NOAA Technical Memorandum NMFS-NE-123

Essential Fish Habitat Source Document:

American Plaice, *Hippoglossoides platessoides*, 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:

American Plaice, *Hippoglossoides platessoides*, 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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Contents

Introduction 1
Life History 1
Habitat Characteristics 3
Geographical Distribution 4
Status of the Stocks 5
Research Needs 6
Acknowledgments 6
References Cited 6

Tables

Table 1. The age and length at maturity of female American plaice, *Hippoglossoides platessoides*, in the northwest Atlantic 9
Table 2. Summary of life history and habitat parameters for American plaice, *Hippoglossoides platessoides* 10
Table 3. Distribution and relative abundance of American plaice in North Atlantic estuaries and rivers by life history stage 12

Figures

Figure 1. The American plaice, *Hippoglossoides platessoides* (from Goode 1884) 14
Figure 2. Distribution and abundance of American plaice from Newfoundland to Cape Hatteras 15
Figure 3. Abundance of the major prey items in the diet of American plaice based on NEFSC trawl survey data 16
Figure 4. Water temperature and depth associated with collections of American plaice eggs during MARMAP surveys 17
Figure 5. Water temperature and depth associated with collections of American plaice larvae during MARMAP surveys 18
Figure 6. Distribution of juvenile and adult American plaice in relation to bottom temperature and depth from NEFSC surveys 19
Figure 7. Distribution of juveniles and adults in relation to bottom temperature and depth from Massachusetts trawl surveys 20
Figure 8. Distribution and abundance of American plaice eggs during MARMAP ichthyoplankton surveys 21
Figure 9. Distribution and abundance of American plaice larvae during MARMAP ichthyoplankton surveys 25
Figure 10. Distribution and abundance of juvenile and adult American plaice from NEFSC bottom trawl surveys 27
Figure 11. Distribution and abundance of juvenile and adult American plaice from Massachusetts inshore bottom trawl surveys 29
Figure 12. Commercial landings and survey indices for American plaice from Gulf of Maine-Georges Bank region, 1963-1996 30
Figure 13. Distribution and abundance of juveniles and adults during low and high abundance periods from NEFSC surveys 31

INTRODUCTION

The American plaice, *Hippoglossoides platessoides*, is an arctic-boreal pleuronectid flatfish that inhabits both sides of the North Atlantic (Figure 1). In Europe, it is known as the long rough dab and occurs from Iceland and Spitzbergen south to the North Sea, the western Baltic, and as far south as the English Channel. In the western Atlantic, it is common from the outer coast of Labrador, south from Hamilton Inlet, Newfoundland, on the Grand Banks, in the Gulf of St. Lawrence, west and south to Cape Cod (Figure 2; Bigelow and Schroeder 1953; Smith *et al.* 1975). It occurs as far south as Montauk Point, NY.

In Canadian waters, American plaice have been exploited since the start of the otter trawl fishery in 1947. It is one of four major species contributing to the Newfoundland and Labrador fisheries and is the most abundant flatfish species in the northwest Atlantic (Bowering and Brodie 1991). In U.S. waters, the fishery for American plaice started to develop around 1975 in the Gulf of Maine as the abundance of other commercially desirable flatfish, such as yellowtail flounder, winter flounder, and summer flounder, began to decrease (Sullivan 1981). Prior to 1973, the primary use of American plaice caught on Georges Bank was for bait (Lange and Lux 1978).

LIFE HISTORY

EGGS

American plaice spawn buoyant eggs which lack oil globules. The eggs have a characteristically large, transparent perivitelline space, which is formed from water entering between the egg and its membrane (Bigelow and Schroeder 1953). The average diameter of an egg is 2.5 mm (range 1.38-3.2 mm). Eggs incubate from 11 to 14 days at 3.9^{o}C (Bigelow and Schroeder 1953). During development, the embryo is covered with a scattered pigment.

In the northwest Atlantic, plaice eggs have been collected during all months of the year (Berrien and Sibunka 1999). In the Gulf of Maine and on the Scotian Shelf, egg abundance peaks in early April and May (Smith *et al.* 1975; Neilson *et al.* 1988).

LARVAE

American plaice larvae hatch at 2.4 mm SL (Fahay 1983) and development of five clusters or groups of pigment begins at 4-6 mm (Klein-MacPhee, in prep.). Yolk absorption is complete about 5 days after hatching when the larva is 6.2-7.5 mm long. Transformation of the larva and migration of the left eye begins when the larva is approximately 20 mm. Although the duration of the transformation process varies with temperature, it is usually complete when the larva is 30-40 mm (Colton and Marak 1969).

Sullivan (1981) found that larval plaice were transported by currents southwest along the coast; some were retained in the Gulf of Maine while others were transported to Georges Bank. Changes in circulation patterns also lead to large numbers of pelagic larvae being transported off Georges Bank (Colton and Temple 1961; Sullivan 1981). Larval plaice that drift into the slope water zone along the southern edge of Georges Bank are susceptible to transport in a northeasterly direction away from Georges Bank and the continental shelf. Differences in temperature between the coastal and slope water zones could affect the transported larvae by subjecting them to thermal stress. Plaice larvae were found in relatively shallow waters on Georges Bank, in Massachusetts Bay, and along coastal Maine (Smith *et al.* 1975).

JUVENILES

The body shape continues to change, flattening and increasing in depth from side to side. As the migration of the left eye across the top of the head to the right side reaches completion, descent towards the bottom begins (Huntsman 1918). Pigment patterns become more abundant and develop on the right side of the body while the left side remains unpigmented. Growth during the first year is greater in warmer, southern climates. Juveniles can reach 7.6 cm by winter.

ADULTS

The body of the adult plaice is broad with a sharp noise and wide gaping mouth. Adults obtain average lengths between 27-66 cm TL. It is the only Gulf of Maine flounder that is right-handed with a large mouth, round tail, and straight lateral line with a slight arch over the pectoral fin (Bigelow and Schroeder 1953).

REPRODUCTION

American plaice is a bottom spawner and the eggs drift into the upper water column after they are released (Colton and Temple 1961). Spawning begins north of Cape Cod in March and continues through the middle of June (Bigelow and Schroeder 1953; Smith *et al.* 1975). Spawning occurs at depths < 90 m and spawning adults migrate from deeper depths into shoaler grounds before spawning (Bigelow and Schroeder 1953).

Ichthyoplankton collections made in Cape Cod Bay revealed that plaice eggs were present from January through July, and larvae were present from January through August (Scherer 1984). Early stage eggs were collected on the northern perimeter of the Bay suggesting that it was a spawning site. The southern distribution of late-stage eggs suggested displacement by counter-clockwise drift patterns in the Bay. It is believed that the American plaice eggs may have been spawned outside of Cape Cod Bay and drifted into the Bay by prevailing currents. The eggs could have drifted as much as 49.0 km from their original spawning location (Scherer 1984). Smith *et al.* (1975) determined from the low larval occurrence and the prevailing circulation patterns off southern New England that spawning had occurred along the southern edge of Georges Bank and that the larvae were subsequently transported by currents into the Middle Atlantic Bight.

MATURITY

The median age at maturity for females in the Gulf of Maine is 3.6 years (O'Brien *et al.* 1993). Growth rates are higher and maturity is reached earlier in the southern areas (Scotian Shelf, Gulf of Maine) than in the north. The lowest growth rates occurred in St. Mary's Bay while the fastest growth rates occurred in the Gulf of Maine (Table 1). Powles (1965) noted that slower growth rates were observed in deeper waters. Differences also occurred between gender and after four years of age, females grew faster than males and both sexes grew faster in southern regions.

Water temperatures control spawning in American plaice resulting in varied times and locations in the northwest Atlantic (Bowering and Brodie 1991). They can thrive in temperatures ranging from -0.5 to 13.0^{o}C (Bigelow and Schroeder 1953; Bowering and Brodie 1991). Water temperatures from 1.7 to 7.7°C represent conditions where highest development occurs.

Areas of maximum spawning occur in the western Gulf of Maine and over southeastern Georges Bank; optimum spawning temperatures range between 3-6^{o}C. These bottom water temperatures exist throughout much of the spawning period within the 100 m isobath from Cape Cod to New Jersey (Colton 1972). Outside this southern boundary, temperatures are too high for survival rather than too high for reproduction (Colton 1972).

FOOD HABITS

American plaice larvae feed on plankton, diatoms, and copepods. Prior to settling, juveniles feed on small crustaceans, polychaetes, and cumaceans (Bigelow and Schroeder 1953). Feeding competition exists between young plaice and cod (Powles 1965). Diets of adults are primarily echinoderms, chiefly sand dollars, sea urchins, and brittle stars (Huntsman 1918; Pitt 1973; Sullivan 1981). The brittle star, *Ophiura sarsi*, makes up 65% of the plaice diet at some locations in the Gulf of Maine (Klein-MacPhee, in prep.). The diets of plaice collected during Northeast Fisheries Science Center (NEFSC) bottom trawl surveys were dominated by echinoderms, arthropods, annelids, and mollusks (Figure 3) [see Reid *et al.* (1999) for a discussion of methods].

Plaice are opportunistic feeders and flexible in their dietary habits, and will take whatever is most abundant or accessible (Langton and Bowman 1981; Macdonald and Green 1986; Langton and Watling 1990; Keats 1991; Zamarro 1992; Klemetsen 1993; Ntiba and Harding 1993; Martell and McClelland 1994; Packer *et al.* 1994; Berestovskiy 1995). The stomach contents of plaice from western Nova Scotia, Gulf of Maine, Georges Bank, and southern New England are generally similar (Powles 1965; Minet 1973; Pitt 1973; Langton and Bowman 1981) although the specific prey consumed can vary geographically.

In southern New England, plaice consume large quantities of amphipods, shrimp (*Crangon*), polychaetes, and bivalves (Klein-MacPhee, in prep.). On Georges Bank, their diet consists primarily of sand dollars, brittle stars, bivalves, pandalid shrimp, and polychaetes (Bigelow and Schroeder 1953). In Sheepscot Bay, Maine, polychaetes, mysids, amphipods, sand shrimp (*Crangon septemspinosa*), and Atlantic herring are important prey (Langton and Watling 1990; Packer and Langton, in prep.). Offshore in the Gulf of Maine, the brittle star *Ophiura sarsi* is one of the dominant epifaunal taxa (Watling *et al*. 1988) and is the primary prey of plaice; crustaceans (euphausiids and pandalid shrimp), bivalve mollusks (*Yoldia* spp., *Chlamys islandica*, *Cerastoderma pinnulatum*), and tube-dwelling polychaetes are of secondary importance (Langton and Bowman 1981; Bowman and Michaels 1984; Packer *et al*. 1994). In Passamaquoddy Bay, Canada, amphipods, mysids, euphausiids, polychaetes, bivalve mollusks and Atlantic herring are the major prey of plaice (Tyler 1971, 1972; Macdonald and Green 1986; Macdonald and Waiwood, 1987).

American plaice can undergo a size-related shift in their diets. Smaller (< 25-30 cm) individuals feed predominately on mysids, amphipods, polychaetes, small brittle stars, and some mollusks. Larger individuals (> 25-30 cm) feed primarily on fish, brittle stars and other echinoderms, and bivalve mollusks (Huntsman 1918; Powles 1965; Pitt 1973; Langton and Bowman 1981; Bowman and Michaels 1984; Martell and McClelland 1994). Bowman and Michaels (1984) report that polychaetes are especially important prey of plaice < 20 cm and note that the largest fish feed mostly on echinoderms. In Sheepscot Bay, Maine, mysids generally decreased in importance with increasing predator size and polychaetes appeared to increase (Packer and Langton, in prep.).

There is little or no feeding during January and February. This is followed by a rapid increase of feeding in May, which continues through September (Powles 1965). The highest feeding rates occur during the summer enabling high-energy production for metabolic use and gonad maturation (MacKinnon 1972).

PREDATION

Plaice ≤ 35 cm are frequently preyed on by cod and other bottom feeding species (Powles 1965; Bowman and Michaels 1984). Adults are consumed by Greenland sharks (Bigelow and Schroeder 1953), goosefish, and spiny dogfish. Plaice larvae are commonly consumed by redfish (Klein-MacPhee, in prep.). Along the Scotian Shelf and in the Gulf of St. Lawrence, grey seals are the primary predators of plaice (Benoit and Bowen 1990).

MIGRATION

In U.S. and Canadian waters, American plaice is regarded as a sedentary species migrating only for spawning and feeding (Pitt 1969; Colton 1972; Bowering and Brodie 1991).

