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Maritimes Region | **Région des Maritimes**

Pre-COSEWIC Review of Atlantic Halibut (*Hippoglossus hippoglossus*) on the Scotian Shelf and Southern Grand Banks (Divs. 3NOPs4VWX5Zc), Gulf of St. Lawrence (Divs. 4RST), Newfoundland and Labrador, and Central and Arctic

Examen préalable à l'évaluation du COSEPAC sur le flétan de l'Atlantique (*Hippoglossus hippoglossus*) du plateau néo-écossais et du sud des Grands Bancs (div. 3NOPs4VWX5Zc) ainsi que du golfe du Saint-Laurent, dans la Régions de Terre-Neuve-et-Labrador, et dans celle du Centre et de l'Arctique

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ABSTRACT

All data relevant to the status of the Atlantic halibut, *Hippoglossus hippoglossus*, in Canadian waters were gathered from four DFO regions: Maritimes, Gulf, Newfoundland, and Quebec with the objective of providing information to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) for their review. In particular, data on life history, habitat, landings, surveys, and bycatch were collated. Correction factors for gear changes in the groundfish surveys were not applied and the results on distribution and trends need to be interpreted with caution. This assumption is probably adequate for most regions as correction factors for flatfish were small, but the gear change to a Campelen trawl in Newfoundland could have a large effect and is unquantified. Halibut continue to be rare on Georges Bank and in the eastern Arctic, their distribution has expanded in the Gulf, but their distribution on the Scotian Shelf and the southern Grand Banks has not changed appreciably. Little is known about the timing and location of halibut spawning, and the location and movement of eggs and larvae. A simple linear regression was fit to the groundfish survey data in each region over the entire survey time period. No trends were calculated for the southern Grand Banks because gear changes were large and no correction factor has been estimated. There was no change in halibut catch rates on the Scotian Shelf and significant increases in the northern and southern Gulf of St. Lawrence. Trends, calculated as the percent difference between the mean catch rate in the first five years in the time series and the last five years of the survey were increasing on the Scotian Shelf (74%) and the northern and southern Gulf of St. Lawrence (>200%).

RÉSUMÉ

Toutes les données sur la situation du flétan de l'Atlantique (*Hippoglossus hippoglossus*) dans les eaux canadiennes dont disposaient quatre Régions du MPO − Maritimes, Golfe, Terre-Neuve et Québec − ont été rassemblées afin de présenter au Comité sur la situation des espèces en péril au Canada (COSEPAC) des éléments d'information à examiner. Ont été réunies en particulier des données sur le cycle biologique, l'habitat, les débarquements, les relevés et les prises accessoires de ce poisson. Les facteurs de correction visant à tenir compte des changements d'engin n'ayant pas été appliqués, les résultats sur les tendances de la répartition doivent être interprétés avec prudence. Cette façon de procéder convient probablement pour la plupart des Régions, les facteurs de correction concernant les poissons plats ayant été faibles, mais dans le cas de Terre-Neuve, le changement au profit d'un chalut Campelen pourrait avoir un effet important, qui n'est pas quantifié. Le flétan continue d'être rare sur le banc Georges et dans l'est de l'Arctique; sa répartition s'est étendue dans le Golfe, mais elle n'a pas beaucoup changé sur le plateau néo-écossais et dans le sud des Grands Bancs. On sait peu de choses de la période et du lieu où le flétan fraye, ainsi que des déplacements des œufs et des larves ou des lieux où ils se trouvent. Un modèle de régression linéaire simple a été calé sur les données du relevé concernant le poisson de fond dans chaque Région pour toute la période du relevé. En raison de l'importance des changements d'engin et de l'absence d'estimation d'un facteur de correction, aucune tendance n'a été établie pour le sud des Grands Bancs. Les taux de prises de flétan n'ont pas changé sur le plateau néo-écossais, tandis que dans le nord et le sud du golfe du Saint-Laurent ils ont nettement augmenté. Les tendances, soit ici la différence de pourcentage dans les taux de prises moyen entre les cinq premières et les cinq dernières années de la série chronologique, étaient à la hausse sur le plateau néo-écossais (74 %) ainsi que dans le nord et le sud du golfe du Saint-Laurent (> 200 %).

1. LIFE-HISTORY CHARACTERISTICS

General Description

Atlantic Halibut (*Hippoglossus hippoglossus*) is the largest of the flatfishes and ranges widely over the North Atlantic and Arctic Ocean (Fig. 1). Atlantic Halibut, like Pacific halibut, is a broadcast spawner (Fig. 2), with pelagic early life history stages that last 6-7 months. Like all members of the *Pleuronectiformes*, Atlantic halibut undergo a change in body form from a symmetrical larva to an asymmetrical juvenile (Saele et al. 2004). Atlantic halibut are right-eyed and about one-third broad as long (Bigelow and Schroeder 1953). The eyes are farther apart than in other flatfish, and the mouth gapes back as far as the eyes. The lateral line is arched. Both the dorsal fin and anal fin fringe almost the entire length of the body. The dorsal fin has 98 to 105 rays and the anal fin is shorter with 73 to 79 rays. The upper pectoral fin is obliquely pointed, while the fin on the lower side is rounded and the caudal fin is concave. The rather small ventral fins are alike. The upper or eyed-side of young fish is mottled. Larger fish are darker and more uniform, sometimes almost black. The lower side is usually white in smaller fish, but larger fish can be blotched, clouded gray or cherry red.

Atlantic halibut is very similar to Pacific halibut (*Hippoglossus stenolepis*). The two species were identified as separate species in 1904 (Trumble et al*.* 1993). As more is known about Pacific halibut, and in particular about the distribution of the early life history stages in the wild, Pacific halibut is commonly used as a model species (Fig. 2, Trumble et al*.* 1993). However, Pacific halibut were not subject to an intense fishery in the 1800s, and more recently Pacific halibut support an order of magnitude larger fishery (Trumble et al*.* 1993).

Growth Parameters

Atlantic halibut are sexually dimorphic, with females being substantially larger than males (McCracken 1958, Bowering 1986). Off the coast of Newfoundland, Bowering (1986) reports males up to 189cm and females up to 229cm, while in US coastal waters the largest halibut caught was a female 220cm and 35 years old (Miller et al*.* 1991, cited in Cargnelli et al*.* 1999).

Length at maturity varies throughout the geographic range (Table 1). The most recent data collected is from the Gulf of St. Lawrence, where females reach 50% maturity at 130cm (DFO 2009a), and males mature at 75cm (DFO 2007). Maturity cycles of Atlantic halibut have not recently been examined on the Scotian Shelf and southern Grand Banks (NAFO Divs. 3NOPs4VWX5Zc). Length-at-age data collected between 1999 and 2005 from the Scotian Shelf and southern Grand Banks, show similar growth rates for males and females up to about 80cm (approximately 6 years), at which point male growth slows, while female growth continues at roughly the same rate until approximately 20 years of age. The ageing data in Table 1 shows a wide range in the estimate of length at 50% maturity, most likely due to the differing methodology of ageing. Consequently we do not recommend comparing these studies across regions. According to Haug (1990), substantial variations occur in age at first sexual maturity; however there is little variation in length at maturity, suggesting that sexual maturity is more a function of growth rate and size than age. Nonetheless, data on age at maturity is required for assessment modeling. Given the careful bomb-calibration done by Armsworthy and Campana (2010), we recommend using their estimates. The age of maturity for the Scotian Shelf and southern Grand Banks was estimated from the maturity-at-length and length-at-age data. Females were estimated to be 50% mature at 119cm or 9 yrs and males at 77cm or 5 yrs (Trzcinski et al. 2011). There also does not appear to be any difference in the growth rate of halibut caught by otter trawl gear in the 1970s and 1990s. Halibut caught in 4VWX tend to grow

to larger sizes, and may grow slightly faster, than those caught in 3NOPs (Armsworthy and Campana 2010).

Growth rate and growth efficiency of juvenile Atlantic halibut varies among populations from Canada, Iceland and Norway (Imsland and Jonassen 2001). The difference in response to changes in the photoperiod and temperature regime is consistent with latitudinal counter gradient variation in growth as hypothesized by Conover and Present (1990). There is also evidence of ontogenetic variation in growth with temperature, such that the temperature optima for growth is lower for older fish (Jonassen et al*.* 1999, cited in Imsland and Jonassen 2001) and the older fish are more tolerant to a sudden drop in temperature (Aune et al. 1997, cited in Imsland and Jonassen 2001).

Fecundity

Large halibut can be extremely fecund. In northern Norway a 90.7 kg female produced over 2 million eggs (Lønning et al*.* 1982) and in another study a 195cm female produced ~7 million eggs (Haug and Gilliksen 1988). In Norway egg diameters of 2.86-2.98mm (mean 2.92mm, Lønning et al*.* 1982) or 3.06-3.49mm (Haug et al. 1984) have been reported. In the Northwest Atlantic, fertilized halibut eggs have a diameter of 3-4mm (Fahay 1983, cited in Cargnelli et al. 1999, Miller et al. 1991).

Generation Time and Natural Mortality

The oldest halibut aged on Scotian Shelf and Southern Grand Banks was a 50 year old male, but most aged halibut were less than 25 years old (Armsworthy and Campana 2010). For long-lived fish, natural mortality is typically assumed to be less than 0.2. In the recent framework stock assessment for the Scotian Shelf and the southern Grand Banks natural mortality was assumed to be 0.1. There does not appear to be changes in growth. There was no difference in the length at age of halibut caught by otter trawl gear in the 1970s and 1990s, although most of these fish are juveniles (<70cm; Trzcinski 2011). Age at maturity is uncertain, but based on length at maturity, Trzcinski et al*.* (2011) estimate males reach 50% maturity at age 5 and females at 9 years of age. Generation time can be estimated from the age at maturity for 50% (A50%) of the population and natural mortality (M). For females, generation time (A50%+1/M) is estimated to be 19 yrs.

Early Life History

The pelagic early life history stages of Atlantic halibut last 6-7 months (Lønning et al. 1982). Very little is known about the distribution of the eggs and larvae in the Northwest Atlantic. Atlantic halibut larvae were captured in only 2 of 1,672 stations sampled during the NEFSC ichthyoplankton surveys (April 1977-1991, Reid et al. 1999 cited in Cargnelli et al*.* 1999), and only a few stations, near the edge of the Scotian Shelf, in the extensive monthly Scotian Shelf Ichthyoplankton Survey (1978-1982) contained Atlantic halibut larvae (Neilson et al. 1993). Based on the absence of halibut larvae in these surveys, Neilson et al*.* (1993) argue that spawning occurs in deep water off the continental shelf. Halibut larvae were also collected in the 1980s in zooplankton surveys on the west coast of Newfoundland and around Prince Edward Island conducted at depths between 10 and 100m between May and August (DFO 2000).

Pacific halibut eggs and larvae have been found in the water column and tracked moving with the currents (Trumble et al*.* 1993). As only 60 presettlement Atlantic halibut larvae have been caught in the wild (Haug et al*.* 1989, Bergstad and Gordon 1993, cited in Saele et al. 2004), what is known about larval development (Pittman et al. 1990*a*, 1990*b*) and metaphorphosis

(Saele et al. 2004) is based on rearing in a captivity. Hatching occurs after 18 days when incubated at 5 ºC, and the yolk sack provides energy for 1.5-2.0 months. Notably this metamorphosis results in the migration of the eye, but the associated morphological and physiological changes extend to nearly all major organ systems. In lab conditions metamorphosis takes about 45 days. At Stage 9 (27-29mm standard length), climax metamorphosis, halibut begin to seek the bottom but may still be feeding pelagically (Saele et al. 2004).

Specialized Niche or Habitat Requirements

Halibut are found in depths less than 50m to more than 1250m, but are typically 200 and 450m. Halibut prefer cold water along the edge of the continental shelf (Neilson et al. 1993, Bowering 1986), and it has been suggested that larger halibut prefer deeper water than smaller halibut (McCracken 1958, Zwanenburg et al. 1997) and that larger halibut move to deeper water in the winter (Bowering 1986). In Northeast USA, halibut catches in Northeast Science Fisheries Centre (NEFSC) bottom trawl surveys were used to test this hypothesis (Sigourney et al. 2006). ANOVA indicates a small but significant increase in the depth distribution of juvenile Atlantic halibut (<40cm, mean depths summer: 79m, autumn: 84m), subadult (40-80cm, summer: 92m, autumn: 94m) and adult (>80cm, mean depths summer: 97m, autumn: 128m), as well as a seasonal difference in depth distribution, with halibut caught in more shallow water in the summer than in the spring and fall. The difference in depth distribution between size classes was not significant in the winter, but fewer samples were available during that period. A preliminary analysis of the distribution of halibut catches in the eastern Scotian Shelf and southern Grand Banks (Trzcinski et al. 2009) is also consistent with this hypothesis.

Spawning areas and times are better known in the Northeast Atlantic than in the Northwest Atlantic. In Norway, spawning occurs in December to April, in Iceland March to May and possibly February to April in the Northwest Atlantic (Trumble et al. 1993). In 4W, spent and ripening halibut have been captured in February to March (Kohler 1967). Neilson et al. (1993) found peak spawning in November and December on the Scotian Shelf and southern Grand Banks. This analysis is consistent with Sigourney et al. (2006) who proposed that the shift to deeper water in the autumn is associated with spawning, while the more shallow distribution in the spring compared to the autumn suggests that halibut are already returning to summer feeding areas. Spawning halibut have been captured in the winter surveys in both the northern and southern Gulf of St. Lawrence.

In Faxa Bay, Iceland (Sigurdsson 1956, cited in Trumble et al. 1993) and off of the Faroe Islands (Tåning 1936, cited in Trumble et al. 1993) nursery areas have been identified on sandy bottom. In the Northwest Atlantic nursery areas have been suggested in southwestern Nova Scotia (Neilson et al. 1993), and the area around Sable Island Gully (Stobo et al. 1988).

Feeding

The main prey items of Atlantic halibut are benthic or demersal in nature (Trumble et al. 1993). As the size of halibut increases, prey selection shifts from invertebrates to fish (Kohler 1967, Trumble et al. 1993). Small halibut (<30cm) feed on hermit crabs, prawns, small crabs, and mysids, while larger halibut (>70cm) consume flatfish (*Hippoglossoides platessoides*), redfish (*Sebastes spp.*), and pollock (*Pollachius virens*) (Trumble et al. 1993). While one early study on Pacific halibut collected in a nursery area identified cannibalism, only a few studies, all before 1960, suggest a low level of cannibalism in Atlantic halibut (Trumble et al. 1993).

A recent review of all 229 Atlantic halibut stomachs collected in NEFC surveys shows the diet to be dominated by gadoids, small pelagics, crabs and cephalopods (Link et al 2002). In the Gulf of St. Lawrence, 896 halibut stomachs were collected between 1994 and 2008, primarily in May to August (Denis Chabot, IML, pers. com). The halibut sampled ranged in size from less than 10cm to 175cm. 27% of the stomachs were empty. Prey items were identified to the lowest taxonomic level possible given the degree of digestion and weighed (±0.01g). The principal species of invertebrates in the diet of small halibut (<30cm) was krill (*Meganyctiphanes norvegica*) and Northern shrimp (*Pandalus borealis*). The most common invertebrates in stomachs of larger halibut were snow crab (*Chionoecetes opilio*) and short-finned squid (*Illex illecebrosus*). On the Scotian Shelf, halibut stomachs have also been collected in RV trawl surveys (1995-2008), the halibut surveys (1999-2001) and non-standard surveys (prior to 1970) (Cook and Bundy, 2010). In total 1335 halibut stomachs have been examined, with 1003 individuals containing prey items. Individuals examined range in size from 18 to 204cm. When prey items are described by frequency of occurrence, small Atlantic halibut (<30cm) mainly consume invertebrates, those between 30-60cm consume equal proportions of invertebrates and fish and halibut >60cm consume predominantly fish. The prey fish of large halibut include Atlantic cod (*Gadus morhua)*, haddock (*Melanogrammus aeglefinus)*, white (*Urophycis tenuis*), red (*Urophycis chuss*) and silver hake (*Merluccius bilinearis)*, redfish (*Sebastes* spp.), wolfish (*Anarhichas denticulatus*), herring (*Clupea harengus)* and sand lance (*Ammodytes* spp.) whereas the medium sized halibut consume predominantly silver hake and sand lance. The invertebrate groups consumed by medium halibut were mainly brachyuran and paguroidean crabs or shrimps, whereas small halibut consume predominantly shrimps.

2. DESIGNATABLE UNITS

The stock structure of Atlantic halibut is not well defined. The management units 3NOPs4VWX5Zc and 4RST (Fig. 3) were established in 1987, based primarily on tagging studies (McCracken 1958, Bowering 1986, Stobo et al. 1988) and differences in growth rates between fish caught on the Scotian Shelf and in the Gulf of St. Lawrence (Neilson and Bowering, 1989). This report will discuss stocks based on the following management units using the Northwest Atlantic Fisheries Organization (NAFO) naming conventions: Maritimes (Divisions 3NOPs4VWX5Zc), Gulf of St. Lawrence (Divs. 4RST), Newfoundland and Labrador (Divs. 2+3LNO), and Central and Arctic (Subarea (SA) 0). Notably 3Pn was not assigned to any larger management unit.

Tagging programs have been conducted in the US (Maine), the Scotian Shelf and southern Grand Banks, and the Gulf of St. Lawrence. Results are difficult to compare because of different tag types, methodologies, and regional variation in fishing effort (low in the US and the eastern Arctic, high in 4X but decreasing to the northeast). While tagged halibut have moved more than 500 km in just a few years (McCracken 1958, Bowering 1986, Stobo et al. 1988, Kanwit 2007), halibut are generally recaptured in the same NAFO division in which they were tagged (Tables 2 and 3). Recent tagging in the Gulf of Maine indicates considerable transboundry movement, as 33% of the recaptured halibut were caught in Canadian waters (Kanwit 2007, Col and Legault 2009). However, none of the 2083 halibut tagged between 2006 and 2008 on the Scotian Shelf and southern Grand Banks were recaptured in US waters (size ranging from 49cm to 207cm and tagged with t-bar anchor tags; Table 2). There is some exchange between the southern Gulf of St. Lawrence and 4Vn (around the tip of Cape Breton), as halibut tagged near the western boundary of 4Vn move into the Gulf of St. Lawrence. Overall, 15% of the halibut recaptured between 1998 and 2008 from tagging (min 35cm, max 177cm, tagged with operculum wire tags) in the Gulf of St. Lawrence were caught in other areas (Table 3). Conversely, 2% of halibut recaptured from tagging in 3NOPs4VWX between 2006 and 2008

were recaptured in 4RST (Table 2). There also appears to be limited exchange between the northern and southern Gulf of St. Lawrence (similar to other species). Halibut from the Scotian Shelf management unit have moved to Iceland (McCracken 1958, Trzcinski et al. 2009) and from Iceland to the waters off of Newfoundland (Bowering 1986, cited in Stobo et al. 1988). There is insufficient data to detect seasonal patterns of movement, and movement has not been clearly linked to spawning activity. Stobo et al. (1988) found that Atlantic halibut less than 75cm, tagged and released on the Scotian Shelf and southern Grand Banks, moved further than halibut greater than 75cm. They suggested that the predominantly northeast movement of fish less than 75cm may represent compensatory movement of juveniles which is counter to the drift of early life history stages, but no data exists on halibut eggs, larvae and 1 year-olds to test this hypothesis. Twelve pop-up satellite tags were deployed in 2009 and 2010, but because halibut prefer deep water (>200m) which is below detectable light levels, these data are unlikely to help describe pathways of movement.

Given the high potential for mixing during pelagic early life history stages, and the mobility of halibut <75cm, it has been suggested that Atlantic Halibut comprise a single panmictic stock. There are no obvious discontinuities in the distribution of halibut in Canadian waters from the US border to Baffin Bay based on surveys and fisheries landings. Interestingly, no tags from any of the tagging programs have been recaptured in 2GH or further north. Atlantic Halibut are found in NAFO SA 0 (Fig. 3 and 4), but there is no directed fishery in this area and bycatch in other fisheries is very low (Table 4). Catches occur right up to the boundary with SA 1 (Greenland waters) and Division 2G (Newfoundland waters) and may reflect an extension of the distribution of stocks from one or both of these areas. There is some anecdotal evidence of morphological differences between areas but the data is lacking, similarly there has been no analysis of parasites. The difference in growth rates of juvenile halibut reared in the lab under common conditions support the hypothesis that the populations in Canada, Norway and Iceland are distinct (Imsland and Jonassen 2001). Genetic analysis also suggests separate populations in the Northwest and Northeast Atlantic (Foss et al. 1998). In the Northeast Atlantic, where individuals have been found to return to the same spawning site in subsequent spawning seasons (Godø and Haug 1988), there is evidence of genetic differentiation suggesting there may be local stocks (Mork and Haug 1983, Haug and Fevolden 1986, Foss et al. 1998). However, a recent study using highly polymorphic microsatellite DNA markers found no evidence for genetic structure in the Northwest Atlantic (Reid et al. 2005). This study had small sample sizes and considered only a limited number of geographic areas. As with other marine species, a greater number of polymorphic markers and larger sample sizes may be needed to detect population genetic structure (Glover et al. 2006). It is appropriate to view the western North Atlantic as a separate designable unit from the eastern North Atlantic. Any further designation is difficult without further data.

3. COSEWIC CRITERIA

There are 4 main COSEWIC criteria by which designatable units are assessed:

1) declining total mature individuals,
2) small distribution and decline or fluctuation,
3) small number of mature individuals and declining, and
4) very small or restricted total population.

First, we will review the data sources and then present analysis of this data for each of the designatable units defined above to address the first two criteria.

3.1 Landings

Maritimes Region (3NOPs4VWX5Zc)

The North American Atlantic halibut fishery began in coastal New England in the early 1800s. Before the collapse of the fishery in the late 1800s, the fishery had expanded to deeper waters and as far as Iceland. Atlantic halibut landings have been recorded since the late 1800s, first by province then by statistical area. Off the coast of Nova Scotia and Newfoundland, Atlantic halibut landings rose steadily for the first half of the century and nearly tripled from 1911 to 1949 (Fig. 5a). It has been speculated that the dramatic increase in landings in 1950 and 1951 and the spike in 1967 and 1968 results from the inclusion of Greenland halibut (i.e. turbot) in the Newfoundland landings. No correction factor was applied to account for this in Fig. 5a; however, a correction factor was applied in Fig. 5b, which does not reflect the higher landings seen in the historical data of Fig. 5a. A comparison of Fig 5a and 5b gives a general idea of the potential extent of the problem of misidentification. The data since 1970 are not expected to have problems with misidentification. Current landings on the Scotian Shelf and Southern Grand Banks (3NOPs4VWX5Zc) are well below peak landings in the late-1960s and mid-1980s, and the fishery has been managed with a Total Allowable Catch (TAC) since 1988 (Fig. 5b).

Gulf Region (4RST)

In the Gulf of St. Lawrence halibut landings were much higher in the first half of the 20th century, and exceeded the total Atlantic halibut landings reported for Statistical Area 3 (SA3-Newfoundland) and Statistical Area 4 (SA4-Quebec) (Fig. 5a). Again, reported landings could be a mix of Atlantic halibut and Greenland halibut. During the second half of the 20th century, Atlantic halibut landings decreased and in the early 1960s landings were around 650 t. The landings steadily declined to a low of 91t in 1982. In the 1980s and 1990s landings seldom exceeded 300t (the TAC from 1988-1998). In 1999 the TAC was increased to 350 t. In 2007, the TAC was increased again to 475 t. As of December 31, 2008, preliminary reported landings for 2008 totaled 514t (Fig. 6).

Newfoundland and Labrador Region (2+3LNO+3Ps)

Canadian landings from Atlantic halibut-directed fishing and bycatch from other fisheries were compiled from the Zonal Interchange Format database (ZIF); available since 1985. Canadian catch of Atlantic halibut inside Canada's 200-mile limit in NAFO Div. 2GHJ3KLNOP (combined) was high in 1985 (1,213 t), declined to its lowest level ever recorded in 1994 (104 t), then fluctuated around an average of 270t in 1995-2008 (Fig. 7). Canadian catches in Div. 3KL and Div. 3N became insignificant in 1992 and 1994 (respectively); while catches in Subdivision 3P averaged 128t in 1995-2008.

With respect to fishing gear used by Canadian fishers, Atlantic halibut was caught primarily by otter trawls and longlines in 1985-1987 (428t average) and 1985-1993 (457t average), respectively (Fig. 8). Although trawl catches became insignificant in 1994 and remained so thereafter, gillnet catches increased in 1995 and subsequently fluctuated around an average of 77 t. Longlines remained the primary gear that caught this species after 1993; averaging 169 t.

In 1985-1987, Atlantic halibut was taken primarily as bycatch in other Canadian fisheries of Div. 2GHJ3KLNOP (combined; Fig. 9). Since then, directed fisheries for this species have caught approximately the same amount as bycatch; averaging 373t in 1988-1991 and 137t in 1992-2008.

Based on NAFO reported catches for 1985-2008, non-Canadian commercial catches of Atlantic halibut outside of Canada's 200-mile limit in Div. 3LNOP (combined) exceeded 1,000 tons on three occasions: 1,082t in 1987, 1,225t in 1991, and 1,076t in 2003 (Fig. 10). The lowest reported non-Canadian catches ever recorded in Div. 3LNOP occurred in 1994-1999; averaging 91 t. Non-Canadian catches in the NAFO Regulatory Area (NRA) of SA 2 and Div. 3K became insignificant in 1992.

Historical NAFO data for 1960-1984 in Divisions 2GHJ3KLNO and Subdivision 3P indicate that Canada usually reported the majority of Atlantic halibut commercial catches; albeit a decreasing trend in 1960-1970 was observed by Canada and other countries (Fig. 11). After declining from 1,342t in 1961 to a low of 356t in 1976, Canadian catches increased from 620t in 1977 to a peak of 1,012t in 1984; while non-Canadian catches averaged 870t for 1960-1967, and 188t for 1968-1984. In addition, catches from NAFO Div. 3O historically appeared significant for commercial catches of this species (averaging 761t in 1960-1963, and 715t in 1984-1987); usually representing the largest catches across Divisions to 1974 (Fig. 12). Subsequently, SA 1 showed the largest commercial catches until 1984; averaging 668t during that period.

Central and Arctic Region (SA0)

There is no directed fishery for Atlantic halibut in SA0. A small amount of Atlantic halibut has been landed as bycatch from the Greenland halibut fishery (from trawl, longline and gillnet) (Table 4) and in the northern shrimp fishery (Table 5). Data are from onboard observer records. Observer coverage in the Greenland halibut fishery for Division 0A has been 100% since it began in 1999 but coverage for the Division 0B fishery has been incomplete, particularly for the fixed gear fleets so these figures do not represent total bycatch. As observer coverage in the northern shrimp fishery has been 100% since 1985, these figures represent total bycatch for this fishery since 1985. The Nordmore grate used to separate finfish from the shrimp became mandatory in 1997. Overall reported bycatch has declined in both fisheries since the mid 1990s and has varied annually between no reported bycatch and approximately 400 kg since 2001.

3.2 Research Surveys

The longest and most comprehensive data on the distribution and abundance of halibut are from DFO Research Vessel (RV) trawl surveys, which are used as an index of abundance, and which measure the sex and length of all halibut caught. Correction factors for gear changes in the groundfish surveys were not applied and the results on distribution and trends need to be interpreted with caution. This assumption is probably reasonable for most regions as correction factors for flatfish were small, but the gear change to a Campelen trawl in Nefoundland could have a large effect and is unquantified.

The RV trawl surveys have low catchability for larger (>81cm) halibut, and do not provide good indices of exploitable biomass, but are accepted as indices of pre-recruits entering the fishable population. The median size of halibut caught in Scotia-Fundy groundfish trawl survey is between 40 and 50cm. The mean size of halibut caught by the RV surveys in the northern Gulf in the 2000s was between 60 and 70cm, while in the southern Gulf the mean size rarely exceeded 50cm. Growth data indicate that these fish will enter the fishery (grow to >81cm) in 2 to 3 years.

For the stratified surveys, the mean catch per tow was weighted by strata area:

$$\text{mean catch per tow} = \Sigma (c_i * a_i / a),$$

where c_i is the mean catch per set for strata i, and a_i is the area of strata i, and a is the total survey area.

The following section describes briefly the design of DFO RV surveys, more details, including strata maps, can be obtained in a recent review of the distribution of smooth skate (Kulka et al. 2006). In addition to the RV surveys there are a number of DFO-Industry surveys. Some of these surveys are directed for larger halibut (>81cm) or other groundfish species, and provide indices of the abundance of exploitable biomass.

Maritimes Region

Summer: The Scotia-Fundy groundfish RV survey has been completed every July since 1970. Each year, about 231 stations are sampled from the Upper Bay of Fundy to the northern tip of Cape Breton and offshore to the 400 fathom contour (app. 700 m) (Branton and Black, 2004). The number of strata covered, the length of the survey, and different vessels vary from year to year. From 1970-1981 the survey was conducted by the *A.T. Cameron* using Yankee 36 trawl. Since 1982 Western IIA trawl gear was used with a variety of boats: In 1982 the survey was completed by the *Lady Hammond*; in 1983-2004, 2006, 2009 and 2010 by the *Alfred Needler*; in 2004, 2005 and 2007 by the *Teleost*; and in 2008 by the *Wilfred Templeman*. In 2005, some stations were surveyed by both the *Teleost* and the *Alfred Needler*. The change of fishing gear in 1982 is known to have important effects on the catchability of cod and haddock, but appears to have had little effect on halibut. Correction factors were not calculated for Atlantic halibut (Figs. 13, 24, 25), as was done for similarly sized flatfish (e.g. plaice in COSEWIC 2009).

