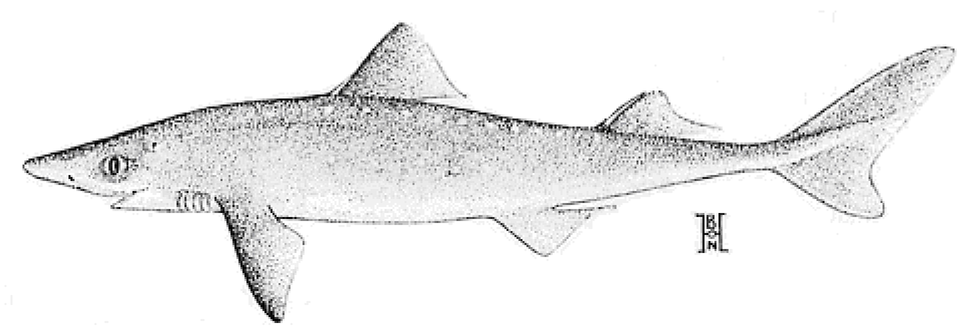
COSEWIC
Assessment and Status Report

on the

Spiny Dogfish
Squalus acanthias

Atlantic population

in Canada



SPECIAL CONCERN
2010

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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For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

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COSEWIC
Assessment Summary

Assessment Summary – April 2010

Common name
Spiny Dogfish - Atlantic population

Scientific name
Squalus acanthias

Status
Special Concern

Reason for designation
This small shark is widely distributed in temperate regions of the world's oceans and appears to be a habitat generalist. The Atlantic population occurs from Labrador to Cape Hatteras; in Canadian waters the species is most abundant in southwest Nova Scotia. An average of six pups are born every two years; the gestation period of 18-24 months is one of the longest known for any vertebrate. The species has few natural predators, but is subject to both targeted and bycatch fishing mortality. The species remains relatively abundant in Canadian waters, but low fecundity, long generation time (23 years), uncertainty regarding abundance of mature females, and demonstrated vulnerability to overfishing in adjacent U.S. waters are causes for concern.

Occurrence
Atlantic Ocean

Status history
Designated Special Concern in April 2010.

COSEWIC
Executive Summary

Spiny Dogfish
Squalus acanthias

Atlantic population

Species information

Spiny Dogfish (*Squalus acanthias*) is an easily identified small shark, with spines in front of both dorsal fins. The colouration is typically grey-brown with irregular white spots on sides and back. In the northeast Atlantic, the species is commonly referred to as spurdog. In French it is known as *aiguillat commun*. This report treats the Atlantic Ocean population as a Designatable Unit (DU). The Pacific DU will be dealt with in a separate report.

Distribution

Spiny Dogfish occurs world-wide on the continental shelf, from the intertidal to the shelf slope, in temperate and boreal waters. In the northwest Atlantic, abundance is highest between Nova Scotia and Cape Hatteras (North Carolina). The Atlantic Canada population is thought to consist of both resident and migrating components.

Habitat

The wide geographic and depth distribution indicates that the species can survive in a variety of habitats. Spiny Dogfish have been observed at depths ranging from surface waters to 730 m, and from intertidal areas to well offshore. They are usually located where water temperatures are 5-15°C and can tolerate a wide range of salinities, including estuarine waters. Research has shown some size and sex segregation, which may reflect habitat preferences; as well, there is a seasonal shift in distribution thought to be driven by temperature preference. Habitat, in a structural sense, is not believed to be a direct factor driving population trends. There is no habitat protection specifically to protect Spiny Dogfish.

Biology

Spiny Dogfish mate during the fall and early winter and have internal fertilization. After a gestation of 18-24 months, an average of six pups are born live in the winter. Growth is slow and varies between males and females, with females maturing later and growing larger than the males. In the Atlantic, 50% of the females are considered mature by age 16, whereas in the Pacific, 50% female maturity does not occur until age 35. Natural mortality is higher in the Atlantic compared to the Pacific. The generation time has been estimated at 23 years for the Atlantic.

Spiny Dogfish do not have many predators. Predation on Spiny Dogfish in the Atlantic has been identified in other sharks, Barndoor Skate, Lancetfish, Bluefin Tuna, Tilefish and Goosefish. Fishing mortality is the largest known cause of mortality for adult Spiny Dogfish. Dogfish are apex opportunistic predators preying upon a wide variety of fish and invertebrate species that change by locality, depth, and season.

In Atlantic Canada and eastern U.S. waters there are several more or less well-defined “groups” of Spiny Dogfish (i.e., southern Gulf of St Lawrence, around Newfoundland, the eastern and central Scotian Shelf, Bay of Fundy and S.W. Nova Scotia, Massachusetts and North Carolina). The groups remain largely separate, and engage in seasonal onshore-offshore migrations. There is occasional mixing between groups, particularly those in the Gulf of Maine. At least one group, the southern Gulf of St. Lawrence, is almost certainly a “sink” population. That is, it was colonized abruptly in 1985, and the same group has resided there ever since with no evidence of outside immigration or recruitment.

Population sizes and trends

Under the assumption that Spiny Dogfish in Atlantic Canada waters constitute a largely separate Canadian population concentrated around the Bay of Fundy and southern Scotian Shelf, the combined results of various surveys suggest that the population as a whole has not declined, despite abundance being very low in one area, the Georges Bank, relative to historical levels. Understanding the overall abundance trend in Canadian waters is hampered by the absence of any long running spring survey at the centre of concentration of the species off Canada, in the southern portion of the Scotian Shelf where most of the dogfish are concentrated.

Limiting factors and threats

Globally and in Canada, overfishing is considered the only proximate threat to Spiny Dogfish at a population level. Life history characteristics of long gestation, slow growth rate, late age of maturity, low intrinsic rate of increase, low fecundity, long life span, and sex and size segregated aggregations all contribute towards the Spiny Dogfish’s vulnerability to fishing. Compounding the problem is the preference of some commercial fisheries to target the larger reproductively mature females, and high, often incompletely reported discard rates.

Special significance of the species

The Spiny Dogfish is the world's most abundant shark species and consequently plays an important role in both natural and human systems. This species has been killed for more varied purposes than any other fish in Canada. Its body oils have been used for industrial lubrications, lighting, and vitamin ;, its flesh for fertilizer, meat, fishmeal; its fins enter the international shark fin trade; and finally they have been the subject of directed eradication programs due to their "nuisance" factor in commercial fisheries.

Existing protection

The IUCN has assessed the Spiny Dogfish as *"vulnerable"* on a global basis. Populations in the northwest and northeast Atlantic are currently assessed as *vulnerable* and *endangered* respectively.

Canadian populations are managed by setting total allowable catches and associated quotas. On the Atlantic coast, the current quotas are 2500 t for fixed gear, and individual vessel quotas of 10 t and 25 t for trawl vessels >65 feet and <65 respectively. Finning, the process of removing and selling only the fins is prohibited in Canada.

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
(2010)

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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Squalus acanthias

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SPECIES INFORMATION

Name and classification

Spiny Dogfish (*Squalus acanthias* Linnaeus 1758) belongs to the order Squaliformes and the family Squalidae. There are 17 genera in the family Squalidae and Spiny Dogfish (commonly referred to as spurdog in the northeast Atlantic) comprises one of nine species in the genus *Squalus* (Compagno 1984). In French this species is known as *aiguillat commun*.

Morphological description

Spiny Dogfish is an easily identified small shark, with spines in front of both dorsal fins (Figure 1). The first dorsal spine originates posterior to the pectoral rear tips. The pectoral fins have curved rear margins and there is no anal fin. The body is slender with the greatest depth found just in front of the first dorsal fin. The mouth is small and straight directed forward and down. The teeth are moderate in size with single cusps directed outward. The eyes are oval and moderate in size with a spiracle close behind and slightly above the eye. The gills are low on the body and are located ahead of the pectoral fin (Hart 1973). Colouration is grey-brown on the upper body with irregular white spots present on their sides and back which may disappear with age. The ventral surface is whitish.

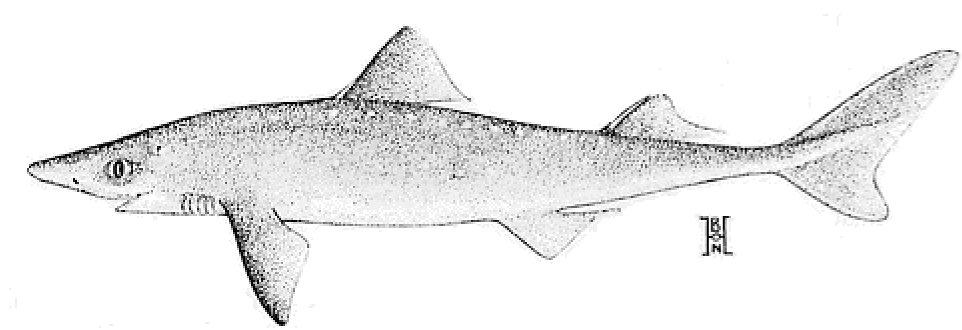

Figure 1. Spiny Dogfish (*Squalus acanthias*). Source: Hart 1973.

Genetic description and population structure

The genetic structure of Spiny Dogfish within ocean basins of the Atlantic and Pacific or between ocean basins has only recently been investigated. Results indicate two major global clades; one comprising the Atlantic and South Pacific, the other in the North Pacific (Hauser *et al*. 2007). These genetic differences correspond well to the different life history characteristics observed between the two ocean basins (see Biology section).