STOCK STRUCTURE

American plaice is managed as one stock under the Multispecies Fishery Management Plan of the New England Fishery Management Council (NEFMC 1993). The principal gear used to harvest it is the otter trawl; recreational and foreign catches are insignificant. Since the mid-1970s, landings from the Gulf of Maine have exceeded those from Georges Bank. In 1993 the catch in the Gulf of Maine was more than twice as large as the catch from Georges Bank (O'Brien 1995).

HABITAT CHARACTERISTICS

The habitat characteristics of American plaice are summarized by life history stage in Table 2. Data from the following surveys were used to determine habitat characteristics: (1) National Marine Fisheries Service (NMFS), Northeast Fisheries Science Center (NEFSC) Marine Monitoring Assessment and Prediction (MARMAP) ichthyoplankton survey, (2) NMFS, NEFSC bottom trawl survey, (3) Massachusetts Division of Marine Fisheries (MDMF) bottom trawl survey, and (4) the NEFSC Food Habits Investigation. A description of survey methods and materials is found in Reid *et al.* (1999).

EGGS

Plaice eggs were collected at temperatures ranging from about 1-12^{o}C (Figure 4). During February through April, most eggs were collected at 2-6^{o}C. During May to July the majority of eggs were found at 5-8^{o}C. From August to December, eggs were found at higher temperatures, with most eggs found at 9-11^{o}C.

Eggs were found over depths ranging from 10-180 m, with the majority occurring between 50-90 m.

LARVAE

Plaice larvae were captured at temperatures ranging from 4-14^{o}C (Figure 5). Larvae were most abundant at 6-8^{o}C from March through June and 10-12^{o}C during July and August.

Larvae were found over depths ranging from 30-210 m, with most occurring at 50-90 m except for August, where about 45% also occurred at 130 m.

JUVENILES

In the Northeast Fisheries Science Center spring bottom trawl survey, juvenile American plaice were found in large numbers at temperatures ranging from 4-6^{o}C with an overall range of 2-10^{o}C (Figure 6). During autumn, large catches were made in areas with temperatures of 6-11^{o}C. They occurred at depths ranging from 15-200 m in the spring and 50-275 m in the autumn. The majority occurred at shallower depths of 50-100 m during the spring to slightly deeper areas of 100-175 m during the autumn.

In the Massachusetts Division of Marine Fisheries bottom trawl survey, juvenile plaice were collected at temperatures ranging from 2-12^{o}C during the spring and 5-17^{o}C during the autumn (Figure 7). They were most abundant at 4-6^{o}C in the spring and 7-10^{o}C in the autumn. In the spring, they were found over depths ranging from 10-80 m, with the majority occurring between 45-60 m. During autumn they were found from 20-80 m with the majority again occurring between 45-60 m.

ADULTS

The geographic boundaries of American plaice distribution appear to be defined by warm summer and fall temperatures. Since the early 1940s, coastal warming and cooling trends have been observed in waters between Cape Sable and Long Island (Colton 1972). These trends are related to changes of subsurface water. Cold years are defined as years when coastal water from Labrador displaces slope water. Warm years occur when there is a low ratio of coastal to central Atlantic water and slope water borders the 200 m isobath.

Huntsman (1918) noted that the maturity of plaice varied as much as 11 years and depended on the water temperatures. The highest temperature, 10°C, for Passamaquoddy Bay and the Cape Cod region had the shortest time of development to maturity (3-5 years). The lowest temperature recorded was 0°C for Newfoundland (Bay of Islands) and plaice had the longest development time (10-13 years) (Huntsman 1918; Bigelow and Schroeder 1953). On the Scotian Shelf, American plaice ranged between 0-13°C with preferences between 1-4°C (Scott 1982a).

Dow (1977) found that water temperatures influence the abundance of American plaice in a study of climatic effects on relative abundance and availability. There were significant positive correlations between the annual catch of fish off the Maine coast and mean annual surface temperatures. These results imply that temperature is a limiting factor in the abundance of American plaice.

On the Scotian Shelf American plaice range between 27-366 m, with preferences between 55-128 m (Scott 1982a). United States research vessel surveys and commercial catch statistics confirm similar movement and depth preferences in the Gulf of Maine (Colton 1972). Plaice normally occur in waters 25-180 m deep, however they have been captured at depths > 800 m (Iglesia *et al.* 1996). They are also found in shoal waters when temperatures are severely cold (Bigelow and Schroeder 1953). In the Gulf of Maine, plaice occur at depths of 15-200 m, more frequently at 30-50 m (Klein-MacPhee, in prep.). With the exception of witch flounder, plaice is considered the most abundant of all flatfish in the Gulf of Maine at depths between 54-90 m (Klein-MacPhee, in prep.). They are also widespread on Georges Bank in 27-366 m of water.

American plaice occur at mean salinities of 20-22 ppt in Hamilton Inlet, Labrador (Backus 1957), 30 ppt or lower in Baltic areas, 32.8 ppt in the Gulf of Maine, and 34 ppt in offshore Atlantic waters (Bigelow and Schroeder 1953).

During a study of fishes of the Scotian Shelf, Scott (1982a) found American plaice had salinity preferences between 31-34 ppt; highest abundance occurred at 33 ppt. Of the 31 species studied by Scott (1982a), American plaice displayed the widest salinity, depth, and temperature ranges.

American plaice are frequently found on fine sand or gravel bottoms (Scott and Scott 1988; Bowering and Brodie 1991). On the Scotian Shelf, plaice were most abundant on sand and gravel substrates (Scott 1982b). They were found in lesser numbers on sand, silt, and clay and were rare on Scotian Shelf drift (a mixed substrate). In eastern Newfoundland, plaice were frequently collected where sandy substrates bordered areas of bedrock. It is believed that their occurrence near bedrock is because bedrock is the preferred habitat of an important prey, green sea urchins, *Strongylocentrotus droebachiensis* (Keats 1991). In some areas, their distribution has been correlated with mud substrates (Walsh 1996; Packer and Langton, in prep.).

In the Northeast Fisheries Science Center spring bottom trawl survey, adults appeared to have similar temperature preferences to juveniles with most found at temperatures from 4-6°C with an overall range of 1-12°C (Figure 6). In autumn, plaice were also mostly found at temperatures of 4-6°C. American plaice were collected at 15-300 m deep in the spring and autumn; they were most abundant between 50-175 m.

In the Massachusetts Division of Marine Fisheries bottom trawl survey, adults had similar temperature preferences to juveniles (Figure 7). Adult plaice were collected at temperatures from 2-9°C during spring surveys and 5-14°C during autumn. Most were found between 4-6°C in the spring and 7-10°C in the autumn. Adults in both spring and autumn were found over depths ranging from 20-80 m, with most occurring at 45-75 m.

GEOGRAPHICAL DISTRIBUTION

American plaice occur on both sides of the North Atlantic. On the western side of the Atlantic, it is common from the outer coast of Labrador, Newfoundland, the Grand Banks, and the Gulf of St. Lawrence west and south to Cape Cod; its southern limit is Montauk Point, NY (Figure 2; Bigelow and Schroeder 1953; Smith *et al.* 1975). It also occurs in North Atlantic estuaries and rivers where it ranges from highly abundant to rare (Jury *et al.* 1994; Table 3).

EGGS

The NEFSC MARMAP ichthyoplankton survey (1978-1987) captured eggs throughout the year (Figure 8). During February and March, eggs were collected on Stellwagen Bank, off Cape Ann, on Jeffreys Ledge, along coastal Maine, and on Georges Bank. During April and May, the highest egg concentrations occurred in the mixed waters and eastern edge of Georges Bank and along the coastal areas off eastern Massachusetts, the Gulf of Maine, southwest Nova Scotia, and Browns Bank. From June through December, eggs were collected almost exclusively along the coastal areas of in the Gulf of Maine; some eggs were collected on Georges Bank and the Scotian Shelf.

LARVAE

Larvae were first captured in the NEFSC MARMAP ichthyoplankton survey (1977-1987) in small numbers during March on the southeastern flank of Georges Bank (Figure 9). By April, numbers increased throughout

Georges Bank and larval distributions spread towards the Great South Channel and onto Nantucket Shoals. Peak abundance occurred during May from Georges Bank as far south as Delaware. The highest May abundance occurred around Cape Cod Bay and along the 60 m contour on Georges Bank. Larval abundance decreased dramatically in June and continued to decline in August.

JUVENILES

In the NEFSC bottom trawl survey, juvenile American plaice occurred from coastal Maine north towards the Bay of Fundy, west to the Scotian Shelf and Georges Bank, and south from Cape Cod, the Great South Channel, and Georges Bank (Figure 10). During winter, juveniles were caught at scattered locations throughout the Gulf of Maine. Juveniles were present in only a few locations along the Great South Channel and the northeast sector of Georges Bank. In the spring, juveniles were abundant between Cape Cod and Cape Ann, out to Stellwagen Bank, and onto Jeffreys Ledge. Juveniles were captured in lower numbers throughout the Gulf of Maine. In the summer, juveniles were found in the inshore and coastal areas of Maine, the Gulf of Maine, along its western perimeter, and within Cape Cod Bay. By autumn the center of abundance was located between Cape Cod and Cape Ann, and along the western part of the Gulf of Maine; a few juveniles were collected on Georges Bank and the northeast sector of the Middle Atlantic Bight. Dense pockets were found within various basins, the northern end of the Great South Channel, and along the 100 m contour.

In the Massachusetts Division of Marine Fisheries bottom trawl survey, juvenile American plaice were abundant around Cape Ann and in Cape Cod Bay during spring and autumn (Figure 11).

ADULTS

In the NEFSC bottom trawl survey, adult American plaice were scattered throughout the Gulf of Maine, the Great South Channel, Georges Bank and Browns Bank in the winter (Figure 10). Their distribution was similar in spring. Larger catches occurred along the Maine coast, Jeffreys Ledge, and Stellwagen Bank. In the summer and autumn, adults appeared to leave Georges Bank. Many were present along the Gulf of Maine, its western perimeter, and within Cape Cod Bay. Those that remained on Georges Bank occurred only on the outer edges of the bank away from the 60 m shoal areas and the eastern edge of the Middle Atlantic Bight. During autumn, large catches occurred within various basins, the northern end of the Great South Channel, and along the 100 m contour.

In the Massachusetts Division of Marine Fisheries bottom trawl survey, American plaice adults occurred in significant numbers around Cape Ann during the spring and autumn (Figure 11).

STATUS OF THE STOCKS

The Gulf of Maine accounts for approximately 72% of the American plaice landings since 1976. The remaining U.S. catch originates mainly on Georges Bank; < 1% of the catch is taken from western Nova Scotia, southern New England, and the Middle Atlantic Bight (Sullivan 1981).

From 1963 through 1974, catches from Georges Bank averaged 2,706 metric tons (mt) or 69% of the U.S. catch (Figure 12). From 1975 to 1979, landings from Georges Bank nearly tripled (O’Brien *et al.* 1992) while catches in the Gulf of Maine increased from 1,507 to 8,835 mt. Landings declined in 1986 and continued to drop through 1990 when landings reached an historic low of 637 mt on Georges Bank. Subsequent increases in landings are probably due to improved recruitment, an increase in spawning stock biomass, and an increase in fishing effort as opposed to an increase in abundance (Sullivan 1981; O’Brien *et al.* 1992). The spawning stock biomass dropped from 41,400 mt in 1980-1982 to 7,700 mt in 1987-1989. By 1991, the presence of the strong 1987 year class raised biomass to 13,400 mt.

Low population indices for the Gulf of Maine and Georges Bank occurred in 1991-1992, but they increased dramatically in 1993 due to the 1989 and 1990 year classes (O’Brien 1995). In 1995, it was estimated that the American plaice stock would remain overexploited due to low abundance, increased fishing effort, and increased discard mortality (O’Brien 1995). In a recent report to Congress from the Secretary of Commerce (National Marine Fisheries Service 1997), the American plaice stock within the jurisdiction of the New England Fisheries Management Council was classified as “overfished.”

The distribution of American plaice was compared between years of low abundance (1985-1989) and high abundance (1976-1981) (Figure 13). When the population was at low levels, juveniles and adults were infrequently caught during spring trawl surveys in the Gulf of Maine and on Georges Bank. Larger catches were only encountered from Cape Cod to Cape Ann. Strong recruitment occurred from 1976 to 1981. Large catches of juveniles and adults occurred in coastal Gulf of Maine and there were scattered catches along Browns Bank and Georges Bank. Adults were caught more frequently in the shoal waters (60 m) of Georges Bank, while the juveniles were caught more frequently along the northern edge of Georges Bank.

