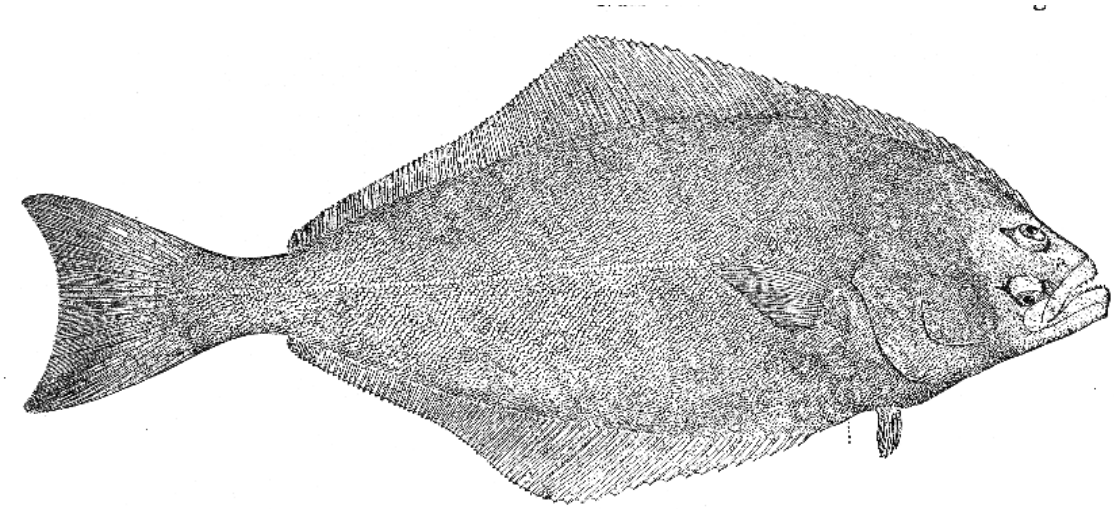
COSEWIC
Assessment and Status Report

on the

Atlantic Halibut
Hippoglossus hippoglossus

in Canada



NOT AT RISK
2011

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Production note:
COSEWIC would like to acknowledge Red Méthot for writing the status report on Atlantic Halibut *Hippoglossus hippoglossus* in Canada, prepared under contract with Environment Canada. This report was overseen and edited by Alan Sinclair, Co-chair of the COSEWIC Marine Fishes Specialist Subcommittee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Flétan atlantique (*Hippoglossus hippoglossus*) au Canada.

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Atlantic Halibut — Drawing by H.L. Todd.

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COSEWIC
Assessment Summary

Assessment Summary – November 2011

Common name
Atlantic Halibut

Scientific name
Hippoglossus hippoglossus

Status
Not at Risk

Reason for designation
Widely distributed in Atlantic Canada, from the Labrador Shelf to Georges Bank and the Gulf of Maine, this species attains a very large maximum size (3 m) and has a relatively long generation time (greater than 21 yr). Abundance in Canada is probably low relative to historical levels due to large fishery removals in the late 1880s and early 1900s. Trawl surveys provide the only long-term abundance indices but provide limited information on mature individuals, which can avoid this gear. Longline indices better sample mature individuals, but time series are relatively short. Since the 1970s, abundance indices on the Grand Banks and Labrador Shelf declined, but have increased since 2002. Abundance indices show increases, particularly since the 1990s, on the Scotian Shelf and in the Gulf of St. Lawrence. Fisheries (directed and bycatch) were essentially unrestricted prior to the 1980s. Management measures since then include catch limits in most areas and a requirement to release small individuals, but catch limits have been exceeded in the past and minimum size is below size at maturity. However, a recent analysis of the Scotian Shelf/Southern Grand Banks population indicates that the population is productive, abundance is above the level which would give maximum sustainable yield, and fishing mortality is below the level of a maximum sustainable yield.

Occurrence
Atlantic Ocean

Status history
Designated Not at Risk in November 2011.

COSEWIC
Executive Summary

Atlantic Halibut
Hippoglossus hippoglossus

Wildlife species description

Class: Actinopterygii

Order: Pleuronectiformes

Family: Pleuronectidae

Latin binomial: *Hippoglossus hippoglossus* (Linnaeus, 1758)

Common names: English: Atlantic Halibut
French: Flétan atlantique; Flétan de l'Atlantique

The Atlantic Halibut can reach a considerable size (up to 3 m in length) and is the largest of the flatfishes. It can be distinguished from other flatfish by its concave caudal fin and eyes on the right side of the head.

Distribution

Atlantic Halibut live in the boreal, arctic and subarctic waters on both sides of the North Atlantic Ocean. In Canadian waters, its distribution extends from the Canadian part of the Gulf of Maine, across the Bay of Fundy, Scotian Shelf, Grand Banks, Gulf of St. Lawrence and Labrador Sea, to Davis Strait and Baffin Bay.

Relatively little information is available to evaluate population structuring for Atlantic Halibut in Canadian waters. The single genetic study did not detect differences in Atlantic Halibut sampled from the Scotian Shelf, the Bay of Fundy, the Gulf of St. Lawrence and Icelandic waters, although population structure, if it exists, may not have been detected due to the timing of sampling. Atlantic Halibut in Canadian waters are therefore considered a single population in this report.

Habitat

The eggs are found in the upper portion of the water column, from the surface to a depth of 700 metres (m), but are concentrated at depths of between 100 and 200 m. Very few eggs are found near the bottom. The eggs can be observed from late fall to early spring and remain suspended in the water column until the larvae hatch. The larvae are thought to have a pelagic lifestyle. When the larva reaches a length of about 35–45 mm, it metamorphoses into a flatfish and adopts a benthic lifestyle. Atlantic Halibut can live at depths of 20 to 1000 m and the juveniles usually live in shallower waters than do the adults.

Biology

Atlantic Halibut spawn between late fall and spring. The absolute fecundity of the females is assessed at 0.5–7 million eggs. The species has a long lifespan and a rapid growth rate resulting in Atlantic Halibut over 3 m in length reported.

The preferred water temperature of juveniles is above 2°C. Adults are able to tolerate temperatures ranging from -0.5 to 13.6^{o}C. Juvenile Atlantic Halibut can migrate long distances.

Population sizes and trends

The assessment of Atlantic Halibut abundance trends is based primarily on scientific trawl surveys conducted by Fisheries and Oceans Canada (DFO), and a collaborative industry/DFO longline halibut survey. The abundance data from DFO research vessel trawl surveys represent the longest data series on this species and cover a vast area. However, given the low vulnerability of adults to bottom trawling, it is difficult to assess trends in mature Atlantic Halibut abundance by means of these surveys. Although the industry/DFO longline halibut surveys have a shorter time series and cover only parts of the Canadian range, they catch a larger number of mature specimens and are therefore more useful in monitoring abundance in areas where fishing occurs.

The available data show considerable variation in overall abundance since the 1970s. In recent years, however, there has been an increase in abundance in all areas. Indices obtained from research vessel trawl surveys increased from 0.47 million fish in 2000 to over 2.9 million fish in 2010 on the Scotian Shelf. In the northern Gulf of St. Lawrence, the Atlantic Halibut abundance index remained below 0.5 million fish in the 1990s, but was over 2 million fish in 2007. An increase was observed during the last 10 years on the Grand Banks and in southern Newfoundland.

Abundance indices from the industry/DFO longline halibut surveys declined in the early 2000s, but increased in recent years.

It is thought that Atlantic Halibut were abundant before the intensification of commercial fishing and that the large landings recorded in the first half of the 20th century are indicative of higher abundance than at present.

Threats and limiting factors

Overfishing is the main threat to Atlantic Halibut populations; however, current management has reduced the threat to a minimum. Adults have few natural predators and live in relatively deep offshore waters with little exposure to human activities outside of fishing.

Special significance of the species

Atlantic Halibut is an important commercial species because of its high economic value. In addition, because of its role as a predator, this species continues to occupy an important place in marine ecosystems.

Existing protection

The Atlantic Halibut is listed as endangered on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. However, this listing may not be relevant to current conditions of the species in Canada. The assessment is dated (1996) and it did not include all of the Canadian distribution. DFO imposes catch quotas on much of the Canadian distribution area, as well as a legal minimum individual landing size.

TECHNICAL SUMMARY

Hippoglossus hippoglossus
Atlantic Halibut Flétan atlantique
Range of occurrence in Canada (province/territory/ocean): Atlantic Ocean

Demographic Information

Generation time	21 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No, there appears to have been an increase
Estimated percent of continuing decline in total number of mature individuals within 2 generations	No decline
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last 3 generations.	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	Not applicable
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	2,006,000 km² within Canada's jurisdiction
Index of area of occupancy (IAO) (based on a 2x2 km grid).	28,000 km²
Is the total population severely fragmented?	No
Number of locations∗	NA
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Total	Several million

∗ See definition of location.

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not done

Threats (actual or imminent, to populations or habitats)

Overfishing is the main potential threat. However, current management has reduced this to a minimum.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? *Gulf of Maine: present in very low numbers.*	
Is immigration known or possible?	Yes
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely? *Populations in US waters are depleted. Immigration from the northeast Atlantic is low.*	No

Previous Status

COSEWIC: None

Reasons for Designation

Status: Not at Risk	**Alpha-numeric code:**
Reasons for designation: Widely distributed in Atlantic Canada, from the Labrador Shelf to Georges Bank and the Gulf of Maine, this species attains a very large maximum size (3 m) and has a relatively long generation time (greater than 21 yr). Abundance in Canada is probably low relative to historical levels due to large fishery removals in the late 1880s and early 1900s. Trawl surveys provide the only long-term abundance indices but provide limited information on mature individuals, which can avoid this gear. Longline indices better sample mature individuals, but time series are relatively short. Since the 1970s, abundance indices on the Grand Banks and Labrador Shelf declined, but have increased since 2002. Abundance indices show increases, particularly since the 1990s, on the Scotian Shelf and in the Gulf of St. Lawrence. Fisheries (directed and bycatch) were essentially unrestricted prior to the 1980s. Management measures since then include catch limits in most areas and a requirement to release small individuals, but catch limits have been exceeded in the past and minimum size is below size at maturity. However, a recent analysis of the Scotian Shelf/Southern Grand Banks population indicates that the population is productive, abundance is above the level which would give maximum sustainable yield, and fishing mortality is below the level of a maximum sustainable yield.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Does not apply because declines in appropriate indices do not meet the thresholds
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because EO exceeds 20,000 km² and IAO is greater than 2,000 km².
Criterion C (Small and Declining Number of Mature Individuals): Does not apply because the estimated population size exceeds 10,000 individuals.
Criterion D (Very Small or Restricted Total Population): Does not apply because the number of mature individuals and the area of occupancy exceeds the thresholds, and the ‘locations’ concept does not apply.
Criterion E (Quantitative Analysis): Not undertaken

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2011)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune
Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Atlantic Halibut
Hippoglossus hippoglossus

in Canada

2011

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WILDLIFE SPECIES INFORMATION

Name and classification

Class: Actinopterygii

Order: Pleuronectiformes

Family: Pleuronectidae

Subfamily: Pleuronectinae

Latin binomial: *Hippoglossus hippoglossus* Linnaeus 1758

Common names: English – Atlantic Halibut
Also: Halibut
French – Flétan atlantique
Also: Flétan, flétan de l'Atlantique

Morphological description

Atlantic Halibut belong to the Pleuronectiformes (flatfish), a group with both eyes on the same side of the head. In the case of Halibut, the eyes are usually on the right side (Pleuronectidae). These fish have a laterally compressed body and swim with their eyes toward the surface.

The Atlantic Halibut is one of the largest fish species in the Canadian Atlantic area (Scott and Scott 1988) and can reach a considerable size. Specimens as much as 3 m in length and weighing 300 kg have been reported (Trumble *et al.* 1993). This fish is also characterized by uniform dark-brown or black colouring on the right side. Its young may be marbled or have paler spots on this side. The left side is usually white. As the fish ages, the left side becomes a mottled grey or cherry red.

The Atlantic Halibut is distinguished from most other flatfish by its concave caudal fin (Figure 1). In the northwest Atlantic, only the Greenland Halibut (*Reinhardtius hippoglossoides*) has a tail similar to that of the Atlantic Halibut. The Greenland Halibut, however, is distinguished by its straighter lateral line, larger mouth and more powerful teeth.

The Pacific Halibut (*Hippoglossus stenolepis*), a very close relative of the Atlantic Halibut, is found along the Pacific coast.

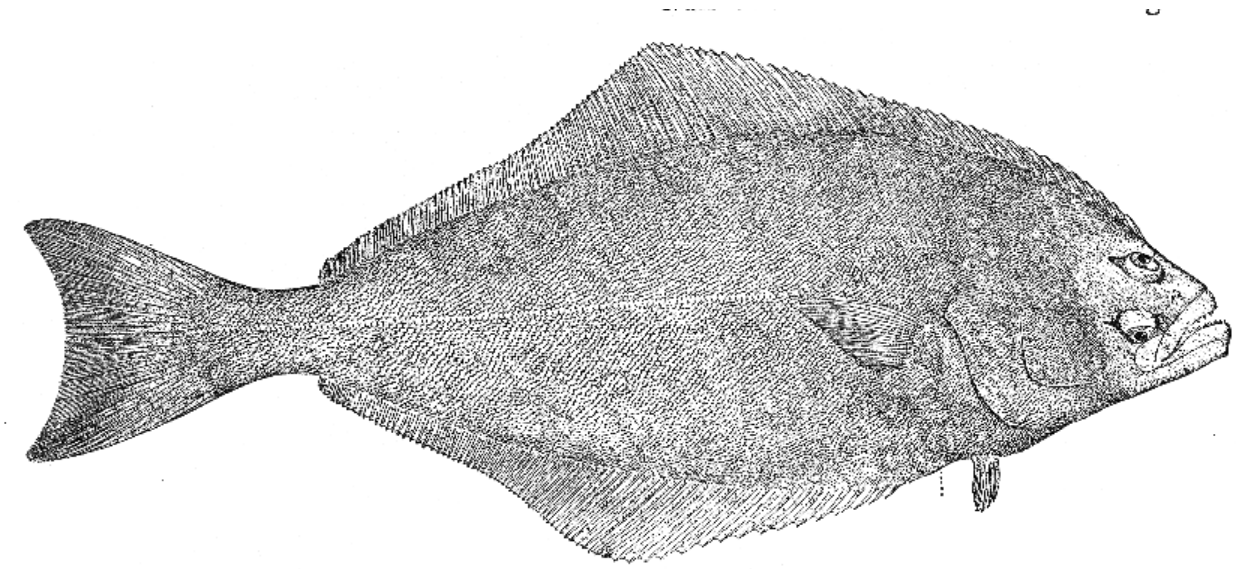


Figure 1. Atlantic Halibut (*Hippoglossus hippoglossus*). Drawing by H.L. Todd.

DISTRIBUTION

Global range

The Atlantic Halibut is found in boreal, arctic and subarctic waters on both sides of the North Atlantic Ocean (Scott and Scott 1988) (Figure 2). On the eastern side, *H. hippoglossus* is found from the Gulf of Gascony as far as the Barents Sea. Its distribution extends westward through the waters off Iceland and Greenland. On the western side of the Atlantic, this species ranges from New Jersey to west of Greenland, in Disko Bay (DFO 2009a).

