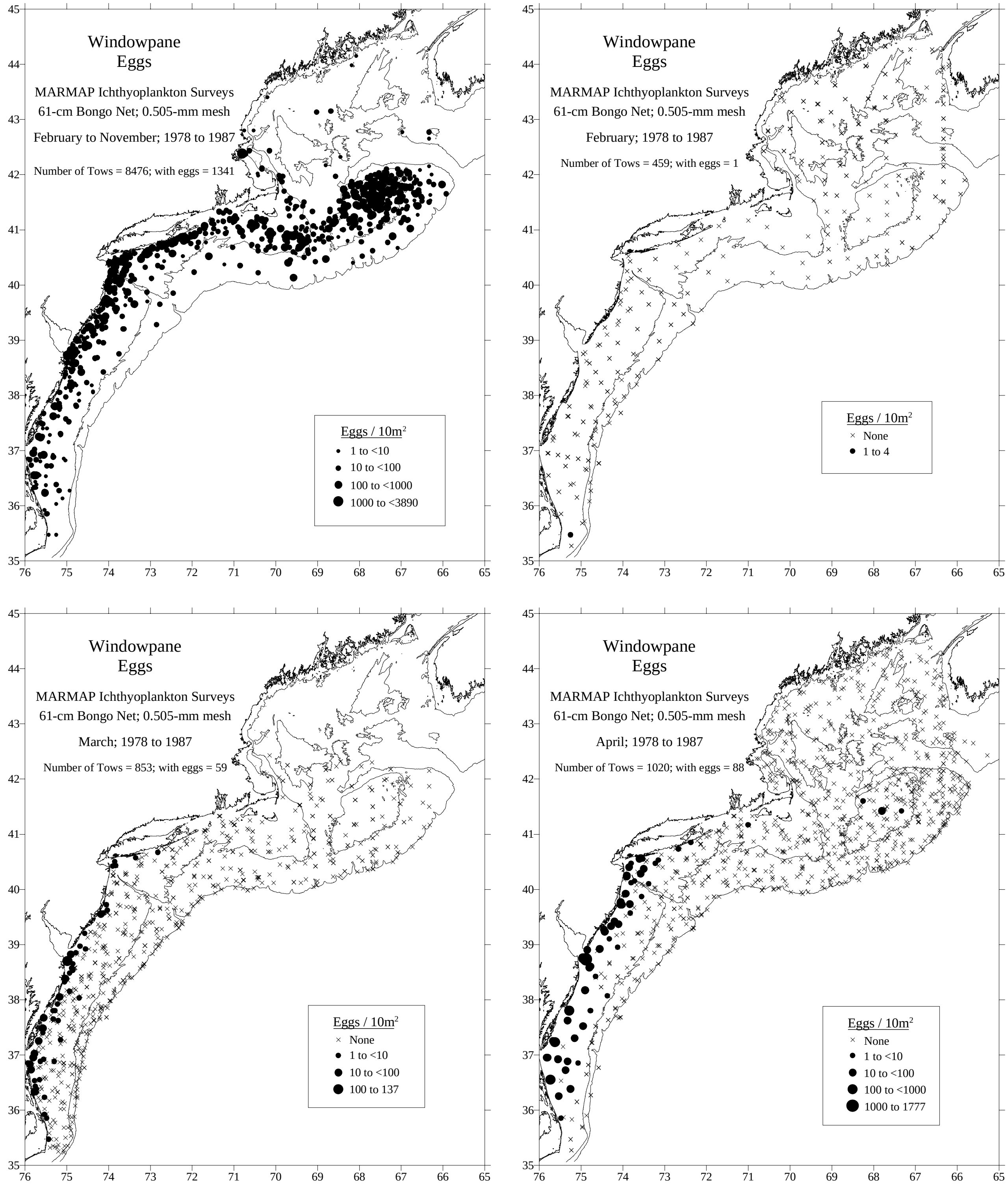


Figure 14. The distribution and abundance of windowpane eggs collected from February to November, 1978-1987 during NEFSC MARMAP ichthyoplankton surveys [see Reid *et al.* (1999) for details].