RESEARCH NEEDS

- Determination of how depth, temperature, and bottom type control the spatial and temporal distribution of plaice; this is especially important for U.S. populations where little research has been conducted.
- Confirmation of vertical migration and seasonal distribution patterns of early life stages.
- Age and growth determination based on otolith microstructure.
- The strength of habitat dependency and/or interaction for juveniles and adults.
- Determination of adult migration patterns (i.e., tagging studies).

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Table 1. The age (A) and length (L) at which 50% of the female American plaice, *Hippoglossoides platessoides*, are mature in the northwest Atlantic.

Area	**A_{50}** (yrs)	**L_{50}** (cm)	**Year**	**Source**
Labrador	8.11	45.84	1978-1988	Bowering and Brodie (1991)
Northern Grand Bank	13.98	42.14	1961-1965	Pitt (1975)
Northern Grand Bank	10.57	40.36	1969-1972	Pitt (1975)
St. Mary's Bay, Newfoundland	15.20	54.00	1964	Pitt (1966)
Flemish Cap	7.80	40.00	1964	Pitt (1966)
Southeastern Grand Bank	8.79	41.45	1971	Pitt (1975)
St. Pierre Bank	9.48	48.26	1978-1988	Bowering and Brodie (1991)
Scotian Shelf	6.00	31.00	1970-1974	Beacham (1983)
Scotian Shelf	4.70	30.80	1975-1979	Beacham (1983)
Nova Scotia to Cape Hatteras	- -	33.60	1979	Morse (1979)
Atl. Coast of N. Am. (77' - 42')	8.00	30.00	1991	Miller *et al.* (1991)
Gulf of Maine	3.80	29.70	1980	Sullivan (1981)
Gulf of Maine	3.60	26.80	1986-1990	O'Brien *et al.* (1993)

Table 2. Summary of life history and habitat characteristics for American plaice, *Hippoglossoides platessoides.* (NTS = NMFS Trawl Survey; MITS = Massachusetts Inshore Trawl Survey).

Life Stage	Size Range	Time of Year Distribution	Habitat/Location	Substrate	Temperature
Spawning Adults [1]		March - mid June, (peak spawning April-May)	American plaice in general occur along the continental shelf from southern Labrador to Montauk Pt. NY. Within Massachusetts Bay, coastal Gulf of Maine, and shelf.		March to June 2.7-4.4°C
Eggs [2]	1.5 to 3.0 mm	Gulf of Maine: Jan - Dec Georges Bank: Jan - June, Dec.	Pelagic, within the 100 m contour, along the coast of Maine, Massachusetts, inshore and shoal waters of Georges Bank. Nursery area = shelf.		Range 1-12°C (most 4-8°C)
Larvae [3]	4 to 6 mm at hatching; 5.1 to 16.4 mm	March - August (peak = May)	Pelagic, within the 100 m contour, along the coast of Maine, Massachusetts, inshore and shoal waters of Georges Bank. Nursery area = shelf.		Range 4-14°C (most 5-10°C)
Juveniles [4]	18 to 34 mm at metamorphosis; 3 cm to < 27cm (Trawl Surveys)	January – December	Latitude range (77°, 42°) Strong concentrations inside and around the 100m isobath in western Gulf of Maine during the spring and autumn surveys. Scattered abundance in deeper waters of western and central Gulf of Maine and the northern sector of Georges Bank.	Fine sand and gravel.	NTS Spring 2-10°C (most 4-6°C); Autumn 4-15°C (most 6-11°C); MITS Spring 2-12°C (most 4-6°C); Autumn 5-17°C (most 7-10°C)
Adults [5]	≥ 27 cm to 66 cm (Trawl Surveys); max size = 81 cm	January - December	Both sides of the North Atlantic, latitude range (77°, 42°) boreal.	Fine sand and gravel.	NTS Spring 1-12°C (most 4 to 6°C); Autumn 3-11°C (most 4-6°C); MITS Spring 2-9°C (most 4-6°C); Autumn 5-14°C (most 7-10°C). 1.7-7.7°C highest development; -1.5°C lower temperature limit; 10-13°C upper temperature limit

[1] Bigelow and Schroeder 1953, Sullivan 1981, Miller *et al.* 1991
[2] Sullivan 1981, Fahay 1983, Miller *et al.* 1991
[3] Smith *et al.* 1975, Sullivan 1981
[4] Sullivan 1981, Miller *et al.* 1991, Wigley and Gabriel 1991
[5] Miller *et al.* 1991

Table 2. cont'd.

Life Stage	Salinity	Bottom Depth	Estuarine Use	Notes
Spawning Adults [1]	32.8 ppt March-April, Gulf of Maine	< 90 m	Inshore and shoal areas, largely an oceanic nursery (see Table 3)	Spawning adults migrate from greater depths into shoaler grounds before spawning.
Eggs [2]	32.8 ppt March-April, Gulf of Maine	Pelagic 10-325 m (most 30-90 m)	Inshore and shoal areas, largely an oceanic nursery (see Table 3)	Spherical with smooth shell. Only Pleuronectid known to have a very wide perivitelline space, no oil globule. 11-14 day incubation duration.
Larvae [3]	32.8 ppt March-April, Gulf of Maine	30-210 m (most 50-90 m)	Inshore and shoal areas, largely an oceanic nursery (see Table 3)	Transformation occurs between 18-34 mm (usually > 25 mm SL).
Juveniles [4]	32.8 ppt March-April Gulf of Maine	Pelagic-shallow shelf (36-713 m); NTS Spring 15-200 m (most 50-100 m); Autumn 50-275 m (most 100-170 m); MITS Spring 10-80 m (most 45-60 m); Autumn 20-80 m (most 45-60 m)	Inshore and shoal areas, largely an oceanic nursery (see Table 3)	Larval - juvenile migration = pelagic to shallow shelf.
Adults [5]	32.8 ppt March-April Gulf of Maine; 30 ppt Baltic, 34 ppt open Atlantic, 20-22 ppt Hamilton Inlet, Labrador	NTS Spring 15-275 m (most 50-175 m); Autumn 25-300 m (most 50-175 m); MITS Spring 5-80 m (most 45-75 m); Autumn 20-80 m (most 45-55, 70 m)	Inshore and shoal areas, largely an oceanic nursery (see Table 3)	

[1] Bigelow and Schroeder 1953, Sullivan 1981, Miller *et al.* 1991
[2] Sullivan 1981, Fahay 1983, Miller *et al.* 1991
[3] Smith *et al.* 1975, Sullivan 1981
[4] Sullivan 1981, Miller *et al.* 1991, Wigley and Gabriel 1991
[5] Miller *et al.* 1991

Table 3. Distribution and relative abundance of American plaice in North Atlantic estuaries and rivers by life history stage (from Jury *et al.* 1994). (*** = Highly Certain; ** = Moderately Certain; * = Reasonable Inference).

Estuaries and Rivers	Life Stage	Distribution and Relative Abundance		Months of Occurrence	Data Reliability
		Mixing	Seawater		
Passamaquoddy Bay	**A**dults (A)		Common	March - Nov	**
	Spawning adults (S)		Common	March - May	**
	Juveniles (J)	Common	Common	March - Nov	*
	Larvae (L)		Common	April - June	**
	Eggs (E)		Common	March - May	**
Englishman / Machias Bay	**A**		Common	March - Nov	*
	S		Common	March - May	*
	J	Common	Common	March - Nov	*
	L		Common	April - June	*
	E		Common	March - May	*
Narraguagus Bay	**A**		Common	March - Nov	*
	S		Common	March - May	*
	J	Common	Common	March - Nov	*
	L		Common	April - June	*
	E		Common	March - May	*
Blue Hill Bay	**A**		Common	March - Nov	*
	S		Common	March - May	*
	J	Common	Common	March - Nov	*
	L		Common	April - June	*
	E		Common	March - May	*
Penobscot Bay	**A**		Common	March - Nov	**
	S		Common	March - May	**
	J	Common	Common	March - Nov	**
	L		Common	April - June	**
	E		Common	March - May	**
Muscongus Bay	**A**		Abundant	March - Nov	**
	S		Common	March - May	*
	J	Common	Highly Abundant	March - Nov	*
	L	Rare	Common	April - June	*
	E		Common	March - May	*
Damariscotta River	**A**		Abundant	March - Nov	**
	S		Common	March - May	**
	J	Common	Highly Abundant	March - Nov	*
	L	Rare	Common	April - June	*
	E		Common	March - May	**
Sheepscot River	**A**		Abundant	March - Nov	***
	S		Common	March - May	***
	J	Common	Highly Abundant	March - Nov	***
	L	Rare	Common	April - June	***
	E		Common	March - May	**
Kennebec / Androscoggin Rivers	**A**		Abundant	March - Nov	**
	S		Common	March - May	*
	J	Common	Highly Abundant	March - Nov	*
	L	Rare	Common	April - June	*
	E		Common	March - May	*
Casco Bay	**A**		Abundant	March - Nov	*
	S		Common	March - May	*
	J	Common	Highly Abundant	March - Nov	*
	L	Rare	Common	April - June	*
	E		Common	March - May	*

Table 3. cont'd.

Estuaries and Rivers	Life Stage	Distribution and Relative Abundance		Months of Occurrence	Data Reliability
		Mixing	Seawater		
Saco Bay	**A**		Abundant	March. - Nov.	*
	S		Common	March - May	*
	J	Common	Highly Abundant	March. - Nov.	*
	L	Rare	Common	April - June	*
	E		Common	March - May	*
Wells Harbor	**A**				*
	S				**
	J		Rare	June - Oct.	*
	L		Rare	April - June	*
	E		Rare	March - May	*
Great Bay	**A**		Rare	March - Nov.	*
	S				**
	J		Rare	March - Nov.	*
	L		Rare	April - July	*
	E		Rare	March - June	*
Merrimack River	**A**				*
	S				**
	J	Rare		March - Sept.	*
	L	Rare		April - July	*
	E	Rare		March - June	*
Massachusetts Bay	**A**		Highly Abundant	Jan. - Dec.	***
	S		Highly Abundant	Feb. - June	**
	J		Highly Abundant	Jan. - Dec.	***
	L		Abundant	March - July	*
	E		Abundant	Feb. - June	*
Boston Harbor	**A**		Abundant	Jan. - Dec.	**
	S		Common	Feb. - June	*
	J		Abundant	Jan. - Dec.	*
	L	Rare	Common	March - July	*
	E	Rare	Common	Feb. - June	*
Cape Cod Bay	**A**		Abundant	Jan. - Dec.	**
	S		Highly Abundant	Feb. - May	**
	J		Highly Abundant	Jan. - Dec.	**
	L	Rare	Highly Abundant	March - July	**
	E	Rare	Highly Abundant	Feb. - July	**

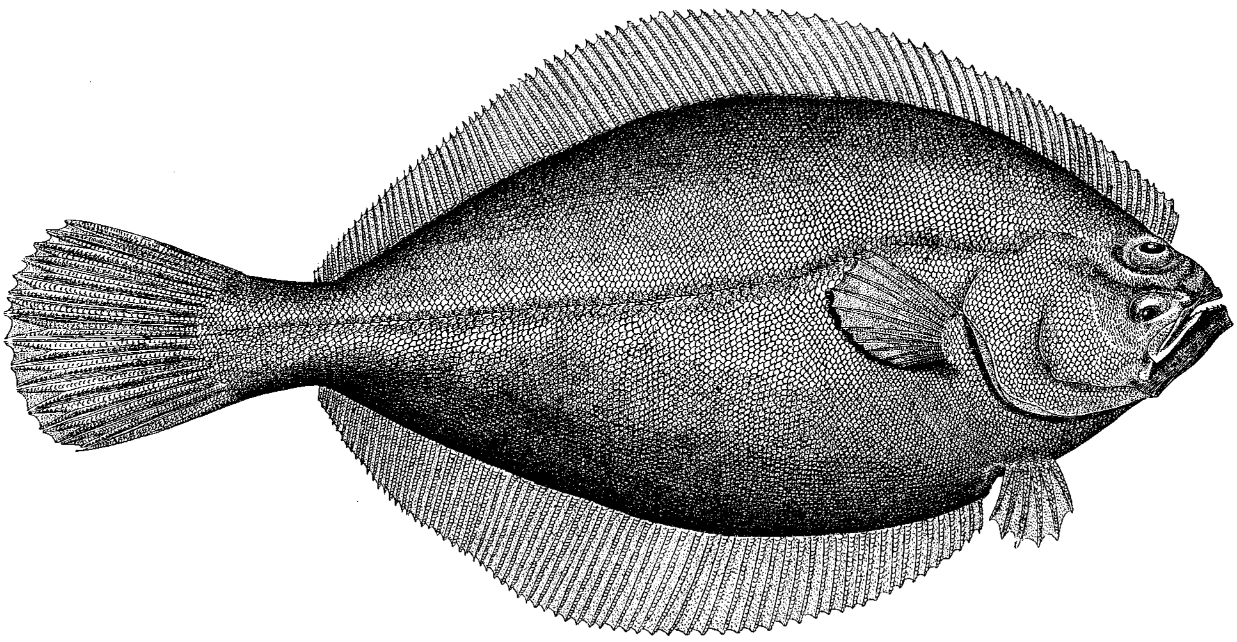


Figure 1. The American plaice, *Hippoglossoides platessoides* (Fabricius 1780) (from Goode 1884).

