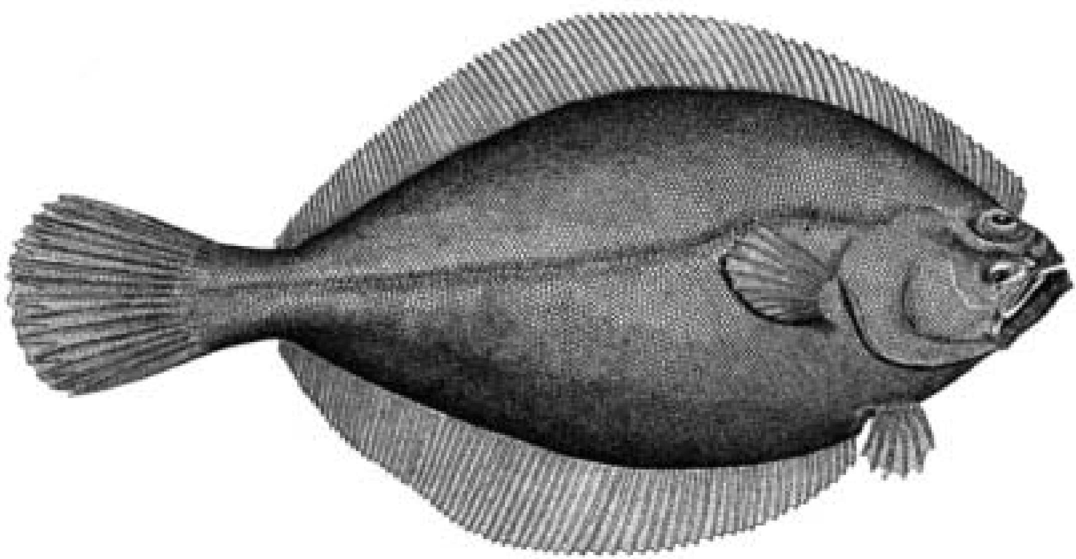
COSEWIC
Assessment and Status Report

on the

American Plaice
Hippoglossoides platessoides

Maritime population
Newfoundland and Labrador population
Arctic population

in Canada



Maritime population - THREATENED
Newfoundland and Labrador population - THREATENED
Arctic population - DATA DEFICIENT
2009

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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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la plie canadienne (*Hippoglossoides platessoides*) population des Maritimes, population de Terre-Neuve-et-Labrador et population de l'Arctique au Canada.

Cover illustration:
American Plaice — Illustration from Goude 1884. From plate 107 of "Oceanic Ichthyology" by G. Brown Goode and Tarleton H. Bean, published 1896.

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COSEWIC
Assessment Summary

Assessment Summary – April 2009

Common name
American Plaice - Maritime population

Scientific name
Hippoglossoides platessoides

Status
Threatened

Reason for designation
This right-eye flounder burrows in the sediment to escape predators and ambush prey. It is widely distributed on both sides of the North Atlantic Ocean, from the Barents Sea to the British Isles in the east, and from northern Baffin Island to Rhode Island in the west. This population occurs in the Gulf of St. Lawrence, the Scotian Shelf, the Bay of Fundy and Georges Bank. A relatively sedentary, non-schooling species, it was likely once the most abundant flatfish in the northwest Atlantic. Over a 36 year time series (about 2.25 generations) abundance of mature individuals has declined about 86% in the Gulf of St. Lawrence, and 67% on the Scotian Shelf. Overfishing is a major cause of the decline, but an apparent increase in natural mortality in the 1990s, when the largest part of the decline occurred, may also have contributed. The decline appears to have ceased in the Gulf but may be continuing on the Scotian Shelf. There are small ongoing directed fisheries in the Gulf with a quota in the south but no quota management in the north. On the Scotian Shelf and in the Bay of Fundy, this species is managed together with other flatfishes as a multispecies stock and there are no specific management measures to ensure sustainability.

Occurrence
Atlantic Ocean

Status history
Designated Threatened in April 2009. Assessment based on a new status report.

Assessment Summary – April 2009

Common name
American Plaice - Newfoundland and Labrador population

Scientific name
Hippoglossoides platessoides

Status
Threatened

Reason for designation
This right-eye flounder burrows in sediment to escape predators and ambush prey. It is widely distributed on both sides of the North Atlantic Ocean, from the Barents Sea to the British Isles in the east, and from northern Baffin Island to Rhode Island in the west. This population occurs from Hudson Strait to the southern limit of the Grand Bank, and westward north of the Laurentian Channel to the southwestern corner of Newfoundland. A relatively sedentary, non-schooling species, it was likely once the most abundant flatfish in the northwest Atlantic, and the fishery for it in Newfoundland waters was once the largest flatfish fishery in the world. Over a 47 year time series (about 3 generations) abundance has declined approximately 96%. Overfishing is a major cause of the decline, but an apparent increase in natural mortality in the 1990s, when the largest part of the decline occurred, may also have contributed. The decline now appears to have ceased, but numbers remain below a precautionary threshold estimated for this stock. The directed fishery is under moratorium but some significant and poorly regulated bycatches are negatively influencing recovery. In addition, fishing gear is size selective, cropping large individuals, and reducing population reproductive potential. There is evidence that natural mortality has increased which reduces the ability of the population to withstand fishing mortality.

Occurrence
Atlantic Ocean

Status history
Designated Threatened in April 2009. Assessment based on a new status report.

Assessment Summary – April 2009

Common name
American Plaice - Arctic population

Scientific name
Hippoglossoides platessoides

Status
Data Deficient

Reason for designation
Information to establish any COSEWIC risk category with assurance is not available. Data on distribution, abundance and specific habitat, including any observed changes over time, are especially needed.

Occurrence
Arctic Ocean

Status history
Species considered in April 2009 and placed in the Data Deficient category. Assessment based on a new status report.

COSEWIC
Executive Summary

American Plaice
Hippoglossoides platessoides

Maritime population
Newfoundland and Labrador population
Arctic population

Species information

Hippoglossoides platessoides, commonly known as American Plaice in English and Plie canadienne in French, is a member of the Pleuronectidae, or right-eyed flounders. It also goes by a variety of other names, often commercially as flounder or sole and in Europe as long rough dab. The body is laterally flattened. As adults, both eyes are on the right side of the head and the animal lies on its left side. The eyed side is typically red to grayish brown and uniform in colour, whereas the blind side is white. The head is generally small but with a relatively large mouth.

Distribution

American Plaice inhabit all areas of the continental shelves on both sides of the North Atlantic. In the east the species range extends from the Barents Sea south to the British Isles, and in the west, from almost as far north as the Arctic Circle south to Rhode Island. It is unlikely that there have been any major changes in the distribution in recent decades. In Canada, American Plaice are distributed contiguously from Georges Bank and the Bay of Fundy in the south, northward over the Scotian Shelf, into the Gulf of St. Lawrence, surrounding Newfoundland and Labrador and along the eastern coast of Baffin Island, Nunavut. Neighbouring the Canadian populations are populations of American Plaice along the west coast of Greenland, on and around the Flemish Cap and in the Gulf of Maine and on Georges Bank.

Habitat

American Plaice exist as pelagic eggs and larvae for the first few weeks of life. Habitat suitability at this stage is based primarily on the availability of sufficient prey and on temperature. Settled juveniles prefer depths of 100-200 m and small particle sediments that they can use to partially or fully bury themselves. Adult plaice have less stringent habitat requirements. They have been collected from areas with a broad range of salinities and temperatures. In the wild, preferred temperatures appear to be between -0.5-4°C, with individuals perhaps actively avoiding temperatures much colder than - 1°C. Like juveniles, adults prefer areas with sediment suitable for burrowing but the range of suitable particle sizes probably increases with fish size. Plaice may occupy non-preferential physical habitats (temperature, sediment type, etc.) in order to gain access to abundant prey.

Biology

The life history of American Plaice varies across the Canadian portion of its range. In the Newfoundland and Labrador population maturity appears to be later than in the Gulf of St. Lawrence and on the Scotian Shelf but recent maturity data are generally lacking for the latter two populations. Where maturity data are available a decline in age at maturity from 10-11 years or older down to 6-8 years appears to have occurred over the past several decades. Generation time is 15-16 years. Eggs are generally 1.5-2.8 mm in diameter. The number of eggs produced by an individual female plaice depends on body size. A 30 cm female can produce as many as 400,000 eggs, while a 60 cm female can produce in excess of 1 million eggs. However, fecundity is highly variable over time and across areas.

American Plaice are batch or serial spawners, with only a portion of the total number of potential eggs being spawned in any single batch and the possibility of spawning as many as 10 egg batches. An individual female can spawn for more than a month. Eggs and larvae are pelagic. Hatched larvae are nourished by yolk reserves for the first few days after hatching and then feed primarily on copepods and other zooplankton. Larvae metamorphose into juveniles between 20 and 40 mm, with the left eye migrating to the right side of the head and the body becoming laterally flattened. Juveniles inhabit a limited depth range (< 200 m) within the range of the adults (primarily 100-300 m). Adults do not appear to undergo large spawning migrations but may move into slightly deeper, warmer waters in winter. Due to steep shelf banks this requires little lateral movement in most areas but a more substantial movement in the Gulf of St. Lawrence where fish move into deeper channels.

Population sizes and trends

Estimates of the mature population size are obtained from catch rates of fish of reproductive age from fisheries-independent research surveys conducted by the Canadian Department of Fisheries and Oceans (DFO). In addition, a fisheries-dependent model, tuned with fisheries-independent research surveys, known as a virtual population analysis (VPA) is available for American Plaice on the Grand Bank (NAFO Divisions 3LNO) and can be used to estimate adult abundance.

All available distribution and biological data were considered along with COSEWIC's guidelines for assigning status below the species level and 3 Designatable Units (DUs) of American Plaice were identified in Canadian waters. Trends in adult abundance are presented whenever sufficient data are available. Each of the DUs encompasses multiple management units used by DFO to assess stock status and, if relevant, allocate fishing quotas.

Arctic population

American Plaice in this population are those found in the waters north of Hudson Strait and east of Baffin Island, Nunavut (NAFO Divisions 0A and 0B). Little is known about plaice in this region and there are insufficient data to examine temporal trends in abundance. However, the neighbouring west Greenland population of American Plaice has undergone a sharp decline in abundance and is in a depleted state.

Newfoundland and Labrador population

American Plaice in this population inhabit the waters from immediately south of Hudson Strait southeast to the Grand Bank (east of Newfoundland) and west to Cape Ray (southwestern tip of Newfoundland). In this area there are three separate stocks for management/assessment purposes: 1 - those off Labrador and the northeast coast of Newfoundland (NAFO 2GHJ3K), 2 - those on the Grand Bank (NAFO 3LNO), and 3 - those on St. Pierre Bank (NAFO 3Ps). This population also includes fish in NAFO 3Pn, which is not formally assessed. The rate of decline in adult abundance for this population depends somewhat on the source of data used for 3LNO, but is in the range of 94-96% over a 28-47 year time period. The major part of the decline occurred in the early 1990s, and despite what may have been a minor amount of recovery in recent years, the biomass of American Plaice in this population remains below B_{lim}, a precautionary threshold for minimum acceptable biomass.

Maritime population

This population includes two major areas, the Gulf of St. Lawrence and the Scotian Shelf. The former encompasses the entire Gulf of St. Lawrence including areas west of Newfoundland, and the lower St. Lawrence estuary (NAFO Divisions 4RS and 4T). The latter includes the entire Scotian Shelf and Bay of Fundy (NAFO 4VW and 4X). The Canadian portion of Georges Bank is also included in this DU. In the absence of a gap in the distribution, the Maritime population is treated as a single DU; however, Gulf of St. Lawrence and Scotian Shelf may be distinct populations, therefore declines were calculated separately for the two regions. The rates of decline in adult abundance over a 36 year (about 2.25 generation) time series for Gulf of St. Lawrence and Scotian Shelf are 86% and 67%, respectively.

Limiting factors and threats

The primary factor thought to be responsible for the decline of American Plaice stocks is overfishing, although there is some suggestion that increased natural mortality due to unusually cold water conditions may also have played a role. Directed fisheries exist in 4T (750 t), and 4R and 3Pn (not under quota). There is also a directed fishery on the Scotian Shelf, where the species is managed as part of a stock complex along with other flatfishes. In other areas there are moratoria on directed fishing for American Plaice. As a result of the various management measures, fishing mortality should, theoretically, no longer be of concern; however, levels of bycatch in other directed fisheries (Atlantic Cod, Yellowtail Flounder, Redfish, Greenland Halibut, Witch Flounder, shrimp) are such that they likely currently pose the greatest threat to population recovery. The potential number of illegally discarded American Plaice in the Gulf of St. Lawrence and on the Scotian Shelf is also a matter of concern.

Special significance of the species

American Plaice was probably at one time the most abundant flatfish in the northwest Atlantic. Commercial harvesting began with the development of bottom trawls and, with the development of a fresh fish market (based on filleting and freezing), American Plaice became the target of dedicated fisheries. The American Plaice fishery on Newfoundland’s Grand Bank was the largest flatfish fishery in the world, at times approaching 10% of the entire Canadian Atlantic groundfish fishery (both landings and value). With the extension of the 200-mile limit, the fishery for plaice evolved into an almost exclusive Canadian fishery until the early 1990s when declines in population size resulted in moratoria on all Newfoundland stocks. Closures of traditional fisheries in the 1990s initially increased commercial interest in American Plaice wherever fishing was still allowed, but a combination of bycatch restrictions on other species, market conditions, stock status concerns, and low total allowable catches (TACS) have kept overall landings at about 1% of historical levels.

Existing protection or other status designations

American Plaice are not listed in the Canadian *Species at Risk Act* or the IUCN Red List of endangered or threatened species, and their Global Heritage Status Rank is GNR (unrated), and so currently receive no special protection.

Directed fisheries for American Plaice exist in 4T (750 t directed fishery), and 4R and 3Pn (not under quota). There is a combined directed species quota of 1000 t in 4VW (American Plaice, Yellowtail Flounder, Witch Flounder) and 2000 t in 4X5Y (American Plaice, Yellowtail Flounder, Witch Flounder, Winter Flounder). All other areas are under moratoria to directed fishing and have bycatch restrictions, but these are ineffective. In some cases fisheries are targeting American plaice despite the “moratorium”.

Inability to enforce bycatch limits is the greatest impediment to recovery of Newfoundland plaice stocks, while in the southern Gulf of St. Lawrence the greatest impediment to recovery may stem from the directed fishery and an inability, at least in the past, to prevent discarding of small fish. On the Scotian Shelf and in the Bay of Fundy flatfish are managed as a multispecies stock and therefore there are no explicit management measures in place to ensure sustainability of American Plaice or any of the other component stocks.

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
(2009)

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.

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TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

SPECIES INFORMATION

Name and classification

The American Plaice (Fig. 1), *Hippoglossoides platessoides* (Fabricius, 1780), belongs to the Class Actinopterygii, Order Pleuronectiformes, and Family Pleuronectidae*,* the right-eyed flounders. Other common names include plaice, Canadian plaice, Plie canadienne (Fr.), sand dab, long rough dab (UK, Isle of Mann, Europe), American dab, dab, flounder, and sole (Scott and Scott, 1988; Wheeler, 1992; Cooper and Chapleau, 1998; Froese and Pauly, 2000; Nelson *et al.*, 2004). Previous species names included *Hippoglossoides limandoides* (Bloch, 1787) and *Pleuronectes platessoides* (Fabricius, 1780). Two subspecies were formerly recognized with *Hippoglossoides platessoides platessoides* in the Western Atlantic and *Hippoglossoides platessoides limandoides* in the Eastern Atlantic (Scott and Scott, 1988).

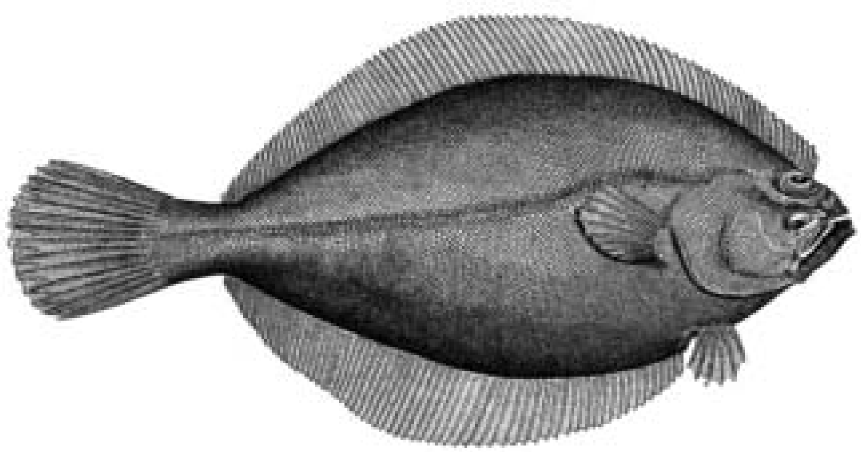

Figure 1. Line drawing of American Plaice (from Goude 1884).

Morphological description

The American Plaice is a benthic marine flatfish with a laterally compressed body. The larval stage is pelagic and bilaterally symmetrical. During metamorphosis, the body becomes laterally compressed and the left eye migrates to the right side of the head. The eyed side of the body is typically uniform in colour, ranging from reddish to greyish brown, although small plaice are frequently seen marked with three to five dark spots along each side of the body (Bigelow and Schroeder, 1953; Scott and Scott, 1988). The blind side is typically white. The head is small with a relatively large mouth that extends to below the middle of the eye and with the lower jaw protruding. Each jaw bears a row of small conical teeth (Scott and Scott, 1988). The dorsal fin (76-101 rays) originates in front of the middle of the left eye and terminates at the base of the caudal peduncle. The anal fin (60-79 rays) extends from under the posterior part of the operculum to the dorsal prominent pre-anal bony spine. The pectoral fins (9-12 rays) are rounded and situated behind the pelvic fins (6 rays). The caudal fin is rounded and convex. The tips of the rays on the long dorsal and anal fins are white. The lateral line on the eyed side is obvious, slightly arched over the pectoral fin but otherwise straight. The scales on the eyed side are ctenoid, giving the upper side of the fish a ‘rough’ feel. The blind side scales are primarily smooth and cycloid. Vertebral counts range from 42-48. The size varies with locality but specimens are usually not longer than 61 cm.

Genetic description

With only a single study completed to date, the population genetic structure of American Plaice is not well known. Stott *et al.* (1992) used an electrophoretic analysis of the products of 40 protein-coding loci as well as restriction length polymorphisms in mitochondrial DNA to examine the genetic population structure of American Plaice within the Gulf of St. Lawrence. Analyses were based on 344 fish collected from NAFO Division 4T in 1988 and 465 and 285 fish collected from Divisions 4RST in 1989 and 1990, respectively. Neither of the analyses found significant differences among six sample sites within the Gulf. A comparison of Grand Bank American Plaice (NAFO Division 3N; n=43) to those from the Gulf suggested no significant genetic differentiation between the two regions (Stott *et al.*, 1992).

GenBank® lists 15 DNA and four protein sequences in its database for *Hippoglossoides platessoides* (http://www.ncbi.nlm.nih.gov/Genbank/).

Designatable units

Current COSEWIC guidelines indicate that to qualify as DUs, populations or groups of populations should meet criteria of discreteness and significance. The extent to which American Plaice populations meet these criteria is discussed below.

<u>Discreteness</u>

As noted above, the only genetic study conducted on American Plaice found no differences among locations in the Gulf of St. Lawrence, or between that region and the Grand Bank (Stott *et al.*, 1992). Comparisons among areas were based on four polymorphic loci in 1988 and six polymorphic loci in 1989 and 1990. Average expected heterozygosity ranged from 0.051-0.071 when based on all 40 loci examined and 0.027-0.040 when based on 35 loci (the products of only 35 loci were resolved in the 1988 samples). It should be noted that the small number and low heterozygosities of variable genetic loci would have conferred relatively low statistical power. DNA analyses based on more variable markers such as microsatellites have revealed genetic population structure for other species such as Atlantic cod that was not evident with allozymes or mtDNA (Carr *et al.*, 1995; Bentzen *et al.*, 1996; Ruzzante *et al.*, 1996; 2001). Moreover, the huge size of pre-fishery populations of American Plaice suggests that the number of generations that have elapsed since the populations were founded post-glacially may be insufficient for detectable neutral genetic differences to have accrued (Hauser and Carvalho, 2008).

Distribution data also provide little evidence of discrete populations of American Plaice. Although population densities vary substantially (for example, high abundance on the Grand Bank), there are no well-defined breaks in distribution throughout the entire range of the species in Canada (Fig. 2).

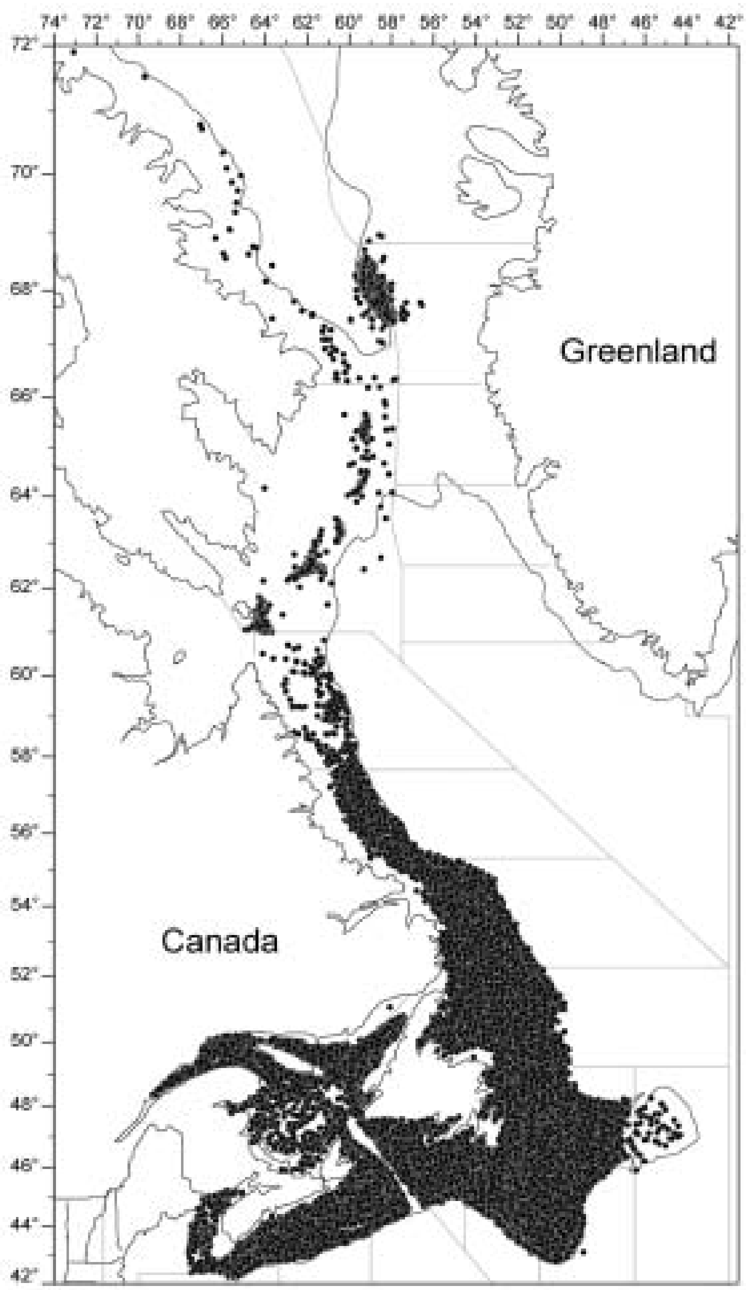

Figure 2. Canadian distribution of American Plaice. Each symbol represents a research vessel survey set (Arctic also includes commercial fishing sets) where at least one American Plaice was collected (includes data from complete available time series).