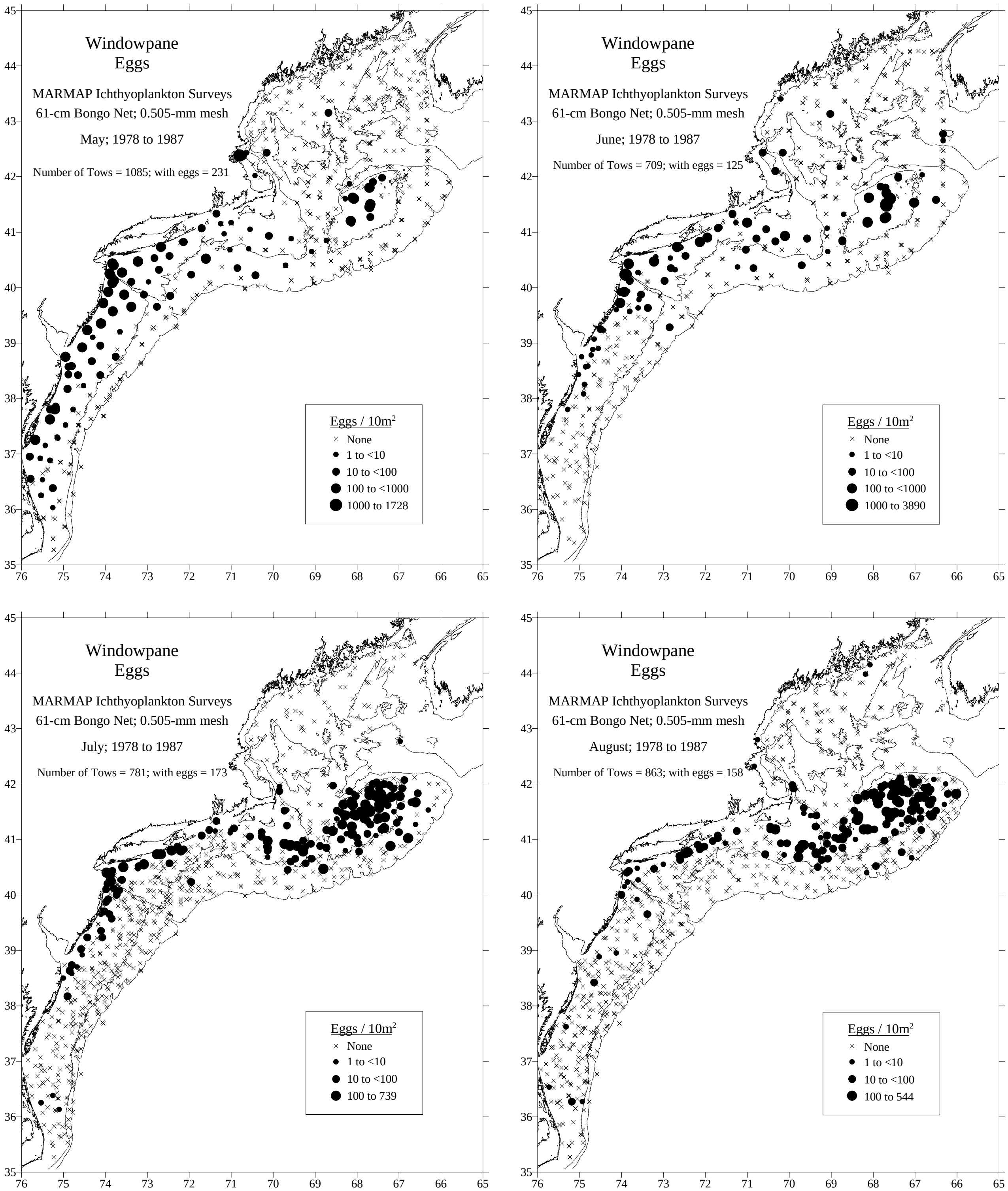


Figure 14. cont'd.