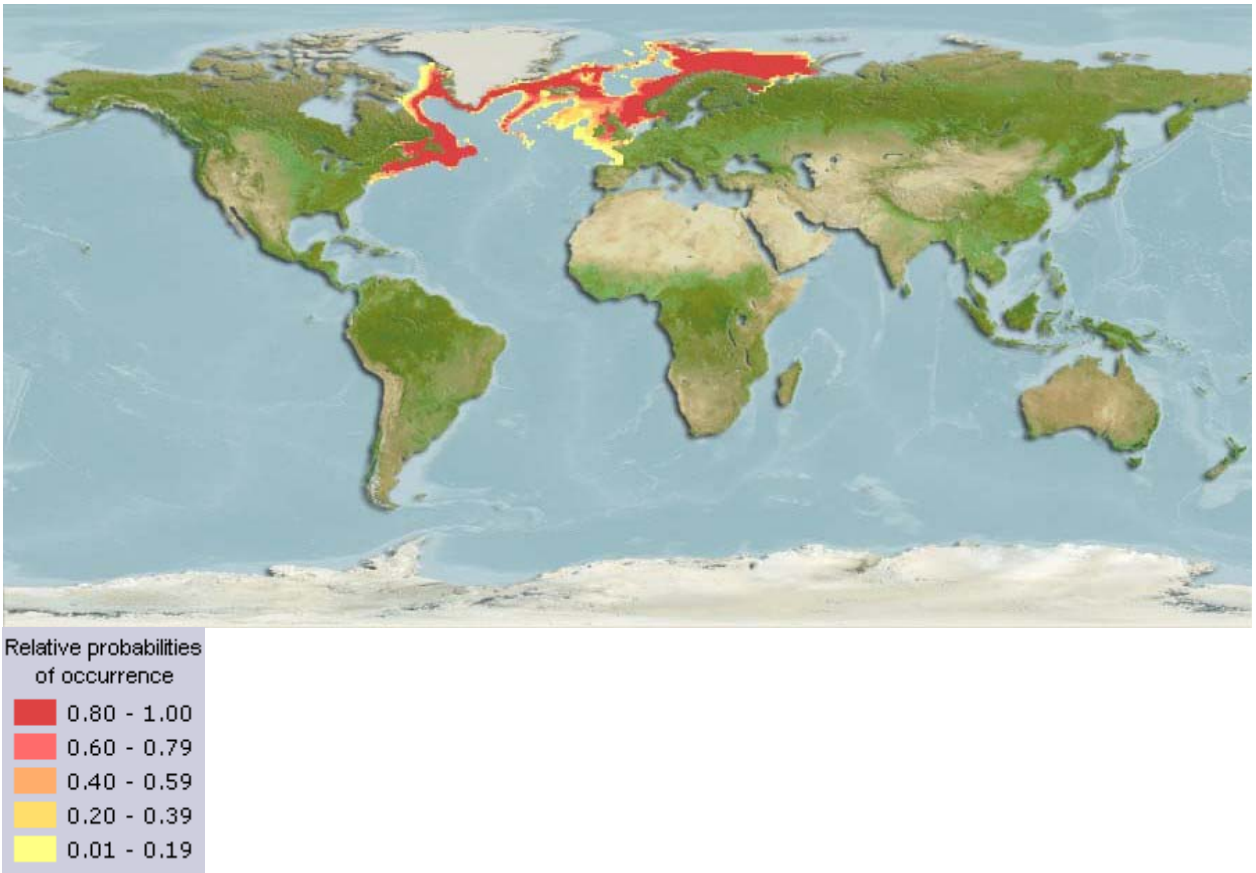
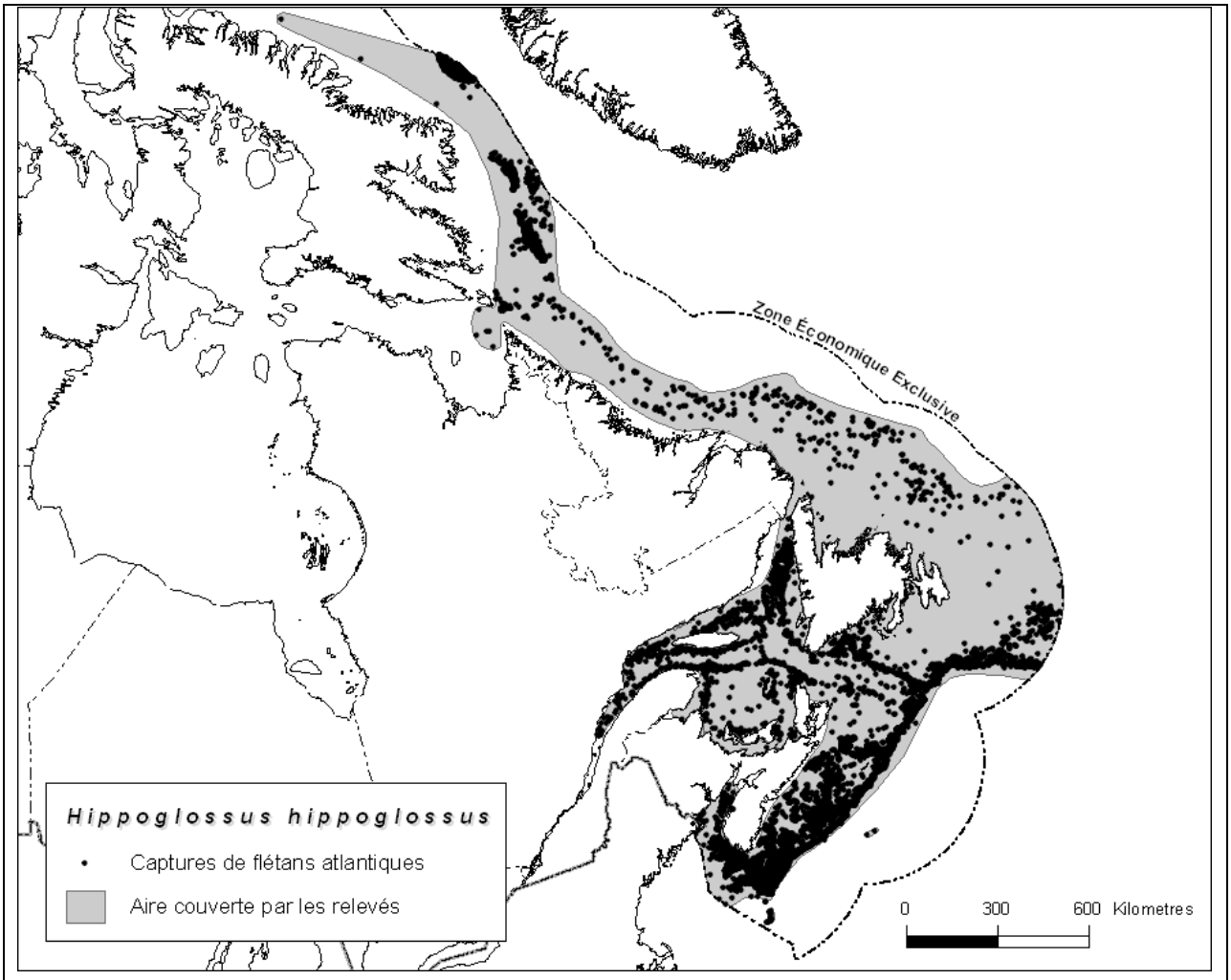


Figure 2. Global range of Atlantic Halibut. See Kaschner *et al.* 2008. Source: Kaschner *et al.* 2008.

Canadian range

In Canadian waters, the Atlantic Halibut occurs in the Gulf of Maine, the Bay of Fundy, the Scotian Shelf, the Grand Banks, the Gulf of St. Lawrence, the Labrador Sea, Davis Strait and Baffin Bay (Figure 3).



Translation of text in Figure 3:
Atlantic Halibut catches
Area covered by the surveys

Figure 3. Canadian range of Atlantic Halibut based on catches during various research surveys conducted by DFO or in conjunction with the fishing industry.

This species is abundant in the southern part of its distribution, particularly on Georges Bank, Sable Island Bank, Banquereau Bank and the Grand Banks (Cargnelli *et al.* 1999). Some concentrations of Atlantic Halibut are also found in the Gulf of St. Lawrence, specifically the Esquiman, Laurentian and Anticosti channels (Figure 4), at depths of more than 200 m.

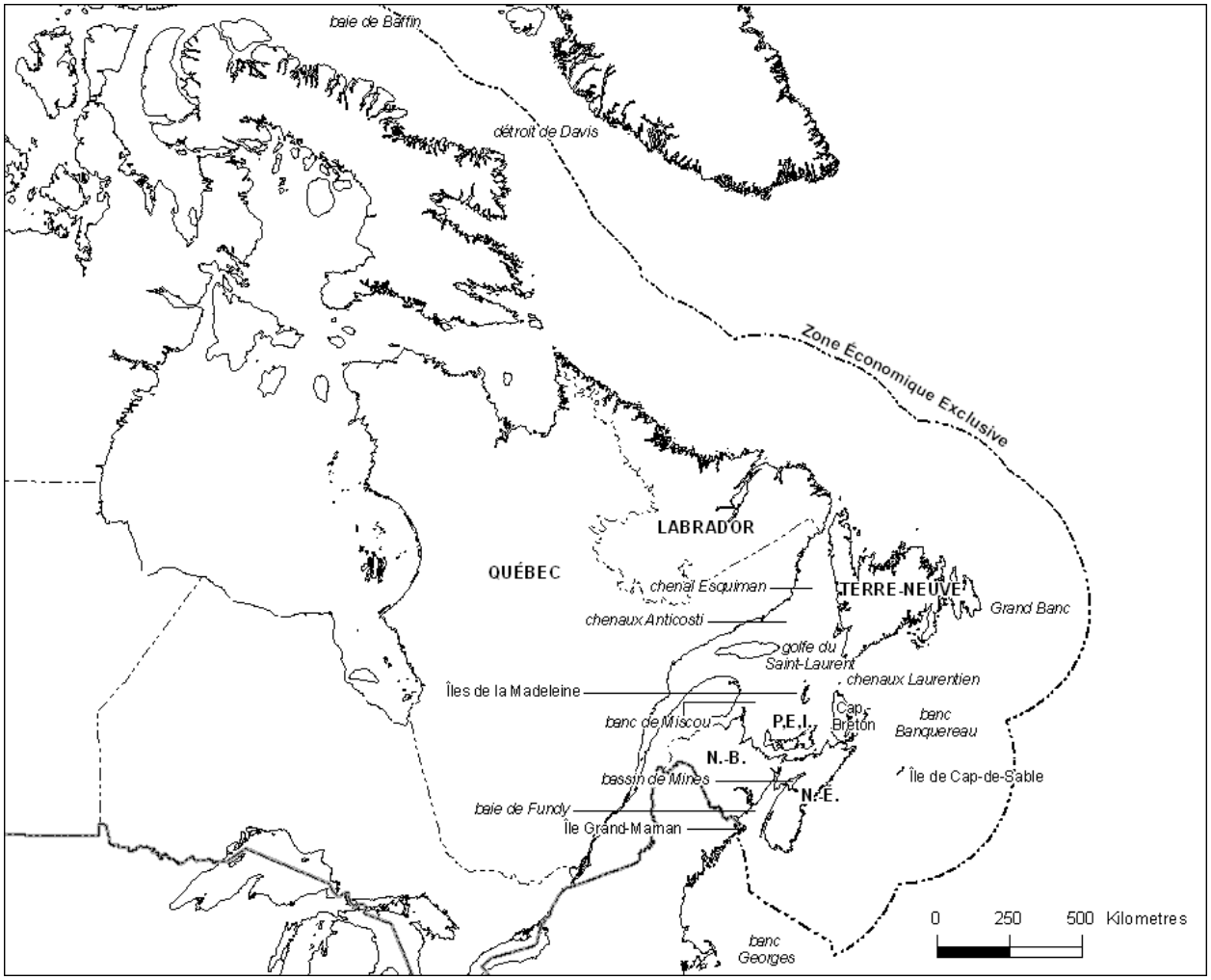


Figure 4. Location map of the Canadian portion of the Northwest Atlantic showing the sites mentioned in this report.

In the southern Gulf of St. Lawrence, in waters shallower than 100 m, it is found near Miscou Bank, north of Prince Edward Island, northwest of Cape Breton and in the waters around the Magdalen Islands (DFO 2009b).

Range of occurrence and area of occupancy

Fisheries and Oceans Canada (DFO) has assessed the spatial distribution (DWAO index) using data from summer research vessel trawl surveys of the Maritimes region (Scotian Shelf and southern Grand Banks stock) (Trzcinski *et al.* 2011). The DWAO index is the design-weighted area occupied.

$A_t = \sum_{i=1}^{n} A_i I$ where I = 1 if $Y_i > 0$, 0 otherwise where n is the number of tows during a survey, Y_i is the number of individuals caught in tow *i* and A_i is the area of the stratum (km^2) sampled in tow *i* divided by the number of fished locations in the stratum.

The DWAO index for the Scotian Shelf calculated on the basis of the Maritimes summer research vessel trawl survey data show significant variability (Figure 5). The index increased through the 1970s to a maximum of about 10,000 km^2 in 1980. It then declined and fluctuated around 5,000 km^2 throughout the 1980s and 1990s. The index increased again in the last decade reaching a value comparable to that in 1980.

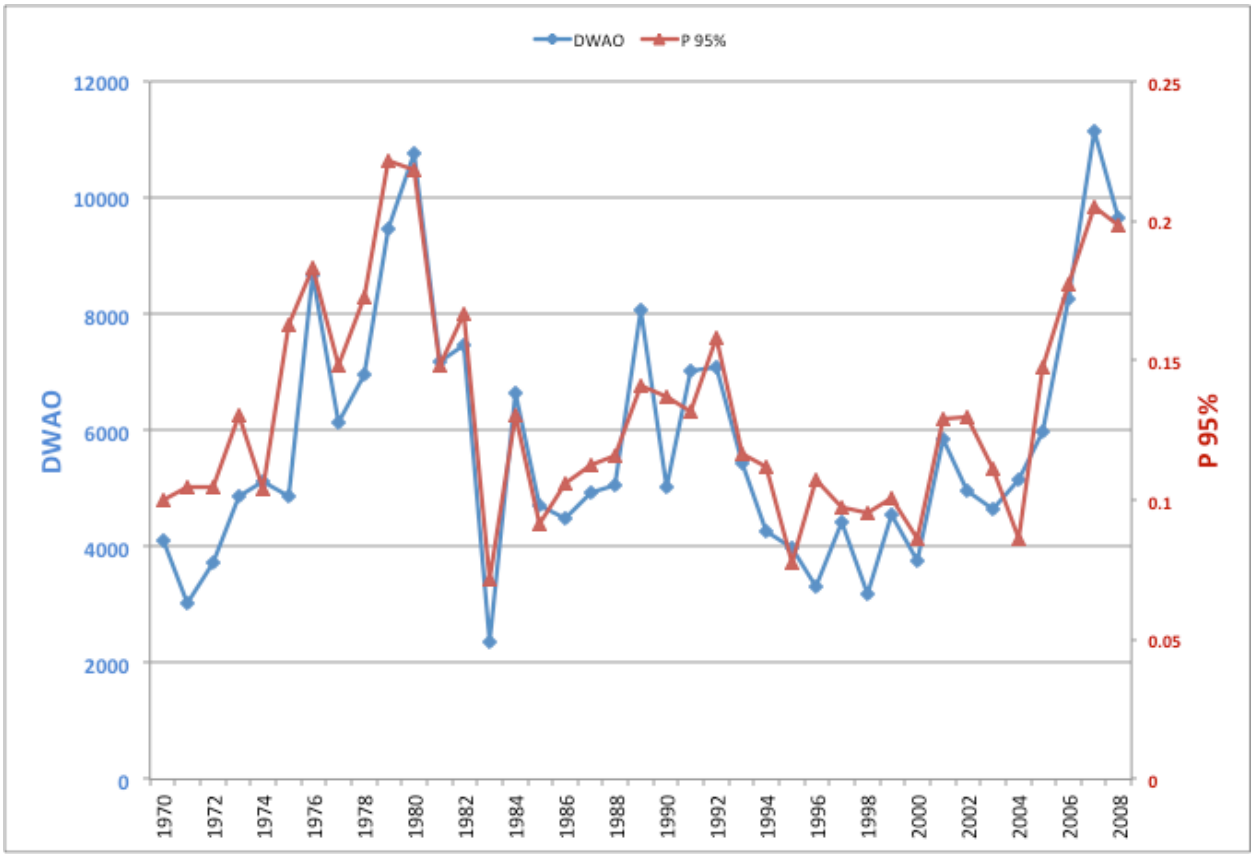
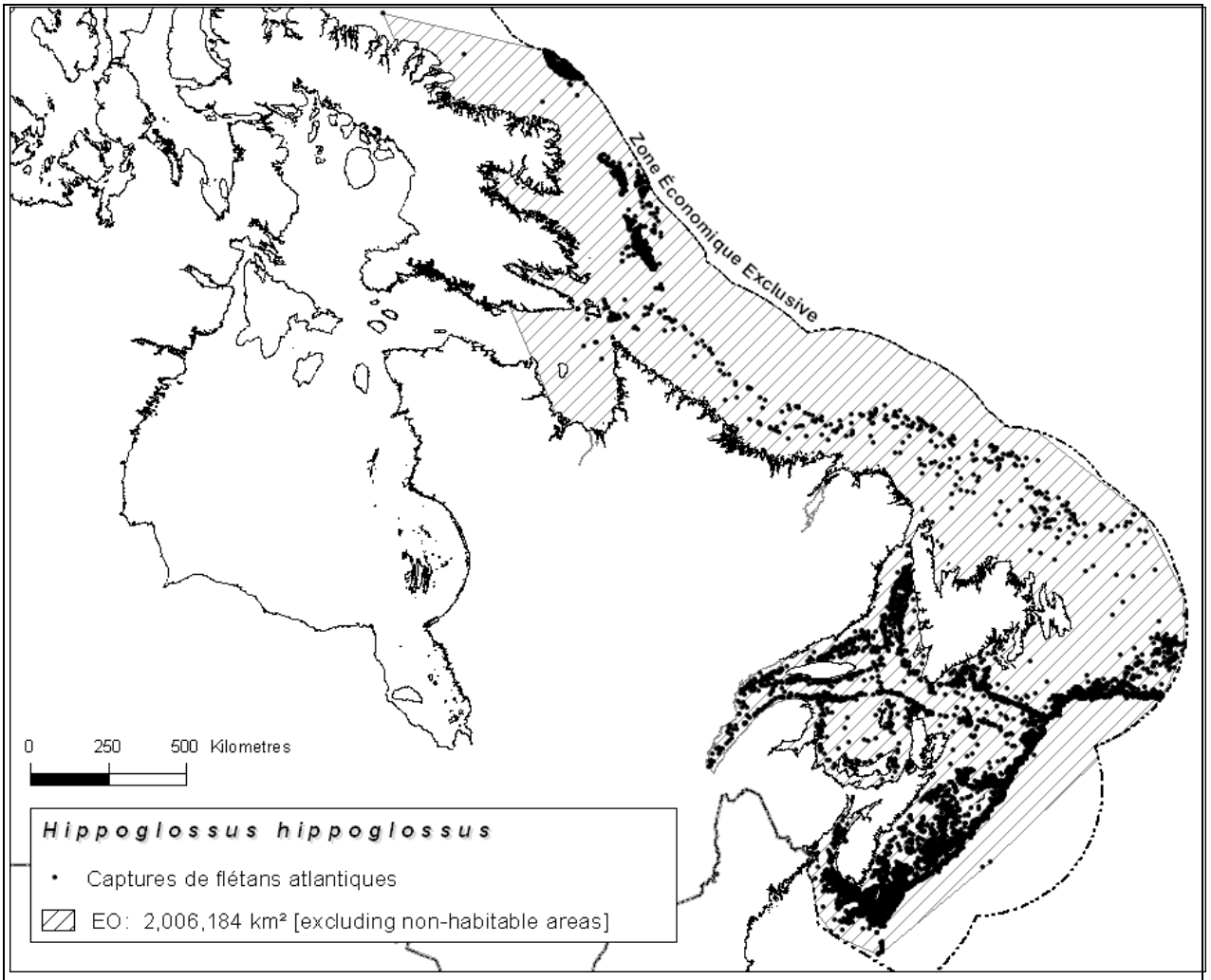