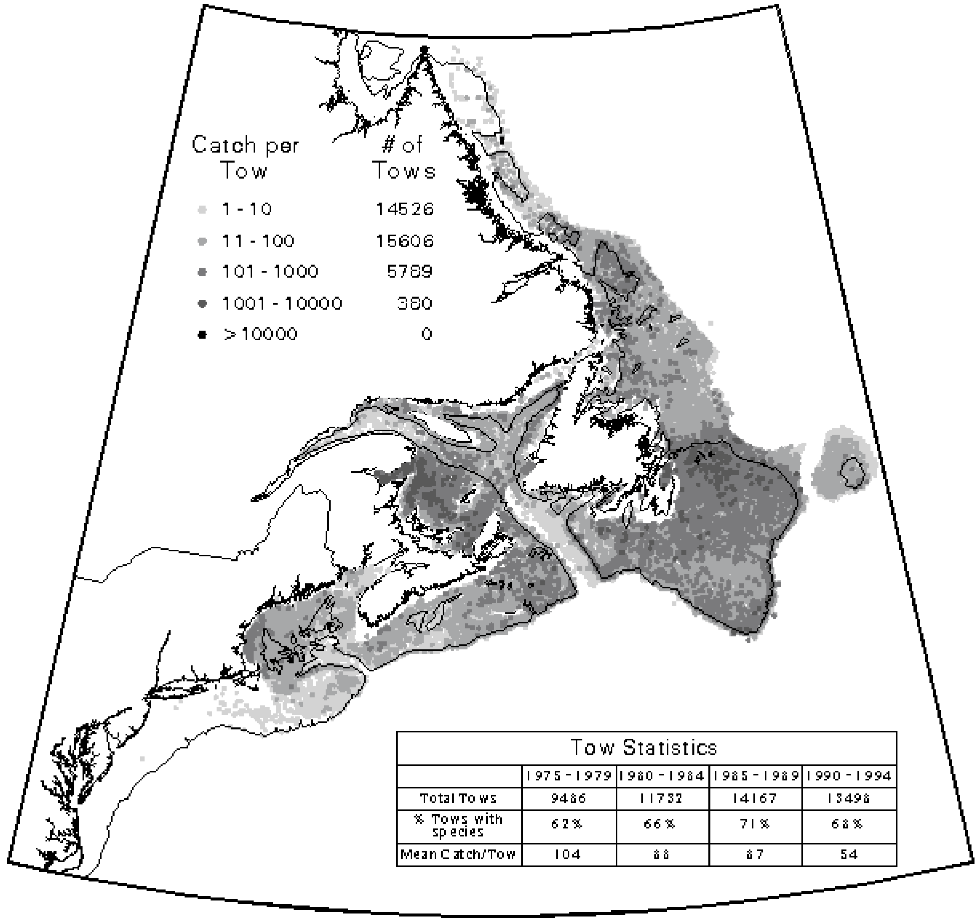


Figure 2. Distribution and abundance of American plaice from Newfoundland to Cape Hatteras based on research trawl surveys conducted by Canada (DFO) and the United States (NMFS) from 1975-1994 (http://www-orca.nos.noaa.gov/projects/ecnasap/ecnasap_table1.html).

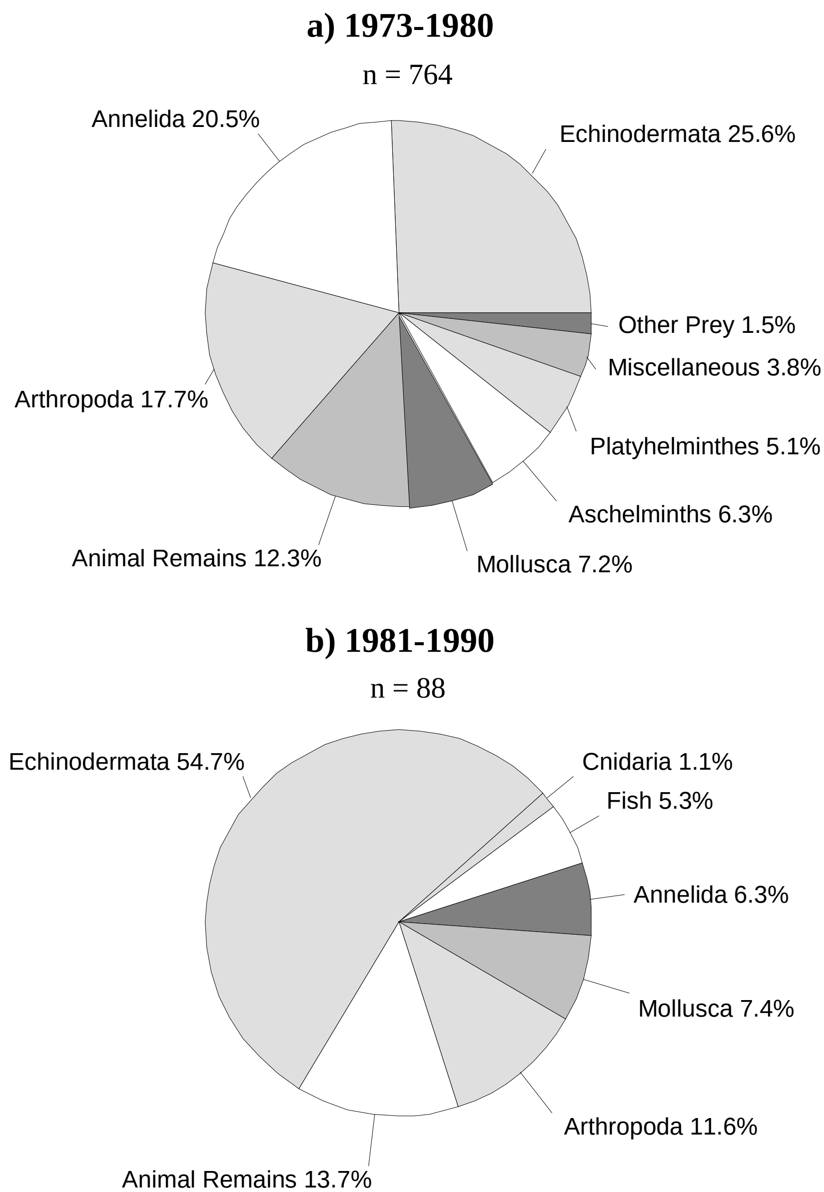


Figure 3. Abundance (percent occurrence) of the major prey items in the diet of American plaice based on NEFSC trawl survey data on food habitats during 1973-1980 and 1981-1990. Methods for sampling, processing, and analysis of samples differed between the time periods [see Reid *et al.* (1999) for details]. The category “animal remains” refers to unidentifiable animal matter.

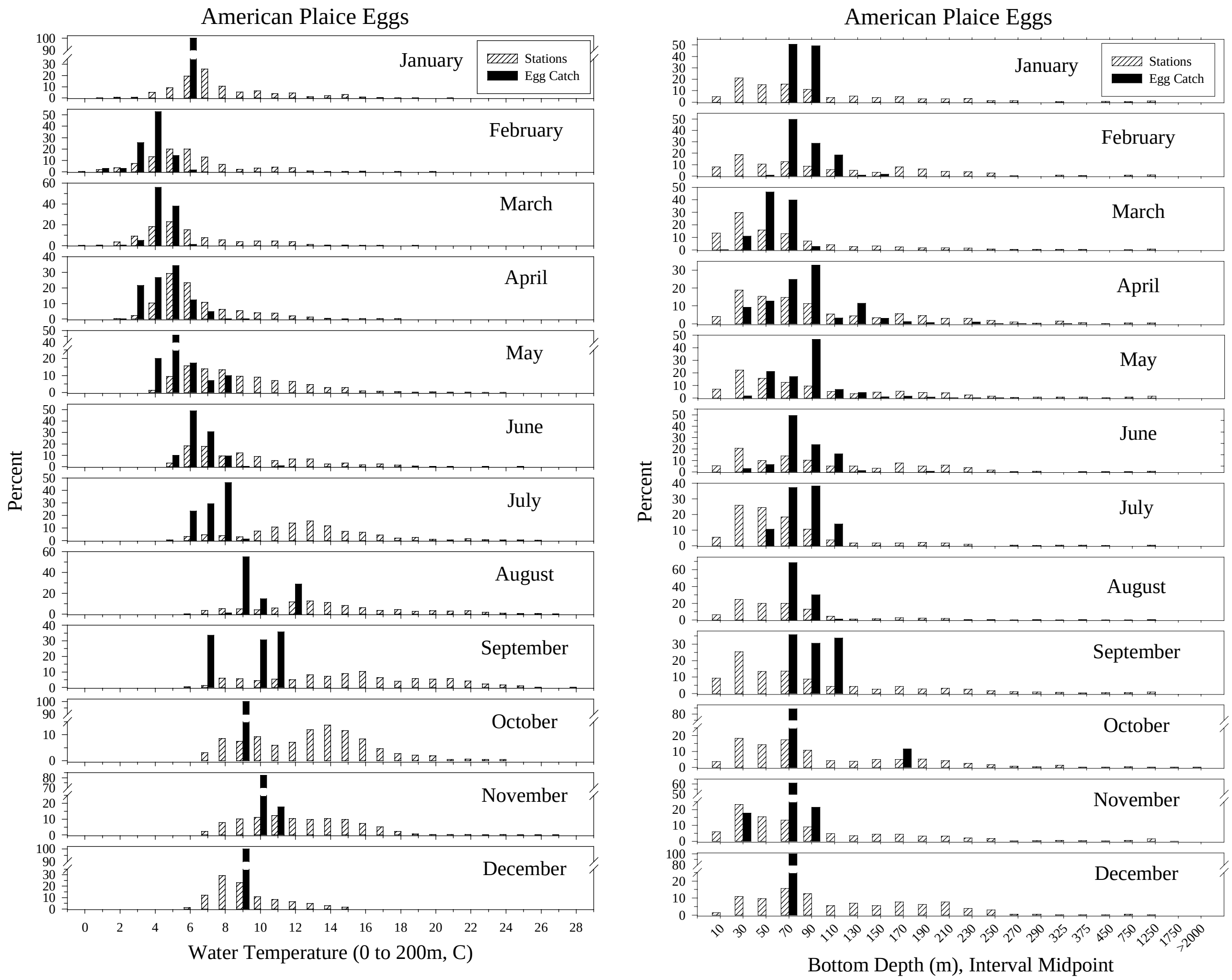


Figure 4. Mean water column temperature (to a maximum of 200 m) and bottom depth associated with collections of American plaice eggs during MARMAP ichthyoplankton surveys, 1978-1987. Open bars represent the proportion of all stations which were surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