The strongest evidence for discrete American Plaice populations comes from studies of dispersal and depth preferences, taken in conjunction with ocean bathymetry in the northwest Atlantic. Tagging and parasite data suggest that American Plaice are relatively sedentary and do not undertake lengthy migrations (Pitt, 1969; Zubchenko, 1985; Morgan, 1996); thus, it seems unlikely that there is much mixing of populations, at least at the juvenile and adult stages. The pelagic eggs and larvae of this species do suggest the potential for dispersal during this phase of the life history, but there is also evidence that eggs and larvae tend to be retained in the general vicinity of spawning areas (Nevinsky and Serebryakov, 1973). The preferred depth range of American Plaice is 100-300m (Bowering and Brodie, 1991), which is shallower than the depths of two broad channels that cut across the Canadian range of the species: the Laurentian Channel between Newfoundland and the other Atlantic provinces, and Hudson Strait between Baffin Island and Labrador. Evidence that the Laurentian Channel is a barrier to mixing between American Plaice populations can be found in a difference in age of maturity between Newfoundland and Scotian Shelf. Beacham (1983) reported female age at 50% maturity between 1975 and 1979 to be 6.7 years and 5.7 years for Sydney Bight and Banquereau Bank American Plaice, respectively, whereas age at maturity of female plaice on St. Pierre Bank during that time period was 10.5-11.5 years (Bowering *et al.*, 1996).

Significance

Acceptable criteria for significance include evidence of local adaptation. There are no data that unequivocally demonstrate adaptive variation in American Plaice; however, the extremely broad latitudinal range occupied by the species suggests the potential for adaptive differences among populations, a possibility also suggested by substantial variation in age of maturity for plaice between the Scotian Shelf and Newfoundland. Moreover, common garden and molecular data for the only two marine fishes that have received detailed study in this regard, Atlantic Cod and European Flounder, have revealed adaptive genetic variation in response to temperature and salinity, in some cases on relatively small spatial scales (Hutchings *et al*., 2007; Hemmer-Hansen *et al.*, 2007a,b; Larsen *et al*., 2007, 2008; Moen *et al*., 2008).

Another acceptable criterion for significance is that the population occupies a significant portion of the Canadian range. Each of the three DUs recognized below for American Plaice is bounded by deep ocean channels that likely demarcate discrete populations (or groups of populations), and each comprises a large fraction (at least 275,000 km^2) of the Canadian range of the species.

Arctic population

American Plaice in this DU are those found in the waters to the east of Baffin Island, Nunavut (NAFO Divisions 0A and 0B) (Fig. 3), extending as far north as Baffin Bay, and south to Hudson Strait (Fig. 4).

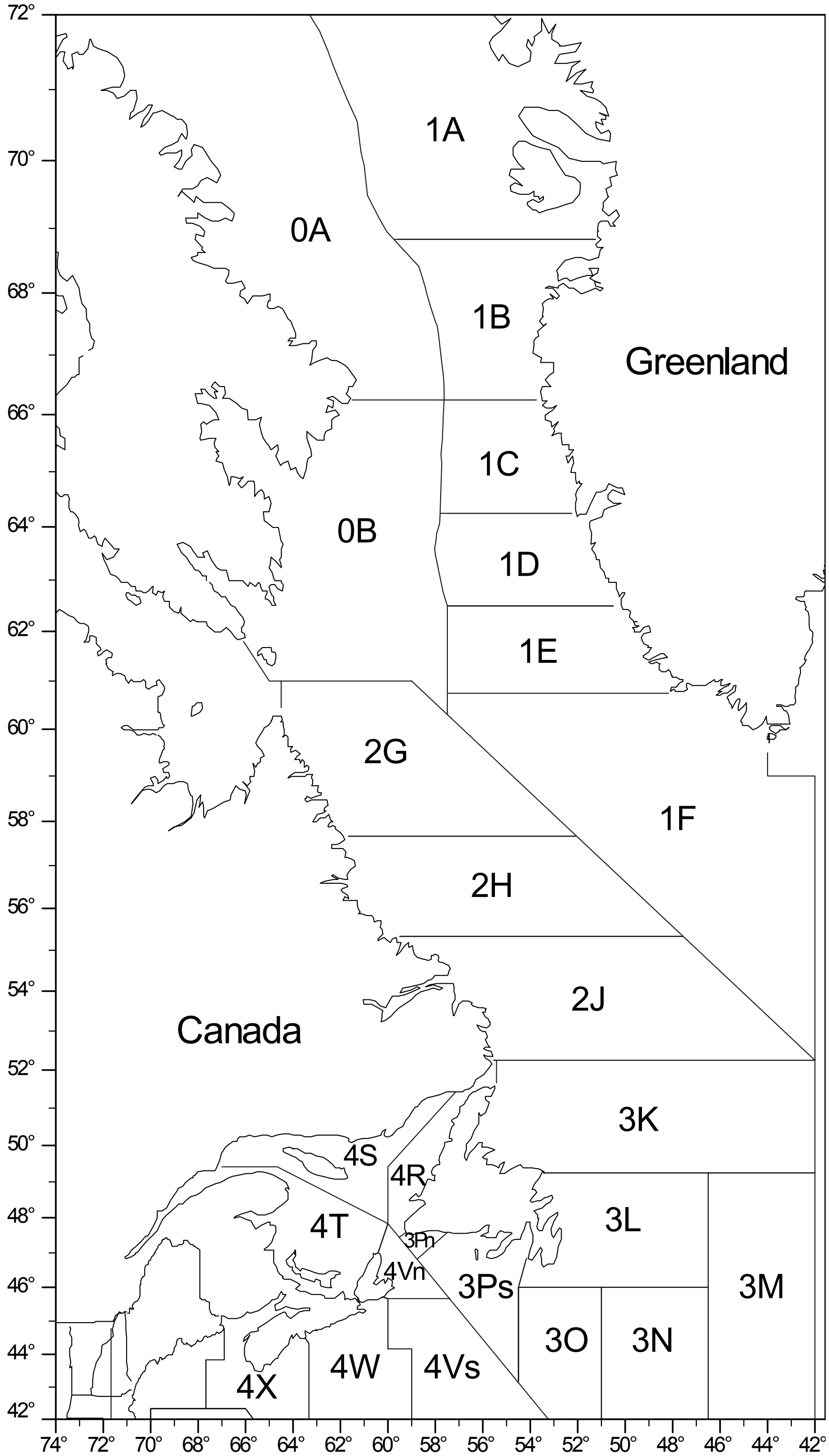

Figure 3. Northwest Atlantic Fisheries Organization (NAFO) Divisions.

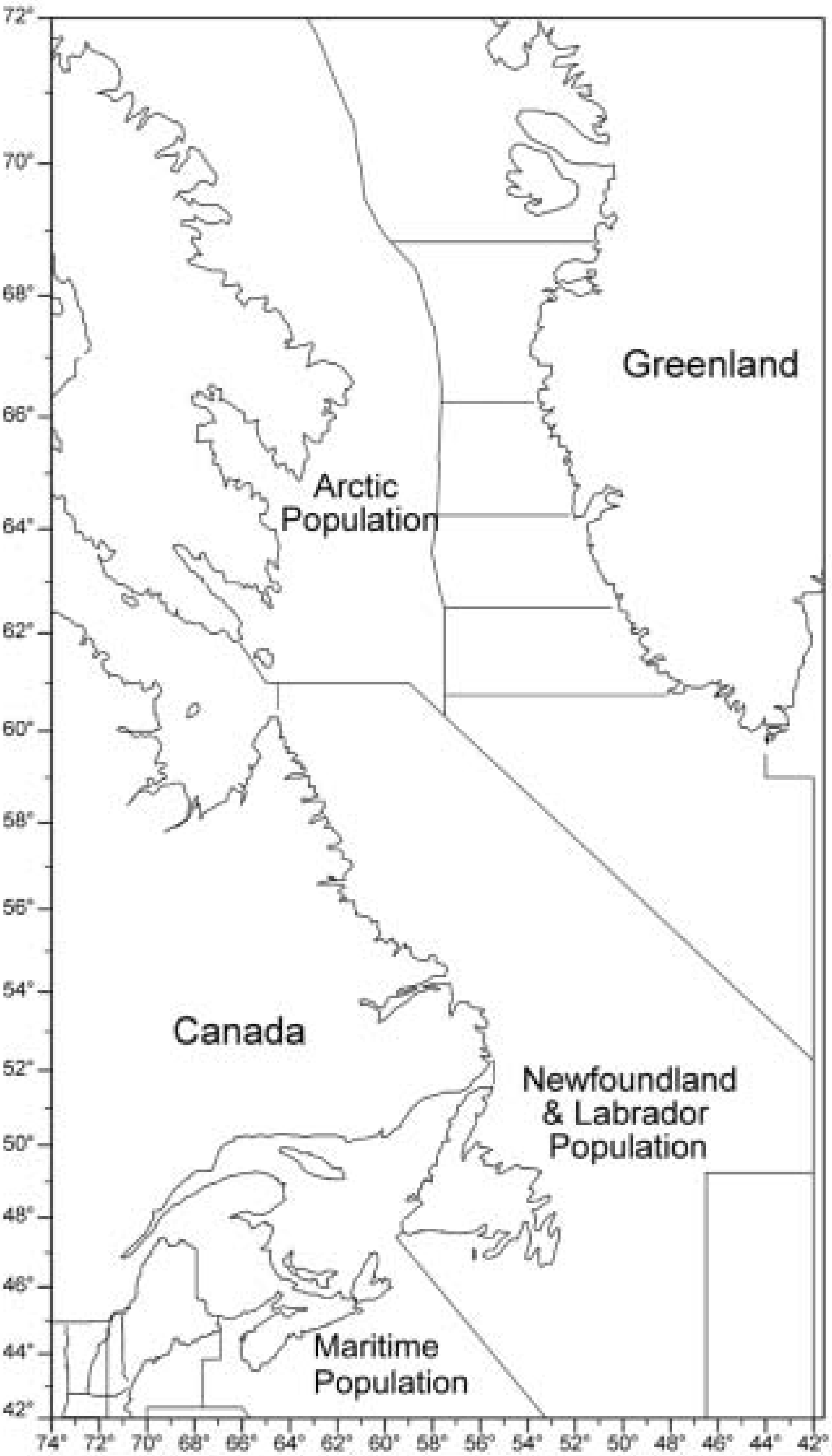

Figure 4. The three DUs suggested for the determination of conservation status of American Plaice in Canada.

Newfoundland and Labrador population

The geographic limits of this population range from Hudson Strait and Cape Chidley (the northern tip of Labrador) southeast to the Grand Bank (east of Newfoundland) and west to Cape Ray (southwestern tip of Newfoundland) (Fig 4). The relatively broad and deep Laurentian Channel bounds the southern limit of this DU (Fig. 5). The Newfoundland and Labrador population comprises three separate stocks for management/assessment purposes: those off Labrador and the northeast coast of Newfoundland (NAFO Divisions 2GHJ3K), those on the Grand Bank (NAFO Divisions 3LNO), and those on St. Pierre Bank (NAFO Subdivision 3Ps) (Fig. 3). This population also includes fish in NAFO Subdivision 3Pn, which is not formally assessed.

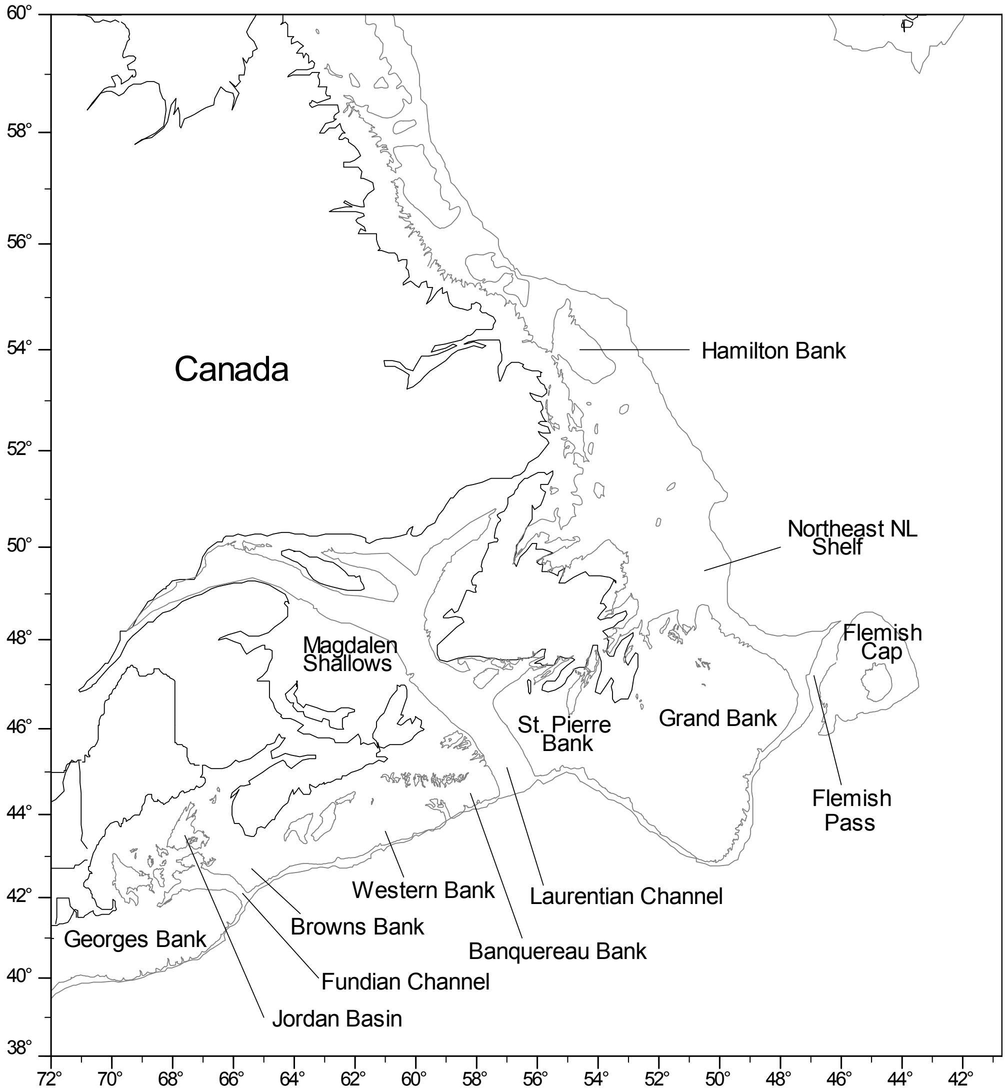

Figure 5. Illustration of the bathymetry of Canada's east coast, with the depth contours indicated. The names of offshore banks and channels mentioned in the text are listed. Depth contours indicate 200m and 1000m.

This is by far the most geographically expansive of the DUs, with American Plaice distributed throughout each of three component management units (Fig. 6). There is some evidence to suggest that the three management units that make up the DU represent discrete populations. Analysis of vertebral numbers supported the existence of multiple populations within the area (Pitt, 1963), although this was not supported by later studies on anal fin ray counts (Pitt, 1975a) and morphometrics was found to be of very limited use in delineating stocks of American Plaice (Bowering *et al.*, 1998).

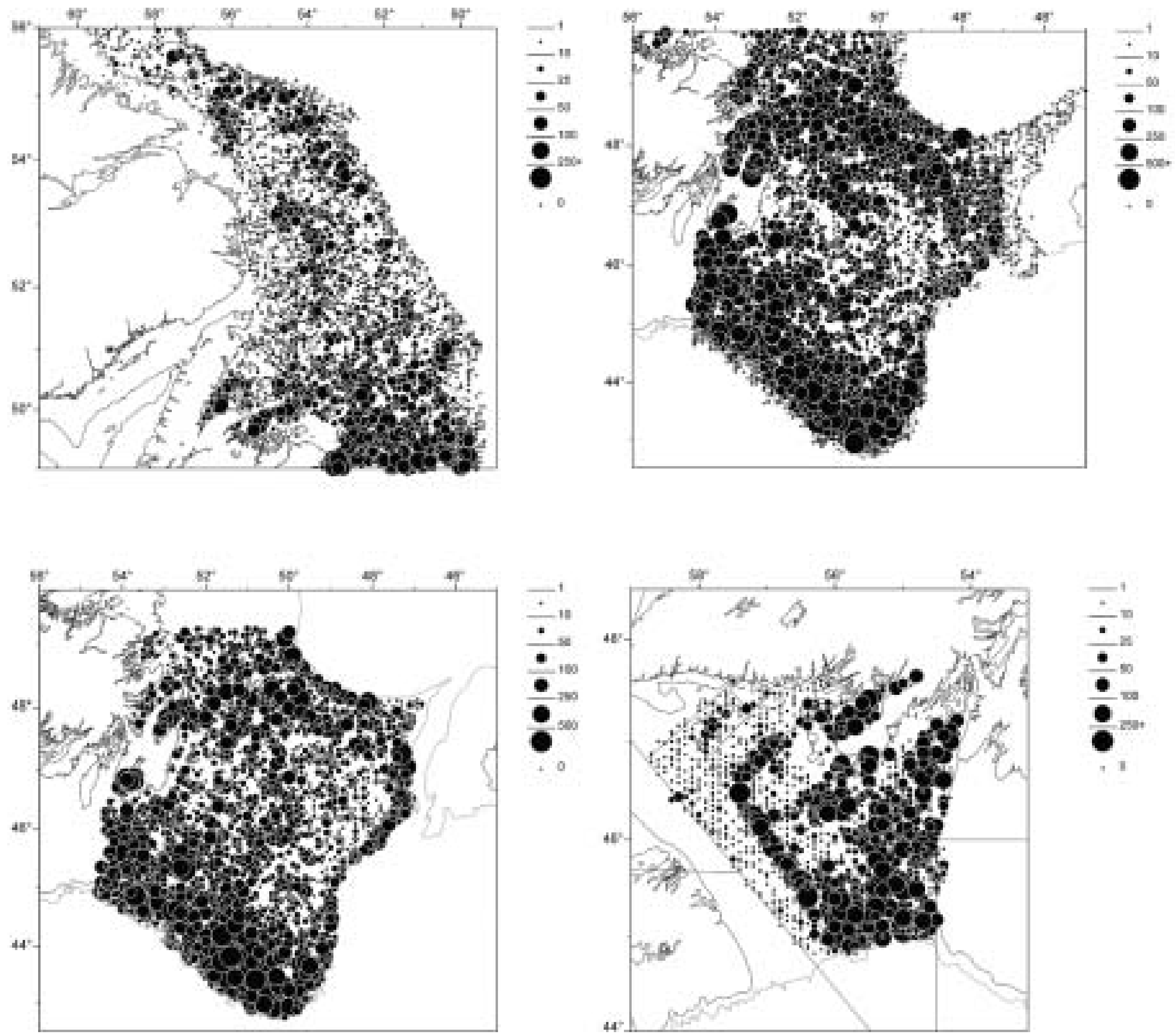

Figure 6. Distribution of American Plaice (kg per Canadian research vessel tow) in the Newfoundland and Labrador region, 1997-2006. top left: NAFO Divisions 2J3K, top right: NAFO Divisions 3LNO (fall survey data), bottom left: NAFO Divisions 3LNO (spring survey data), bottom right: NAFO Subdivision 3Ps.

Plaice in this area exhibit little movement. This is illustrated by the fact that fish from Hamilton Bank (2J), Funk Island Bank (3K), Flemish Cap (3M) and Grand Bank (3LNO) all exhibited different parasite composition and degrees of infestation (Zubchenko, 1985). Two conventional tagging studies have been conducted on Grand Bank (3LNO) American Plaice and reported fish to have moved very little (mean distance of 52 nautical miles [96 km] or less) from the release site, even after multiple years (Pitt, 1969; Morgan, 1996). Tagging returns suggested mixing of American Plaice among Divisions 3LNO, but no mixing with either of the neighbouring stocks (NAFO 2J3K or 3Ps). However, release sites were generally restricted to the eastern slope of the Grand Bank (Pitt, 1969) or somewhat centralized on the 3L portion of the Bank (Morgan, 1996). Perhaps results would have been different if individuals were tagged closer to the northern edge of Division 3L or the western limit of Division 3O. In fact, Pitt (1969) did report a small number of tag returns from plaice tagged in St. Mary's Bay (an inshore portion of Division 3O near the boundary for Subdivision 3Ps) that confirmed movement into Subdivision 3Ps. Also no tagging has been done in Divisions 2J3K or 3Ps to investigate whether or not these fish move onto the Grand Bank.

The potential for mixing among these different areas via egg and larval drift has not been explored for American Plaice but has been for cod. Initially particle drift models suggested eggs and larvae produced on Hamilton Bank and the Northeast Newfoundland shelf were not carried onto the Grand Bank by the Labrador current (Helbig *et al.*, 1992). However, more recently it has been demonstrated that storm or eddy induced current fluctuations can lead to significant settlement on the Grand Bank (Pepin and Helbig, 1997). Helbig *et al.* (1992) also reported potential egg and larval drift from the Grand Bank to areas of 3Ps and suggested that under certain conditions 3Ps could serve as a nursery site for juvenile cod of Grand Bank origin. Drift of plaice eggs and larvae have not been studied but could follow a similar pattern as observed for cod. With the contradictory nature of many of the studies on stock delineation in this area there is no irrefutable evidence as to whether or not the three stocks in the Newfoundland region should be combined or separated. In the absence of clear evidence the areas are combined here into a single DU.

<u>Maritime population</u>

This population includes two major areas, the Gulf of St. Lawrence and the Scotian Shelf (Fig. 3, 4, 5). The former encompasses the entire Gulf of St. Lawrence including areas west of Newfoundland, and the lower St. Lawrence estuary (NAFO Divisions 4RS and 4T). The latter includes the entire Scotian Shelf, Bay of Fundy and the Canadian portion of George's Bank (NAFO 4VW and 4X). Gulf of St. Lawrence American Plaice are managed as two stocks (NAFO 4RS and 4T) but only Southern Gulf (4T) plaice are assessed. DFO manages Scotian Shelf plaice as two stocks (NAFO 4VW and 4X).

