NOAA Technical Memorandum NMFS-NE-125

Essential Fish Habitat Source Document:

Atlantic Halibut, *Hippoglossus hippoglossus*, 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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NOAA Technical Memorandum NMFS-NE-125

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Essential Fish Habitat Source Document:

Atlantic Halibut, *Hippoglossus hippoglossus*, 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

Tables

Figures

INTRODUCTION

The Atlantic halibut, *Hippoglossus hippoglossus*, is the largest of all flatfish (Figure 1). It is found on both sides of the North Atlantic Ocean and in parts of the Arctic Ocean. A directed fishery for Atlantic halibut in U.S. waters began in the early 19th century and peaked from 1845 to 1900 (A.B. Howe, Massachusetts Division of Marine Fisheries, personal communication). By the 1940's it had collapsed and for many years there was no directed Atlantic halibut fishery in U.S. waters. Consequently, no management plan was developed for the species.

Currently, a small-scale fishery for "chicken" halibut (3.6-6.8 kg) exists off the coast of Maine. The September 1997 'Status of Fisheries of the United States' (National Marine Fisheries Service 1997) reports that the U.S. Atlantic halibut population is currently in an overfished condition, and the New England Fishery Management Council intends to place Atlantic halibut within the Northeast Multispecies Fishery Management Plan (NEFMC 1996).

This Essential Fish Habitat Source Document provides information on the life history and habitat characteristics of Atlantic halibut.

LIFE HISTORY

A synopsis of the life history of Atlantic halibut is presented here. More detailed information is provided in reviews by Haug (1990), Trumble *et al.* (1993), and Collette and Klein-MacPhee (in prep.).

EGGS

The halibut egg is among the largest of planktonic fish eggs (Russell 1976). Fertilized halibut eggs in the western Atlantic have a diameter of 3-4 mm (Fahay 1983; Scott and Scott 1988; Miller *et al*. 1991). In Norway, eggs range from 2.86-2.98 mm (Trumble *et al*. 1993) to 3.06-3.49 mm (Haug *et al*. 1984).

The eggs are bathypelagic, floating not at the surface, but rather, suspended in the water column at depths ranging from 54 m (Scott and Scott 1988) to 200 m (Blaxter *et al*. 1983). In the eastern Atlantic, eggs rise for 2-4 days after deposition to a depth of neutral buoyancy (Haug 1990; Trumble *et al*. 1993). Laboratory studies indicate that eggs are neutrally buoyant at salinities of 35-37 ppt (Blaxter *et al*. 1983; Trumble *et al*. 1993); however, this is considerably higher than salinities found on the continental shelves of the North Atlantic. Thus, eggs are negatively buoyant due to their high organic matter content (Riis-Vestergaard 1982) and sink towards the bottom where development is thought to proceed (Blaxter *et al*. 1983). In northern Norway, eggs were found at intermediate depths, temperatures of 4.5-7^{o}C, and salinities of 33.8-35.0 ppt (Haug *et al*. 1984). The incubation period is strongly temperature-dependent, lasting from 13-20 days at 4.7-7^{o}C (Miller *et al*. 1991; Collette and Klein-MacPhee, in prep.).

LARVAE

Information on larvae is scarce since they have been difficult to catch in sufficient numbers (Haug 1990; Trumble *et al*. 1993). The 6 to 7 mm long larvae (Lonning *et al*. 1982; Blaxter *et al*. 1983) hatch at an early stage of development, with no pigment, functional eyes or mouth, and possess a very large yolk sac (Blaxter *et al*. 1982; Lonning *et al*. 1982; Haug 1990). Little information on the distribution of the pelagic stages is known, but larvae are thought to remain close to the water surface until metamorphosis (Nickerson 1978). Browns Bank may be a significant rearing area for young Atlantic halibut (Neilson *et al*. 1993).

The larval development period is long. Exogenous feeding commences 28-35 days after hatching, and the yolk sac is completely absorbed 50 days after hatching at 5.3^{o}C (Blaxter *et al*. 1983), at which point the larvae are 11.5-13.0 mm in length (Pittman *et al*. 1987). Metamorphosis begins with the migration of the left eye about 80 days after hatching, at a length of about 20 mm at 6^{o}C (Pittman *et al*. 1987). Settlement occurs at 34-40 mm, prior to completion of eye movement and metamorphosis is complete by approximately 50 mm (Haug 1990). However, Nickerson (1978) reports that the left eye completes its migration one year after hatching, at a length of 10 cm, at which point settlement to the bottom occurs.

JUVENILES

In the western Atlantic, juveniles are known to exist in distinct nursery grounds (Haug 1990; Miller *et al*. 1991). Metamorphosis into the adult stage begins at a length of approximately 24 mm and, depending on temperature, after approximately 90 days of development. Transformation is complete by 4-10 cm, and may take up to one year (Miller *et al*. 1991).

ADULTS

Atlantic halibut show considerable sexual dimorphism in size at length, with females attaining a substantially larger size than males (McCracken 1958; Bowering 1986). Sizes as large as 3 m in length and 300 kg in weight, and ages of 50 years have been documented (Trumble *et al*. 1993). During the height of the halibut fishery in the 19th century, the average size of females was 100 to 150 pounds and males rarely exceeded 50 pounds (Goode 1884). More recent studies report smaller sizes: Bowering (1986) reported captures of males up to 189 cm and females up to 229 cm in length off Newfoundland, and Miller *et al*. (1991) reported females up to 220 cm and 35 years of age. Most halibut caught in recent years weighed less than 100 kg (Nickerson 1978).

In the northeast Atlantic, adults are thought to leave spawning areas and disperse randomly, apparently in search of food (Haug 1990), to shallow and deep waters as well as inshore and offshore areas (Godø and Haug 1988). Similar observations have been made in North American waters (McCracken 1958; Bowering 1986). Stobo *et al*. (1988) hypothesized that larger, sexually mature halibut (i.e., adults) exhibit limited dispersal and an annual return migration to spawning grounds.

REPRODUCTION

The age and size at maturity of Atlantic halibut vary considerably; females mature at a much larger size and older age than males (Table 1).

Atlantic halibut are annual, group-synchronous spawners (Neilson *et al*. 1993). Females are batch spawners, able to ovulate several batches of eggs in a single reproductive season (Methven *et al*. 1992). Depending on body size, females can produce from 0.5-7 million eggs in a single season (Haug and Gulliksen 1988). Spawning in the western Atlantic is believed to occur on the slopes of the continental shelf and on the offshore banks (McCracken 1958; Nickerson 1978; Neilson *et al*. 1993), at depths of at least 183 m (Scott and Scott 1988), over rough or rocky bottom (Collins 1887). In Norwegian coastal waters, halibut spawning has been reported over soft clay or mud bottom, in deepwater (300-700 m) locations at temperatures ranging from 5-7^{o}C and salinities of 34.5-34.9 ppt (Haug 1990).