Spring: The 4VW cod survey has been conducted in the spring since 1986, except for 1998 and 2004. The stratification scheme was developed to optimize the abundance estimates of cod. The survey was conducted by the *Alfred Needler* using a Western-IIA trawl in 1986-2006, 2009 and 2010, and by the *Wilfred Templeman* in 2007 and the *Teleost* in 2008. For comparison, the survey was also completed by the *Teleost* using the same gear in 2005 and 2006. Catches in the deep water strata added to the survey in 1993 are presented in the distribution map but not included in the plot of abundance or spatial analysis (Figs.13, 26).

Georges Bank: The Georges Bank survey in Div. 5Z has been conducted in February and March since 1986. From 1986-2010, the survey was conducted by the *Alfred Needler* using a Western-IIA trawl, except in 1993, 2004, 2007 and 2008 when the survey was completed by the *Wilfred Templeman*. For comparison, the survey was also completed by the *Teleost* using the same gear in 2005 and 2006 (Figs.13, 27).

Quebec Region

Northern Gulf of St. Lawrence RV surveys are depth stratified and cover Divs. 4RST (strata deeper than 183m in 4T) and Subdiv. 3Pn. The January survey was conducted by the *Gadus Atlantica* using an Engel 145 trawl from 1978-1994. The total area surveyed varies annually because of ice coverage and other factors. The summer RV surveys have been conducted annually since 1984. From 1984-1990 the survey was conducted by the *Lady Hammond* using Western IIA trawl gear, with a codend liner of 32/19mm. From 1990-2005, the summer survey was conducted by the *Alfred Needler* equipped with a URI 81'/114' (University of Rhode Island) shrimp trawl, with a codend liner of 19mm. The Estuary (4T) was well surveyed, but 3Pn was only sampled from 1994-2003. And, since 2005 the survey has been done with the *Teleost* using a Campelen shrimp trawl, with a codend liner of 12.7mm. During this time, 3Pn was not covered by the northern Gulf survey. A comparative study between tandems *Teleost*/Campelen

and *Alfred Needler/*URI indicates that no correction factor has to be applied for the Atlantic halibut between the two surveys (Bourdages et al., 2007).

Gulf Region

Southern Gulf of St. Lawrence surveys were conducted every September since 1971. Surveys are stratified by depth and geographic region. From 1971-1985, the survey was completed by the *E. E. Prince* using a Yankee 36 trawl. Since 1985, the survey has been completed by a number of different boats using a Western IIA trawl. The survey was completed by the *Lady Hammond* from 1985-1991, the *Alfred Needler* from 1992-2002, the *Wilfred Templeman* in 2003, and both the *Alfred Needler* and the *Teleost* from 2004-2009.

Newfoundland

The Department of Fisheries and Oceans Canada has been conducting research surveys in the waters off of Newfoundland and Labrador since 1946. During that period, numerous changes occurred in survey design, research vessels, trawl gear, and area surveyed. Although these research surveys are conducted to monitor groundfish resources off of Newfoundland and Labrador, they extend beyond the Canadian Exclusive Economic Zone (i.e., outside Canada's 200-mile limit).

From 1946-1970, groundfish abundance was estimated using line transect surveys over a range of depths. These Canadian research surveys were conducted in 1946-1958 utilizing the *Investigator II* with a Yankee-36 otter trawl. In 1959-1970, this vessel was replaced by the *A.T. Cameron* with a Yankee-41.5 otter trawl. In 1971-1982, the *A.T. Cameron* was then redeployed annually for new stratified-random surveys in the spring in NAFO Divisions 3LNO. This survey design was stratified based on depth, with the allocation of sets proportional to the stratum area (Doubleday and Rivard, 1981). In 1984, the *A.T. Cameron* was replaced by the *Alfred Needler*, and the Yankee trawl was replaced with an Engels-145 high-lift otter trawl. From 1996-2009, this spring survey was conducted using a Campelen-1800 shrimp trawl.

Canadian spring stratified-random surveys were also conducted in Subdivisions 3Ps and 3Pn since 1972. Survey coverage was relatively constant in recent years; with the exception of 2006, when research vessels' mechanical problems prevented the sampling of Subdiv. 3Ps, and allowed only minimal coverage of Div. 3NO. Essentially, Canadian spring survey indices can be divided into three time series, based on the trawl used: Yankee-36 in 1971-1982, Engel-145 in 1983-1995, and Campelen-1800 from 1996- present. For many fish species, conversion factors were not derived during periods of comparative tows between different survey trawls; therefore comparisons across these periods is difficult and should be made cautiously.

Canadian autumn stratified-random research surveys were conducted from 1977-1994 in Div. 2J and 1978-1994 in Div. 3K by the research vessel *Gadus Atlantica* using an Engel-145 trawl. In Div. 3L, autumn surveys were conducted by the *A.T. Cameron* using a Yankee-41.5 trawl in 1981-1982, and in 1983-1994 by either the *Alfred Needler* or the *Wilfred Templeman* using an Engel-145 trawl. In autumn 1995, the *Gadus Atlantica* was replaced by the *Teleost*, and Engel-145 trawls were replaced with Campelen-1800 shrimp trawls. In 1995-2008, autumn surveys in NAFO Areas 2 and 3 were conducted using a Campelen-1800 shrimp trawl by the research vessels *Teleost*, *Wilfred Templeman*, and *Alfred Needler*.

In 1990, the Canadian autumn research survey was expanded to cover the southern Grand Banks in Div. 3NO. This survey was also expanded into offshore areas of Divisions 2J, 3K, and 3L to 1000-m depths (i.e., from the previous 731-m maximum). Furthermore, this survey

expanded into both shallower inshore strata and deeper offshore areas in 1995. Throughout the autumn time series, the survey has undergone some variation for different reasons (e.g., vessel breakdown). Consequently, some years had reduced survey coverage; particularly in deepwater strata. Most notable is the reduced coverage in 2004 and 2006. In addition, NAFO Div. 2G has been excluded from the annual autumn survey, and Div. 2H is sampled only every second year.

Canadian juvenile groundfish surveys were conducted annually in 1985-1994 to investigate distribution of juvenile flatfish on the Grand Banks. This survey used a stratified-random sampling design similar to that used in annual Canadian multispecies groundfish surveys. Survey gear was a Yankee-41 shrimp trawl (see McCallum and Walsh, 1996 for details) aboard the *Wilfred Templeman*.

Additional surveys, implemented by foreign governments within Newfoundland and Labrador Region waters and adjacent areas have also been conducted, but are not reported here.

Central and Arctic Region (SA0)

Depth stratified random surveys have been conducted by DFO in Division 0A (1999, 2001, 2004, 2006 and 2008), Division 0B (2000 and 2001) and Hudson Strait (DFO Shrimp Fishing Area 3) (2007) using the RV *Paamiut*. The surveys included depths between 400m and 1500m from the Div. 0B2G boundary to 75^{o} 30' N. In 2006 and 2007 depths from 100m to 400m were added. Only one Atlantic halibut has been caught and that was during the 2000 survey in Div. 0B (located at 62^{o} 46' N and 59^{o} 19' W and in 1062 m). In these surveys, Alfredo otter trawl gear with a mesh size of 140mm and a 30mm mesh liner in the cod end was used for deep strata (400-1500m) in all years and valid tows were 30 minutes in duration. Cosmos shrimp gear was used for shallow strata (100-800m) in 2006 and 2007 and valid tows were 15 minutes in duration. Additional information on the Div. 0A surveys can be found in Treble, 2009.

3.3 Industry-DFO Surveys

Maritime Region and Southern Grand Banks

Halibut survey: On the Scotian Shelf and southern Grand Banks, an Industry-DFO the halibut survey, with established stations and directed fishing, was developed to monitor the abundance and distribution of a broader size range of halibut (50-230cm) over a wide range of depths (50 – 800m). The survey is completed between May and July and has a fixed station design. At its conception in 1998, there were 222 stations. In 1999, stations were rearranged and reallocated, and between 2005 and 2008, 73 stations were added to increase coverage in the Bay of Fundy, north of Cape Breton and Georges Bank. Commercial fishermen complete the survey following protocols that prescribe the hook-size (#14), number of hooks, and minimum soak times (Zwanenburg and Wilson, 1999). Not all stations in the halibut survey were fished annually.

Halibut Commercial Index: The halibut commercial index is completed in conjunction with the halibut survey. The commercial index is completed by commercial fishermen, who fish at a location of their choosing. Participants tend to use the same protocol as the survey, but may add more hooks or extend the soak time.

4VsW Sentinel Survey Program: The 4VsW sentinel survey program is a joint project of the Fishermen and Scientists Research Society (FSRS) and the Department of Fisheries and Oceans that began in 1995. The program consists of two components. One is a Sentinel Survey that uses a stratified random survey design and the depth stratification scheme from the July RV survey, and includes 3 additional inshore strata, that are shallower than the RV survey strata.

The survey is conducted during September and October. Fishing locations are selected randomly within each depth stratum, proportional to the stratum area. It is a longline survey using standardized gear in sets of 1500 #12 circle hooks. Gear construction, bait type, and soak time are all prescribed. The number of sets was reduced from 250 to 200 in 2001. In 2004, the number of strata covered was reduced from 27 to 6, and the number of sets was reduced to 53 (Fig. 15). The second component was a commercial index which permits a limited amount of commercial fishing, using standardized gear. Participation in the commercial index was poor and that component was discontinued in 2006.

4Vn sentinel fishery: The 4Vn sentinel fishery program began in 1994. This program also has several components including a stratified longline survey using No. 12 hooks. The strata are similar to that used by the July groundfish survey (Fig. 15).

ITQ Survey: The mobile gear fleet (<65ft) has conducted a survey of 4X, including inshore areas, since the summer of 1995. The survey is completed by 3 vessels with standardized gear and the same size codend liner as the DFO research vessel survey. Participating vessels fish during daylight hours. The standard trawl gear is a 280 Balloon trawl, rigged with 14 inch cookie foot gear, without ground warps, with 120 foot bridles and all rigging as uniform as possible. Vessels tow in a standard manner (i.e. into the tide, in a fairly straight course, for a distance of 1 nautical mile as determined by GPS/Loran C/track plotter, at a speed of 2.5 knots) (Figs. 14, 28).

Quebec Region

Mobile Sentinel Survey in the Northern Gulf of St. Lawrence: The mobile sentinel fishery is a depth stratified survey, as for the RV surveys, consisting of 300 randomly selected stations covering NAFO divisions 3Pn4RST (limited to waters deeper than 183m in 4T). At each station a standard tow of 30 minutes and 2.5 knots is completed using 300 star balloon mounted Rockhopper gear with a mesh size of 145mm and a liner of 40mm in the cod end. Sampling is completed by trawlers from Newfoundland and Quebec. Observers are assisted by crew members in collecting the data. The survey has run from 1995-Present.

Central and Arctic and Newfoundland Regions (NAFO Divs. 0B and 2GH)

In 2005, the *Northern Shrimp Research Foundation* initiated an industry survey directed towards shrimp in Div. 0B and 2GH that includes depths less than 400 m. This is potentially another source of information for Atlantic halibut distribution in this area.

3.4 Bycatch

Halibut are caught in a number of groundfish fisheries and shrimp fisheries, but the data have yet to be compiled into a format where this can be looked at in detail for most management units. On the Scotian Shelf and southern Grand Banks halibut are caught as part of a multispecies groundfish fishery. Bycatch in the halibut fishery was highly variable in time and space. When halibut was directed for, typically 40 to 60% of the catch weight were species caught incidentally. Sixteen species showed up regularly in the bycatch but most were in small proportions. White hake was the most frequently caught bycatch species averaging approximately 30% of the catch and ranging from 5 to 75%. Cod averaged approximately 7% and cusk 5% of the catch. Bycatch was estimated by area and season in Trzcinski et al. 2009.

3.5 Discard Mortality

Neilson et al. (1989) estimated a 77% survival of juvenile halibut caught on longline gear, and 35% survival of halibut caught by an otter trawl. The survival of adults may be as high as 99% (Neilson et al. 1989).

For the Gulf of St Lawrence halibut stock, discard mortality may be significant in the turbot directed gillnet fishery, as most of the halibut caught by gillnet are less than minimum legal size (Table 6). Preliminary results from an ongoing study in the northern Gulf of St. Lawrence indicate that only 50% of the halibut in gillnets were alive when the nets were raised (DFO 2009a). Discard survival of larger halibut may be lower because it is more difficult to handle these fish.

3.6 Abundance Indices

Scotian Shelf and Southern Grand Banks (NAFO Divs. 3NOPs4VWX5Zc)

The DFO summer RV survey mean catch is the abundance index with the longest time series. Over the length of the time series, which is our closest approximation to 3 generations, halibut catches have increased, although current levels are just slightly higher than catches in the late 70s and early 80s (Fig. 13). The 4VW Cod survey has higher mean catch rates than the summer survey, but is a shorter series (Fig. 13). It shows the same pattern as the summer survey, with a peak catch in the late 80s and early 90s, followed by low catches around 2000 and higher catches in more recent years. Notably, the increase between 2007-2008 in the summer survey is not seen in the spring survey, nor is it seen in the ITQ survey in 4X/5Z (Fig. 14) which occurs during the summer. The Georges Bank survey indicates very little change in the abundance of halibut in 5Z, but the catch rates are so low it is inconclusive. Of the 460 fish caught in the ITQ survey since 1996, the mean length is 48.9cm (median length-46cm, min. length-16cm, max. length-145cm).

The stratified median length of halibut caught in the ITQ survey ranged from 64-92cm The Georges Bank survey indicates very little change in the abundance of halibut in 5Z, but the catch rates are so low it is inconclusive.

Halibut are also caught in the sentinel longline fisheries in 4VsW and 4Vn (Fig. 15). Notably these surveys use #12 hooks, which catch halibut between 21 and 157cm. The stratified median length of halibut caught in the 4VsW survey ranged from 64-92cm. These surveys should be interpreted cautiously as there is variable effort (number of sets), the catch rates are low and in the 4Vn survey the mean catch has not been weighted for strata area (Fig. 15).

The halibut survey results suggest a possible increase in catch rates in 4VWX in recent years and a relatively stable catch prior to 2003 (Fig. 16). The commercial index catch rates are more variable and lower in recent years. Four separate catch rate analyses were compared to determine whether irregular station sampling over the course of the survey affected the catch rate estimate. The four analyses examined were: 1) data for all stations covered in 4VWX (n = 126 to 225), 2) data for stations completed since 1999 (n = 50), 3) a GLM applied to the 50 stations completed since 1999 (GLM 50), and 4) data for all stations covered in 5 or more years and standardized using a generalized linear model (GLM ALL). In general, all analyses indicate that halibut survey catch rates have increased in the past 5-7 years (Trzcinski et al. 2011).

Model Results

The assessment model for the Scotian Shelf and the southern Grand Banks Atlantic halibut can be broadly described as a length-based age-structured model (Trzcinski et al. 2009). The primary inputs to the model are catch at length and several abundance indices. Between 1970 and 2008, both the spawning stock biomass and the total biomass follow a similar pattern (Fig. 17). At the beginning of the time series there is a decline and then slight increase in biomass, followed by a sharp drop between the early 80s and early 90s, and a steady increase since the early 90s. The abundance of halibut is higher currently than during the early 1970s, although it is still below the maximum seen in the peak abundance of the mid-1970s.

Gulf of St. Lawrence (NAFO Divs. 4RST)

Abundance and biomass indices from the summer RV surveys in the southern and northern Gulf have more than tripled in the last 10 years (Fig. 18), and the values over the last 3 years are some of the highest in the 18-year time series. Since 2003, the catch per unit effort (CPUE) of the halibut directed longline fishery has also increased in all NAFO divisions in the Gulf and for the area as a whole (Fig. 19). The halibut CPUE for the cod directed longline fishery and the turbot gillnet fishery has increased over the same time period (Fig. 20). For the cod directed longline fishery, the halibut CPUE for all of 4RST is at its highest level since 1997. Notably the gillnet fishery catches smaller halibut than the longline fisheries (Table 6), and as such these fisheries are monitoring different size classes. There are also differences in the distribution of these fisheries described below.

Newfoundland (NAFO Divs. 2+3LMNO+3Ps)

Catch rates of Atlantic halibut in NAFO divisions 3LNOPs increased during the 1970s and subsequently declined during the 1980s and early 90s (Fig. 21). During the late 1990s and early 2000s the catch rates have been variable, though increasing in recent years. Fall survey catch rates are highly variable, however they show a similar pattern to the spring survey with catch rates peaking during the late 70s and early 80s, followed by a decline (Fig. 22). In recent years, catch rates have remained highly variable and in northern areas (NAFO divisions 2J3K), catch rates have not recovered. In NAFO divisions 3NO, catch rates have fluctuated without trend in recent years. No correction was made for gear type, and it should be noted that Campelen gear does not catch halibut as effectively as alternate types. The juvenile survey exhibited variable catch rates throughout the time series (Fig. 23). A linear regression for mean catch per tows was applied for research trawl surveys on the Scotian Shelf, Gulf of St. Lawrence and the southern Grand Banks over time with the assumption that catch rate was similar (Table 7). The southern Grand Banks was treated as a replicate when running the linear model, and one mean number per tows was calculated for the entire stock of the Scotian Shelf and the Gulf of St. Lawrence. The linear regression showed a significant decreasing trend in catch per tows in Grand Banks, a significant increasing trend in the Gulf of St. Lawrence and an insignificant increasing trend on the Scotian Shelf. Percent change (decline/increase) was calculated for a five-year average of the start and end of the survey time series for each area. The Grand Banks (2+3LMNO+3Ps) fall and spring survey demonstrated significant declines in catch per tow, Scotian Shelf (4VWX) showed insignificant increases and the Gulf of St. Lawrence showed significant increases (Table 7).

Central and Arctic Region (0) and Newfoundland (2GH)

There is insufficient information to determine trends in abundance of Atlantic halibut in SA 2GH and SA 0.

3.7 Changes in Distribution

Depth Weighted Area of Occupancy: Area of occupancy can be calculated from the stratified research surveys. For each depth-stratified survey, the depth weighted area of occupancy (DWAO) was calculated for each year:

$$DWAO = \sum_{i=1}^{S} \sum_{j=1}^{n} I*(a_i / n_j) \text{ where } I = 1 \text{ if } Y_j > 0 \text{ or } I = 0$$

where s is the number of strata, n_i is the number of sets in stratum i, and a_i is the area of stratum i. Y_j is the number of fish caught in set j.

Scotian Shelf and Southern Grand Banks (NAFO Divs. 3NOPs4VWX5Zc)

Maps of the distribution of catches in the RV surveys do not indicate a trend over time (Figs. 24-27). The map of the Georges Bank survey highlights the low catch rates in that survey and shows that halibut are caught in the channels and on the shelf edge. Maps of the ITQ Survey, halibut survey and the commercial index also show no obvious trend in the distribution over a decade of sampling (Figs. 28-30), although survey coverage in 3NOPs is variable for both surveys. Notably the commercial index focuses on continental shelf while the halibut survey extends into more shallow waters.

The plots for the DWAO for the Maritimes RV groundfish trawl surveys are highly variable, but roughly reflect the abundance of halibut catch in their respective surveys (Figs. 31-33). Again, the summer survey provides the longest time series and indicates that there has been an overall increase in the distribution of halibut since the beginning of the series, with the current high distribution of roughly 22% of the area occupied being matched in 1980. The spring survey appears to have a higher percentage of the area occupied, but it is more variable and shows no distinct trend over time. Owing to the small numbers of halibut caught in the Georges Bank survey the area occupied is very low.

Gulf of St. Lawrence (NAFO Divs. 4RST)

In the Gulf of St. Lawrence, halibut catches for both northern and southern Gulf DFO RV trawl surveys and the Northern Gulf Mobile sentinel fishery are concentrated in, and on the slopes and channels (Figs 34-36). During the 1990s, the number of halibut caught per set was few and limited to a few stations per survey. During the 2000s, there was an increase of stations with halibut catch, mainly along the 200m isobath in the Northern Gulf and throughout the Southern Gulf area. From 2005 to 2009 the number of halibut caught per set increased dramatically (Fig. 18). DWAO has also increase dramatically since 1970s in both the northern and southern Gulf from <0.01 to ~0.14 (Figs. 37, 38)

Mean numbers per tow increased from 2008 to 2009 in the sentinel survey, but mean weight per set decreased (Fig. 39) probably indicating a pulse in recruitment to the fishery. The distribution of halibut caught in the sentinel survey is shown in Fig. 40.

The halibut catch per unit effort (CPUE) in the Gulf for the halibut directed longline and the cod directed longline in 2007 and 2008 closely followed the distribution of halibut in the DFO RV surveys in the Gulf (Fig. 41). The Turbot directed gillnet fishery was limited to the Estuary and

the northern Gulf. In this fishery the highest catches of Atlantic halibut were on the northwest edge of the Esquiman Channel.

Newfoundland (NAFO SAs 2+3)

Atlantic halibut are distributed throughout NAFO SAs 2+3 generally in low numbers. They are most abundant along the edge of the continental shelf and in deepwater channels between banks. Atlantic halibut in the Newfoundland-Labrador area are distributed from NAFO Division 2G and the Hudson Strait southward to the southern Grand Bank and St. Pierre Bank. The distribution is contiguous with the distribution of Atlantic halibut north in NAFO Division 0B and south-west in NAFO SA 4. In NAFO divisions 3LNO (Grand Banks) catches of Atlantic halibut are mainly outside the 200 mile limit and the Canadian EEZ (Figs 42-43). DWAO indices for Atlantic Halibut the NL RV groundfish trawl surveys are variable, but reflect catch rate trends in the surveys (Fig. 44-46). The spring survey DWAO index shows a decline during the late 1980's followed by a stable area occupied since the early 1990's. The index in 3Ps was highly variable and shows no distinct trend over time. In NAFO divisions 2J3K, the fall survey DWAO reflects the observed decline in abundance followed by a highly variable DWAO indicative of the low catch levels in this area.

Central and Arctic Region (NAFO 2GH and 0B)

There is insufficient information to determine changes in distribution of Atlantic halibut in SA 0.

4. HABITAT

Adult (>77cm)

Atlantic halibut are primarily demersal, have a wide distribution and are generalist predators. What is considered an adult or juvenile can be defined different ways, but given that males reach 50% maturity at 77cm on the southern Grand Banks (Trumble et al. 1993), an adult will be considered to be any halibut larger than this size regardless of sex.

New data from an archival pop-up satellite tag deployed in 2007, suggest that halibut may also use the water column (S. Armsworthy, BIO, unpublished data). Additionally from this tagging data, halibut appear to prefer a narrow temperature range of 3 to 5°C (S. Armsworthy, BIO, unpublished data).

In the northern Atlantic waters, larger halibut are found in a larger depth range, and are also found in more shallow water in the summer (Bowering, 1986, Sigourney et al. 2009). In the southern Gulf of St. Lawrence, halibut are found at more shallow depth than in the northern Gulf. Near Miscou Bank, north of Prince Edward Island, northwest of Cape Breton, and around the Magdalen islands, halibut occur at greatest concentrations at about 100 m (DFO 2009a). In the northern Gulf and Scotian Shelf and Southern Grand Banks, halibut are most abundant in the deep-water channels running between the banks and along the edge of the continental shelf (200-500m depth) (DFO 2009a, Trzcinski et al. 2009).

Juvenile (≤77cm)

Stobo et al. (1988) speculated that the area around the Sable Island Gully may be near spawning/rearing grounds based on the abundance of juveniles in the area. A higher proportion

of smaller halibut in 4X around Browns Bank (Nielsen et al. 1993) and the southern half of the Gulf of St. Lawrence may also indicate a rearing or nursery grounds.

Spawning and Distribution of Larval Stages

The distribution of the pelagic eggs and larval halibut in the Northwest Atlantic is not well known. Larvae were captured in only 2 (1 tow was near Petite Manan Island, Maine; the other was east of Georges Bank) of 1,672 stations sampled during the NEFSC ichthyoplankton surveys (April 1977-1991, 61cm Bongo net, 0.505 mm mesh, Reid et al. 1999 cited in Cargnelli et al. 1999). Only 3 Atlantic halibut larvae were captured in the Scotian Shelf Ichthyoplankton Program (SSIP) survey between 1978 and 1982 (Neilson et al. 1993). Some halibut larvae were found between May and August on the west coast of Newfoundland and around Prince Edward Island, in waters between 10 and 100m (DFO 2000).

5. EXPLOITATION AND THREATS

Fishing activities are the main threat to Atlantic halibut. The North American Atlantic halibut fishery began in coastal New England in the early 1800s. Before the collapse of the fishery in the late 1800s, the fishery had expanded to deeper waters and as far as Iceland. Landings of Atlantic halibut in Europe declined from an all time high of 10,000-15,000t between 1950-1965, to less than 2,000t in 2004 (Glover et al. 2006). Until 1988, the halibut fishery was unregulated in Canada. Total reported Canadian and foreign landings for the Scotian Shelf and southern Grand Banks (3NOPs4VWX5Zc) are provided in Table 8 and Figure 5. Landings for 5Zc were only separated from the rest of 5Z in 1986. In 1988, a total allowable catch (TAC) of 3,200t was set for the Scotian Shelf and southern Grand Banks (Fig 5). The TAC was reduced to 1500t in 1994, and was further reduced to 850t in 1995. In 1999, recommendations made by the Fisheries Resource Conservation Council (FRCC) resulted in an increase in the TAC from 850 to 1000 t. Annual TACs have increased several times since 2000 (Table 8). Average landings from 1960 to 2007 for Divs. 3NOPs4VWX have been approximately 1800t annually, with a range of just under 1000 to approximately 4200t (Table 8, Fig. 5). The TAC for 2009 was set at 1700t, and as of November 2009: 146t was caught in 3NOPs, 1191t in 4VWX, 13t in 5Zc, and totaling 1350t for the management unit. Catches from the halibut survey are included in the landings. Since 2007, these catches have also been counted against the TAC.

In 4RST, the TAC is divided between 8 geographic fleets within Quebec and the four Maritime provinces based on historic share (Table 9, DFO 2009a). Directed fishing for halibut is done by longline on a competitive basis. Since 2007, discarding undersized halibut (<81cm) caught in the cod directed longline fishery is mandatory in the Maritimes and prohibited in Quebec.

There is currently no directed Atlantic halibut fishery in US waters but halibut are landed (between 18 and 84t annually, between 1995-2007, Col and Legault, 2009) as bycatch in other groundfish fisheries (Kanwit, 2007). Foreign fleet landings are generally less than 20% of total landings.

Experimental aquaculture of Atlantic halibut was initiated in Norway and Iceland in the mid-1980s. Since the late-1990s there has been commercial production. Five countries report some level of Atlantic halibut aquaculture production: Canada, Norway, UK, Iceland and Chile. In 2005, aquaculture, mostly in Norway, produced close to 1000t of halibut (Glover et al. 2006). At present, there is one aquaculture operator in Nova Scotia, and it is the only year-round supplier in North America (http://www.dfo-mpo.gc.ca/aquaculture/finfish-poissons/halibut-fletan-eng.htm). In 2006, there was no selective breeding program in Europe (Glover et al. 2006), and

the majority of halibut production used wild captured individuals as broodstock. However, a breeding program to improve egg quality is being conducted as part of the Marine Finfish Reproduction and Broodstock Development Program at DFO's Biological Station in St. Andrews, NB (http://www.dfo-mpo.gc.ca/aquaculture/finfish-poissons/halibut-fletan-eng.htm).

6. OTHER

The Atlantic halibut is listed as endangered on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Sobel, 1996).

Size Composition

On Scotian Shelf and southern Grand Banks, both the median length and the 95th size percentile for both the DFO-Industry halibut survey (Fig. 47) and the commercial index (Fig. 48) has remained constant for the entire time series, suggesting that there has been no depletion of large fish from the population in the last 10 years.

Areas Closed to Fishing

Fishery Closure Areas

Since 2002, several areas in NAFO Divisions 2, 3, 4 and 5 have been closed to bottom fishing activities to protect corals, sponges and other vulnerable ecosystems (Table 10, Fig. 49). Closed areas in 3LMNO are temporary and will be reviewed by the Fisheries Commission in 2012. A portion of 4W (the haddock box) has been closed since 1987 to protect juvenile haddock. There are also seasonal closures of portions of Georges and Browns Bank to protect spawning groundfish. According to the conditions included in DFO fishing licenses, there are also seasonal closures for certain areas in the Gulf of St. Lawrence to protect spawning stocks, mainly cod. The impact of closed areas on Atlantic halibut had not been investigated.

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Table 1. Reported ages and lengths at maturity for Atlantic halibut (Hippoglossus hippoglossus).

Area	Age at 50% maturity,yr	Fork length at 50% maturity,cm	Reference
Gulf of St. Lawrence		130 ♀	DFO 2009a CSAS 2009/023
		115 ♀	DFO 2007 CSAS 2007/007
		75 ♂	
Scotian Shelf and Grand Bank		100 ♀	Kohler 1967
		66-70 ♂	
SA 4	10-12 ♀	110-119 ♀	McCracken 1958
	8-11♂	80♂	
Gulf of Maine-Georges Bank	7.3 ♀	103 ♀	Sigourney 2006
	6 ♂	80 ♂	
Newfoundland	12 ♀	119 ♀	Trumble et al. 1993
	8 ♂	77 ♂	
Grand Banks		115-120♀	Methven et al. 1992
		80 ♂	
Newfoundland and Labrador (1972-1984)	12 ♀	125 ♀	Bowering, 1986
	8 ♂	80 ♂	
Western North Atlantic	7-12 ♀	105-150♀	Miller et al. 1991
Iceland	>9 or 10 ♀ or ♂		Jespersen 1917
Faroese (1986-1986)	7 ♀	110-115 (18kg) ♀	Jákupsstovu and Haug 1988
	4.5 ♂	55 (1.7kg) ♂	
Northern Norway (1936-1938)	13 ♀		Haug and Tjemsland 1986
	12 ♂		
Northern Norway (1955-1960)	8-18 ♀		Devold 1938
	7-17 ♂		

Table 2. Cross tabulation of release and recapture by NAFO division of Atlantic halibut tagged as part of the most recent (2006-2008) DFO-Industry tagging program in 3NOPs4VWX. (n=2064, release period of 12 days to 4 years).