American Plaice also exist on Georges Bank, south of the Maritimes. However, only the northeast tip of Georges Bank is within Canada's jurisdictional boundary, and plaice are not abundant on this portion of the bank. Although the Fundian Channel between Georges Bank and Browns Bank may provide at least a partial barrier to mixing of plaice, for the purposes of this report, American Plaice on the Canadian portion of Georges Bank are included in the Maritime DU. DFO does not assess American Plaice on Georges Bank, probably because the majority of the Bank is in American waters.

Like the Newfoundland and Labrador population, there is some evidence to suggest that American Plaice in this DU may comprise multiple discrete populations. For example, the two major regions, Gulf of St. Lawrence and Scotian Shelf may harbour independent populations. Within the Gulf of St. Lawrence, northern Gulf plaice (NAFO 4RS) are not under quota management and there have been no studies of stock identity in this area. Still, it is managed separately from the southern Gulf by DFO, with the separation point being the Laurentian Channel. Few fish are found in the deep parts of this channel (Fig. 7). In the Southern Gulf, an analysis of the presence of two acanthocephalan parasites suggests that American Plaice from eastern and western areas might constitute separate stocks (McClelland and Melendy, 2007). Growth, morphology and distribution data support the idea of fish from the southeastern and southwestern portions of the Gulf perhaps being biologically discrete, with two centres of distribution (Powles, 1965; Morin *et al.*, 2001; Stobo and Fowler, 2006), but not necessarily discrete stocks (larval drift, etc.).

There are other arguments against separating the Gulf of St. Lawrence into multiple stocks. Although few plaice are captured below the 200 m contour of the Laurentian and Esquiman Channels, the distribution appears to be continuous between the northern and southern Gulf where the two areas meet near the Gaspé Peninsula, suggesting potential mixing between the two areas (Busby *et al.*, 2007). Swain and Morin (1996) used data collected during 1971-1992 and found no difference in year-class abundance between the eastern and western portions of the southern Gulf. Morin *et al.* (1998) extended the analyses to include an examination of mortality, year-class strength and growth and again reported no evidence to support the separation of the southern Gulf into eastern and western components. Finally, as described above, the only genetic study carried out on American Plaice to date found no significant genetic differences among areas in the Gulf of St. Lawrence (Stott *et al.*, 1992).

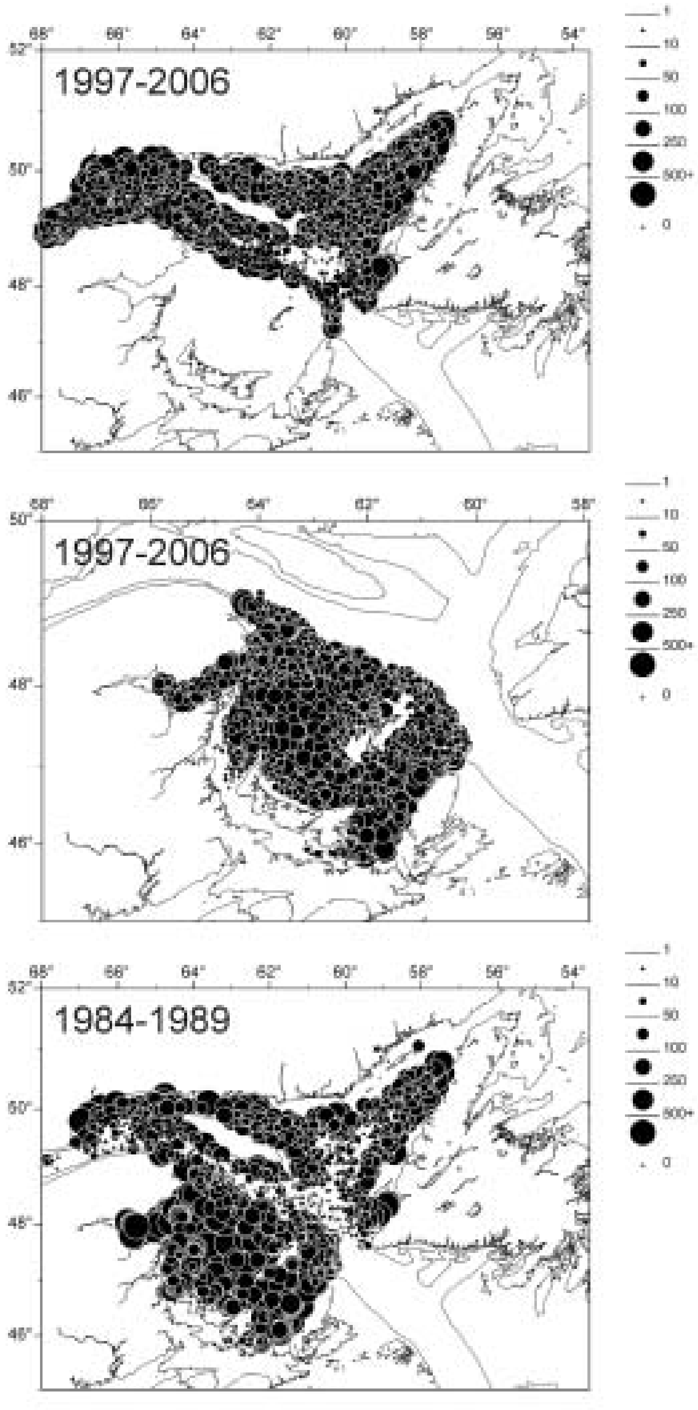

Figure 7. Distribution of American Plaice (kg per Canadian research vessel tow) in the Gulf of St. Lawrence. The top two panels show the distribution for the Northern and Southern Gulf in 1997-2006. During 1984-1989, sampling of groundfish throughout the entire Gulf was made with the same vessel and trawl, allowing the distribution of American Plaice for both the Northern and Southern Gulf to be plotted together (bottom panel).

American Plaice on the Scotian Shelf are managed as two units (4VW and 4X) by DFO, with the largest concentration of fish generally found on Banquereau Bank (Fig. 8). The management units, however, are not meant to represent different stocks of American Plaice and were actually established for the management of other species. Plaice in this area are managed as part of a stock complex, along with Yellowtail Flounder, Witch Flounder and Winter Flounder.

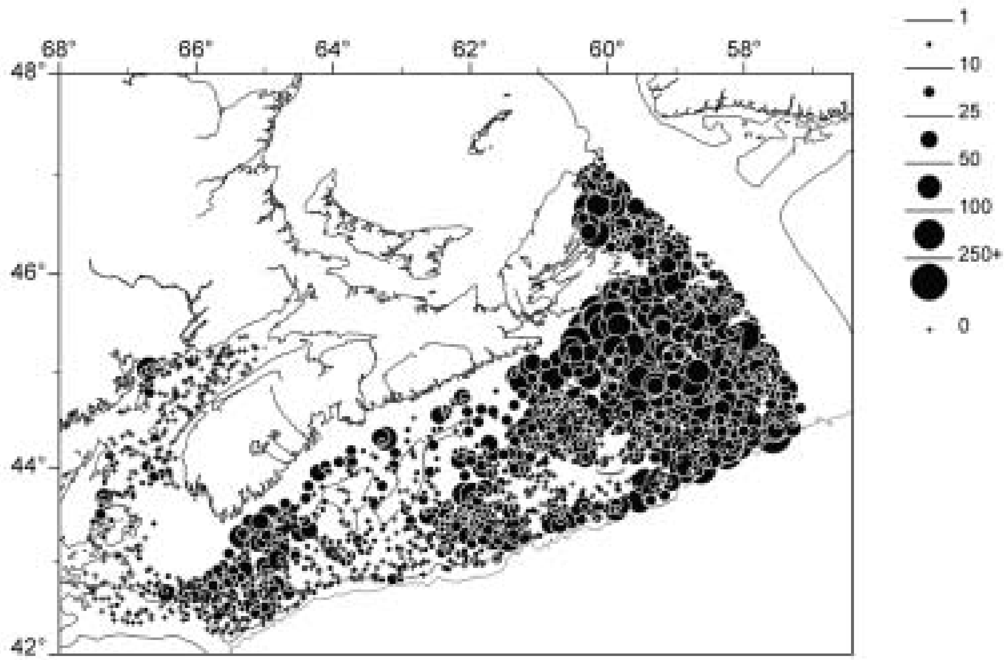

Figure 8. Distribution of American Plaice (kg per Canadian research vessel tow) on the Scotian Shelf, 1997-2006.

The area where the Scotian Shelf, Gulf of St. Lawrence and Newfoundland and Labrador population are closest together is an area with a high potential for interpopulation mixing and could therefore be considered an important and controversial area for the determination of American Plaice DUs in the northwest Atlantic. Tagging data suggest that American Plaice in the southwestern part of the Gulf migrate to the Sydney Bight area northeast of Cape Breton (NAFO Division 4Vn) and mix with Scotian Shelf American Plaice (M. Fowler, DFO, Dartmouth, personal communication). However, this migration and mixing is thought to be seasonal, with southern Gulf fish moving into 4Vn in the winter and then returning back to the Gulf prior to spawning, leaving it unclear whether there is reproductive separation between the two areas. This picture could be even more complicated than suggested here, with some speculation that the resident Sydney Bight population of American Plaice might also be distinct from the Scotian Shelf population (Fowler and Stobo, 2000). Until proven otherwise, however, these fish are treated as part of the Scotian Shelf population and broader Maritime DU.

DISTRIBUTION

Global range

American Plaice is an Arctic-boreal to temperate-marine species occurring on both sides of the North Atlantic on the continental shelves of northeastern North America and Northern Europe (Fig. 9). On the eastern side of the Atlantic, it ranges from approximately 70^{o}-50^{o}N, occurring from Iceland and along the Norwegian coast to Spitsbergen and the Barents Sea. It can be found in the North Sea, the western Baltic, and as far south as the British Isles and English Channel (Bigelow and Schroeder, 1953; Scott and Scott, 1988). It is common in west Greenland waters as far north as Upernavik (near the Arctic circle, near latitude 72^{o} N) (Bigelow and Schroeder, 1953). In the western Atlantic, it is found from the Davis Strait, southwards along the Labrador coast, Newfoundland Bank and the Flemish Cap and southwards to the Gulf of Maine and Rhode Island (Scott and Scott, 1988; Pitt, 1989; Bowering and Brodie, 1991).

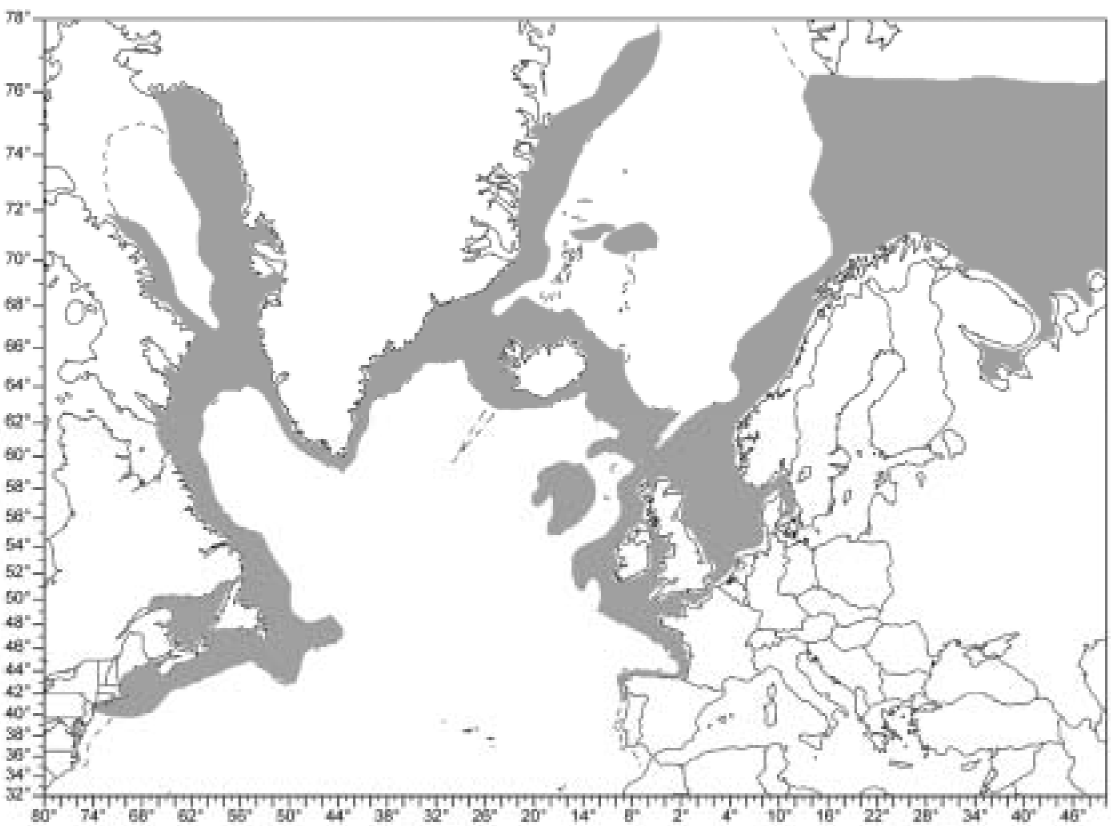

Figure 9. Global distribution of American Plaice (modified from Froese and Pauly (2000).

Canadian range

American Plaice occur throughout the Northwest Atlantic and at one time were probably the most abundant flatfish species in this area (Pitt, 1989). The Canadian distribution (Fig. 2) extends as far north as Baffin Bay and Eastern Hudson Bay, although plaice are found in greater numbers south of 56° latitude. Historically, catches have been highest on the Grand Bank, southeast of Newfoundland, particularly the northern 3L portion (Bowering and Brodie, 1991), but other fishing banks along Newfoundland and Labrador also produced major catches, including Hamilton Bank (2J), northeastern Newfoundland shelf (3K) and St. Pierre Bank (3Ps) (Figs. 3 & 5 show NAFO management divisions and major fishing banks, respectively). Plaice are also found throughout the Gulf of St. Lawrence, particularly on the Magdalen shoals, and off the coast of Nova Scotia from Sidney Bight (northeast coast of Cape Breton) to the Bay of Fundy (Bigelow and Schroeder, 1953; Scott and Scott, 1988). The northeast tip of Georges Bank represents the southernmost component of this species' distribution in Canada (Pitt, 1989). However, the distribution of this species continues south to Cape Cod.

In terms of a species' range and distribution, COSEWIC defines extent of occurrence as “the area contained within the shortest continuous boundary drawn to encompass all the known, inferred or projected sites of present occurrence”, whereas area of occupancy is defined as “the area within its extent of occurrence that is occupied by a taxon”. Differences between extent of occurrence and area of occupancy exist when there are areas within the extent of occurrence that contain unsuitable or unoccupied habitat. Deep water channels constitute potentially unsuitable habitat within the extent of occurrence, but these are of limited spatial extent. Hence, the extent of occurrence and area of occupancy are essentially the same (approximately 1 million square kilometres) and have remained relatively stable or even increased slightly over the available time series (see POPULATION SIZES AND TRENDS below).

HABITAT

Habitat requirements

The habitat requirements of American Plaice are not known in great detail, but the small number of laboratory studies that have been completed can be combined with information obtained during the sampling of plaice in various locations to give some insight into the animal's environment.

The eggs and larvae are pelagic, so habitat requirements are probably primarily related to temperature and prey availability. Increased temperature results in increased larval development rate (Shepherd *et al.*, 2000), which could lead to less time spent at the highly vulnerable larval stage (Houde, 1987). However, excessive temperature (≥14°C) results in mortality during the egg stage (Howell and Caldwell, 1984). The primary prey items during the larval stage are diatoms, copepods and other zooplankton (Pepin and Penney, 1997).

Juvenile and adult American Plaice are benthic and cryptically coloured. They regularly burrow in the sediment as a means of predator avoidance, and possibly concealment from prey as ambush predators. Thus sediment type is likely an important habitat consideration and might be particularly important for juvenile flatfish (Gibson and Robb, 1992). Small juvenile fish are likely only capable of generating small forces and thus only capable of burying in finer sediments. Juveniles on the Grand Bank have been found in highest numbers on sand/shell hash sediments and less abundant on (or in some cases almost absent from) mud, muddy sand, rock/sand and boulder/rock (Walsh *et al.*, 2004a).

The wide range of environmental conditions from which adult American Plaice have been caught suggests the species is a generalist without tightly constrained habitat requirements. Adults, like juveniles, commonly bury themselves in sediment, presumably as a predator avoidance behaviour. Under laboratory conditions plaice have demonstrated a clear preference for gravely sand particles over coarser gravel substrate, continuing to choose the preferred substrate even in temperatures outside of their preference (Morgan, 2000). Larger flatfish are able to produce greater forces and thus can bury themselves in larger sediment particles than smaller individuals. Sediment preference, however, might vary spatially. For example, in the deeper western side of the Gulf of St. Lawrence, plaice have been caught in high numbers from soft mud substrates (Bigelow and Schroeder, 1953). It is also possible that the sediment type that individuals are collected from might better reflect the preferred habitat of prey animals rather than the fish being studied. For example, in eastern Newfoundland, plaice have been found occupying sandy areas near bedrock outcroppings, likely because bedrock is the preferred habitat of green sea urchins, which are an important prey species (Keats, 1991).

American Plaice typically prefer depths of 100-300 m (Bowering and Brodie, 1991). There have been reports of catches from greater depths, including concentrations of fish in excess of 700 m (Walsh and Brodie, 1987) and catches as deep as 1400 m in Division 3L (Iglesias *et al.*, 1996) but both are considered to be anomalies. Variability in depth distribution of American Plaice on the Grand Bank has normally been associated with spawning and feeding near the shelf edges (Bowering and Brodie, 1991), where movement between depth strata generally does not require a large lateral movement (Pitt, 1969). Seasonal changes in depth preference are thought to be linked to temperature selection, with fish moving into deeper and warmer waters in winter (Powles, 1965; Morgan and Brodie, 1991). On the Grand Bank, juveniles tend to occupy restricted habitats within the range of the adults and are found mostly in the 100 to 200 m depth range in the northern area and in waters less than 100 m in the southern areas (Walsh, 1994a; Walsh *et al.*, 2004a).

In the wild, American Plaice are usually found at temperatures ranging from -1.5 to 13^{o}C. Preferred temperature (Tp) is reported to be -0.5^{o}C to 2.5^{o}C in the Newfoundland and Labrador area (Bowering and Brodie, 1991) and 1-4^{o}C on the Scotian Shelf (Scott, 1982), with fish to the south having a higher Tp (Scott, 1982). Morgan (1992) reported that plaice in captivity had a wide temperature tolerance (-1.4^{o}C - 15^{o}C) but that they did not feed and lost weight at very cold temperatures. Plaice on the Grand Bank have been found to move out of areas of colder water (≤ -1.2^{o}C) under some circumstances, resulting in what seems to be a seasonal distribution pattern related to water temperature (Morgan and Brodie, 1991; Swain *et al.*, 1998).

Adult American Plaice do not appear to have stringent salinity or prey requirements. They have been collected at a range of salinities from 31-34 ppt (Scott, 1982), with a single report of plaice collected from Hamilton Inlet off Labrador at salinity of 20-22 ppt (Backus, 1957). Plaice are highly opportunistic feeders (see section on Interspecific Interactions) and are therefore not likely to be dependent on the availability of any single prey item. Common groups of prey items include polychaetes, echinoderms, mollusks, crustaceans and small fish, with spatial differences often existing (see section on Interspecific Interactions). The species' oxygen requirements have not been studied but would be of particular interest for the Gulf of St. Lawrence population since large areas of the Gulf are temperature stratified and can experience chronic hypoxic conditions (Gilbert and Pettigrew, 1997).

Habitat trends

There have been no obvious habitat trends for American Plaice over the timeframe of available survey series, perhaps with the exception of ocean temperature. The late 1980s – early 1990s was a markedly cold period in the northwest Atlantic. (Colbourne *et al*., 1997) At that time American Plaice on the Grand Bank and in the Flemish Pass were found in deeper water, likely avoiding shallow, colder water. It is difficult, however, to fully assess trends in the number of plaice in deeper water since these deeper strata were not always surveyed.

Habitat protection/ownership

Although Newfoundland stocks are currently under fishing moratorium, there are no geographical areas that are completely protected from fishing based on concern for American Plaice. There is an area (the "haddock box") on Emerald and Western Banks of the Scotian Shelf (4W) that has been closed to fishing in order to protect haddock nursery grounds (DFO, 2001). While not created based on concern for American Plaice, this closure appears to have resulted in increased abundance of plaice within the restricted area (Frank *et al.*, 2000). For a species such as American Plaice, with widespread spawning, the identification of key habitat and the implementation of such a protection program might be more problematic. However, Walsh (1992) identified certain areas on the Newfoundland Grand Bank that had high numbers of juvenile plaice and suggested the existence of preferred nursery areas. Although there appears to be no spatial separation between juveniles and adults, juvenile plaice occupy a restricted habitat (< 200 m) within the range of adults (40-1500 m) (Walsh *et al.*, 2004a). While the range of American Plaice along the coast of North America lies primarily within Canada's 200 mile jurisdictional limit, the 'nose' and 'tail' of the Grand Bank, which are outside of Canada's jurisdiction, appear to be important nursery areas. Protecting these juvenile habitats would likely be very difficult.

BIOLOGY

Life cycle and reproduction

Spawning of American Plaice generally occurs throughout the range the population inhabits (Walsh, 1994b), but certain areas are associated with much greater spawning activity, perhaps simply because of a greater abundance of fish rather than selection of spawning grounds. Around Newfoundland and Labrador, spawning has been identified on Hamilton Bank and the Northeast Newfoundland Shelf (Pitt, 1966), and is widespread over the entire Grand Bank and St. Pierre Bank (Pitt, 1966; Nevinsky and Serebryakov, 1973; Morgan, 2001; Ollerhead *et al.*, 2004). In the Gulf of St. Lawrence, the major spawning grounds appear to be east and west of the Magdalen Shallows (Powles, 1965) and extending into Chaleur Bay (de Lafontaine, 1990). Specific spawning areas in the northern Gulf have not been identified but the presence of eggs and larvae (Able, 1978) would suggest at least some spawning activity in that area (Rod Morin, DFO, Moncton, personal communication). On the Scotian Shelf, the major spawning component is on Banquereau Bank but spawning activity appears continuous over Western Bank and also occurs to a smaller extent over Browns Bank (Neilson *et al.*, 1988). South of its Canadian distribution, spawning occurs on Georges Bank and inshore areas of the Gulf of Maine (Johnson, 2004). Spawning locations have not been identified for the Arctic population. However, Pitt (1966) suggested that it is likely that American Plaice spawn over the entire continental shelf, including Davis Strait.

Timing of spawning for Northwest Atlantic American Plaice is geographically variable. Spawning commences earliest for Gulf of Maine/Georges Bank (Feb), followed by Flemish Cap (mid-March), then the Scotian Shelf, St. Pierre Bank, Grand Bank and Northeast Newfoundland Shelf (Apr-May) and finally the northerly areas along the Labrador coast (May). The onset of spawning is likely related to environmental cues such as increasing water temperature or day length (Nevinsky and Serebryakov, 1973). Larger fish and fish in deeper waters generally begin spawning earlier than younger fish and fish in shallower waters (Pitt, 1966). Spawning typically occurs in cold waters with temperatures from 0-2.5^{o}C on the Grand Bank (Pitt, 1966) to 4.4^{o}C in the Gulf of Maine/Georges Bank area (Bigelow and Schroeder, 1953; Nevisnky and Serebryakov, 1973).