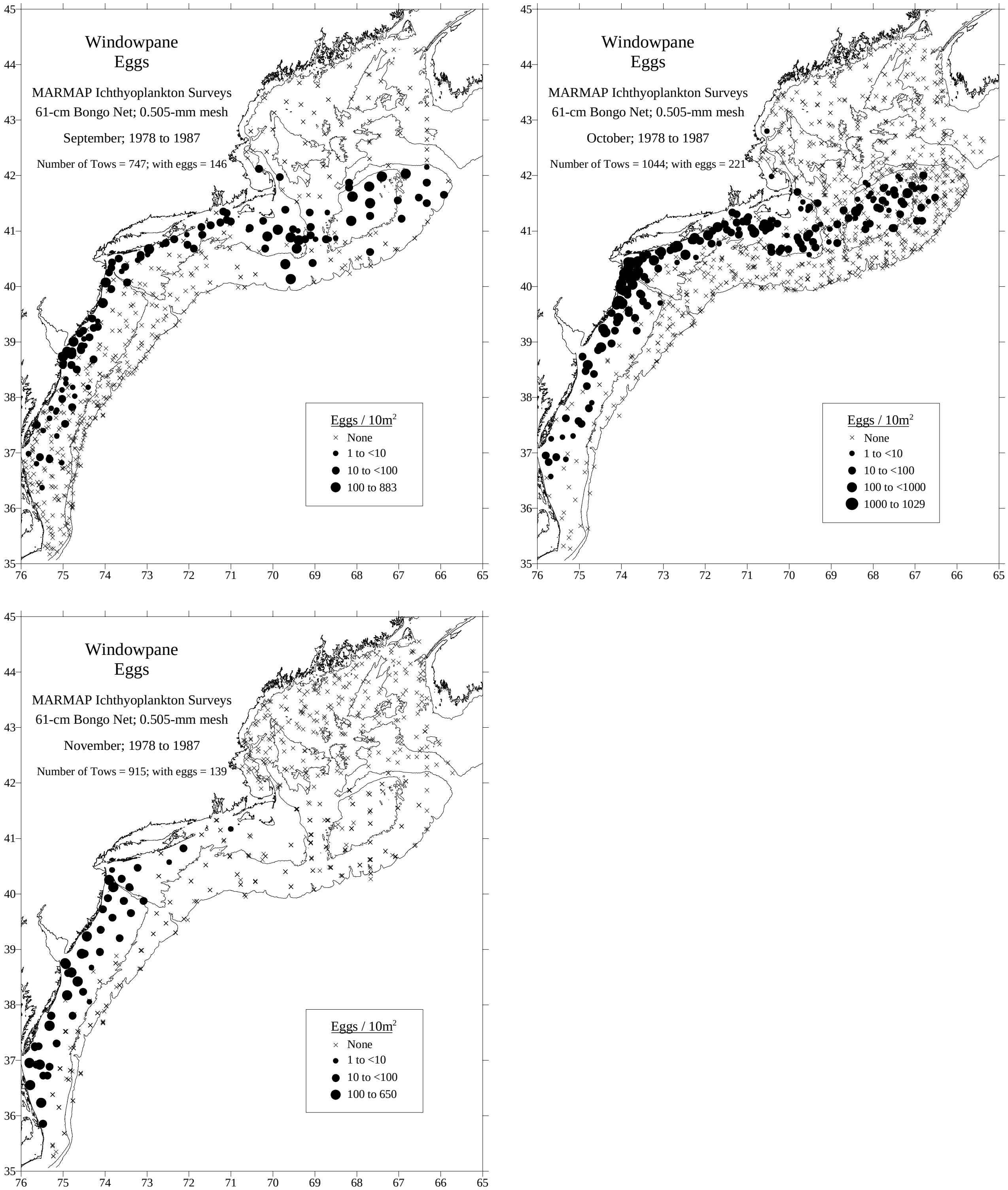


Figure 14. cont'd.