Release Area	Total Released	Return Area										Total Recaptured
		3N	3O	3P	4R	4T	4V	4W	4X	5Y	Unknown	
3N	201	5	44	2					2		4	57
3O	147		5	7	1						1	14
3P	410	1	8	63			10		2		6	90
4V	554		1	10	2	6	85	10			9	123
4W	463			3			4	35	6		13	61
4X	289			5			3	10	40	3	5	66
Total	2064	6	58	90	3	6	102	55	50	3	38	411

Table 3. Cross tabulation of release and recapture by NAFO division of Atlantic halibut tagged by commercial fishermen in the Gulf of St. Lawrence (4RST) and 3Pn between 1998 and 2008 (Diane Archambault, pers. comm.). The time between release and recapture events was between one day and 9 years.

		Return Area							
Release Area	**Total Released**	**3Pn**	**3Ps**	**4R**	**4S**	**4T**	**4Vn**	**Unknown**	**Total Recaptured**
3Pn	213	17	0	5	0	0	1	0	23
4R	5984	5	0	147	31	0	0	7	190
4S	127	0	0	0	12	0	0	0	12
4T	997	5	2	2	7	55	16	1	88
Total	7321	27	2	154	50	55	17	9	313

Table 4. Atlantic halibut bycatch reported by observers in the NAFO SA 0 Greenland halibut fishery since 1995. Observer coverage for the Division 0A fishery has been 100% since it began in 1999 but coverage for the Division 0B fishery has been incomplete, particularly for the fixed gear fleets so these figures do not represent total bycatch.

Year	Gear	Observed Sets	Bycatch (t)	Overall Bycatch (t)
2007	Trawl (single & double)		0	.
	Gillnet		0	0.000
2006	Trawl (single & double)	839	0.189	.
	Gillnet	898	0.015	0.204
2005	Trawl (single & double)	1196	0.228	.
	Gillnet	367	0.034	0.262
2004	Trawl (single & double)	1375	0	.
	Gillnet	10	0	0.000
2003	Trawl (single & double)	1442	0.190	.
	longline	675	0	0.190
2002	Trawl (single & double)	821	0.002	.
	Gillnet	71	0.014	.
	Longline	1100	0.152	0.168
2001	Trawl (single & double)	962	0	.
	Gillnet	30	0	0.000
2000	Trawl (single & double)	427	0.158	.
	Gillnet	71	0.513	.
	Longline	56	0.050	0.721
1999	Trawl (single & double)	610	0.431	.
	Gillnet	76	0.066	0.497
1998	Trawl (single & double)	527	1.564	.
	Gillnet	44	0.260	1.824
1997	Trawl (single & double)	1517	2.854	2.854
1996	Trawl (single & double)	1203	8.395	.
	Gillnet	60	0.051	8.446
1995	Trawl (single & double)	1000	1.593	.
	Gillnet	41	0.094	.
	Longline	280	2.565	4.252

Table 5. Atlantic halibut bycatch in the Northern shrimp fishery, DFO Shrimp Fishing Areas 0, 1, 2 and 3 since 1979 from observer data. Since 1985 observer coverage has been 100% so these figures represent total bycatch. The Nordmore grate used to separate finfish from the shrimp became mandatory in 1997.

Year	Observed Sets	Bycatch (t)
2007	1802	0
2006	2151	0
2005	2037	0
2004	3731	0
2003	2901	0.184
2002	3535	0
2001	3038	0.001
2000	3009	0
1999	3451	0.002
1998	2413	0.005
1997	3590	0.02
1996	4503	2.88
1995	1978	0.336
1994	3917	1.119
1993	3117	0.928
1992	5307	3.306
1991	6632	8.943
1990	4679	1.74
1989	7688	2.182
1988	3416	2.893
1987	1359	0.39
1986	2015	0.708
1985	1825	0.56
1984	1251	0.359
1983	1712	1.058
1982	2203	0.671
1981	4923	0.711
1980	511	0.523
1979	158	0.015

Table 6. Abundance and weight of sublegal, commercial and large Atlantic halibut in the longline and gillnet landings in 4RST (Table taken from DFO 2009).

Year (Gears)	Proportion (%) of total catches at sea					
	Sublegal size (<81cm)		Commercial size (≥81cm)		Large size (≥120cm)	
	Weight	Number	Weight	Number	Weight	Number
Longlines						
2007	11.60	34.06	88.40	65.94	32.22	8.07
2008	15.89	39.73	84.11	60.27	24.77	6.54
Gillnets						
2007	54.77	84.51	45.23	15.49	12.50	0.98
2008	45.13	86.54	54.87	13.46	14.06	1.34

Table 7. Linear regression of Atlantic halibut (Hippoglossus hippoglossus) catch per unit effort (catch per tows) from research trawl surveys on the Scotian Shelf, Gulf of St. Lawrence and the southern Grand Banks. Percent change (decline/increase) in the five-year average of the start and end of the survey. Trends were calculated without regard for vessel or gear changes. No trends were calculated for the southern Grand Banks because gear changes were large and not correction factor has been estimated.

Management Area	Years	Linear model			Percent change	Figure No.
		Intercept	Slope	P value		
4VWX (summer)	1970-2009	-2.567	0.001	0.311	74%	13a
4RST (northern)	1990-2009	-39.627	0.019	2.72×10^{-6}	2285%[1]	18a
4T (southern)	1971-2009	-17.609	0.008	9.65×10^{-8}	3220%	18a

[1]The number of fish caught per tow in 4T from 1971-1975 was 0, therefore a catch rate of 0.01 was assumed to calculate percent change.

Table 8. Total reported Canadian and foreign landings (t) of Atlantic halibut from NAFO divisions 3NOPs4VWX5Zc[1]. Ten year annual average landings are presented for 1960 to 1999.

	Year(s)	3NOPs	4VWX	5Zc	3NOPs4VWX5Zc Landings[2]	TAC[3] (3NOPs4VWX5Zc)
Avg	1960-69	996	1464		2460	
Avg	1970-79	488	850		1338	
Avg	1980-89	955	1561	50	2536	
Avg	1990-99	503	790	30	1323	1855
	2000	397	541	6	944	1000
	2001	641	761	11	1413	1150
	2002	682	768	10	1460	1150
	2003	982	819	14	1815	1300
	2004	554	873	12	1439	1300
	2005	483	825	9	1317	1375
	2006	452	916	10	1378	1475
	2007	558	944	32	1534	1475
	2008	450	979	29	1458	1475
	2009					1700

[1] Landings from NAFO Table 21A dated 2 September 2009.
[2] Landings from 2000 to present are based on calendar year, and do not correspond to the April-March fishing year.
[3] The Total Allowable Catch (TAC) from 2000 to present was set for April through March.

Table 9. Atlantic halibut landings in the Gulf of St. Lawrence, NAFO Divs. 4RST (Table taken from DFO 2009a).

Division	Year						
	1988-2002[1]	2003	2004	2005	2006	2007	2008[2]
TAC	300-350	350	350	350	350	475	475
4R	85	138	140	155	144	142	243
4S	86	87	141	82	101	163	126
4T	93	82	135	177	144	127	145
Total	263	307	416	413	388	432	514

[1] *Average*
[2] *Preliminary data as of December 31, 2008*

Table 10. Closure areas which may affect Atlantic halibut fisheries in NAFO divisions 2, 3, 4 and 5.

Name	Management Area	Size (km2)	Intent	Year established	Restrictions
Groundfish Closure Area 2J	2J	8585		2002	No commerical fishing except crab
Funk Island Deep Box	3K			2002	No bottom Trawling, no gill netting
Coral closure areas (8): Flemish Cap	3LM		Protect corals		No bottom fishing activities
Sponge closure areas (11): Flemish Cap, Flemish Pass, Beothuk Knoll, Sackville Spur, Tail of Grand Bank	3LMN		Protect sponges and corals	January 2010-December 2011	No bottom fishing activities
Coral closure area	3O		Protect corals	2008-2012	No bottom fishing activities
	3Ps		Protect corals		No fishing in water <91m by vessels <65ft
	3Ps cdefgh		Protect corals		No halibut fishing by vessels <65ft
	3Ps ab		Protect corals		Fishing by vessels <65ft restricted to west of Boxey Point in Fortune Bay
Gully (Zone 1)	4VsW	476	Marine Protected Area	2004	All fishing activities
Coral Closure	4Vs	15	Protect *Lophelia*	2004	No bottom fishing activities
	4Vs[4Vsb]	14,764			Seasonal closure to bottom fishing Jan 1-April 30
Northeast Channel Coral Conservation Area	4X+5ZE	424	Protect octocorals	2002	No bottom fishing activities
Haddock Box	4W	12,777	Protect juvenile haddock	1987	All groundfish fishing since 1993 (scallop fisheries allowed)
Browns Bank	4Xnop	12,495	Protect spawning haddock	1972	Seasonal closure to groundfish fisheries Feb 1- June 15
Fogo Seamounts (2)	3O+4Vs			2008	No bottom fishing activities
Georges Bank	5Z	14,452	Protect spawning fish	Circa 1980	Seasonal closure to groundfish fisheries Mar 1-May 31

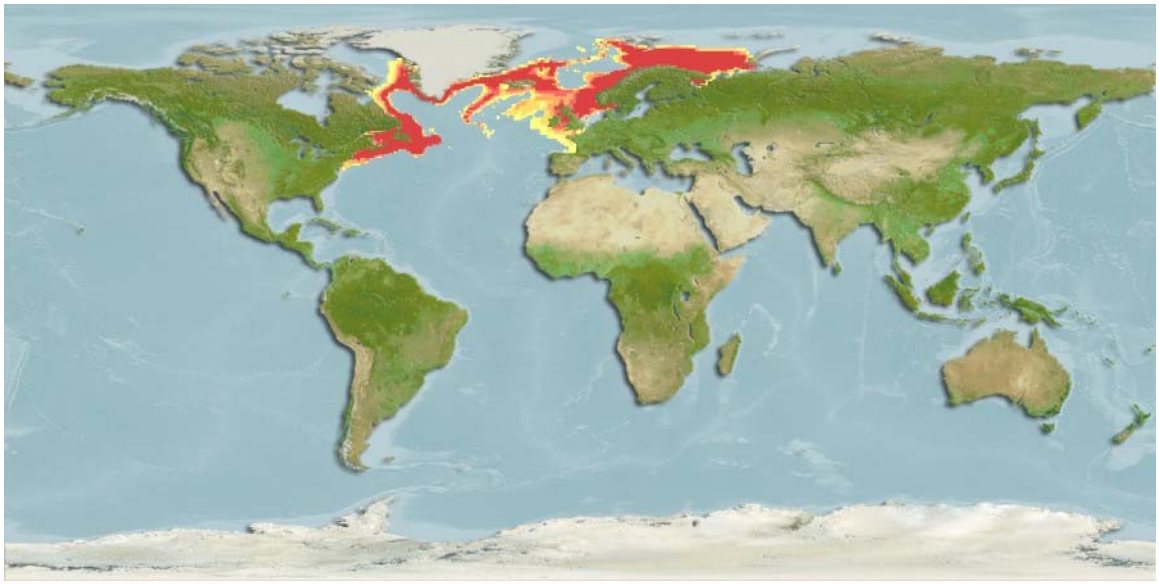


Figure 1. Computer generated native distribution map of Atlantic halibut (Hippoglossus hippoglossus). The bias of sampling points in US waters was balanced by extending the preferred values of envelopes as follows: salinity p max=35, temperature p min=0, primary productivity p min=100. Additionally depth p min was set to 51 (Jonathon Ready, 2009-02-05).

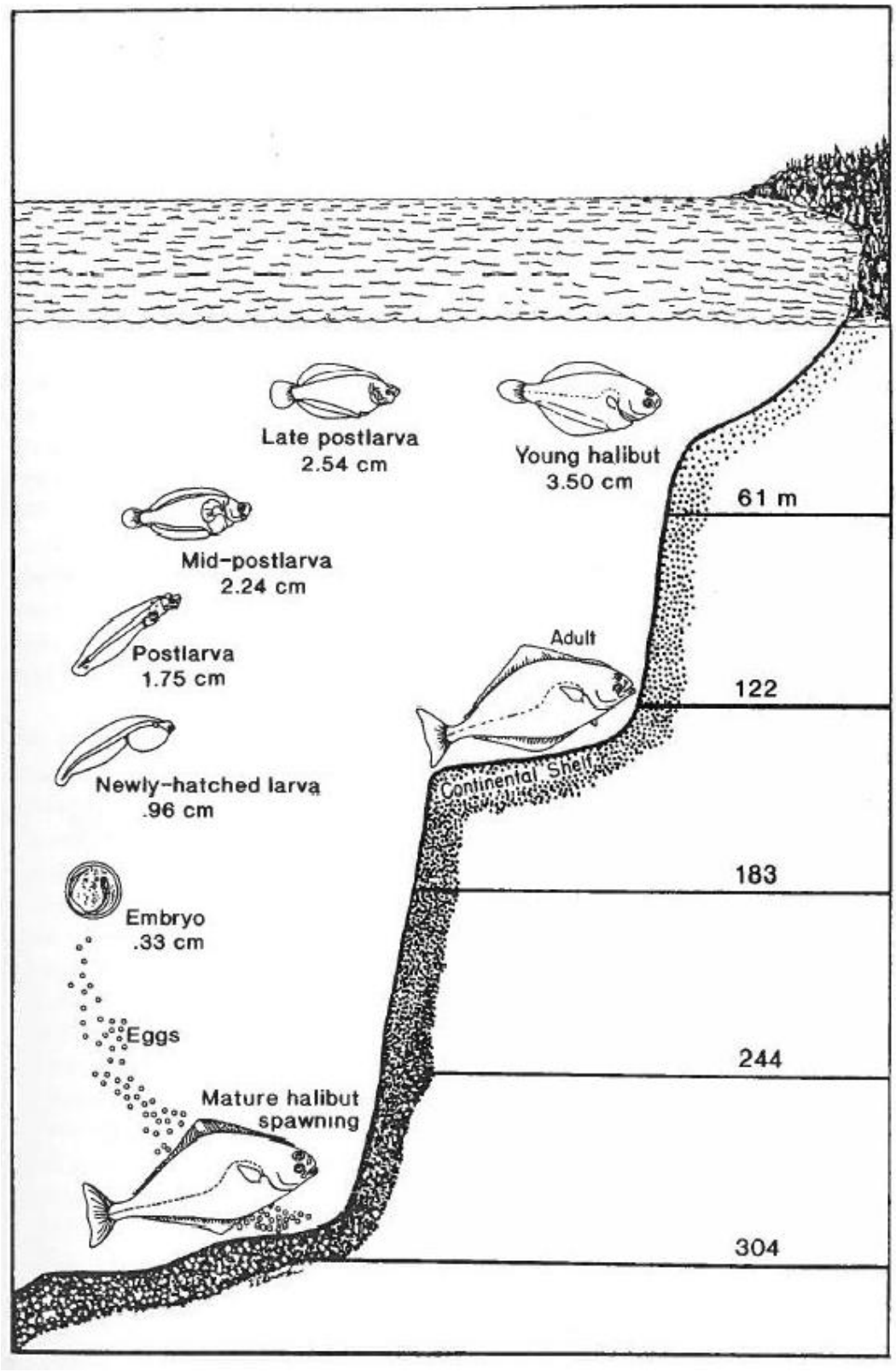


Figure 2. Life cycle of Pacific halibut (Hippoglossus stenolepis) (Taken from Trumble et al. 1993).

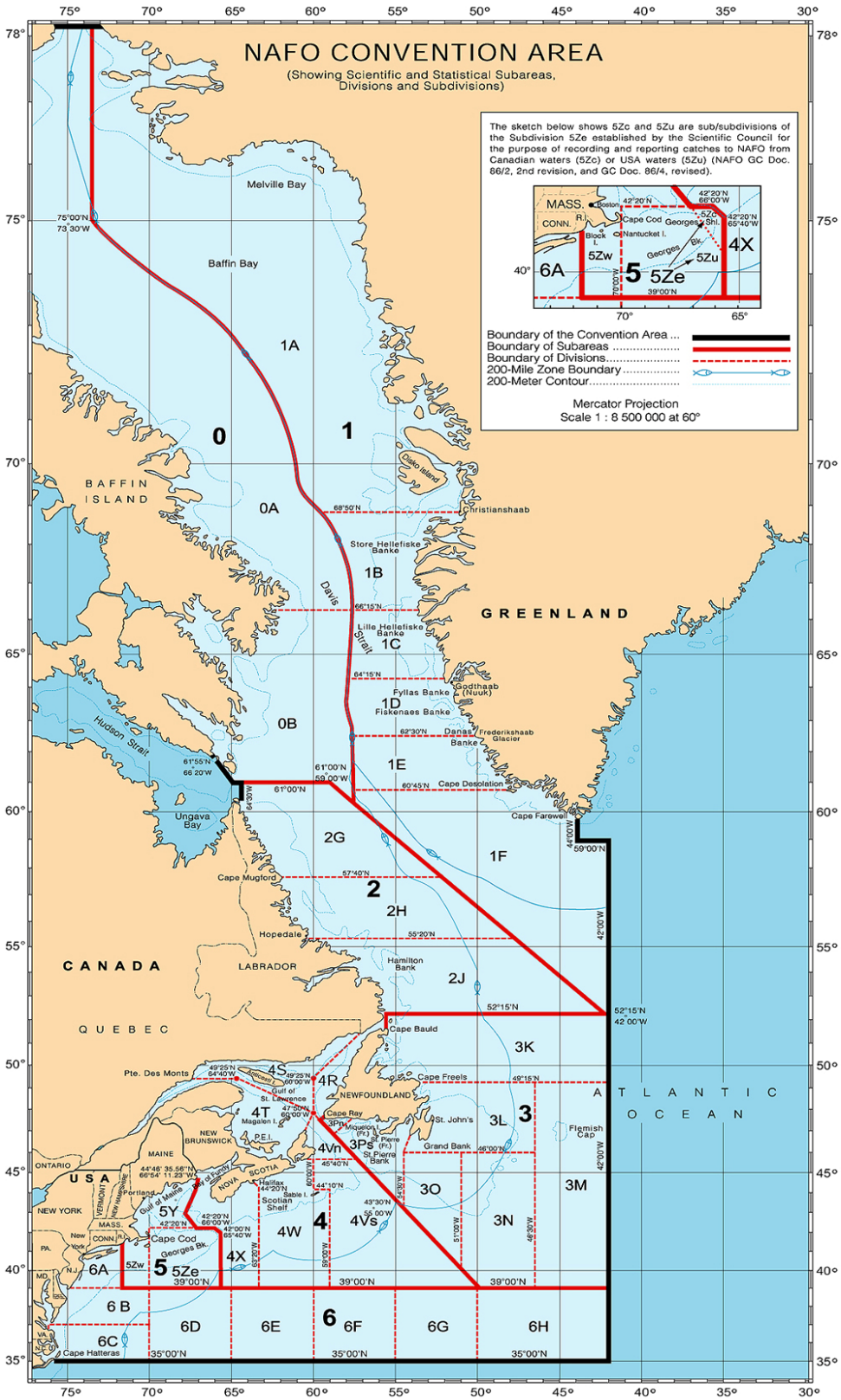


Figure 3. Map of NAFO divisions and the territorial areas.

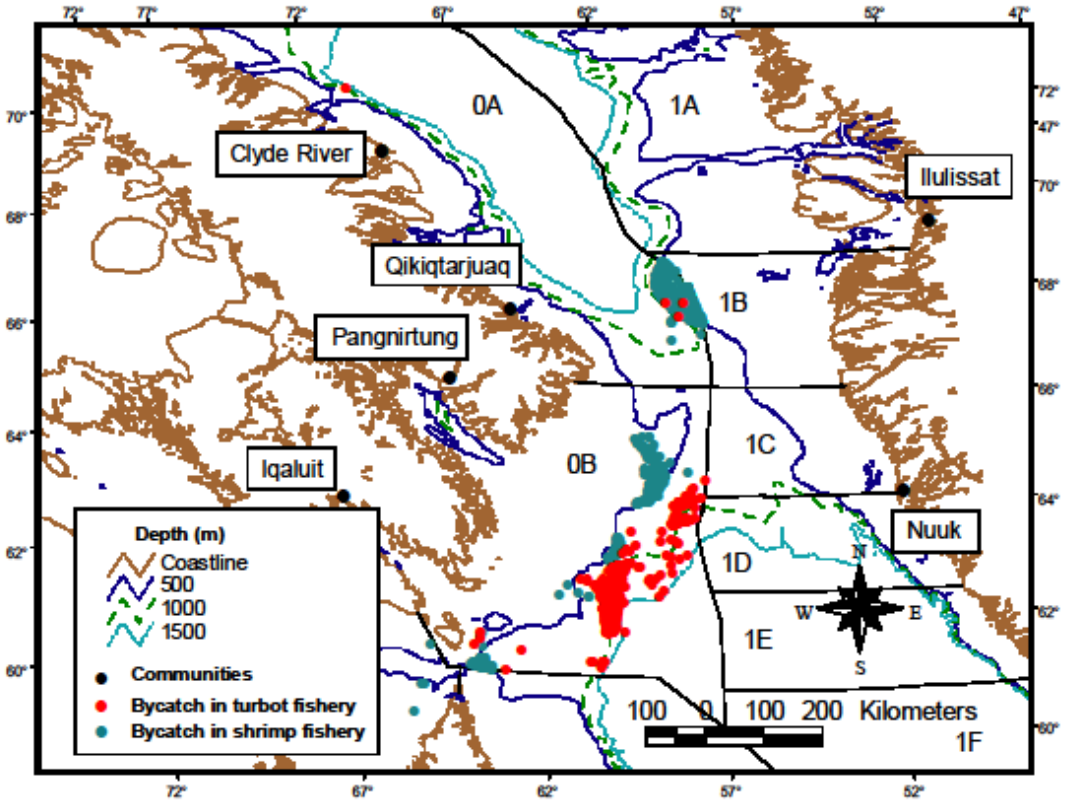


Figure 4. Distribution of Atlantic halibut bycatch in northern shrimp (1979-2007) and Greenland halibut (1995-2007) fisheries off the east coast of Baffin Island. Data are from onboard observers with varying coverage levels among the fisheries and fleets.

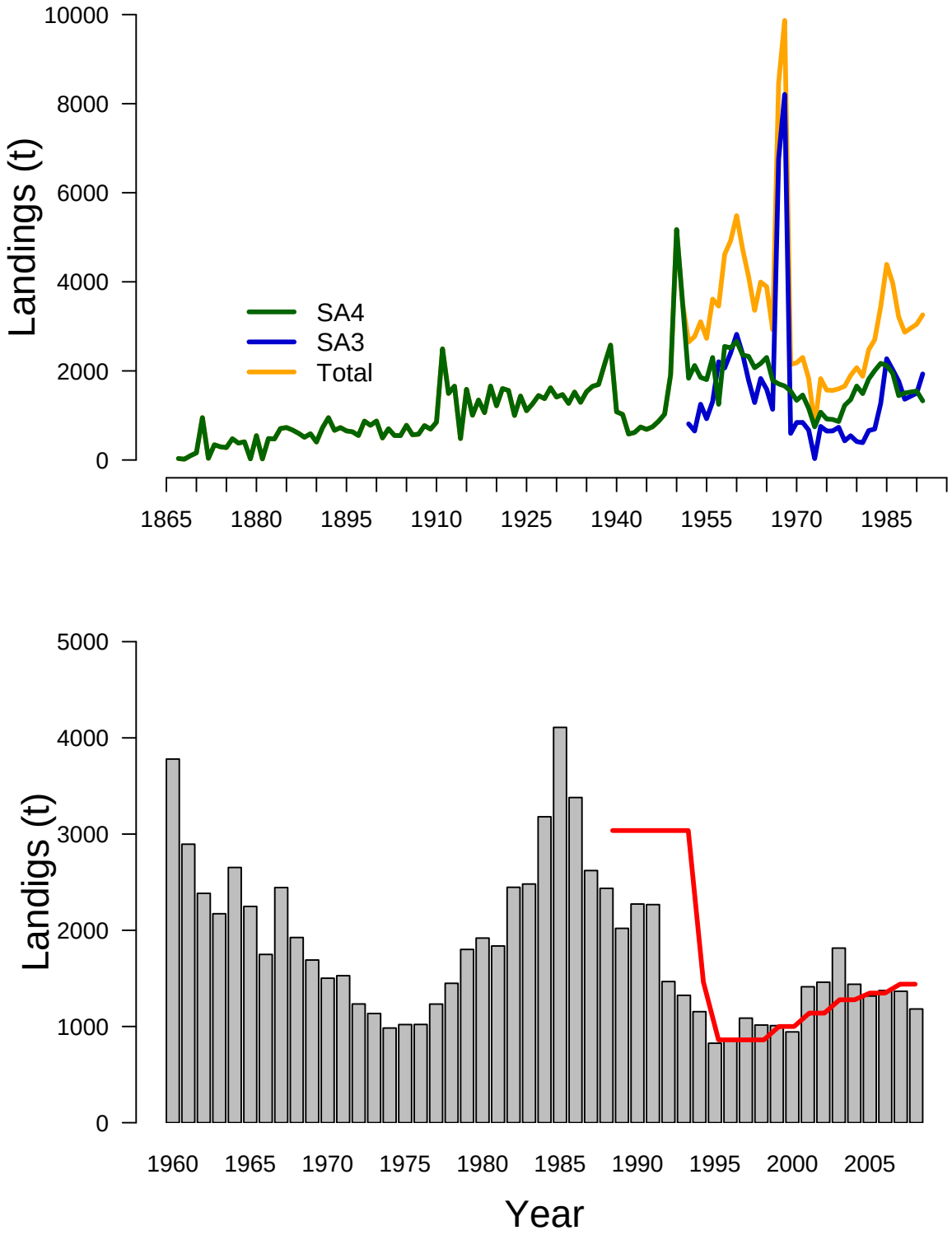


Figure 5. A) Atlantic halibut landings in Nova Scotia, New Brunswick, Prince Edward Island, and Quebec (SA4) and Newfoundland (SA3). The spike seen in the mid-1960s is believed to be due to the inclusion of Greenland halibut landings data. B) Atlantic halibut landings in NAFO Divs. 3NOPs4VWX5Zc and Total Allowable Catch (TAC) in red. A correction was applied to account for the inclusion of Greenland halibut landings data in the mid-1960s.

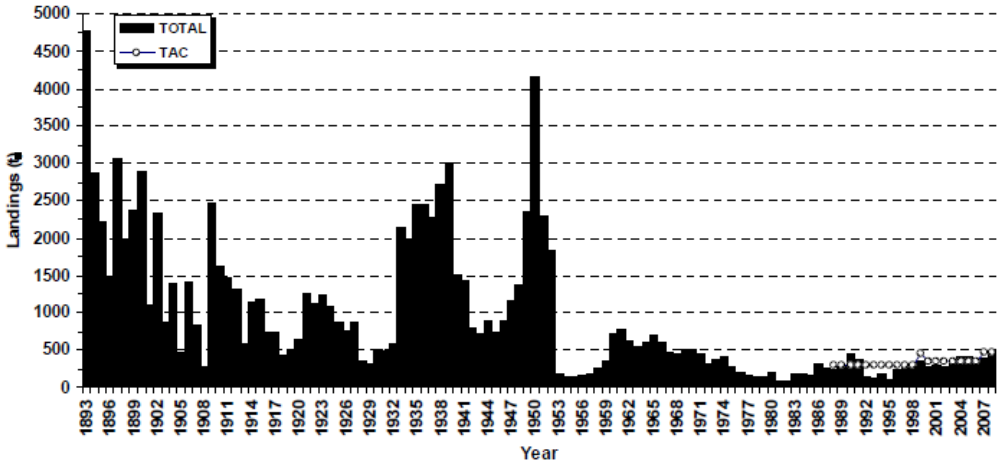


Figure 6. NAFO Divs. 4RST Atlantic halibut annual landings (t) and Total Allowable Catches (TAC). The 2008 data are preliminary. (Figure taken from DFO 2009a).

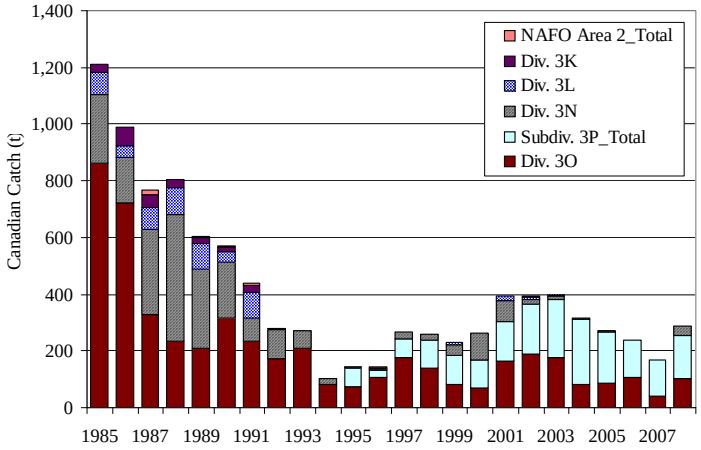


Figure 7. Canadian commercial landings of Atlantic halibut in NAFO SA 2, Divisions 3KLNO, and Subdivision 3P, 1985-2008. Data do not include discards at sea. Landings were tabulated from ZIF, and the 2008 statistics are preliminary.