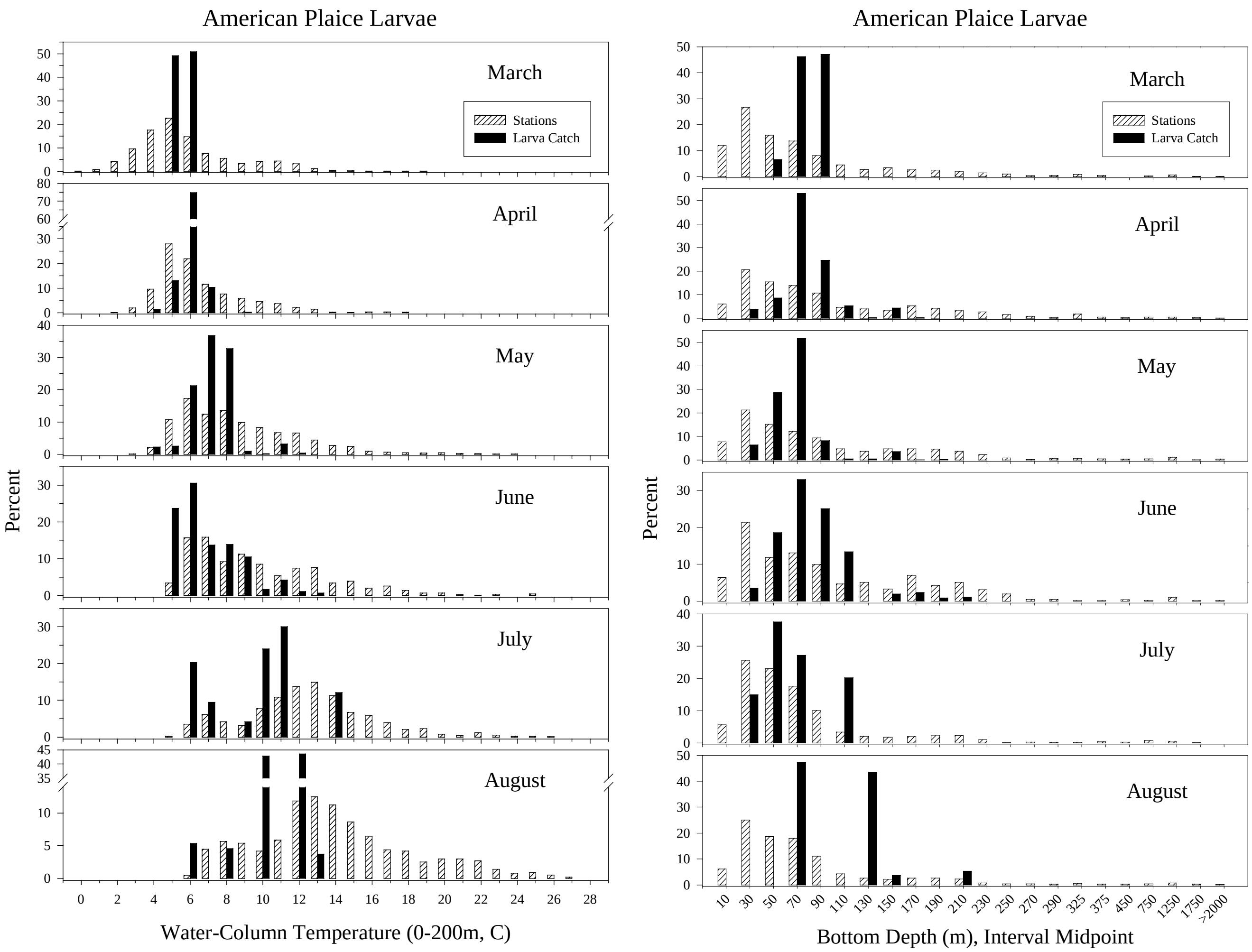


Figure 5. Mean water column temperature (to a maximum of 200 m) and bottom depth associated with collections of American plaice larvae during MARMAP ichthyoplankton surveys, 1977-1987. Open bars represent the proportion of all stations which were surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

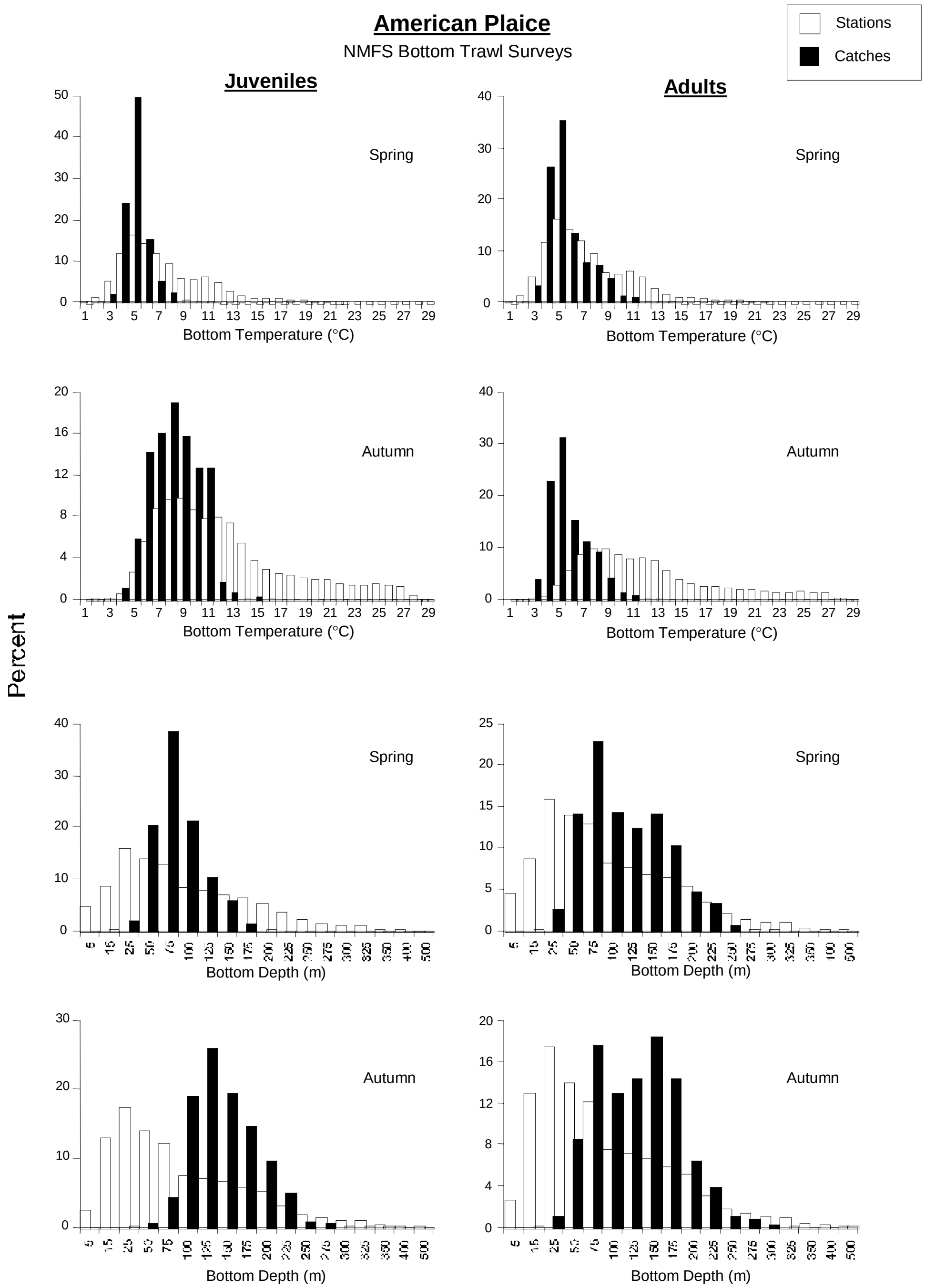


Figure 6. Distribution of juvenile and adult American plaice in relation to bottom temperature and depth based on spring (1968-1997) and autumn (1963-1996) NEFSC bottom trawl surveys. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

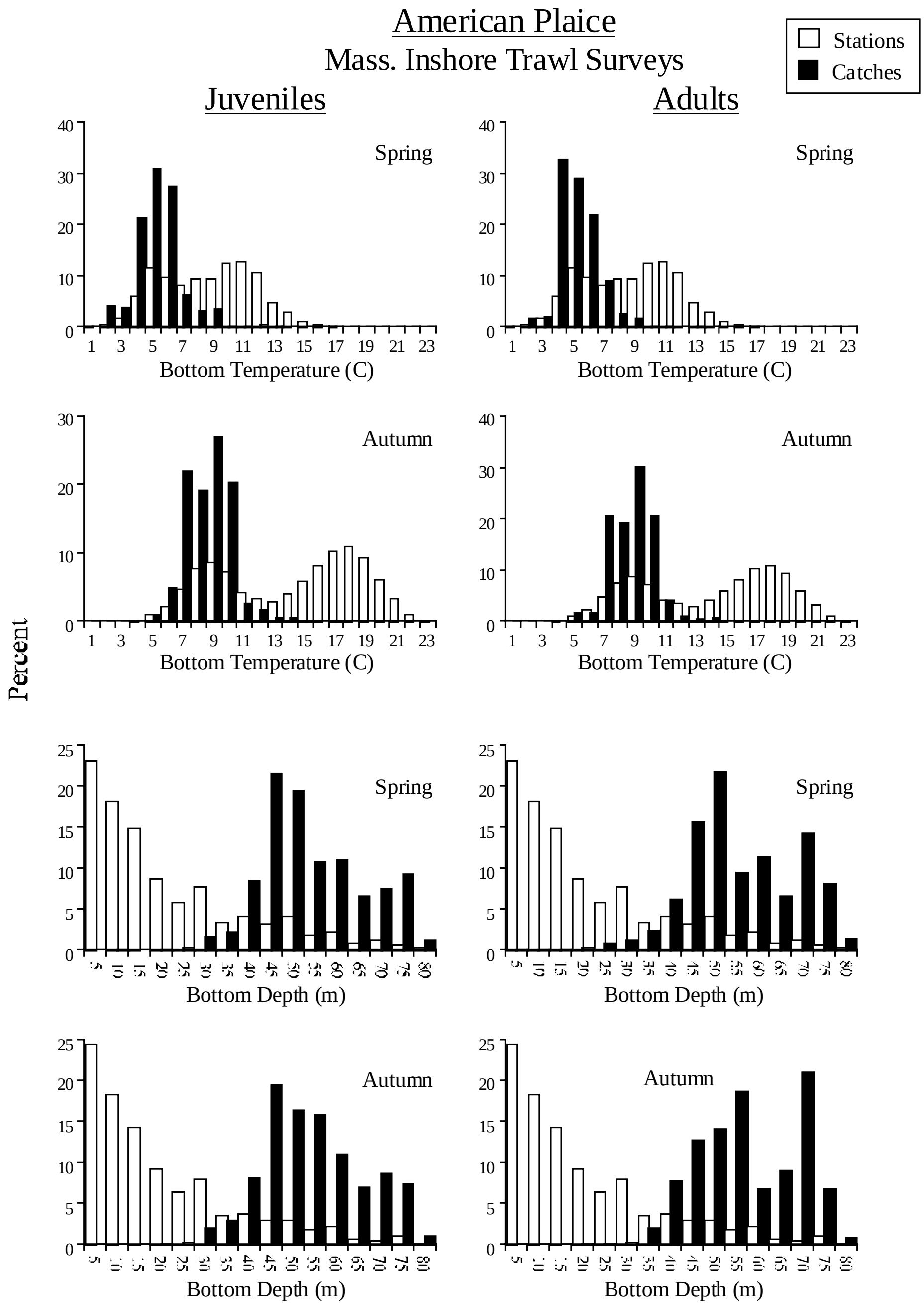


Figure 7. Distribution of juvenile and adult American plaice in relation to bottom temperature and depth based on spring and autumn Massachusetts inshore bottom trawl surveys, 1978-1996. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum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