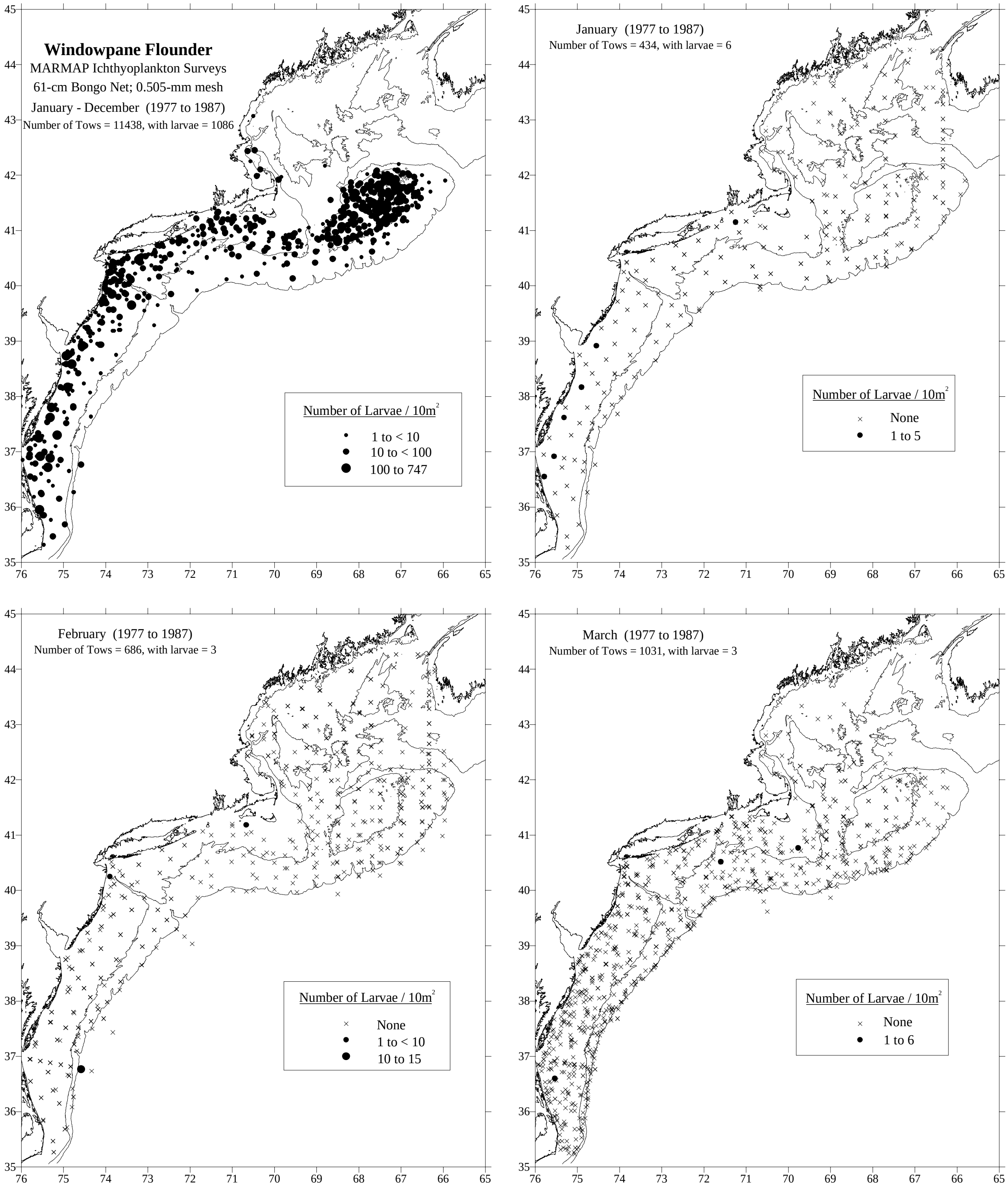