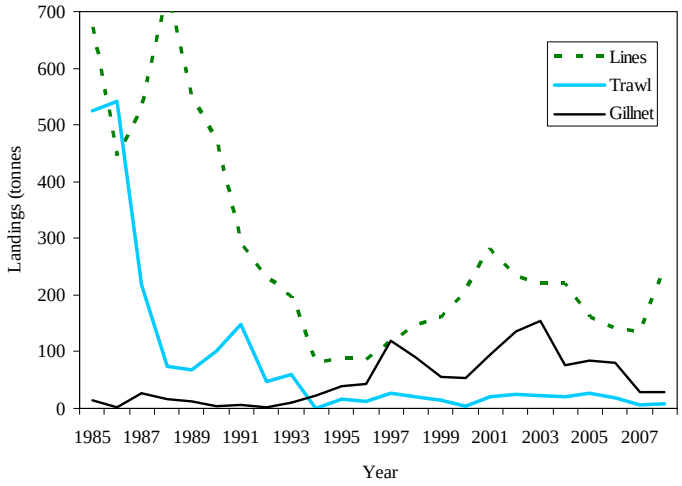


Figure 8. Canadian commercial landings of Atlantic halibut by gear type in NAFO SA 2, Divisions 3KLNO, and Subdivision 3P, 1985-2008. Data do not include discards at sea. Landings were tabulated from ZIF. The 2008 statistics are preliminary.

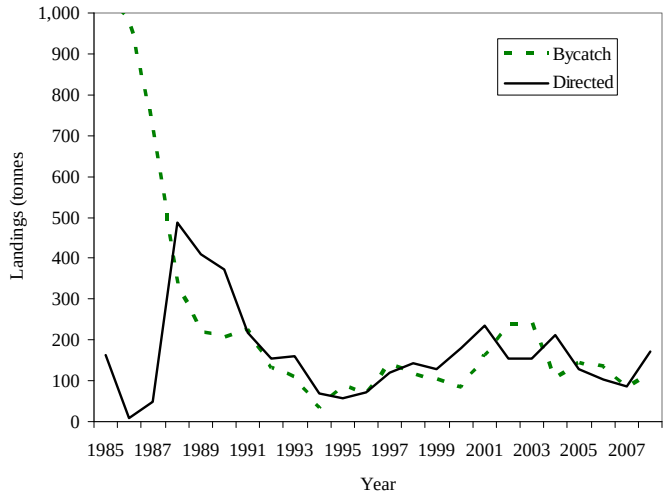


Figure 9. Directed and non-directed Canadian commercial Atlantic halibut landings in NAFO SA 2, Divisions 3KLNO, and Subdivision 3P, 1985-2008. Data do not include discards at sea. Landings were tabulated from ZIF. The 2008 statistics are preliminary.

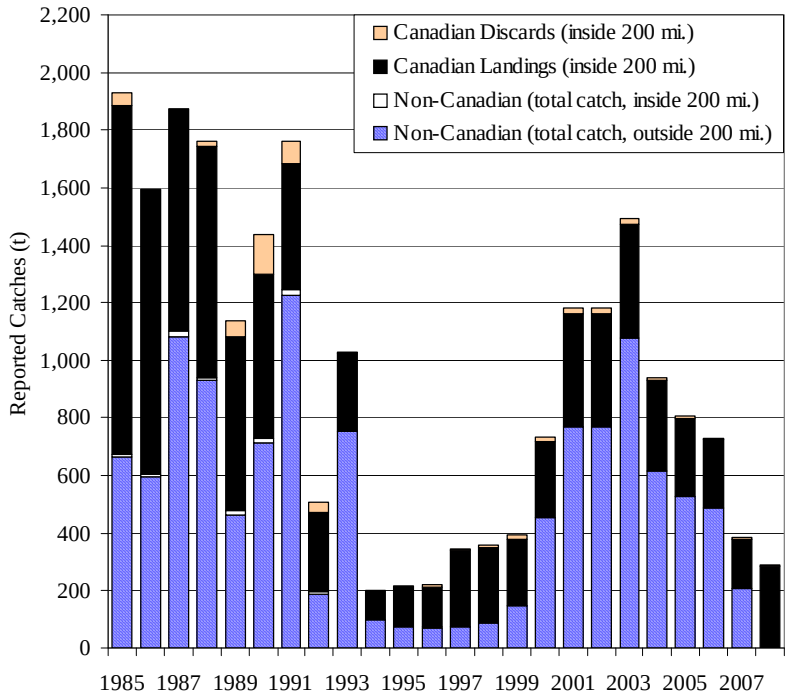


Figure 10. Commercial landings of Atlantic halibut in NAFO SA 2, Divisions 3KLNO, and Subdivision 3P, 1985-2008. Canadian landings were tabulated from ZIF; discards and non-Canadian catches inside Canada's 200-mile limit were estimated from at-sea Canadian Fisheries Observers data, and non-Canadian catches outside the 200-mile limit were collated from NAFO–reported catches (Statlant-21A). The 2008 statistics are preliminary.

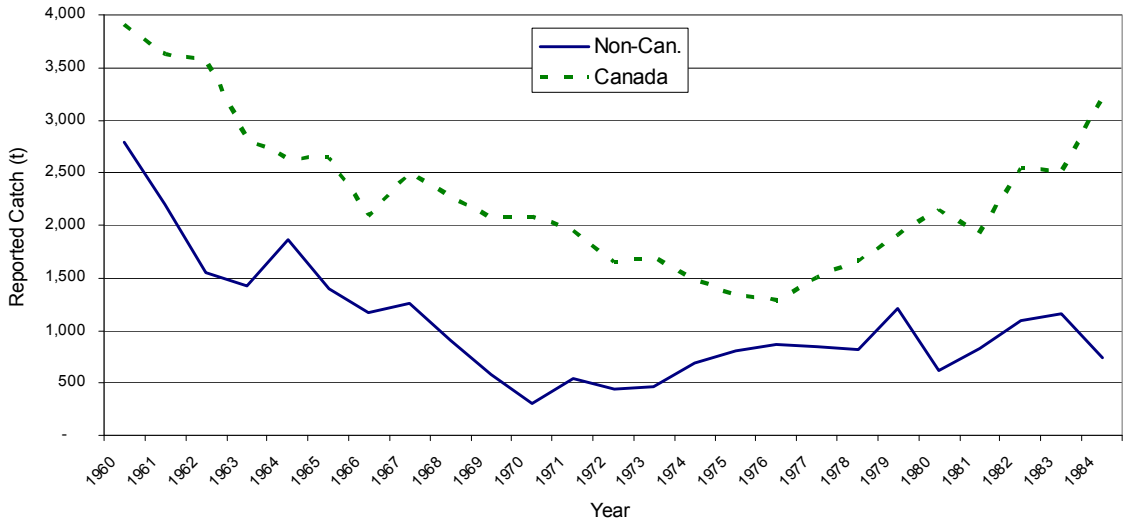


Figure 11. Canadian and non-Canadian commercial catches of Atlantic halibut in NAFO SAs 1 and 2, Divisions 3KLMNO, and Subdivision 3P, 1960-1984. Data do not include discards at sea. Data were collated from NAFO–reported catches (Statlant-21A).

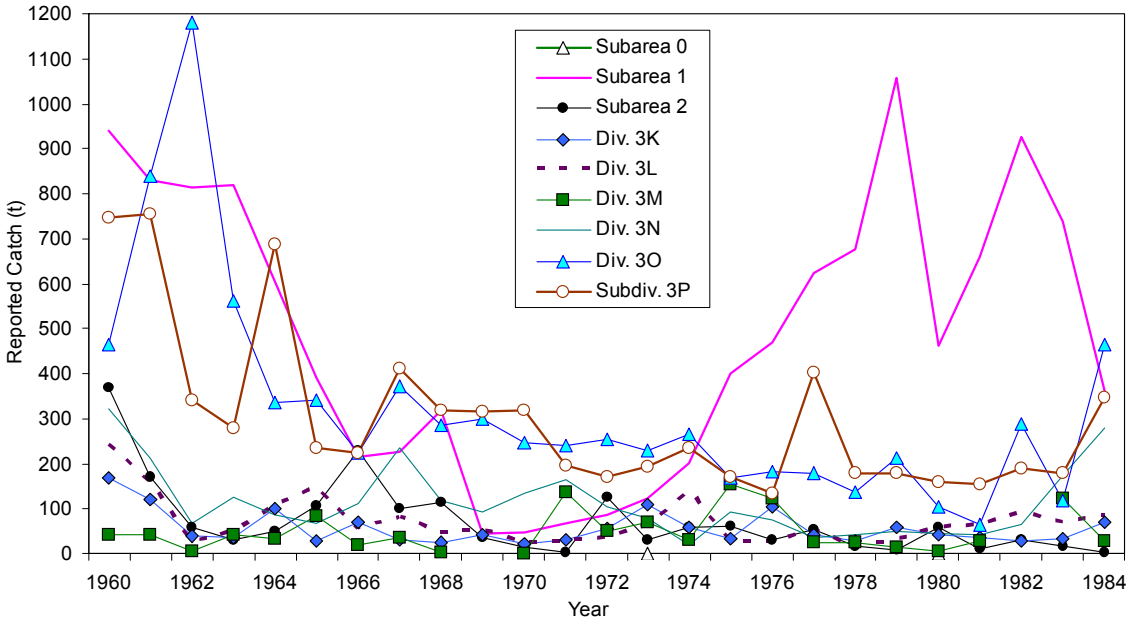


Figure 12. Historical catches (all countries combined) of Atlantic halibut in NAFO SAs 0, 1, and 2, Divisions 3KLMNO, and Subdivision 3P, 1960-1984. Data do not include discards at sea. Data were collated from NAFO–reported catches (Statlant-21A).

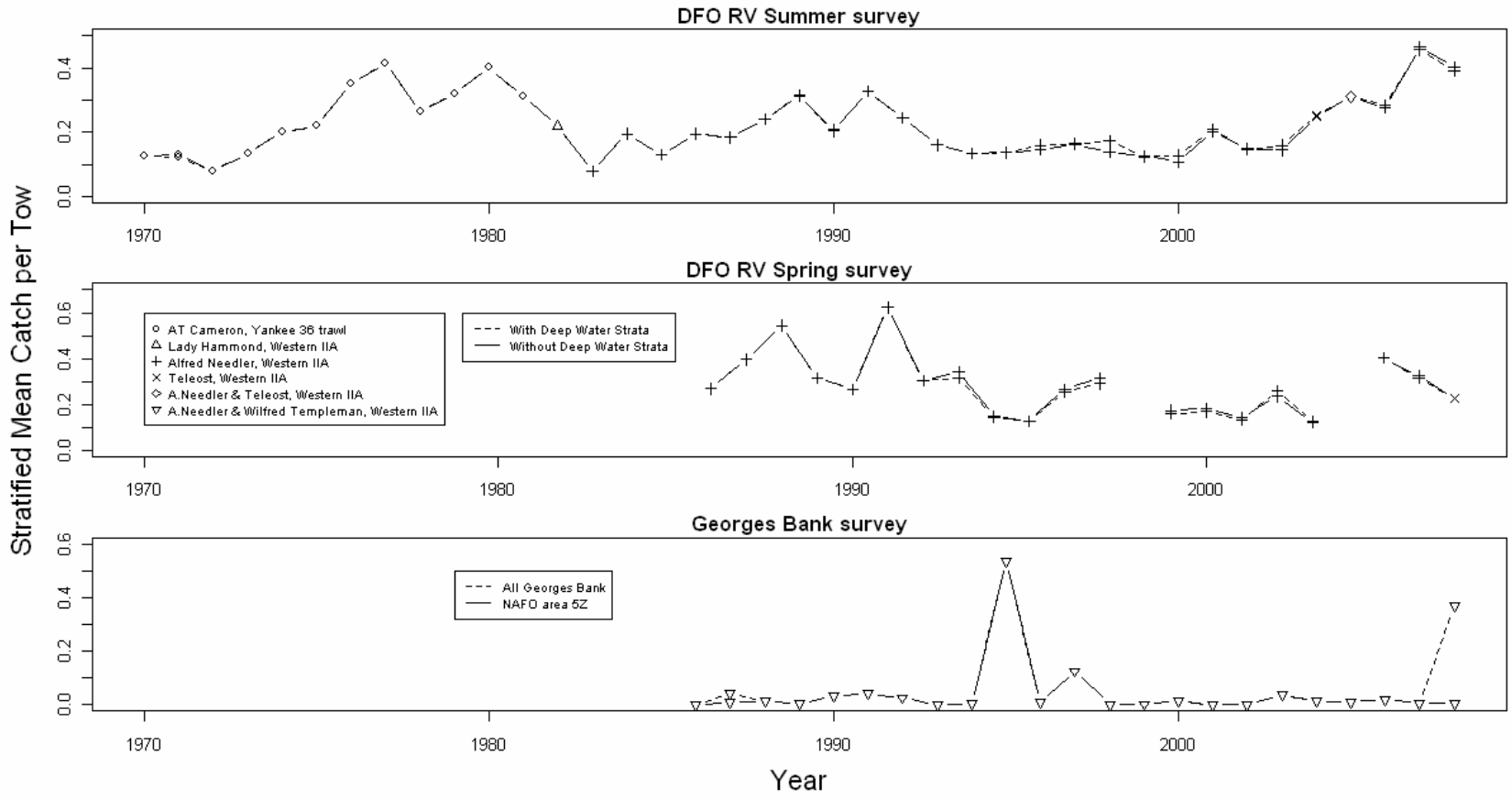


Figure 13. The stratified mean catch per tow of Atlantic halibut for three DFO groundfish trawl surveys: Top: Summer 4VWX (1970-Present), Middle: Spring (4VWCod) (1986-Present), and Bottom: Georges Bank (1986-Present). The various vessels and gear type combinations are indicated by the symbols defined in the legend. The summer and spring surveys are plotted with and without deepwater strata, and the Georges Bank Survey is plotted in total and with just the sets in NAFO 5Z. The spring survey was not conducted in 1998 and 2004.

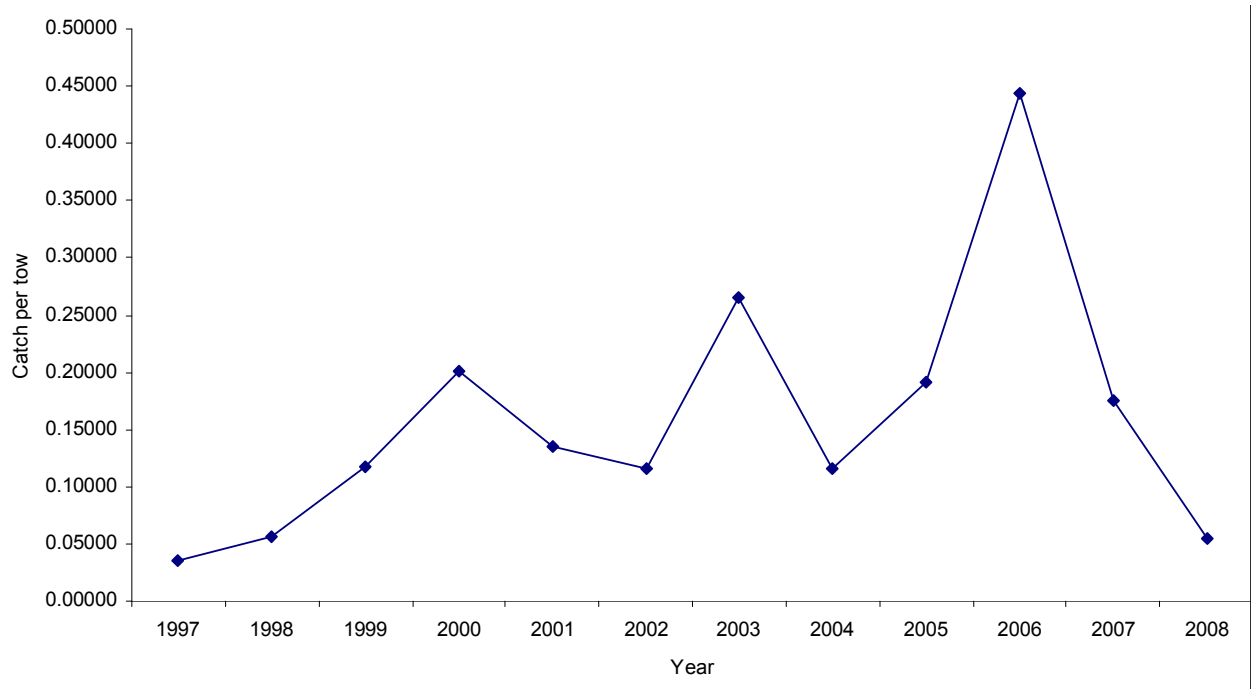


Figure 14. The stratified mean catch per tow of Atlantic halibut in the ITQ survey in 4X. Only catches since 1997 were plotted as the survey was modified after the first year (1995) and the data are not available for 1996.

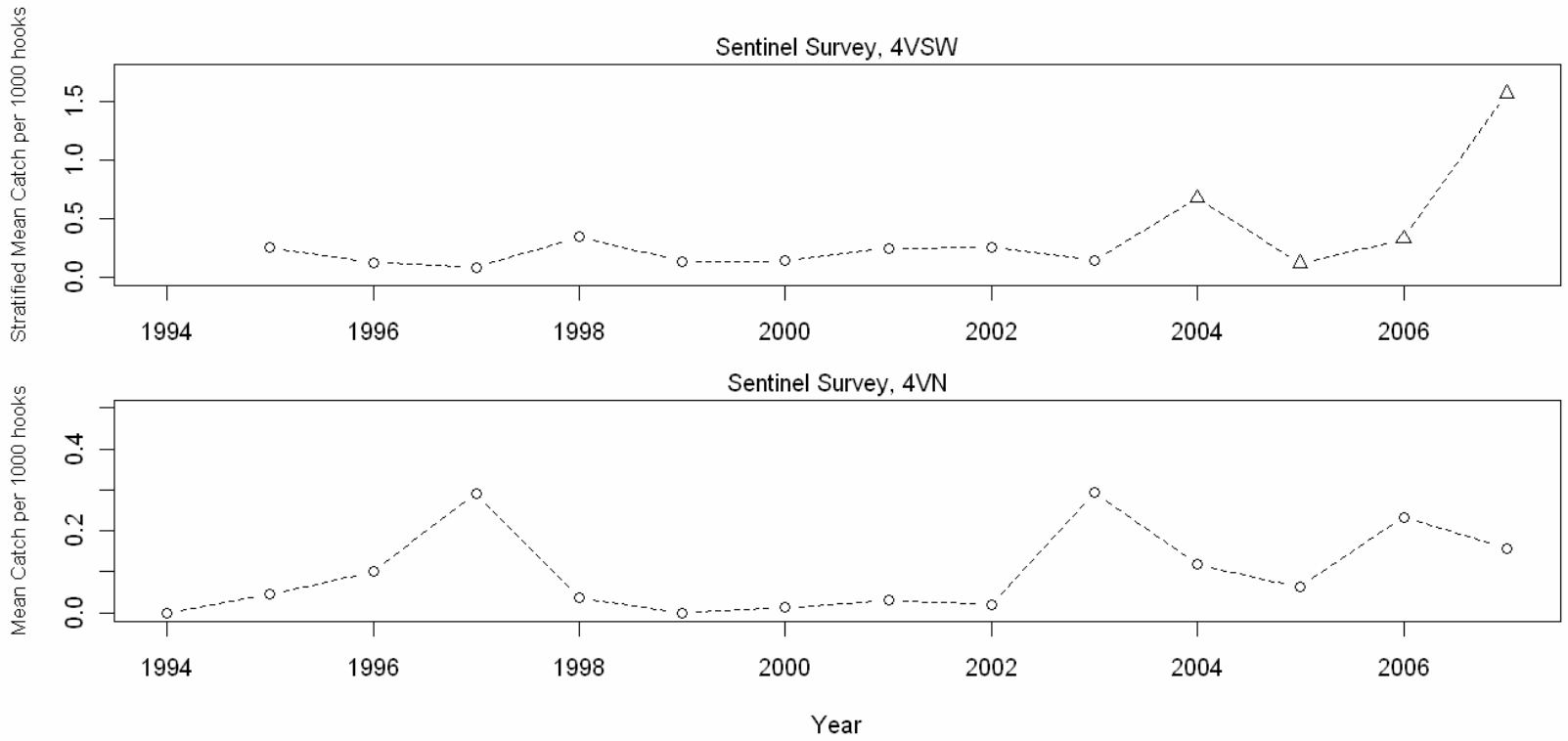


Figure 15. The catch per set of Atlantic halibut for two DFO-Industry stratified random longline surveys: 4VsW and 4Vn sentinel surveys. The stratified mean number per 1000 hooks is plotted for the 4VsW survey, and the mean catch per 1000 hooks is plotted for the 4Vn survey. Note that the area surveyed in 4VsW changed in 2004.

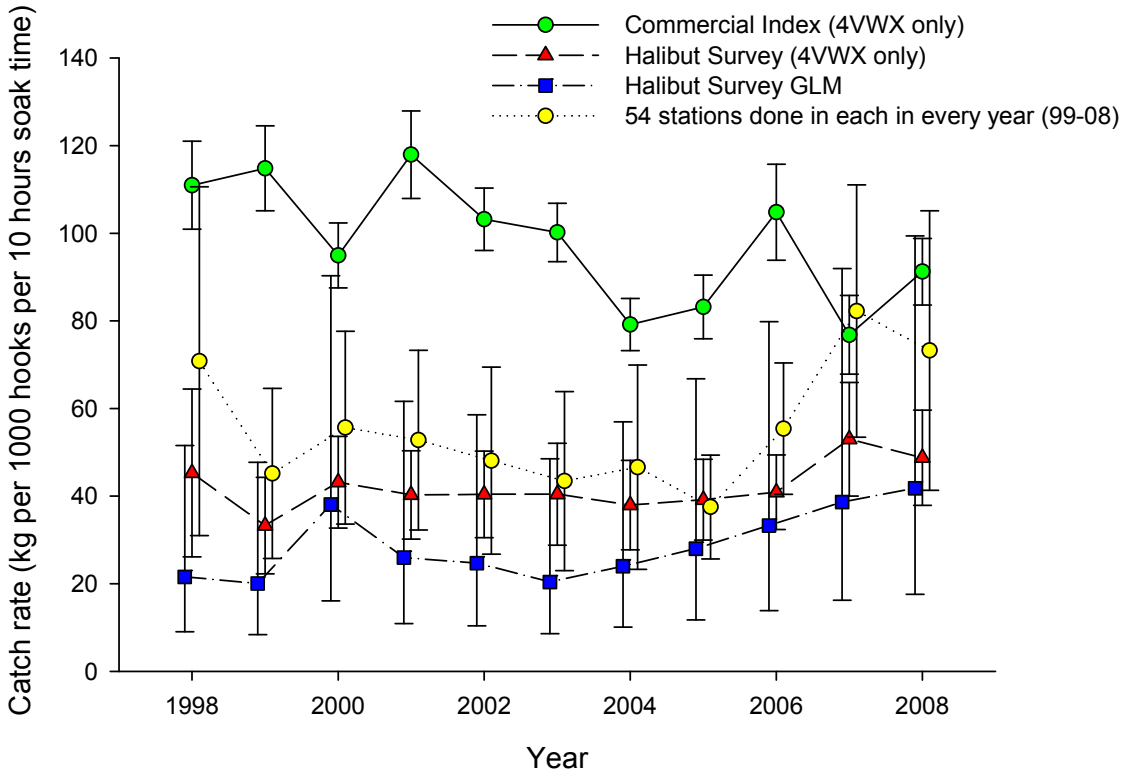


Figure 16. Trends in the Atlantic halibut catch rates (+/- 2SE) from the commercial index and halibut survey. The survey was analyzed three different ways: All stations in 4VWX, the 54 stations that have been covered each year since 1999, and all stations covered five or more years and standardized with a GLM.

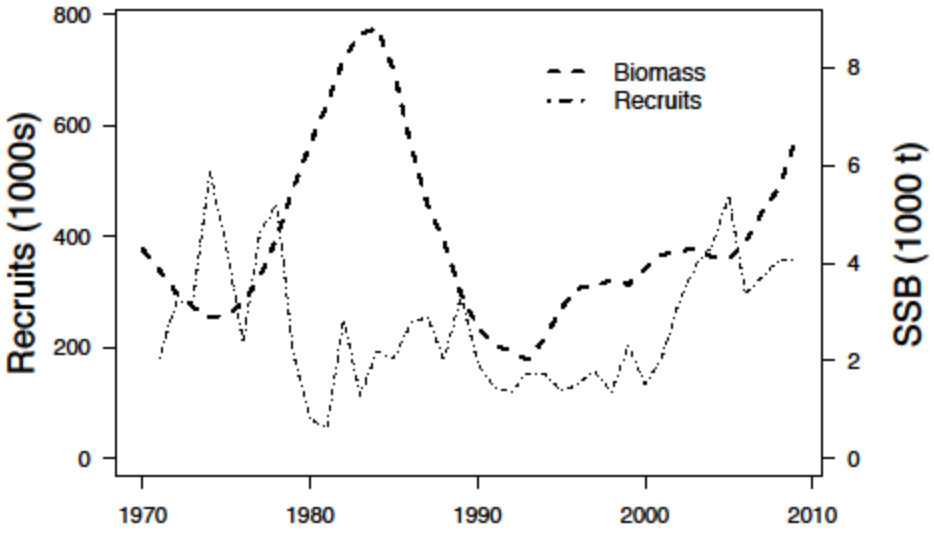


Figure 17. Estimates of spawning stock biomass and age-1 (Figure taken from Trzcinski et al. 2011).

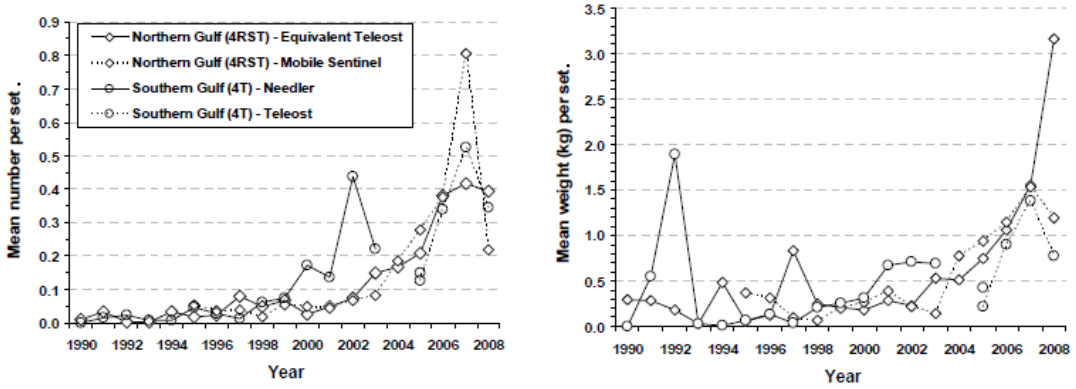


Figure 18. Abundance and biomass indices for Atlantic halibut calculated from summer research vessel (RV) trawl surveys in NAFO division 4RST between 1990 and 2008. No halibut were caught in 4T between 1971 and 1979, and from 1980 to 1989 the catch rate was under 0.05 mean number per set.

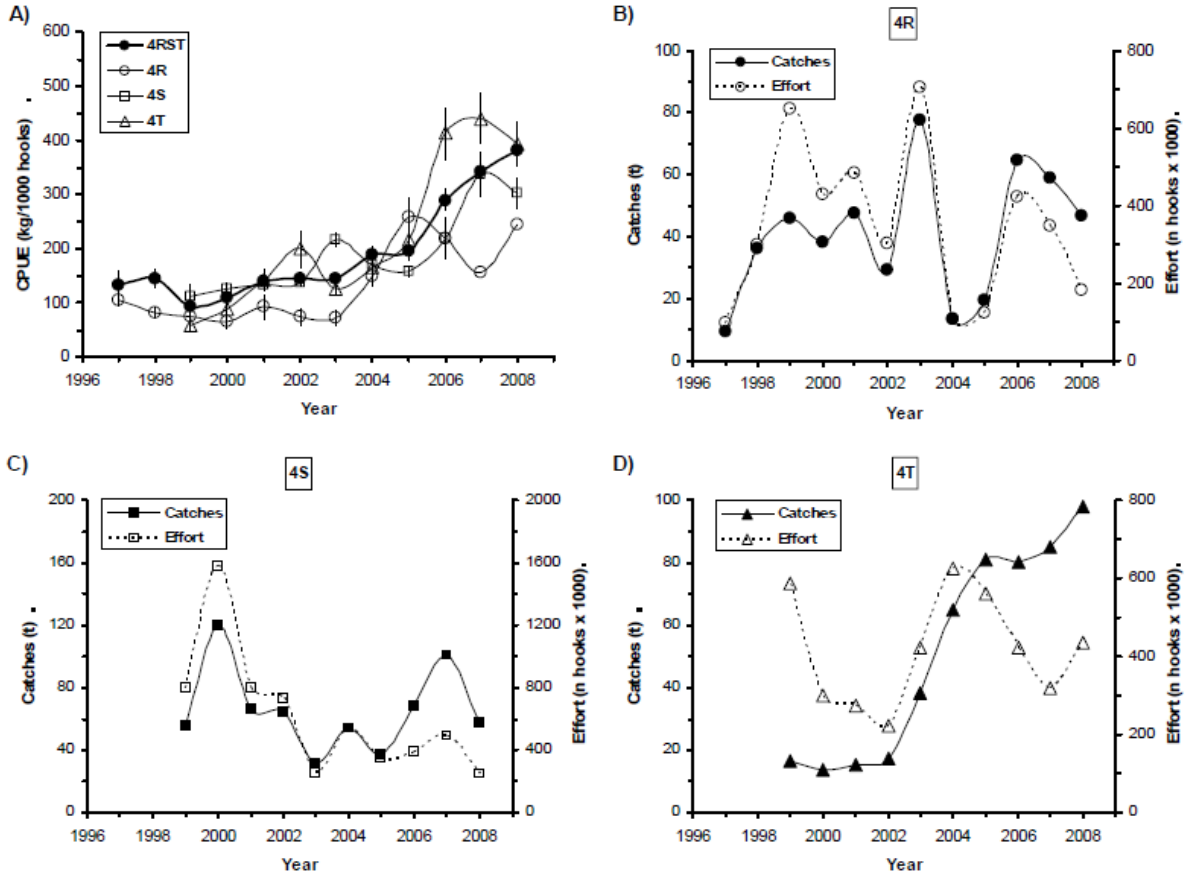


Figure 19. Atlantic halibut directed longline commercial fishery indicators, per NAFO Div. 4RST from 1997 to 2008. (A) Standardized annual catch per unit effort. (B-D) Annual catches and efforts.