Although there are reports of this species making significant spawning migrations in the Barents Sea (Milinsky, 1944), no significant spawning migration occurs for American Plaice throughout most of its Canadian distribution. In the Gulf of St. Lawrence, however, plaice overwintering in or along the edge of the Laurentian Channel make a return journey to the Magdalen Shallows region prior to spawning.

American Plaice are group synchronous, batch spawners that can produce upwards of 10 batches of eggs with a spawning duration of more than a month (Nagler *et al.*, 1999). Fecundity increases with fish size and is thought to be determined at the onset of vitellogenesis (Zamarro, 1992), although there may be some potential to recruit and quickly develop vitellogenic oocytes during the spawning period (Maddock and Burton, 1999). Pitt (1964) reported spatial differences in fecundity between the southern Grand Bank (417,000 eggs at 30 cm), northern Grand Bank (148,000 eggs at 30 cm) and southern Labrador Shelf (125,000 eggs at 32 cm). Rideout and Morgan (2007) reported temporal as well as spatial variability in fecundity for this species and suggested that failure to recognize this variability can lead to strong misconceptions about stock reproductive potential.

American Plaice eggs are spherical, 1.5-2.8 mm in diameter, buoyant, with a large perivitilline space and no oil globule (Fahay, 1983). Although little or nothing is known regarding reproductive behaviour in this species, spawning is thought to occur near the bottom (Pitt, 1989). Once fertilized the eggs become buoyant and rise up in the water column to float near the surface. Time to hatching is temperature dependant and has been reported to be 11-14 days at around 4^{o}C with a hatching size of 4-6 mm; the yolk sac is absorbed approximately five days after hatching when larvae are 6.2-7.5 mm (Fahay, 1983). Eggs and larvae tend to be retained over the area where they were spawned by eddying and low water current velocities over the major spawning areas (Nevinsky and Serebryakov, 1973).

American Plaice is generally a slow growing and moderately long-lived species (Scott and Scott, 1988). Females grow faster and are larger than the males for any given age. Sex ratios at older ages are heavily skewed towards females.

Size and age at maturity for American Plaice varies geographically, and has also changed over time. Early maturity estimates for plaice around Newfoundland and Labrador were generally 12-15 years (43-54 cm) for females and 5-7 years (24-29 cm) for males, except for on the Flemish Cap where females matured much earlier at 7-8 years (41 cm (Pitt, 1966)). More recent analyses suggest considerable declines in size (28% for males, 10% for females) and age at maturity (35% for males, 24% for females) since the late 1960s for all three Newfoundland stocks of American Plaice, with mean estimates for females dropping from around 11 years to 8.5 years in the late 1980s / early 1990s (Morgan and Colbourne, 1999). Such changes might be a result of fishery-induced size selective mortality (Barot *et al.*, 2005). The earliest (1959-1968) maturity estimates for Scotian Shelf plaice were 10.5-11.5 years (33.0-41.4 cm) for females whereas males matured much earlier at 4-5 years (22-23 cm) (Beacham, 1983; Bakken, 1987). By 1979, age and size at maturity had undergone large reductions so that females were maturing at 4.7-6.7 years (27.2-30.8 cm) (Beacham, 1983; Bakken, 1987). Maturity data for the more recent decades are not available. In the Gulf of St. Lawrence the earliest maturity data suggested that plaice matured at 10 years (41 cm) for females and 6 years (25 cm) for males (Powles, 1965). More recent survey data for the southern Gulf suggest a decline in the size and age at maturity, with median values since 1997 being 6.1 years (26.4 cm) for females and 3.7 years (18.9 cm) for males (Rod Morin, DFO, Moncton, personal communication).

Attempts to estimate instantaneous natural mortality for American Plaice in Canada have produced variable results ranging from 0.13-0.26 (Huntsman, 1918; Powles, 1969; Pitt, 1972; 1982; Bakken, 1987), with the conclusion that an estimate of 0.2 is reasonable for this species (Busby *et al.* 2007). Morgan and Brodie (2001) found that the VPA formulation that best improved the fit of the model to the data for Div. 3LNO plaice used M = 0.53 for all ages in 1989-1996 and M=0.2 for all other years. The fact that estimates of total mortality for Newfoundland plaice stocks continued to be high after the introduction of the fishing moratorium in 1995 suggested that natural mortality might be unusually high and contributing to population decline (Bowering *et al.*, 1997; Morgan *et al.*, 2002). Morin *et al.* (2008) estimated recent natural mortality on Southern Gulf American Plaice to be 0.53. Despite low exploitation rate, they considered that a declining biomass coupled with the low productivity of the stock indicated poor prospects for improvement of the stock.

COSEWIC usually defines generation time as the average age of parents in the current cohort but suggests that under circumstances where generation time varies under threat it should be estimated for the pre-disturbance period. Generation time is calculated as age at first reproduction + 1/M, where M is the instantaneous rate of natural mortality. Age at first reproduction is estimated by age at 50% maturity as close to the unexploited state as possible (i.e. earliest available maturity data). The earliest A50 for each of the three American Plaice populations is approximately 11 years, which translates into a generation time of 16 years.

Predation

American Plaice are preyed upon by various animals throughout different developmental stages, depending partially on relative size of predator and prey. Eggs and larvae are prey items for most species that feed in the upper pelagic zone during the spring. Unfortunately stomach sampling of pelagic species such as herring, mackerel, and capelin from offshore areas is scant, as the fisheries for them tend to be inshore.

Perhaps the best known (or at least best studied) predator of small American Plaice is Atlantic cod, in particular large (≥ 35 cm) cod (Morissette *et al.*, 2003). A review of diet studies of cod in the southern Gulf suggested that plaice and other flatfish made up less than 6% (by mass) of the diet of cod larger than 46 cm (Hanson and Chouinard, 2002). Cod predation on plaice, however, appears to be temporally variable. A mass-balance ecosystem model suggested that the proportion of plaice in the diet of large cod in the southern Gulf increased from 2.9% in the 1980s to as much as 22% in the 1990s (Savenkoff *et al.*, 2004), and in the northern Gulf increased from around 3% in the 1980s and 1990s to as much as 13% in the early 2000s (Morissette *et al.*, 2003; Savenkoff *et al.*, 2005). A similar model suggested plaice to generally make up 1-5% of the diet of large cod in the Newfoundland and Labrador region (Bundy *et al.*, 2000). Powles (1958; 1965) was the only one to attempt to estimate the impact of cod predation on American Plaice populations. He estimated that approximately 1.5% of plaice under 35 cm in length were consumed annually by cod, although he noted that the number of large cod in the southern Gulf stock was in decline and that his estimate of mortality due to cod predation was likely overestimated.

American Plaice are also known prey items for harp and grey seals on the Scotian Shelf, Gulf of St Lawrence (Benoît and Bowen, 1990a; 1990b) and off Newfoundland (Lawson *et al.*, 1998; Hammill and Stenson, 2000). In the Gulf of St. Lawrence, plaice represent 3-5% of the diet composition (by weight) of these seals (Savenkoff *et al.*, 2004; 2005).

Physiology

The physiology of American Plaice has not been exhaustively studied but some information is available, primarily pertaining to temperature/salinity tolerance, and swimming endurance/aerobic capacity.

American Plaice can withstand a wide range of environmental conditions, but that does not mean that this full range of conditions is suitable for growth and reproduction of this species. The suitability of various environmental conditions has been examined not only with respect to performance traits (growth, etc.) but also blood parameters such as cortisol level, a physiological indicator of stress. For example, Munro *et al.* (1994) examined the physiological responses of plaice to low salinities and determined that although the species is moderately tolerant to changes in salinity, individuals exposed to low salinity (7g/L) exhibited elevated levels of plasma cortisol concentrations compared to control fish (28g/L). They also demonstrated dramatically decreased plasma sodium and potassium concentrations and increased muscle water content. In addition, Berthiaume *et al.* (1993) reported a significant increase in lymphocystis tumors in plaice held at this low salinity.

American Plaice have also demonstrated tolerance to a wide range of environmental temperatures, even as low as -1.8^{o}C (Pitt, 1975b). Morgan (1992) showed that plaice can withstand rapid declines in temperature over 96 hours and are able to survive up to at least 77 days at -1.4^{o}C water temperatures. This tolerance may be related to the presence of an almost entirely alpha-helical, highly symmetrical antifreeze protein that has recently been identified in American Plaice (Gauthier *et al.*, 2005). Nevertheless, Audet *et al.* (1993) did report elevated plasma cortisol levels in plaice in January, suggesting that cold temperatures may cause some degree of physiological stress. However, in some instances plaice may prefer colder temperatures. Morgan (1993) showed that plaice maintained at low food rations moved to lower temperature environments, perhaps suggesting that they use temperature to down-regulate their metabolism and save energy in times of food shortage.

It has been suggested that the aerobic capacity of some flatfish species may be insufficient to allow them to swim at their optimum swimming speeds (Priede and Holliday, 1980). Swimming endurance studies of American Plaice, examined in terms of implications for catchability, indicate that plaice are capable of a number of swimming strategies including steady cruising, swim and settle and burst and glide, with fish size and water temperature determining to some extent which strategy is utilized (Winger *et al.*, 1999). Routine oxygen consumption (ROC) measurements of plaice indicate significant differences in consumption rates of this species compared to yellowtail and winter flounder (MacIsaac *et al.*, 1997). At cold (2^{o}C) temperature, plaice ROC was slightly higher than the other flatfish, but at increased temperatures (11 and 14^{o}C), it was able to maintain ROC at significantly lower rates than the other flatfish.

Dispersal/migration

Throughout most of their Canadian range, American Plaice do not undergo significant migrations (Walsh, 1994b) but are limited to local movements made seasonally for temperature selection and/or feeding (Powles, 1965; Pitt, 1969; Morgan and Brodie, 1991; Swain *et al.*, 1998). In the Grand Bank area, plaice have been observed to move seasonally to avoid prolonged exposure to cold water temperatures (Morgan and Brodie, 1991) but on the slopes of the Grand Bank, this movement does not necessarily mean a large lateral migration because of rapidly changing depth profiles (Pitt, 1969). In the Gulf of St. Lawrence, however, the apparent fall movement from inshore feeding grounds to the deeper waters along the edge of the Laurentian Channel in pursuit of warmer water (Powles, 1965; Swain *et al.*, 1998) represents a more significant migration. Tagging studies on the Grand Bank off Newfoundland also give a hint of possible inshore/offshore migrations (Pitt, 1969; Konstantinov and Noskov, 1972) but returns were not sufficient to confirm whether or not this was a regular seasonal movement or the random non-directional dispersal of a very few individuals.

Dispersal of American Plaice through egg and larval drift is not well understood, but inferred from known spawning times and locations and knowledge of current flows. Nevinsky and Serebryakov (1973) examined the temporal and spatial distribution of plaice spawning in the northwest Atlantic from icthyoplankton samples taken by PINRO (Polar Research Institute of Marine Fisheries) during the period 1959 to 1970. They found that spawning occurred on the continental shelves at depths of 50-250 m, in areas of eddying and turbulence caused by the cold Labrador Current in the Grand Bank area, and by the cold waters flowing out of the Gulf of St. Lawrence in the northern Scotian Shelf area. Plaice eggs and larvae in different stages of development (3-22 mm in length), were generally observed together in the same habitat over or near the spawning grounds. Based on these observations, it was concluded that plaice in the early stages of development do not drift far from the spawning grounds. Similar conclusions were reached by Frank *et al.* (1992) who found that the early larval stages of plaice on the Grand bank tended to be retained on the bank because of the broad plateau and weak sub-tidal currents in the area.

Interspecific interactions

American Plaice interactions with other species can be in the form of both predator and prey. Plaice can also compete for resources with other species but this is dealt with to a much lesser extent in the literature. Predation on plaice was previously discussed. Here information is presented on the primary prey of American Plaice.

American Plaice are considered highly opportunistic feeders at all life stages. They feed on whatever appropriately sized prey items are available, with diet varying based on fish size, locality and season. Larvae feed primarily on copepods and other zooplankton. Adults and juveniles feed on polychaetes, echinoderms, molluscs, crustaceans and fish (capelin, sand lance, other flatfish, etc.). Small plaice (0-9cm) tend to feed on polychaetes and small crustaceans with fish forming a relatively larger portion of the diet as individuals grow, as much as 80% in 30-50 cm fish (Powles, 1965; Pitt, 1973; Zamarro, 1992; Link *et al.*, 2002; González *et al.*, 2003; Johnson, 2004). Little incidence of cannibalism is observed (González *et al.*, 2003). On the Grand Bank (Pitt, 1973; Zamarro, 1992) and in the Gulf of St. Lawrence (Powles, 1965) winter feeding cessation is followed by intensive feeding from May to October.

In the Northern Gulf, the diet of American Plaice was composed mainly of echinoderms and capelin for the mid-1980s (Morissette *et al.*, 2003), of echinoderms, large zooplankton (length size >5 mm), molluscs and capelin in the mid-1990s (Savenkoff *et al.*, 2004), and of large zooplankton, molluscs, other benthic invertebrates and capelin for the 2000-2002 period (Savenkoff *et al.*, 2005). The diet of small plaice (<35 cm) in the Southern Gulf in the mid-1980s and mid-1990s was mainly composed of large zooplankton and other benthic invertebrates (Savenkoff *et al.*, 2004). Large plaice (≥35 cm) fed mainly on echinoderms and large zooplankton in the mid-1980s, and echinoderms, large zooplankton and polychaetes in the mid-1990s.

Adaptability

American Plaice are considered euryhaline and eurybathic and should therefore be able to withstand and adapt to moderate changes in their environment. They occupy a wide range of substrates over their distribution and are opportunistic feeders that appear capable of adjusting to changes in the available prey spectrum. They are capable of tolerating a wide range of temperatures but are also known to actively seek out preferred temperatures, or at least move to avoid cold areas (Morgan and Brodie, 1991; Swain *et al.*, 1998).

Ollerhead *et al.* (2004) recently mapped the spawning areas of American Plaice on the Grand Bank. With offshore oil and gas exploration and extraction activities in recent years there is some concern for the disruption of these potentially critical plaice habitats. In addition there is no information as to whether or not such activities could influence critical fish behaviour. The fact that flatfish swim directly away from a fishing trawl before they could be expected to see it suggests some ability to sense the approach of the trawl. The degree to which plaice might sense seismic exploration activities is uncertain at this time, as is the potential for such activities to interfere with behaviour related to critical life processes such as reproduction.

The decline in American Plaice size and age at maturity is thought to be an evolutionary response to increased mortality (Barot *et al.*, 2005). Selective removal of both immature and mature individuals from the population through either fishery-induced or natural mortality results in a selective pressure to reduce the length of the juvenile period in order to increase the probability that individuals reproduce before they die. So, the decline in size and age at maturity is considered an adaptive response of the population to maintain a high reproductive output in the face of high mortality and typically declining population size.

POPULATION SIZES AND TRENDS

Information about fish population sizes and trends can be obtained either from fisheries-independent survey data or from virtual population analysis (VPA). However, the only currently accepted VPA for American Plaice is for the Grand Bank (NAFO Divisions 3LNO) portion of the Newfoundland and Labrador population. Both survey and VPA information are used here to estimate rate of decline for the Newfoundland and Labrador population, and survey data are used to estimate rate of decline for the Maritime population. A lack of data prevent the calculation of decline estimates for the Arctic population. For comparison purposes, the estimated rate of decline for the entire Canadian American Plaice population treated as a single unit is also presented.

Methodology

For a single management unit, the rate of population decline can be estimated from the slope of the linear regression of the natural log Ln ($\log_e$) abundance (N_t) versus time (t, in years). The resulting regression equation is: $\text{Ln}(N_t) = \alpha + \beta*t$ and the percentage decline over t years (number of years in time series) can be calculated as: $(1-\exp(\beta*t))*100$. Each of the American Plaice populations identified here is made up of more than one management unit. In theory then the abundance numbers could be determined for each management unit, added together to get the abundance of adults for each population, and the rate of decline for the population calculated in the same manner.

With such an approach, the rate of decline can only be calculated over the time series that is common to the management units being combined. However, there is a much greater problem with this technique. It assumes that the catchability of American Plaice (i.e. the proportion of plaice available to be caught by the survey gear that is actually caught) is constant across space and time; however, it is unlikely that catchability is the same among management units within each population, or even among seasons within the same management unit (i.e. 3LNO spring versus 3LNO fall survey data). Therefore a slightly different approach to calculating population decline was employed here.

Rate of decline was calculated using a generalized linear model with a log link and Gamma error structure. Survey was included as a factor, which should account for at least some of the differences in catchability. Year was included as a covariate with a common slope over all surveys.

$$abundance = e^{intercept + \gamma + B}$$

where: $\gamma = year\ effect\ (the\ common\ slope)$
$B = survey\ effect$

In a further effort to address the potential for differential catchability among management units, analyses were run with a weighting factor (area covered by the survey) as well as without. In all cases abundance (in thousands) of adult fish (or proxy of adult fish) was used. Differences in estimated rate of decline between the weighted and non-weighted analyses were less than 1% for the Newfoundland and Labrador population and Gulf of St. Lawrence population and less than 2% for the Scotian Shelf population; and therefore only the results of the weighted analyses are presented here (Detailed model fit information for all models is presented in Appendix 3.) Results are presented in comparison to those from the more simplistic approach of assuming constant catchability.

The number of years in each time series was used to calculate rate of decline (Table 2, Appendix 3) because in each case there were fewer than 3x the generation time recommended by COSEWIC (e.g. 3*16 years = 48).

Rate of decline can be analyzed based either on (1) total fish abundance or (2) abundance of adult fish. Throughout this report emphasis is placed on the change in abundance of the adult component of the stock. Data on total abundance are presented in Appendix 1.

Some fish species demonstrate a tendency to contract to areas of preferred habitat at reduced population size (MacCall, 1990; Simpson and Walsh, 2004). Therefore, in addition to changes in abundance, spatial data were examined for changes in area of occupancy of the population. Both design-weighted area occupied (DWAO) and the minimum area occupied by 95% of the population (D95), were calculated. A detailed description of the methodology is presented in Appendix 2.

Newfoundland and Labrador population

Search effort

Annual multi-species, stratified-random bottom trawl surveys have been conducted by the Newfoundland Region of Fisheries and Oceans Canada in NAFO Divisions 3LNO in the spring (April-June) since 1971 and in autumn (late-September to mid-December) since 1977. Surveys covered depths from 45 to 731 m until 1984 for the spring surveys and 1990 for the fall surveys, when they were expanded to cover offshore areas of Divisions 2J, 3K and 3LNO. A vessel change in 1995 resulted in a gear change from the Engel 145 trawl to the Campelen 1800 shrimp trawl and extended coverage of Divisions 3KL, 3M and 2GH, including strata deeper than 1000 m (Brodie, 2005). The current survey design involves two vessels. Typically the RV *Wilfred Templeman* surveys Div. 3LNO out to 731 m and part of Div. 3K, generally the inshore and western strata. The RV *Teleost* is usually scheduled to survey Subarea 2, most of Div. 3K, the deeper portion (> 731 m) of Div. 3LNO, and the 9 deep strata in Div. 3M (Flemish Pass and adjacent area). On two occasions (1996, 2001), the RV *Alfred Needler*, outfitted with an identical Campelen 1800 trawl, was used in the survey.

Coverage for the spring survey has been relatively constant in recent years; the notable exception to this is 2006, when mechanical problems allowed only minimal coverage in Division 3NO, primarily in the shallowest strata and, with the survey extending to near the end of June, much later than usual. The fall survey has been subject to more variability. Vessel breakdowns resulted in missed coverage, particularly in the deepwater strata, in some years, notably 2004 and 2006. In five years, including 2002 to 2005, the survey extended into January because of vessel breakdowns. With survey time at a premium and the high rate of vessel problems, the decision was made to remove Division 2G from the survey and to survey Division 2H every second year. A full survey of 3M was carried out in 1996 but since that time only the deep strata in the northern and western areas of the Flemish Cap were included in the survey design. Complete survey design details are available elsewhere (Doubleday, 1981; Walsh *et al.*, 2004b; Brodie, 2005; Brodie and Stansbury, 2007).

In addition to the regular surveys, a juvenile groundfish survey on the Grand Bank covered depths inside the 91 m depth contour from 1985 to 1988. The maximum depth was increased to 183 m in the 1989 to 1991 surveys and further to 273 m in the 1992 to 1994 surveys. A stratified-random sampling design similar to that used in the regular groundfish surveys was employed but the gear was a two-bridle Yankee 41 shrimp trawl with a mesh size of 38 mm and a 12-mm stretched mesh liner codend (McCallum and Walsh, 1996). The surveys were generally conducted from mid-August to mid-September in 1985-86 and 1988-93, September-October in 1994, and November 1-13 in 1987 (Morgan *et al.*, 1997). When the regular groundfish surveys switched to the use of the Campelen trawl in 1995 the juvenile surveys were discontinued because the new gear adequately sampled juvenile fish.

Stratified-random surveys have been conducted by Canada in Subdivision 3Ps and 3Pn in each year from 1972 to 2005 but coverage was poor prior to 1980. Surveys were primarily in February/March prior to 1993 and April since 1993. In 1993 there were two surveys, one in February and one in April. There have been two gear changes during this time series with the Yankee 36 trawl used for 1971-1982, Engel 145 for 1983-95 and Campelen 1800 for 1996-2005. There is a conversion available to translate data from the second trawl into Campelen units for 3Ps (Morgan *et al.*, 1998) but no conversion exists for the first gear type (Morgan *et al.*, 2005), and no conversions are available for the three trawls for 3Pn. Subdivision 3Pn was also surveyed by the Quebec region of DFO from 1993 to 2003 but those data are not included here.

Indexed strata have been used wherever possible for assessment of the populations. Due to incomplete coverage over the time series, the recently added inshore and deep water strata from the fall surveys have been excluded from the analysis. Additionally, the 2004 fall 3LNO and 3Ps and 2006 spring 3LNO surveys are excluded because of poor coverage.

<u>Population trends</u>

The number of mature individuals in Div. 2J3K, Div. 3LNO spring, Div. 3LNO fall and Div. 3Ps surveys were calculated by applying male and female maturity ogives by length to the males and females, respectively, in the stock. These numbers were added together to produce the number of mature individuals. Additionally, for Div. 3LNO, population numbers from the Virtual Population Analysis (VPA) were applied to a female sex ratio, and then a maturity ogive applied to get the proportion of females mature; the males were derived from the total stock estimate minus the females and a male maturity ogive applied to produce the proportion of males mature for each year. Again, these numbers were added to produce the number of mature individuals. NAFO Divisions 2GH and Subdivision 3Pn were excluded from these analyses due to the sporadic nature of survey data, problems converting data between multiple gear types used during the surveys, and in the case of 3Pn a lack of maturity data (Appendix 1 presents available total abundance data for these areas).