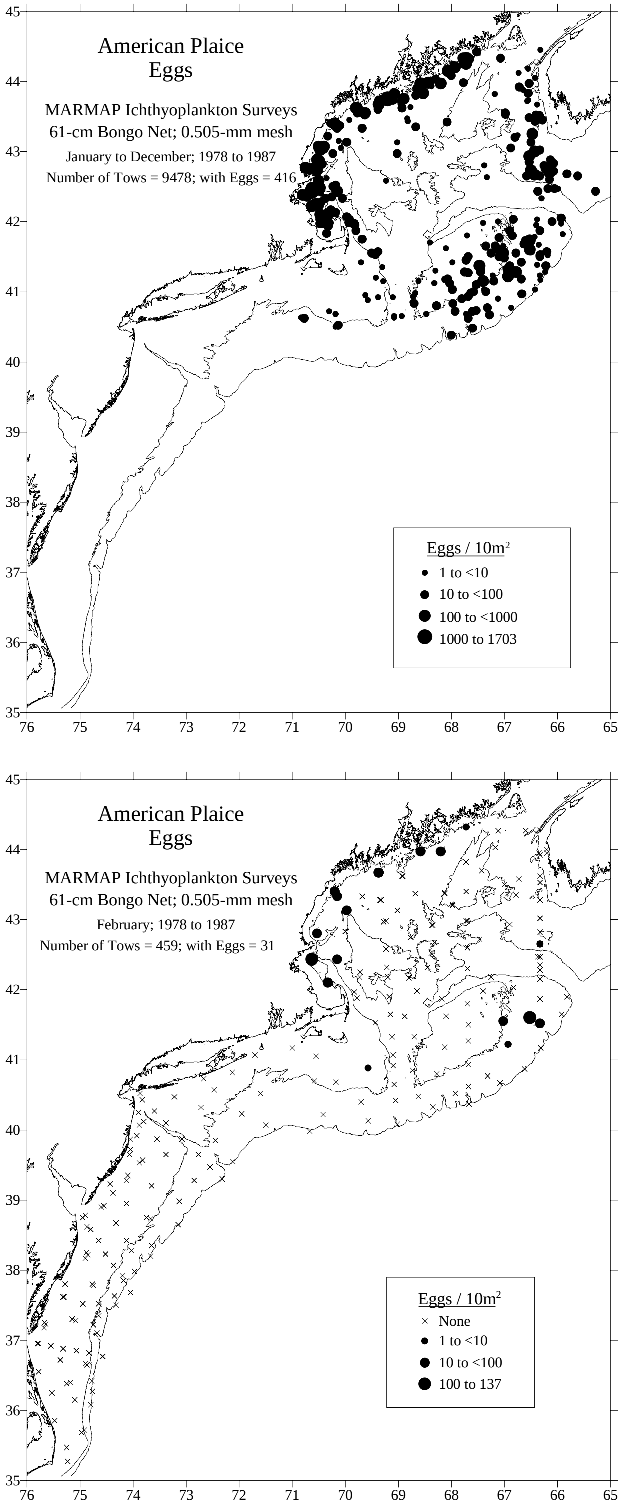
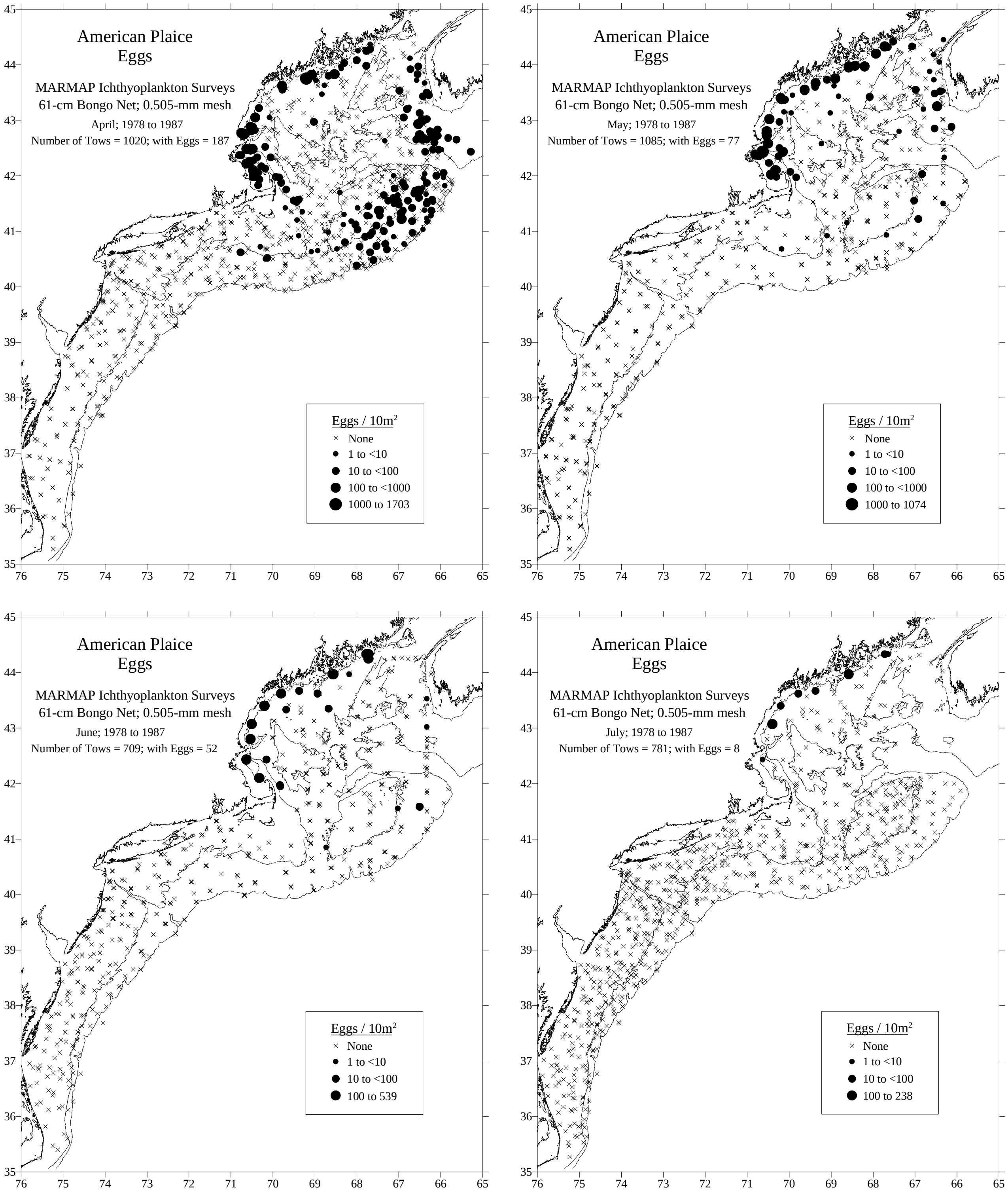


Figure 8. Distribution and abundance of American plaice eggs during MARMAP ichthyoplankton surveys, January to December, 1978-1987.



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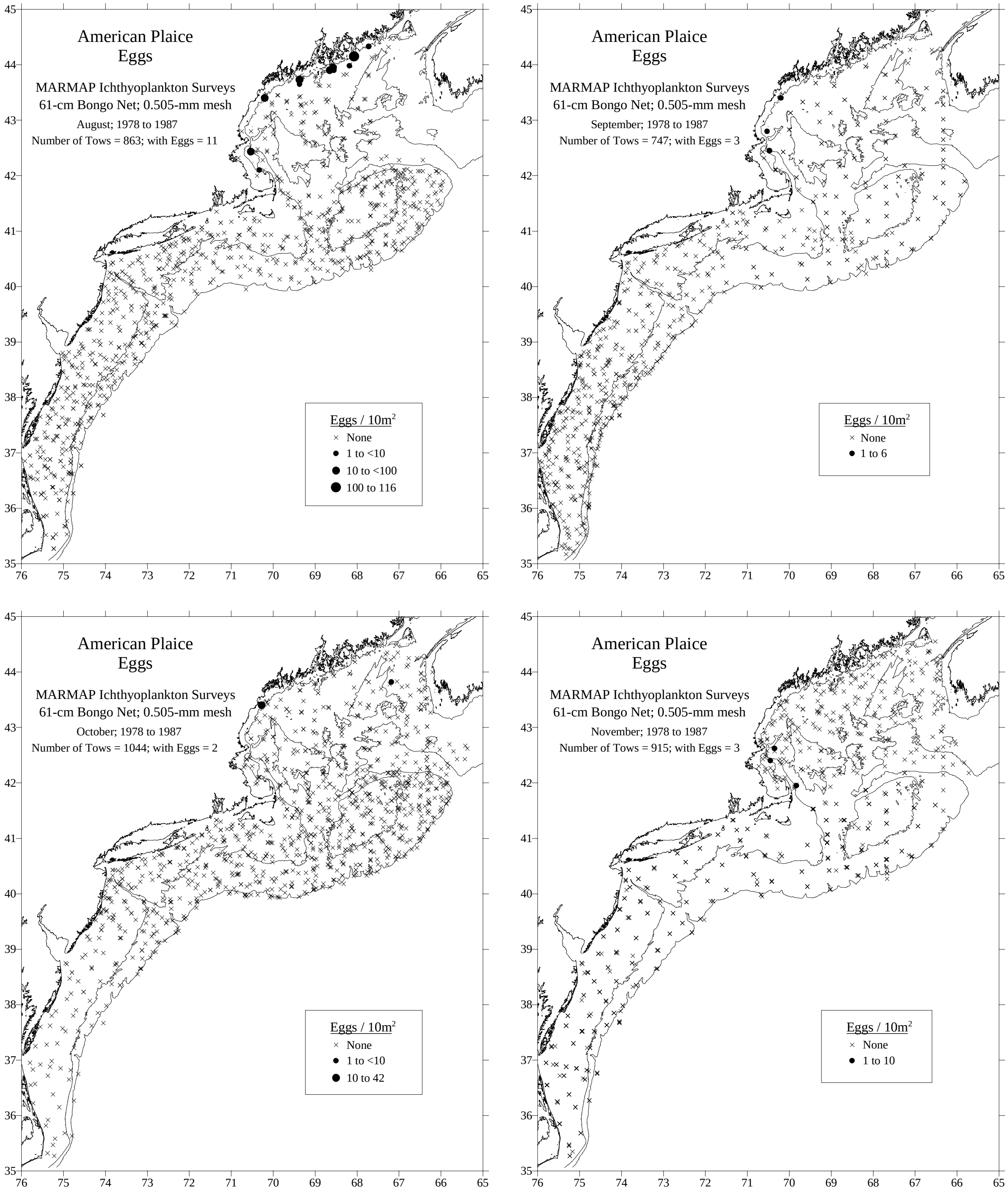

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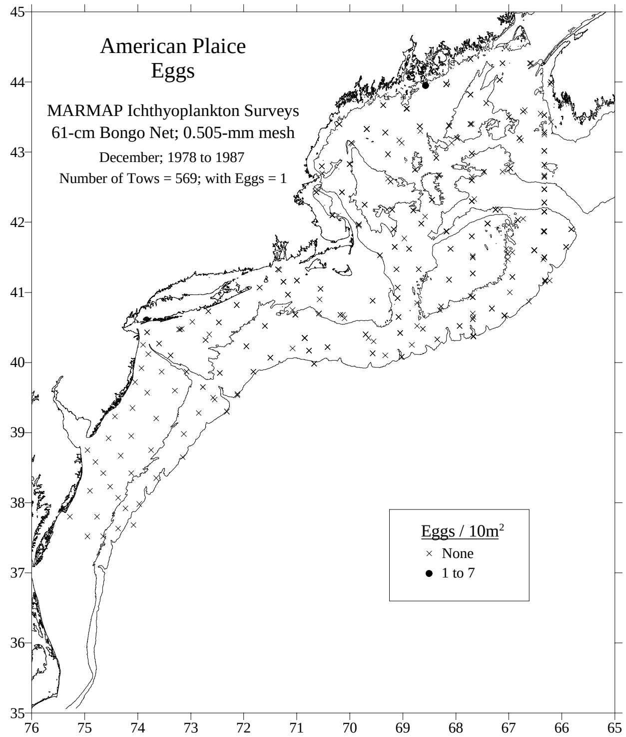

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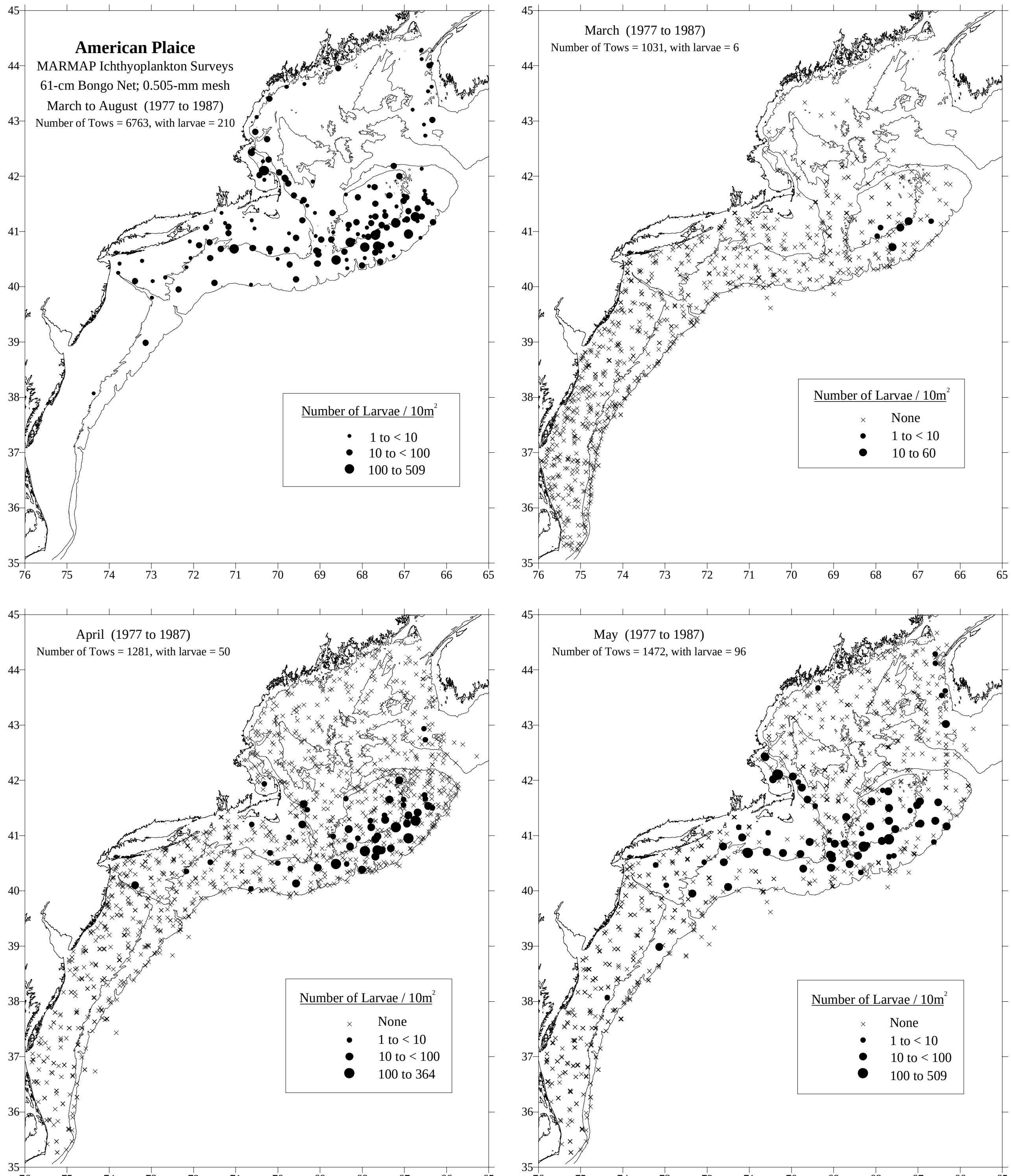

Figure 9. Distribution and abundance of American plaice larvae during MARMAP ichthyoplankton surveys, March to August, 1977-1987.