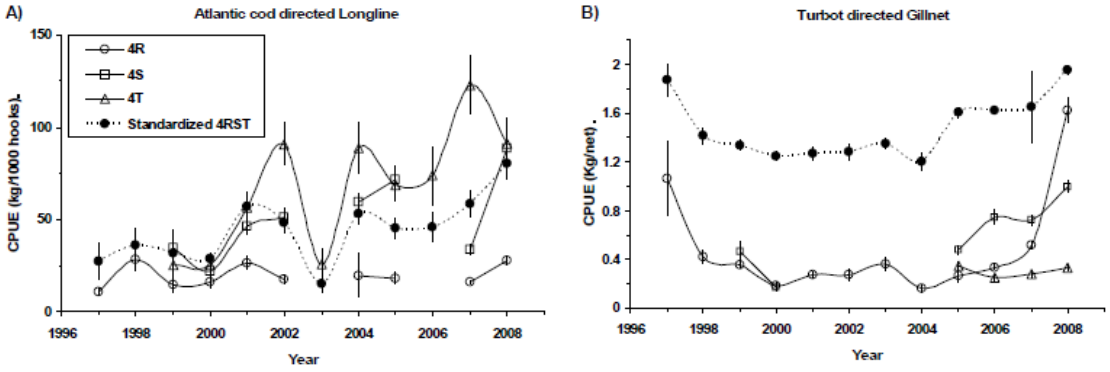
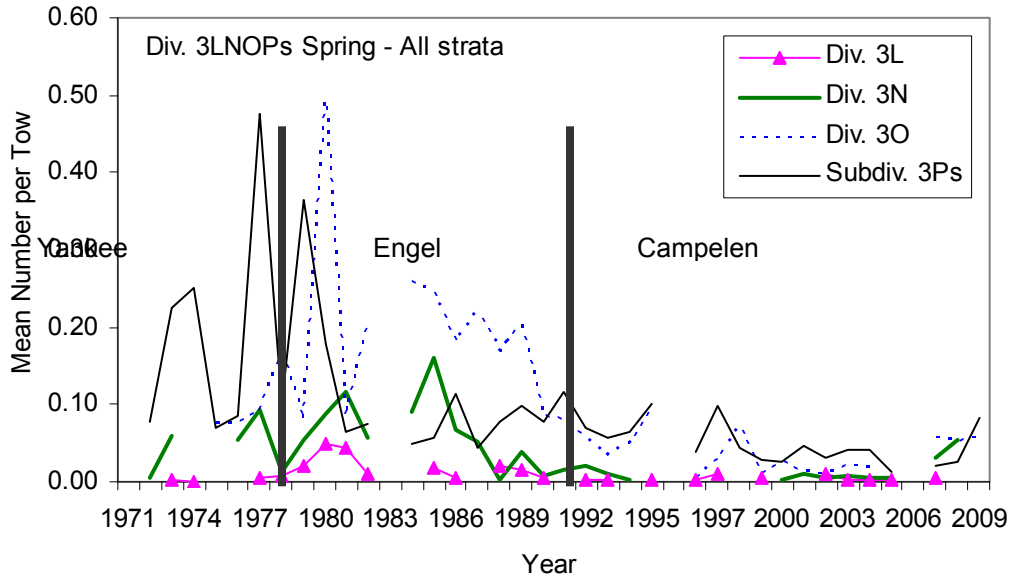


Figure 20. Atlantic halibut catch rates in the cod and turbot commercial fishery in NAFO Div. 4RST from 1997 to 2008. A) Annual catch per unit effort for the Atlantic Cod directed longline fishery. B) Annual catch per unit effort for the turbot directed gillnet fishery.

A)



B)

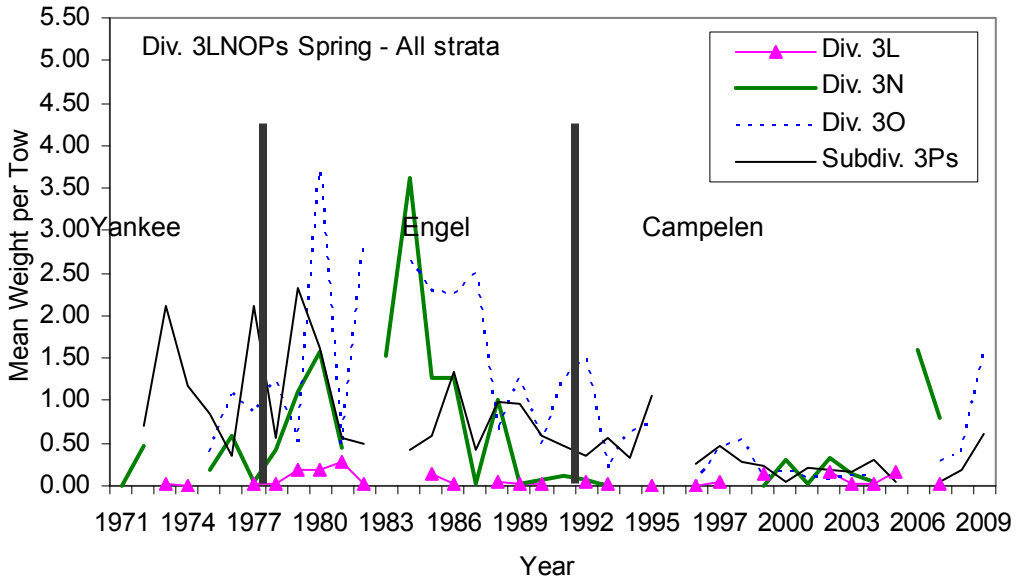
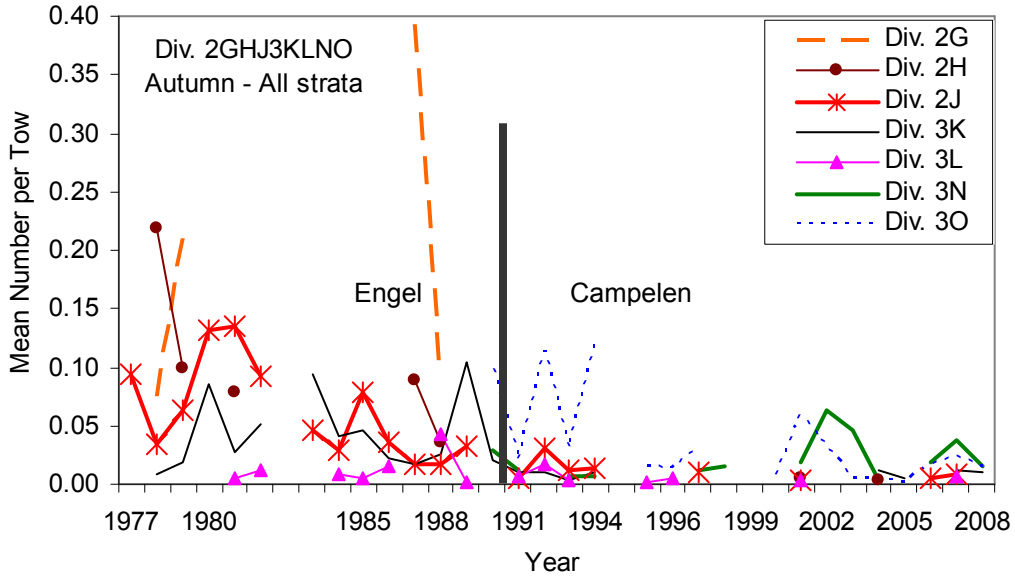


Figure 21. (A) Catch rates of Atlantic halibut (mean numbers per tow) in NAFO Div. 3LNO and Subdiv. 3Ps from DFO-NL spring research vessel surveys, 1972-2009. (B) Catch rates of Atlantic halibut (mean weight per tow in NAFO Div. 3LNO and Subdiv. 3Ps from DFO-NL spring research vessel surveys, 1972-2009.

A)



B)

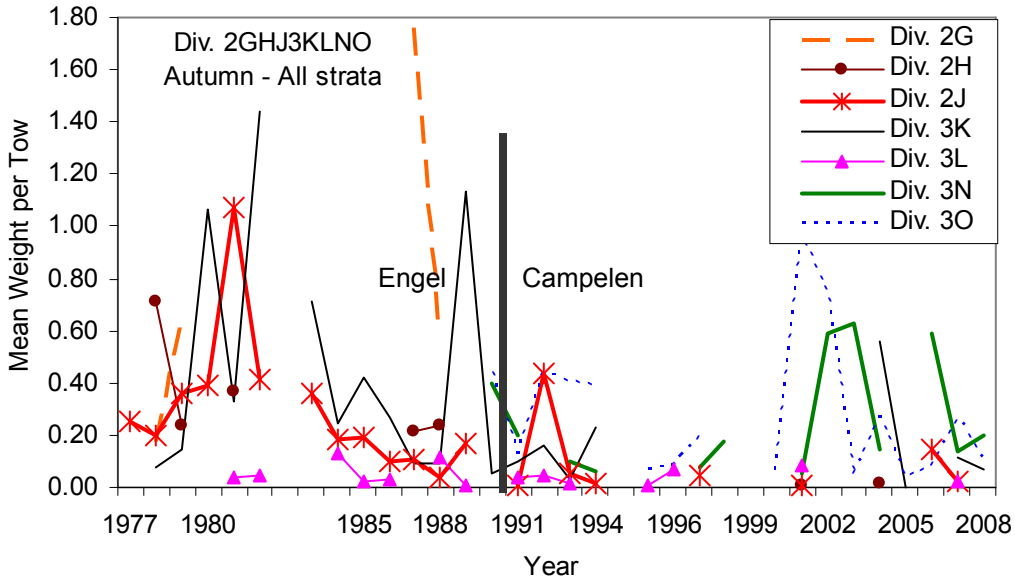


Figure 22. (A) Catch rates of Atlantic halibut (mean numbers per tow) in NAFO Div. 2GHJ and Div. 3LNO from DFO-NL fall research vessel surveys, 1978-2009. (B) Catch rates of Atlantic halibut (mean weight per tow in NAFO Div. 2GHJ and Div. 3LNO from DFO-NL fall research vessel surveys, 1978-2009.

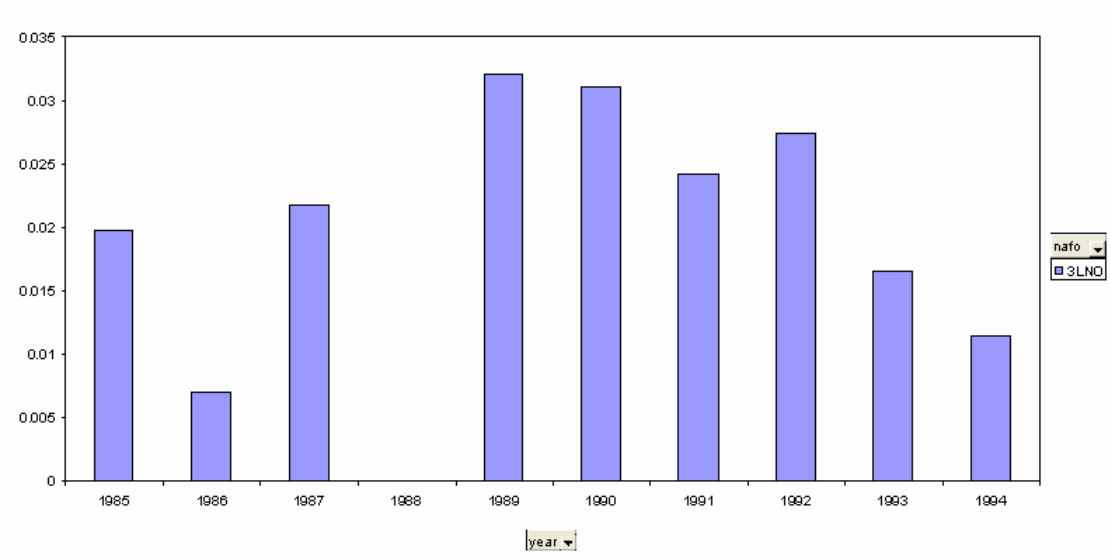


Figure 23. Catch rates of Atlantic halibut in NAFO Div. 3LNO from DFO-NL juvenile flatfish research vessel surveys, 1985-1994.

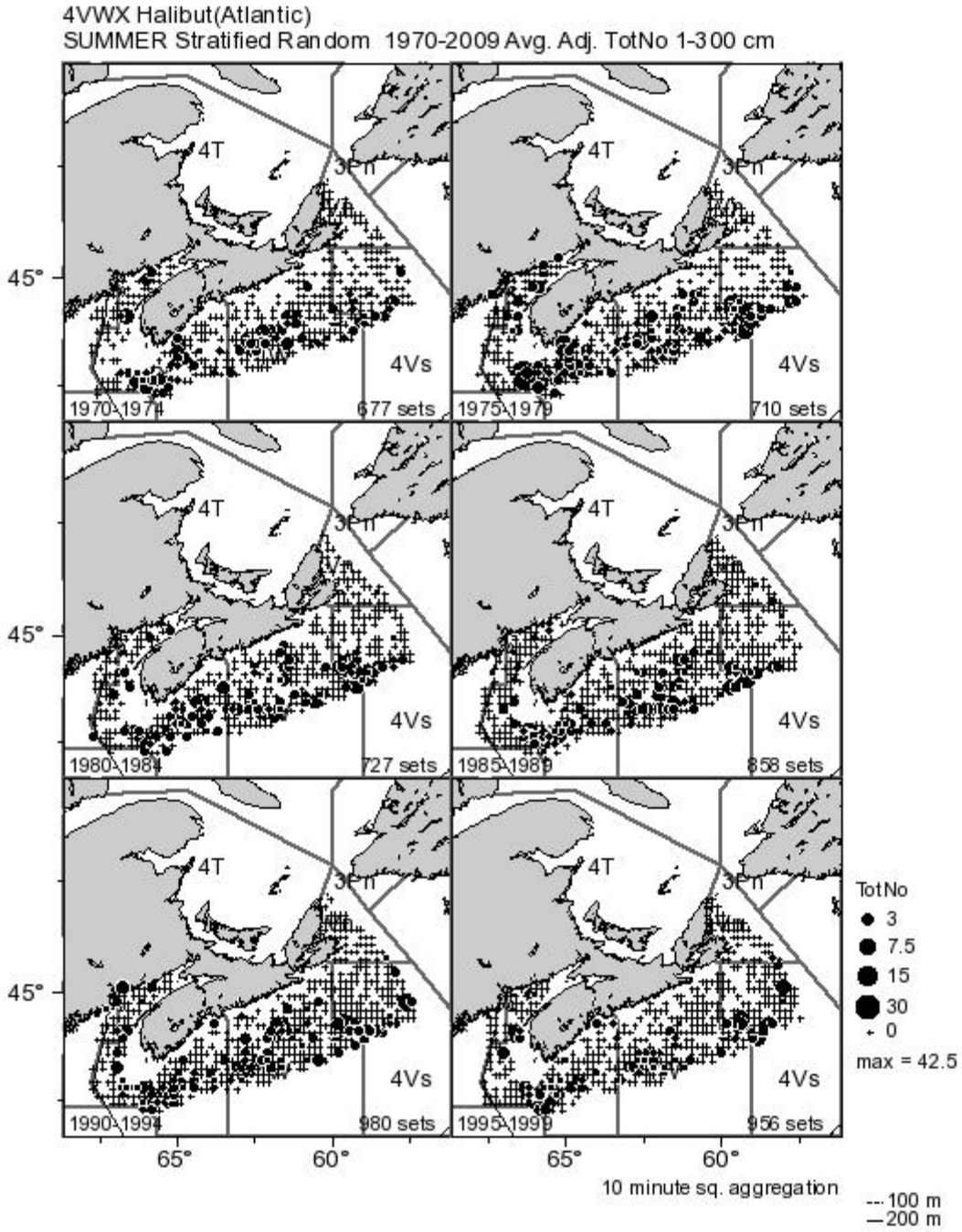


Figure 24. Maps of the total number of Atlantic halibut caught per set during the 4VWX DFO Summer research vessel (RV) trawl survey. This survey has a stratified random design and has been conducted since 1970. The years 2004 and 2007 are not included because of a change in vessel. Three deepwater strata along the continental shelf (Sable Island Bank region) were added to this survey in 1995.

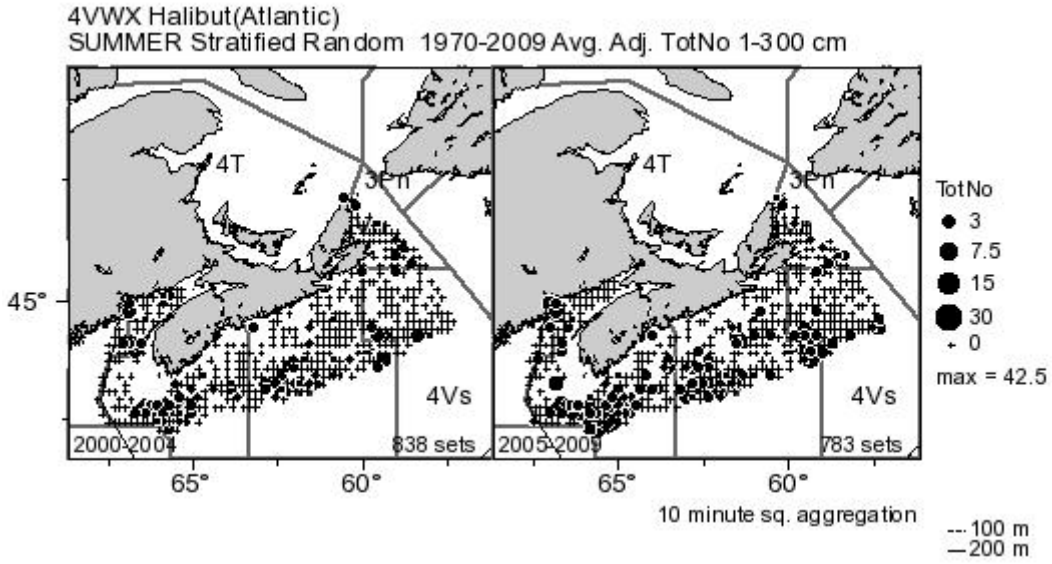


Figure 24. (Continued.)

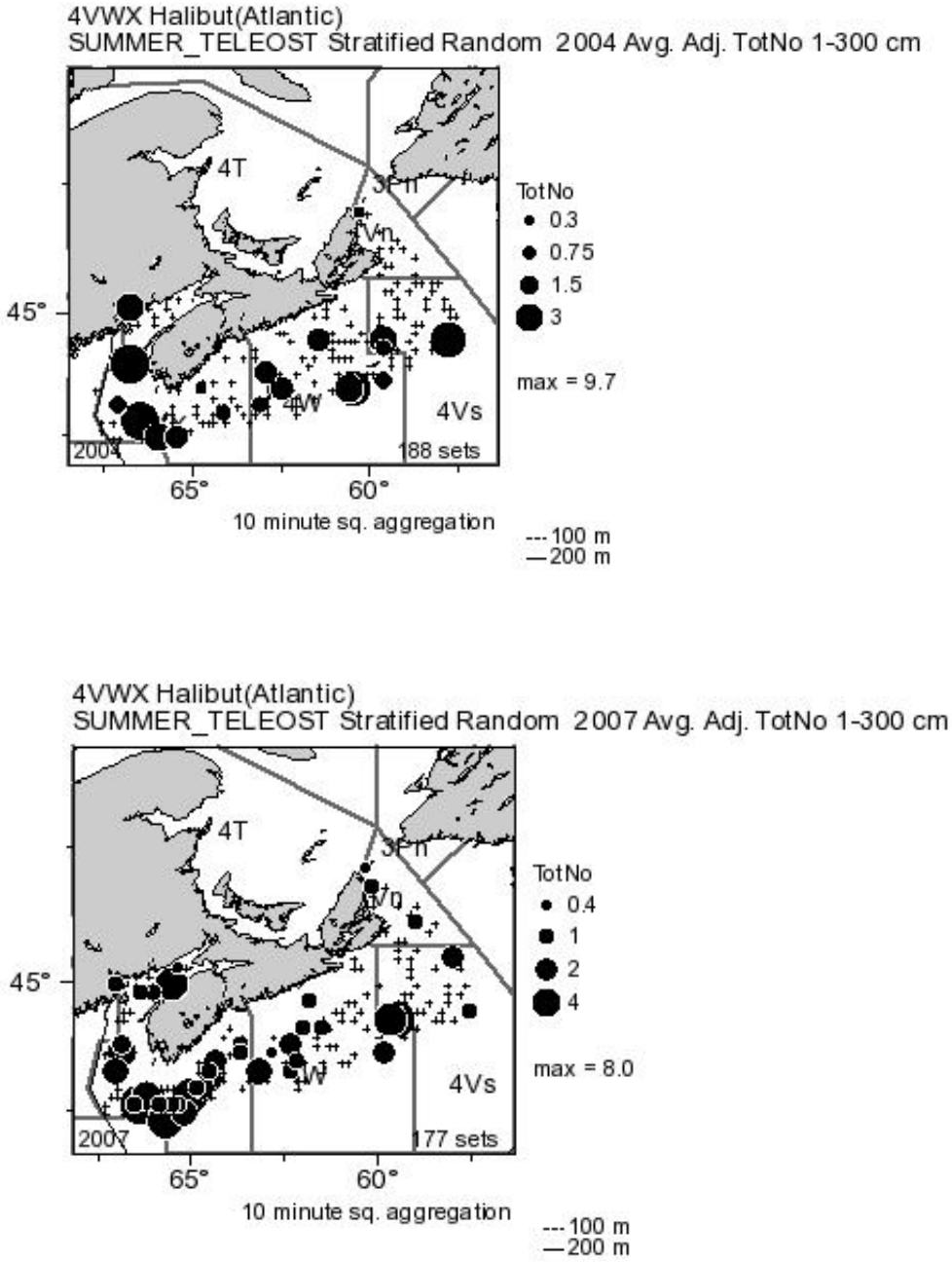


Figure 25. Maps of the total number of Atlantic halibut caught per set during the 4VWX DFO Summer research vessel (RV) trawl survey by the Teleost in 2004 and 2007. This survey has a stratified random design and has been running since 1970. The data for the years 2004 and 2007 are housed separate from the rest of the surveys because of a change in vessel.

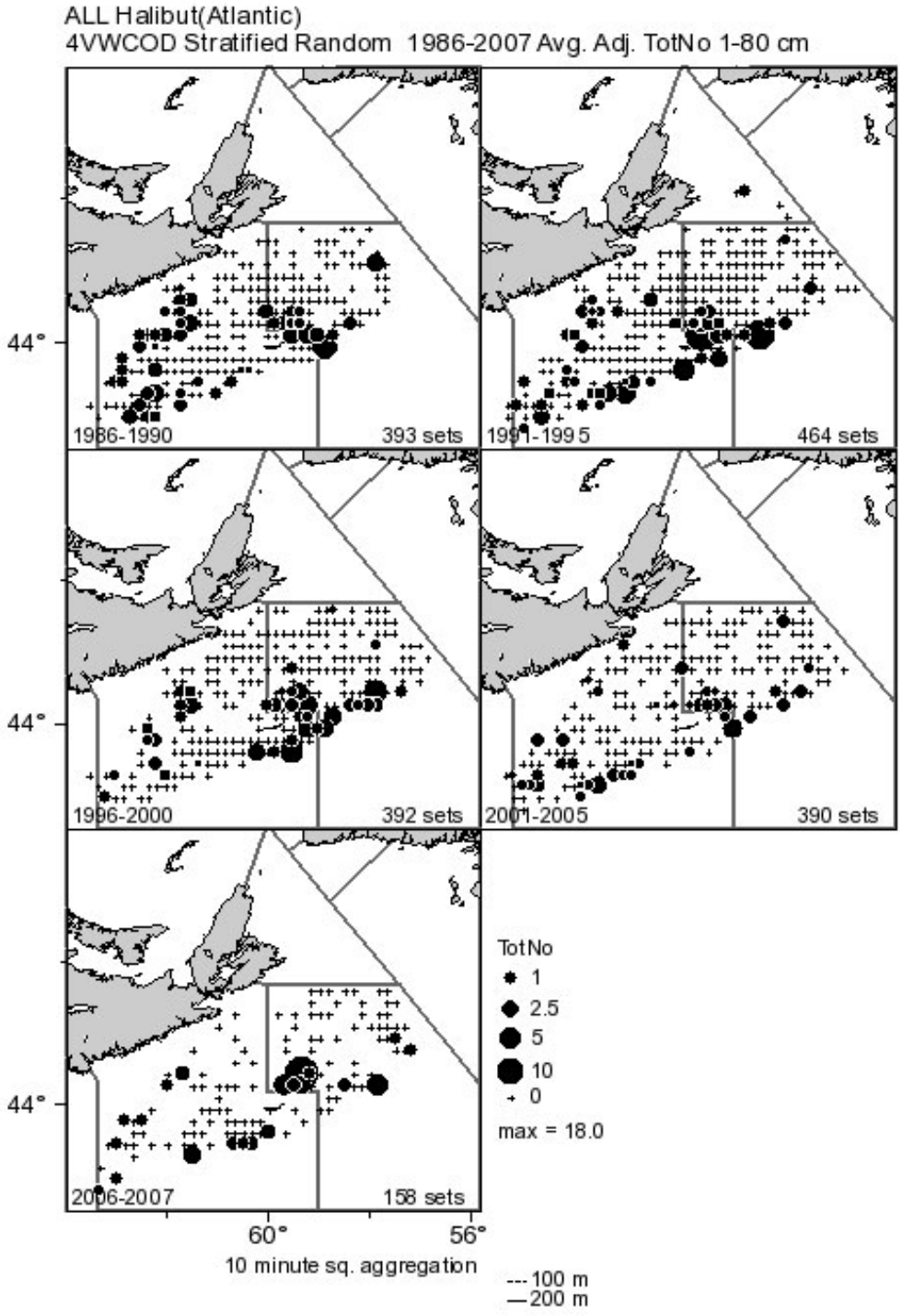


Figure 26. Map of the total number of Atlantic halibut caught per set during the DFO Spring (4VWCod) research vessel (RV) trawl survey. This survey has a stratified random design and has been running since 1986. The survey was not conducted during the years 1998 and 2004. Deepwater strata in the Laurentian channel were added to this survey in 1993, and more were added in NAFO area 4X in 1999.

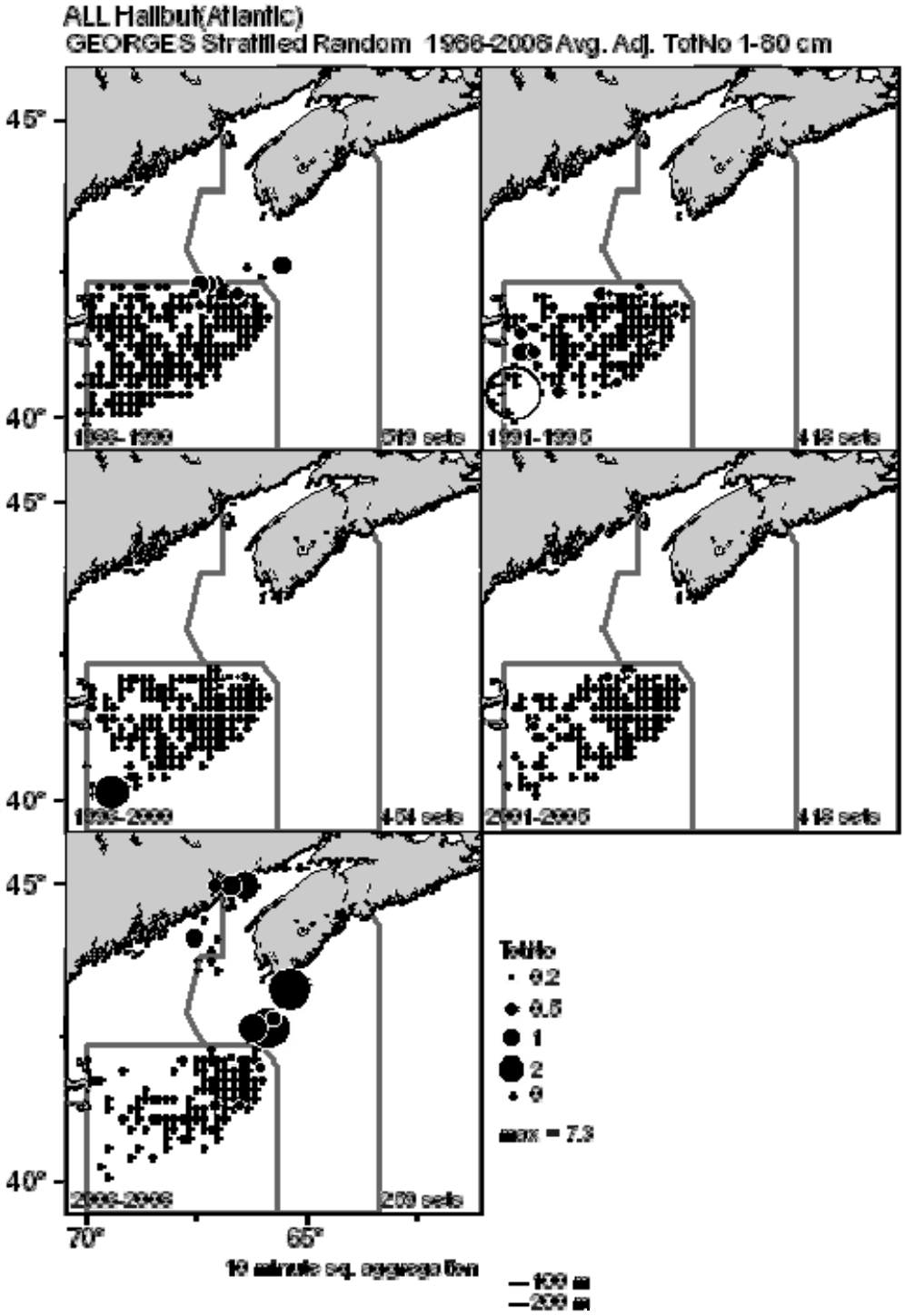


Figure 27. Maps of the total number of Atlantic halibut caught per set during the DFO Georges Bank research vessel (RV) trawl survey. This survey has a stratified random design and has been conducted during February/March since 1986.