A single genetic analysis of Spiny Dogfish population structuring in Canada's Atlantic waters did not find evidence of population structuring based on the loci used F_{st} =0.00845. DNA samples (n=307) were taken from dried muscle on the spines of specimens collected around Nova Scotia and Newfoundland. The samples were collected from six locations in three different years. The analysis involved seven microsatellite loci developed for dogfish (McCauley *et al*. 2004).

Summary statistics for all loci at each sampling location indicate that deviations from Hardy-Weinberg expectations were significant for 9 of the 42 sample location and locus combinations, in every case reflecting a deficit in heterozygotes, and the overall probability of the combined sample set deviating from Hardy-Weinberg expectations was highly significant with all loci included (see Table 1 *in* Campana *et al*. 2007). As the number of loci and their level of polymorphism were limited, analyses could not be run with and without loci suspected of having null alleles. The pairwise F_{ST} values (measured as Weir and Cockerham's Θ) were all very small (see Table 2 in Campana *et al*. 2007). Of these values, only one was significant, the Sambro and Upper Bay of Fundy samples (P=0.01646±0.0019). This is the only significant difference seen in this sample set. It is possible that a larger sample size and a larger number of polymorphic loci, or sampling of mating aggregations, would have detected population structuring.

Table 1. Life history parameters of Spiny Dogfish in the North Atlantic and North Pacific.

Parameter	Atlantic	Source
Longevity (yrs)	35-40	Nammack *et al*. 1985
50% mat. females (yrs)	16	Campana *et al*. 2007
50% maturity males (yrs)	10	"
50% mat. females (cm)	82	"
50% maturity males (cm)	63.6	"
L max-female (cm)	105.7	"
K	0.106	"
Rate of increase/yr (%)	4.7;3.4	Heesen 2003; Smith *et al*. 1998
Gestation period (months)	18-24	Compagno 1984
Natural mortality (adults)	0.15	Campana *et al*. 2007
Generation time 1	25-40	Germany CITES prop. 2003
Generation time 2	23	This report

Table 2. Research survey data used to assess trends in Spiny Dogfish abundance in Atlantic Canada (RV refers to demersal research vessel survey).

Survey	Years Covered	Location	Trend	Suitability for Status Report
Scotian Shelf (Summer) Trawl	1970-2007	NAFO (4VWX)	Increasing	Good (near-shore not sampled where most mature females are located)
Georges Bank (February) Trawl	1986-2006	NAFO (5Ze)	Decline, continued	Very good
Spring RV Trawl	1979-1984	NAFO (4VWX)	Increase, variable	Poor, short early series but the only spring 4X data
Spring (March) RV Cod Trawl	1986-2007	NAFO (4VW)	Decline, continued	Good (recent years have less sets)
Gulf of St. Lawrence (September) Trawl	1971-2006	NAFO (4T)	Highly variable	Very good
Newfoundland (spring) RV Trawl	1972-2005	NAFO (3LNOP)	Highly variable	Very good
Sentinel Longline (Sept.-Oct.)	1995-2005	NAFO (4VsW)	Decline	Good
4Vn Sentinel Longline	1994-2001*	NAFO (4Vn)	Decline	Poor, short series, missing years, few sets, dogfish not common in 4Vn.
Halibut Longline Survey	1998-2006	NAFO (4VWX)	Variable, Increasing	Good but short time series.

* No survey in 1996-97

An earlier single electrophoretic study of protein loci by Annand and Beanlands (1986) found no differences between samples from the Gulf of Maine and the central Scotian Shelf.

Tagging studies in both the Atlantic and the Pacific oceans indicate that Spiny Dogfish are capable of movements at the scale of ocean basins as well as mixing between regional populations (Templeman 1984; McFarlane and King 2003). However, in the North Atlantic, the genetic exchange across the Atlantic basin (northwest and northeast) is considered to be very limited, based on historical tagging studies (Hammond and Ellis 2005).

An analysis of all available Spiny Dogfish tagging data in the northwest Atlantic supports the view that there are several non-independent dogfish stock components there (Campana *et al*. 2007). Spiny Dogfish movements between Canadian and American waters are not the predominant pattern, accounting for only 10-20% of tag recaptures. Large-scale annual migrations occur along the east coast of the U.S., but are primarily limited to the area between North Carolina and the Gulf of Maine. Cross-border mixing does occur, but on average annually for only 10% of the population (Campana *et al*. 2007). Therefore, there appear to be both migratory and resident components, as Templeman (1976) hypothesized for Newfoundland dogfish populations.

Campana *et al*. (2007) suggest that Spiny Dogfish in Atlantic Canada share characteristics of a metapopulation. There are several more or less well-defined 'groups' of Spiny Dogfish (i.e., southern Gulf of St Lawrence, around Newfoundland, the eastern and central Scotian Shelf, Bay of Fundy and SW Nova Scotia, Massachusetts and North Carolina). The groups remain largely separate, and engage in seasonal onshore-offshore migrations. Some groups undertake seasonal north-south migrations, particularly those in the south. There is occasional mixing between groups, particularly those in the Gulf of Maine. At least one group, the southern Gulf of St Lawrence, is almost certainly a "sink" population. That is, it was colonized abruptly in 1985, and the same group has resided there ever since, growing larger in average size but smaller in numbers, with no evidence of outside immigration or recruitment. Similarly, the Eastern Shelf dogfish component appears to have remained resident for many years in NAFO 4VW, then abruptly disappeared in 1992. At around the same time, the Georges Bank component disappeared.

Designatable units

The Atlantic and Pacific populations of Spiny Dogfish occupy two distinct biogeographic zones; the Atlantic and Pacific Oceans. They prefer temperate and boreal waters which would limit migration across the equator and between ocean basins via the Arctic or around South America. A recent study revealed significant divergence (0.7% based on mitochondrial DNA sequencing) between the North Pacific and Atlantic populations, implying that they are genetically isolated from each other (Hauser *et al*. 2007), which corresponds with marked life history differences between the two ocean basins.

Although tagging studies and interpretation of some surveys suggest further population structuring within Canadian waters in both basins, more detailed studies are required to confirm this. Therefore, for the purposes of this report, Spiny Dogfish in the Atlantic waters will be assessed as a separate designatable unit.

DISTRIBUTION

Global range

Spiny Dogfish occur world-wide (Figure 2). They are primarily found in temperate and boreal waters on the continental shelf, from the intertidal to the shelf slope, and within a temperature range of 5-15°C (Figure 3; Compagno 1984, Kulka 2006). The species is most common in coastal waters in 10-100 m although they are found as deep as 730 m. The main populations are found in the northwest and northeast Atlantic (including Mediterranean and Black seas), northeast and northwest Pacific (including the Sea of Japan), the South Atlantic and southeast Pacific off South America, and New Zealand, with smaller populations off South Africa and southern Australia (Germany CITES proposal 2003).

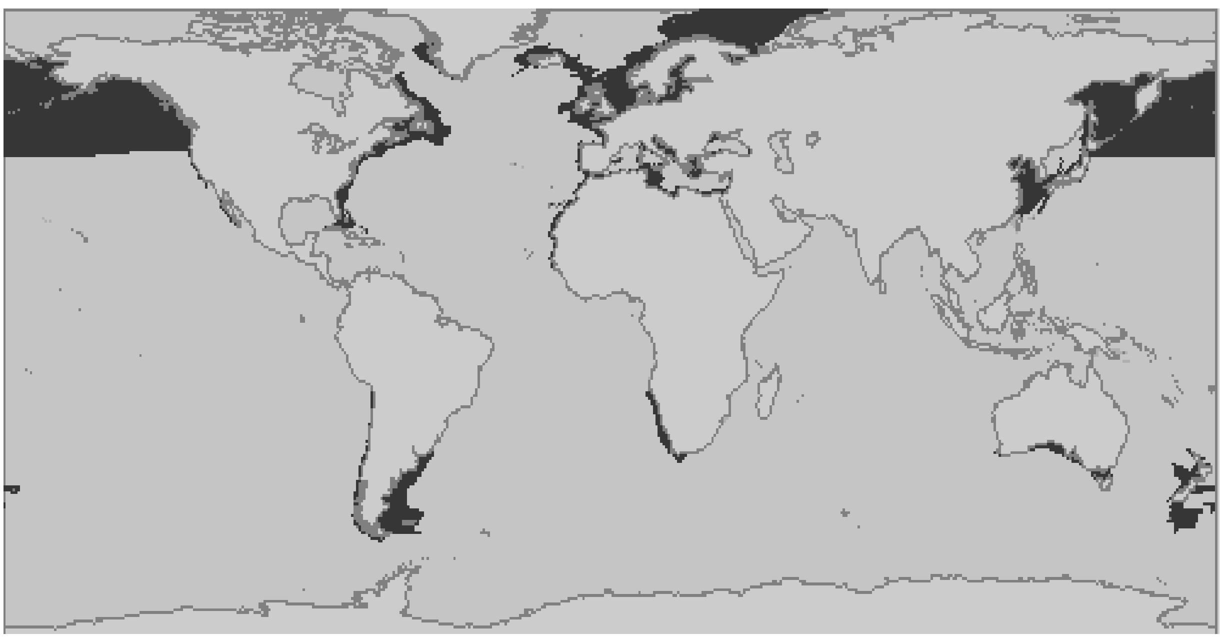

Figure 2. Global distribution of Spiny Dogfish (dark grey). Source: FAO 2004.