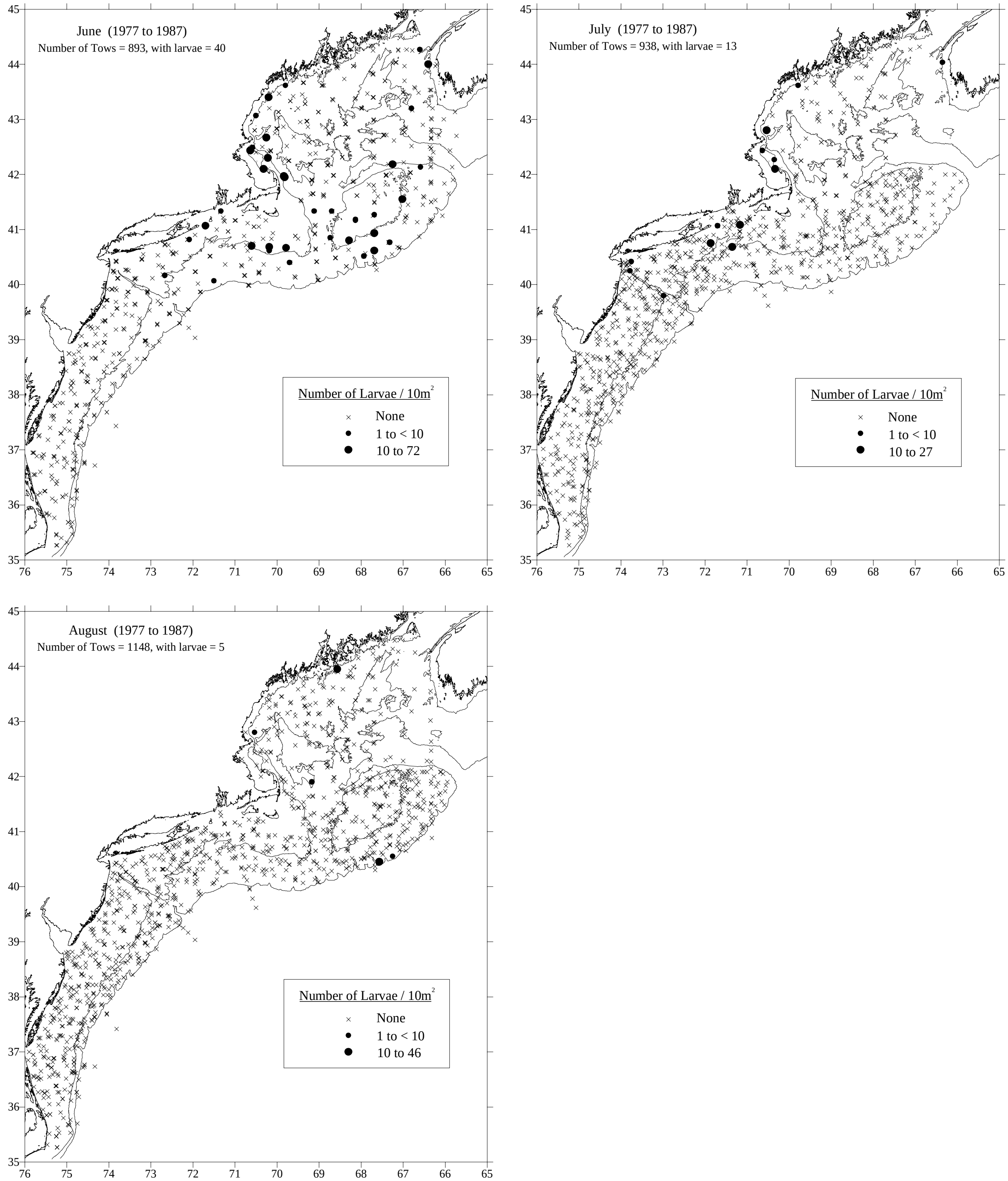

Figure 9. cont'd.

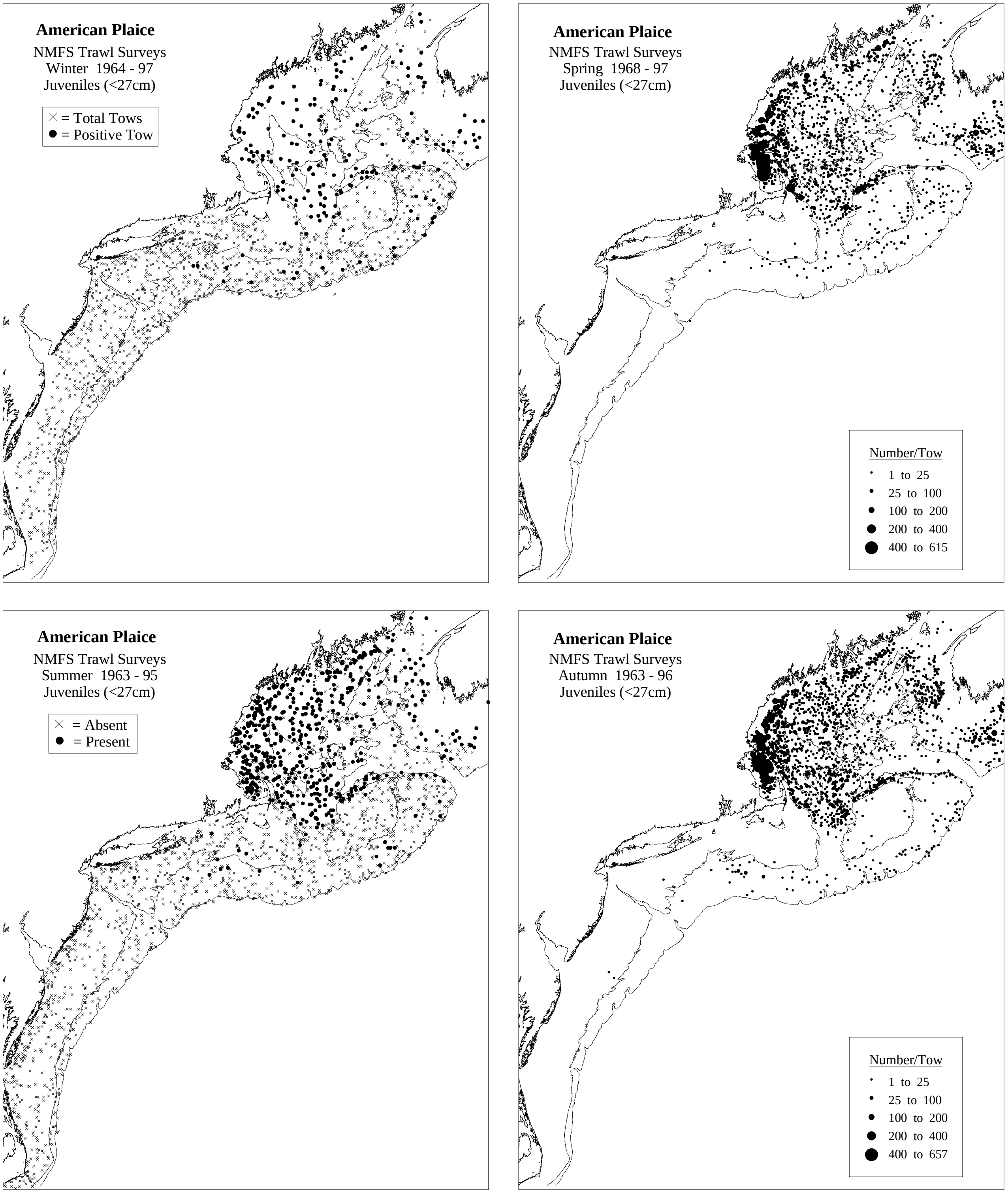

Figure 10. Distribution and abundance of juvenile and adult American plaice from winter (1964-1997), spring (1968-1997), summer (1963-1995), and autumn (1963-1996) NEFSC bottom trawl surveys. Densities are represented by dot size in spring and autumn plots, while only presence and absence are represented in winter and summer plots [see Reid *et al*. (1999) for details].

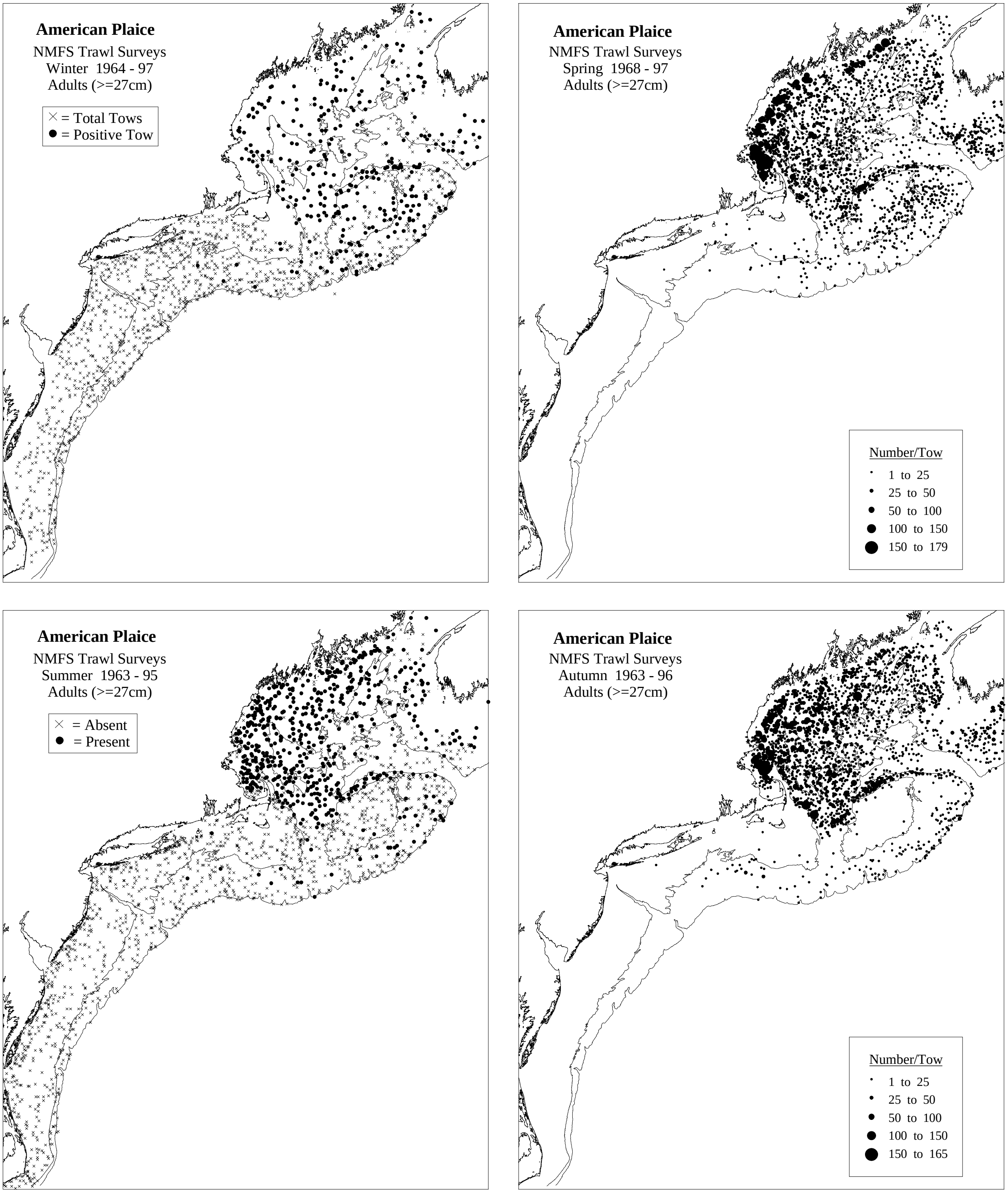

Figure 10. cont’d.