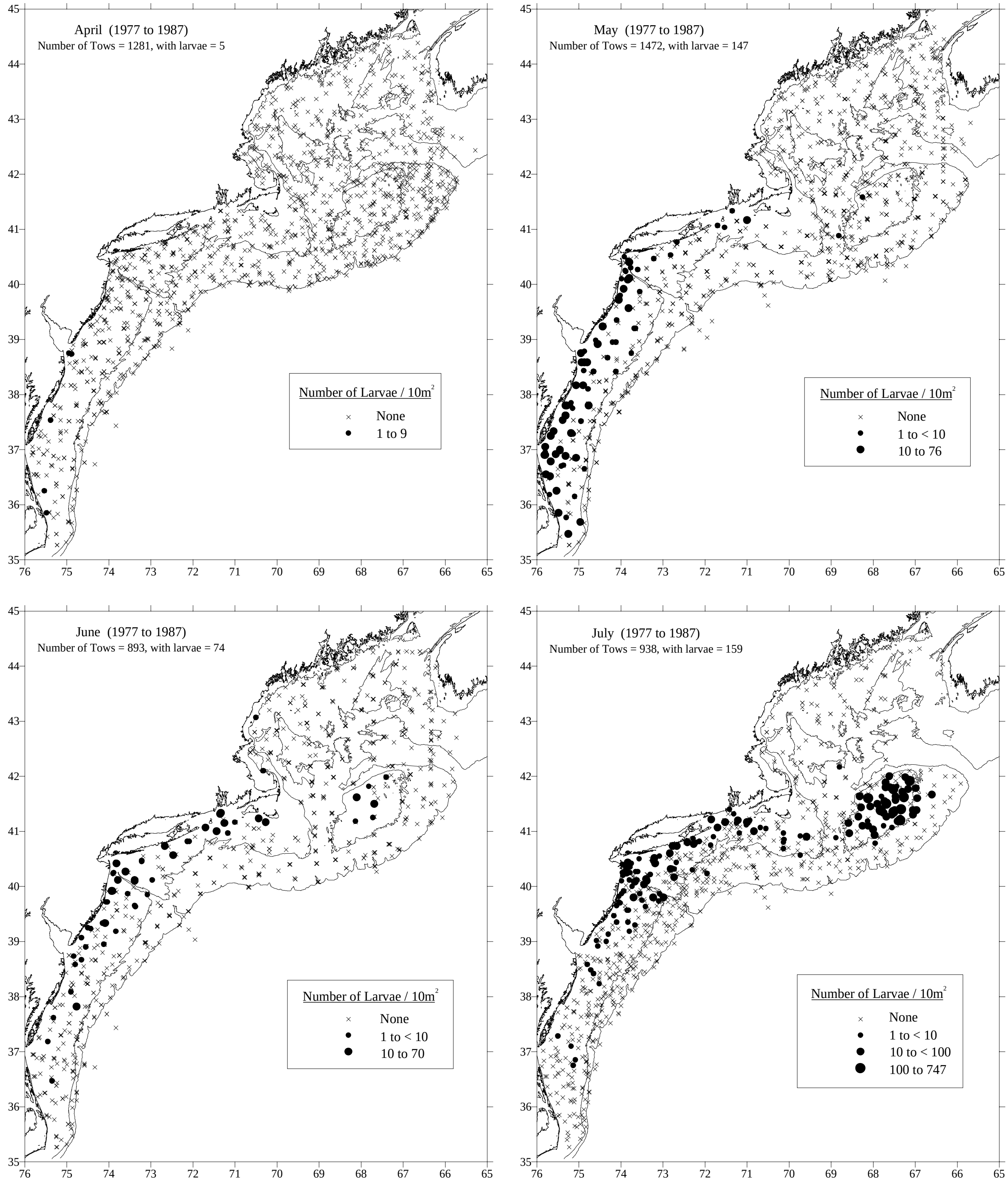