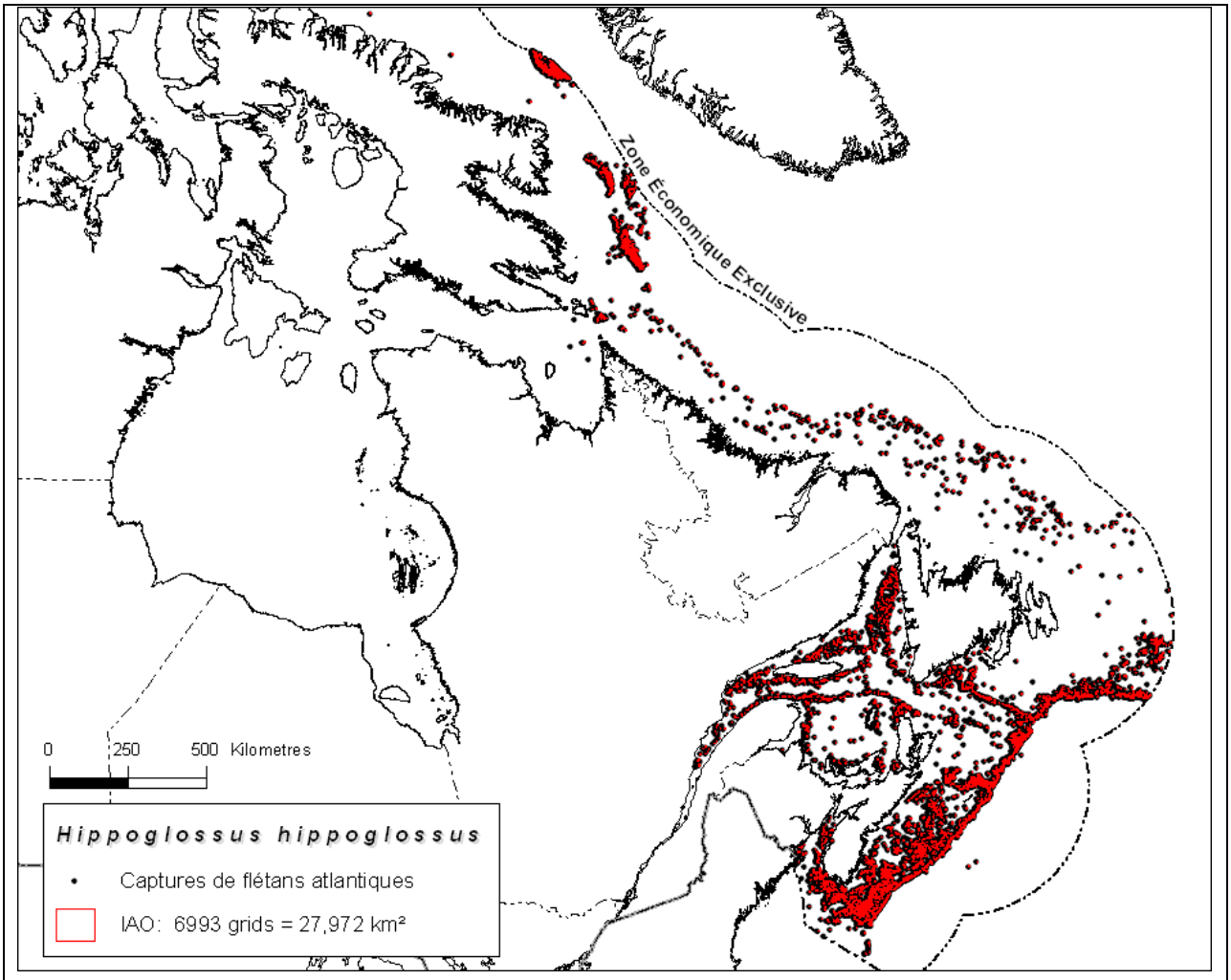
Figure 5. DWAO index (km^2) and percentage of the area occupied by 95% of the Atlantic Halibut stock (P 95%) calculated on the basis of Maritimes summer research vessel trawl surveys on the Scotian Shelf (NAFO divisions 4VWX).

The extent of occurrence was calculated using the minimum convex polygon method, which includes all habitable areas (i.e. excluding land) within Canadian territory (Figure 6). The estimated extent of occurrence was 2,006,184 km^2. In addition, the index of the area of occupancy is 27,972 km^2. It was calculated by overlaying a 2 km x 2 km grid over the entire range covered by the Atlantic Halibut (Figure 7) (J. Wu, COSEWIC, pers. comm. 2011).



Translation of text in Figure 6:
Atlantic Halibut catches

Figure 6. Extent of occurrence of Atlantic Halibut in Canadian waters.



Translation of text in Figure 7:
Atlantic Halibut catches

Figure 7. Index of area of occupancy of Atlantic Halibut in Canadian waters.

Population structure

Table 1 provides a summary of the key elements regarding the discrimination of populations.

Table 1. Summary of key evidence for the spatial differentiation of Atlantic Halibut populations in the Northwest Atlantic.

Observation	Study area	Sources of uncertainty	References
Tagging studies			
Separate spawning grounds	North Atlantic	Numbers tagged, area examined for recaptures	Stobo *et al.* 1988 Godø and Haug 1988
The deep channels are not barriers to adult Atlantic Halibut	Northwest Atlantic	_	Neilson *et al.* 1987
Movements over large distances in juveniles	North Atlantic	_	Neilson *et al.* 1987 Stobo *et al.*1988 Godø and Haug 1988 Kanwit 2007
Genetic studies			
No genetic differences as determined on the basis of 18 microsatellite markers	Scotian Shelf, Bay of Fundy, Gulf of St. Lawrence, Iceland	Samples captured outside the spawning period	Reid *et al.* 2005
Low heterogeneity as determined on the basis of four allozyme loci	Northeast Atlantic	Low sample size (n = 38) for the sample that shows the greatest genetic difference	Haug and Fevolden 1986 Fevolden and Haug 1988
Some genetic heterogeneity between Atlantic Halibut of Norway and of other study areas. Homogeneity between the rest of the samples.	Northeast Atlantic	_	Foss *et al.* 1998
Growth patterns			
Similar growth patterns in Atlantic Halibut from different regions	Newfoundland, Gulf of St. Lawrence and Scotian Shelf	_	Bowering 1986
Different growth patterns between Atlantic Halibut from the Gulf of St. Lawrence and Scotian Shelf	Newfoundland, Gulf of St. Lawrence and Scotian Shelf	Concerns only a few large individuals	Neilson *et al.* 1987
Other			
Egg and larval dispersal during the pelagic phase	Northwest Atlantic	_	Miller *et al.* 1991 Collette and Klein-MacPhee 2002

Beginning in the 1950s, it was hypothesized that several populations of Atlantic Halibut could be differentiated (Joensen 1954; McCracken 1958). Tagging studies done on both sides of the Atlantic Ocean show that the Atlantic Halibut gathers in spawning grounds during the breeding season (Stobo *et al.* 1988; Godø and Haug 1988), suggesting that distinct populations may exist within this species.

However, a recent study did not detect genetic differences between samples of Atlantic Halibut caught at different locations in the North Atlantic (Reid *et al.* 2005). The samples, consisting of 26 to 52 individuals, were taken from the Scotian Shelf, the Bay of Fundy, the Gulf of St. Lawrence and Icelandic waters. A total of 18 microsatellites were used to compare the genetic composition of the different groups of fish. The absolute value of the comparisons F_{st} between sample pairs varied between <0.001 and 0.004 (Table 2). No significant difference was found after a Bonferroni correction was applied for multiple tests. A cluster analysis also established homogeneity within the different samples. It should be noted that the small sample size might potentially limit the implications of this study's findings. Although, according to its authors, a sufficient number of loci (18) were analyzed to detect differences among the samples despite the small numbers, Reid *et al.* (2005) caution that population structure might not have been detected due to the timing of sampling: the samples were collected outside the spawning season, when there could have been a mixing of populations.

Table 2. Comparison of F_{st} value pairs in four samples of Atlantic Halibut (values in parentheses represent *P*, which indicates whether or not the difference is significant).

	Scotian Shelf	Gulf of St. Lawrence	Iceland
Gulf of St. Lawrence	0.001 (0.25)	-	-
Iceland	0.003 (0.10)	-0.002 (0.93)	-
Bay of Fundy	0.004 (0.01)	0.000 (0.56)	0.000 (0.64)

Source: Reid *et al.* 2005.

Similar studies have been done in the Northeast Atlantic. The electrophoretic patterns of four allozymes were used to compare the genetic composition of Atlantic Halibut from West Greenland, the Faroe Islands and three sites off the coast of Norway (Haug and Fevolden 1986; Fevolden and Haug 1988). The samples (n = 38 to 257) were taken during the breeding season, a time when spawning populations should have occupied distinct regions. Little genetic heterogeneity was observed among the different groups of fish. The F_{st} values for each of the four loci were weak (between 0.001 and 0.027). Only one in three loci showed any heterogeneity among the samples (G-test; $P < 0.001$). This heterogeneity was caused by a single sample from central Norway. A cluster analysis also identified two distinct groups: the first comprising the samples from northern Norway, the Faroe Islands and West Greenland, and the second represented by the same sample from central Norway.

Foss *et al.* (1998) did a study similar to that of Haug and Fevolden, adding samples from Iceland to the regions previously studied (i.e. Greenland, Faroe Islands and Norway). A number of differences were found among the samples from Norway and those from the other regions. Considering all the loci analyzed, significant differences were found between Norway and Greenland (chi-square test; $P < 0.01$) and between Norway and Iceland (chi-square test; $P < 0.05$). In addition, the dendrogram of genetic distances also showed that Atlantic Halibut off the coast of Norway are genetically different from those in the other regions studied. The groups from Greenland, Iceland and the Faroe Islands, however, are relatively homogeneous.

Several studies (e.g. Neilson *et al.* 1987; Stobo *et al.* 1988; Godø and Haug 1988; Kanwit 2007) have shown that Atlantic Halibut can migrate hundreds of kilometres. A number of specimens tagged in Greenland or Iceland were recaptured in eastern Canada (McCracken and Martin 1955), and vice-versa (Trzcinski *et al.* 2009). Exchanges among Greenland, Iceland and Norway have also been reported (Godø and Haug 1988). Juveniles may have a greater migratory range (Stobo *et al.* 1988; Godø and Haug 1988). Movements of Atlantic Halibut indicate potential exchanges among different groups; however, this assumption remains hypothetical.

A total of 1296 Atlantic Halibut were tagged between 1958 and 1973 on the Scotian Shelf and Grand Banks (Stobo *et al.* 1988). Most of the tagging (over 85%) was done between January and June, from 1958 to 1964. In brief, some Atlantic Halibut tagged on the Scotian Shelf moved across the Grand Banks to the Labrador Sea. Also, two individuals tagged on the Scotian Shelf were recaptured off the west coast of Newfoundland, in the Gulf of St. Lawrence. Movements of individuals tagged on the Grand Banks were also detected—recaptures occurred on the Scotian Shelf and in the Gulf of St. Lawrence (one specimen).

In Canadian waters, Atlantic Halibut is currently managed as two management units—the Gulf of St. Lawrence (NAFO divisions 4RST; see Figure 8) and the Scotian Shelf and southern Grand Banks (NAFO divisions 3NOPs4VWX5Zc). These units were defined by DFO in 1987 primarily on the basis of the tagging studies of Stobo *et al.* (1988) and certain biological parameters, such as growth (see Nielson *et al.* 1987).

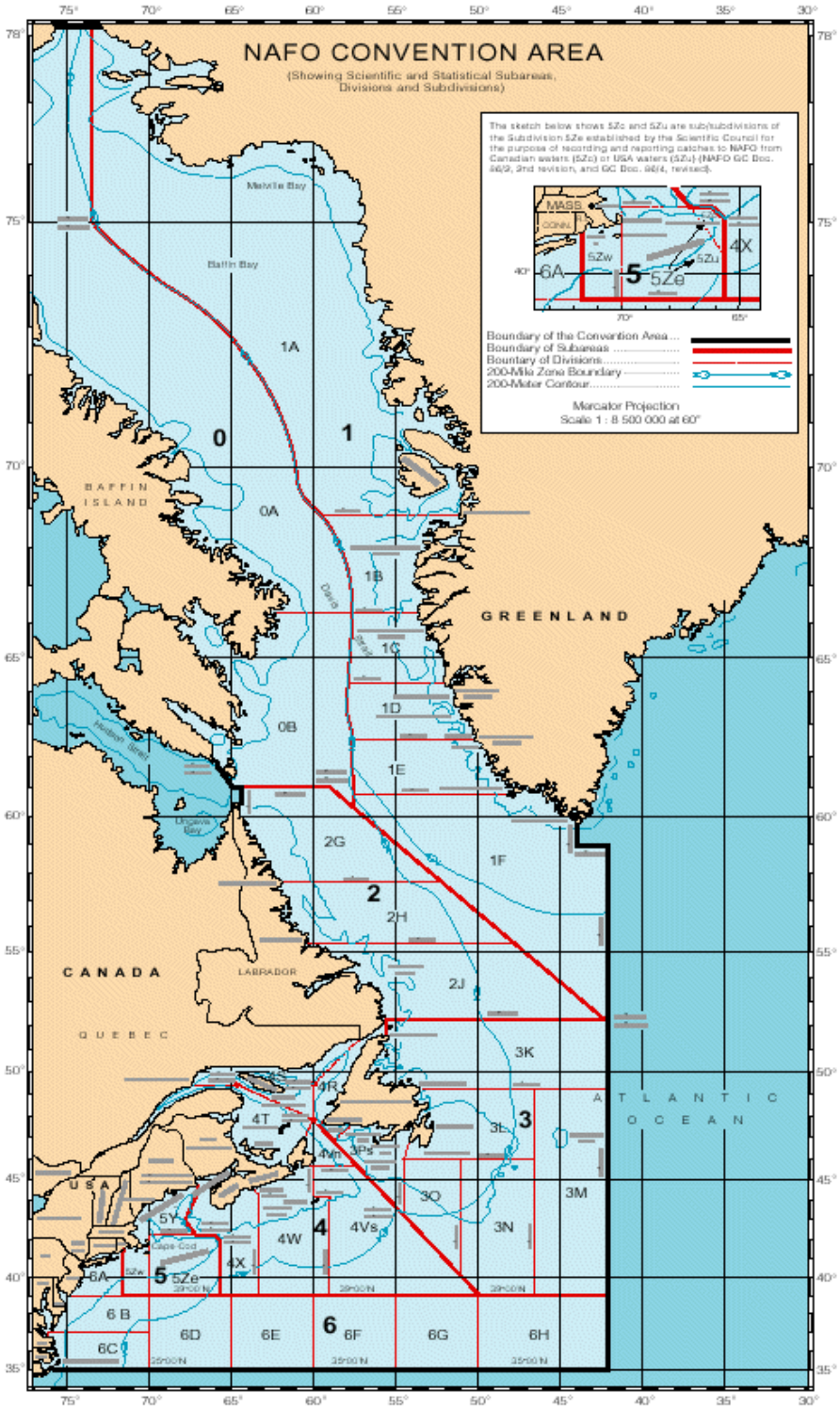


Figure 8. NAFO divisions.