Spawning occurs during late winter and early spring (McCracken 1958; Scott and Scott 1988; Miller *et al*. 1991; Methven *et al*. 1992; Trumble *et al*. 1993), with peak spawning having been reported during November to December (Neilson *et al*. 1993). Kohler (1964) reported that spawning occurred during winter to early spring on the Scotian Shelf, during February to April in the Gulf of St. Lawrence, and during winter to late spring off Newfoundland (Kohler 1964). In northern Norway, spawning has been reported during December to March, with peak spawning at the end of January/beginning of February (Haug 1990). However, historical descriptions of spawning have reported ripe halibut as late as August (Goode 1884).

FOOD HABITS

The diet of Atlantic halibut changes with increasing size. Fish up to 30 cm in length feed almost exclusively on invertebrates, mainly annelids and crustaceans (crabs, shrimps); those 30-80 cm in length feed on both invertebrates (mainly crustaceans, some mollusks) and fish; and those greater than 80 cm in length feed almost exclusively on fish (Kohler 1967). In the Gulf of Maine, the most important prey of adult halibut during 1977-1980 were squid (*Illex*), crabs (*Cancer*), and fish (silver hake, northern sand lance, ocean pout, and alewife) (Collette and Klein-MacPhee, in prep.). Maurer and Bowman (1975) report that 91% of the stomach contents of juvenile and adult halibut (by weight) were fish (> 50% were longhorn sculpin and its eggs, but also cod and other gadids), and 8% were crustaceans. Nickerson (1978) reports that the fish prey of halibut includes cod, cusk, haddock, ocean perch, sculpins, silver hake, herring, capelin, skates, flounder and mackerel.

The Northeast Fisheries Science Center (NEFSC) bottom trawl survey data on food habits [see Reid *et al.* (1999) for details] show a similar ontogenetic shift in the diet of Atlantic halibut (Figure 2). The 1973-1980 data clearly illustrate that, while crustaceans dominate the diet of smaller halibut, fish increase in importance with size to dominate the diets of larger halibut (Figure 2a). Halibut 21-30 cm in length fed exclusively on crustaceans, especially decapods. Those 31-80 cm in length fed on crustaceans (45%, mostly decapods), fish (33%, including gadids and clupeids), and mollusks (6.5%, all cephalopods). The occurrence of fish and mollusks (cephalopods) in the diet of 81-120 cm halibut increased to 50% and 17% respectively, while the occurrence of crustaceans decreased to 25%. The 1981-1990 data show a similar trend (Figure 2b). The diet of 31-80 cm halibut was dominated by crustaceans (66%, mostly decapods); fish and mollusks comprised 25% and 4% respectively. The diet of 81-134 cm long halibut was almost exclusively comprised of fish (80%), but also included decapods (20%, all Majidae).

MIGRATION

Juveniles start to emigrate from nursery areas when the fish are 3-4 years old (Haug and Sundby 1987). They then undergo a period during which most movement occurs; juveniles (< 75 cm) undergo greater migrations than adults (Stobo *et al*. 1988). Although most tagging study recaptures have been made within the same main region where the juvenile fish were tagged, very long distance migrations have been documented from Labrador to the western coast of Greenland (Godø and Haug 1988), the Gulf of St. Lawrence to Iceland (McCracken and Martin 1955), the Scotian Shelf to the Grand Bank (Jensen and Wise 1961; Kohler 1964; Stobo *et al*. 1988), and the western coast of Greenland to the Grand Bank (Godø and Haug 1988). Extensive migrations have also been documented from northern Norway to the White Sea, Iceland and Greenland, from the Faroe Islands to the North Sea and Iceland, and from Iceland to the Faroe Islands, Greenland and Newfoundland (Haug 1990).

HABITAT CHARACTERISTICS

Detailed information on the habitat characteristics of Atlantic halibut follows and is summarized in Table 2.

EGGS AND LARVAE

The eggs of Atlantic halibut are spawned at temperatures of 4-7^{o}C (Miller *et al*. 1991), depths as deep as 700 m (Blaxter *et al*. 1983), salinities of $\leq$ 35 ppt (Blaxter *et al*. 1983; Haug *et al*. 1986), and on harder substrates of sand, gravel, and clay (Collette and Klein-MacPhee, in prep.). The larvae are pelagic, floating within 50 m of the surface (Nickerson 1978), are buoyant at salinities of 34.8-36.4 ppt, and prefer salinities in the 30-34 ppt range (Blaxter *et al*. 1983).

JUVENILES AND ADULTS

Juvenile Atlantic halibut are quite localized, being found in apparently well-defined nursery grounds and in coastal areas 20-60 m deep with sandy bottoms (Haug 1990). Stobo *et al*. (1988) hypothesize that the area around Sable Island Gully on the Scotian Shelf may serve as a nursery area for juveniles before they begin their dispersive phase. Juveniles are able to survive sub-zero temperatures, but prefer temperatures > 2^{o}C (Goff *et al*. 1989). Adults are found over sand, gravel or clay substrates (Collette and Klein-MacPhee, in prep.), at temperatures ranging from -0.5 to 13.6^{o}C (Mahon 1997). However, most are caught within 3-9^{o}C, and generally prefer temperatures > 4^{o}C (McCracken 1958; Bowering 1986). They are typically found at depths of 100-700 m (720-900 m is their depth limit) (Bowering 1986, Miller *et al*. 1991), and most commercial catches are made at depths of 200-300 m (Scott and Scott 1988).

Most of the Atlantic halibut taken during the NEFSC trawl surveys (see Geographical Distribution below) were at temperatures of 4-13 ^{o}C and depths of 25-200 m.

GEOGRAPHICAL DISTRIBUTION

Atlantic halibut in the northwest Atlantic were distributed from north of Labrador south to Long Island during 1975-1994 (Figure 3). The areas of highest abundance of the species seem to be along the southern edge of the Grand Bank and on the Scotian Shelf from Browns Bank to Banquereau Bank. This corresponds to their accepted center of abundance (Trumble *et al*. 1993). In U.S. waters, halibut are found on the northeast part of Georges Bank, Nantucket Shoals, Stellwagen Bank, and off the coast of Maine and Massachusetts. Although Atlantic halibut have been taken as far south as Virginia, these are few and considered stragglers from the main population (Smith *et al*. 1975).

In Canadian waters, historical distributions of Atlantic halibut ranged along the entire coast of Labrador and Newfoundland, the Gulf of St. Lawrence, the eastern shores of Nova Scotia, and the Bay of Fundy. In U.S. waters, halibut were abundant on Georges Bank, Nantucket Shoals, and between Gloucester and Cape Cod, Massachusetts, and were occasionally found as far south as New Jersey (Goode 1884, 1887).

EGGS AND LARVAE

No Atlantic halibut eggs were captured during the 1977-1991 NEFSC offshore ichthyoplankton surveys. They are negatively buoyant and thought to develop on or near the sea bed (Riis-Vestergaard 1982; Blaxter *et al*. 1983) and thus are not sampled in the ichthyoplankton surveys.