Figure 15. The distribution and abundance of windowpane larvae collected from January to December, 1977-1987 during NEFSC MARMAP ichthyoplankton surveys [see Reid *et al.* (1999) for details].



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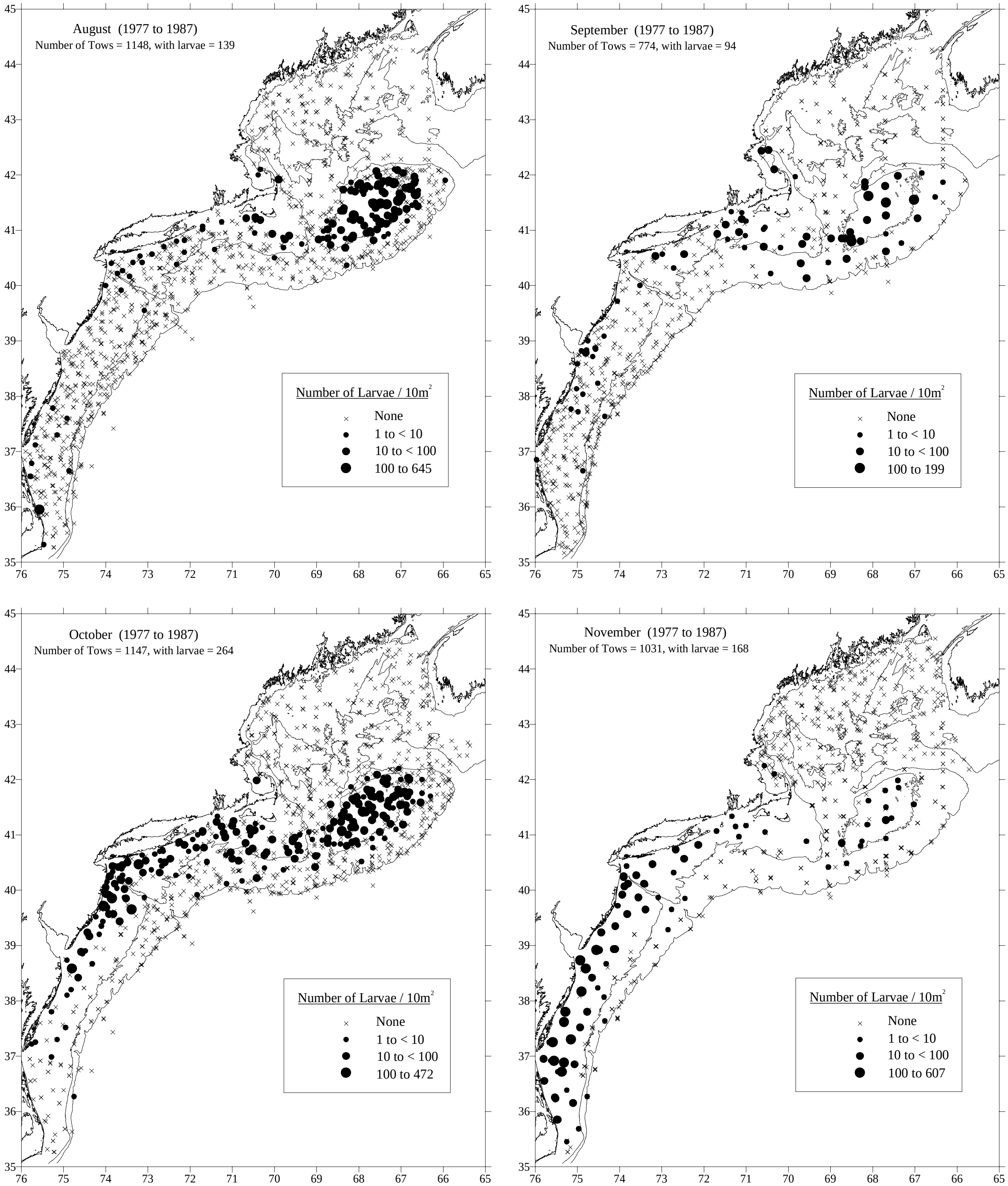

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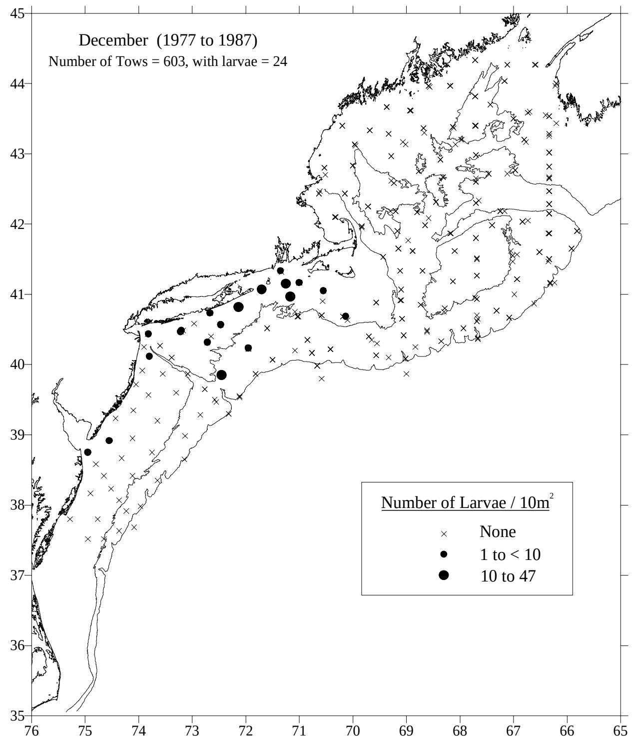

Figure 15. cont'd.