There are three sources of data that can be used to calculate adult abundance for 3LNO American Plaice: spring survey data, fall survey data, and VPA estimates. The most recent estimate of total abundance of mature individuals is approximately 171 million. Analyses of population trends were first run including only spring data, then spring and fall survey data, and then only estimates from the 3LNO VPA. The calculated percent decline in adult abundance for the Newfoundland and Labrador population was similar for all three approaches (94-96%), with the time series being shorter for the survey data (1978-2006) than the VPA estimates (1960-2006). Extending this rate of decline to 3 x the generation time results in a 97-99% decline.

With the more simplistic approach (assumption of constant catchability) the rate of decline of the Newfoundland and Labrador American Plaice population and the length of the time series depends greatly on which index of 3LNO abundance is used in the calculation. With this approach the percent decline in the adult stock and length of the time series is 85% and 21 years when 3LNO spring survey data are used, 52% and 16 years when fall survey data are used, and 93% and 23 years when estimates from the 3LNO VPA are used.

When the three management units that make up this population are analyzed separately, rates of decline for the adult stock are 97% over a 28 year period for 2J3K (representative of Subarea 2+3K), 94% over a 47 year period for 3LNO (based on VPA estimates) and 85% over a 23 year period for 3Ps. Model fits were generally poor ($r^2 < 0.50$), with the exception of 3LNO ($r^2 = 0.75$), because abundance has not continuously declined over the entire time period. Instead, the general pattern is a period of rapid decline followed by a stable period or even a period of slight increase in abundance (Fig. 10). Despite the slight increase in abundance in recent years, the 3LNO portion of the population still remains below B_{lim} (a precautionary threshold below which the probability of poor recruitment is considered high, considered to be 50,000 tons for this stock). In 2007 NAFO Scientific Council (NAFO 2007) predicted that 3LNO plaice could potentially reach B_{lim} by 2009 if F was kept at 0 but that B_{lim} would not be reached until sometime after 2012 at $F_{current}$ (0.31).

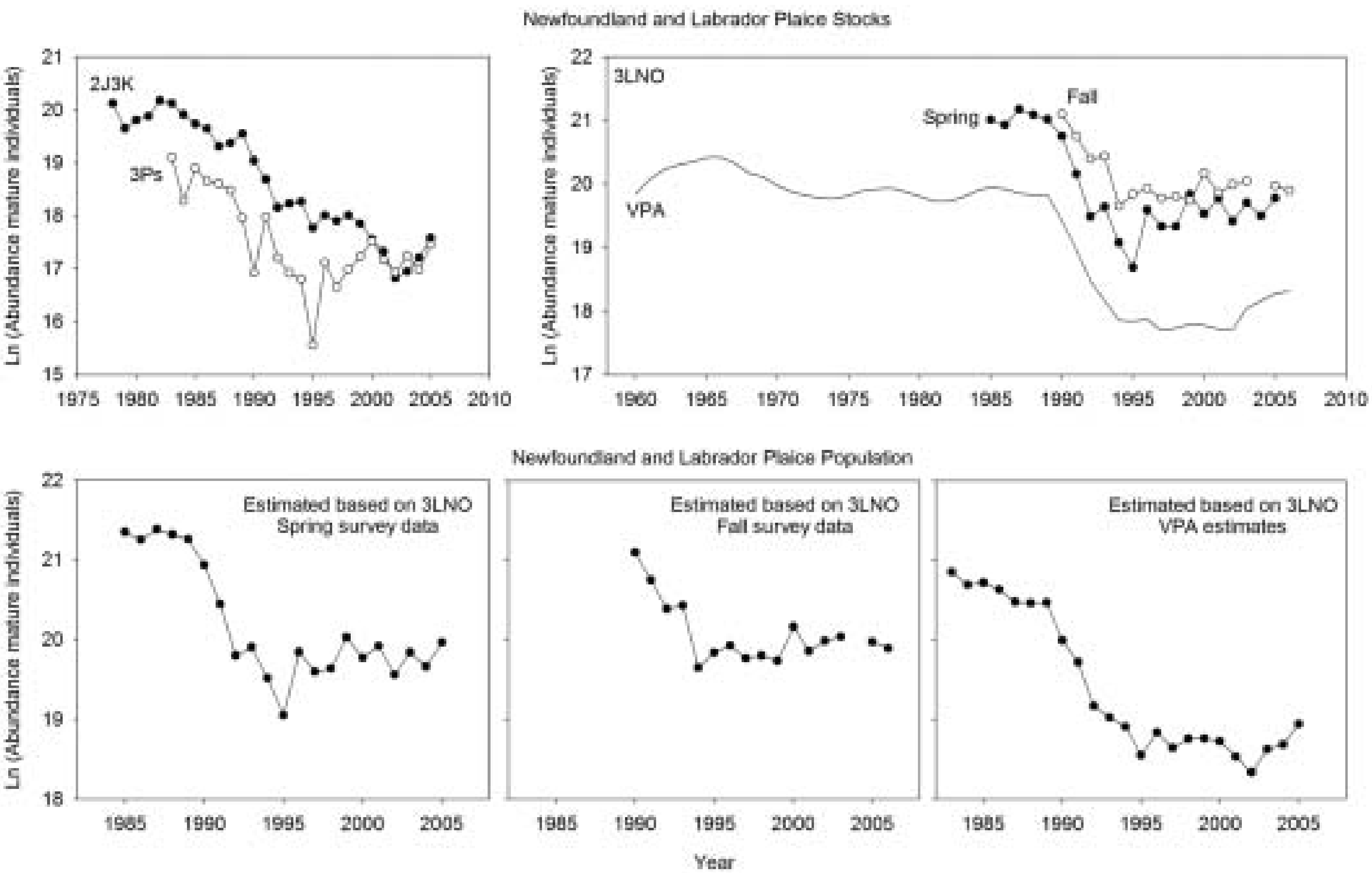

Figure 10. Abundance of mature individuals in the Newfoundland and Labrador population of American Plaice.

Design-weighted area occupied (DWAO) for the Newfoundland and Labrador population was slightly greater than 450,000 km^2 in 2005 and demonstrated no significant trend, regardless of whether fall or spring survey data were used for 3LNO (Fig. 11). There was also no trend in DWAO for the stocks that make up this population, except for 3Ps which actually demonstrated an overall slight increase. The minimum area occupied by 95% of the population (D95) exhibited a slight positive trend for both 2J3K and 3Ps, but no overall trend for 3LNO (fall or spring survey data). D95 was approximately 36,000 km^2 for 2J3K in 2006, 46,000 km^2 for 3LNO in 2006, and 8000 km^2 for 3Ps in 2005.

Age at maturity	**Generation time (years)**	**Data source**	**Data type**	**Time period**	**Decline rate**
Males 5-7 Females 12-15	16	survey data & VPA	number of mature individuals	1960-2006	94-96%

Maritime population

Abundance trends were calculated separately for the Gulf of St. Lawrence and Scotian Shelf, to allow for the possibility of treating these two areas as separate DUs.

<u>Gulf of St. Lawrence search effort</u>

Surveys of the northern and southern Gulf of St. Lawrence are the responsibility of the DFO Quebec and Gulf Regions, respectively, although strata deeper than 100 fathoms (183 m) in division 4T are also surveyed by the Quebec Region. The northern Gulf survey generally occurs in August and stretches from the Lower Estuary, across the northern Gulf. The survey began in 1984 with the RV *Lady Hammond* using a Western IIa trawl but switched to the trawler CCGS *Alfred Needler* and URI shrimp trawl 81’/114’ (codend liner mesh size of 19 mm) in 1990. The same depth-stratified sampling protocol was maintained, but other procedures, such as tow speed and duration, were changed. A comparative fishing experiment conducted in 1990 between the two vessel-gear combinations (Hammond-Western IIA and Needler-URI) could not establish a conversion factor for American Plaice. As a result, a new time series for this survey began in 1990. The northern Gulf survey incurred a second change of vessels and survey gears in 2004 when the CCGS *Teleost* and the Campelen 1800 shrimp trawl (codend liner mesh size of 12.9 mm) were adopted. Comparative fishing experiments were conducted in 2004 and 2005 (Bourdages *et al.*, 2007) and a length-based conversion factor was established to make catch rates comparable between the two vessels-gear combinations (Needler-URI and Teleost-Campelen).

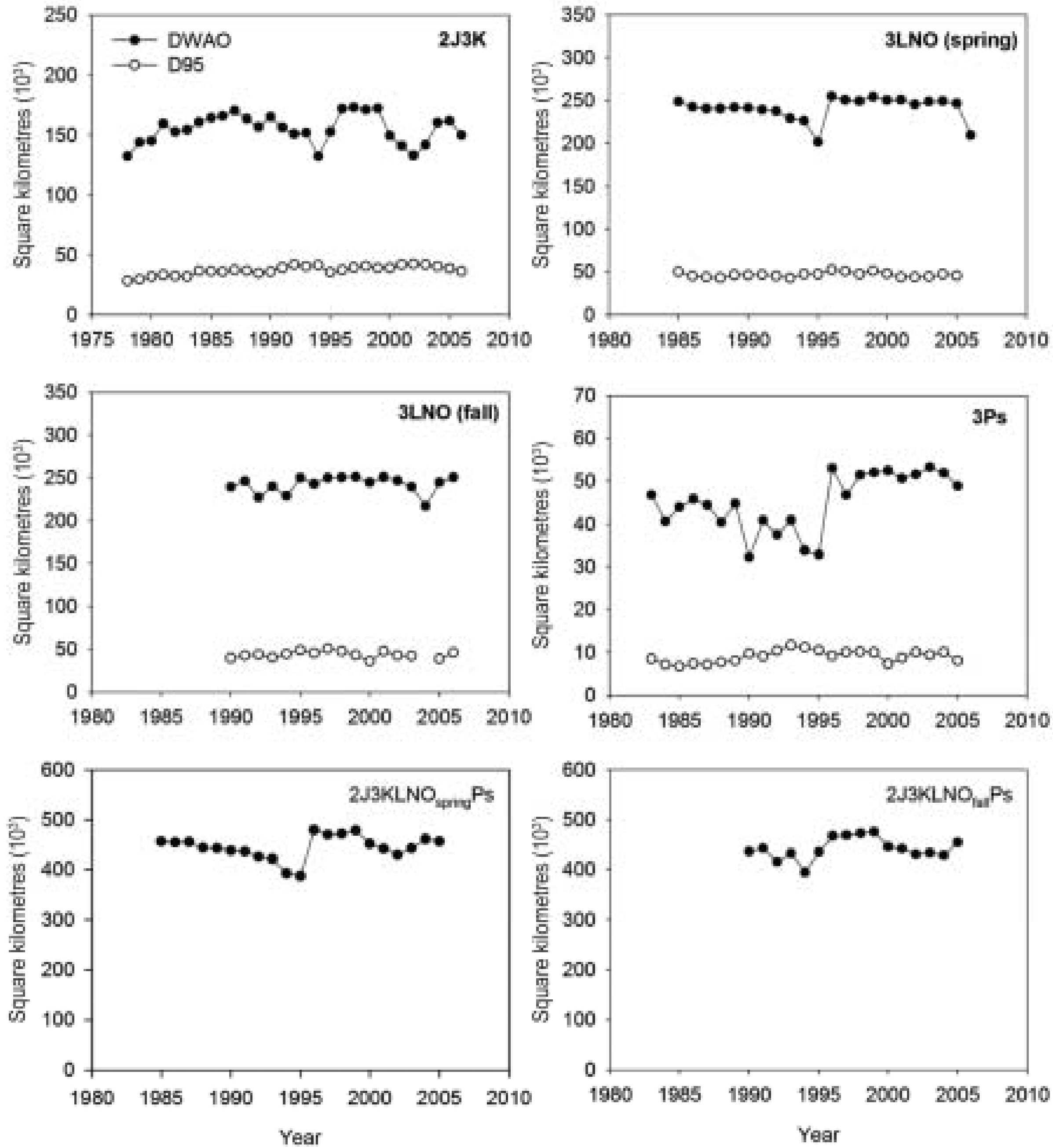

Figure 11. Area of occupancy of the Newfoundland and Labrador population of American Plaice.

In 1991, survey coverage was extended to include strata off western Newfoundland and northward to the Strait of Belle-Isle. As a result, abundance trends for the northern Gulf summer surveys are presented for 1991 to 2006. Mechanical vessel failures during the 2004 survey caused 6 strata to be missed and an additional 10 strata to be sampled only once. As a result the 2004 survey was omitted from the analyses of abundance and area of occupancy. These and other vessel problems that led to time limitations have also resulted in Stratum 840, located in the Strait of Belle-Isle, being missed nine times in surveys since 1991. The survey index is based on 51 strata, covering an area of 115,350 km^2.

Surveys of the southern Gulf (NAFO 4T) have been conducted every September since 1971. The southern Gulf survey area is divided into 24 strata (three inshore strata were added in 1984, but these are not used in analyses of American Plaice). Four research trawlers have been used in this survey: the *E.E. Prince* from 1971 to 1985, the *Lady Hammond* from 1985 to 1991, the *Alfred Needler* from 1991 to 2005, and the *Teleost* since 2004. One change was made to the fishing gear: the Yankee 35 trawl was used until 1985, replaced by the Western IIa trawl. Comparative fishing experiments were conducted in 1985, 1992, and during 2004 and 2005 to establish conversion factors, as required (Benoît and Swain, 2003; Benoît, 2006). The 2003 survey has been excluded from analyses of abundance and area of occupancy because an un-calibrated research trawler was used due to vessel problems.

Gulf of St. Lawrence population trends

American Plaice in this population are a combination of the stocks identified for management purposes as (1) Northern Gulf of St. Lawrence (NAFO Divisions 4RS); and (2) Southern Gulf of St. Lawrence (NAFO Division 4T). Adult abundance in 2006 was estimated as greater than 315 million individuals. The rate of decline in adult abundance for this population over the period 1971-2006 estimated from the combined Northern and Southern Gulf survey data is 86%. Extending this rate of decline to 3 x the generation time results in a decline of 92%.

When rate of decline is calculated with assumed constant catchability among areas, a much shorter data series must be used (1991-2006). Over that time span (16 years) this approach suggests that abundance of adults in the Gulf declined by 57%. A much longer time series (1971-2006) is available for the southern Gulf portion of the population (Fig. 12), where adult stock size has declined by 85% since the start of the time series. The adult stock in the northern Gulf portion of the population shows no trend in abundance for the short time series.

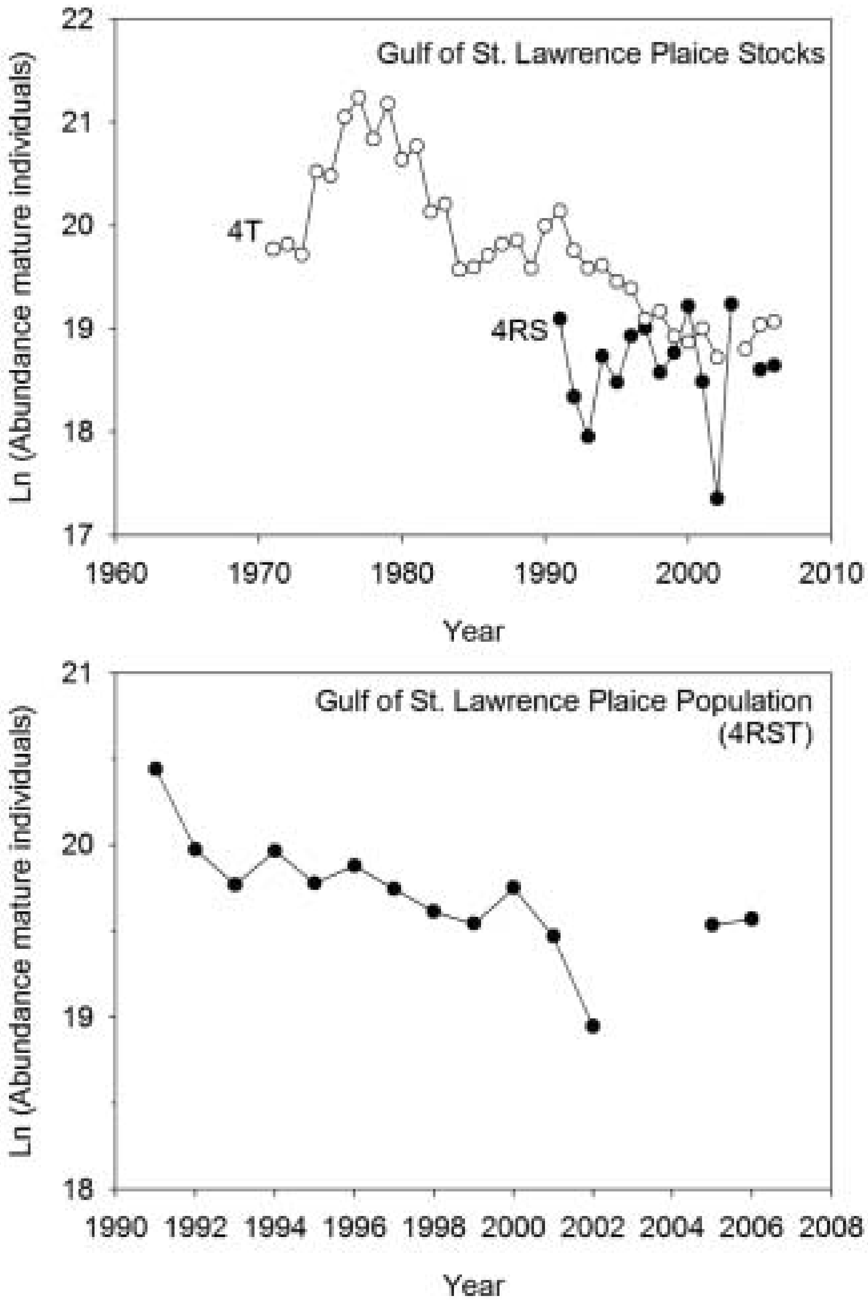

Figure 12. Abundance of mature individuals in the Gulf of St. Lawrence population of American Plaice.

American Plaice are relatively widely distributed in the Gulf with the exception of the deeper waters of the Laurentian and Esquiman channels. In 2006, design weighted area occupied (DWAO) for plaice in the Gulf was greater than 160,000 km^2. DWAO demonstrated a significant increasing trend for the entire Gulf population (Fig. 13) as well as the northern Gulf portion but showed no significant trend for the southern Gulf over the longer time series. The minimum area occupied by 95% of the population was approximately 48,000 km^2 and 38,000 km^2 for the Northern and Southern Gulf, respectively, with both regions demonstrating a positive temporal trend.

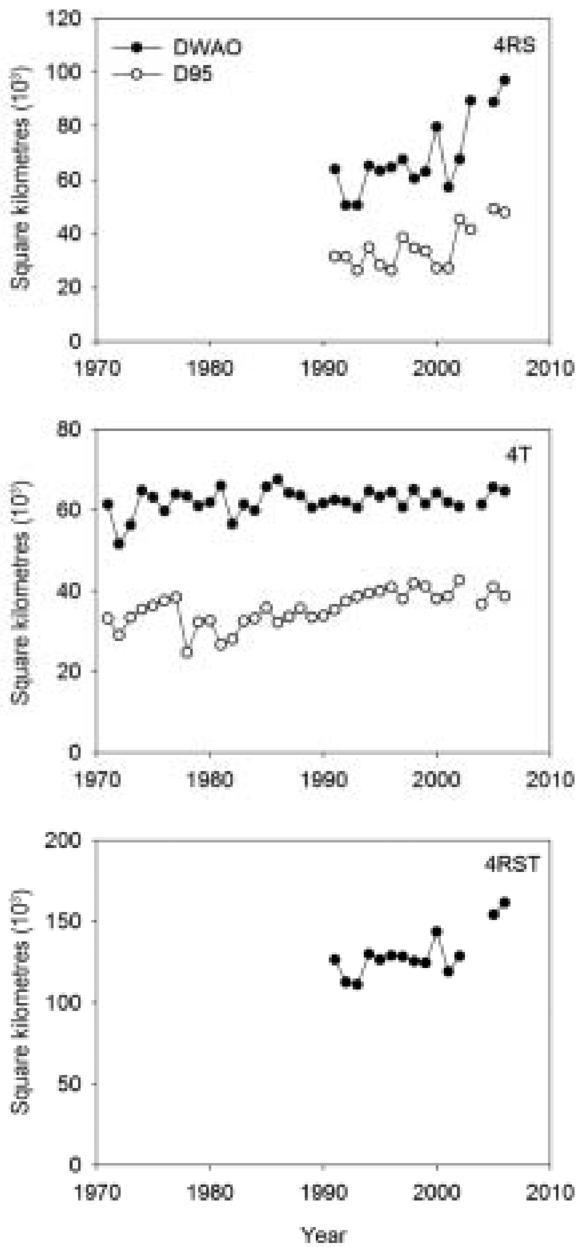

Figure 13. Area of occupancy of the Gulf of St. Lawrence population of American Plaice.

Scotian Shelf search effort

American Plaice on the Scotian Shelf have been subject to summer random stratified research vessel surveys every year since 1970. Throughout the time series low numbers of sets per stratum and perhaps questionable catchability of the species by the survey trawl has resulted in highly variable estimates. Therefore, abundance estimates are often considered relative indices. Such estimates, however, should be fine here considering the long-term decline trend for Scotian Shelf American Plaice (Busby *et al.* 2007).

The survey time series for the Scotian Shelf is missing abundance indices for 2004, 2006 and 2007. This was caused by a vessel change in 2004 and an error in data compilation. Preliminary analyses indicate that the addition of the 2004, 2006 and 2007 data will not alter any conclusions in this report.

Scotian Shelf population trends

There are no recent maturity data for this population so the current practice (based on a combination of historical maturity data and typical size of recruitment to the fishery) is to treat fish larger than 30 cm as adults (Mark Fowler, DFO, Dartmouth, personal communication).

Abundance of adult American Plaice on the Scotian Shelf was estimated at approximately 29 million individuals in 2005. Adult abundance declined by 67% over the time series (1970-2005) when analyzed via generalized linear model. Extending this rate of decline to 3 x the generation time results in a decline of 77%. A simplistic linear regression model (i.e. ignoring differences in catchability between areas) suggests a decline of 69% over the time series. When northern (4VW) and southern (4X) parts of the population were analyzed separately the rate of decline was 70% and 56%, respectively (Fig. 14). The number of plaice in 4X is low compared to 4VW and appeared to have less influence on the trend for the whole population. It should be noted that the lack of data about male and female proportions mature at age may influence the computation of decline rates for this DU relative to those DUs for which this information is available.