Larvae were captured at only two of 1,672 stations sampled during the NEFSC ichthyoplankton surveys [see Reid *et al.* (1999) for details], on the northeast part of Georges Bank, and near Petit Manan Island off the eastern coast of Maine (Figure 4). This is not surprising since very few larvae have ever been captured in the wild (Haug 1990) and since spawning is believed to no longer occur in the Gulf of Maine (Collette and Klein-MacPhee, in prep.).

JUVENILES AND ADULTS

NEFSC Bottom Trawl Survey

In the western Atlantic, juveniles are typically found on the southwestern Scotian Shelf, but rarely off Newfoundland, supporting the view that the former is an important rearing or nursery area (Neilson *et al*. 1993). Catches of juvenile and adult Atlantic halibut from the 1963-1997 NEFSC bottom trawl surveys [see Reid *et al.* (1999) for details] are presented in Figure 5. Halibut were caught in low numbers from throughout the Gulf of Maine area, as far south as Nantucket Shoals; a single halibut was caught southwest of Cape Cod. The highest concentrations were found in Canadian waters, on Browns Bank and off southwestern Nova Scotia. In U.S. waters, lower concentrations were found on the northern slope of Georges Bank, Nantucket Shoals, Stellwagen Bank, and off the coast of Maine. There does not appear to be a significant seasonal effect on distribution and abundance (Figure 5).

There was a definite seasonal effect on the temperature inhabited by Atlantic halibut (Figure 6). In spring, > 70% of halibut were caught at 4-6^{o}C, while in autumn, > 65% were caught at 9-13^{o}C. Similarly, Scott and Scott (1988) found that commercial catches were most common at 3-9^{o}C. Halibut were caught at depths ranging from 25-200 m, with the majority caught between 50-100 m (Figure 6). In spring, > 65% were found at 75-100 m, whereas in autumn, > 70% were caught at 50-75 m. Miller et al. (1991) states that Atlantic halibut in the western North Atlantic have been found over depths ranging from 37-1000 m.

Massachusetts Inshore Trawl Survey

Only 18 Atlantic halibut (all juveniles, 19-75 cm in length) have been taken in Massachusetts inshore waters between 1978 and 1997.

STATUS OF THE STOCKS

Historical landings of Atlantic halibut in the Gulf of Maine/Georges Bank area are presented in Figure 7. In 1900, landings had already declined 95% from 1879 levels (A.B. Howe, Massachusetts Division of Marine Fisheries, personal communication), and catches have since declined even further.

Prior to 1930, landings were variable, but often exceeded 600 metric tons (mt) annually, and catches exceeding 800 mt were common. Since then, landings have exceeded 400 mt only twice, and have generally been well below 200 mt. Landings averaged 756 mt per year from 1893 to 1930 (516 mt if the two especially high years are omitted), compared to only 164 mt annually from 1931 to the present. Since 1953 U.S. landings have been 100 mt or below, and have hit historical lows in recent years. Canadian landings in area 5 were more than twice the U.S. landings in the 1960's, but have since also declined considerably. Currently, the area of highest exploitation of the species in the northwestern Atlantic is the Scotian Shelf area (Neilson *et al*. 1993).

NEFSC survey indices have fluctuated considerably since the 1960's (Figure 7), and overall, have declined considerably. Mean weight per tow during spring surveys has remained at an historic low since 1988. During both spring and autumn surveys, mean number per tow has been considerably higher than mean weight per tow, indicating a decrease in the size of halibut. In fact, based on size, almost all halibut caught in the NEFSC surveys from 1988-1998 were juveniles (Figure 8).

The September 1997 'Status of Fisheries of the United States' (National Marine Fisheries Service 1997) reports that the U.S. Atlantic halibut population is currently in an overfished condition.

RESEARCH NEEDS

- There is very little information in the published literature on the biology of northwest Atlantic stocks (relative to European stocks), and almost no information from U.S. waters.
- Information on the egg and larval stages is very scarce. They have proven to be very difficult to catch in large enough numbers to be useful (Haug 1990). More directed sampling effort, better sampling techniques, and better information about the location of spawning events are required. Data on these highly dispersive, pelagic stages are important to understanding recruitment and stock structure.
- Information on the spawning event and the location of spawning sites is vague.
- Information on the migratory patterns of juveniles is lacking. It is believed that the juvenile stage is highly dispersive, but no migration patterns have been shown.
- Mapping of size groups relative to habitat types (e.g., bottom type) based on groundfish survey catches would be of great benefit to defining EFH for the species.
- Improved information on the onset of maturity and stock identification (e.g., genetic differentiation of stocks) is required.

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Table 1. Age and size at maturity of Atlantic halibut, *Hippoglossus hippoglossus*.

Location	**A_{50} (years)**		**L_{50} (cm)**		**Reference**
	male	*Female*	*male*	*female*	
Scotian Shelf, Grand Bank	-	-	66-70	100	Kohler (1967)
Newfoundland, Labrador	8	12	80	125	Bowering (1986)
Western North Atlantic	-	7-12	-	105-150	Miller *et al*. (1991)
Grand Bank, Newfoundland	-	-	80*	115-120*	Methven *et al*. (1992)
**minimum length at maturity*					

Table 2. Summary of life history and habitat parameters for Atlantic halibut, *Hippoglossus hippoglossus*.