A total of 1864 Atlantic Halibut were tagged in the Gulf of St. Lawrence and Subdivision 3Pn between 1998 and 2004. By the end of 2004, 174 recaptures had been made. Of these, 90% were recaptured within 200 km of the tagging sites and very few were recaptured outside the Gulf of St. Lawrence (DFO 2005a). The intensity of the Atlantic Halibut fishery varies among the different regions of study. Total annual landings from the Gulf of St. Lawrence stock were between about 250 and 800 tonnes (t) from 1958 to 1964, compared to over 3000 t for the Scotian Shelf and southern Grand Banks stock. For this reason, the likelihood of recapture was perhaps lower in the Gulf of St. Lawrence.

In order to discriminate among Atlantic Halibut stocks, Neilson *et al.* (1987) also took into account the differences in growth patterns of Atlantic Halibut from different regions. Several large individuals from the Gulf of St. Lawrence had a different length-weight ratio than did Atlantic Halibut from the Scotian Shelf. Bowering (1986) found no difference among the growth rates of Atlantic halibut caught off Newfoundland and Labrador, on the Scotian Shelf or in the Gulf of St. Lawrence.

While there is mixing of Atlantic Halibut from the Gulf of St. Lawrence, Scotian Shelf and Grand Banks, and while the movement of individuals between the Gulf of St. Lawrence and the Scotian Shelf appears lower than between the Scotian Shelf and Grand Banks, there is no clear evidence to determine whether Atlantic Halibut of the Gulf of St. Lawrence form a distinct population from those of the Scotian Shelf and Grand Banks. To date, no genetic difference has been demonstrated among Atlantic Halibut from the different regions of Canadian waters, although studies focused at times when populations would be expected to be isolated are lacking.

Designatable units

To date, no population structure has been detected that makes it possible to geographically differentiate populations of Atlantic Halibut. The species will therefore be treated as a single unit in Canadian waters in this report. The assessment covers only wild populations of Atlantic Halibut; farmed specimens are not included in the designatable unit.

HABITAT

Habitat requirements

The Atlantic Halibut lives in different habitats according to its life history stage. The eggs and larvae are pelagic, while the juveniles move to deeper waters. In the waters of the Northeast Atlantic, the eggs of the Atlantic Halibut are distributed to a depth of 700 m (McIntyre 1958). Haug *et al.* (1986) indicate that in the northeast Atlantic, eggs may be found close to the surface, but were generally concentrated at depths of about 100 to 200 m. Very few eggs are found near the seabed. Eggs were observed from late fall to early spring.

Very little information is available on Atlantic Halibut larvae due to the low frequency of capture. Surveys in the Northeast Atlantic targeting the larvae of this species have harvested only one specimen (Haug and Sundby 1987). According to Cargnelli *et al.* (1999), Atlantic Halibut larvae occupy a wide range of depths. They can be found near the surface and at depths of over 100 m (DFO 1999). According to some authors, the distribution of most Atlantic Halibut larvae is mostly at 5–50 m (Tåning 1936, Smidt 1968; cited in Haug *et al.* 1989). After metamorphosis, Atlantic Halibut adopt a benthic lifestyle.

Atlantic Halibut juveniles and adults are closely associated with the seabed. Atlantic Halibut are typically found at depths of 100–700 m (Bowering 1986; Miller *et al.* 1991), in the deep channels between banks and along the continental slope. Atlantic Halibut can be found, however, at depths of 20–1000 m (Neilson *et al.* 1987; Miller *et al.* 1991; Cargnelli *et al.* 1999; Sigourney *et al.* 2006). In the Gulf of St. Lawrence, this species is concentrated at around the 200-m isobath in summer, but can live at greater depths in winter (DFO 1999). Juveniles generally occupy shallower waters than do adults. Juveniles are reportedly found at depths of 20–60 m (Sigourney *et al.* 2006).

Adults and juveniles are found on sandy, gravel or clay bottoms (Cargnelli *et al.* 1999). While spawning in the Northeast Atlantic, Atlantic Halibut occupy areas with a sandy or clay bottom (Haug *et al.* 1984).

Habitat trends

A significant reduction in oxygen levels has been observed in the deep waters extending from the St. Lawrence estuary to the northwestern Gulf (DFO 2005b). Indeed, in certain parts of the estuary, oxygen levels are 50% lower than in 1930. Generally speaking, the areas with low dissolved oxygen levels are in waters deeper than 275 m (DFO 2005b). Gilbert *et al.* (2005) showed that there has been an overall decline in oxygen saturation in the deep waters of the Cabot Strait (55–60% lower) and extending to the head of the Laurentian Channel (20% lower), into the deep waters of the Anticosti and Esquiman channels (25% lower).

BIOLOGY

There is relatively little information on the biology of the Atlantic Halibut, owing primarily to the current low abundance of this species relative to other commercial species. Since the mid-1980s, several studies have been done on the biology of the Atlantic Halibut (e.g. Bowering 1986; Stobo *et al.* 1988). Other studies of Atlantic Halibut were done before the 1960s. A report produced by the National Oceanic and Atmospheric Administration (NOAA) of the United States synthesizes the available information on the life cycle and habitat of the Atlantic Halibut (Cargnelli *et al.* 1999).

Life cycle and reproduction

In the southern part of its Canadian range, 50% of females reach sexual maturity at about 120 cm, while males reach maturity at about 80 cm (DFO 2006). Males can reach sexual maturity at about 7 to 8 years of age and females at about 11 to 12 years of age (DFO 2010). In the Gulf of St. Lawrence, 50% of females reach sexual maturity at 130 cm (DFO 2009b); no age of maturity is specified. No data are available for males in the Gulf of St. Lawrence.

Spawning takes place primarily on the continental slope and offshore banks at depths of at least 180 m (Neilson *et al.* 1993). This species is said to return to the same spawning grounds each year (Stobo *et al.* 1988) and individuals congregate for spawning (Neilson *et al.* 1993). The females produce several egg batches each year (Methven *et al.* 1992) and the total number of eggs released ranges from 0.5 to 7 million (Haug and Gulliksen 1988).

The Atlantic Halibut has a rather lengthy spawning season. It is estimated that spawning can take place from early winter until spring. Historically, spawning has been reported as late as August (Goode 1884, cited in Cargnelli *et al.* 1999). According to Neilson *et al.* (1993), most spawning takes place in November and December on the Scotian Shelf and south of Newfoundland. In the Gulf of St. Lawrence, Atlantic Halibut in spawning condition were observed between January and May (DFO 2009b).

The fertilized eggs of the Atlantic Halibut measure 3–4 mm in diameter. The egg incubation period is highly dependent on the water temperature. It is estimated that the larvae take 13–20 days to hatch at a temperature of 4.7–7°C (Miller *et al.* 1991; Collette and Klein-MacPhee 2002).

As previously mentioned, Atlantic Halibut larvae are difficult to study because of low capture numbers. According to Nickerson (1978), the larvae stay near the surface until metamorphosis. The pelagic life stage is estimated at 6–7 months (DFO 1999). Then, when they reach a length of about 35–45 mm, the larvae metamorphose into flatfish and adopt a benthic way of life.

Most immature Atlantic Halibut are caught in a few key regions, notably in the southwestern part of the Scotian Shelf. Browns Bank is also believed to be a nursery area for this species. After three or four years, the juveniles leave these nursery areas to disperse (Haug and Sundby 1987).

The Atlantic Halibut grows rapidly, at an estimated rate of 7.5–8.5 cm/yr. (Archambault and Grégoire 1996). This fish can grow to over 2 m long by age 20. Atlantic Halibut can live for up to 50 years and reach a length of over 3 m and a weight of more than 300 kg (Trumble *et al.* 1993, Armsworthy and Campana 2010).

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) defines generation length as the average age of parents of the current cohort. The following formula is generally used to determine the generation length of marine fish species:

$G_t = A_{female} + 1/M$ where A_{female} (or A50) is the age at which 50% of adult females are mature and M is the instantaneous rate of natural mortality. It is estimated that this species reaches sexual maturity at about age 11 (DFO 2010). An instantaneous mortality rate of 0.1 can be used for this species. This is the value used to assess the Scotian Shelf and southern Grand Banks stock (DFO 2009a; 2010). It takes into account this species' longevity. The Atlantic Halibut's generation length is therefore estimated at 21 years.

Predation

Owing mainly to its large size, the adult Atlantic Halibut has few predators. During the initial life stages (eggs, larvae and juveniles), however, it is subject to predation by other fish. However, little is known about the predation of Atlantic Halibut. Some seal species may eat small Atlantic Halibut, but little or no information is available on this subject.

Diet

The Atlantic Halibut is known to be a voracious feeder. Juveniles less than 30 cm long feed on invertebrates, mostly annelids and crustaceans (Kohler 1967). According to recent studies of stomach contents (collected between 1994 and 2008) in the Gulf of St. Lawrence, Atlantic Halibut smaller than 30 cm in length feed mostly on krill and shrimp (*Pandalus* spp.) (D. Chabot pers. comm. 2008).

When they reach a length of 30–80 cm, Atlantic Halibut add small fish (such as sand lance) and larger invertebrates, like small crabs, to their diet. After reaching 80-cm long, they feed mostly on fish. These prey include flatfish, redfish (*Sebastes* sp.), gadoids and small pelagic fish (Link *et al.* 2002). The Atlantic Halibut may also feed on cephalopods such as squid (*Illex* sp.) and Snow Crab (*Chionoecetes opilio*) (Cargnelli *et al.* 1999; D. Chabot 2008 pers. comm.). Atlantic halibut can also be cannibalistic (Trumble *et al.* 1993; Collette *et al.* 2002)

Physiology

Water temperature and salinity are important environmental variables for marine fish. According to a study done on the Scotian Shelf and in the Bay of Fundy, the Atlantic Halibut can tolerate water temperatures of -0.5 to 13.6^{o}C (Mahon 1997). However, most Atlantic Halibut are caught in areas where the temperature range is 3–9°C (Bowering 1986). Juveniles prefer temperatures above 2°C (Goff *et al.* 1989). Finally, areas where Atlantic Halibut are captured are characterized by a salinity level of 35‰ or less (Blaxter *et al.* 1983; Haug *et al.* 1986).

The eggs are released at temperatures of 4–7°C (Miller *et al.* 1991). There is little available information on the physiological requirements of the larvae. The single larva captured during a targeted mission (Haug and Sundby 1987) was taken from waters with a temperature of 2.4^{o}C and a salinity level of 34.18‰. According to Blaxter *et al.* (1983), the larvae prefer a salinity of 30–34‰.

Dispersal and migration

The extent of pelagic egg and larval dispersal of the Atlantic Halibut is not well documented. The pelagic stage is estimated at 6–7 months (DFO 1999), which may allow for extensive dispersal; however, no information is available due to difficulty in sampling these stages (Haug *et al.* 1989).

It has been shown that juveniles may disperse by migrating over great distances. Migrations have been reported from Labrador to West Greenland (Godø and Haug 1988) and from the Gulf of St. Lawrence to Iceland (McCracken and Martin 1955). Tagging studies on the Scotian Shelf and south of Newfoundland have shown that juveniles can migrate over long distances (Stobo *et al.* 1988; Trzcinski *et al.* 2009). Juveniles from the Scotian Shelf move mostly eastward and to the northeast, farther offshore from Nova Scotia or toward the Grand Banks. Some fish have also been recaptured in the Gulf of St. Lawrence and north of Newfoundland. The results of tagging programs show no movements from Canadian into U.S. waters (Gulf of Maine) in recent years (Col and Legault 2009). However, the low fishing effort in American waters (limited to experimental fisheries and bycatches) limits the likelihood of recapture.

Several tagged Atlantic Halibut from the Scotian Shelf and south of Newfoundland have been recaptured farther offshore, beyond Canada's exclusive economic zone (EEZ) (Trzcinski *et al.* 2009). As for the Atlantic Halibut that occupy the northern part of the distribution (Labrador Sea and off the coast of Greenland), their movements are not well documented because of their low abundance and the absence of directed fishing.

Adults appear to be more sedentary than juveniles. They may, however, make seasonal migrations linked to the annual movements between spawning grounds and feeding grounds (Godø and Haug 1988; Stobo *et al.* 1988).

POPULATION SIZES AND TRENDS

Search effort

Trends in the abundance of Atlantic Halibut have been estimated using three main data sources (see Table 3), research vessel trawl surveys conducted by DFO, a joint DFO/industry longline survey on the Scotian Shelf and southern Grand Banks, and a sentinel trawl survey designed by DFO and conducted with commercial trawlers in the northern Gulf of St. Lawrence. A similar sentinel survey has also been conducted in the southern Gulf of St. Lawrence. However, Halibut catches in this survey were too few to provide a useful index of abundance. The research vessel trawl and the sentinel trawl surveys were directed at a range of groundfish species while the longline survey was designed specifically for Atlantic Halibut.

Table 3. Description of research vessel surveys used in this assessment. Gaps in survey coverage are given in Table 4.

Survey	NAFO Division	Year	Gear
DFO Research Vessel Trawl Surveys			
Summer survey (Maritimes)	4V, 4W and 4X	1970–1981	Yankee 41.5 trawl
		1982–present	Western IIA trawl
Northern Gulf survey	4RS and deep areas of 4T	1990–2003	URI 81'/114' trawl
		2004–present	Campelen trawl
Southern Gulf survey	4T	1971–1985	Yankee trawl
		1986–present	Western- IIA trawl
Spring surveys (Newfoundland)	3N, 3O, 3Ps and 3L	1971–1982	Yankee 41.5 trawl
		1983–1995	Engel 145 trawl
		1996–present	Campelen trawl
Fall surveys (Newfoundland)	2G, 2H, 2J, 3N, 3O, 3K and 3L	1977–1994	Engel 145 trawl
		1994–present	Campelen trawl
Industry/DFO surveys			
Industry/DFO longline Atlantic Halibut surveys	4VWX and 3NOP (fixed-station phase) 4VWX (commercial index)	1998–present	Longline
NGSL mobile gear sentinel fisheries	4RS and deep areas of 4T	1995–present	Commercial trawlers

Table 4. NAFO subdivisions visited as part of the spring and fall scientific trawl surveys by DFO Newfoundland (shaded squares indicate that a survey was carried out; white squares indicate no survey was done).

Year	NAFO Subdivisions										
	Fall Research Vessel Trawl Survey							Spring Research Vessel Trawl Survey			
	2G	2H	2J	3K	3L	3N	3O	3L	3N	3O	3Ps
1971								■	■		
1972								■	■		■
1973								■	■		■
1974								■	■		■
1975								■	■	■	■
1976								■	■	■	■
1977			■	■				■	■	■	■
1978	■	■	■	■				■	■	■	■
1979	■	■	■	■				■	■	■	■
1980			■	■				■	■	■	■
1981	■	■	■	■	■			■	■	■	■
1982			■	■	■			■	■	■	■
1983			■	■	■						■
1984			■	■	■			■	■	■	■
1985			■	■	■			■	■	■	■
1986			■	■	■			■	■	■	■
1987	■	■	■	■	■			■	■	■	■
1988	■	■	■	■	■			■	■	■	■
1989			■	■	■			■	■	■	■
1990			■	■	■	■	■	■	■	■	■
1991	■	■	■	■	■	■	■	■	■	■	■
1992			■	■	■	■	■	■	■	■	■
1993			■	■	■	■	■	■	■	■	■
1994			■	■	■	■	■	■	■	■	■
1995			■	■	■	■	■	■	■	■	■
1996	■	■	■	■	■	■	■	■	■	■	■
1997	■	■	■	■	■	■	■	■	■	■	■
1998	■	■	■	■	■	■	■	■	■	■	■
1999	■	■	■	■	■	■	■	■	■	■	■
2000			■	■	■	■	■	■	■	■	■
2001		■	■	■	■	■	■	■	■	■	■
2002			■	■	■	■	■	■	■	■	■
2003			■	■	■	■	■	■	■	■	■
2004		■	■	■	■	■	■	■	■	■	■

Year	NAFO Subdivisions										
	Fall Research Vessel Trawl Survey							Spring Research Vessel Trawl Survey			
	2G	2H	2J	3K	3L	3N	3O	3L	3N	3O	3Ps
2005											
2006											
2007											
2008											
2009											

The research vessel trawl and the sentinel trawl surveys follow a stratified random sampling design and certain surveys have been conducted for over 40 years. Taken together, the surveys cover most of the Canadian range of Atlantic Halibut. The areas not covered by the research vessel trawl surveys are coastal areas and the northern end of the range (NAFO area 0) and there is only occasional coverage of Divisions 2GH. The survey results were used to estimate abundance for the entire survey area and are presented in units of “minimum trawlable numbers”. It is likely these surveys underestimate the true population numbers because not all fish in the path of the trawl are captured and because some fish may be distributed higher in the water column than the net. This is particularly true for adults because they are seldom observed in the catches as they can escape from or avoid the gear. As a result, the abundance indices derived from the surveys indicate primarily the abundance of small fish before recruitment to the commercial fishery (Figure 9). This observation also applies to mobile gear sentinel surveys, which also use bottom trawls.