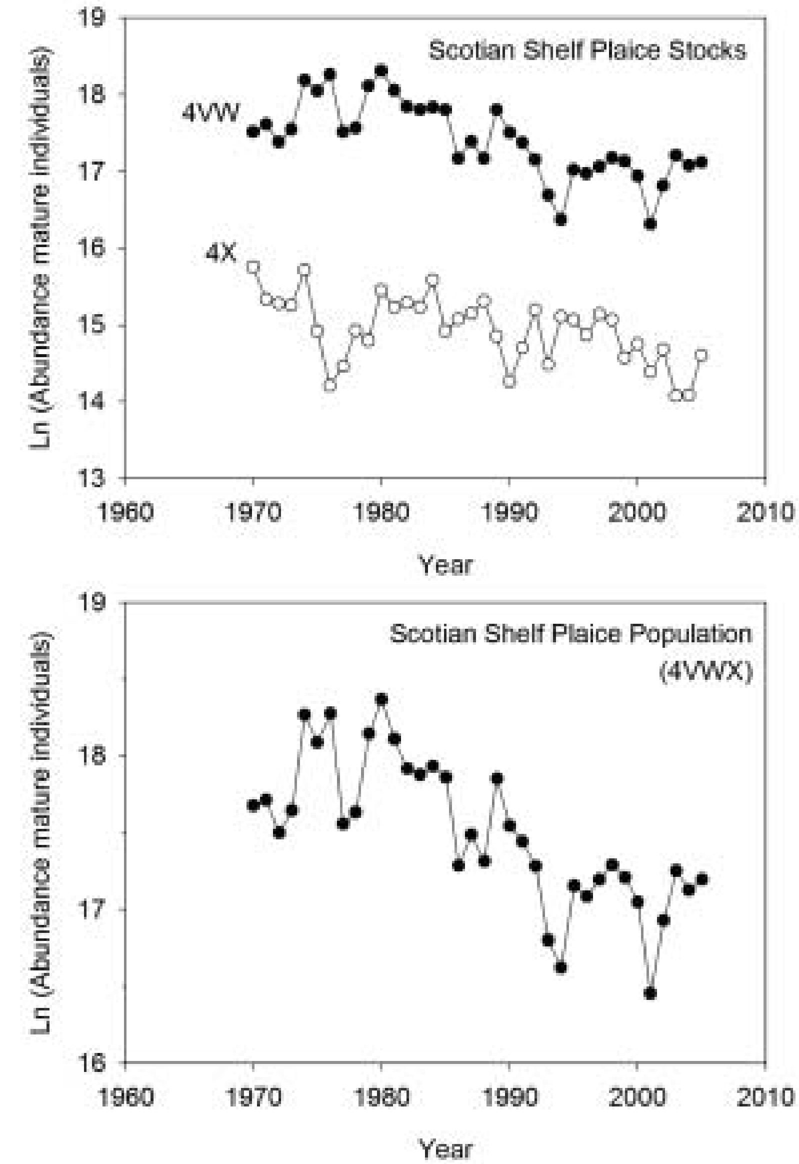

Figure 14. Abundance of mature individuals in the Scotian Shelf population of American Plaice.

Design weighted area occupied (DWAO) for American Plaice on the Scotian Shelf was approximately 112,000 km^2 in 2005. DWAO demonstrated no trend over time (Fig. 15) for the whole Scotian Shelf population or for the western component (4X) but showed a slight negative trend for the eastern component (4VW). The minimum area containing 95% of the population (D95) was nearly 49,000 km^2 for 4VW and 22,000 km^2 for 4X, with neither showing a significant temporal trend.

Region	Age at maturity	Generation time (years)	Data source	Data type	Time period	Decline rate
Gulf of St. Law.	Males 6 Females 10	16	survey data	number of mature individuals	1971-2006	86%
Scotian Shelf	Males 4-5 Females 10.5-11.5	16	survey data	number of mature individuals	1970-2005	67%

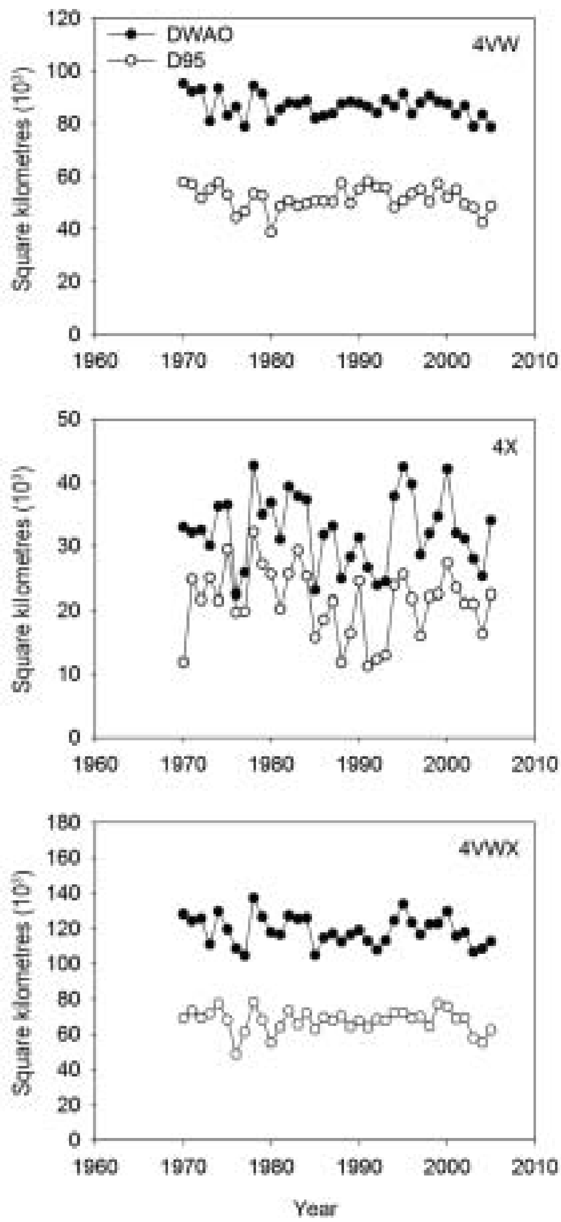

Figure 15. Area of occupancy for the Scotian Shelf population of American Plaice.

The entire Canadian population

A generalized linear model with a log link and Gamma error was used to estimate decline over the entire Canadian population. Survey was included as a factor and year as a covariate with a common slope over all surveys.

$$abundance = e^{intercept + \gamma + B}$$

where: $\gamma = year\ effect\ (the\ common\ slope)$
$B = survey\ effect$

Some model fits included a weighting factor, where the weighting was the area covered by the survey. In all cases abundance (in thousands) of adult fish (or proxy of adult fish) was used. There are three sources of abundance data for 3LNO (spring survey, fall survey, VPA estimates), which led to three separate models being run. In the first set of model fits the spring survey data for 3LNO was included along with the surveys of all other areas: 2J3K (1978-2005), 3LNO spring (1985-2005), 3Ps (1983-2005), 4RS (1991-2006, no 2004), 4T (1971-2006, no 2003), 4VW (1970-2005) and 4X (1970-2005). In the second set of model fits both spring and fall survey data for 3LNO were included. In the third set of model fits the 3LNO surveys (spring and fall) were replaced by the VPA for that stock (1960-2006). Each set of model fits included a run with and without the weighting factor.

Rates of decline for the Canadian population ranged from 87-95% (Table 1). Goodness of fit information for all models is given in Appendix 3.

Table 1. Estimates of rate of decline of adult American plaice for the entire Canadian population. Results of 6 model runs are presented combining data from all areas to estimate a common slope which is used to calculate rate of decline.

Indices included for 3LNO	Time period	Number of years	Slope	SE slope	% decline	
					Time series	3x GenTime
3LNO spring						
weighted	1970-2006	37 years	-0.074	0.0046	93.5	97.1
not weighted	1970-2006	37 years	-0.055	0.0041	86.9	92.9
3LNO fall, spring						
weighted	1970-2006	37 years	-0.072	0.0044	93.0	96.8
not weighted	1970-2006	37 years	-0.055	0.0039	86.9	92.9
3LNO VPA						
weighted	1960-2006	47 years	-0.063	0.0032	94.8	95.1
not weighted	1960-2006	47 years	-0.055	0.0034	92.5	92.9

Rescue effect

The potential for a diminished or extirpated population of American Plaice to experience a rescue effect from a neighbouring population will be dependent on the amount of mixing between the populations, the status of the neighbouring population and the likelihood that individuals from the neighbouring population will survive and reproduce in their new environment. Rescue could come either from adjacent populations within Canada or from those that are partially or entirely outside of Canada.

Within Canada, a lack of data for the Arctic population of American Plaice and the neighbouring northern portion (Div. 2G) of the Newfoundland population make it impossible at this point to evaluate the degree of mixing between these two populations and the potential for either population to rescue the other. The Laurentian channel impedes the mixing of members of the Newfoundland and Labrador population with those from the Maritime population. It is not, however, a complete physical barrier to mixing and hence a small degree of immigration/emigration might be possible. Plaice in the Gulf of St. Lawrence and Scotian Shelf regions can mix in Div. 4V without having to cross the Laurentian Channel and tagging data suggest that this happens to varying degrees on a seasonal basis. Thus it is concluded here that for all Canadian populations there is in theory at least some potential for a rescue effect from neighbouring Canadian populations.

There is also a possibility that Canadian populations of American Plaice could be rescued by populations outside of Canadian jurisdiction. For example, it is not known if and to what extent the Canadian Arctic population mixes with the population on the Greenland side (SA1) of the Davis Strait. The SA1 stock was last assessed by NAFO in 2005 and NAFO Scientific Council concluded that the stock remained in a depleted state and that even low amounts of bycatch in the shrimp fishery would be sufficient to reduce recovery potential (Siegstad *et al.*, 2005). Recent data from EU-Germany and Greenland surveys within SA1 show that plaice abundance and biomass continue at a level below that seen in the mid-1980s (Fock *et al.*, 2007; Sünksen and Jørgensen, 2007). So while a rescue effect from the West Greenland population of American Plaice might be possible, the low abundance in that population make it unlikely.

The Flemish Cap is immediately east of the Grand Bank and just outside Canadian jurisdiction, and at first glance looks like a prime suspect to generate a rescue effect of the Newfoundland and Labrador population of American Plaice, particularly those on the Grand Bank. Between these two populations, however, is the Flemish Pass, an area with depths reaching greater than 1500 m. The fact that plaice have not been collected from the deepest parts of this channel, coupled with the fact that parasite fauna (Zubchenko, 1985) and also heritable traits such as size and age at maturity differ between the two sides of the channel suggests that the populations do not mix much, if at all (Morgan and Bowering, 2006). Hence, the potential for rescue via the movement of adults across the Flemish Pass appears extremely low. In addition, the drift of eggs and larvae from the Flemish Cap onto the Grand Bank would be extremely unlikely considering that the southward flow of the Labrador Current is strong through the

Flemish Pass. Also the Flemish Cap population appears to have undergone the same dramatic reduction in abundance as the Newfoundland and Labrador population (Casas and Troncoso, 2005), which also might reduce the probability of a rescue effect.

South of the Scotian Shelf in American waters is the Gulf of Maine - Georges Bank population. Again the potential for mixing between these populations is thought to be reduced by the deeper waters of the Fundian Channel and Jordan Basin. There are two narrow shallower regions, one between the Jordan Basin and the Fundian Channel and one between the Jordan Basin and the mainland, that offer possible avenues of transit between the two populations. However, the only evidence of mixing between the two populations is a single fish tagged in the Bay of Fundy in 1973 that was reported off Portland, Maine about 4 years later (Mark Fowler, DFO, Dartmouth, personal communication). Even if some mixing does occur, the potential for a rescue effect from the Gulf of Maine – Georges Bank population is likely very low since this population is currently at historically low levels (O'Brien, 2006).

It is important to re-emphasize the fact that American Plaice are highly sedentary. Thus even when there is potential for mixing, the potential for sufficient movement from one population to another so as to rescue that second population is highly unlikely and any rescue effect that could occur would almost certainly have to occur over a very long time period. Also, it should be emphasized that all Canadian and neighbouring populations are at historical low levels reducing the likelihood of a rescue effect.

LIMITING FACTORS AND THREATS

The major decline in most American Plaice populations is thought to be a direct result of overfishing. However, there may be other contributing factors. In most cases, the early 1990s was a period of major decline but was also a period of unusually cold ocean temperatures, which may have resulted in increased natural mortality (Colbourne *et al*. 1997; Morgan *et al*. 2002).

There has never been a directed fishery for American Plaice in NAFO Divisions 0A and 0B (i.e. Arctic population). Plaice are frequently taken as bycatch in both the shrimp and Greenland halibut fisheries in these areas, with the shrimp fishery account for the vast majority. The introduction of the Nordmore sorting grid into the shrimp gear in the mid-1990s has resulted in a reduction of the bycatch to < 20 t annually (Margaret Treble, DFO, Winnipeg, personal communication). Population size is unknown for the Arctic population of American Plaice and therefore the extent of the impact of this level of bycatch cannot be determined.

All three Newfoundland stocks (2J3K, 3LNO, 3Ps) are under fishing moratoria but plaice are taken as bycatch in directed fisheries for other species. The moratorium in Subarea 2+3K was implemented in 1994 with a bycatch limit of 500 t. This limit was reduced to 100 t per year for 1995-1997. In 1998-2003, the bycatch limit was not referenced and the TAC was set at 0. The reported bycatches from 1994-1999 were in effect less than 30 t per year, primarily from gillnet fisheries. The low bycatch was due to a strong reduction in the TAC in 1994 and the moratorium and limited fisheries for northern (2J3KL) cod which, after 1992, essentially eliminated a major source of American Plaice bycatch (Dwyer *et al.*, 2003). An increase in the catch of plaice in 2000-2002 was observed mainly as a result of the increased effort directed toward Greenland Halibut in Division 3K (Brodie and Power, 2003). It is of some concern that bycatch sampled in 2001 and 2002 from the Greenland halibut fishery consisted of 97-98% females. In most years the bycatches came from Division 3K; catches from 2GH have been negligible (zero reported since 1990). Only 2 tons of catch has been reported in Division 2J from 1993-2002 (Dwyer *et al.*, 2003). There has been debate (Hutchings, 1996; Bowering *et al.*, 1997; Morgan *et al.*, 2002) about whether or not population collapse in this region can be attributed to fishing mortality (including bycatch).

On the Grand Bank, American Plaice are taken as bycatch in fisheries directed for Skate, Redfish, Yellowtail and Greenland Halibut. Catches decreased for a few years following the initiation of the moratorium in 1995, but increased again with the opening of the Yellowtail Flounder fishery in 2000. In 2005, the total bycatch of American Plaice in 3LNO was 4100 t. Canadian vessels accounted for 1464 tons of this bycatch, primarily (97%) from the directed fishery for Yellowtail Flounder. In 2006, total bycatch of plaice was 2800 t. Only 92 t of this was taken by Canadian vessels. Canadian bycatch in this year was primarily from the 3O Redfish fishery, since there was virtually no fishery for Yellowtail (Dwyer *et al.*, 2007). Shelton and Morgan (2005) concluded that levels of bycatch on Grand Bank American Plaice were sufficient to prevent recovery and advised that unless steps were taken soon to substantially reduce bycatches, there appeared to be little prospect for rebuilding to within safe biological limits. More recent analyses suggest that the current level of fishing mortality would allow the American Plaice population on the Grand Bank to increase slightly. However, the level of increase in medium term (5 year) projections would only be half of that expected under no fishing mortality and the stock would remain below the spawner biomass Precautionary Approach limit reference point of 50 kt (the level below which no good recruitment has previously been observed) at the end of the 5 years (Dwyer *et al.*, 2007).

Bycatch of American Plaice on St. Pierre Bank (NAFO Subdivision 3Ps) is also considered a serious threat to the stock and stock recovery. Plaice in this area have been protected by a moratorium since 1993, but bycatch from directed fisheries for Atlantic Cod and Witch Flounder have increased substantially since 1995. Since 1999, the bycatch of plaice as a percentage of the Witch Flounder fishery has been over 20%. In the cod fishery it was less than 5% overall, except for 2002 when the percentage was 6.5. From 1999-2005, 25-30% of the total American Plaice catch has been taken in the directed Witch Flounder fishery being conducted by the otter trawl fleet. While the allowable bycatch of plaice in this fishery is 50%, compared to 10% in other fisheries, actual bycatch rates have been in the range of 49 to 143% (Morgan *et al.*, 2005). Clearly the fishery in 3Ps is targeting American Plaice, even through it is under “moratorium”. Whether or not fishing was the ultimate cause of American Plaice population collapse, the lack of ability to enforce bycatch limits of Newfoundland plaice stocks, especially by foreign and domestic fisheries on the Grand Banks and domestic fisheries in 3Ps, might be the greatest impediment to recovery of these stocks (Shelton and Morgan, 2005).

A 750 t directed fishery TAC for American Plaice exists in the southern Gulf of St. Lawrence. This TAC was reduced to 500 t in 2008. There is a non-quota plaice fishery in the Northern Gulf. The discarding of small fish in the mobile gear fishery in this region was very prevalent in the past, accounting for an additional third of the landed catch. As plaice landings declined in the 1980s in the Southern Gulf, discarding and high-grading contributed to the failure of the plaice stock to recover. Despite several management measures introduced in 1993 to prevent discarding, some infractions continued to occur in the plaice fishery, resulting in periodic fishery closures (Morin *et al.*, 2001). Recruitment continues to be low and there is an ongoing fishery; however, with the current level of natural mortality the spawning stock is projected to decline without any fishery (Morin *et al*., 2008).

The fisheries for American Plaice on the Scotian Shelf (4VW and 4X) are managed under multi-species flatfish TACs. These multispecies flatfish stocks do not facilitate management strategies at the level of a species or population. The component species are undifferentiated so as not to require identification in the commercial landings data. This system is thought to prevent fishers from targeting a single flatfish species and from discarding any species due to quota restrictions. In recent years the quotas have been appropriate with respect to whichever species was in the worst shape. The TACs are frequently taken as bycatch in 4X cod and haddock fisheries. In 4VW, flatfish is one of the only open bottom trawl fisheries along with Pollock and Redfish. Market demand for flatfish species in general has been poor in recent years, such that the absence of any other shallow trawl ground fisheries in 4VW precludes the potential for discarding. Allowance of labelling flatfish species as ‘unspecified flounder’ has proven a major problem for assessing the status of the various flatfish populations on the Scotian Shelf and in the Bay of Fundy. Past and potential magnitudes of unspecified flounder confound and often preclude the use of commercial catch data for assessment purposes.

SPECIAL SIGNIFICANCE OF THE SPECIES

American Plaice was probably at one time the most abundant flatfish in the northwest Atlantic and one of the major commercially exploited groundfish species (Pitt, 1989). Because it does not school and tends to bury itself in the sediment it did not become commercially harvested until the introduction of bottom trawls in the 1930-1940s. Initially it was a target of ‘pulse’ fisheries on offshore banks whenever traditional species (cod, herring, mackerel, halibut, haddock, pollock) were depleted. In the 1950s, the use of filleting and freezing led to the development of a fresh fish market and American Plaice became the target of dedicated fisheries. The American Plaice fishery on the Grand Banks of Newfoundland was the largest flatfish fishery in the world, at times approaching 10% of the entire Canadian Atlantic groundfish fishery (both landings and value). With the extension of the 200-mile limit (1978), the fishery for plaice evolved into an almost exclusive Canadian fishery until the early 1990s when declines in population size resulted in moratoria on all Newfoundland stocks. Closures of traditional fisheries in the 1990s initially increased commercial interest in American Plaice wherever fishing was still allowed, but a combination of bycatch restrictions on other species, market conditions, stock status concerns, and low TACS have kept overall landings at about 1% of historical catches.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

American Plaice are not listed in the Canadian *Species at Risk Act* or the IUCN (2006) Red List of endangered or threatened species, and their Global Heritage Status Rank is GNR (unrated), and so currently receive no special protection.

Directed fisheries for American Plaice exist in 4T (500 t directed fishery), and 4R and 3Pn (not under quota). There is a combined directed species quota of 1000 t in 4VW (American Plaice, Yellowtail Flounder, Witch Flounder) and 2000 t in 4X5Y (American Plaice, Yellowtail Flounder, Witch Flounder, Winter Flounder). All other areas are under moratoria to directed fishing and have bycatch restrictions, but these restrictions appear to be largely ineffective. These restrictions vary depending on the area, vessel size, and directed species. For example, there is a 5% bycatch limit for the 65’-100’ mobile gear fleet when directing for any groundfish species in 3LNO but a 50% by-catch limit when directing for witch flounder in 3Ps. Dockside monitoring is required on all landed American Plaice for all regions. There is also a variable percentage of observer coverage. A small fish protocol exists, whereby if ≥ 15% of catch is < 30 cm the area is closed to fishing for 10 days and may be closed long-term if there are two such occurrences in a single year.

Current management strategies are inadequate to allow recovery of American Plaice stocks. Inability to enforce bycatch limits is the greatest impediment to recovery of Newfoundland plaice stocks, while in the Gulf of St. Lawrence the greatest impediment stems from the directed fishery, coupled with some illegal discarding of small fish. On the Scotian Shelf and in the Bay of Fundy flatfish are managed as a multispecies stock and therefore there are no specific management measures in place to ensure sustainability of American Plaice or any of the other component stocks.

TECHNICAL SUMMARY - Maritime population

Hippoglossoides platessoides
American Plaice – Maritime population Plie canadienne
Range of Occurrence in Canada: Newfoundland and Labrador, Quebec, New Brunswick, Prince Edward Island, Nova Scotia/Gulf of St. Lawrence, Scotian Shelf, Bay of Fundy

Demographic Information

Generation time (estimated)	16
Estimated percent reduction in total number of mature individuals over the last 3 generations.	67-86%
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 or 5 years, or 3 or 2 generations].	unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 or 5 years, or 3 or 2 generations] period, over a time period including both the past and the future.	N/A
Are the causes of the decline clearly reversible?	Yes
Are the causes of the decline understood?	Yes
Have the causes of the decline ceased?	Uncertain
[Observed, inferred, or projected] trend in number of populations	Stable
Are there extreme fluctuations in number of mature individuals?	No
Are there extreme fluctuations in number of populations?	No

Extent and Area Information

Estimated extent of occurrence	275,000km²
[Observed, inferred, or projected] trend in extent of occurrence	Stable
Are there extreme fluctuations in extent of occurrence?	No
Index of area of occupancy (IOA)	275,000 km²
[Observed, inferred, or projected] trend in area of occupancy	Stable
Are there extreme fluctuations in area of occupancy?	No
Is the total population severely fragmented?	No
Number of current locations	N/A
Trend in number of locations	N/A
Are there extreme fluctuations in number of locations?	N/A
Trend in [area and/or quality] of habitat	None

Number of mature individuals in each population

Population	**N Mature Individuals**
Northern Gulf of St. Lawrence (NAFO 4RS)	~125 million
Southern Gulf of St. Lawrence (NAFO 4T)	~190 million
Eastern Scotian Shelf (NAFO 4VW)	~27 million
Western Scotian Shelf (NAFO 4X)	~2 million
Total	~344 million
Number of populations (locations)	N/A

Quantitative Analysis

	Not carried out

Threats (actual or imminent, to populations or habitats)

Directed fishing, bycatch in other directed fisheries, illegal discarding of small fish.