Life Stage	Size and Growth	Habitat	Substrate	Temperature
Eggs [1]	Eggs are spherical and large. Average egg diameter (post-fertilization) = 3-4 mm. Average incubation = 18 days at 5°C. Norwegian studies show eggs achieve higher specific gravity with age (i.e., become less buoyant).	Unfertilized eggs are not buoyant, but sink to bottom where they are fertilized by males. Norwegian studies show vertical distribution of eggs associated with hydrography. In areas with strongly defined pycnocline, vertical distribution had one clear peak; in areas with less defined pycnocline and weaker stratification, vertical distribution less distinct. In well-stratified areas, older eggs found deeper than younger eggs (but not in more mixed areas).		Optimal temperatures in lab experiments: 5 and 7°C. Incubation time to 50% hatch varies with temperature: 20 days at 4.7°C, 18 days at 5°C, and 13 days at 7°C.
Larvae [2]	Hatch at an immature stage, with no pigmentation and mouth closed, and very large yolk sac, at size of: 6-7 mm length. Norwegian studies found larvae are able to feed 28-35 days post-hatch at 5°C (still with large yolk sac), at a body length of 11 mm; yolk sac resorption complete after 50 days post-hatch at 5.3°C; growth 0.1mm/d up to day 50. Metamorphosis begins with left eye migration at ~2 cm.	Larvae are pelagic and tend to rise toward surface and drift inshore until metamorphosis. The smallest bottom stages collected from waters < 50 m.		
Juveniles [3]	Metamorphosis begins at ~24 mm, at ~90 days. Transformation complete by 4-10 cm and up to 1 year.	Juveniles are most common in shallow water, 20-60 m, in Atlantic Canada. Nursery areas located on the shelf; Sable Island Gully area may serve as nursery area before juveniles begin their dispersive phase.		In a Newfoundland laboratory study, juveniles were able to survive extended periods at subzero winter temperatures in good condition. Became inactive and ceased to feed at temps < 2.0°C.
Adults [4]	Historically halibut caught off US east coast weighed up to > 300 kg; more recently < 100 kg. In NF and Labrador males range from 40-189 cm TL (majority 50-79 cm); females range from 40-229 cm TL (majority 80-89 cm). Full grown females in the Gulf of Maine average 45.5-68 kg. Female max. age/size = 35 yrs/220 cm; male max. size = 89% of female size at same age. Growth: females grow faster and attain larger size than males. Halibut older than 10 years exhibit a more rapid rate of growth than any other flatfish. Maturity: males mature at an earlier age than females. SS: male L_{50}=66-70 cm, female L_{50}= 100 cm; NW Atlantic: female A_{50}=7-12 yrs, L_{50}=105-150 cm; NF/Labrador: male L_{50}=8 yrs, A_{50}=80 cm, first appeared sexually mature at 40-59 cm (4 yrs), all mature by 110-119 cm; female A_{50}=12 yrs, L_{50}=125 cm; first mature at 50-79 cm (6 yrs), all were mature by 130-149 cm; GrB: males first mature at 80 cm, females first mature at 115-120 cm.	Range from Labrador shelf, along edges of the Grand Bank, outer Scotian Shelf and Georges Bank, south to Virginia (but very few south of Long Island). Range from 37-1000 m; depth limit uncertain. Gulf of Maine: shift from deeper waters in winter to shallower in summer, food supply influences seasonal distribution. Scotian Shelf: found mainly on banks and in the head of the BF, in deeper waters, 165-229 m; most abundant in deep water in spring and early fall, shallower in summer (< 37 m); commercial catches most common at 200-300 m. Newfoundland/Labrador: most abundant in deepwater channels (100-700 m); absent from shallower areas and along coastline; peak numbers caught in Aug.; max. abundance during Jan-June at 501-600 m, and during July-Dec at 300-500 m.	Usually found on sand, gravel or clay; not on soft mud or on rock bottom.	Found at temperatures ranging from -0.5 to 13.6°C, avoid < 2.5°C. Most halibut caught within temperatures of 3-9°C, average 5-6°C.

[1] Nickerson (1978), Blaxter *et al.* (1983), Haug *et al.* (1986), Scott and Scott (1988), Miller *et al.* (1991), Collette and Klein-MacPhee (in prep.)
[2] Nickerson (1978), Blaxter *et al.* (1983), Collette and Klein-MacPhee (in prep.)
[3] Nickerson (1978), Scott and Scott (1988), Goff *et al.* (1989), Miller *et al.* (1991), Stobo *et al.* (1993)
[4] McCracken (1958), Kohler (1967), Nickerson (1978), Scott (1982), Bowering (1986), Scott and Scott (1988), Miller *et al.* (1991), Methven *et al.* (1992), Neilson *et al.* (1993), Stobo *et al.* (1993), Mahon (1997), Collette and Klein-MacPhee (in prep.)

Table 2. cont'd.

Life Stage	Salinity	Prey	Predators	Spawning	Notes
Eggs [1]	Various reports of neutral buoyancy of eggs at 34.7-36.5 ppt; thus at lower salinities eggs are negatively buoyant and thought to develop on or near the sea bed. Norwegian studies show negative buoyancy is due to high organic matter content of the egg; older eggs found at higher salinities (i.e., greater depths) than earlier egg stages in well-stratified areas.		High specific density of eggs is a possible adaptation to reduce mortality; i.e., sinking eggs are less vulnerable to predation near sea floor than in pelagic zone.	Spawning occurs at great depths (see adults section for details).	Very large eggs are unusual when compared to most other marine teleosts. Eggs bathypelagic: they're buoyant but don't float at surface; drift suspended in water column (> 54-90 m in the Gulf of Maine). Tend to sink toward bottom as development proceeds.
Larvae [2]	Norwegian lab experiments have shown that salinities of 30-35 ppt are preferred and that larvae are neutrally buoyant in 35.8 ppt sea water at hatching, in 34.8 ppt on day 12, and in 36.4 ppt on day 35.				Long time to first exogenous feeding and in general long period of larval development is unusual compared to other marine fish larvae in this part of the Atlantic.
Juveniles [3]					The juvenile phase is when most movement occurs. The area near BB may serve as a nursery area for immature halibut; tagging data suggests that many NF fish originated from BB nursery area.
Adults [4]	Scotian Shelf: found at salinities ranging from 30.4-35.3 ppt, average ~33 ppt.	Voracious feeders. Diet changes with size: 1) up to 30 cm: almost exclusively invertebrates, mainly annelids and crustaceans, also mollusks; 2) 30-80 cm: invertebrates, fish or both; 3) > 80 cm: almost exclusively fish. Most important prey in GM (1977-1980) were squid (*Illex*), crabs (*Cancer*), silver hake, northern sand lance, ocean pout, and alewife. Other commonly eaten fish species: cod, cusk, haddock, ocean perch, sculpins, herring, capelin, skates, flounder and mackerel.	Halibut are a staple for Greenland sharks (*Somniosus microcephalus*); also preyed on by seals and spiny dogfish (*Squalus acanthus*).	Spawning grounds not well known; various spawning areas from Georges Bank to Grand Bank; no longer any spawning population in the Gulf of Maine. Believed to occur on the slopes of offshore banks as well as on the continental slope. Depths of spawning not clear but are thought to spawn in deep waters (> 180 m, to 700 m), on the bottom. Time of spawning: a) Scotian Shelf: winter-early spring (mostly Feb-April); b) Gulf of St. Lawrence: Feb-April; c) Newfoundland: winter-later spring; d) Browns Bank to Grand Bank: peaks Nov-Dec. Large females may produce up to 2 million eggs; can spawn numerous batches of eggs within a single reproductive season.	Halibut in the GM are thought to originate from halibut immigrating from east and north of Cape Sable rather than from local production. Smaller fish generally exhibit more extensive movement than adults. Typically not highly migratory; most fish remain in main shelf areas where they are tagged. Recaptures show movement to east; deepwater crossing of channels probable. Some movement from sw NS to GB and GrB (distance traveled ranges from 161-968 km); possible return to SS for spawning. Capable of extensive movement; one fish tagged in GSL recovered in Iceland (1600 miles away).