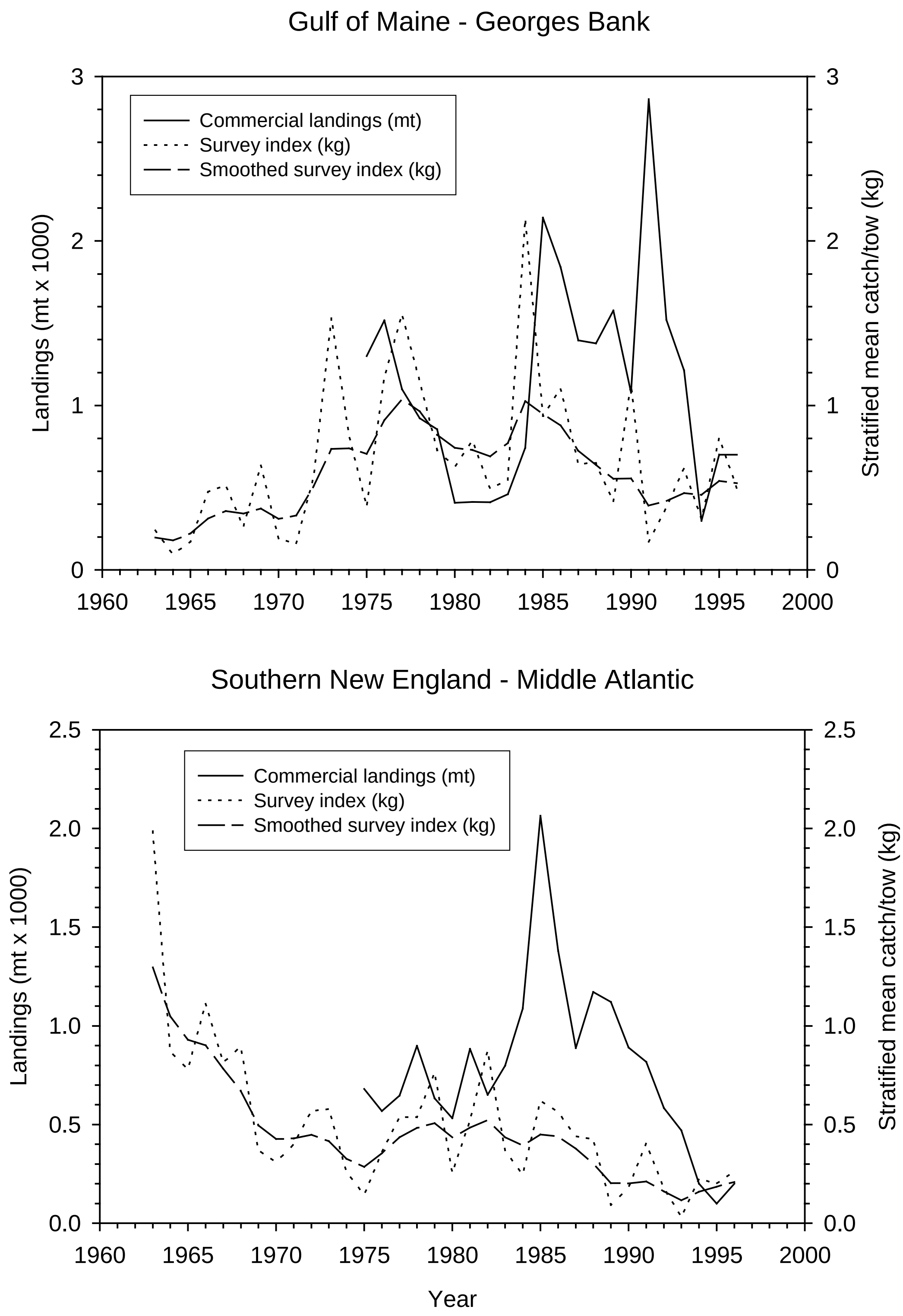

Figure 16. Commercial landings (mt), bottom trawl survey indices (stratified mean catch per tow), and smoothed survey indices (3 year moving average of first order autoregression model to compensate for inter-year variability) for windowpane in the Gulf of Maine-Georges Bank region and the southern New England-Middle Atlantic Bight region.