Canadian range

Atlantic

Based on various groundfish research surveys, Spiny Dogfish are most abundant between Nova Scotia and Cape Hatteras (North Carolina) (Figure 3), with some of the population in the Gulf of St. Lawrence and the western Grand Banks, and few records north of the Grand Banks (Templeman (1954, 1984). Fishery observers have also irregularly recorded dogfish north of the Grand Banks. Canadian landings and observer records are primarily from the Scotian Shelf region (Figure 4) where Spiny Dogfish are most highly concentrated in Canadian waters. There is no evidence of either expansions or contractions at the centre of their range on the Scotian Shelf/Bay of Fundy, although they have become more concentrated (constant abundance, smaller area occupied) at the northern extent of their distribution on the western extent of the Grand Banks to the north (Kulka 2006). The extent of occurrence and area of occupancy is estimated to be 425 000 km^2, which is the area of the Gulf of St. Lawrence, southern Newfoundland, Scotian Shelf, and the Gulf of Maine.

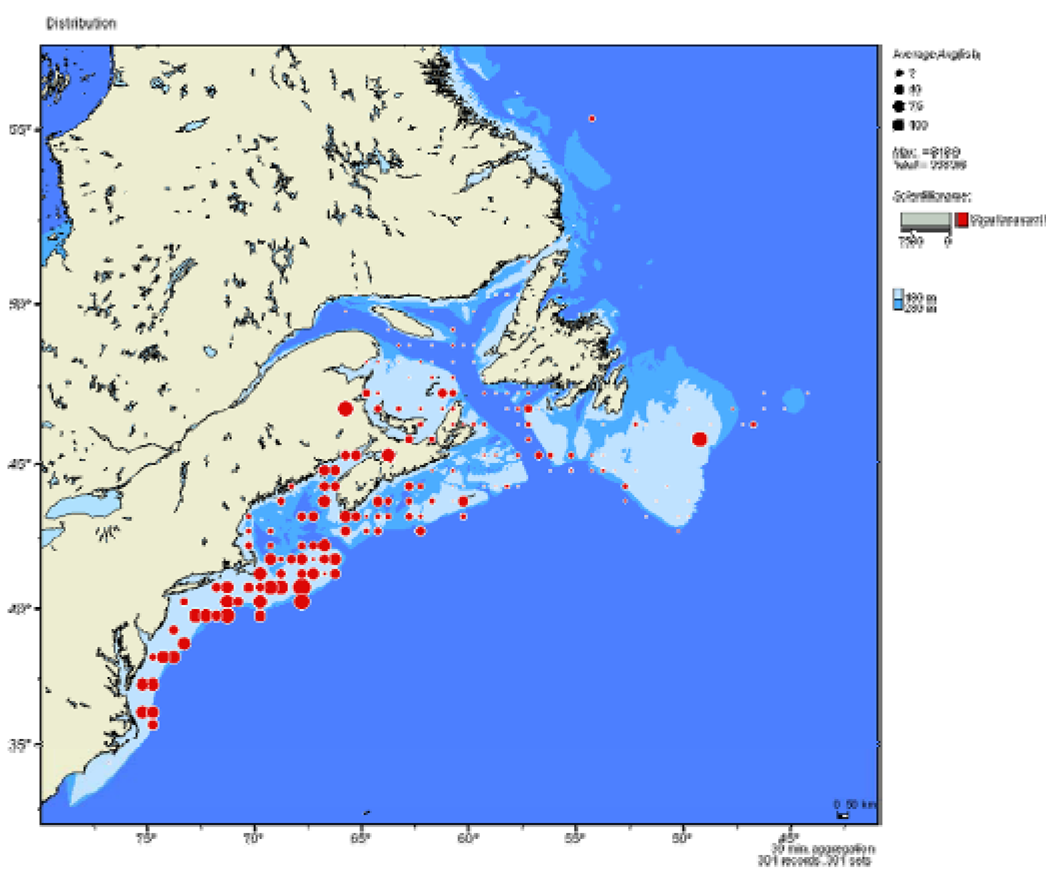

Figure 3. Distribution of Spiny Dogfish in the northwest Atlantic based on Canadian and American research surveys from 1975-1994. Source: ECNASAP - East Coast of North America Strategic Assessment Project (all the years in that database).

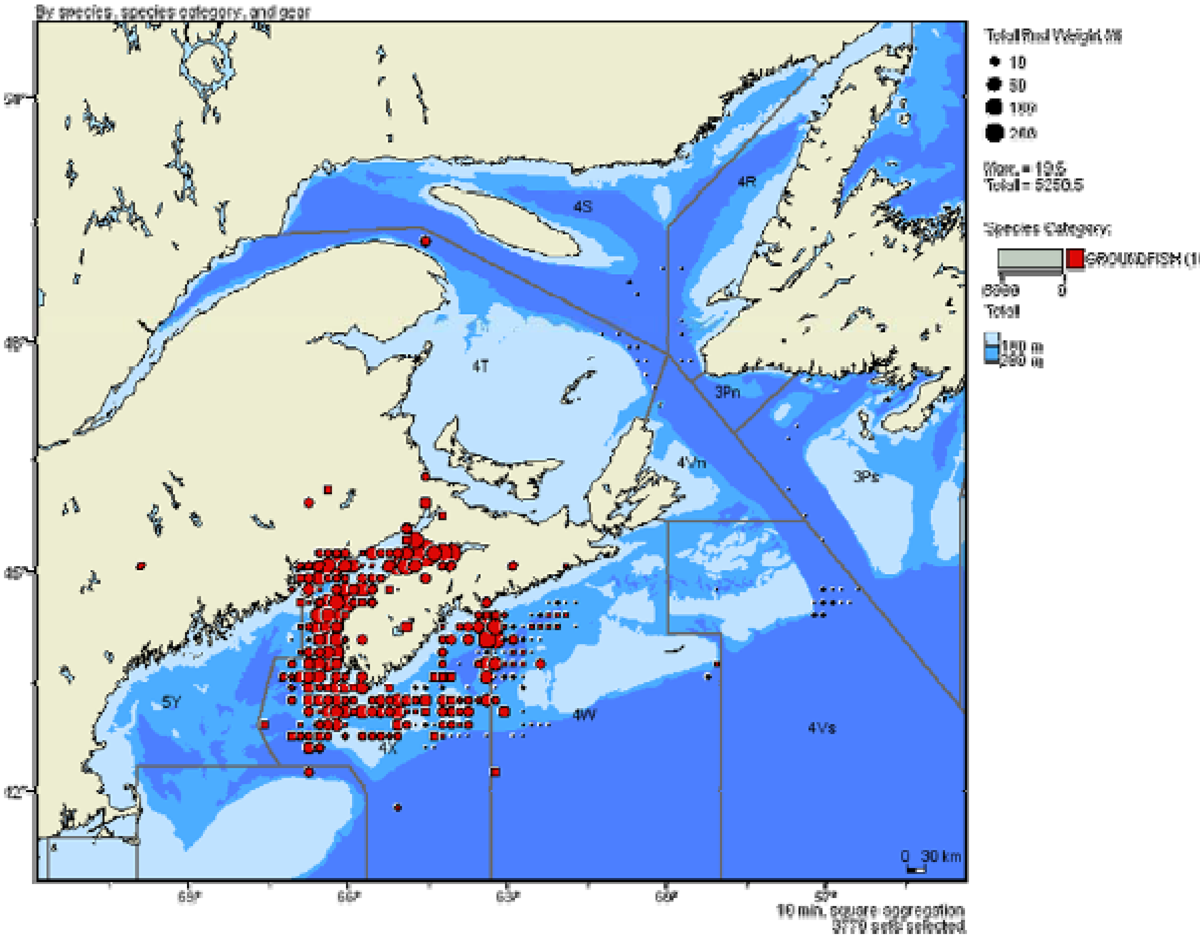

Figure 4. Distribution of Spiny Dogfish commercial landings in the Maritimes Region (Fisheries and Oceans, Canada). Source: MARFISH database. Source: Fisheries and Oceans PacHarvHL and PacHarvTrawl databases.

HABITAT

Habitat requirements

The wide geographic and depth distribution indicates that the species can survive in a variety of habitats. Spiny Dogfish have been observed at depths ranging from surface waters to depths of 730 m, and from intertidal areas to well offshore, and can also tolerate a wide range of salinities including estuarine waters (Compagno 1984).

Surveys from the northwest Atlantic indicate Spiny Dogfish are associated with 0-15ºC bottom water temperatures throughout the year, with a preference for 6-12ºC (Campana *et al*. 2007, Kulka 2006). They are epibenthic, usually found swimming in large schools just above the seabed, but also move through the water column on the continental shelf in waters between 50-200 m and show no strong association with any particular type of substrate (McMillan and Morse 1999; Campana *et al*. 2007). At the northern limit of their range dogfish in Newfoundland waters (NAFO 3LNOP) prefer water temperatures of >5ºC and water depths of 100-250 m; this restricts their distribution in this area mainly to the western edge of the St. Pierre and Grand Banks where the water is sufficiently warm (Kulka 2006). Research has shown some size and sex segregation, which may reflect habitat preferences (Ketchen 1986; McMillan and Morse 1999). There is a seasonal shift in distribution thought to be driven by temperature preference. Generally speaking, both juveniles and adults prefer deeper warmer waters during the winter. Mature females and large males aggregate during winter/spring in deep warm waters off the edge of the continental shelf (DFO 2007a, Campana *et al*. 2008); mating and pupping may occur here. During the summer and fall, the preference is for warmer, shallower shelf waters.