[1] Riis-Vestergaard (1982), Blaxter *et al.* (1983), Haug *et al.* (1986), Scott and Scott (1988), Collette and Klein-MacPhee (in prep.)
[2] Blaxter *et al.* (1983)
[3] Neilson *et al.* (1993), Stobo *et al.* (1993)
[4] McCracken and Martin (1955), McCracken (1958), Wise and Jensen (1959), Jensen and Wise (1961), Kohler (1964, 1967), Maurer and Bowman (1975), Nickerson (1978), Riis-Vestergaard (1982), Scott (1982), Godo and Haug (1988), Scott and Scott (1988), Miller *et al.* (1991), Methven *et al.* (1992), Neilson *et al.* (1993), Stobo *et al.* (1993), Mahon (1997), Collette and Klein-MacPhee (in prep.)

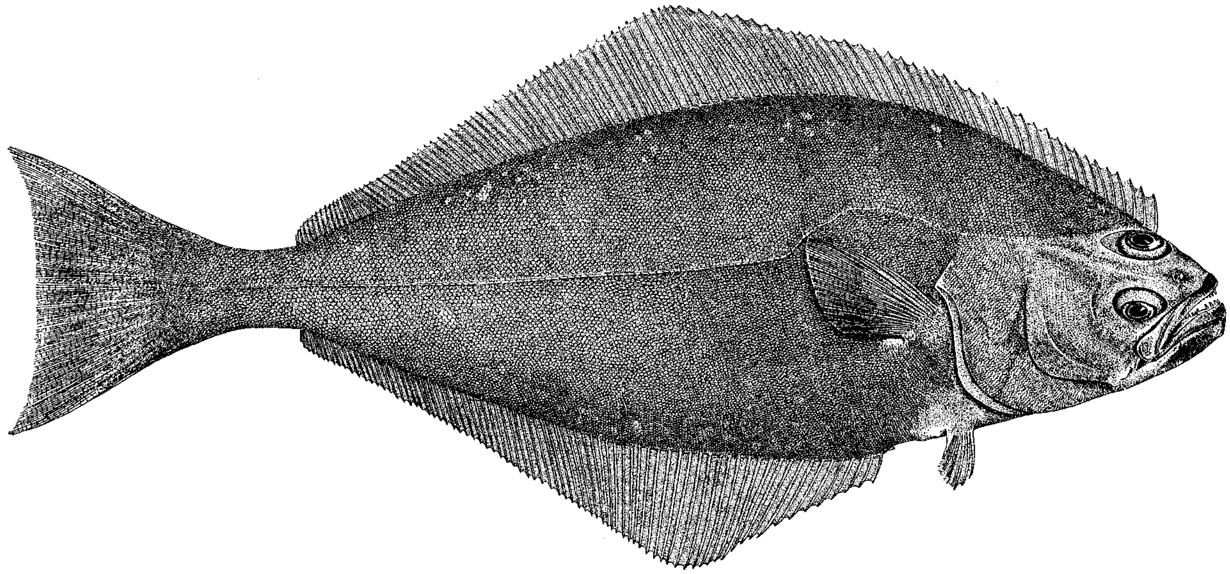

Figure 1. The Atlantic halibut, *Hippoglossus hippoglossus* (from Goode 1884).

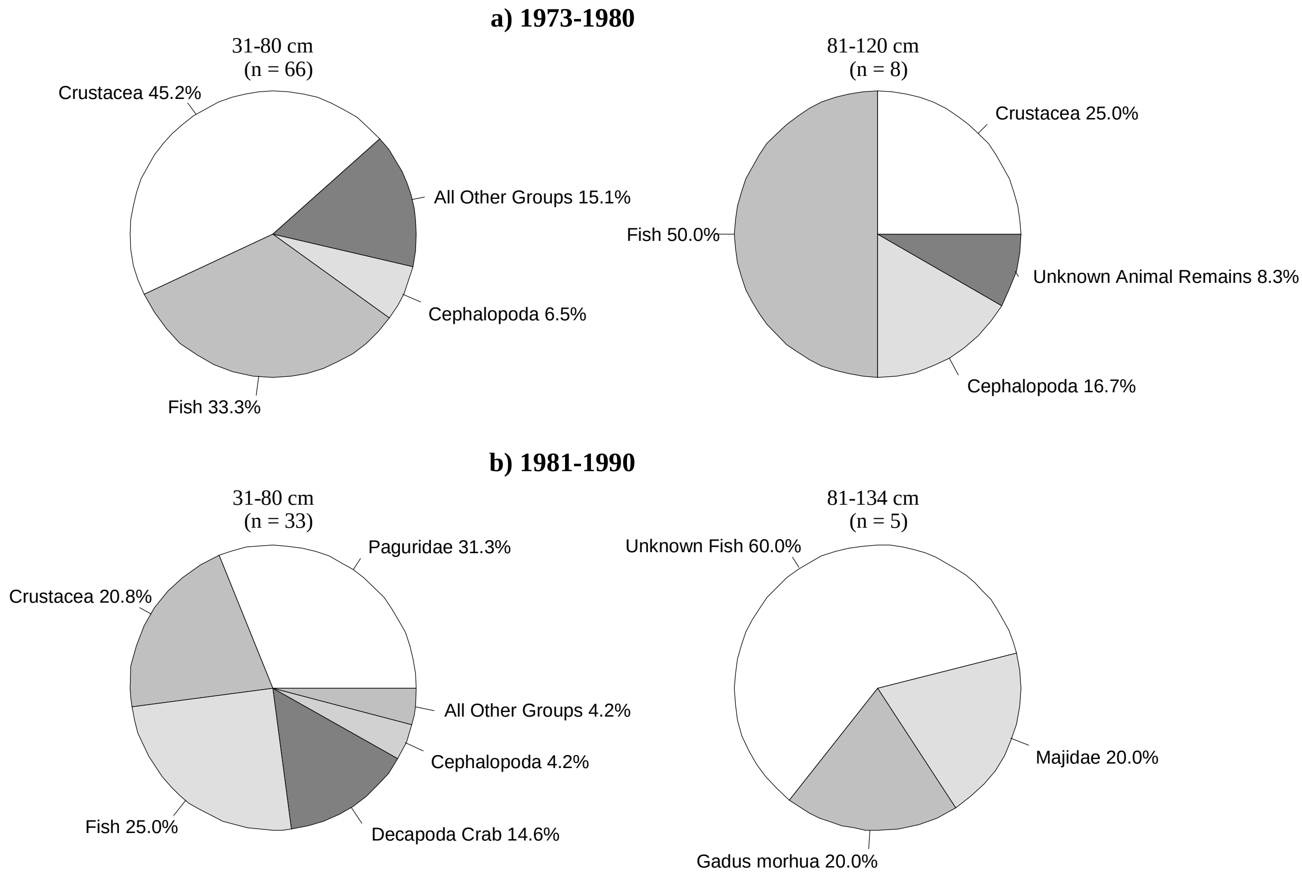

Figure 2. Abundance (% occurrence) of the major prey items in the diet of Atlantic halibut from NEFSC trawl surveys. Methods for sampling, processing, and analysis of samples differed between the time periods [see Reid *et al.* (1999) for details]. The category "unknown animal remains" refers to unidentifiable animal matter.