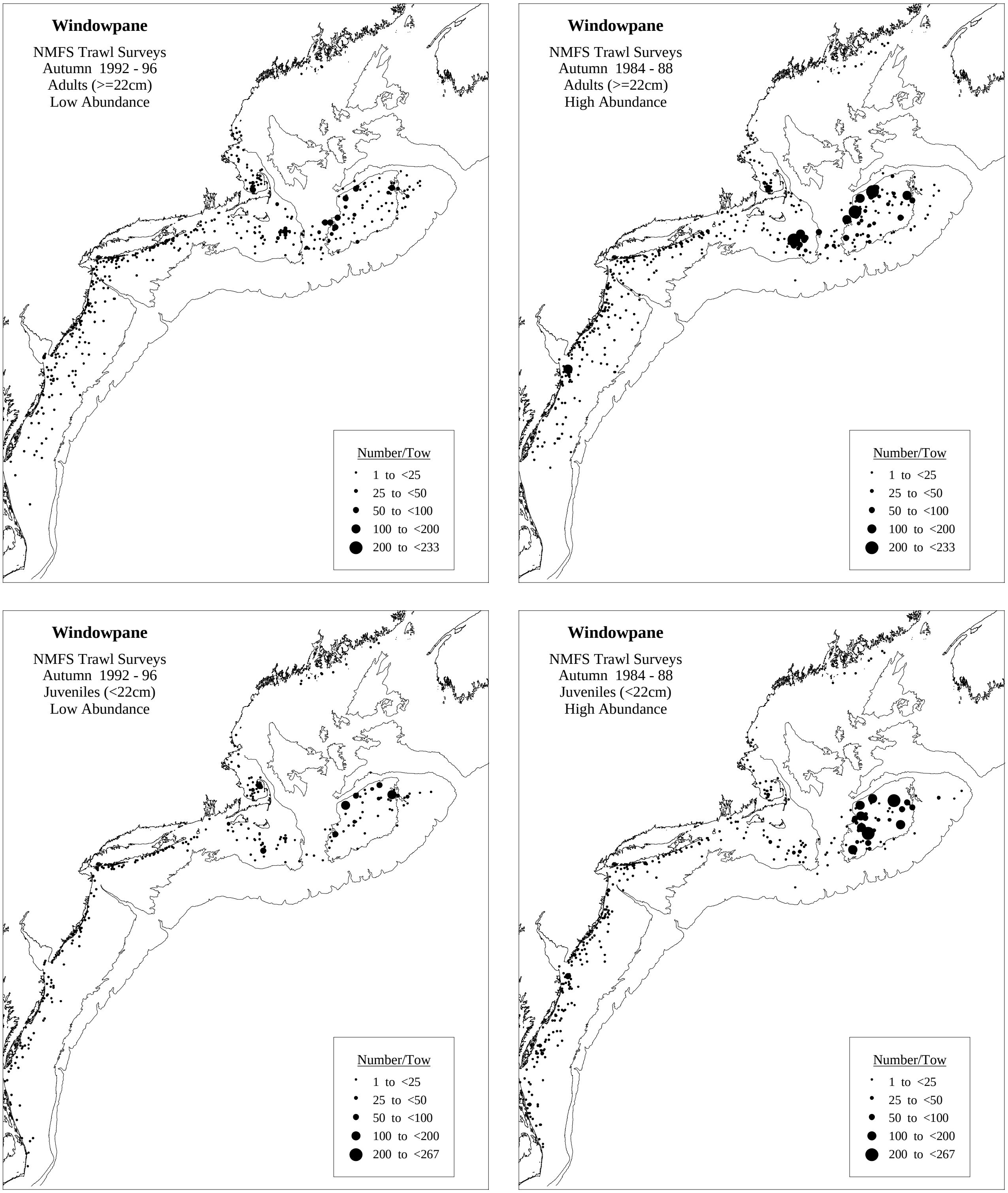

Figure 17. Distribution and abundance of juvenile (< 22 cm) and adult (≥ 22 cm) windowpane during a period of relatively low abundance (1992-1996) and a period of relatively high abundance (1984-1988) from autumn NEFSC bottom trawl surveys.

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