Habitat trends

Numerous threats have been identified as potentially negatively affecting Spiny Dogfish habitat, including coastal development, pollution, non-point source pollution, and mobile fishing gear that comes into contact with the bottom (ASMFC 2002). It is difficult to quantify the impact these habitat threats might have at the population level. The general biology of Spiny Dogfish (next section) suggests that habitat, in a structural sense, is not believed to be a direct factor driving population trends. However, in the Canadian Atlantic, since mature females move inshore to warmer waters in summer, it is at this time that they are perhaps more susceptible to target and bycatch fisheries (Campana *et al*. 2008) as well as potential coastal impacts.

Habitat protection/ownership

All waters frequented by Spiny Dogfish in Canada are under federal jurisdiction. There are no protective habitat measures specifically created to protect Spiny Dogfish.

BIOLOGY

Life cycle and reproduction

Spiny Dogfish mate during the late fall and early winter and have internal fertilization (Ketchen 1986). The embryos develop for 18-24 months before parturition of live young in the winter. This gestation period is the longest known for any vertebrate. Females typically give birth once every two years. In Atlantic Canada, mature females were found to carry 1-14 embryos with a mode of five (Campana *et al*. 2007, 2009). This is consistent with an earlier study indicating a range from 2-15 pups (average 6) (Soldat 1979). Fecundity increases with length, such that a 90-cm FL female had on average four times as many free embryos as a female 60-cm FL (Campana *et al*. 2007). At birth during late winter pups are typically 22-25 cm (Campana *et al*. 2007, 2009). Growth is slow and sexually dimorphic with 50% maturity in females in the northwest Atlantic being reached by a size of 82 cm (total length) and an age of 16 years and males at 63.6 cm TL and 10 years (Campana *et al*. 2007). Reproductive capacity is very low and contributes to one of the lowest population growth rates for any shark species.

Natural mortality estimates are 0.15 on the Atlantic coast (Smith *et al*. 1998; Campana *et al*. 2007). Reported generation time varies from 25-42 years depending on age of maturities and natural mortality rates by region (Germany CITES Proposal 2003; Courtney *et al*. 2004; Campana *et al*. 2007). Using an age of 50% maturity of 16 and natural mortality rates of 0.15 results in generation times of 23 years for the Atlantic (e.g., generation time=16+1/0.15=22.7).

Herbivory/predation

Spiny Dogfish give birth to large (22-25 cm) live young. Predation on Spiny Dogfish in the Atlantic has been identified in other sharks (Mackerel, Great White, Tiger, Blue, Porbeagle), Barndoor Skate, Lancetfish, Swordfish, Bluefin Tuna, Tilefish, Goosefish and seals (Scott and Scott 1988, Jensen 1965).

Physiology

As detailed earlier (*habitat* section), Spiny Dogfish are tolerant to a wide range of physical conditions including temperature, depth and salinity. This tolerance allows for a widespread distribution which is beneficial for survival. Spiny dogfish is not considered a “warm-blooded” shark, therefore would have a relatively low metabolic rate.

There are at least 524 papers published on aspects of dogfish physiology (see http://www.ncbi.nlm.nih.gov/pubmed?term=Physiology%20of%20spiny%20dogfish&itool=QuerySuggestion), likely because the species is widespread, common and a conveniently small representative of sharks.

Dispersal/migration

Additional information on migratory patterns and population structure can be found in the section *Genetic description and population structure*.

Campana *et al*. (2007) summarized both tagging and demersal research survey data to generalize the migration pattern of Spiny Dogfish. Although some north-south movement has been observed through tagging studies, the dominant pattern appears to be seasonal migration between inshore (summer-fall) and offshore (winter-spring) areas. This conclusion is based on demersal research survey biomass estimates in both Canadian and U.S. waters that indicate a higher stratified abundance in early spring surveys. Prior to the Campana *et al*. (2007) study, the greater abundance in the U.S. spring demersal research survey compared to U.S. fall RV survey was interpreted as evidence of additional overwintering fish migrating from Canadian waters. The exact cause of increased abundance in early spring surveys is unclear but may be related to catchability (related to swimming speeds, distribution in the water column), or a more likely explanation is that in summer, a significant proportion of the population utilizes nearshore waters not surveyed by the survey gear (Campana *et al*. 2007).

As well, demersal research surveys consistently catch significantly more mature females in the spring compared to summer; summer surveys typically have <5% mature females. In contrast, the summer commercial fisheries that typically operate in inshore shallow waters not accessible to research surveys catch a high proportion of mature females (~45%) (Campana *et al*. 2007).

Overall, it appears that Spiny Dogfish reside in Canadian waters year round, concentrated primarily on the southwest Scotian Shelf, outer Bay of Fundy and Georges Bank but are less accessible to research surveys during the summer due to utilization of shallow inshore habitats not accessible to research surveys. The overall migration pattern is between inshore (summer/fall) and offshore (winter/spring) rather than north-south.

Interspecific interactions

In the northwest Atlantic, Spiny Dogfish have been found to preferentially eat fish such as herrings (several species), Atlantic Mackerel, American Sand Lance, and codfishes, including species such as Atlantic Cod, Haddock, Silver Hake, Red Hake, White Hake and Spotted Hake (Bowman *et al*. 1984). Other important contributors to the diet of Spiny Dogfish include invertebrates such as squid, ctenophores, crustaceans (principally decapod shrimp and crabs) and bivalves (principally scallop viscera). Di*et al*so changes by season and year and appears to reflect the abundance of whatever prey species is most available.

Overall, Spiny Dogfish are considered to be apex opportunistic predators with a wide prey base (Compagno 1984). There are no particular prey items considered to limit the abundance of Spiny Dogfish populations.

Adaptability

Globally, the largest threat to this species is from commercial fisheries, both directed and bycatch (Germany CITES Proposal 2003). Spiny Dogfish have few predators, relatively high fecundity (for a shark species), and wide prey base and distribution, which may provide some resilience to both natural variations and human caused mortality. Spiny Dogfish may be able to withstand changes in short-term environmental conditions (i.e., shifting prey species, depth, temperature), but adaptability to long term changes (e.g., climate) is unknown.

FISHERIES AND MANAGEMENT

Commercial landings and fishery

Commercial catch time series are likely biased as indicators of abundance because they do not cover the entire distribution of the fish, areas fished and vessels in the fishery vary from year to year, and capture vessels, gear and methods vary. Thus, they are not used for understanding abundance trends *per se*, but these data do provide the context necessary for understanding the research survey trends in the subsequent sections.

Over most of the last 40 years, Canadian Spiny Dogfish landings have been minimal and mostly in Div. 4X (Figure 4); however, since 1997 there has been a general increase in landings (Figure 5). Since 2001, Canadian landings have increased while at the same time, just to the south, the U.S. landings have decreased (due to harvest restrictions) to the point where Canadian landings now exceed American landings. Canadian landings are primarily taken from (NAFO) North Atlantic Fisheries Organization Division 4X (southwestern Scotian Shelf and Bay of Fundy) from June through to September since 2000 (Figure 5). Canadian landings, primarily taken by directed handline and longline, have averaged about 2500 mt annually since 2000 (Campana *et al*. 2007, Wallace *et al*. 2009).