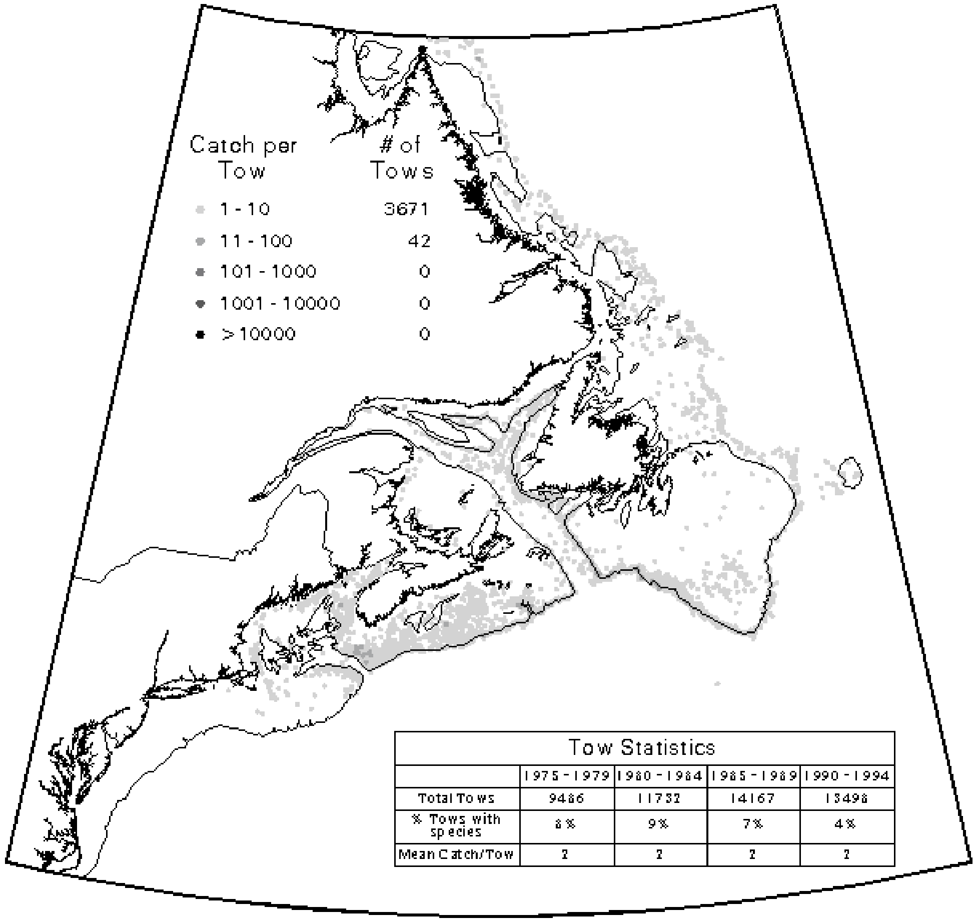

Figure 3. Distribution and abundance of Atlantic halibut from Newfoundland to Cape Hatteras during 1975-1994. Data are from the U.S. NOAA/Canada DFO East Coast of North America Strategic Assessment Project (http://www-orca.nos.noaa.gov/ projects/ecnasap/ecnasap_table1.html).

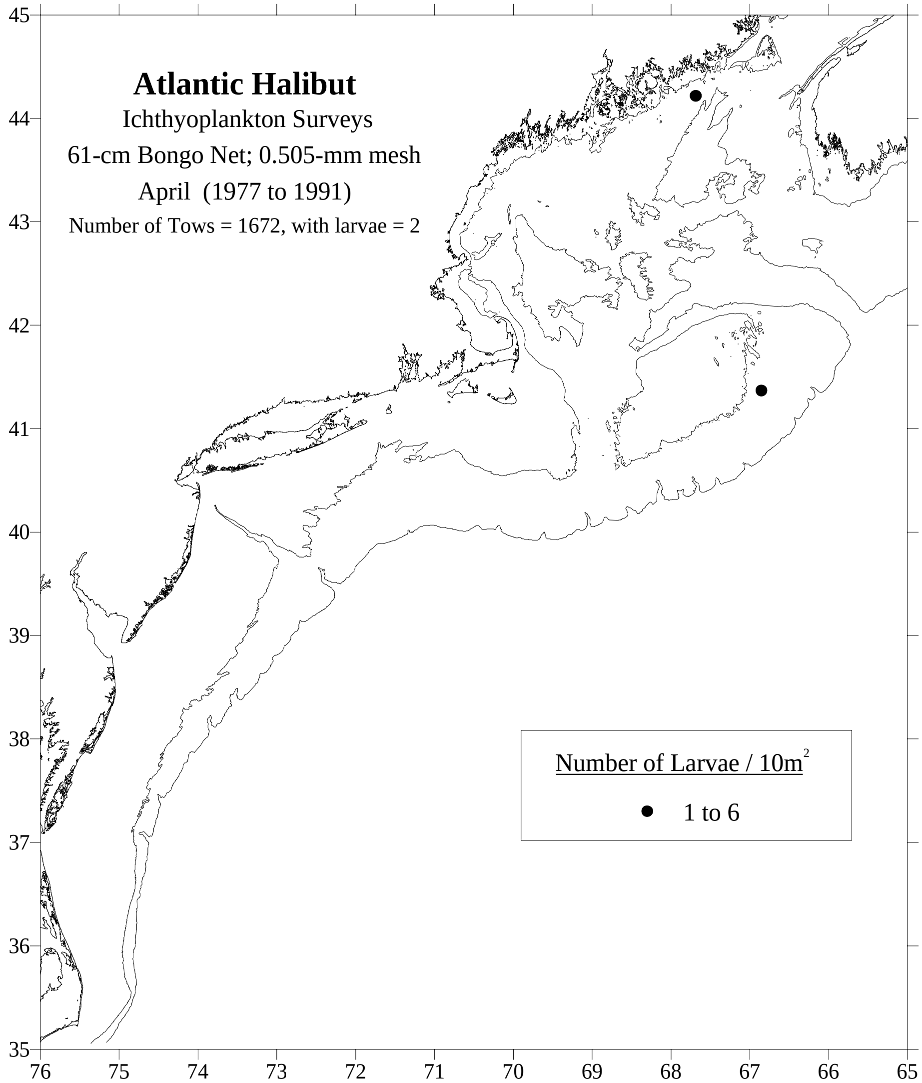

Figure 4. Distribution of Atlantic halibut larvae collected during NEFSC ichthyoplankton surveys, 1977-1991 [see Reid *et al.* (1999) for details]. Larval densities are represented by dot size; the 60 and 200 m contour lines are also shown.