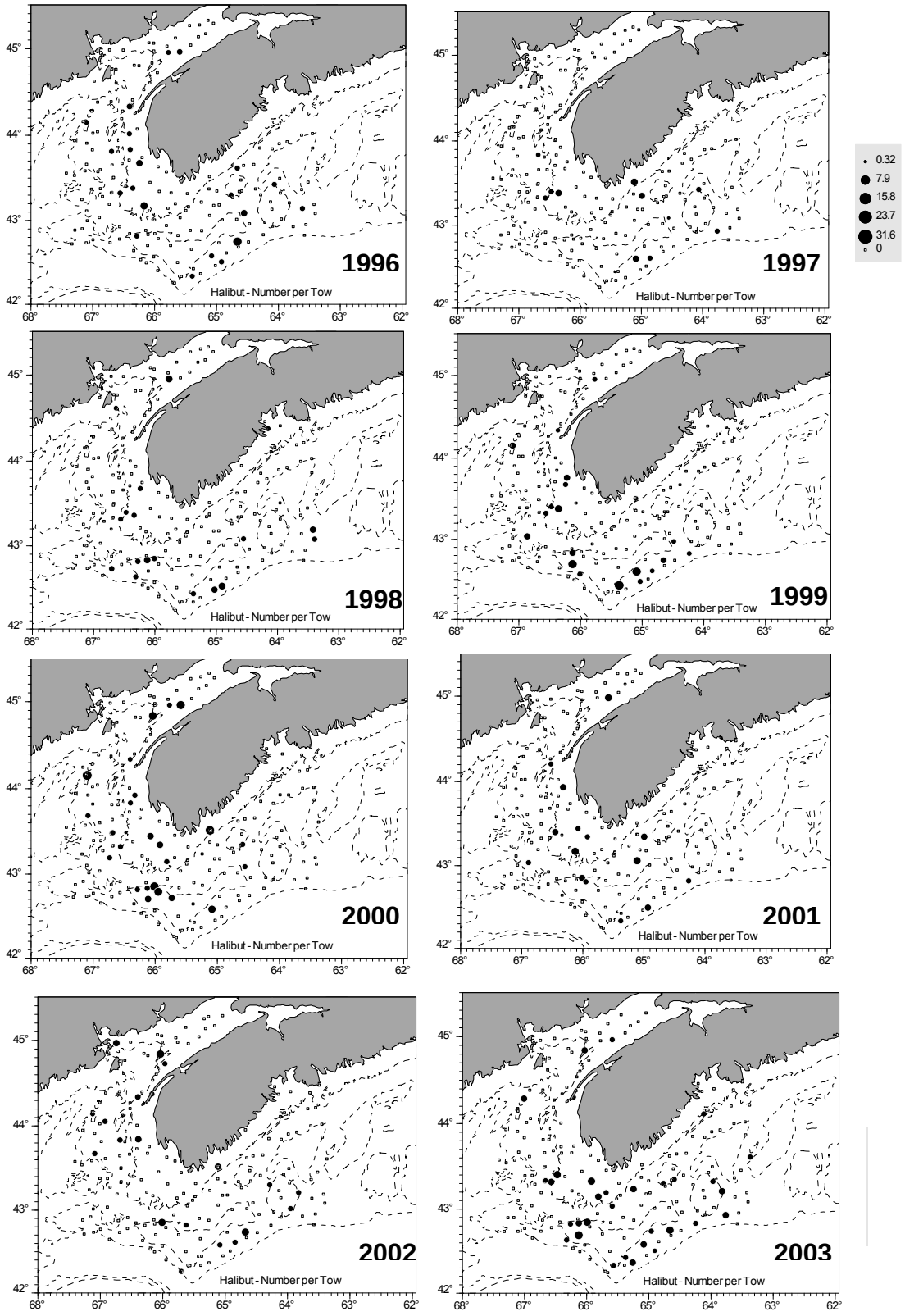


Figure 28. Maps of the number of Atlantic halibut caught per set during the ITQ survey in 4X between 1996 and 2008. The survey has been conducted since 1995, but we present only the data since 1996 when the protocol and stations were standardized.

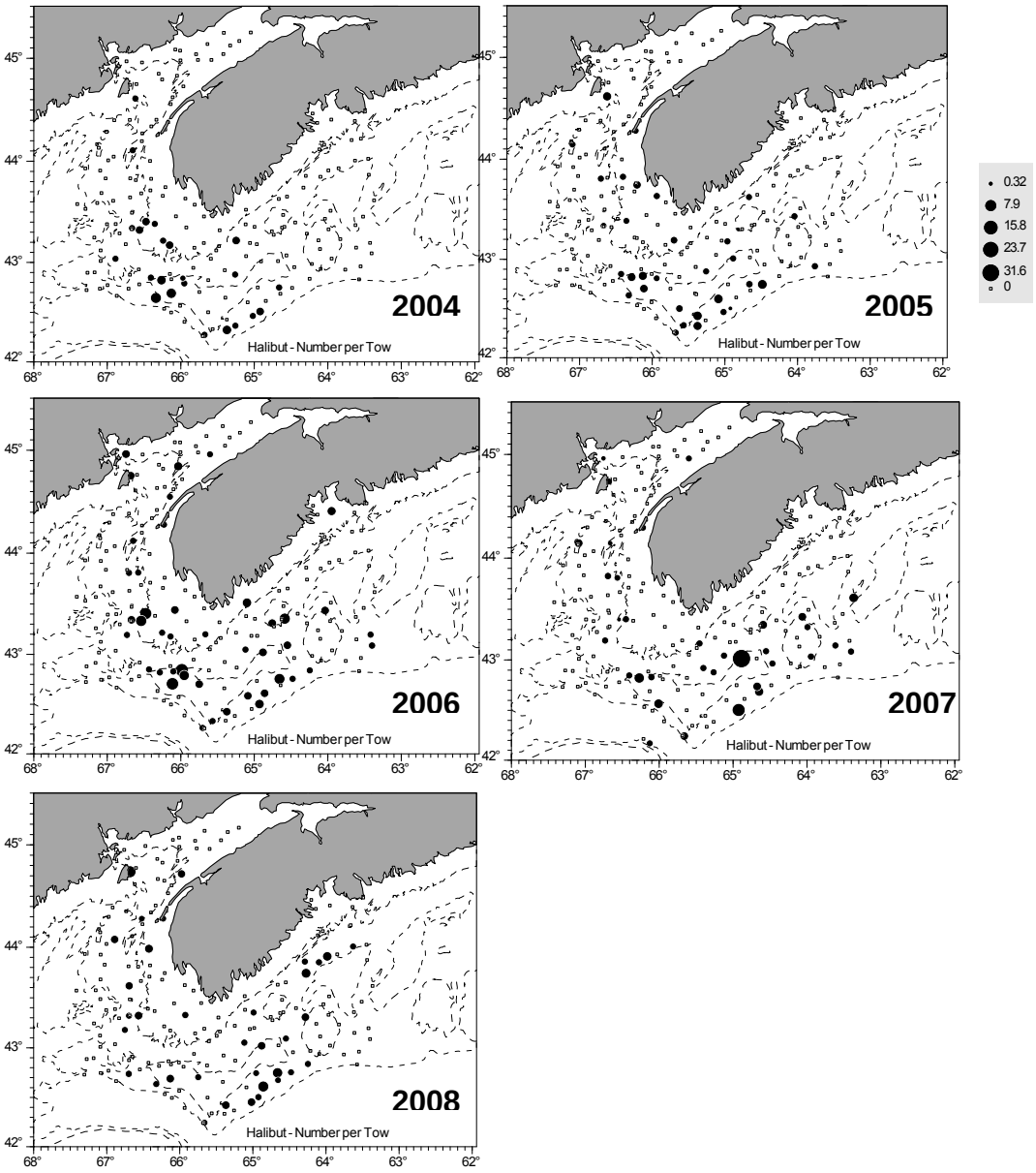


Figure 28. (Continued.)

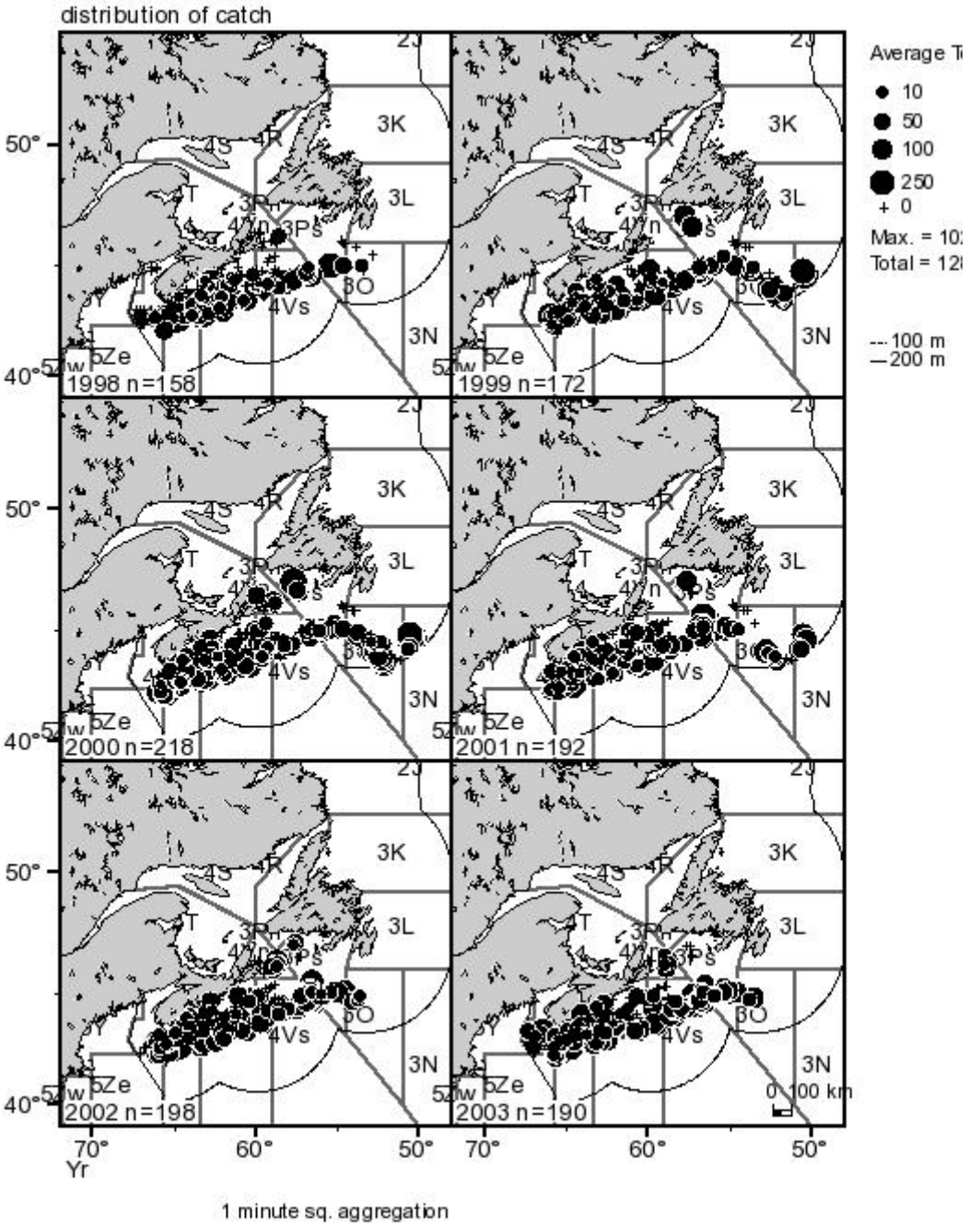


Figure 29. The distribution and average total weight of Atlantic halibut catch in the halibut survey. Circles in legend indicate total average weight (kg), and n is the number of stations sampled. The grey lines indicated NFAO areas and the white line is the EEZ boundary. Coverage in 3NO was variable.

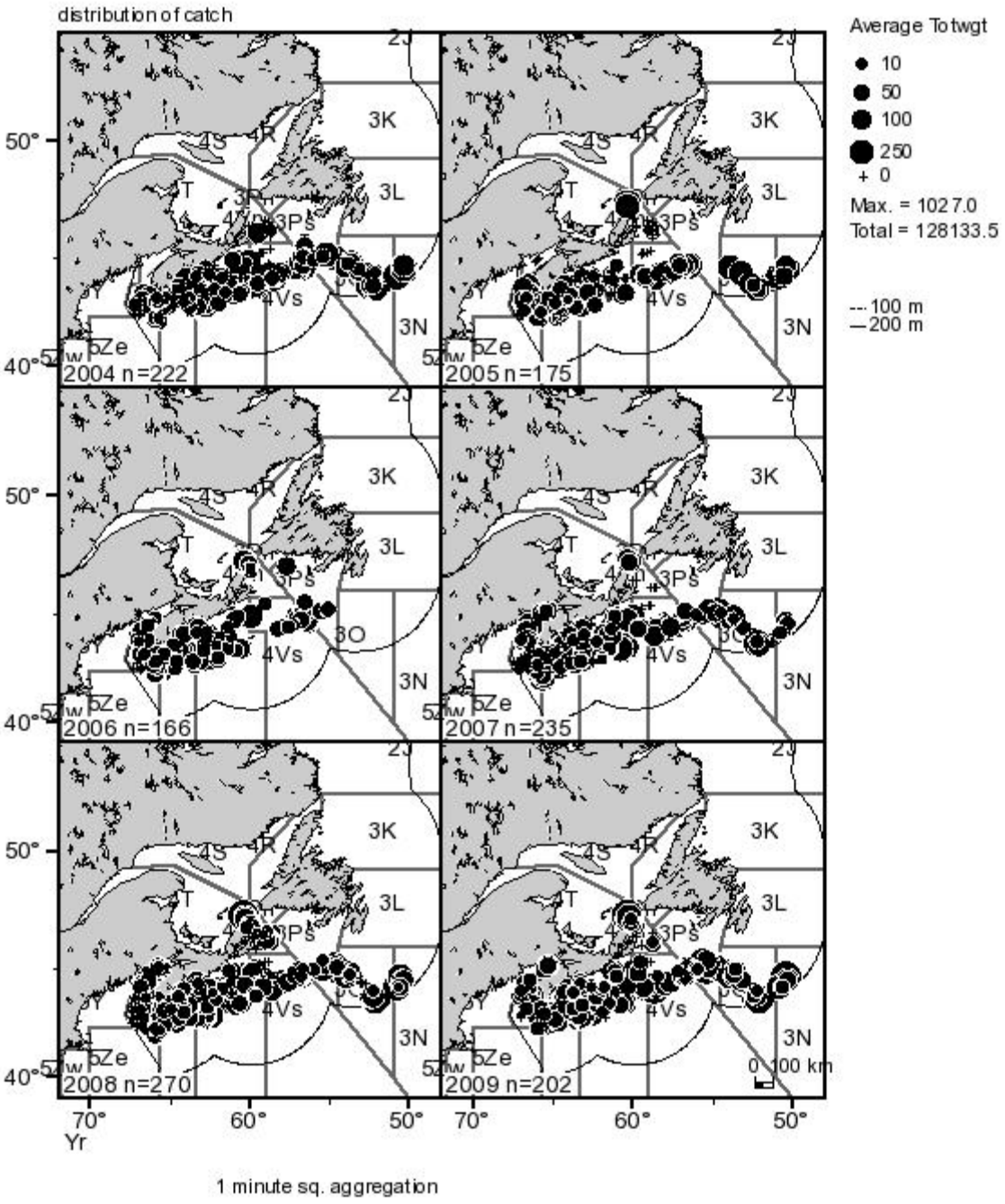


Figure 29. (Continued.)

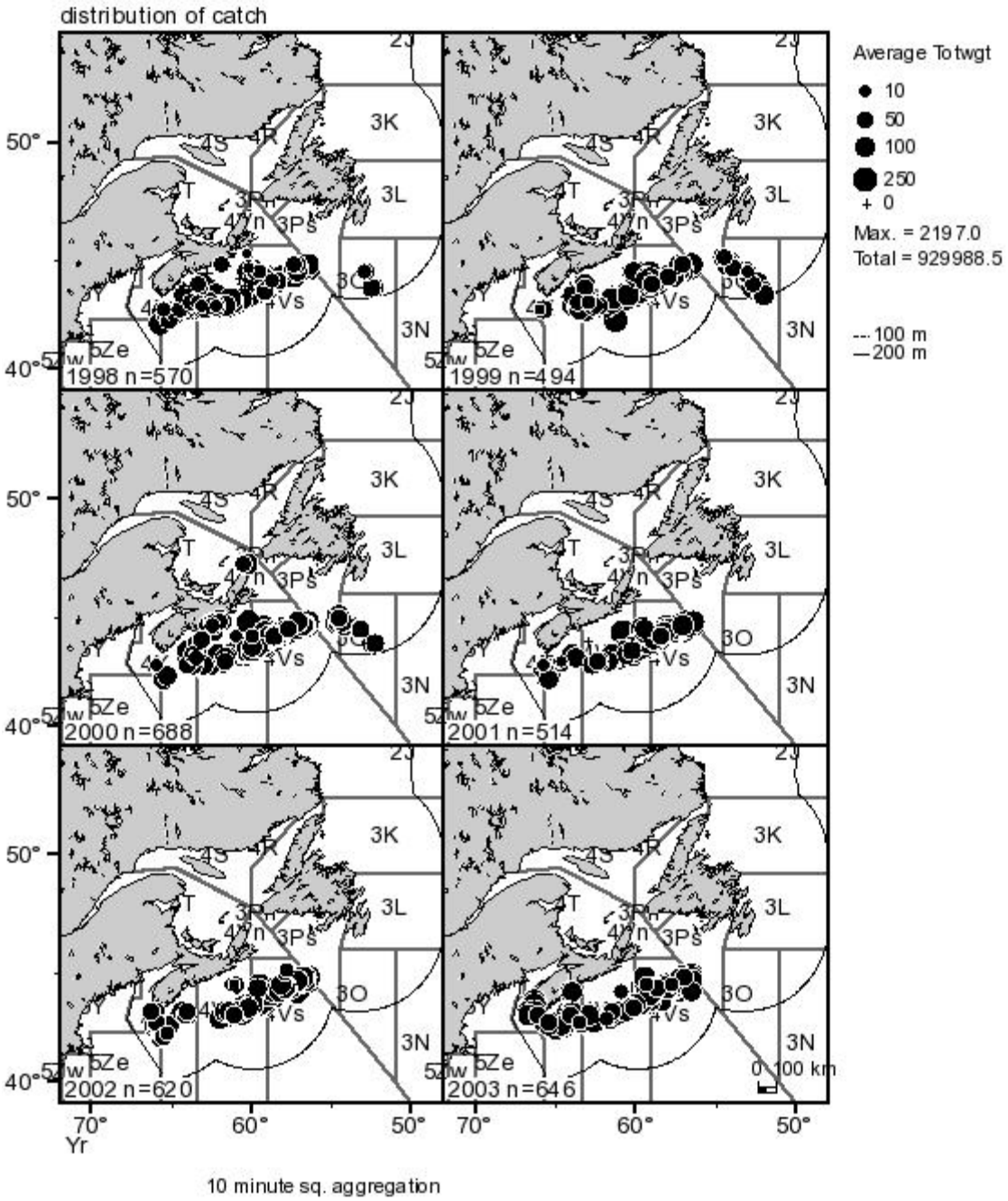


Figure 30. The distribution and average total weight of Atlantic halibut catch during the Commercial index. Circles in legend indicate total average weight (kg), and n is the number of stations sampled. The grey lines indicated NFAO areas and the white line is the EEZ boundary. Coverage in 3NO was variable.

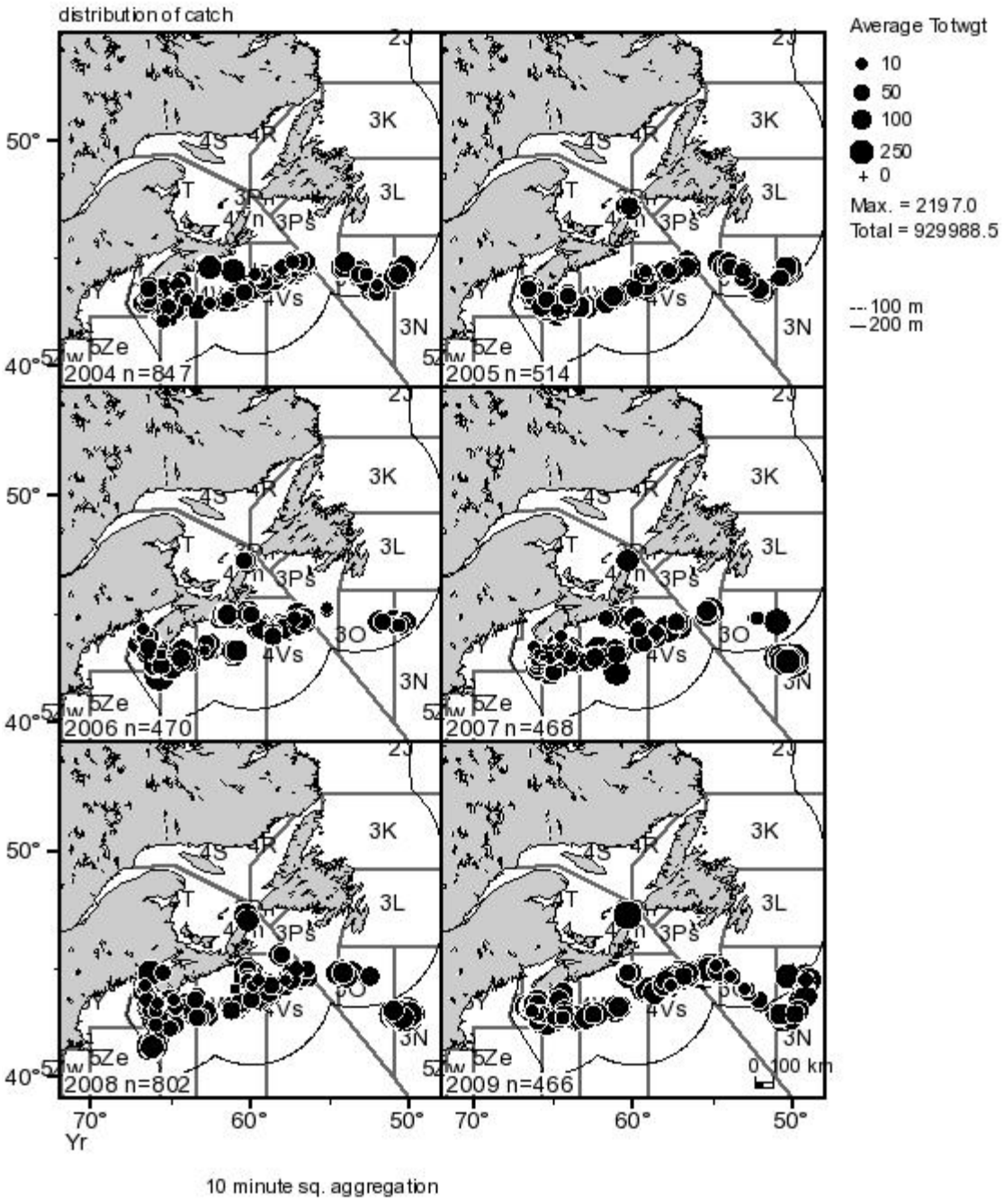


Figure 30. (Continued.)

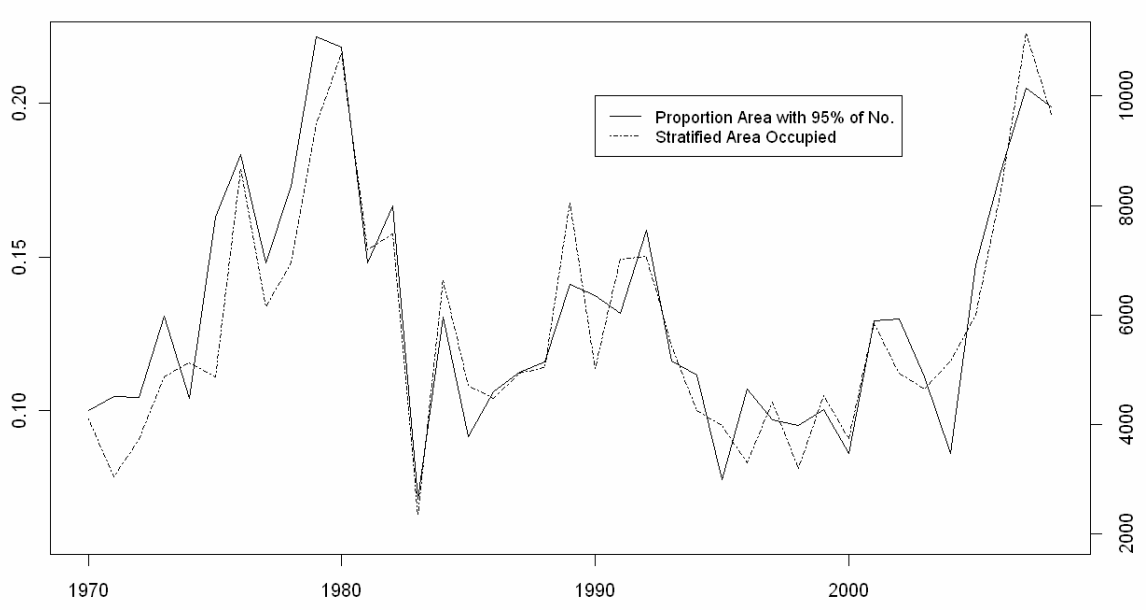


Figure 31. The proportion of area containing 95% of Atlantic halibut catch in the DFO Summer research vessel (RV) trawl survey, and the stratified mean area occupied by year in NAFO area 4VWX plotted for each year of the survey. The deep water strata added to the survey in 1995 were not included in the estimates.

Figure 32. The proportion of area containing 95% of Atlantic halibut caught in the 4VW Cod research vessel (RV) trawl survey, and the stratified area occupied plotted by year. The deep water strata added in 1993 and the sets in 4X in 1999 were not included in the analysis. The survey did not run in 1998 and 2004.

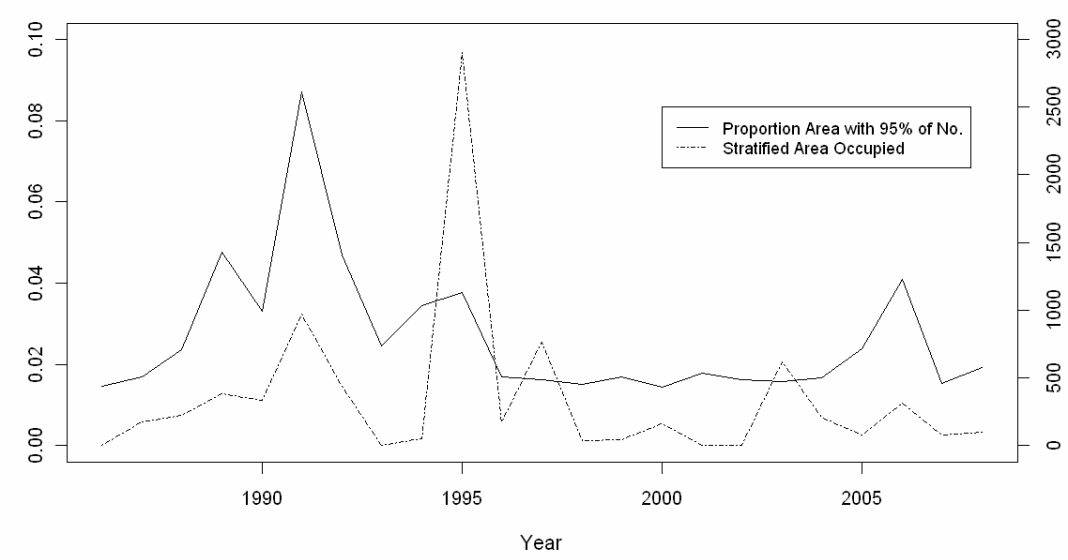


Figure 33. The proportion of area containing 95% of Atlantic halibut caught in NAFO area 5Z during the Georges Bank research vessel (RV) trawl survey, and the stratified area occupied plotted by year.