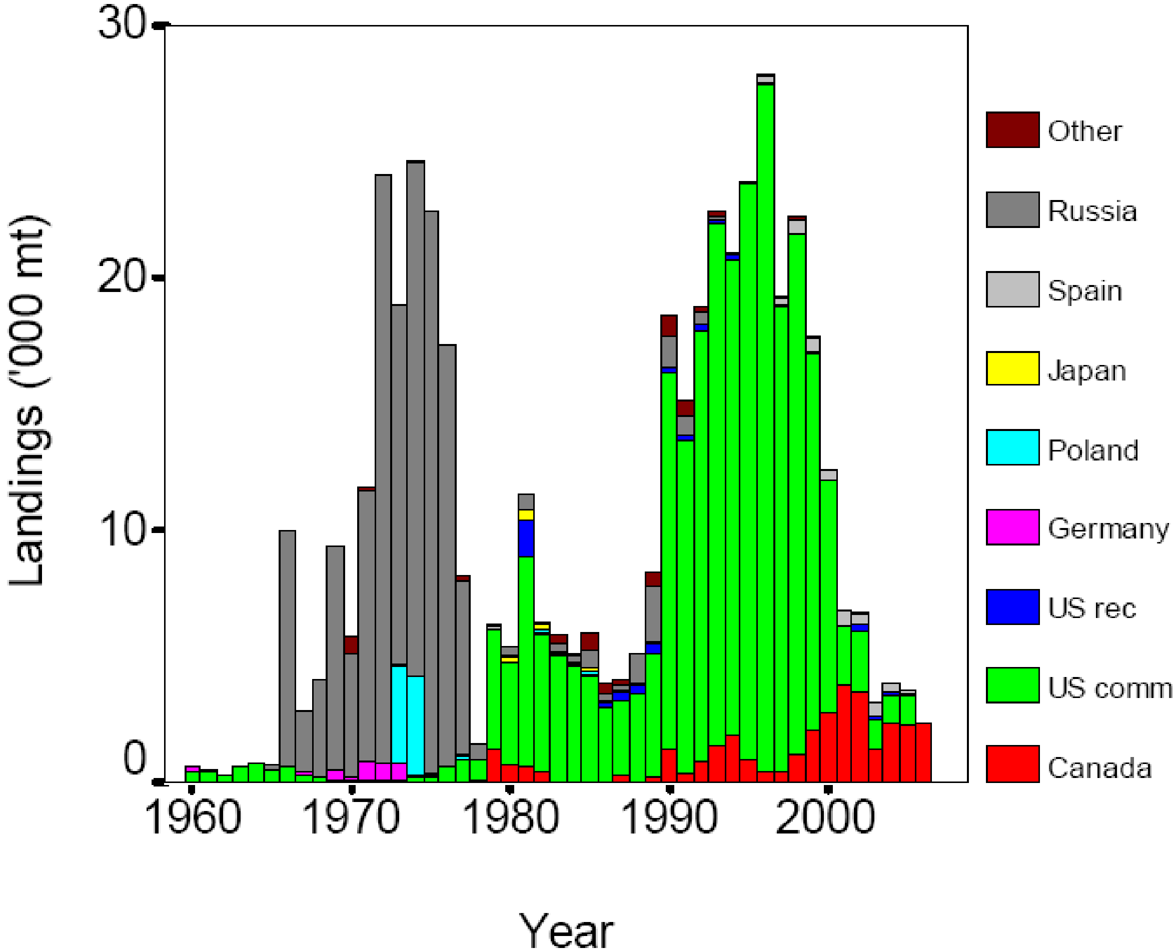

Figure 5. Total reported Spiny Dogfish landings (t) by country in the northwest Atlantic (NAFO Areas 2-6, encompassing the Canadian Atlantic) from 1960-2006. Figure: Campana *et al*. 2007.

Discarding of Spiny Dogfish in the Atlantic has long been thought to be substantial. Until recently there had been no attempt to quantify the level of discarding and subsequent mortality. Campana *et al*. (2007) used observer data from all fleets that capture Spiny Dogfish to estimate the full extent of Spiny Dogfish discarding. Mortality rates were applied to the total discards to determine the overall discard mortality. On average, the amount discarded averaged 850 t/year since 1986, and since 2000 has contributed to about 24% of the overall fishing mortality.

Quotas for Spiny Dogfish have now been put in place, but are not based on scientific advice. Since 2004, the quota for fixed gears has been set at 2500 mt and vessels with mobile gear (i.e., trawl) are restricted to 25 t per year per vessel <65 feet and 10 t per year per vessel >65 feet. There are currently no restrictions on discarding and therefore the quota only accounts for landings.

Age and size composition of the commercial catch

Recent analysis of the length composition of Spiny Dogfish in the commercial catch between 2002 and 2006 in NAFO Div. 4X indicated that females ranged in length from 46-112 cm (median size 81 cm) total length (TL), while males ranged from 36-94 cm (median size 74 cm) (Figure 6) (Campana *et al*. 2007). Thus, most of the catch consisted of sub-adults and adults. By number, immature and mature females comprised, respectively, 40% and 26% of the catch. In the adjacent U.S. fishery, median body size of females in the catch was 86 cm TL and females made up 91% of the catch numbers in 2002-2005 (NFSC 2006). The mean age of Spiny Dogfish in the Canadian commercial catch was a mean age of 16 yr for males (n=450) and 18 yr for females (n=1085) (Campana *et al*. 2007).

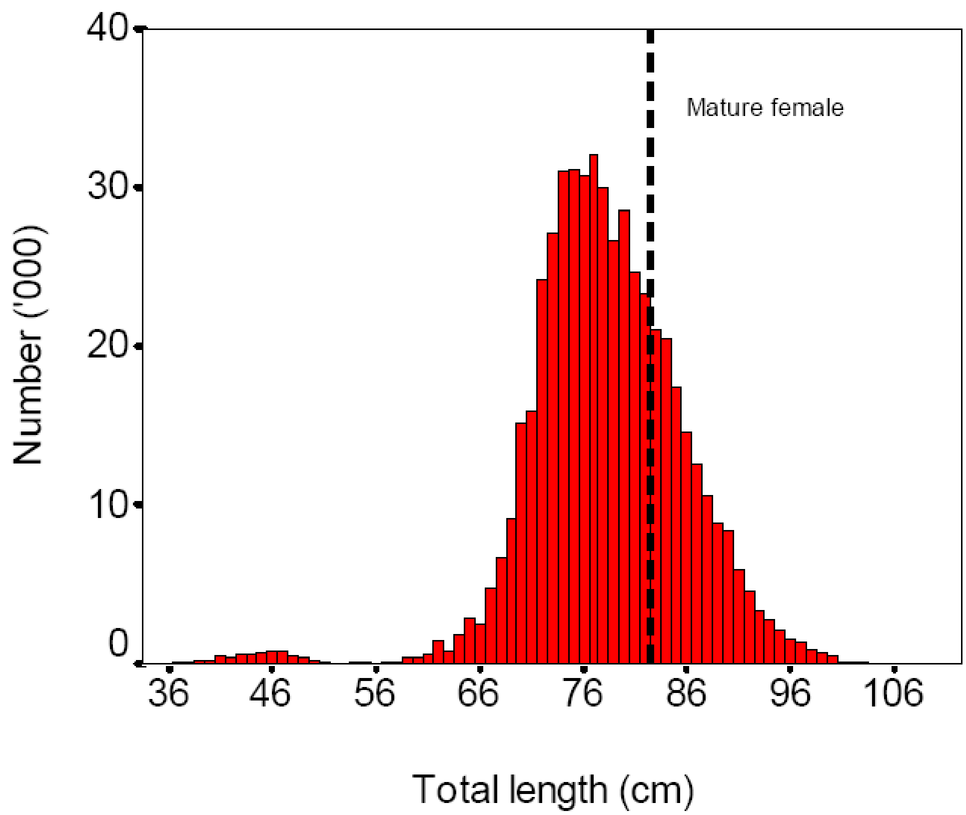

Figure 6. Size composition of the commercial catch in NAFO Div. 4X between 2002 and 2006, aggregated by sex. The dashed line indicates the size corresponding to female 50% maturity; almost all of the catch (26%) exceeding that size is female. Source: Campana *et al*. 2007.

There is no indication of high-grading at sea for larger individuals. This was tested by Campana *et al*. (2007) who compared the size composition of the landings to at-sea observer data.

The current quotas in the Atlantic are thought to be consistent with the low natural mortality rate of the species, although primarily based simply on historical catch levels because the population productivity and overall abundance is not well determined.

United States

In the early 1990s, the combination of high abundance of Spiny Dogfish (Fogarty and Murawski 1998) and good markets in Europe resulted in strong fishing pressure. There is little question that the high U.S. landings that followed coupled with the life history of Spiny Dogfish negatively affected the population. During the 15-year period spanning 1988-2002 the U.S. removed ~230,000 t or 75,000,000 mature females from U.S. Atlantic waters (Figure 5). During this period, 93% of the landings were female and in six of these years the ratio was over 99% female (NEFSC 2003). Accordingly, the mean size of females landed by the U.S. commercial fishery also decreased by 15 cm during this period, which is consistent with the research survey trends (NEFSC 2003).

In 1998 the National Marine Fisheries Service declared U.S. Spiny Dogfish *overfished*. Since that time, a number of management measures and rebuilding targets have been introduced. Landings in 2003/04 were reduced to 1300 t resulting from a fisheries mortality goal of $F_{rebuild}$=0.03 ($F_{rebuild}$ - for stocks currently under rebuilding programs and for which the fishing mortality rate required to rebuild the stock - is less than F_{msy}). The most recent full assessment (NEFSC 2006) concludes that spawning biomass (106,000 t) is above the “overfished” threshold. A supplementary assessment utilizing two additional years of survey data further supports the conclusion of a rebuilding trend of the population with current spawning stock biomass estimated at 194, 616 mt (Rago and Sosebee 2008). In October 2008, based on the determination of the stock’s rebuilt status, the U.S. increased the 2009/2010 quota to 5,430 mt (12 million lbs.).

POPULATION SIZES AND TRENDS

Search effort

The population size and trends in the northwest Atlantic are estimated from: (1) Canadian and U.S. commercial catch and landings data; (2) research survey trends on the Scotian Shelf, Georges Bank, the Gulf of St. Lawrence and the southern Grand Banks; (3) biological data (i.e., length-frequencies) from Department of Fisheries and Oceans (DFO) research surveys and commercial fisheries; and (4) U.S. National Marine Fisheries Service (NMFS) research survey data.

Abundance and trends

Canadian research surveys

Trends in Spiny Dogfish abundance in Atlantic Canadian waters are derived from several independent demersal research trawl and longline surveys (Table 2, Wallace *et al*. 2009). The surveys consist of random stratified sampling (randomly distributed sets within depth strata). However, there are some issues associated with the surveys in terms of sampling Spiny Dogfish. This species tends to form patchily distributed dense aggregations, which causes significant variance between sets ranging from zero (in between aggregations) to a few cases with several thousand animals per set when the gear encounters a dense aggregation. When and where the gear will encounter a dense aggregation is unknown. Because of this, intra and inter-annual variability can be very large. In addition to the behavioural aspects, environmental factors can influence a species distribution under varying temporal scales. Annual total values presented in this report represent the annual mean of all sets multiplied by the number of *trawlable units* to give an expanded swept area biomass estimate. Trawl surveys assume that all Spiny Dogfish within the path of the research trawl are captured and that there are no Spiny Dogfish outside of the expanded area. Both of these assumptions are not true. Dogfish may be found above the gear in the water column or outside of the surveyed area, such as in coastal locations. As a result, survey values represent a minimum estimate of biomass or abundance. Longline surveys provide an index of abundance but not biomass.