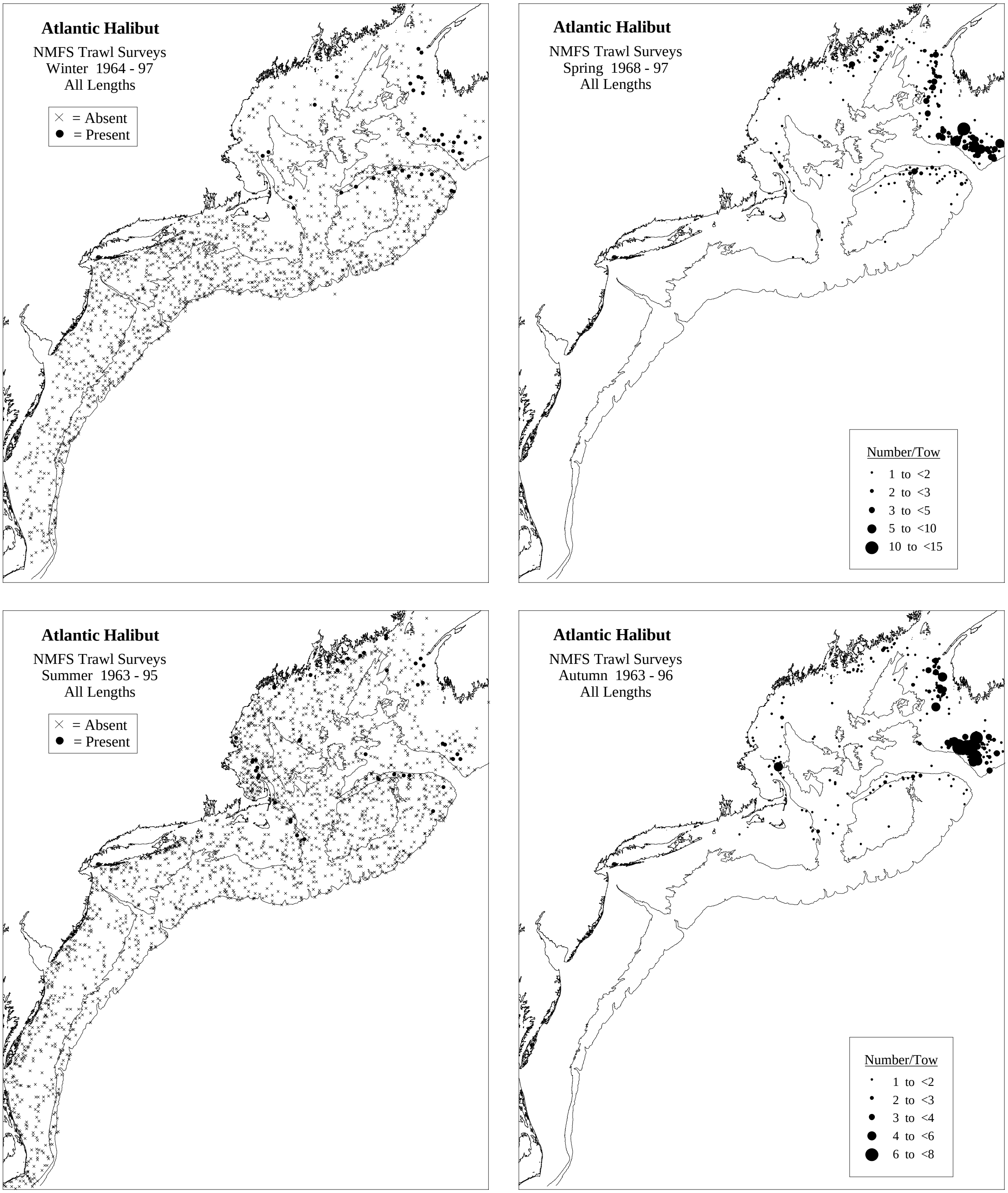

Figure 5. Distribution of juvenile and adult Atlantic halibut collected during NEFSC bottom trawl surveys (winter, spring, summer, and autumn, 1963-1997). Densities (number per tow) are represented by dot size in spring and autumn plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].

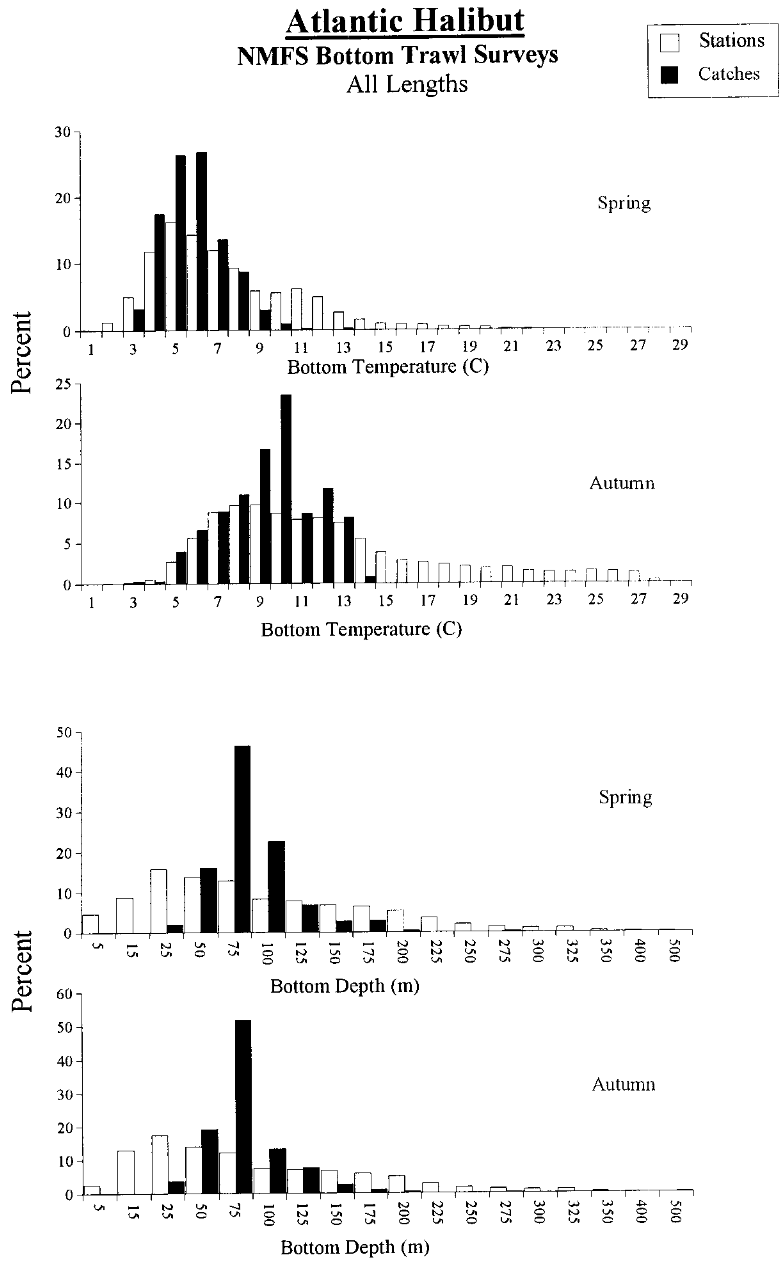

Figure 6. Abundance of juvenile and adult Atlantic halibut relative to water temperature and depth based on spring and autumn NEFSC trawl surveys (1963-1997). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