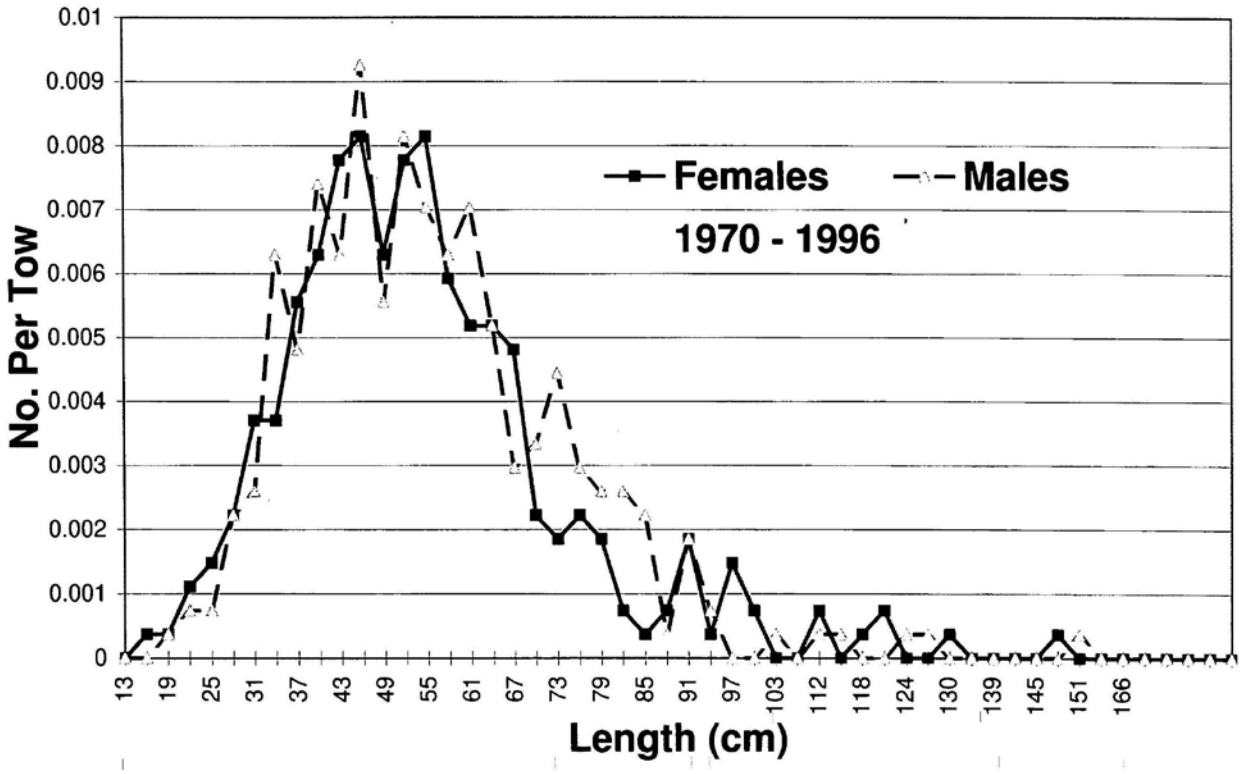


Figure 9. Length frequency of Atlantic Halibut captured in summer trawl surveys on the Scotian Shelf between 1970 and 1996. Data from Zwanenburg *et al.* 1997. Taken from Zwanenburg *et al.* 1997.

With respect to the industry/DFO longline Atlantic Halibut surveys, the data series is shorter than those of the research vessel trawl surveys. In addition, it covers a smaller portion of the Canadian range of this species. However, this survey directly targets Atlantic Halibut in areas that are fished commercially. The survey also catches larger individuals than those caught in the research-vessel trawl surveys (Figures 10 and 11), and therefore it is better suited to assessing the abundance of adult fish. However, because the gear used is baited, the catchability of Atlantic Halibut could be dependent on its density with catchability declining as abundance increases due to hook saturation, and possibly increasing at low abundance due to attraction. This could introduce a bias into the results.

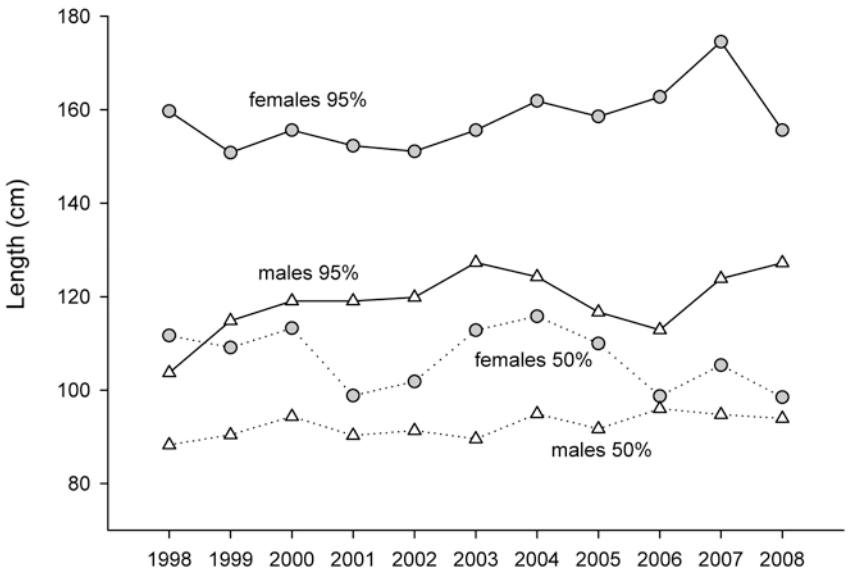


Figure 10. Size composition of male and female Atlantic Halibut caught in NAFO divisions 4VWX during the fixed-station phase of the industry/DFO longline Atlantic Halibut survey, reported as a median and 95th percentile. (Trzcinski *et al.* 2011). Taken from Trzcinski *et al.* in prep.

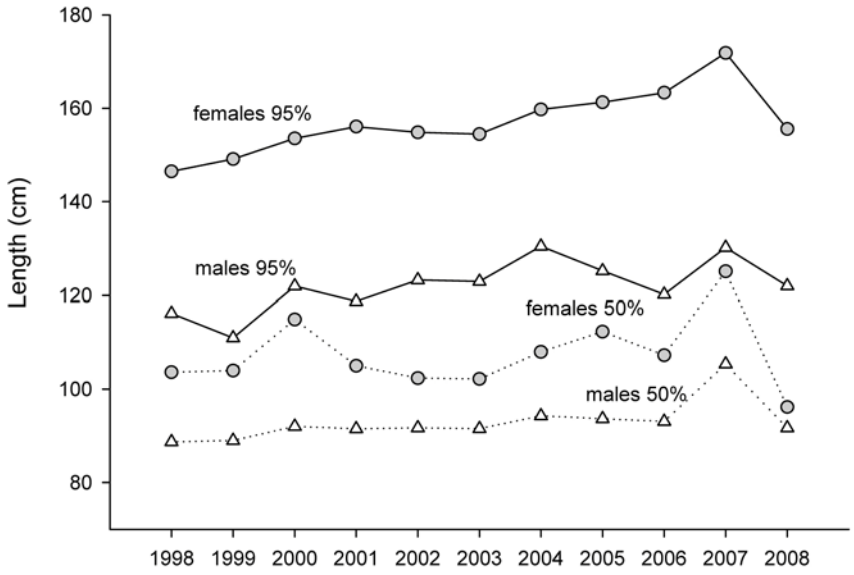


Figure 11. Size composition of male and female Atlantic Halibut caught in NAFO divisions 4VWX during the commercial phase of the industry/DFO longline halibut survey, reported as a median and 95th percentile. (Trzcinski *et al.* 2011). Taken from Trzcinski *et al.* in prep.

Research vessel trawl survey results are available since 1970 for the Scotian Shelf and Bay of Fundy regions. A gear change was implemented in 1982 (the Western IIA trawl replaced the Yankee 41.5). Vessel changes were also made in 1982 and 1991. These changes may potentially affect Atlantic Halibut catch rates; however, catches of Atlantic Halibut during comparative fishing experiments conducted at the time were insufficient to estimate correction factors (Fanning 1985). For technical reasons, relief vessels were also used in 2004, 2007 and 2008.

The DFO spring and fall research vessel trawl surveys in Newfoundland are conducted on the Grand Banks off Newfoundland and in the Labrador Sea. Vessel and gear changes were also made during these surveys (Table 3). As was the case with the Scotian Shelf and Bay of Fundy surveys, catches of Atlantic Halibut were insufficient to estimate correction factors. The coverage also varied in certain areas. Similarly, certain areas were not visited in some years. Table 4 shows the NAFO subdivisions that were covered by the surveys from 1971 to 2009 in these regions.

DFO conducts two research vessel trawl surveys in the Gulf of St. Lawrence: one covers areas 4R, 4S and the Laurentian Channel of 4T (northern Gulf scientific trawl survey) and the other covers division 4T (southern Gulf research vessel trawl survey) (Table 3). For the northern Gulf research vessel trawl survey, CCGS *Alfred Needler* equipped with a URI 81'/114' bottom trawl was used from 1990 to 2003. It was subsequently replaced by the CCGS *Teleost* equipped with a Campelen 1800 trawl. The two data series (1990–2003 and 2004–2009) are comparable, with no differences in Atlantic Halibut catchability observed between the two ships following comparative surveys (Bourdages *et al.* 2007). Trawl surveys conducted in collaboration with industry (mobile gear sentinel surveys) also make it possible to monitor changes in Atlantic Halibut abundance in the northern Gulf of St. Lawrence. Such surveys have been conducted in the northern Gulf since 1995. In the southern Gulf, the research vessel trawl survey has been carried out during September since 1971. The survey was conducted by the *E.E. Prince* using a Yankee 36 trawl from 1971 to 1985. Fishing was conducted in daylight hours only (Benoit *et al.* 2003). The *Lady Hammond* was used from 1985 to 1991 with a Western IIA trawl and fishing was carried out on a 24-hour-a-day basis. The vessel changed again in 1992 when the CCGS *Alfred Needler* was used. Like in the northern Gulf, CCGS *Alfred Needler* was replaced by CCGS *Teleost* in 2006. While comparative fishing experiments were conducted to test for differences in fishing power of the different vessels, nets, and hours of operation, tests specific to Atlantic Halibut were not possible because of low catches.

The joint DFO/industry longline survey has been conducted since 1998 on the Scotian Shelf and southern Grand Banks. This survey is done in two stages. The first stage consists of a survey conducted at predetermined locations according to a standard protocol (fixed-station halibut survey). A general linear model (GLM) is used to assess catch rates that take into account missing stations and differences in survey protocols. The second phase, the commercial index phase, involves participants who fish according to their own protocol in areas of their choosing. It should be noted that this phase is carried out only on the Scotian Shelf (NAFO divisions 4VWX). The survey catches mainly mature individuals but covers only part of the species distribution and is short (11 years) relative to generation time. The details of the survey methods used may be found in Armsworthy *et al.* (2006).

The available data on the northern part of the species' Canadian range (NAFO Subarea 0 and Divisions 2GH) are spotty and the species' abundance is too low to allow an assessment of trends.

Abundance

The rate of change of each index was estimated from the slope of the linear regression of $\log_e$ abundance index (I_t) versus time (t, in years). The resulting regression equation is $\ln(I_t) = \alpha + \beta * t$. The percentage change over *t* years can be calculated as $(e^{\beta t} - 1) * 100$. *t* was set equal to the number of years between the first data point and the last data point in each series (the span). To compare between series the calculation was also extrapolated to 21 years (one generation) for each series. The index values applied in the analysis are given in Appendix 1 and the results are summarized in Table 5. The fitted time series are plotted in Figure 17.

Table 5. Surveys used to assess trends in abundance of Atlantic Halbut in Canada. The table summarizes the time period covered, the number of years spanned, the number of observations, the slope of a log-linear regression of the time series, the residual standard error and the percent change estimated over the span of the index and over a period of 1 generation (21 years).

Index	Years	Span	nobs	Slope	SE	Pval	% Span	% Gen	Suitability for Status Report
Scotian Shelf Research Survey	1970-2010	40	41	0.0107	0.0063	0.099	53	25	Moderate. Index covers mainly juvenile fish over part of the species range
Northern GSL Research Survey	1990-2009	19	20	0.2238	0.0291	<0.0001	6926	10893	Moderate. Index covers mainly juvenile fish over part of the species range
Northern GSL Sentinel Survey	1995-2009	14	15	0.2061	0.0352	<0.0001	1690	7472	Moderate. Index covers mainly juvenile fish over part of the species range
Southern GSL Research Survey	1980-2009	29	24	0.1493	0.0244	<0.0001	7492	2200	Moderate. Index covers mainly juvenile fish over part of the species range
Grand Banks Southern Newfoundland Research Survey	1973-2010	37	35	-0.0174	0.0093	0.069	-47	-31	Moderate. Index covers mainly juvenile fish over part of the species range
Halibut Longline Survey	1998-2009	11	12	0.0578	0.0250	0.043	89	237	Moderate. Index covers mainly mature fish but only for part of the species range and for a short period of time (less than 1 generation)

Abundance estimates have varied significantly over the course of the Scotian Shelf and Bay of Fundy research vessel trawl surveys since 1970 (Figure 12). The index increased in the 1970s to early 1980s, then declined rapidly to a minimum in 1983. The index increased again to the early 1990s and this was followed by a decline to 2000. The index increased again beginning in 2004 and reached the highest estimate in the time series in 2010 of close to 3 million fish (Trzincski *et al.* 2011). It is important to bear in mind, however, that changes in the research trawl and research vessel described in Table 3 may have influenced these trends. The survey spans 40 years, close to 2 generations. A log-linear regression of the index gave a non-significant slope of 0.107 yr^{-1} ($p = 0.099$) and the estimated change in abundance of 53% over the span of the survey (Table 5).

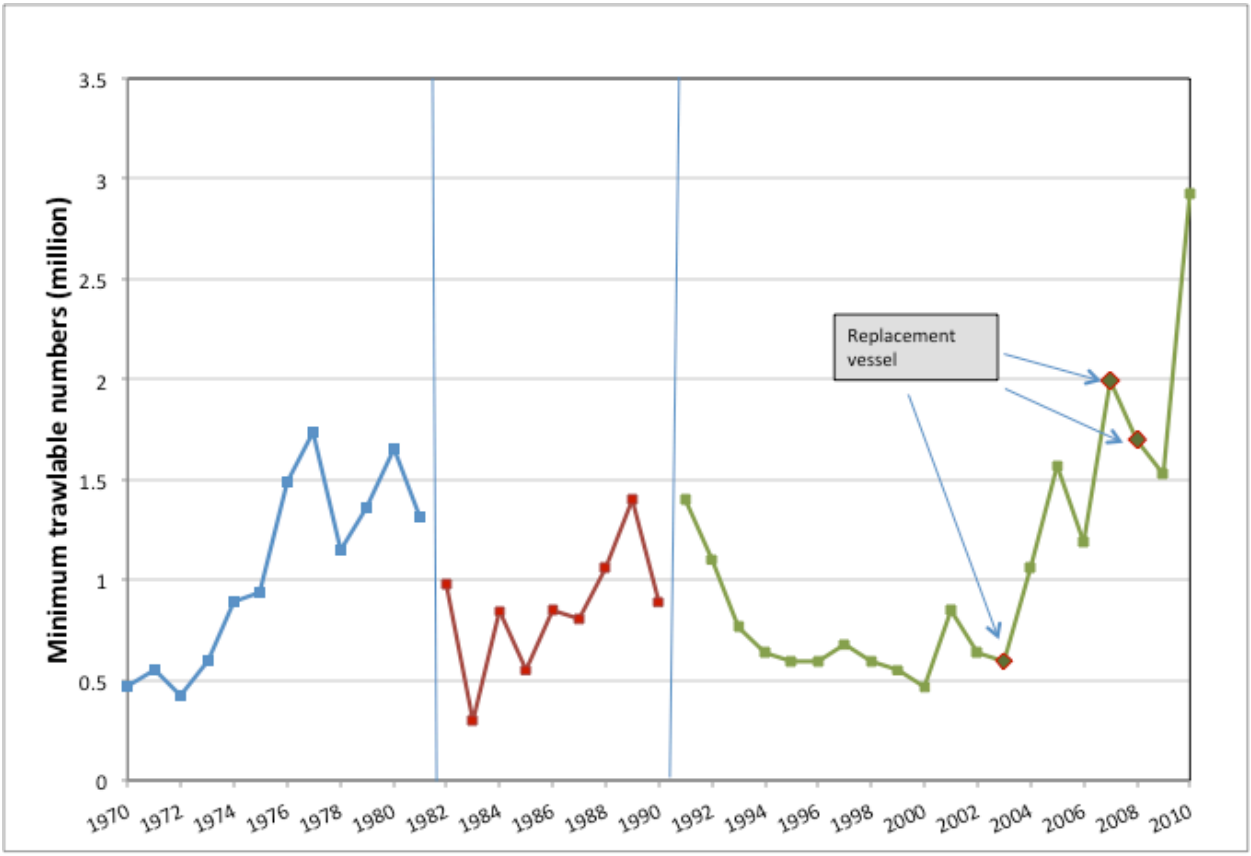


Figure 12. Atlantic Halibut abundance estimates based on the Maritimes summer research vessel trawl survey on the Scotian Shelf (NAFO divisions 4VWX). Note: vertical lines indicate the year of vessel changes. Source: K. Trzcinski, pers. comm.