Scotian shelf summer trawl survey 1970-2007 (4VWX)

The Scotian Shelf trawl survey is undertaken annually and typically consists of 220 stratified random sets covering the shelf area from northern Nova Scotia around the eastern shelf to the southern tip of Nova Scotia and into the Bay of Fundy (Figure 7) at the centre of distribution of Spiny Dogfish in Canadian waters. The same area has been consistently surveyed using the same gear over the life of the survey.

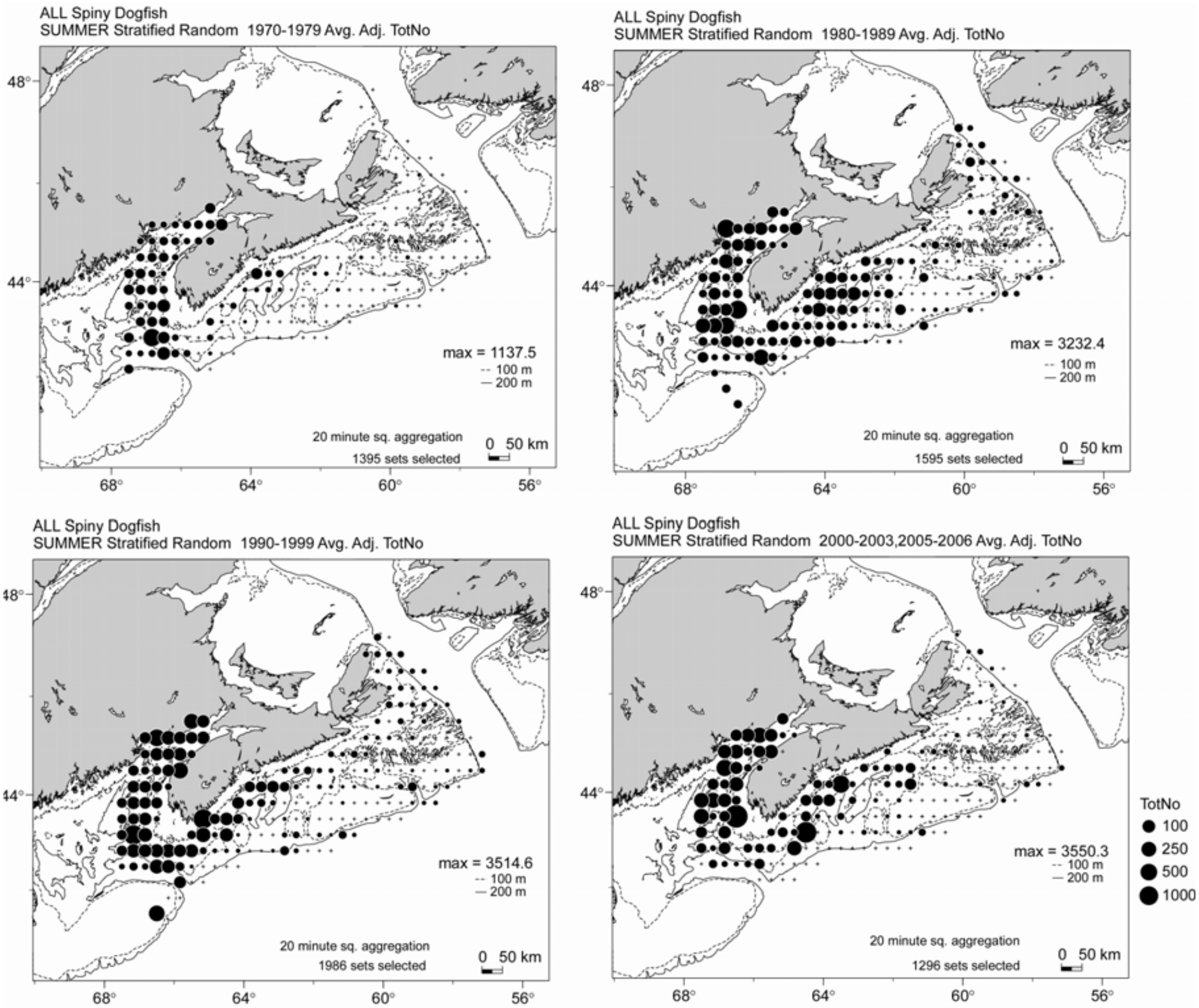

Figure 7. Scotian Shelf Div. 4VWX (summer) stratified random groundfish survey 1970-2006; survey catches (kg/tow) aggregated in 20 min. squares & 10-year blocks.

Ninety-five percent of the survey biomass occurred in 4X around southwestern Nova Scotia. Dogfish abundance appears greatest in nearshore areas, and the highest densities found in the southern part of the survey, particularly the Bay of Fundy. Over the 37-year period the abundance estimate has ranged from a low of 0.8 million animals in 1978 to a high of 295 million in 2002, with considerable interannual variability. Since 1985, the survey abundance index for Spiny Dogfish (all size classes) has on average been considerably higher than what was observed between 1970 and 1984 (Figure 8a). Estimated average abundance of 226 000 t over the last five years is greater than the long-term average of 131 000 t (Figure 8a). The average number of individuals in this area between 2003 and 2007 is estimated to be about 150 million although this is a minimum estimate of abundance for the reasons elaborated above.

Five percent of the biomass was taken in the northeast portion of the shelf (Div. 4VW) portion of the survey area. Thus, this was a relatively minor portion of the biomass in 4VWX. There the biomass index was close to zero until about 1982 and has fluctuated at a higher level since (Figure 8b).

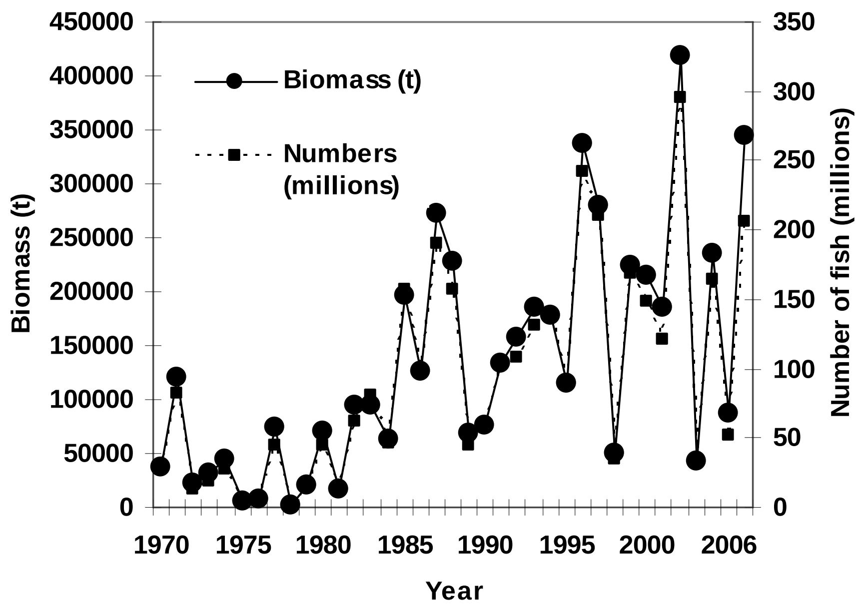

Figure 8a. Scotian Shelf (Div. 4VWX, summer) stratified random groundfish survey 1970-2006 trend in relative (minimum) abundance (number of fish) and biomass (weight). Source: Figure compiled from data tables in Campana *et al*. 2007.

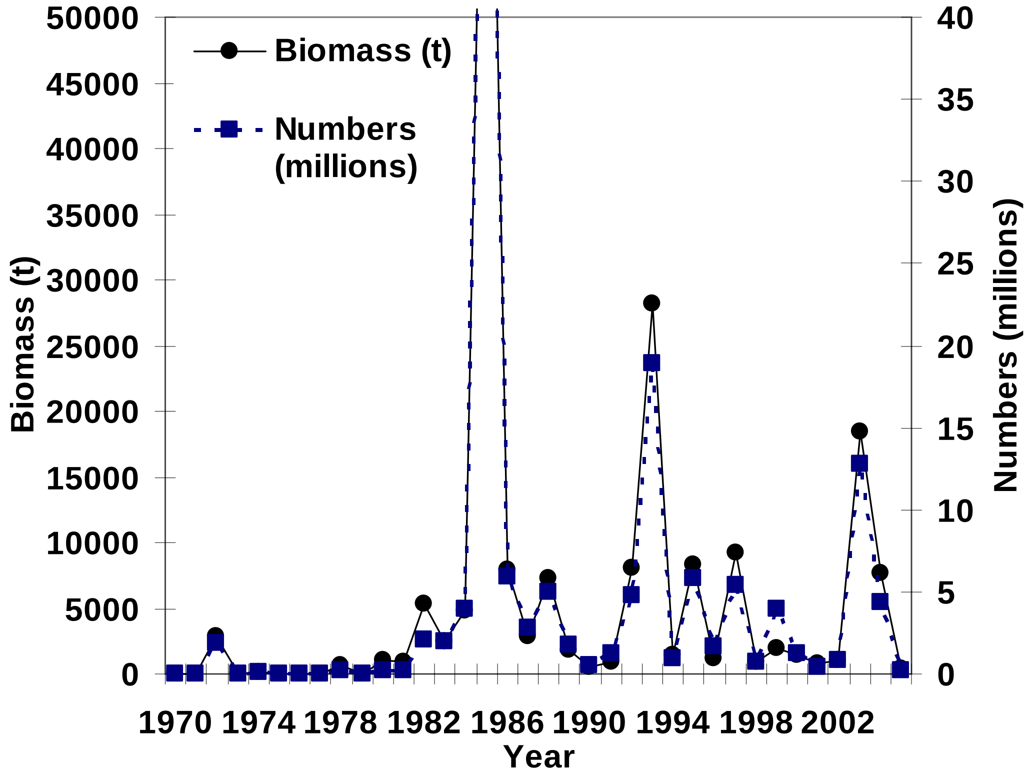

Figure 8b. Div. 4VW portion of the summer 4VWX stratified random groundfish survey 1970-2006 trend in relative (minimum) abundance (number of fish) and biomass (weight).