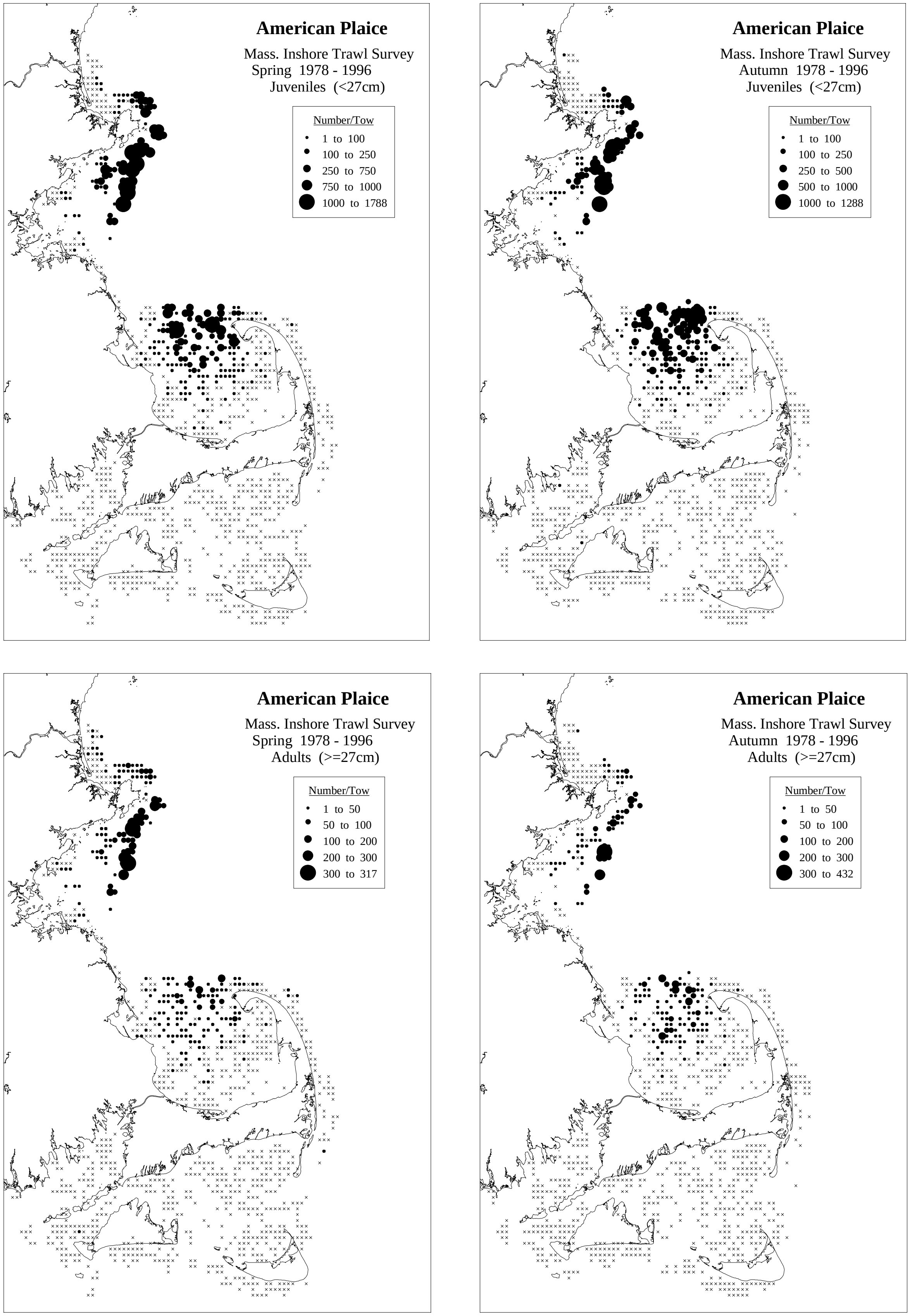

Figure 11. Distribution and abundance of juvenile and adult American plaice from the Massachusetts inshore bottom trawl surveys, 1978-1996.

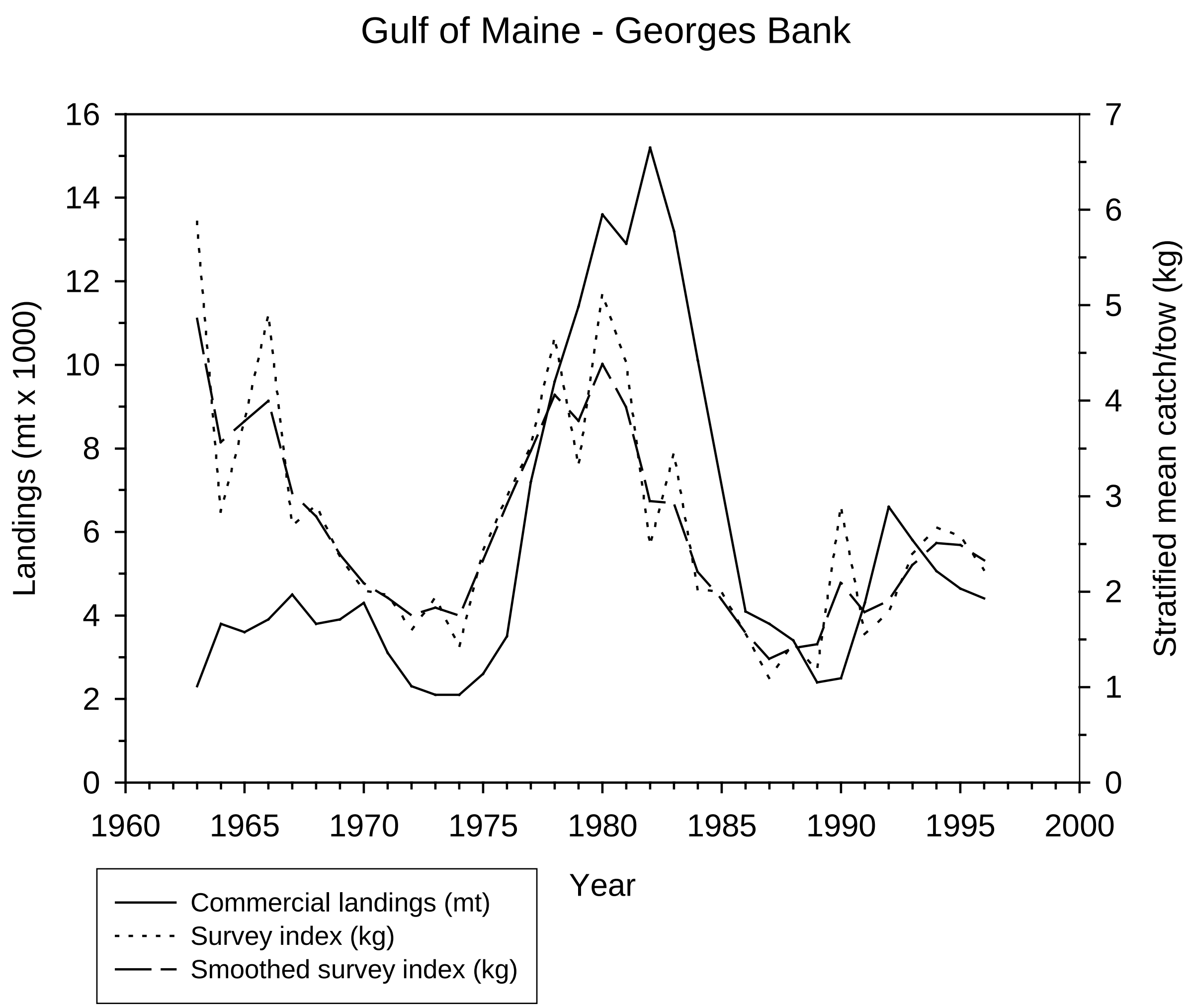

Figure 12. Commercial landings and survey indices for American plaice from the Gulf of Maine-Georges Bank region, 1963-1996.

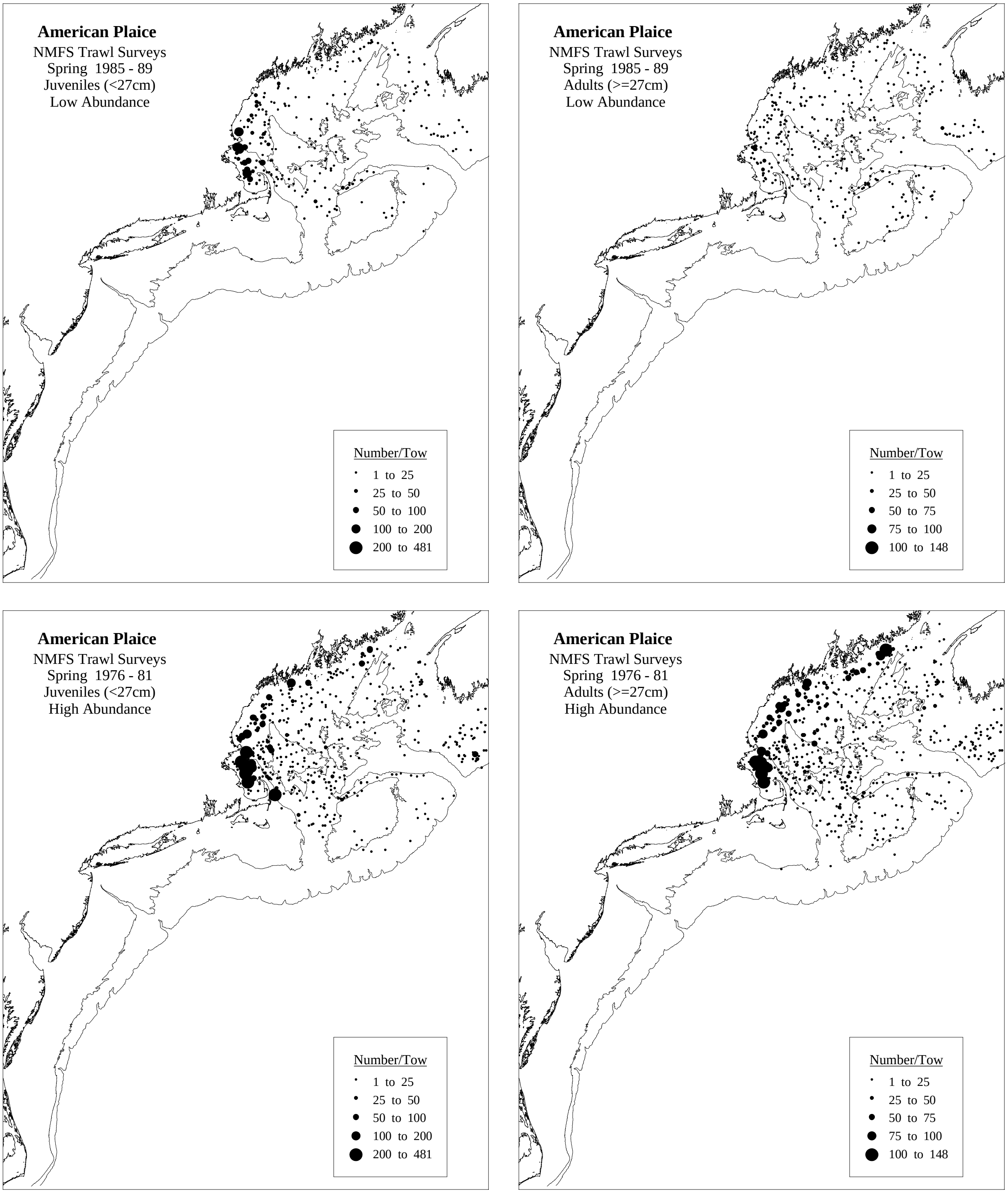

Figure 13. Distribution and abundance of juvenile and adult American plaice during a period of low abundance (1985-1989) and a period of high abundance (1976-1981), from spring NEFSC bottom trawl surveys.

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