Rescue Effect (immigration from an outside source)

Status of outside population(s)? Georges Bank (USA): depleted Newfoundland and Labrador: at or near historical lows	
Is immigration known?	No
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Probably
Is rescue from outside populations likely?	Unlikely

Current Status

COSEWIC: Threatened (April 2009)

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Threatened	Met criteria for Endangered, A2b, but designated Threatened, A2b, because of large, stable area of occurrence and large remaining number of adults.

Reasons for designation:

This right-eye flounder burrows in the sediment to escape predators and ambush prey. It is widely distributed on both sides of the North Atlantic Ocean, from the Barents Sea to the British Isles in the east, and from northern Baffin Island to Rhode Island in the west. This population occurs in the Gulf of St. Lawrence, the Scotian Shelf, the Bay of Fundy and Georges Bank. A relatively sedentary, non-schooling species, it was likely once the most abundant flatfish in the northwest Atlantic. Over a 36 year time series, (about 2.25 generations) abundance of mature individuals has declined about 86% in the Gulf of St. Lawrence, and 67% on the Scotian Shelf. Overfishing is a major cause of the decline, but an apparent increase in natural mortality in the 1990s, when the largest part of the decline occurred, may also have contributed. The decline appears to have ceased in the Gulf but may be continuing on the Scotian Shelf. There are small ongoing directed fisheries in the Gulf with a quota in the south but no quota management in the north. On the Scotian Shelf and in the Bay of Fundy, this species is managed together with other flatfishes as a multispecies stock and there are no specific management measures to ensure sustainability.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A2b because of a decline greater than 50%, and the cause is not fully understood, and may not have ceased.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because the extent of occurrence exceeds 20,000 km^2 and the area of occupancy is greater than 2,000 km^2
Criterion C (Small and Declining Number of Mature Individuals): Does not apply, because population is greater than 10,000 individuals.
Criterion D (Very Small Population or Restricted Distribution): Does not apply because the number of mature individuals exceeds 1,000 and area of occupancy is greater than 20 km^2.
Criterion E (Quantitative Analysis): None.

TECHNICAL SUMMARY - Newfoundland and Labrador population

Hippoglossoides platessoides
American Plaice – Newfoundland and Labrador population Plie canadienne
Range of Occurrence in Canada: Newfoundland and Labrador/Atlantic Ocean

Demographic Information

Generation time (estimated)	16
Estimated percent reduction in total number of mature individuals over the last 3 generations.	94-96%
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 or 5 years, or 3 or 2 generations].	unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 or 5 years, or 3 or 2 generations] period, over a time period including both the past and the future.	N/A
Are the causes of the decline clearly reversible?	Uncertain
Are the causes of the decline understood?	Partly
Have the causes of the decline ceased?	Uncertain
[Observed, inferred, or projected] trend in number of populations	Stable
Are there extreme fluctuations in number of mature individuals?	No
Are there extreme fluctuations in number of populations?	No

Extent and Area Information

Estimated extent of occurrence	456,000km²
[Observed, inferred, or projected] trend in extent of occurrence	Stable
Are there extreme fluctuations in extent of occurrence?	No
Index of area of occupancy (IOA)	456,000 km²
[Observed, inferred, or projected] trend in area of occupancy	Stable
Are there extreme fluctuations in area of occupancy?	No
Is the total population severely fragmented?	No
Number of current locations	N/A
Trend in number of locations	N/A
Are there extreme fluctuations in number of locations?	N/A
Trend in [area and/or quality] of habitat	None

Number of mature individuals in each population

Population	**N Mature Individuals**
NAFO Subarea 2 +3K	~43 million
Grand Bank (NAFO 3LNO)	~90 million
St. Pierre Bank (NAFO 3Ps)	~38 million
Total	~171 million
Number of populations (locations)	N/A

Quantitative Analysis

	Not carried out

Threats (actual or imminent, to populations or habitats)

Directed fishery (currently under moratorium), bycatch in fisheries directed at other species.

Rescue Effect (immigration from an outside source)

Status of outside population(s)? Flemish Cap (international waters): depleted Arctic population: status unknown Maritime population: at or near historical level of depletion	
Is immigration known?	No
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Probably
Is rescue from outside populations likely?	Unlikely

Current Status

COSEWIC: Threatened (April 2009)

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Threatened	Met criteria for Endangered, A2b, but designated Threatened, A2b, because the distribution has remained stable, and the present level of abundance appears to be such that it is unlikely that there is a 20% chance of extinction within 5 generations (80 yrs).
Reasons for designation: This right-eye flounder burrows in sediment to escape predators and ambush prey. It is widely distributed on both sides of the North Atlantic Ocean, from the Barents Sea to the British Isles in the east, and from northern Baffin Island to Rhode Island in the west. This population occurs from Hudson Strait to the southern limit of the Grand Bank, and westward north of the Laurentian Channel to the southwestern corner of Newfoundland. A relatively sedentary, non-schooling species, it was likely once the most abundant flatfish in the northwest Atlantic, and the fishery for it in Newfoundland waters was once the largest flatfish fishery in the world. Over a 47 year time series, (about 3 generations) abundance has declined approximately 96%. Overfishing is a major cause of the decline, but an apparent increase in natural mortality in the 1990s, when the largest part of the decline occurred, may also have contributed. The decline now appears to have ceased, but numbers remain below a precautionary threshold estimated for this stock. The directed fishery is under moratorium but some significant and poorly regulated bycatches are negatively influencing recovery. In addition, fishing gear is size selective, cropping large individuals, and reducing population reproductive potential. There is evidence that natural mortality has increased, which reduces the ability of the population to withstand fishing mortality.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A2b because of greater than 90% decline over 3 generations, the causes of which are not completely understood, and which may not have ceased.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because the extent of occurrence exceeds 20,000 km^2 and the area of occupancy is greater than 2,000 km^2
Criterion C (Small and Declining Number of Mature Individuals): Does not apply, because population is greater than 10,000 individuals.
Criterion D (Very Small Population or Restricted Distribution): Does not apply because the number of mature individuals exceeds 1,000 and area of occupancy is greater than 20 km^2.
Criterion E (Quantitative Analysis): None.

TECHNICAL SUMMARY - Arctic population

Hippoglossoides platessoides
American Plaice – Arctic population — Plie canadienne
Range of Occurrence in Canada: Nunavut/Arctic Ocean

Demographic Information

Generation time (average age of parents in the population)	unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 or 5 years, or 3 or 2 generations].	unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 or 5 years, or 3 or 2 generations].	unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 or 5 years, or 3 or 2 generations] period, over a time period including both the past and the future.	unknown
Are the causes of the decline clearly reversible?	N/A
Are the causes of the decline understood?	N/A
Have the causes of the decline ceased?	N/A
[Observed, inferred, or projected] trend in number of populations	unknown
Are there extreme fluctuations in number of mature individuals?	unlikely
Are there extreme fluctuations in number of populations?	unlikely

Extent and Area Information

Estimated extent of occurrence	250,000km²
[Observed, inferred, or projected] trend in extent of occurrence	unknown
Are there extreme fluctuations in extent of occurrence?	unlikely
Index of area of occupancy (IOA)	unknown
[Observed, inferred, or projected] trend in area of occupancy	unknown
Are there extreme fluctuations in area of occupancy?	unlikely
Is the total population severely fragmented?	unlikely
Number of current locations	N/A
Trend in number of locations	N/A
Are there extreme fluctuations in number of locations?	N/A
Trend in [area and/or quality] of habitat	unknown

Number of mature individuals in each population

Population	**N Mature Individuals**
Total	unknown
Number of populations (locations)	unknown

Quantitative Analysis

	Not carried out

Threats (actual or imminent, to populations or habitats)

Unknown

Rescue Effect (immigration from an outside source)

Status of outside population(s)? Greenland: depleted	
Is immigration known?	No
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Probably
Is rescue from outside populations likely?	Unlikely

Current Status

COSEWIC: Data Deficient (April 2009)

Status and Reasons for Designation

Status: Data Deficient	**Alpha-numeric code:** N/A
Reasons for designation: Information to establish any COSEWIC risk category with assurance is not available. Data on distribution, abundance and specific habitat, including any observed changes over time, are especially needed.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): N/A
Criterion B (Small Distribution Range and Decline or Fluctuation): N/A
Criterion C (Small and Declining Number of Mature Individuals): N/A
Criterion D (Very Small Population or Restricted Distribution): N/A
Criterion E (Quantitative Analysis): N/A

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Joanne Morgan is a research scientist at the Department of Fisheries and Oceans' Northwest Atlantic Fisheries Centre in St. John's, Newfoundland and Labrador. Her current research focuses on the reproductive potential of marine fishes and how changes in reproductive potential affect population productivity. She is also involved in the assessment of fish stocks.

Corina Busby is a biologist working at the Department of Fisheries and Oceans' Northwest Atlantic Fisheries Centre in St. John's, Newfoundland and Labrador. Her research experience has focused on the physiology of marine and freshwater fish, primarily with respect to aquaculture species.

Appendix 1. Trends and rate of decline in total abundance for American Plaice populations in Canada.

Throughout this report abundance has been used to represent the abundance of only mature fish. Here the available data on total abundance are presented.

Total abundance of American Plaice in Div. 2J3K has declined from the beginning of the time series in 1978 and remained at a very low level since 1990 with no indication of recovery since that time (Fig. 16). Both spring and fall surveys of Divisions 3LNO suggest a steep decline in total abundance in the late 1980s – early 1990s, with perhaps a slight increase in the past 10-15 years. Abundance declined rapidly at about the same time for 3Ps American Plaice but has shown no subsequent sign of recovery.

Trends in abundance of American Plaice in Divisions 2GH and Subdivision 3Pn are presented separately because there are problems converting data between multiple vessels, gear types and surveys (described previously). It is difficult to discern any trend in total abundance for either area (Fig. 17).

Trends in abundance in the Gulf of St. Lawrence (Fig. 18) mirrored trends in adult abundance with a declining trend in 4T and no trend in 4RS.

Abundance of American Plaice on the Scotian Shelf declined around 70% from the mid-1970’s through the early 1990’s (Figure 19) and has remained low since that time.

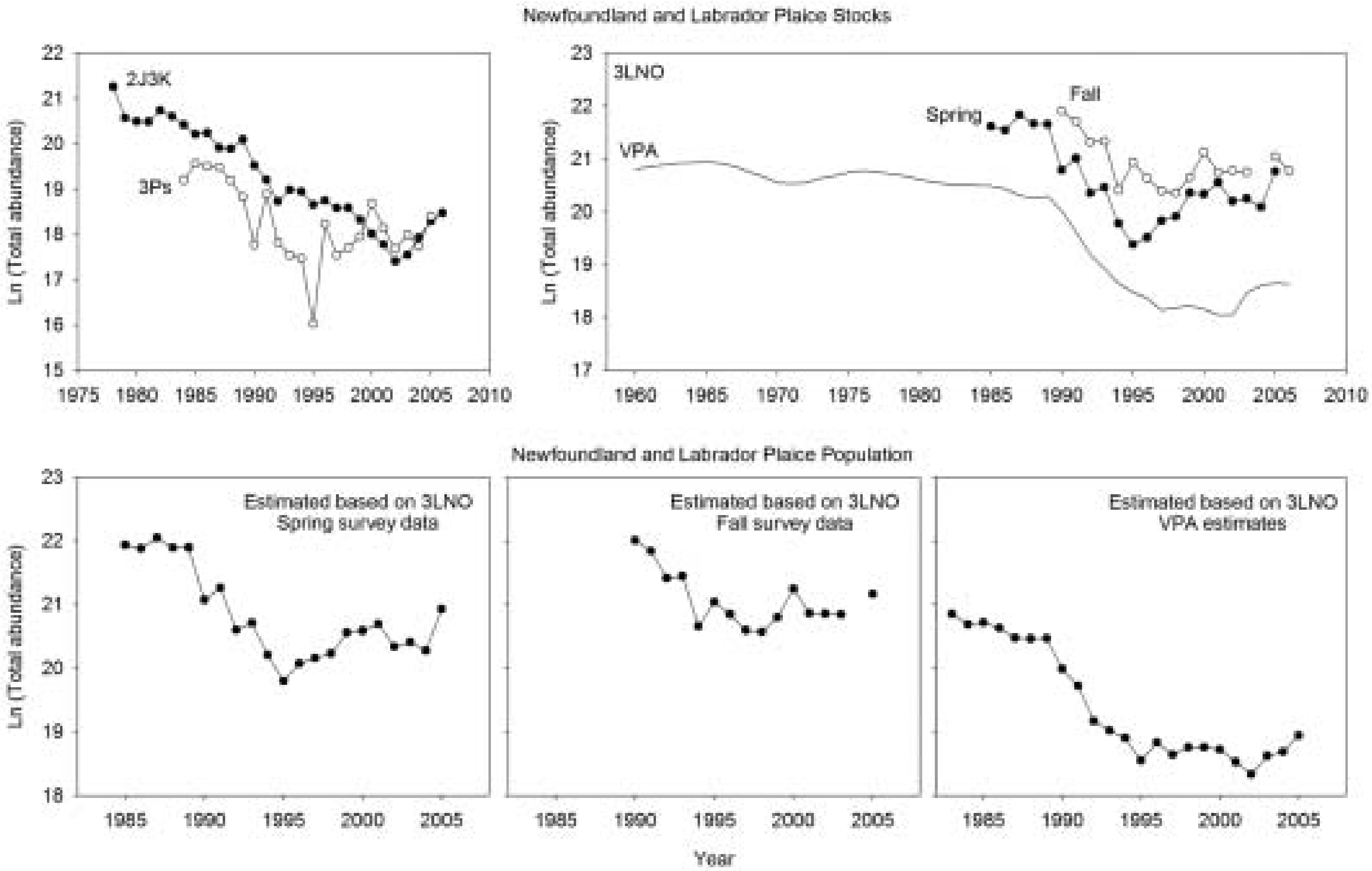


Figure 16. Total abundance of American Plaice in the Newfoundland and Labrador population.

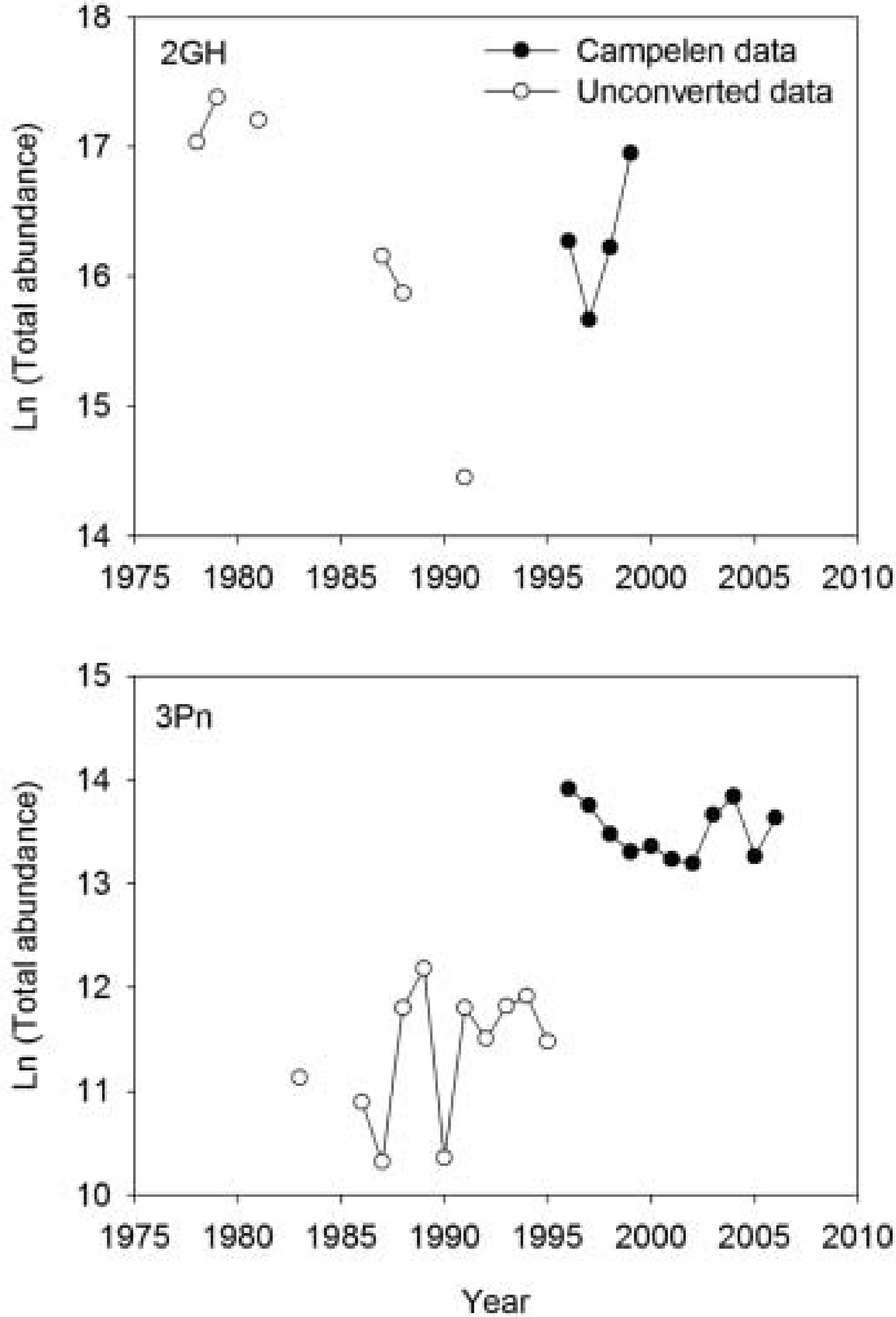
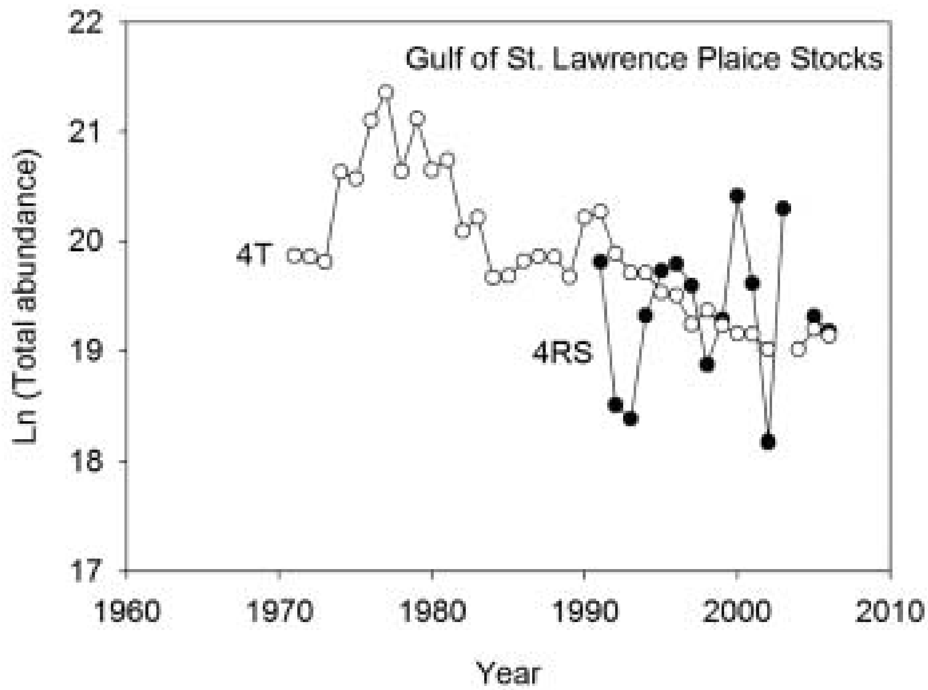


Figure 17. Total abundance of American Plaice in NAFO Divisions 2GH and Subdivision 3Pn.



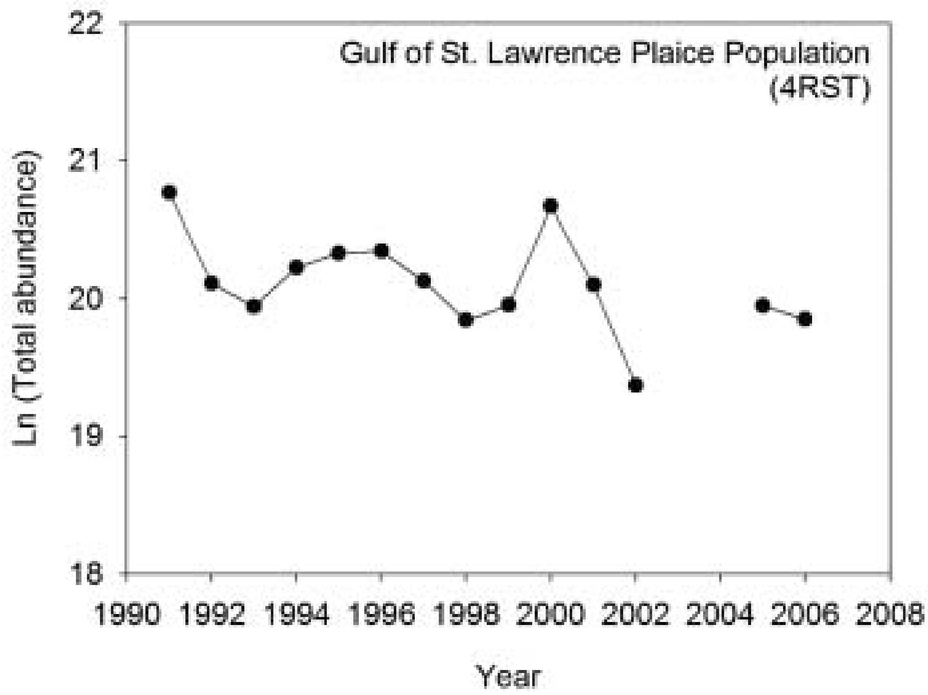


Figure 18. Total abundance of American Plaice in the Gulf of St. Lawrence population.