Abundance estimates for Atlantic Halibut from the various surveys in the Gulf of St. Lawrence are presented in Figure 13 (DFO 2009b; D. Archambault, pers. comm.). Prior to 1990, the indices showed low abundance of Atlantic Halibut in southern Gulf catches. Similarly, few catches were reported in the northern Gulf in the early 1990s. However, in the early 2000s, the catch rate for Atlantic Halibut increased significantly in both research vessel surveys and the sentinel survey, and the estimates in the northern Gulf were much larger than in the southern Gulf. The abundance index peaked at over 2 million in 2007. It has since declined, but remains high. The results of a log-linear regression of the three indices are given in Table 5. All three were significant and they indicated increases in abundance ranging from factors of 17 to 108 over the span of the respective surveys.

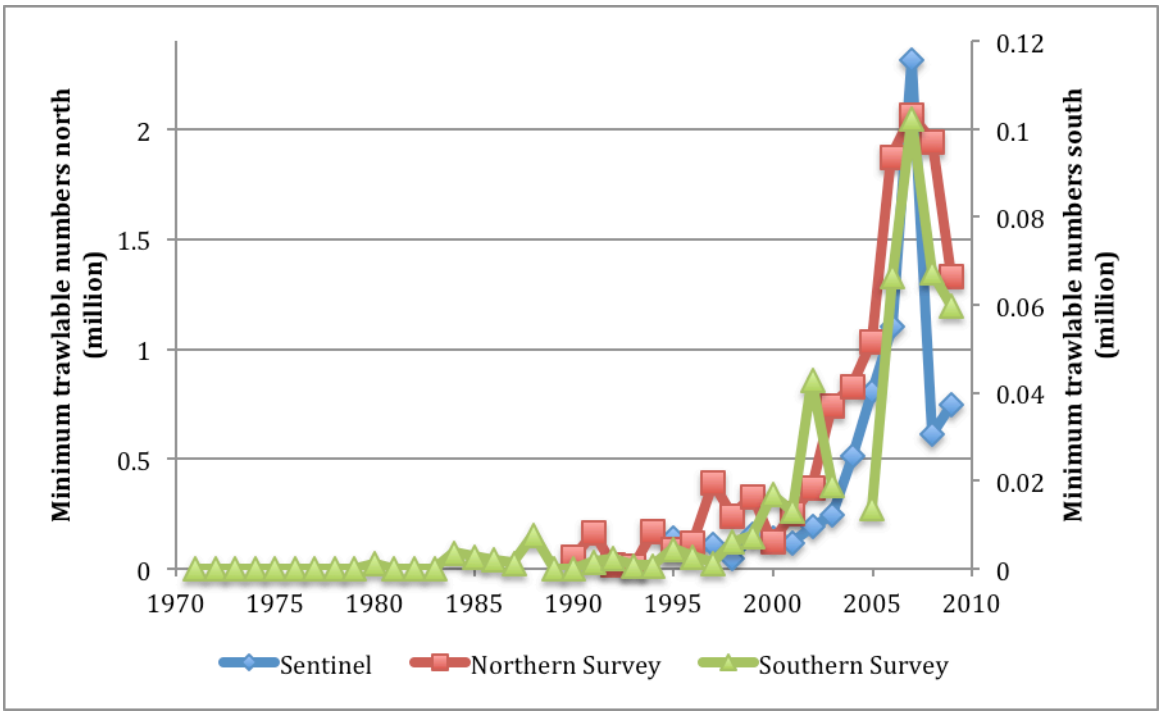


Figure 13. Atlantic Halibut abundance estimates based on research vessel trawl surveys in the northern Gulf (4RST) and southern Gulf (4T) and the summer mobile gear sentinel survey (4RST). Source: DFO 2009b for 4RST and D. Archambault (pers. comm.) for the other data

Abundance estimates increased from the mid-1970s to the early 1980s on the Grand Banks and in southern Newfoundland (NAFO divisions 3LNO and 3Ps) (Figure 14). This was followed by a decline to 2005. No survey was conducted in 2006. The four subsequent estimates (2007–2010) were considerably higher than in 2005, averaged around 0.4 million fish, and were above the survey average. A log-linear regression of the index produced a non-significant slope estimate of -0.0174 yr^{-1} ($p = 0.069$) with an estimated change in abundance of -31% over the span of the survey (Table 5). The fall research vessel trawl survey (Figure 15) has some spatial overlap with the spring survey, but it does not cover NAFO Subdivision 3Ps, an important area based on the spring survey. The fall survey index has much higher interannual variability and is generally lower than the spring index making its interpretation difficult. However, there appears to have been a decline in the index in the early 1990s to a minimum around 1999, followed by an increase in the 2000s. The most recent estimates are above the survey average. As with the Scotian Shelf and Bay of Fundy surveys, it is important to bear in mind that changes in the research trawl and research vessel may have influenced these trends.

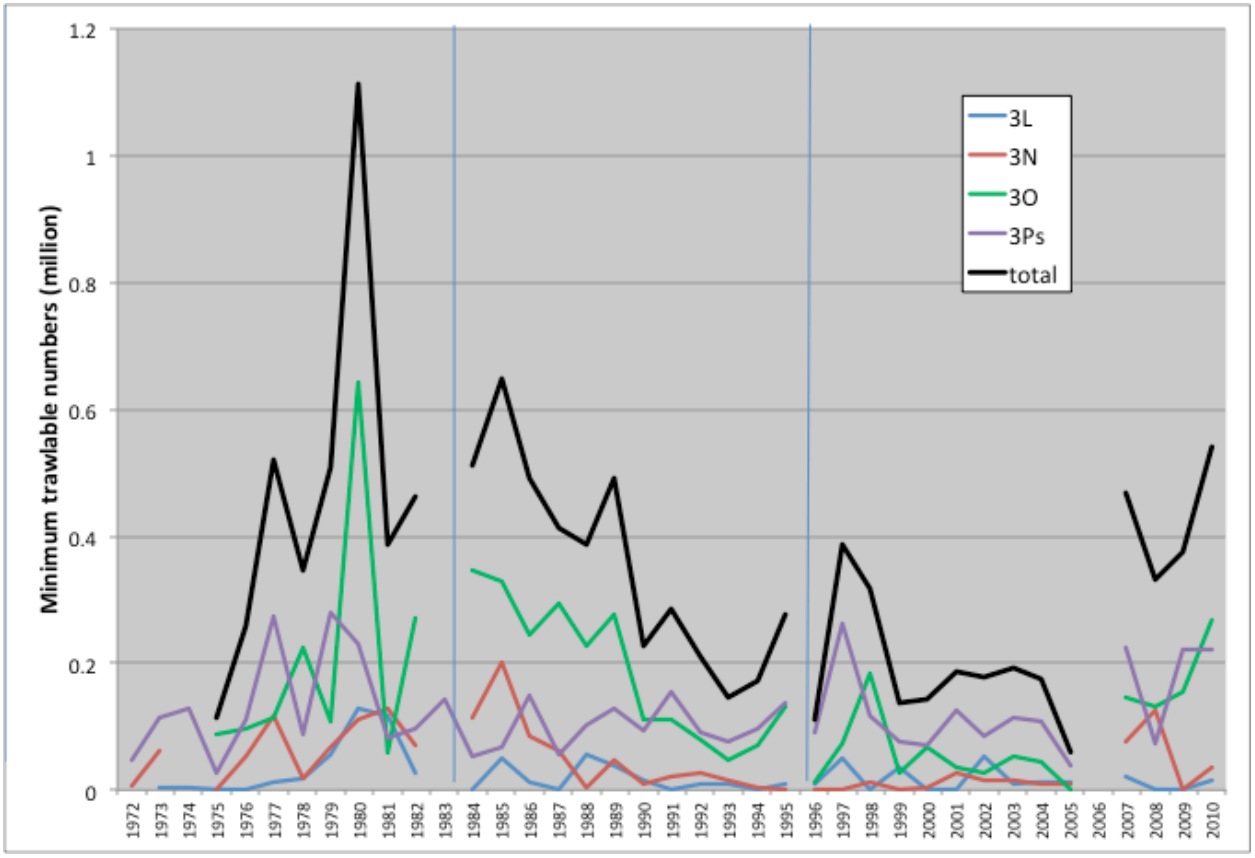


Figure 14. Atlantic Halibut abundance estimate based on spring trawl surveys on the Grand Banks and southern Newfoundland (NAFO divisions 3LNOPs). The “total” curve indicates the sum of the estimates of each area in years in which all areas were surveyed. Note: Vertical lines indicate the year of vessel changes. Data provided by M. Simpson (pers. comm.).

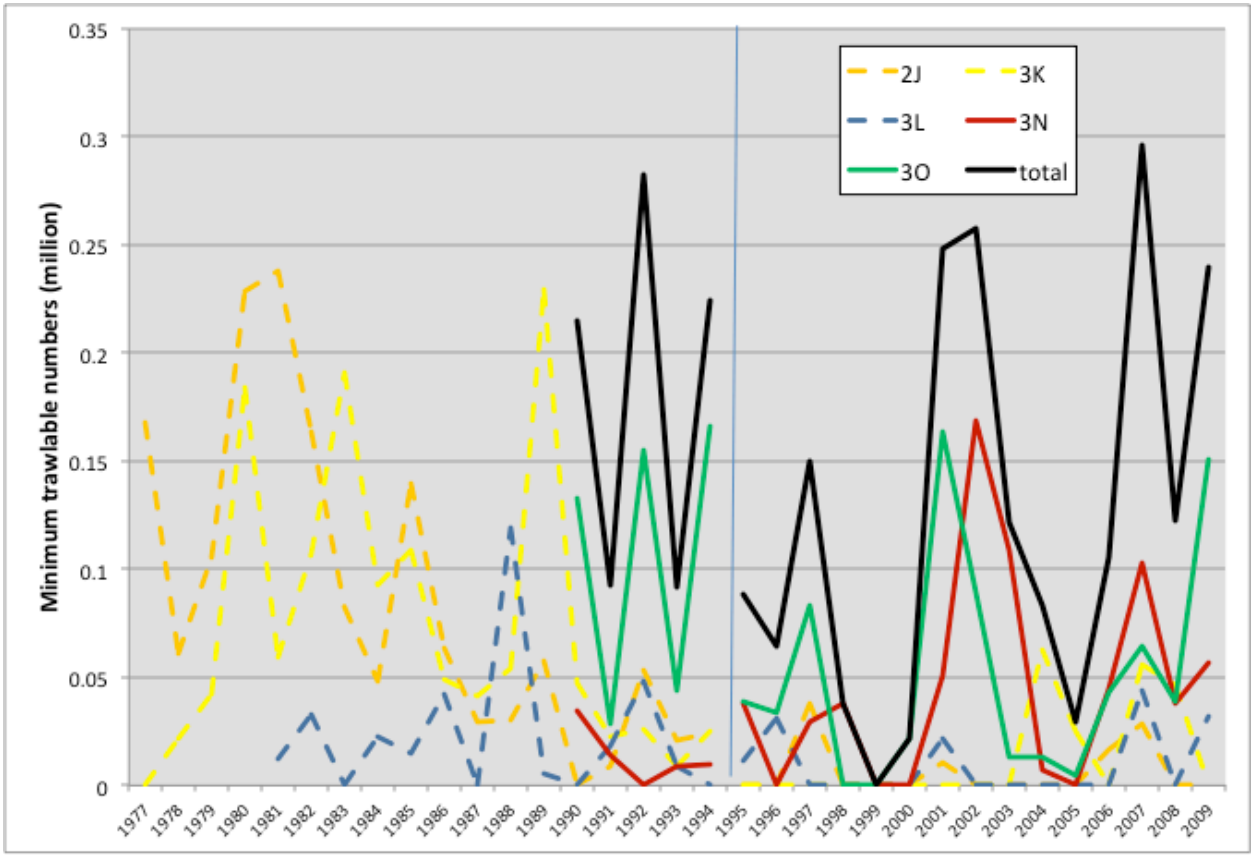


Figure 15. Atlantic Halibut abundance estimate based on fall trawl surveys in the Labrador Sea, eastern and southern Newfoundland and the Grand Banks (NAFO divisions 2J3KLNO). The "total" curve indicates the sum of the estimates of each area in years in which all areas were surveyed. Note: Vertical line indicates a vessel change. Data provided by M. Simpson (pers. comm.).

The industry/DFO longline Atlantic Halibut survey carried out on the Scotian Shelf and southern Grand Banks is relatively short compared to the trawl surveys. Both the fixed station and commercial portions of the survey show a similar pattern (Figure 16). There was a slight decrease in the indices in the early years, but the indices have increased beginning in about 2004. The most recent estimates are the highest in the time series. A log-linear regression of the fixed-station index produced a significant slope estimate of 0.0578 yr^{-1} ($p = 0.043$) with an estimated change in abundance of 89% over the span of the series (Table 5).

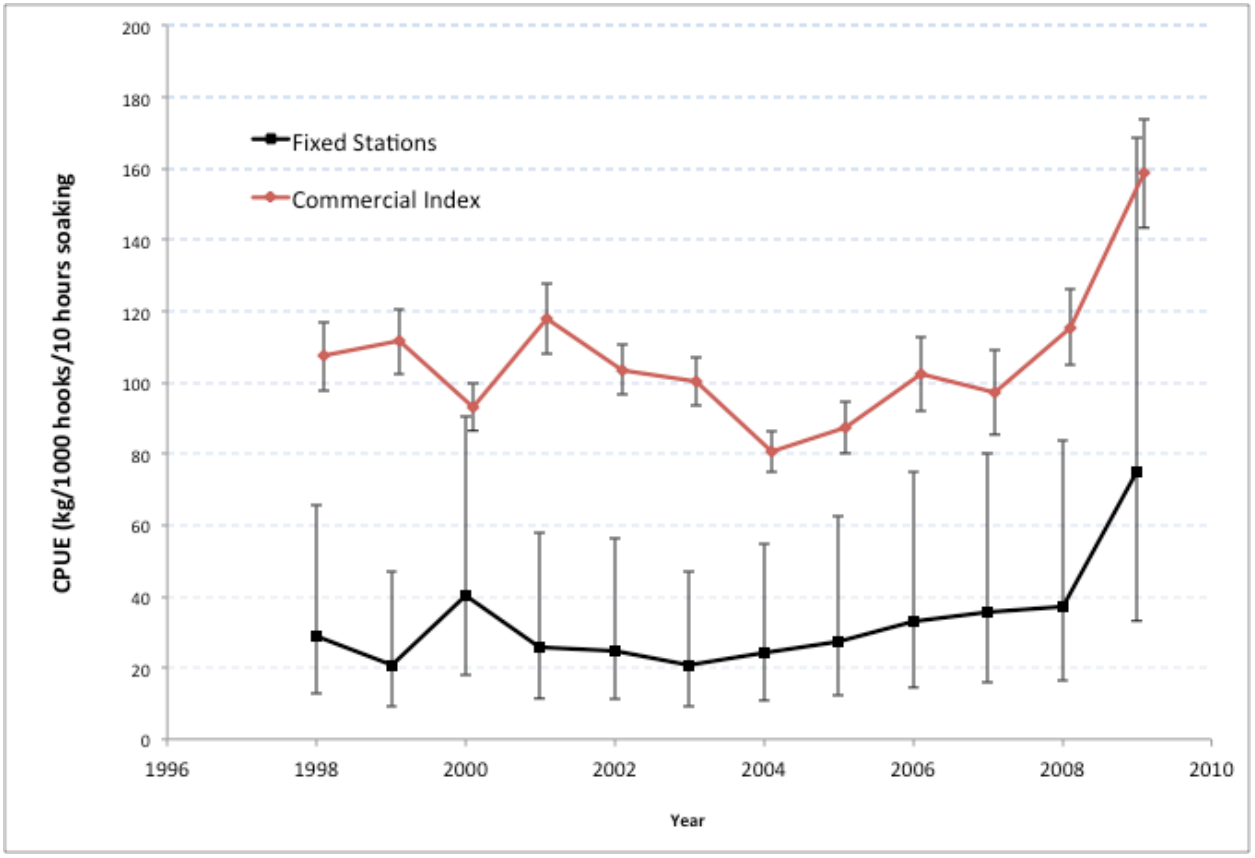


Figure 16. Catch rate in industry/DFO longline Atlantic Halibut surveys (± 2 standard errors). For the fixed-station phase, the results are obtained from a general linear model that includes all stations covered for 5 years or more in NAFO divisions 4VWX (Scotian Shelf and Bay of Fundy) and 3NOP (southern Grand Banks). For the commercial index, the results are limited to divisions 4VWX. Source: Trzcinski *et al.*, in prep.