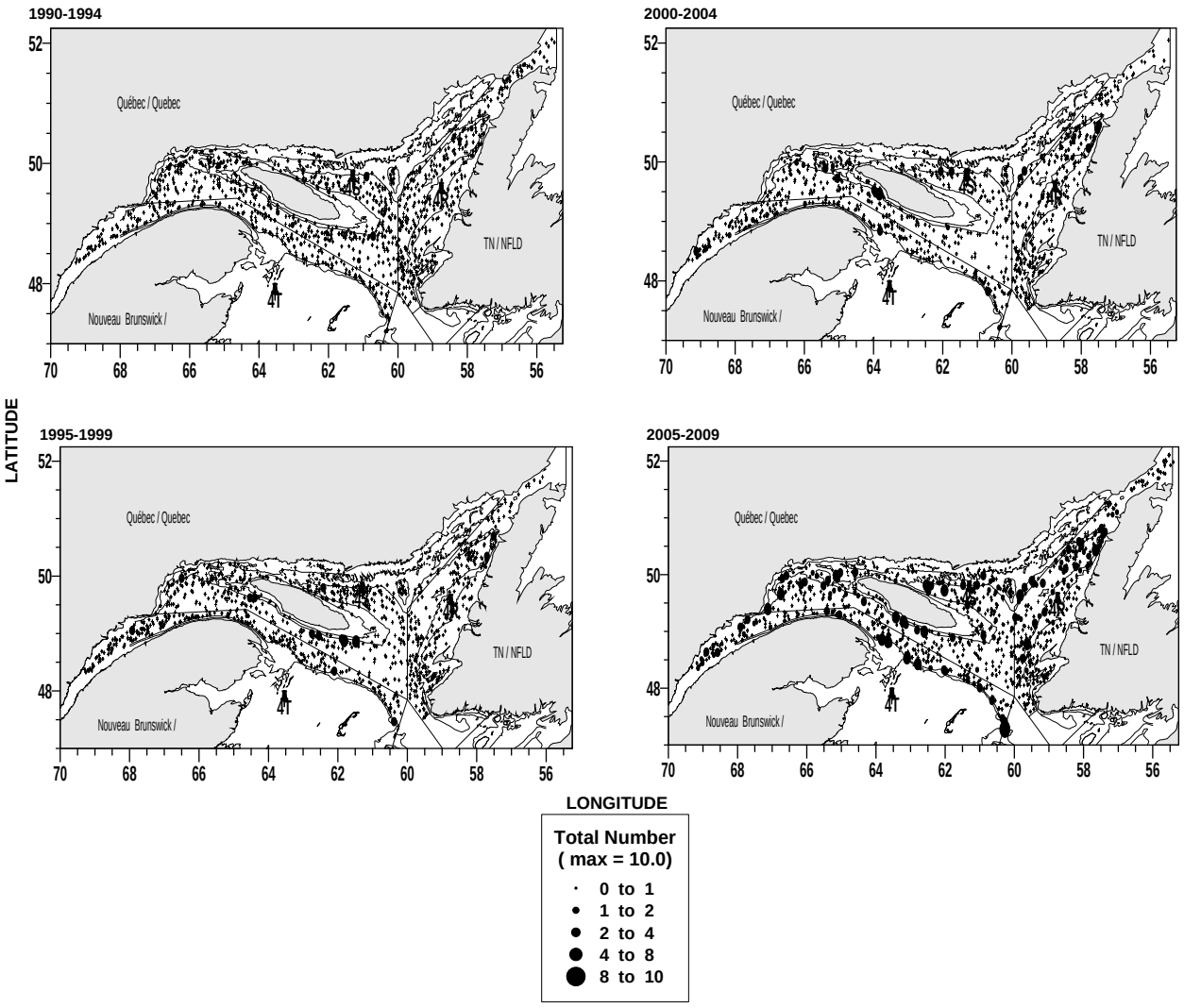


Figure 34. Maps of the total number of Atlantic halibut caught per set during the DFO Summer Northern Gulf research vessel (RV) trawl survey. This survey has a stratified random design and has been conducted since 1990.

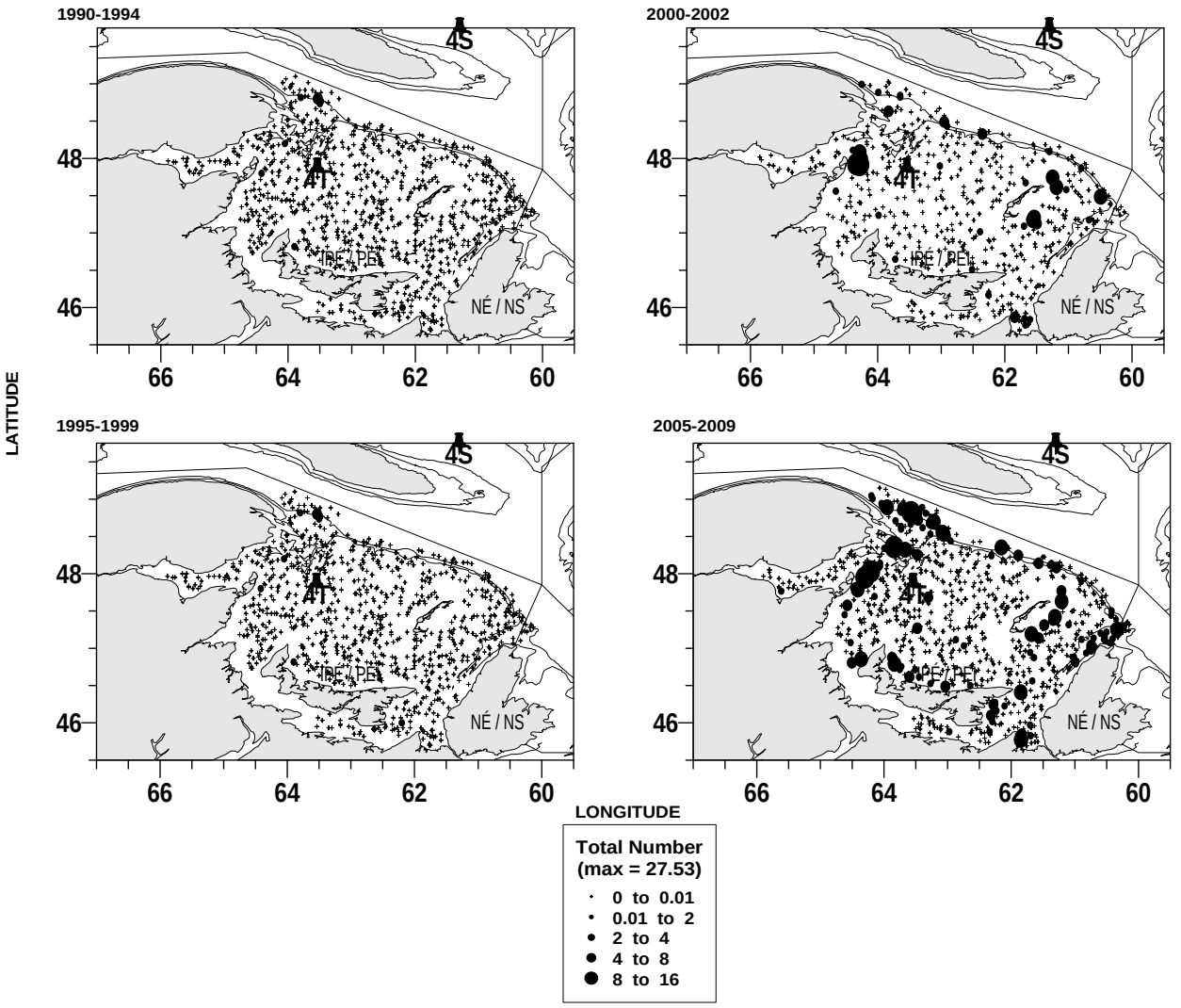


Figure 35. Maps of the total number of Atlantic halibut caught per set during the DFO Summer Southern Gulf research vessel (RV) trawl survey. This survey has a stratified random design and has been conducted since 1971. No halibut was captured during 1971-1979 and 1989 surveys. Not more than 2 halibuts per set were reported caught for surveys during 1980-1988 surveys.

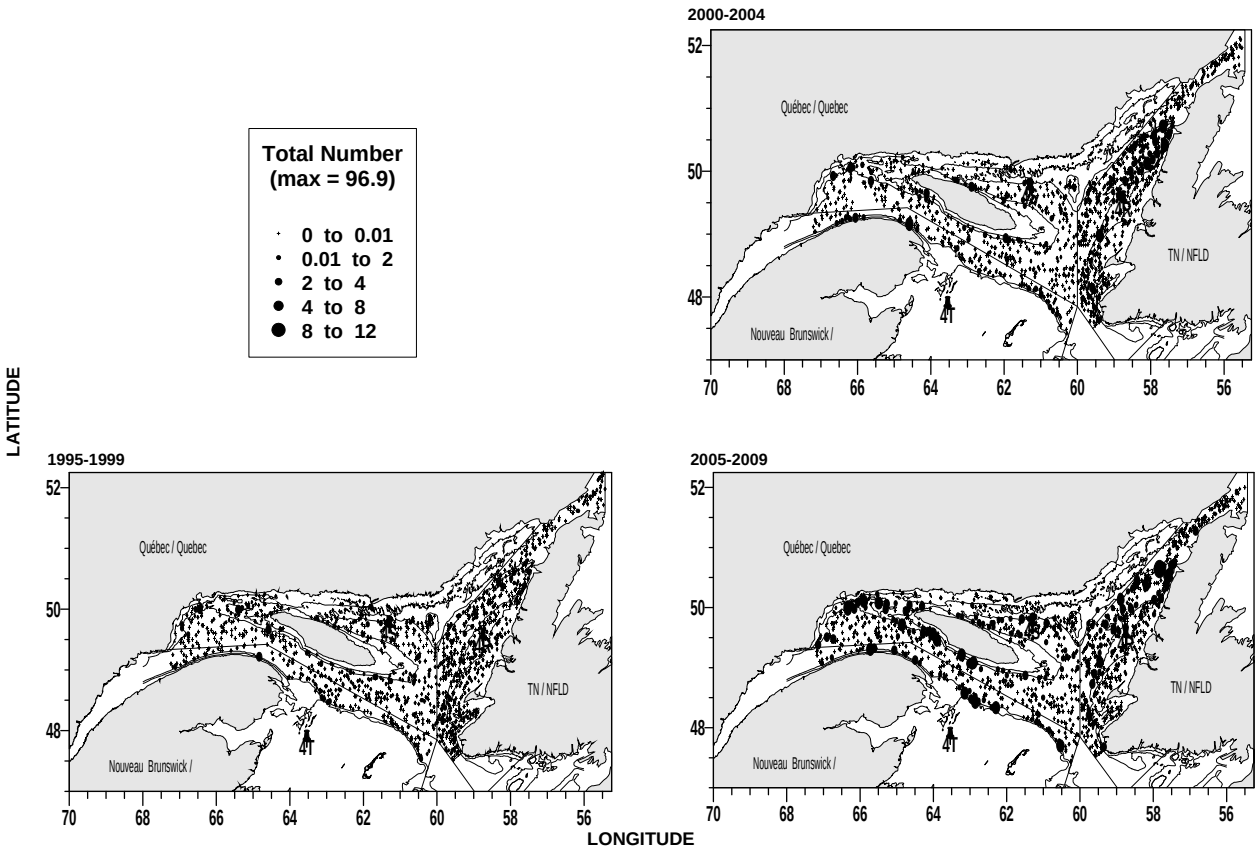


Figure 36. Maps of the total number of Atlantic halibut caught per set during the Summer Northern Gulf Mobile Sentinel trawl survey. This survey has a stratified random design and has been conducted since 1995.

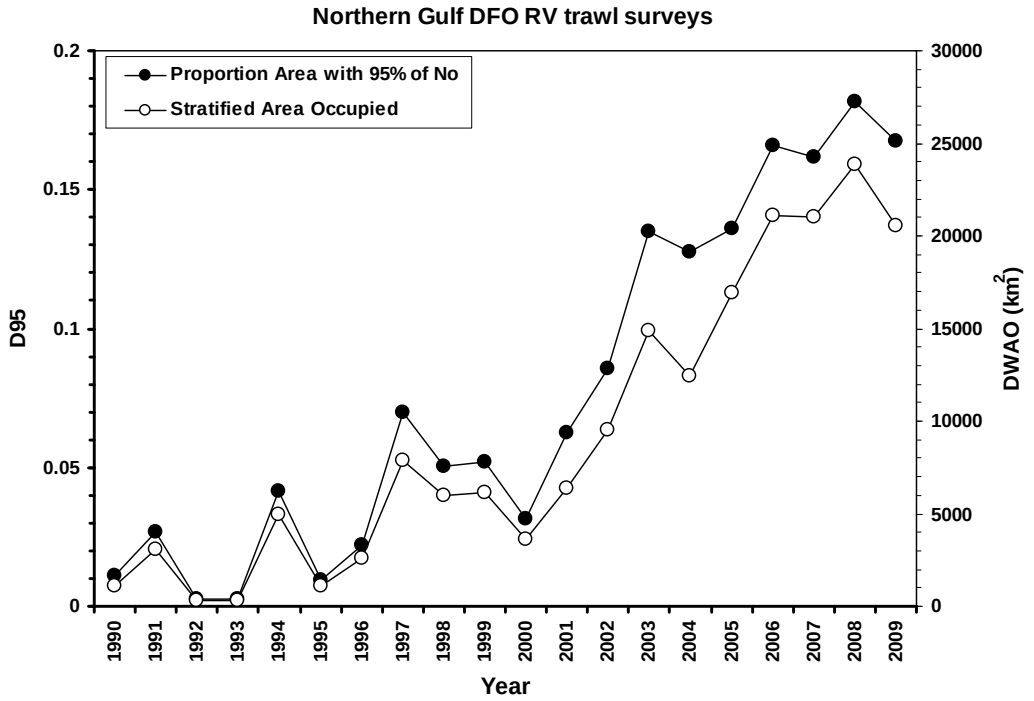


Figure 37. The proportion of area containing 95% of Atlantic halibut catch (D95) in the Northern Gulf DFO Research Vessel (RV) trawl surveys, and the stratified mean area occupied (DWAO) by year in NAFO areas 4RST.

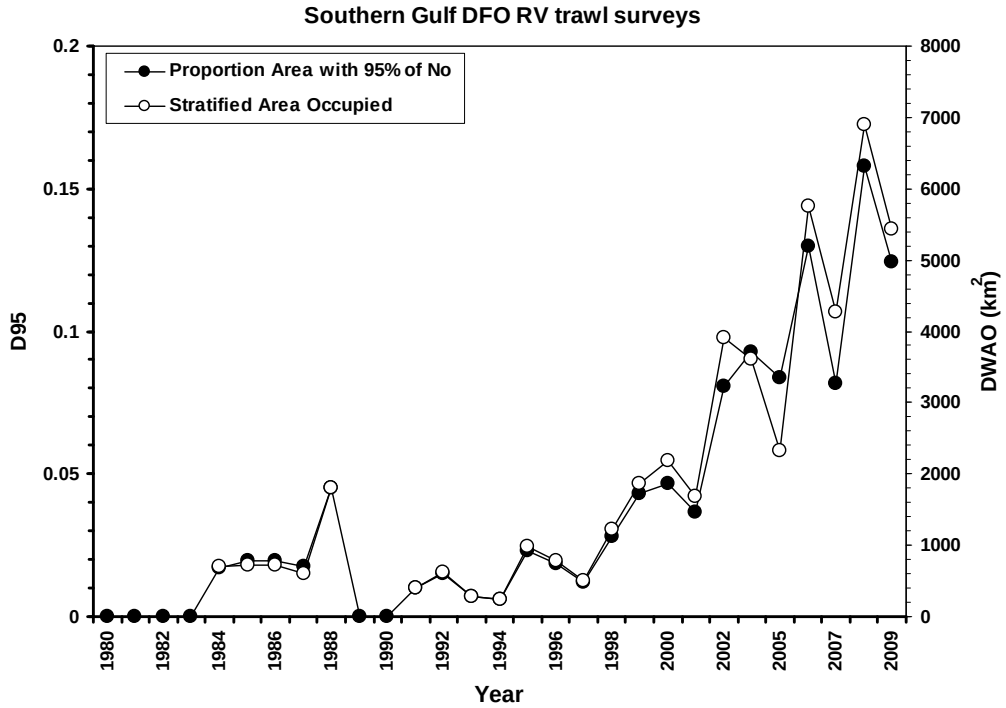


Figure 38. The proportion of area containing 95% of Atlantic halibut catch (D95) in the Southern Gulf DFO Research Vessel (RV) trawl surveys, and the stratified mean area occupied (DWAO) by year in NAFO area 4T. No halibut were caught in 4T between 1971 and 1979, and from 1980 to 1989 the catch rate was under 0.05 mean number per set.

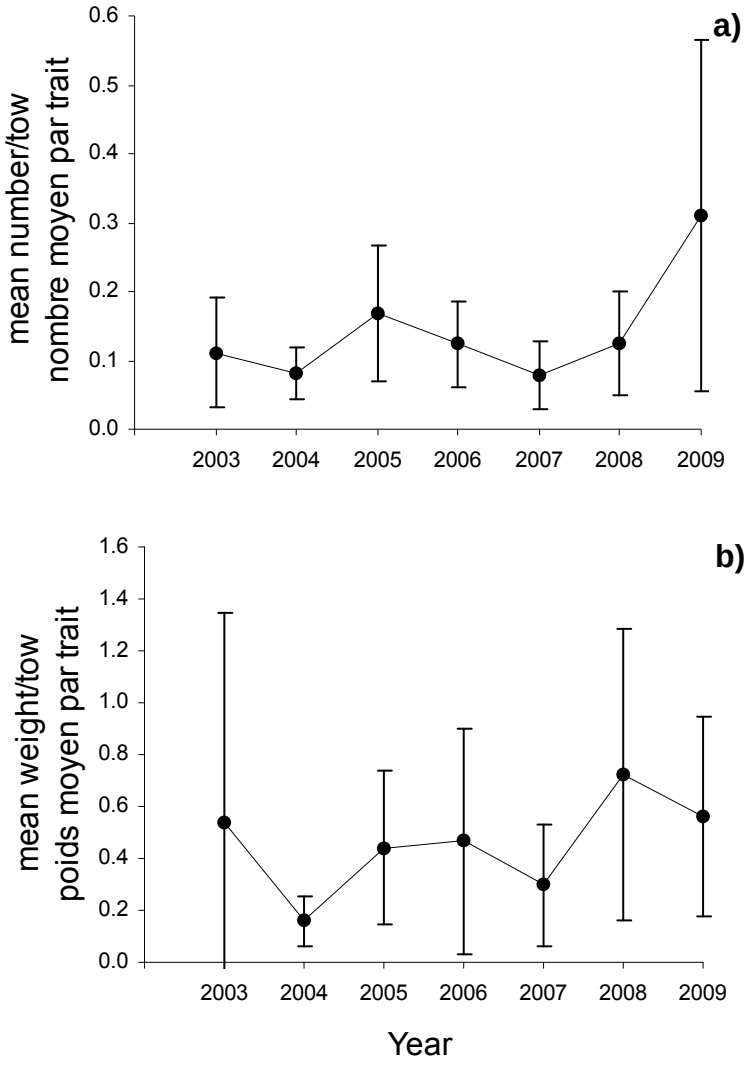


Figure 39. Sentinel bottom trawl mean annual catch abundance (top) and weight (bottom) per tow for Atlantic halibut in the southern Gulf of St. Lawrence. Error bars indicate approximate 95% confidence intervals. Halibut catch weights since 2007 are based on visual estimates.

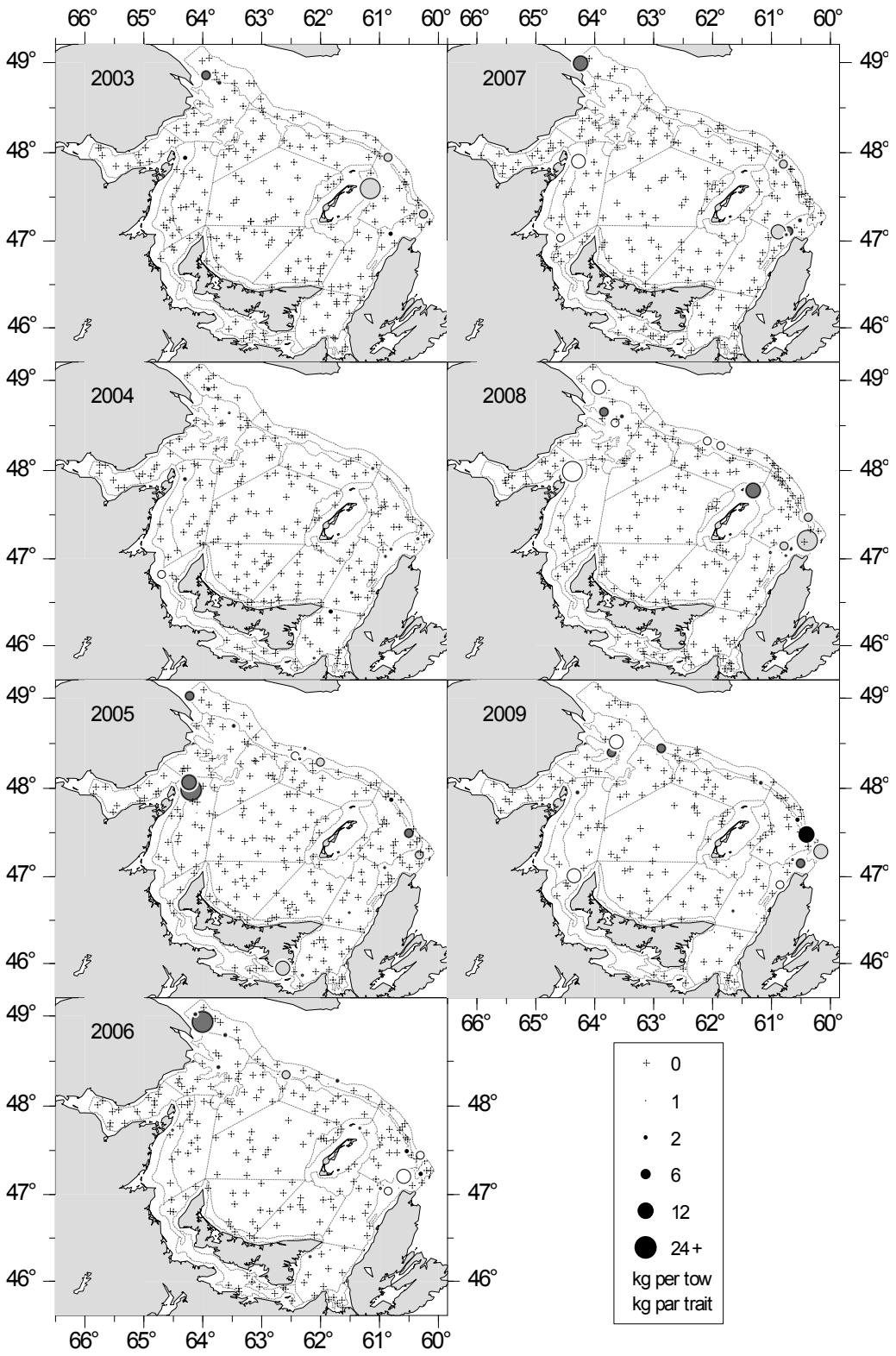


Figure 40. Atlantic halibut catches (in kilograms) for each sentinel bottom trawl survey set. Each participating vessel is color coded as follows: Riding It Out (2003-2006) and Atlantic Quest I (2007-2009) as black, L'Alberto (2003) and Viking II (2004-2009) as dark grey, Manon Yvon (2003-2005) and Cap Adèle (2006-2009) as light grey, Miss Lamèque as white.

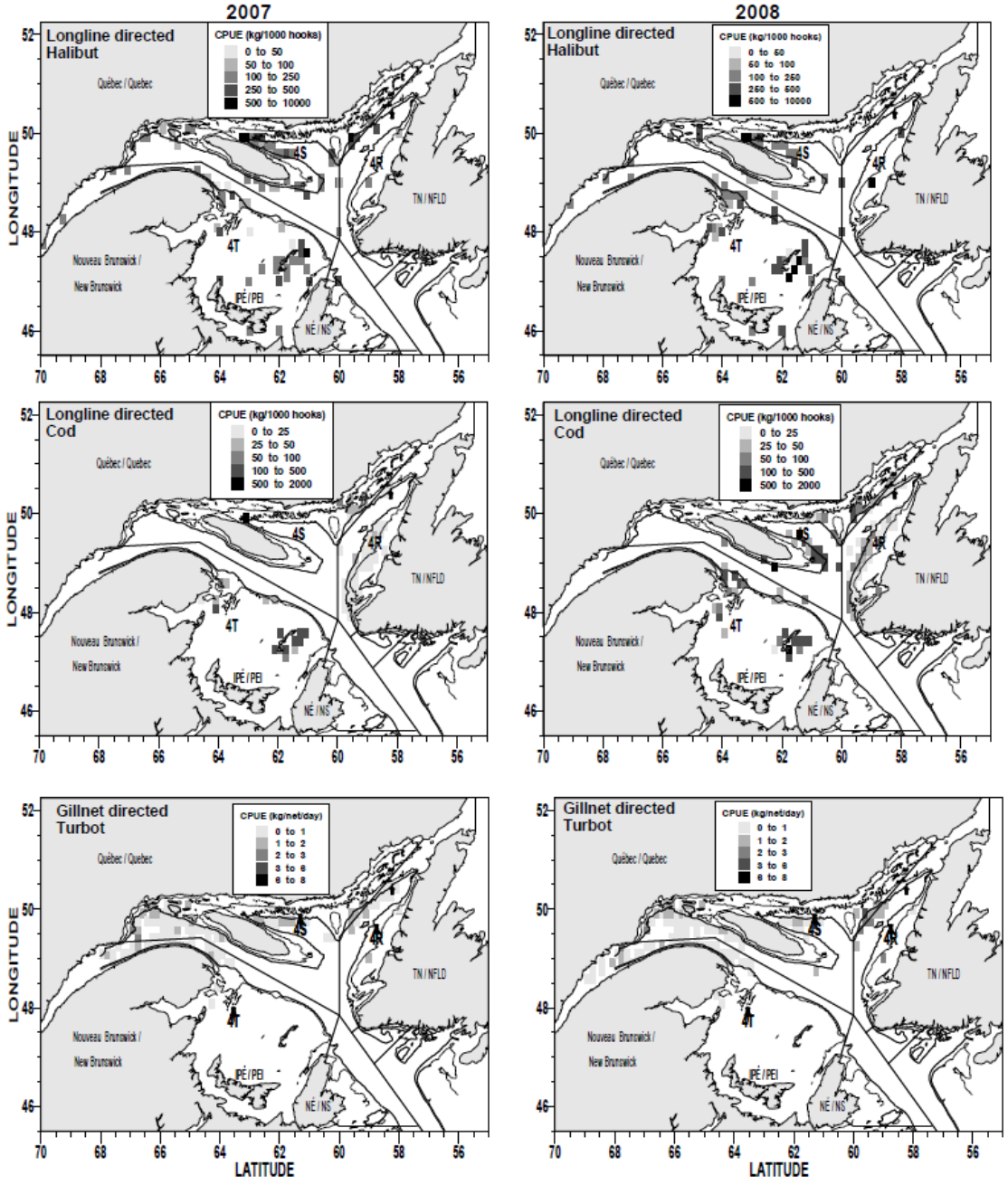


Figure 41. NAFO Divs. 4RST catch rate distribution per fishing activity in 2007 and 2008 (Figure taken from DFO 2009a).

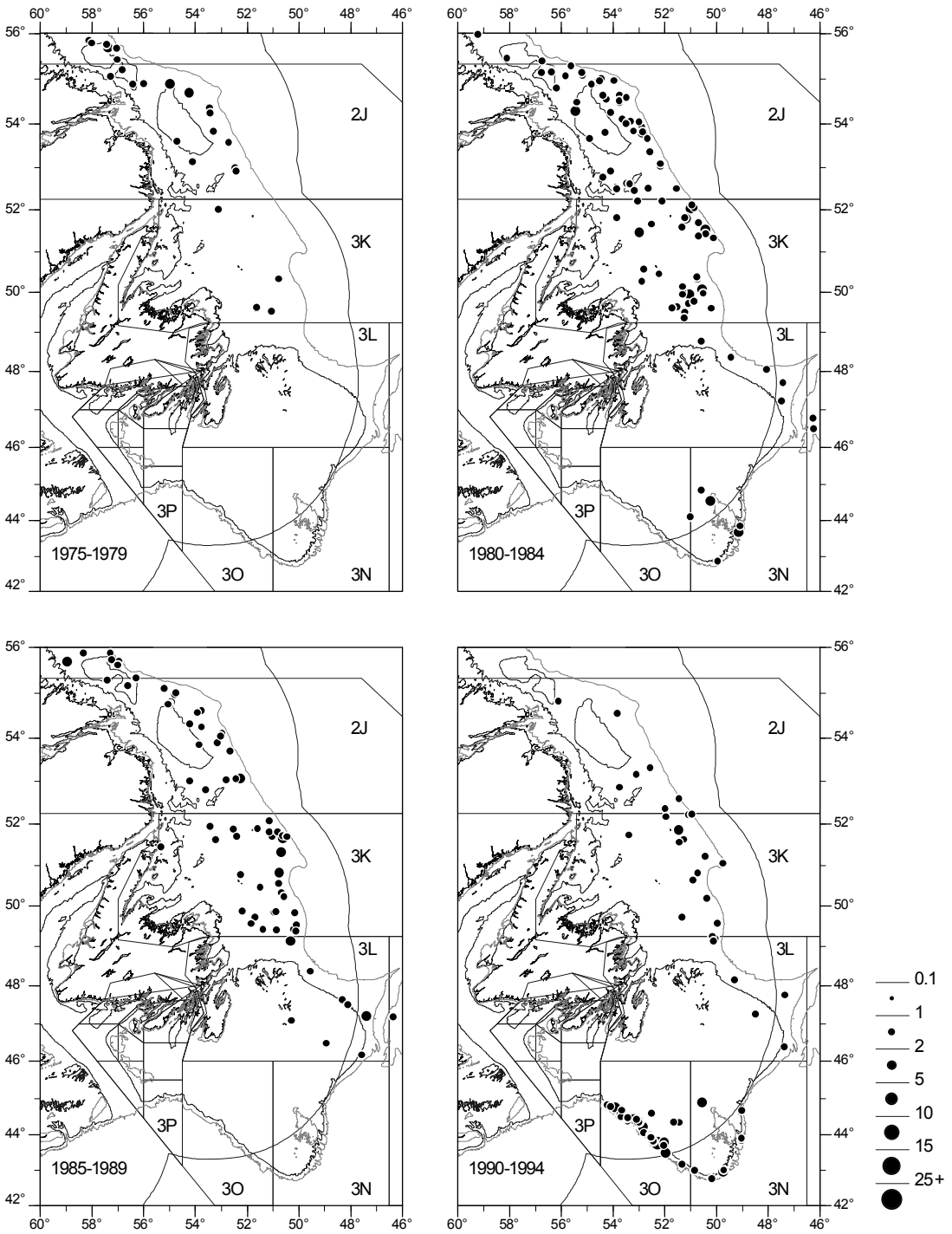


Figure 42. Location of positive catches of Atlantic halibut in DFO-NL region fall research vessel surveys, 1977-1994.