Mature females (≥82 cm) on average comprise less than 5% of the 4VWX summer survey abundance (Figure 9). The present number of mature females can be conservatively estimated by multiplying the mature female ratio (i.e., 5%) by the estimated total abundance (i.e., 150 million) to result in an estimate of ~7.5 million. However, the catch of summer commercial fisheries that typically operate in inshore shallow waters not accessible to research surveys is ~45% mature females (Campana *et al*. 2007). Thus, the summer survey likely misses most of the mature females because they are located shoreward of the survey area.

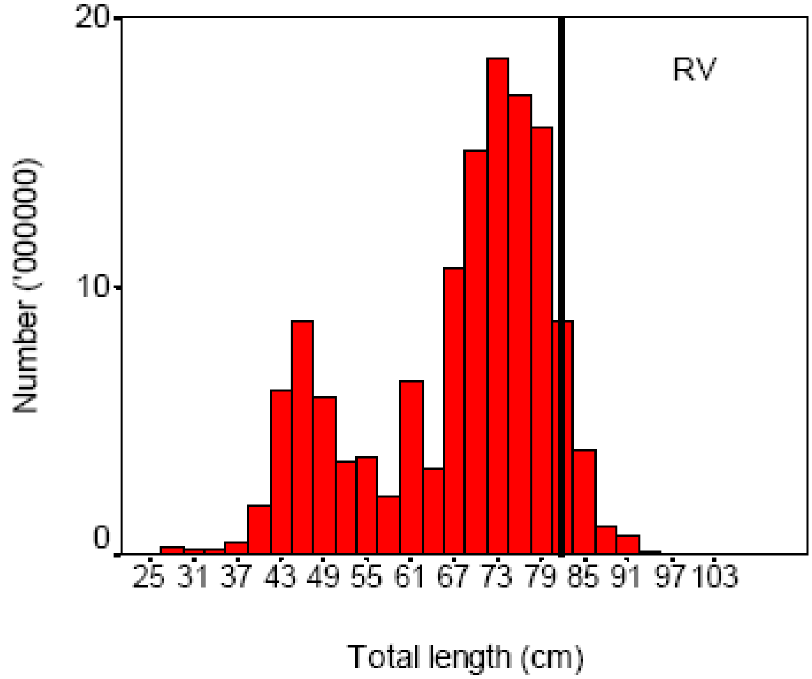

Figure 9. Number of females captured in the Scotian Shelf Div. 4VWX summer demersal research survey between 2003-2006. Source: Campana *et al*. (2007). Line indicates length of female at maturity.

There is no indication of a decline at the centre of concentration of Spiny Dogfish in Canadian waters over the period of this survey.

Change (decrease) in mean length may be an indicator of excessive fishing pressure. There has been no obvious change in the mean length of Spiny Dogfish captured in the summer Scotian Shelf survey (Campana *et al*. 2007, Wallace *et al*. 2009).

Georges Bank Div. 5Z (February) survey 1986-2006

This survey covers the southern-most extent of Spiny Dogfish in Canadian waters. It straddles the Canada/USA border and thus includes fish from both Canada and the USA. The majority of the survey area falls within USA waters. It takes place each February and typically comprises 45-132 stratified random sets restricted to Georges Bank (both U.S. and Canadian waters) (Figure 10). The highest dogfish abundance is found on the edge of the bank with much of the top of the bank consistently devoid of dogfish (Figure 10).

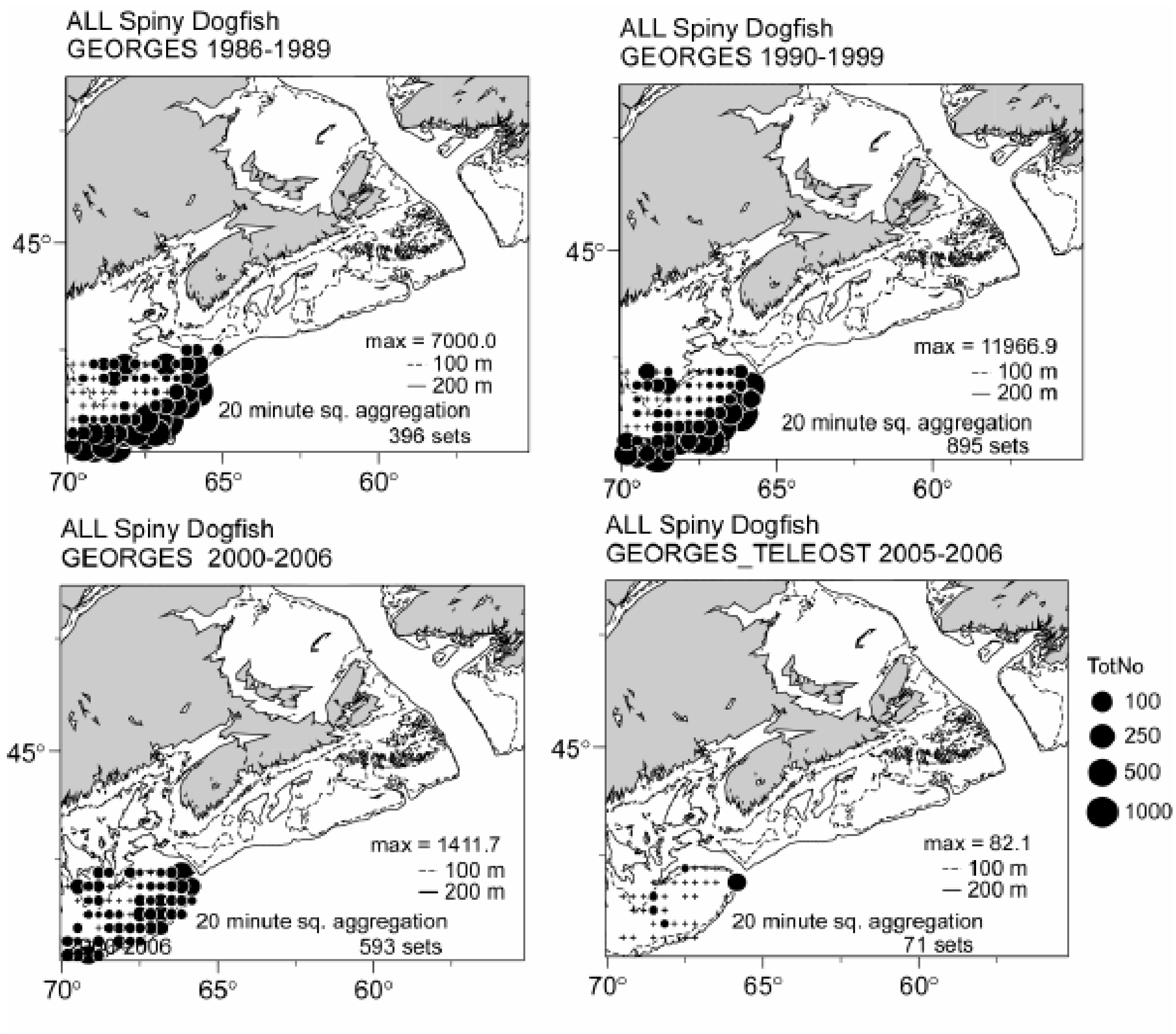

Figure 10. Georges Bank Div. 5Z (February) stratified random groundfish survey 1986-2006; set locations and relative abundance of Spiny Dogfish (numbers) by aggregated years. This survey straddles the Canada/USA border and thus includes fish from both Canada and the USA. The majority of the survey area falls within USA waters. Source: Campana *et al*. 2007.

In contrast to the results of the Scotian Shelf Div. 4VWX summer survey to the north, fully within Canadian waters, the Georges Bank Div. 5Z survey has shown a rapid and continued decline in abundance to a historical low in 2006 (Figure 11). From 1986-1995 the estimated number of Spiny Dogfish was on average about 240 million individuals. From 1996-2007 the abundance had declined to an average of about 9 million individuals, a 95% reduction. Since 2005 the number of Spiny Dogfish on Georges Bank in the survey is estimated to be less than one million individuals (Figure 11). However, most of this survey occurs in USA waters, and the fish at the northern tip of this survey correspond to only a very small portion of the distribution of dogfish in Canadian waters.