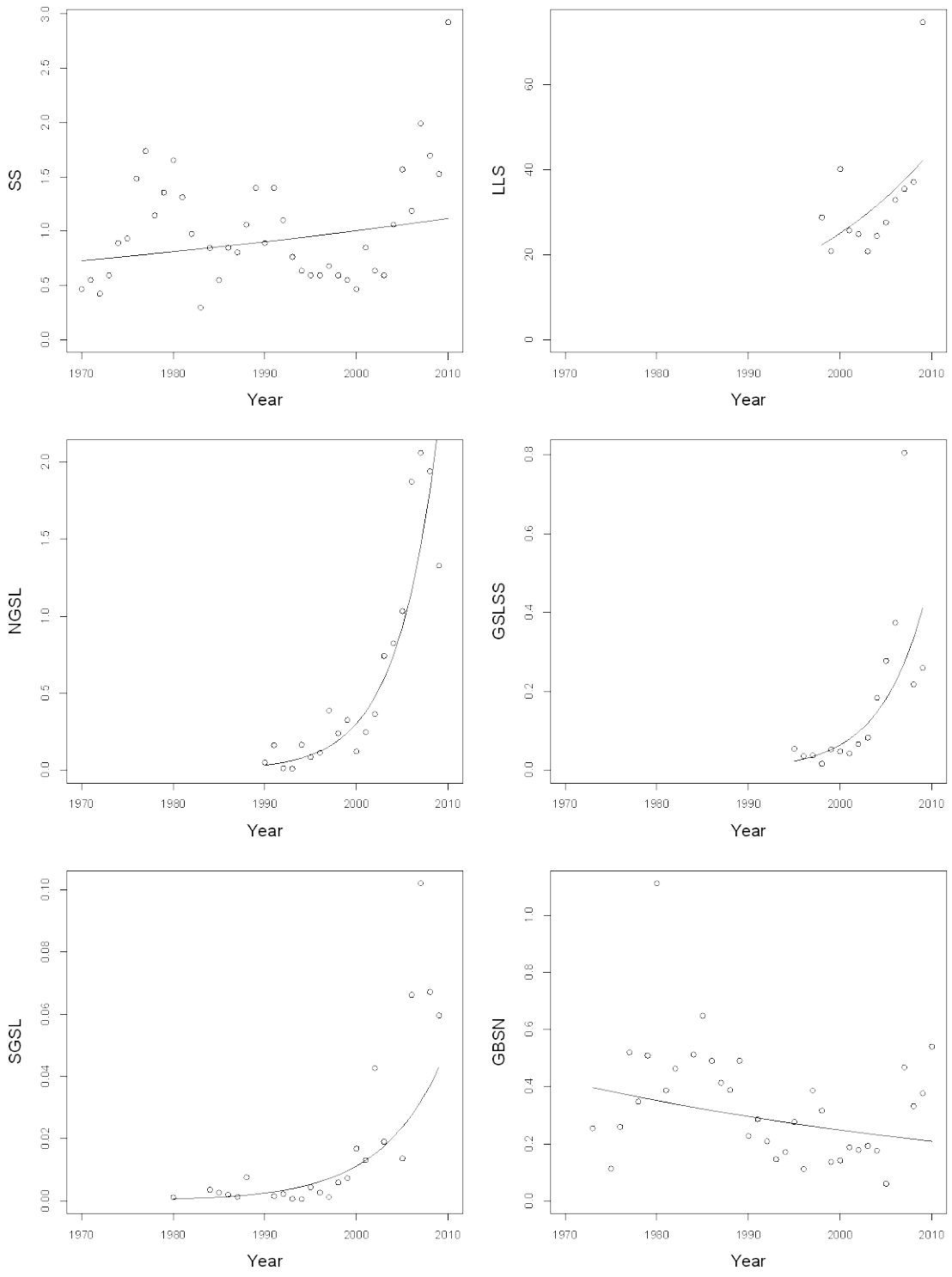


Figure 17. Observed and predicted trends of Atlantic Halibut abundance from six indices; SS, Scotian Shelf survey, LLS, longline survey; NGSL, northern Gulf of St. Lawrence survey; GSLSS, northern Gulf of St. Lawrence sentinel survey; SGSL, southern Gulf of St. Lawrence survey; GBSN, Grand Banks and southern Newfoundland survey. The lines were fitted using log-linear regression and are plotted in the arithmetic scale.

The research vessel trawl surveys and the sentinel survey tend to catch immature halibut and therefore provide a recruitment index. They indicate substantial increases in the Gulf of St. Lawrence and Scotian Shelf since about 2000. The most recent estimates on the Scotian Shelf are the largest observed over the 40-year time series. Those from the northern Gulf of St. Lawrence are also high; however, this survey did not operate in the 1970s and it is not known how abundant the species was then. There was also an increase on the southern Grand Banks in the past 4 years, although this increase has not been as large as elsewhere. The longline survey catches a much higher proportion of mature Atlantic Halibut. It indicates an increase since about 2004. This is consistent with increases in abundance of immature fish beginning around 2000. In total, the status of Atlantic Halibut appears to be improving with the current abundance being considerably higher than that in the 1990s.

Abundance estimates for this species are unavailable prior to 1970. However, historically, Atlantic Halibut was a prized commercial species with a lengthy history going back to the mid-19th century (Grasso 2008). This would suggest that the species abundance observed in the early 1970s when the research vessel surveys began was considerably lower than what it was historically. Additional information on the commercial fishery is given in the **LIMITING FACTORS AND THREATS** section.

Rescue effect

Recent tagging studies have shown Atlantic Halibut moving from U.S. waters into Canadian waters (Kanwit 2007). A large proportion (28%) of the recaptures of fish tagged in the Gulf of Maine occurred in Canada. However, the once-abundant United States stock (Gulf of Maine and Georges Bank) is now considered to be very low (Col and Legault 2009). Two research vessel trawl surveys have been carried out in the Gulf of Maine since the 1960s, one in the spring and one in the fall. Significant interannual variability is observed in the index (Figure 18). It should be noted that it is difficult to compare the status of Atlantic Halibut stocks relative to the historical level in the Gulf of Maine on the basis of these surveys because the significant population decline is believed to have occurred over 80 years before surveying first began. According to a replacement yield model (Col and Legault 2009), it is estimated that Atlantic Halibut biomass in the Gulf of Maine and Georges Bank was approximately 4000 to 5000 t in the early 1900s and approximately 1300 t in 2007 (Figure 19). In addition, a significant decline in this species is believed to have occurred in the 19th century. The likelihood that a contribution from the Gulf of Maine could increase abundance in the Canadian zone is therefore very low if stocks remain at their current levels.

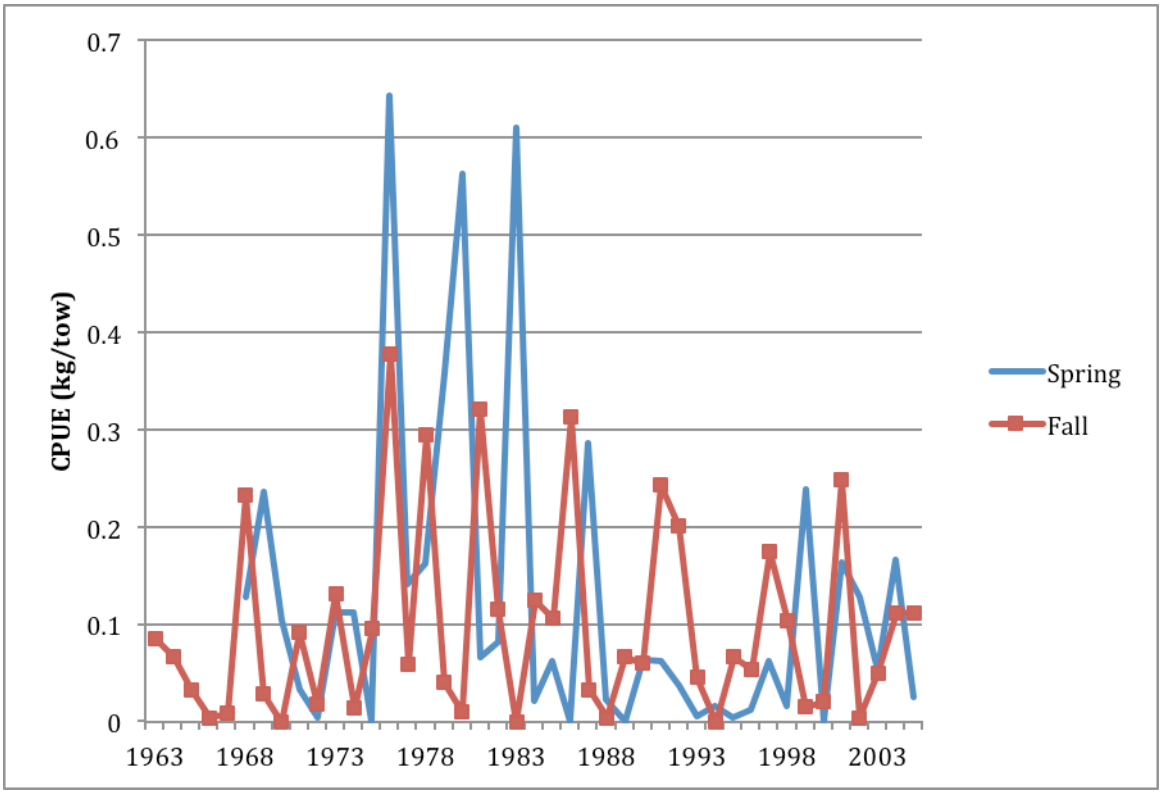


Figure 18. Research vessel catch per unit effort (CPUE) for Atlantic Halibut in the Gulf of Maine and Georges Bank (U.S.). Source: Col and Legault 2007.

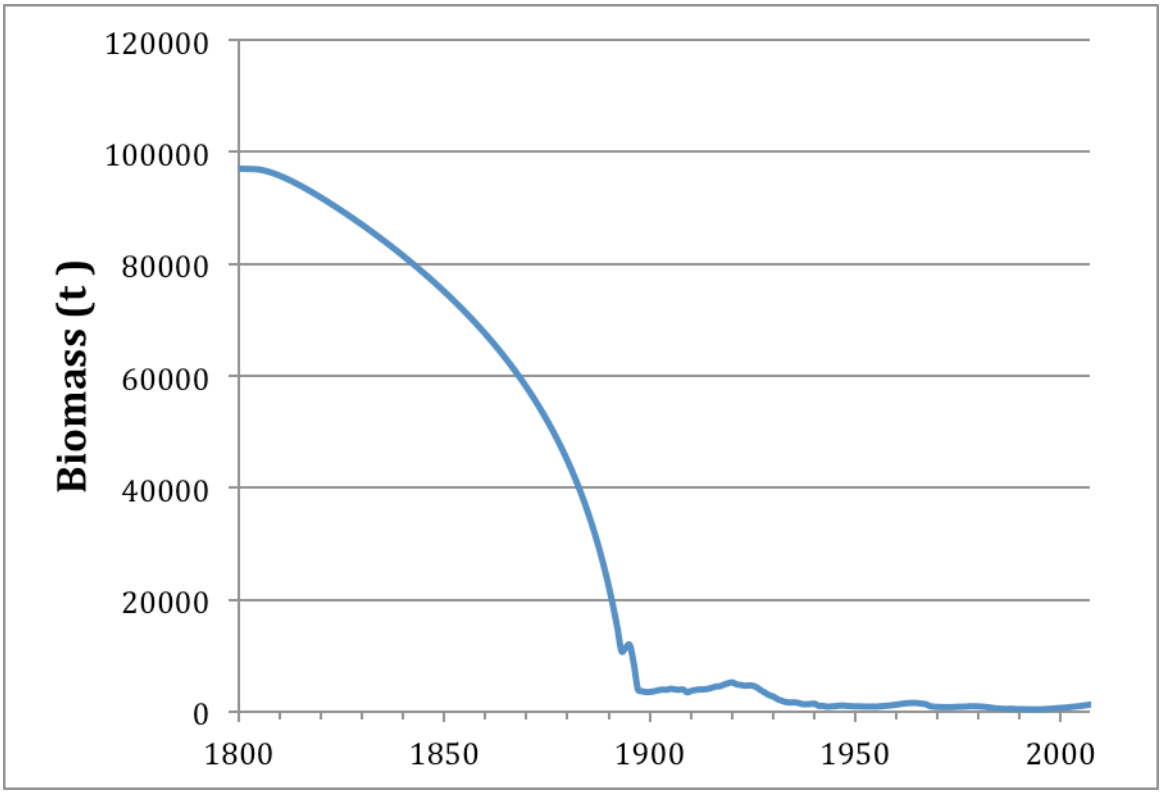


Figure 19. Estimated Atlantic Halibut biomass in the Gulf of Maine and Georges Bank (U.S.) according to a replacement yield model (from Col and Legault 2009). Source: Col and Legault, 2009.

LIMITING FACTORS AND THREATS

Because it matures late, Atlantic Halibut is vulnerable to heavy fishing pressure. It is deemed to not be very resilient. It is estimated that it takes more than 14 years for a *H. hippoglossus* population to double (Froese and Pauly 2008).

Overfishing is the main threat to Atlantic Halibut populations. Adults have few natural predators and live in relatively deep offshore waters with little exposure to human activities outside of fishing. Directed fishing and bycatch from other fisheries can have a significant impact on the abundance of this species. Additional mortality may result from discarding, unreported catches and mortality after being released back into the water. However, within the current fisheries management framework, this threat appears to be well controlled and the threat appears to be minimal.

Atlantic Halibut landings were recorded intermittently between 1883 and 1910 (Figure 20). Landings between 1910 and 1939 varied between 1000 and 3000 t annually. Landings declined during WW II to less than 1000 t. Following the war, there was a large increase to a peak of 6000 t in 1950. Following a decline in the mid-1950s, landings increased again to a peak of 5600 t in 1960. A breakdown of landings by NAFO areas since 1960 is given in Figure 21.

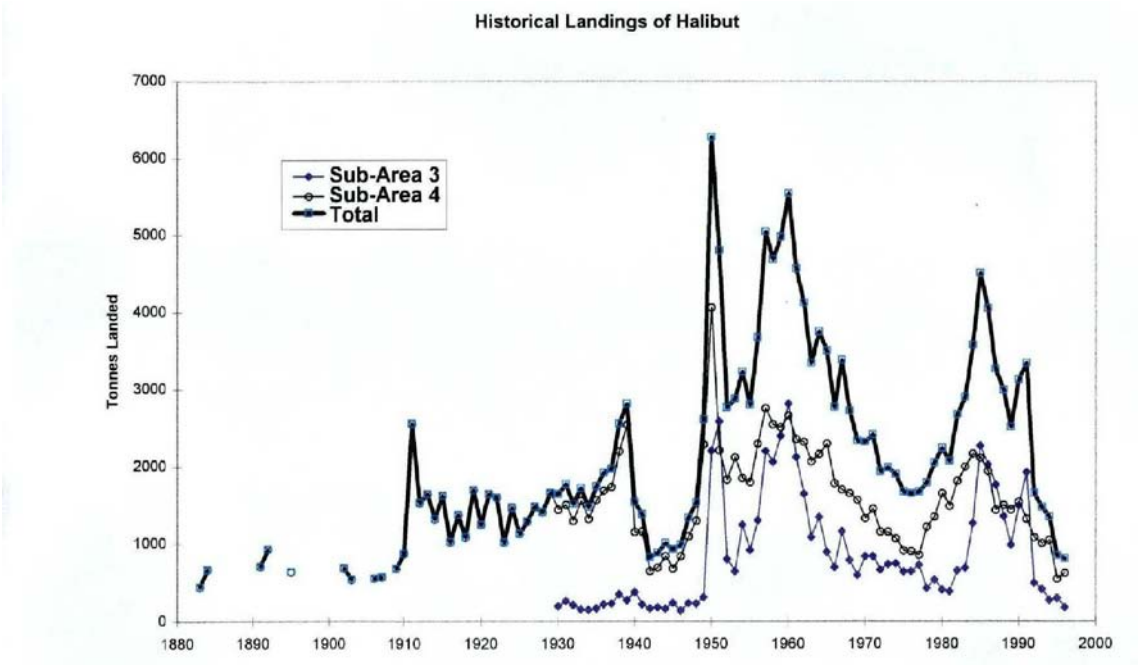


Figure 20. Historical landings of Atlantic Halibut from the East Coast of Canada. Taken from Zwanenburg *et al.* 1997. Note: Prior to 1929 all landings are for NAFO Sub-area 4 combined and exclude what is presently the province of Newfoundland. From 1930 to the present landings are by NAFO Sub-area as indicated . From 1961 to 1966 all landings were derived from NAFO statistics.