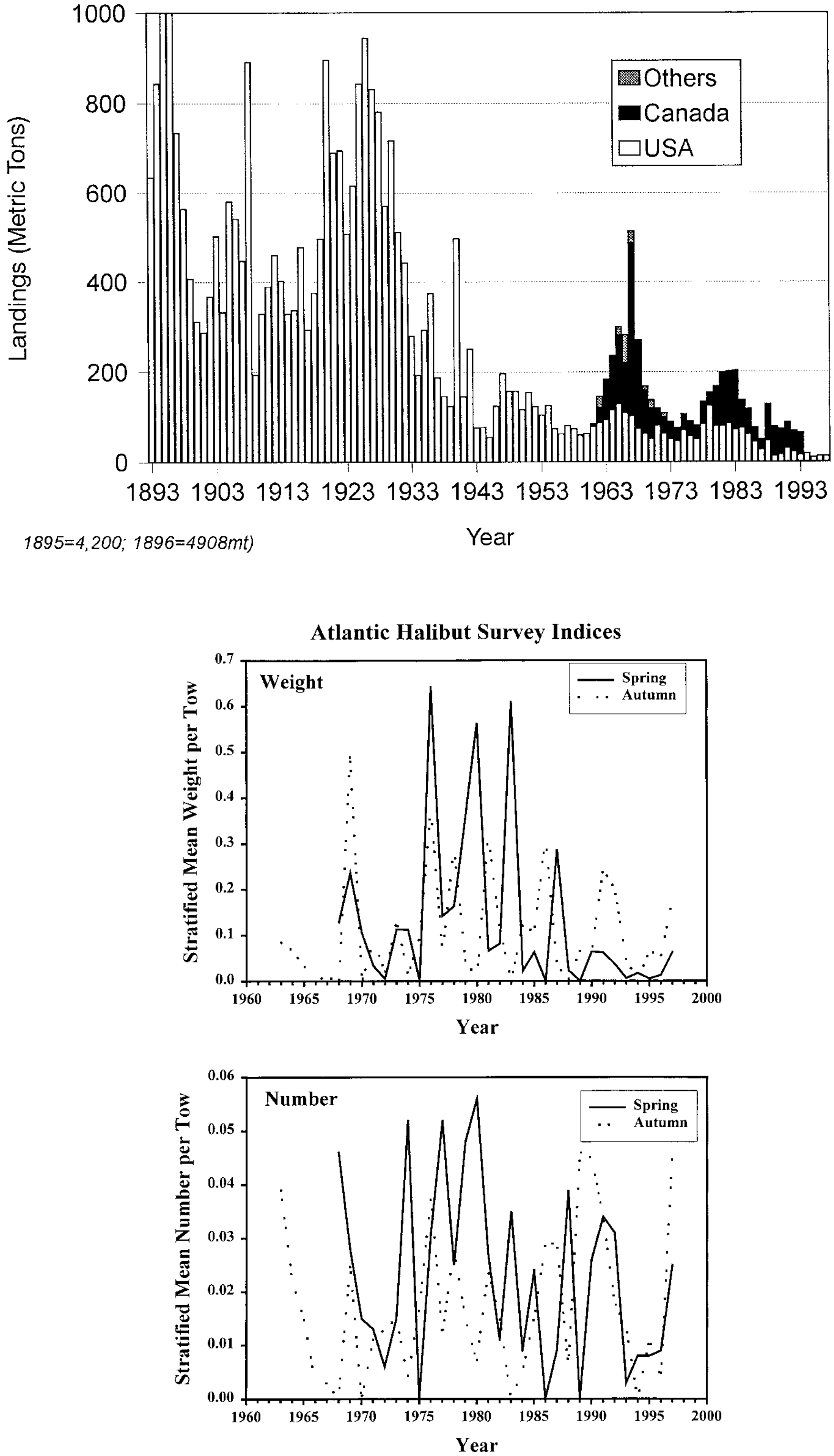

Figure 7. Commercial landings (1893-1997) and survey indices (1963-1997) for Atlantic halibut in the Gulf of Maine and Georges Bank.

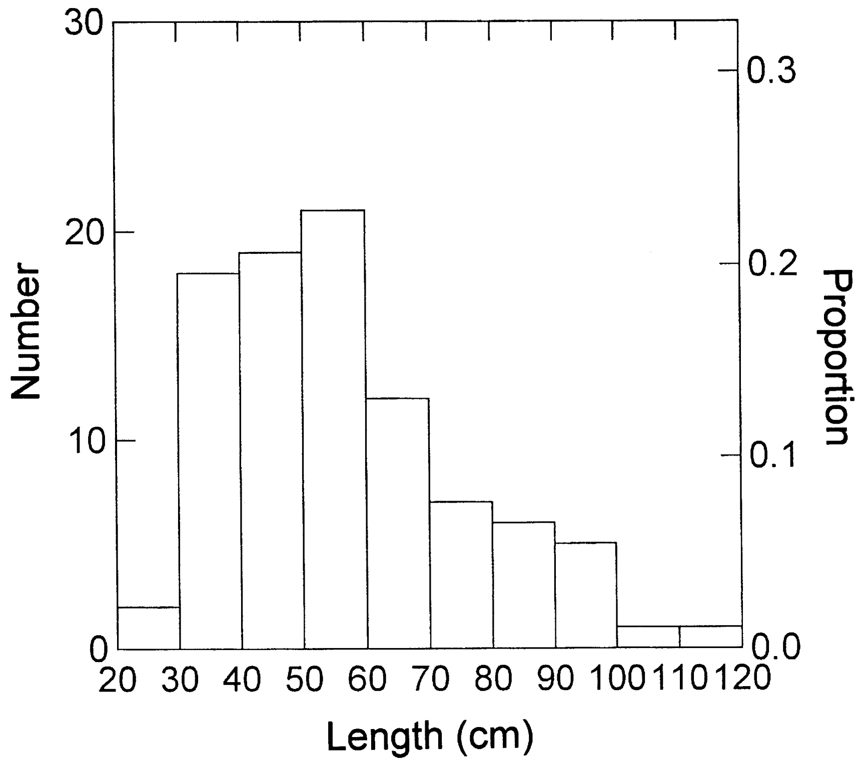

Figure 8. Length distribution of Atlantic halibut caught in NEFSC trawl surveys during 1988-1998.

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