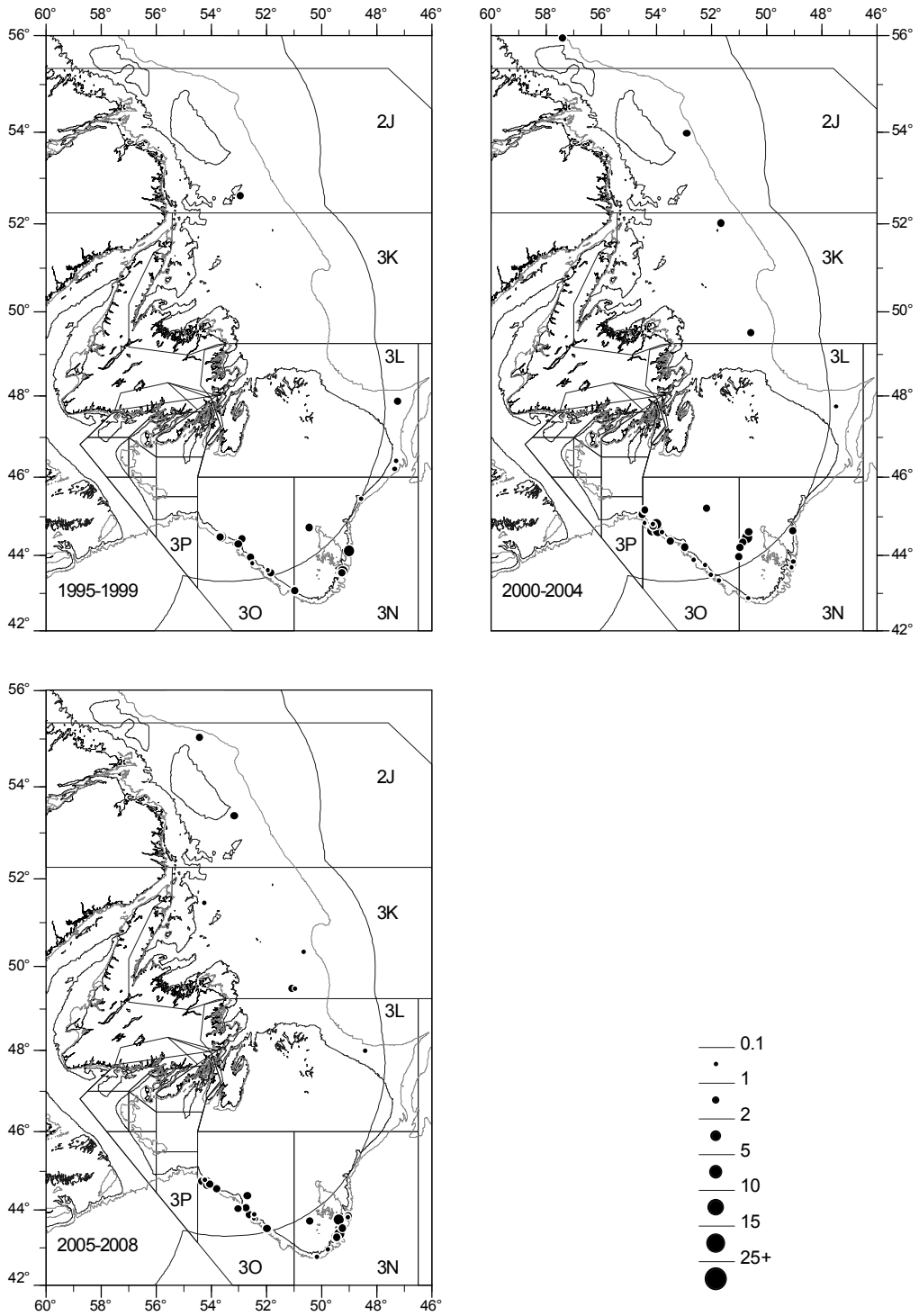


Figure 42. (Continued.) Locations of positive catches of Atlantic halibut in DFO-NL region fall research vessel surveys, 1995-2008.

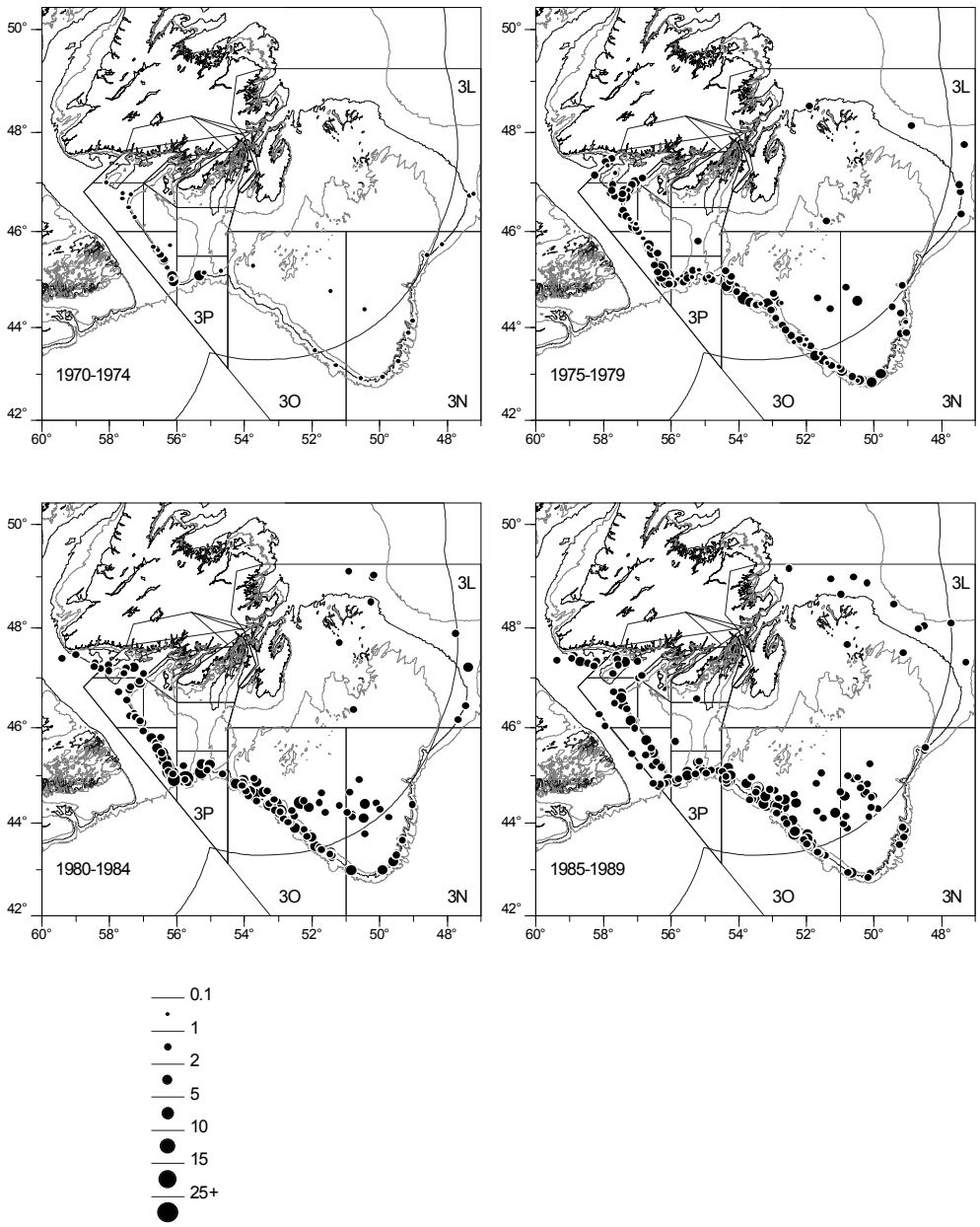


Figure 43. Locations of positive catches of Atlantic halibut in DFO-NL region spring research vessel surveys, 1970-1989.

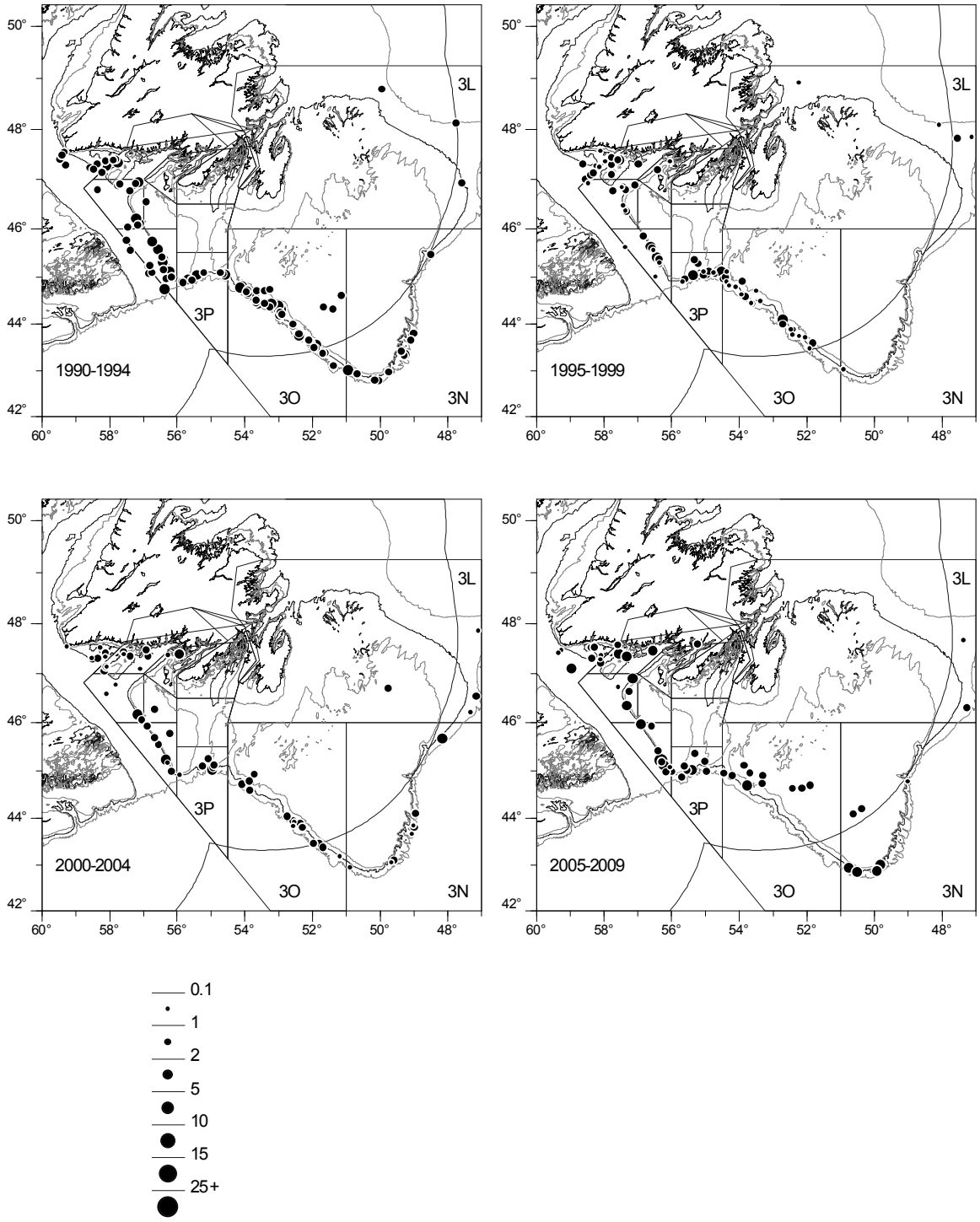


Figure 43. (Continued) Locations of positive catches of Atlantic halibut in DFO-NL region spring research vessel surveys, 1990-2009.

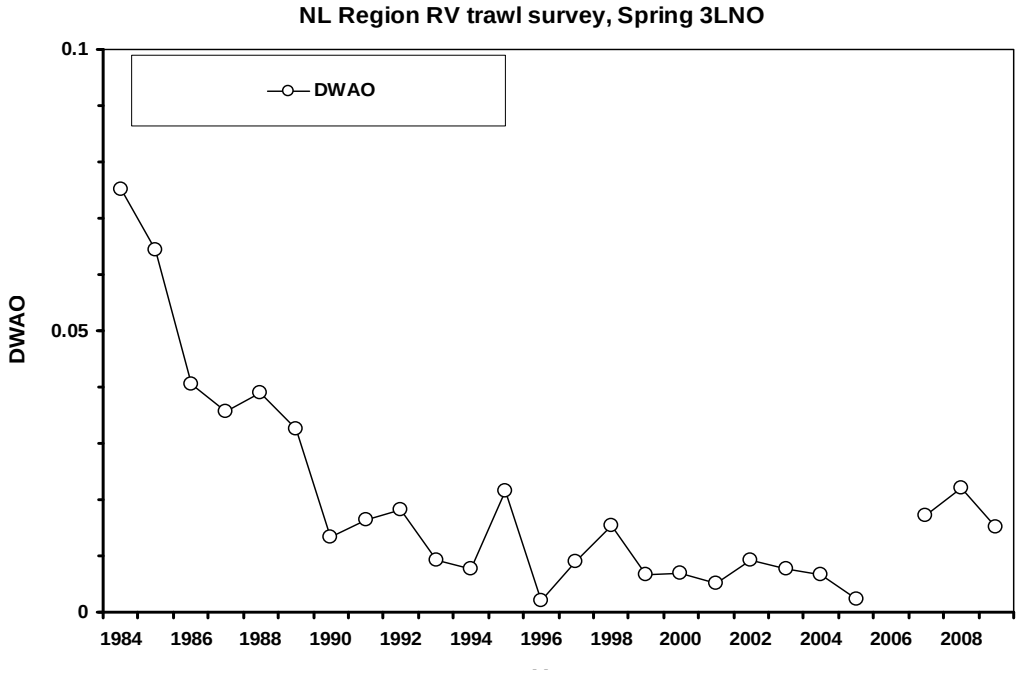


Figure 44. Stratified mean Area Occupied Index (DWAO) for Atlantic halibut catch in the NL Region Spring 3LNO Research Vessel Survey

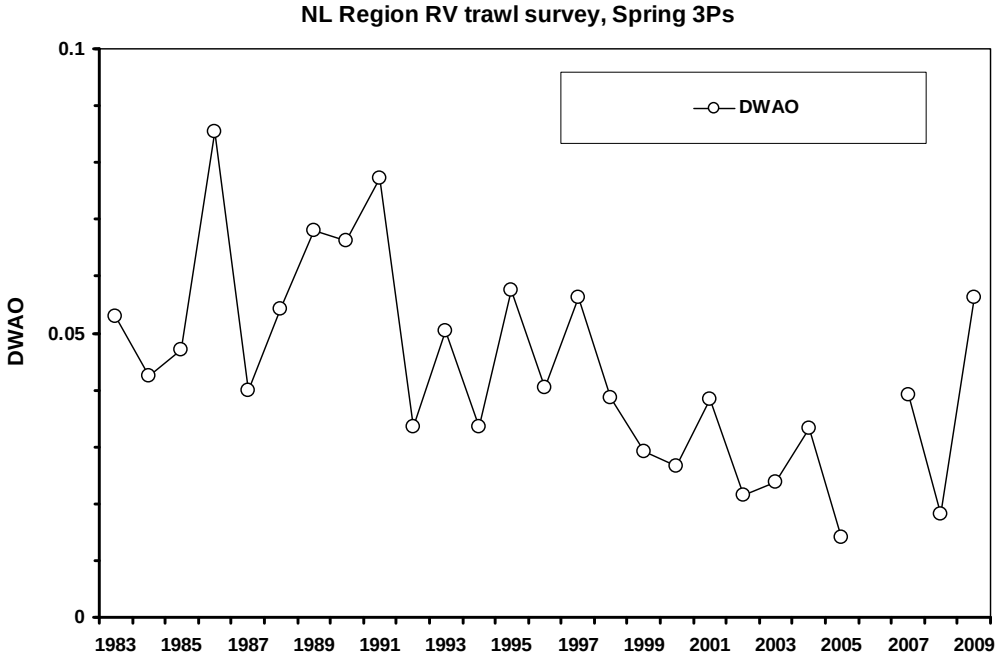


Figure 45. Stratified mean Area Occupied Index (DWAO) for Atlantic halibut catch in the NL Region Spring 3Ps Research Vessel Survey.

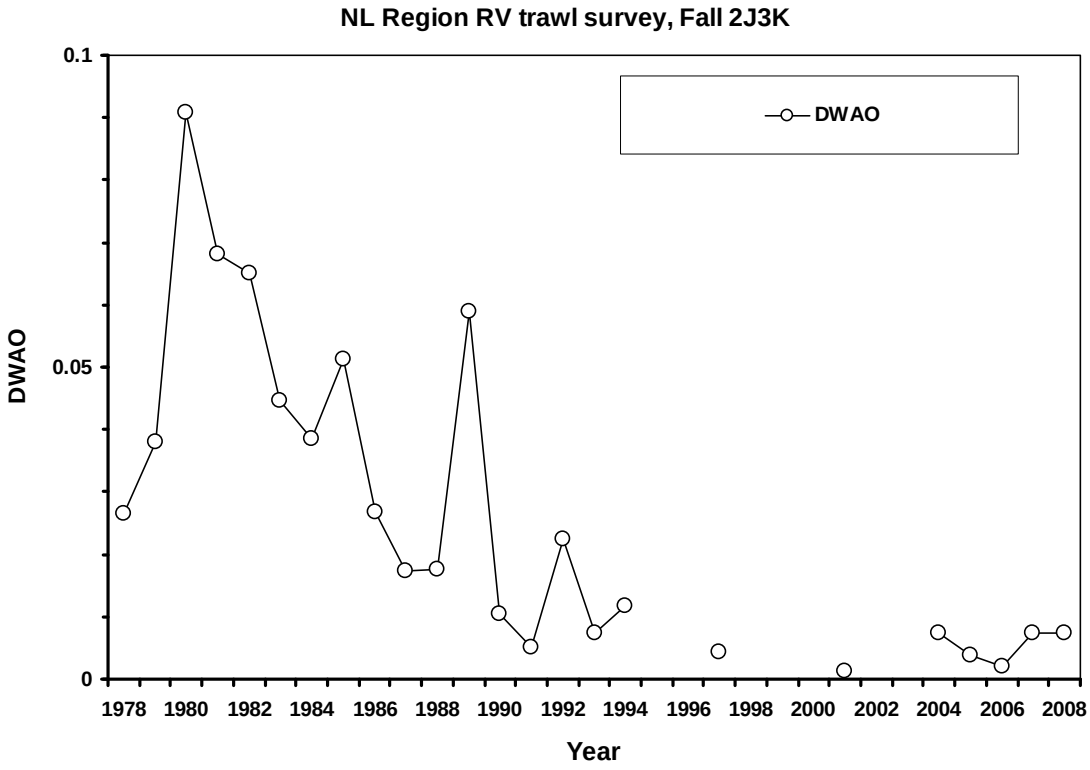


Figure 46. Stratified mean Area Occupied Index (DWAO) for Atlantic halibut catch in the NL Region Fall 2J3K Research Vessel Survey.

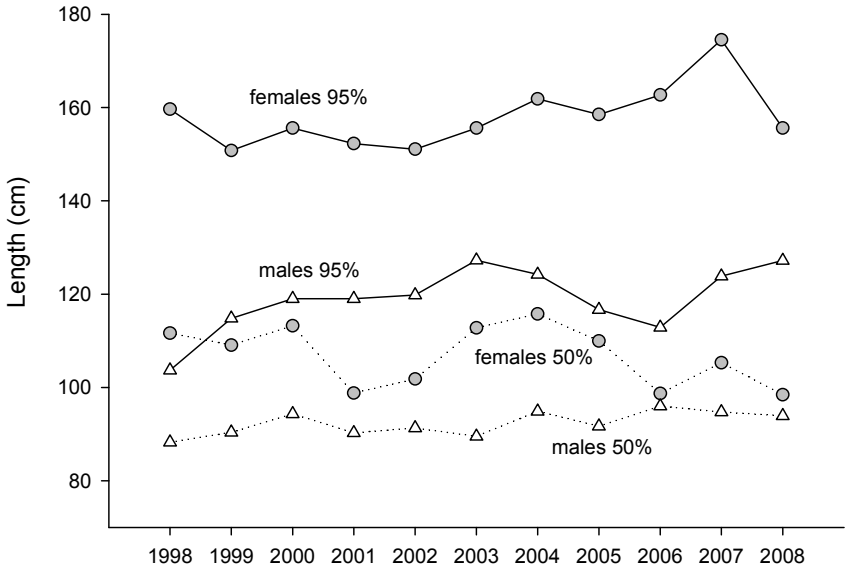


Figure 47. Size composition of male and female Atlantic halibut caught in the 4VWX portion of the halibut survey, expressed as the median (50 %) and 95th percentiles.

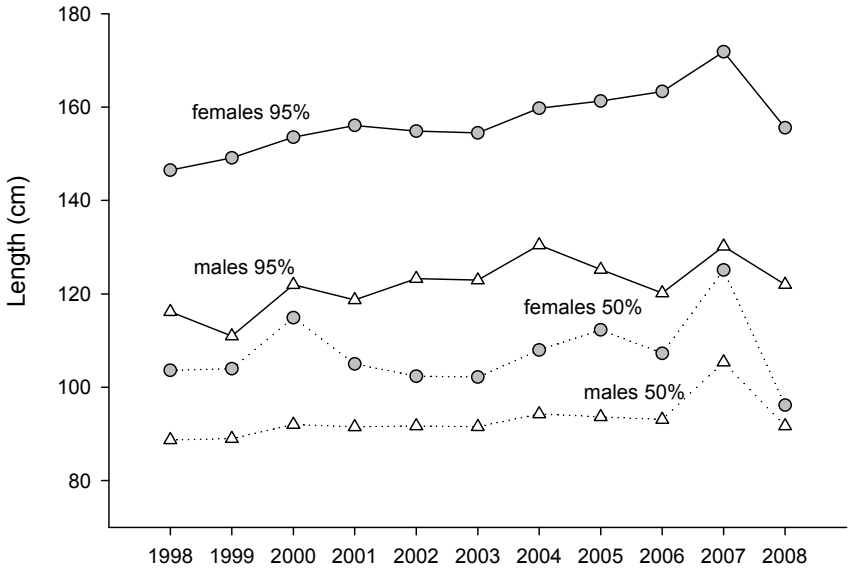


Figure 48. Size composition of male and female Atlantic halibut caught in the 4VWX portion of the commercial index, expressed as the median (50 %) and 95th percentiles.

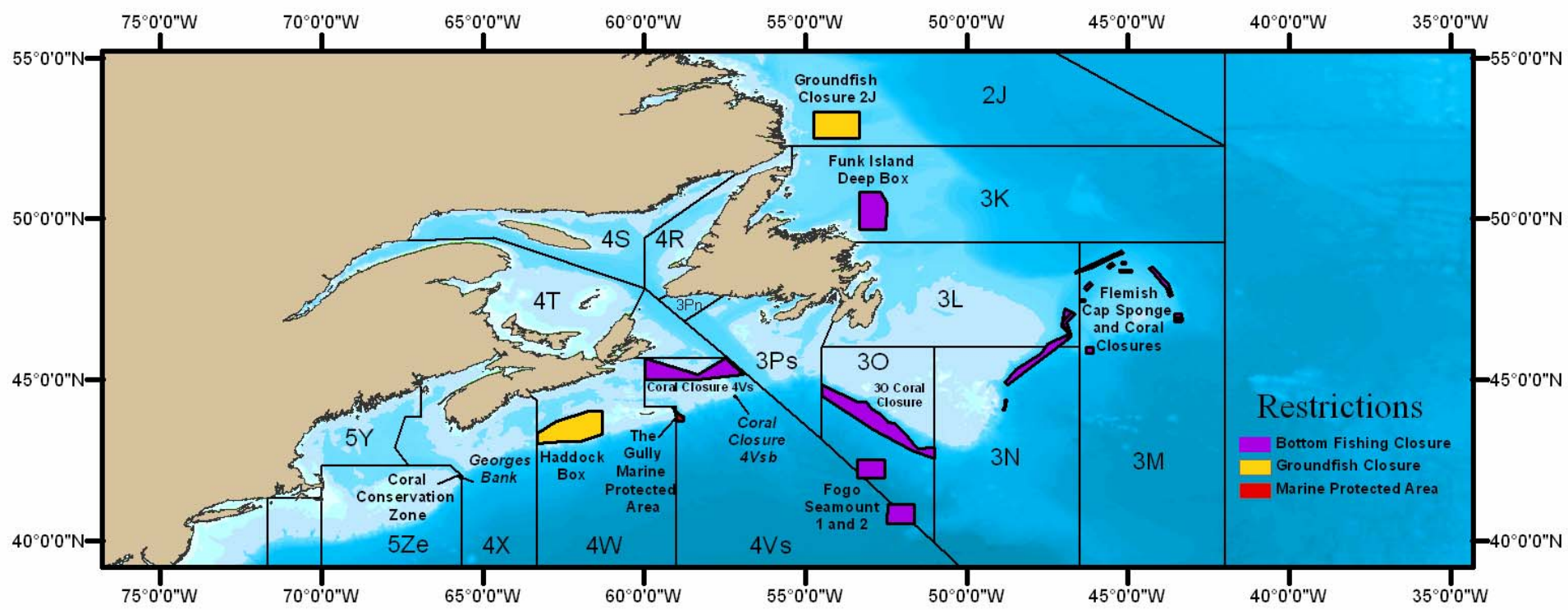


Figure 49. Fishery closures in Areas 2J3K3LMNOP4VsWX5Ze which may impact Atlantic halibut (Hippoglossus hippoglossus). Names that are italicized indicate seasonal closures. Browns Bank and Coral closure area 3Ps are not displayed due to insufficient data.

APPENDIX

Appendix A.1. List of Data files and corresponding Pre-COSEWIC document figure and tables provided to author of Atlantic halibut COSEWIC assessment.

Data Product	Provider	*Pre-COSEWIC* Tables	*Pre-COSEWIC* Figures
Literature review of length at maturity	Pre-COSEWIC REPORT	1	
3NOPs4VWX DFO-Industry Atlantic halibut tagging program release and recapture data for 2006-2008	Pre-COSEWIC REPORT	2	
Gulf of St. Lawrence (4RST) and 3PN commercial Atlantic halibut tagging program release and recapture data for 1998-2008	Diane Archambault	3	
Maps of Atlantic halibut native distribution, lifecycle and NAFO areas	Pre-COSEWIC REPORT		1, 2, 3,
Atlantic halibut bycatch data and distribution maps in northern shrimp (1979-2007) and Greenland Halibut (1995-2007) fisheries off the east coast of Baffin Island	Margaret Treble	4, 5	4
Landings by NAFO area for Scotian Shelf and southern Grand Banks region by year	Shelley Armsworthy	8	5
4RST landings be year, gear, fleet and month	Diane Archambault	9	6
NL catch/landings summary with graphs	Mark Simpson		7, 8, 9, 10, 11, 12,
Summer RV Survey (4VWX) distribution data and plots	Shelley Armsworthy		13, 24, 25, 31
Spring RV Survey (4VsW) distribution data and plots	Shelley Armsworthy		13, 26, 32
ITQ Survey of NAFO Division 4X Distribution Plots	Peter Comeau		14, 28
pre-COSEWIC halibut survey catch rate data and prerecruits (RV & survey) for 3NOPs4VWX5Zc	Shelley Armsworthy		15, 47, 48
Halibut survey catch and distribution plots (fixed stations and comm. index)	Shelley Armsworthy		16, 27, 29, 30, 33
Halibut assessment model results	Kurtis Trzcinkski		17

Data Product	Provider	*Pre-COSEWIC* Tables	*Pre-COSEWIC* Figures
DFO-QC Summer Groundfish Surveys - Northern Gulf (1990-2009)	Diane Archambault		18, 34, 37
DFO-Gulf Summer Groundfish Surveys - Southern Gulf (1971-2009)	Diane Archambault		18, 35, 38
Mobile Sentinel Surveys - Northern Gulf (1995-2009)	Diane Archambault		18, 36
Halibut catch and cpue for the Northern and Southern Gulf	Diane Archambault	6	19, 20, 41
NL catch rates of Atlantic halibut in NAFO Div. 3LNO and Subdiv. 3Ps from DFO-NL spring RV surveys, 1972-2009	Mark Simpson		21, 43, 44
NL catch rates of Atlantic halibut in NAFO Div. 2J3KLMNO from DFO-NL fall RV surveys, 1977-2009	Mark Simpson		22, 42, 45, 46
NL catch rates of Atlantic halibut in NAFO Div. 3LNO from DFO-NL juvenile flatfish RV surveys, 1985-1994	Mark Simpson		23
Mobile Sentinel Surveys - Southern Gulf (2003-2009)	Rod Morin		39, 40
Linear regression of Atlantic halibut catch per unit effort from research trawl surveys on the Scotian Shelf, Gulf of St. Lawrence and the southern Grand Banks..	Pre-COSEWIC REPORT	7	
Fishery closure areas which may affect Atlantic halibut in NAFO divisions 3, 4 and 5	Pre-COSEWIC REPORT	10	49