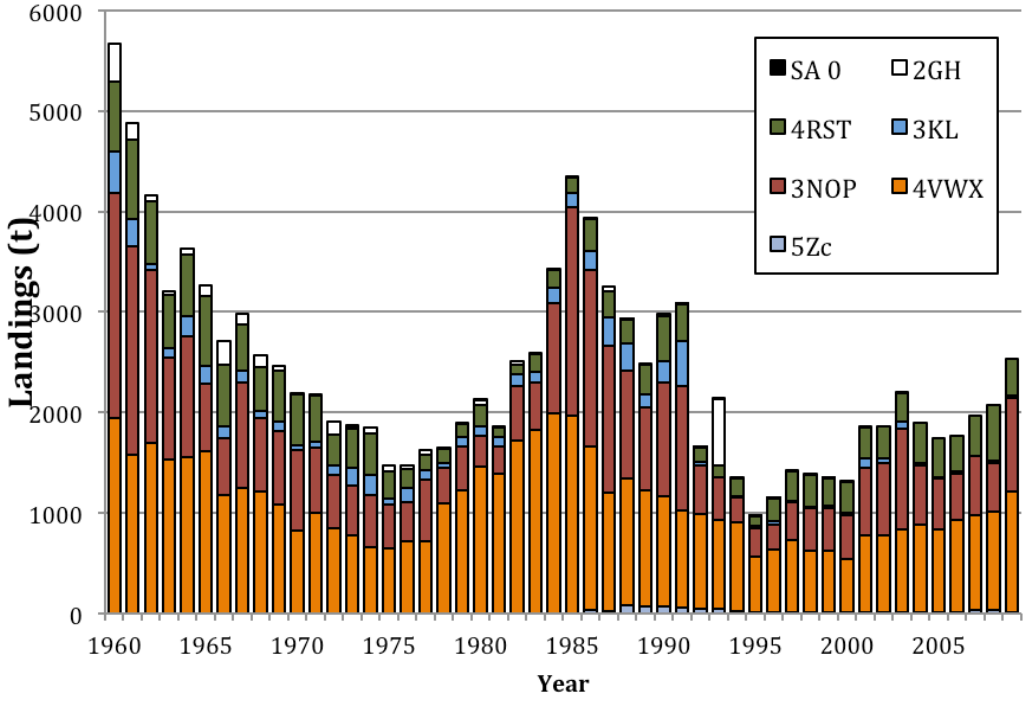


Figure 21. Reported landings of Atlantic Halibut by Canadian and foreign vessels (NAFO divisions are indicated in parentheses in the legend). Source: NAFO Fishery Statistics 2010 (21A database).

The average annual landings since 1960 for the Scotian Shelf and southern Grand Banks management unit were approximately 1900 t (DFO 2006) (Figure 22). Since 1960, landings fluctuated significantly: from over 3500 t in 1960, catches fell to close to 1000 t in 1974. Landings then increased to over 4000 t in 1985. Subsequently, landings decreased again and have remained between 1000 t and 2000 t since the mid-1990s. The Atlantic Halibut fishery in the area has been managed by total allowable catches (TAC) since 1988 (Table 6). The TACs apply to all catches whether directed or bycatch. From an initial level of 3200 t, the TAC was gradually reduced in 1994 and 1995 to 850 t. This reduction in the TAC was imposed due to the steady decline in landings in the preceding eight years (DFO 2009a). Since 1999, the TAC has gradually increased in accordance with the recommendations of the Fisheries Resource Conservation Council (FRCC), which suggested that the species was in good condition (FRCC 2001; 2004). The TAC was increased to 1700 t for the Scotian Shelf and Grand Banks management unit in 2009 (DFO 2011a) and to 1850 t in 2011.

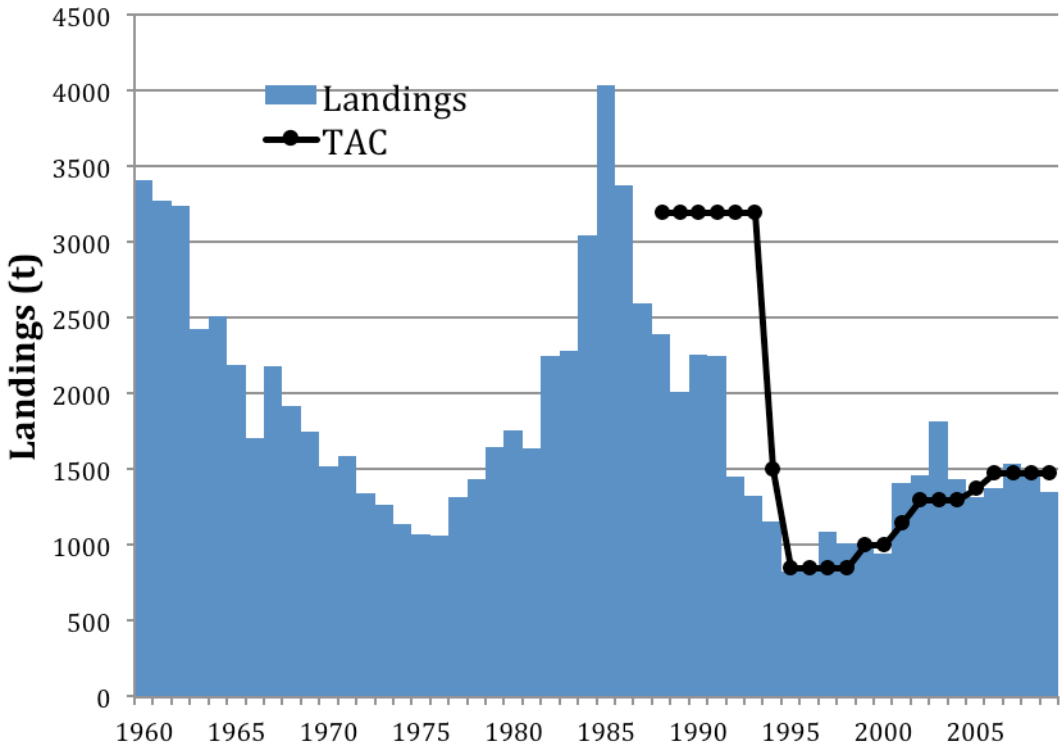


Figure 22. Reported landings and TAC for Atlantic Halibut on the Scotian Shelf and southern Grand Banks. Source: NAFO Fishery Statistics 2010.

Table 6. Atlantic Halibut landings and total allowable catch (TAC).

Year	3NOPs4VWX5Zc[1]		4RST[2]	
	TAC	Landings	TAC	Landings
1990–1999	1855 (average)	1323 (average)	315 (average)	247 (average)
2000	1000	944	350	314
2001	1150	1413	350	313
2002	1150	1460	350	319
2003	1300	1815	350	307
2004	1300	1439	350	416
2005	1375	1317	350	413
2006	1475	1378	350	388
2007	1475	1534	475	432
2008	1475	1458	475	560
2009	1700	2081	475	645
2010	1700	1684	600	626
2011	1850	1310	720	625
2012			720	

1 DFO 2011a
2 DFO 2011b

In the Gulf of St. Lawrence, landings of Atlantic Halibut have fluctuated greatly since 1883. The maximum landings were 4774 t and 4160 t in 1893 and 1950, respectively (Figure 23). After the 1950s, landings were significantly lower (under 650 t). Landings reached their lowest level in 1982 (91 t). Since 1996, there has been a slight increase in landings due to increased effort (mainly by longliners). A total allowable catch (TAC) for halibut was established in 1988. Initially set at 300 t, it was increased to 350 t in 1999 on the basis of an FRCC recommendation, and then to 475 t in 2007, in response to a recommendation made in the DFO science advisory report (DFO 2007) (Table 6). The TAC increased again to 600 t in 2010 (DFO 2011b) and to 720 t in 2011.

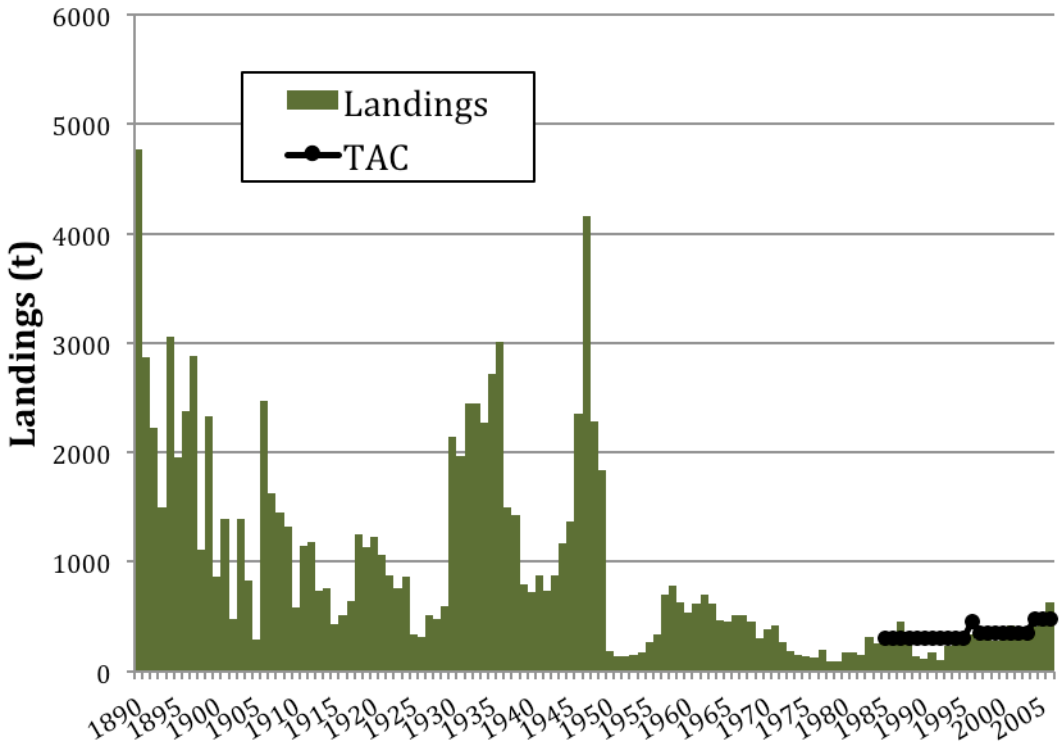


Figure 23. Reported landings and TAC for Atlantic Halibut in the Gulf of St. Lawrence. Source: DFO 2009b.

The other Canadian regions (i.e. the Labrador Sea and the northern Grand Banks—NAFO divisions 2GHJ3KL) are not subject to a TAC for Atlantic Halibut. With the exception of landings from NAFO divisions 3KL off eastern Newfoundland, which were significant before the early 1990s, catches of Atlantic Halibut in the other Canadian regions are limited (Figure 21). Also, Subdivision 3Pn, located south of Newfoundland, is not subject to a TAC. Landings in this sector have ranged from 5 to 156 t since 1960.

Minimum size limits have been imposed for Atlantic Halibut in order to promote recruitment of the species. The initial limit was imposed in 1994 when Atlantic Halibut under 81 cm in length had to be released. The size limit was increased to 85 cm in 4RST in 2010–2011. Atlantic Halibut catches contain a significant percentage of individuals under 81 cm (DFO 2009b). A considerable percentage of these fish could die. Rapid depressurization, muscle fatigue or injuries from fish-hooks could affect fish survival. It should be kept in mind that fishing gear has a significant impact on the Atlantic Halibut mortality rate. Neilson *et al.* (1989) have shown that, after having spent 48 hours in tanks, the mortality rate was 65% among Atlantic Halibut caught with trawl-nets as opposed to 23% among those caught with longlines. Larger specimens caught with longlines are difficult to handle and gaffs are often needed to haul them aboard, which seriously injures the fish.

SIGNIFICANCE OF THE SPECIES

Atlantic Halibut is the groundfish species with the greatest value per unit of weight in Atlantic Canada. In 2006, total landings of 2046 t generated CAN$24 million on the Atlantic coast (DFO Statistical Services 2010).

Atlantic Halibut is not only important in economic terms, but also for its place at the top of the food chain. As a large predator, it must have played a more important role in the ecosystem during the past when it was likely more abundant.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Atlantic Halibut is on the International Union for Conservation of Nature (IUCN) Red List (Sobel 1996). Its status is described as EN A1D (i.e. a reduction of at least 50% of abundance over the last three generations because of the current or potential exploitation rate). This listing is somewhat dated and may not be relevant to the current status of Atlantic Halibut in Canada. The geographic area given in the IUCN listing does not include a large part of the Canadian distribution of the species. The listing was published in 1996 and there has been an increase in Atlantic Halibut abundance since then.

DFO management practices control Atlantic Halibut catches using TACs. In addition, the minimum legal size has been 81 cm since 1994 and has increased from 81 cm to 85 cm in 2010–11 for 4RST. Currently, any Atlantic Halibut less than 81 cm long on the Scotian Shelf or 85 cm long in the Gulf of St. Lawrence must be returned to the water.

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Appendix 1. Abundance indices used to assess trends of Atlantic Halibut in Canada. GBSN, Grand Banks and southern Newfoundland; GSLSS, Gulf of St. Lawrence sentinel survey; LLS, longline survey; NGSL, northern Gulf of St. Lawrence trawl survey; SGSL, southern Gulf of St. Lawrence trawl survey; SS, Scotian Shelf trawl survey. Units for the trawl surveys and sentinel survey are minimum trawlable numbers (million) and for the longline survey CPUE (kg/1000 hooks/ 10 hours soaking.

Year	GBSN	GSLSS	LLS	NGSL	SGSL	SS
1970						0.4664
1971					0.0000	0.5512
1972					0.0000	0.4240
1973	0.2543				0.0000	0.5936
1974					0.0000	0.8904
1975	0.1129				0.0000	0.9328
1976	0.2592				0.0000	1.4839
1977	0.5196				0.0000	1.7383
1978	0.3477				0.0000	1.1447
1979	0.5089				0.0000	1.3567
1980	1.1115				0.0011	1.6535
1981	0.3875				0.0000	1.3143
1982	0.4633				0.0000	0.9752
1983					0.0000	0.2968
1984	0.5120				0.0036	0.8452
1985	0.6484				0.0027	0.5512
1986	0.4904				0.0020	0.8480
1987	0.4134				0.0013	0.8056
1988	0.3884				0.0076	1.0599
1989	0.4908				0.0000	1.3991
1990	0.2272			0.0513	0.0000	0.8904
1991	0.2867			0.1635	0.0015	1.3991
1992	0.2089			0.0141	0.0022	1.1023
1993	0.1458			0.0112	0.0007	0.7632
1994	0.1710			0.1660	0.0006	0.6360
1995	0.2765	0.0548		0.0858	0.0044	0.5936
1996	0.1119	0.0360		0.1140	0.0027	0.5936
1997	0.3863	0.0378		0.3881	0.0013	0.6784
1998	0.3164	0.0168	28.7860	0.2402	0.0060	0.5936
1999	0.1367	0.0532	20.8578	0.3268	0.0074	0.5512
2000	0.1418	0.0480	40.1752	0.1226	0.0168	0.4664
2001	0.1878	0.0429	25.7257	0.2474	0.0131	0.8480
2002	0.1793	0.0665	24.9226	0.3639	0.0427	0.6360
2003	0.1925	0.0830	20.8125	0.7422	0.0190	0.5936
2004	0.1761	0.1839	24.4471	0.8247		1.0599
2005	0.0599	0.2776	27.6051	1.0325	0.0136	1.5687
2006		0.3742	32.9408	1.8720	0.0663	1.1871
2007	0.4677	0.8049	35.4847	2.0606	0.1021	1.9927
2008	0.3320	0.2177	37.1326	1.9414	0.0672	1.6959
2009	0.3766	0.2596	74.7514	1.3283	0.0597	1.5263
2010	0.5402					2.9255