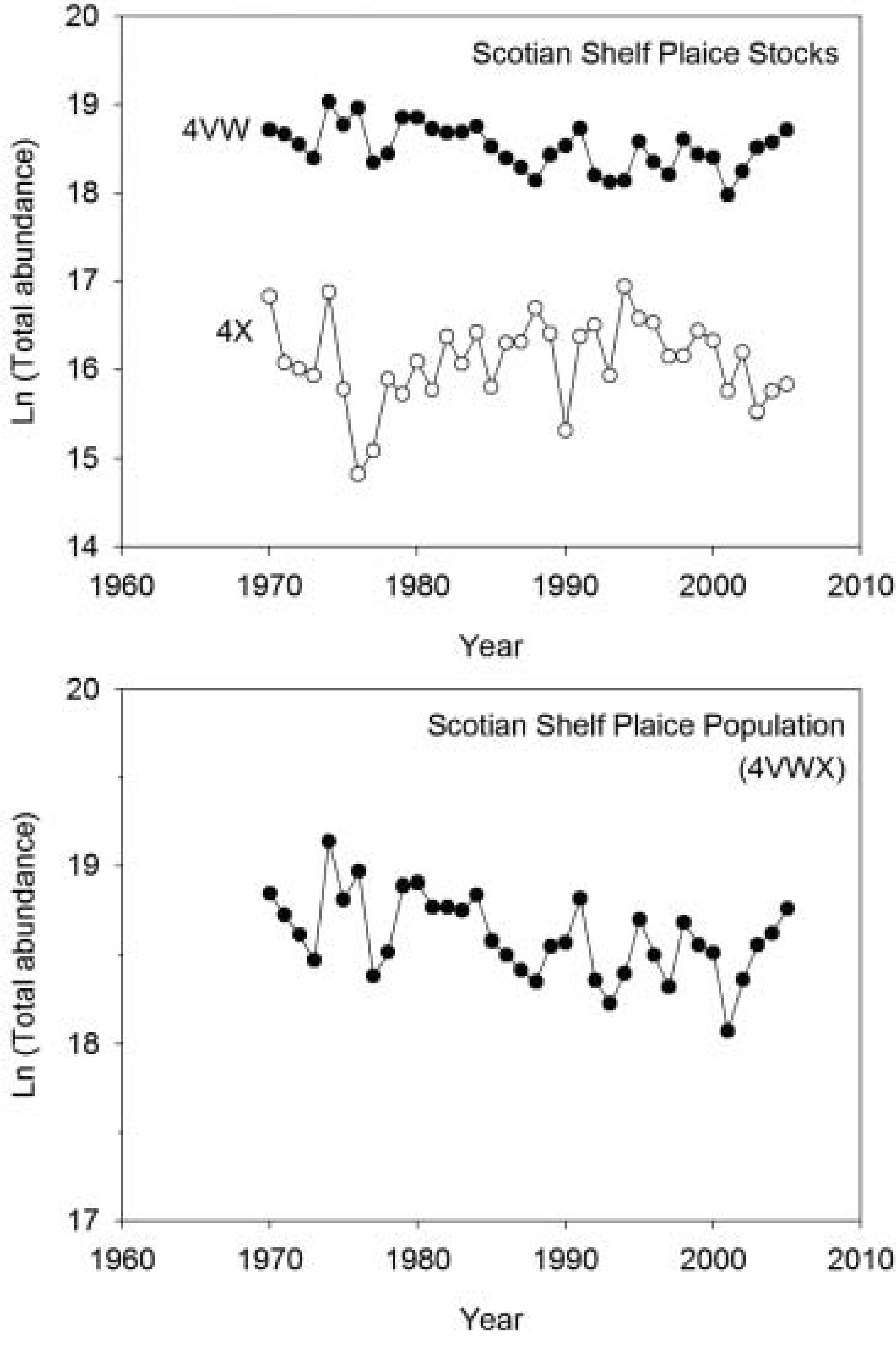


Figure 19. Total abundance of American Plaice in the Scotian Shelf population.

Appendix 2. Calculation of Area of Occupancy

This section provides details on the methodology used to estimate area occupied and degree of concentration of American Plaice in Canadian waters. The data used are from stratified random surveys (Doubleday and Rivard, 1981) and the indices calculated are based on this design.

Design weighted area occupied (DWAO) was calculated as:

$$A_t = \sum_{i=1}^{S} \sum_{j=1}^{n} \frac{a_i}{n_i} I \ where\ I = \begin{cases} \frac{1\ if\ Y_j > 0}{0\ otherwise} \end{cases}$$

where A_t is the DWAO in year t, S is the number of strata, n_i is the number of sets in stratum i, a_i is the area of stratum i, and Y_j is the number of fish caught in set j.

The area containing 95% of the population (D_{95}) was also calculated. To do this catch-weighted cumulative distribution functions were first caculated

$$F(c)_t = \sum_{j=1}^{n} w_j \frac{Y_j}{\overline{Y}} I \ where\ I = \begin{cases} \frac{1\ if\ Y_j \le c}{0\ otherwise} \end{cases}$$

where w_j is the proportion of the survey area in the stratum fished by tow j divided by the number of sets in that stratum, $\overline{Y}$ is the stratified mean number per tow of American Plaice. $F(c)_t$ is an estimate of the number of fish that occur at a density of c or less in year t. F was evaluated at intervals of 0.01 and the density corresponding to $F=0.05$, calculated (c_{05}). This is the density at or below which the most sparsely distributed 5% of the fish are estimated to occur. The area containing this most sparsely distributed 5% of American Plaice was calculated as:

$$G(c_{05}) = \sum_{i=1}^{S} \sum_{j=1}^{n} \frac{a_i}{n_i} I \ where\ I = \begin{cases} \frac{1\ if\ Y_j \le c_{05}}{0\ otherwise} \end{cases}$$

The area containing 95% of American Plaice is:

$$D_{95} = SA_T - G(c_{05})$$

where SA_T is the total survey area.

Data for the Arctic population of American Plaice were insufficient to allow DWAO and D95 to be calculated.

For the other populations only index strata were used.

Within the Newfoundland and Labrador population, data for NAFO Divisions 2GH were sporadic and therefore removed from the analyses. Data from Subdivision 3Pn were also excluded (see below). Thus only data from Div. 2J3KLNOPs were used to construct indices of area occupied for this population. For 3LNO, the deeper water strata and inshore strata that were added to the survey area in recent years were not included. Data from both the spring (1985-2005) and fall (1990-2006, excluding 2004) were used. Surveyed area was lower in the spring survey until 1992 and in the fall survey before 1994. For 3Ps, inshore strata that were added to the survey area in recent years were not included. Surveyed area in 3Ps was lower after the modification of 5 strata in 1994.

Appendix 3. Model fit information for linear regression and generalized linear models used to calculate the rate of population decline for American Plaice in Canada.

Both linear regression and generalized linear models were used to calculate the rate of population decline for American Plaice in Canada. Linear regression is suitable for calculating rate of decline for single management units (Table 2). In order to use linear regression to calculate rate of population decline for combined management units one has to make the major assumption of constant catchability across surveys and is limited to a common time series among the respective data sets.

Table 2. Summary of linear models used to calculate the degree of decline for American Plaice in Canada.

Management Unit(s)	Time Period	No. Years	Slope	SE slope	Model fit	Model significance	% decline
2J3K	1978-2005	28	-0.127	0.008	0.915	<0.0001	97.11
$3LNO_{spring}$	1985-2005	21	-0.083	0.020	0.482	0.0005	82.61
$3LNO_{fall}$	1990-2006	17	-0.046	0.018	0.331	0.0196	54.33
$3LNO_{VPA}$	1960-2006	47	-0.061	0.005	0.756	<0.0001	94.34
3Ps	1983-2005	23	-0.084	0.021	0.440	0.0006	85.35
4RS	1991-2006	16				0.9699	
4T	1971-2006	36	-0.053	0.007	0.622	<0.0001	85.22
4VW	1970-2005	36	-0.034	0.006	0.500	<0.0001	70.17
4X	1970-2005	36	-0.023	0.006	0.300	0.0006	55.67
$2J3KLNO_{spring}Ps^{*}$	1985-2005	21	-0.090	0.018	0.573	<0.0001	84.77
$2J3KLNO_{fall}Ps^{*}$	1990-2005	16	-0.055	0.018	0.406	0.0106	52.17
$2J3KLNO_{VPA}Ps^{*}$	1983-2005	23	-0.119	0.012	0.818	<0.0001	93.49
4RST*	1991-2006	16	-0.052	0.014	0.538	0.0028	56.69
4VWX*	1970-2005	36	-0.033	0.005	0.536	<0.0001	69.30

*assumes constant catchability among areas and is calculated using only years common to all included management units

In an attempt to deal with potentially different catchabilities among survey areas/times generalized linear models were used to estimate a common slope for the areas being grouped together and models were run both with and without being weighted by survey area.

Model fit information for a GENMOD applied to all of the survey data are presented in Figure 20. The overall model predicted curves with alternative selections of data for NAFO Divisions 3LNO are plotted together with the individual data for each survey.

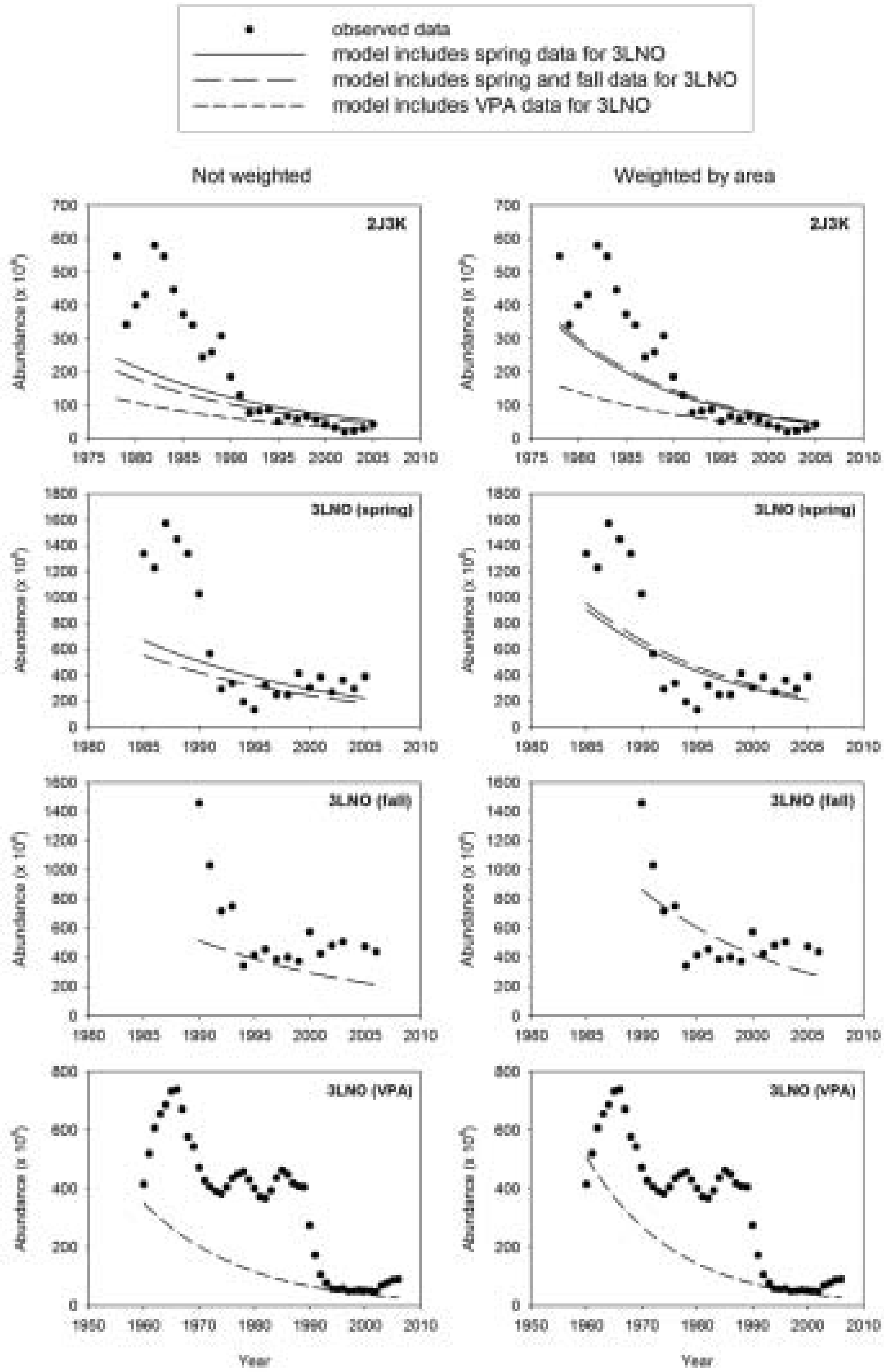


Figure 20. Generalized linear model fits used to calculate the rate of decline of mature individuals when all American Plaice in Canada are treated as a single DU. The model incorporates data for all areas to come up with a common slope. Curves vary depending on what source of data is used for NAFO Divisions 3LNO (see legend). Analyses were run both with (right) and without (left) weighting by survey area (figure continues on next page).

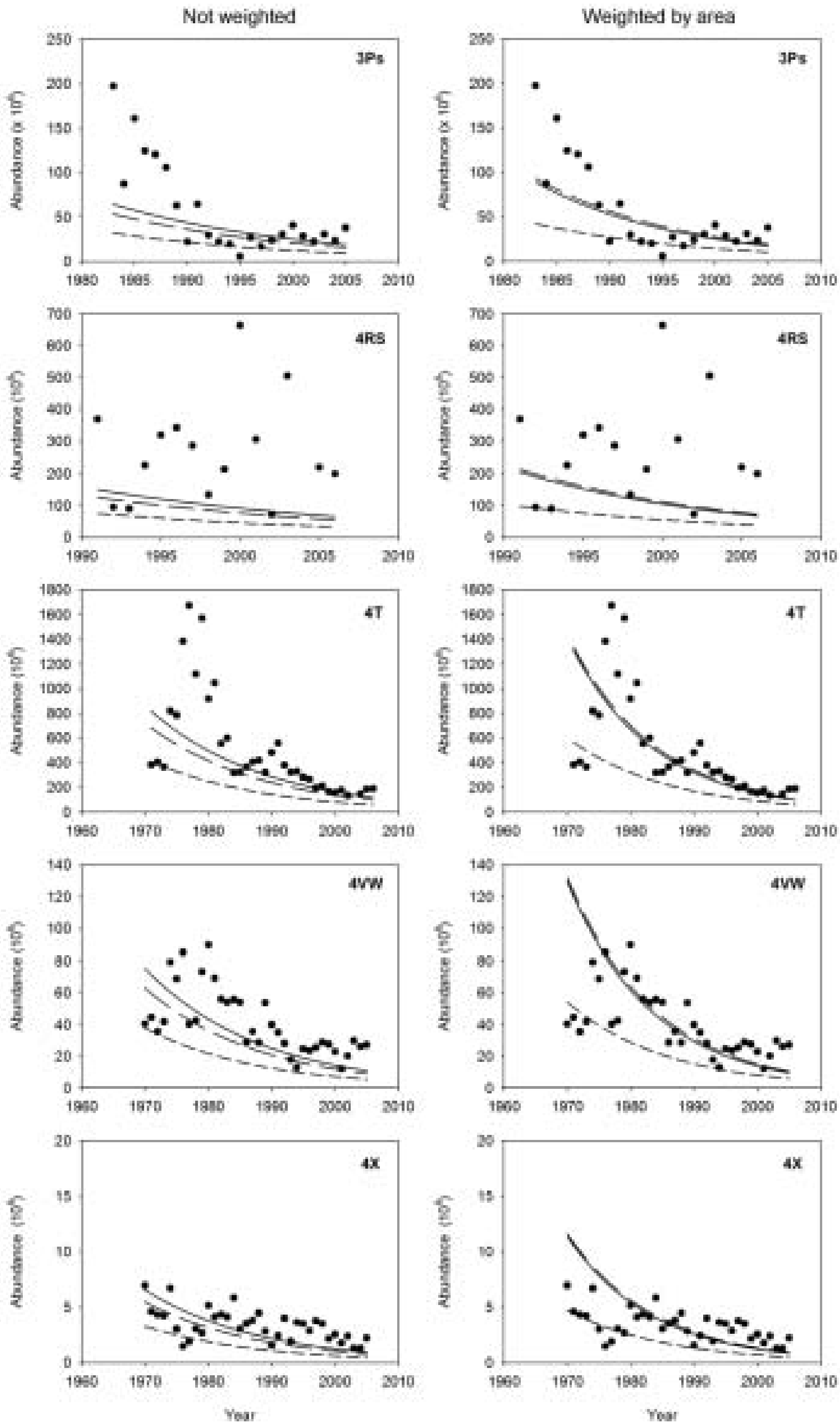


Figure 20 continued.

Model fit data for American Plaice in Canada treated as a single DU.

Including only spring data for 3LNO

Unweighted

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	186	46.8121	0.2524
Scaled Deviance	186	201.7773	1.0848
Pearson Chi-Square	186	43.7318	0.2351
Scaled Pearson X2	186	180.7764	0.9719
Log Likelihood		-2286.6304	

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Conf Limits		Chi-Square	Pr > ChiSq
Intercept		1	117.1397	8.1582	101.1460	133.1255	206.16	<.0001
year		1	-0.0548	0.0041	-0.0629	-0.0468	179.07	<.0001
stock	3J3K	1	4.0407	0.1246	3.7964	4.2850	1051.12	<.0001
stock	3LNOsp	1	5.4452	0.1356	5.1794	5.7110	1611.64	<.0001
stock	3Ps	1	2.9950	0.1315	2.7373	3.2527	518.79	<.0001
stock	4RS	1	4.2930	0.1553	3.9886	4.5974	764.15	<.0001
stock	4T	1	4.8767	0.1174	4.6445	5.1088	1723.76	<.0001
stock	4VW	1	2.4429	0.1160	2.2155	2.6703	443.47	<.0001
stock	4X	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		1	4.1339	0.4039	3.4133	5.0063		

Weighted by area

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	186	5058241.7242	27194.8480
Scaled Deviance	186	205.9237	1.1066
Pearson Chi-Square	186	4403446.5921	23658.3098
Scaled Pearson X2	186	179.0575	0.9627
Log Likelihood		-2315.6594	

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Conf Limits		Chi-Square	Pr > ChiSq
Intercept		1	155.1221	9.0674	137.3503	172.8938	292.67	<.0001
year		1	-0.0739	0.0046	-0.0828	-0.0650	263.83	<.0001
stock	3J3K	1	3.9670	0.1579	3.6574	4.2766	630.95	<.0001
stock	3LNOsp	1	5.4849	0.1567	5.1676	5.8019	1230.10	<.0001
stock	3Ps	1	3.0222	0.1964	2.6373	3.4071	236.81	<.0001
stock	4RS	1	4.4457	0.1941	4.0653	4.8261	524.72	<.0001
stock	4T	1	4.8178	0.1735	4.4779	5.1578	771.39	<.0001
stock	4VW	1	2.4255	0.1778	2.0771	2.7739	186.16	<.0001
stock	4X	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		1	0.0000	0.0000	0.0000	0.0000		

Including spring and fall data for 3LNO

Unweighted

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	201	50.3894	0.2507
Scaled Deviance	201	218.9482	1.0846
Pearson Chi-Square	201	45.2901	0.2253
Scaled Pearson X2	201	195.9836	0.9750
Log Likelihood		-2504.2651	

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Conf Limits		Chi-Square	Pr > ChiSq
Intercept		1	116.9589	7.8508	101.5716	132.3462	221.94	<.0001
year		1	-0.0548	0.0039	-0.0625	-0.0470	192.74	<.0001
stock	3J3K	1	4.0410	0.1218	3.8023	4.2797	1100.89	<.0001
stock	3LNOfa	1	5.6404	0.1472	5.3520	5.9288	1469.23	<.0001
stock	3LNOsp	1	5.4449	0.1325	5.1851	5.7047	1687.51	<.0001
stock	3Ps	1	2.9948	0.1285	2.7429	3.2467	543.08	<.0001
stock	4RS	1	4.2922	0.1517	3.9949	4.5895	800.96	<.0001
stock	4T	1	4.8769	0.1148	4.6510	5.1028	1805.28	<.0001
stock	4VW	1	2.4430	0.1134	2.2208	2.6652	464.28	<.0001
stock	4X	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		1	4.3272	0.4071	3.5986	5.2033		

Weighted by area

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	201	5513350.1372	27429.6425
Scaled Deviance	201	222.1910	1.1054
Pearson Chi-Square	201	4834743.3671	24053.4496
Scaled Pearson X2	201	194.8425	0.9694
Log Likelihood		-2531.7971	

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Conf Limits		Chi-Square	Pr > ChiSq
Intercept		1	151.2034	8.6985	134.1546	168.2522	302.16	<.0001
year		1	-0.0719	0.0044	-0.0805	-0.0634	271.59	<.0001
stock	3J3K	1	3.9741	0.1586	3.6633	4.2850	627.90	<.0001
stock	3LNOfa	1	5.7535	0.1638	5.4325	6.0745	1234.30	<.0001
stock	3LNOsp	1	5.4905	0.1574	5.1819	5.7990	1216.47	<.0001
stock	3Ps	1	3.0199	0.1973	2.6332	3.4067	234.19	<.0001
stock	4RS	1	4.4311	0.1949	4.0492	4.8130	517.13	<.0001
stock	4T	1	4.8236	0.1743	4.4821	5.1652	766.17	<.0001
stock	4VW	1	2.4271	0.1788	2.0770	2.7772	184.61	<.0001
stock	4X	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		1	0.0000	0.0000	0.0000	0.0000		

Including only VPA data for 3LNO

Unweighted

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	212	53.4326	0.2520
Scaled Deviance	212	228.5274	1.0780
Pearson Chi-Square	212	48.8029	0.2302
Scaled Pearson X2	212	208.7365	0.9846
Log Likelihood		-2610.7128	

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Conf Limits		Chi-Square	Pr > ChiSq
Intercept		1	116.4544	6.7704	103.1848	129.7241	295.86	<.0001
year		1	-0.0545	0.0034	-0.0612	-0.0478	258.78	<.0001
stock	3J3K	1	4.0418	0.1223	3.8021	4.2816	1091.72	<.0001
stock	3LNOvpa	1	4.1182	0.1108	3.9015	4.3348	1387.61	<.0001
stock	3Ps	1	2.9944	0.1292	2.7411	3.2476	536.99	<.0001
stock	4RS	1	4.2900	0.1515	3.9930	4.5870	801.48	<.0001
stock	4T	1	4.8767	0.1153	4.6508	5.1026	1790.18	<.0001
stock	4VW	1	2.4432	0.1140	2.2198	2.6667	459.13	<.0001
stock	4X	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		1	4.2769	0.3929	3.5722	5.1207		

Weighted by area

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	212	6513768.6846	30725.3240
Scaled Deviance	212	233.7962	1.1028
Pearson Chi-Square	212	6272782.0923	29588.5948
Scaled Pearson X2	212	225.1465	1.0620
Log Likelihood		-2648.6010	

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Conf Limits		Chi-Square	Pr > ChiSq
Intercept		1	132.5708	6.4265	119.9751	145.1665	425.55	<.0001
year		1	-0.0626	0.0032	-0.0689	-0.0563	376.37	<.0001
stock	3J3K	1	4.0061	0.1676	3.6777	4.3346	571.85	<.0001
stock	3LNOvpa	1	4.0545	0.1596	3.7418	4.3673	645.60	<.0001
stock	3Ps	1	3.0075	0.2091	2.5977	3.4173	206.89	<.0001
stock	4RS	1	4.3682	0.2062	3.9668	4.7695	450.89	<.0001
stock	4T	1	4.8519	0.1844	4.4904	5.2133	692.25	<.0001
stock	4VW	1	2.4353	0.1893	2.0644	2.8063	165.56	<.0001
stock	4X	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		1	0.0000	0.0000	0.0000	0.0000		