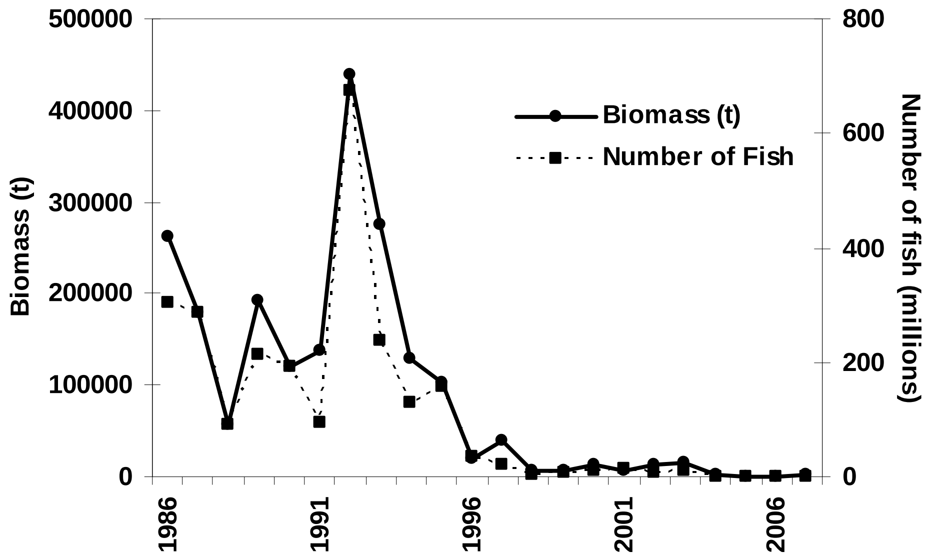

Figure 11. Georges Bank (February) stratified random groundfish survey 1986-2006 trend in biomass and numbers of fish based on extrapolations of swept area biomass. Figure compiled from data tables in Campana *et al*. 2007.

<u>Spring (March) demersal research survey, northeast Scotian Shelf 4VW cod survey 1986-2007</u>

This survey was designed to sample for Atlantic cod but has maintained a record of Spiny Dogfish since its inception in 1986. Distribution of Spiny Dogfish in the 4VW cod survey is centred offshore and in the deeper basins of the Scotian Shelf (Figure 12). However, it does not cover the centre of abundance of the species located in 4X which comprises 95% of the biomass. The size composition has been variable and has tended to be dominated by larger fish (Campana *et al*. 2007). Relative abundance remained high but variable until 1992, after which it dropped abruptly to about 15% of its previous level until 2000 followed by very low abundance until present (Figure 13). This contrasts with an increase in the Div. 4VW index from the summer survey (Figure 8b). It should be noted that the survey has been reduced to about 20% of its historical effort in recent years. It should also be noted that the biomass increased in 4VWX in the summer survey as a whole when the biomass declined in 4VW. However, the summer survey is missing the majority of mature females.

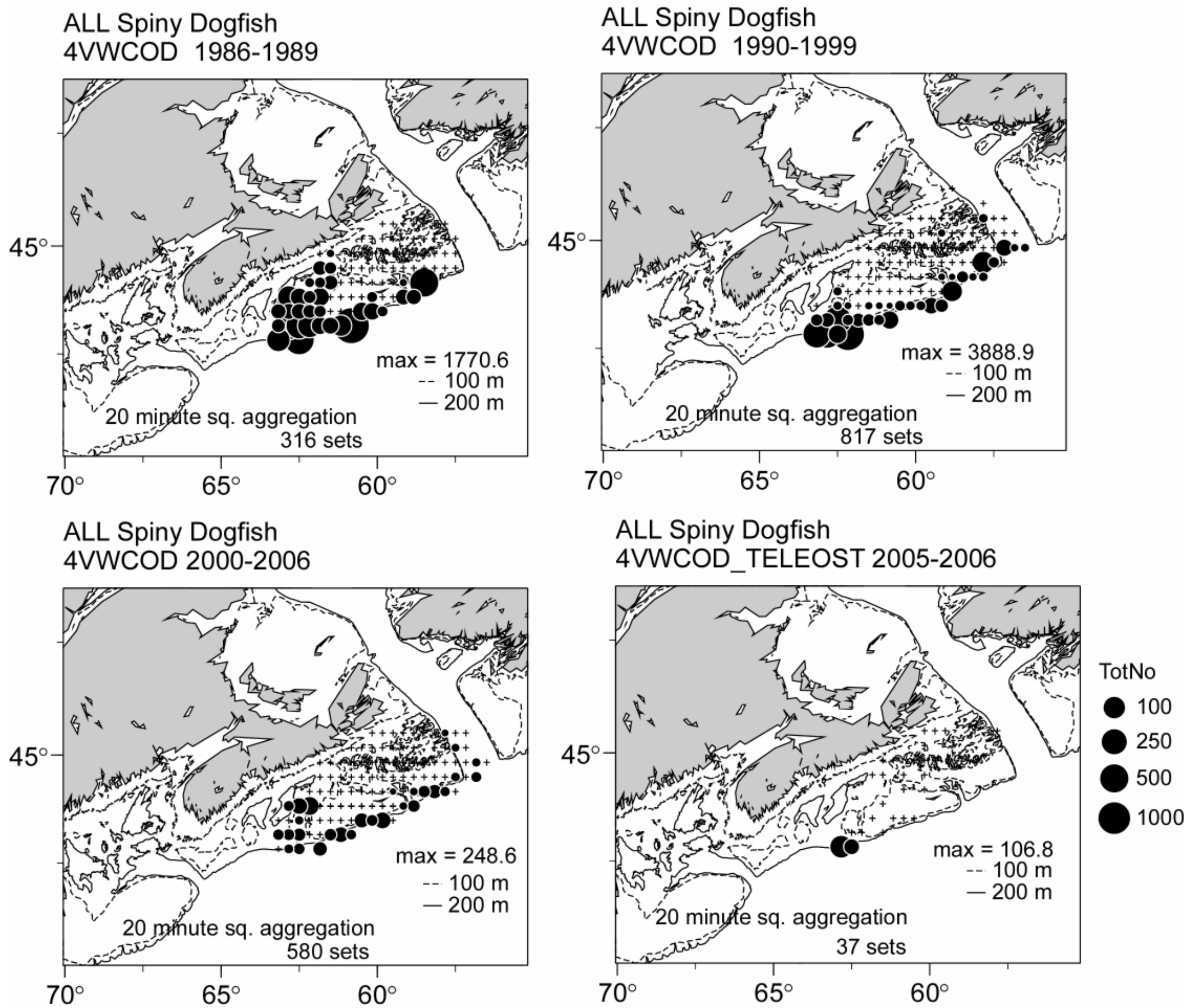

Figure 12. Distribution of Spiny Dogfish in the spring demersal research cod survey off the Eastern Scotian Shelf (NAFO Div. 4VW). Source: Campana *et al*. 2007.

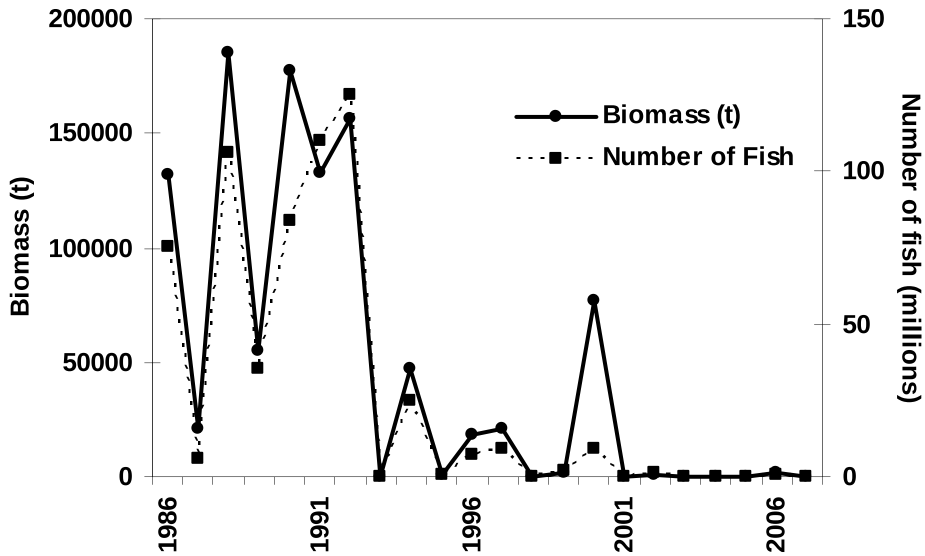

Figure 13. Trend in swept area biomass (t) and number of Spiny Dogfish (millions) estimated from the spring (March) demersal research NAFO Div. 4VW cod survey between 1986-2007. Figure compiled from data tables in Campana *et al*. 2007.

Southern Gulf of St. Lawrence (Div. 4T September) survey 1971-2006

This survey covered the southeast Gulf of St. Lawrence between the Gaspé Peninsula and Cape Breton Island, south to Prince Edward Island, with partial coverage of the Northumberland Strait, with an average of 132 sets during 1971-2005, and 184 during 1995-2005 (Figure 14). Between 1971 and 1983 this survey recorded no Spiny Dogfish. When they first appeared in 1984 they were found concentrated inshore around the periphery of the survey area (Figure 14). Since the early 1990s there has been a reduction in the distribution and abundance of Spiny Dogfish in the survey area (Figures 14 and 15).

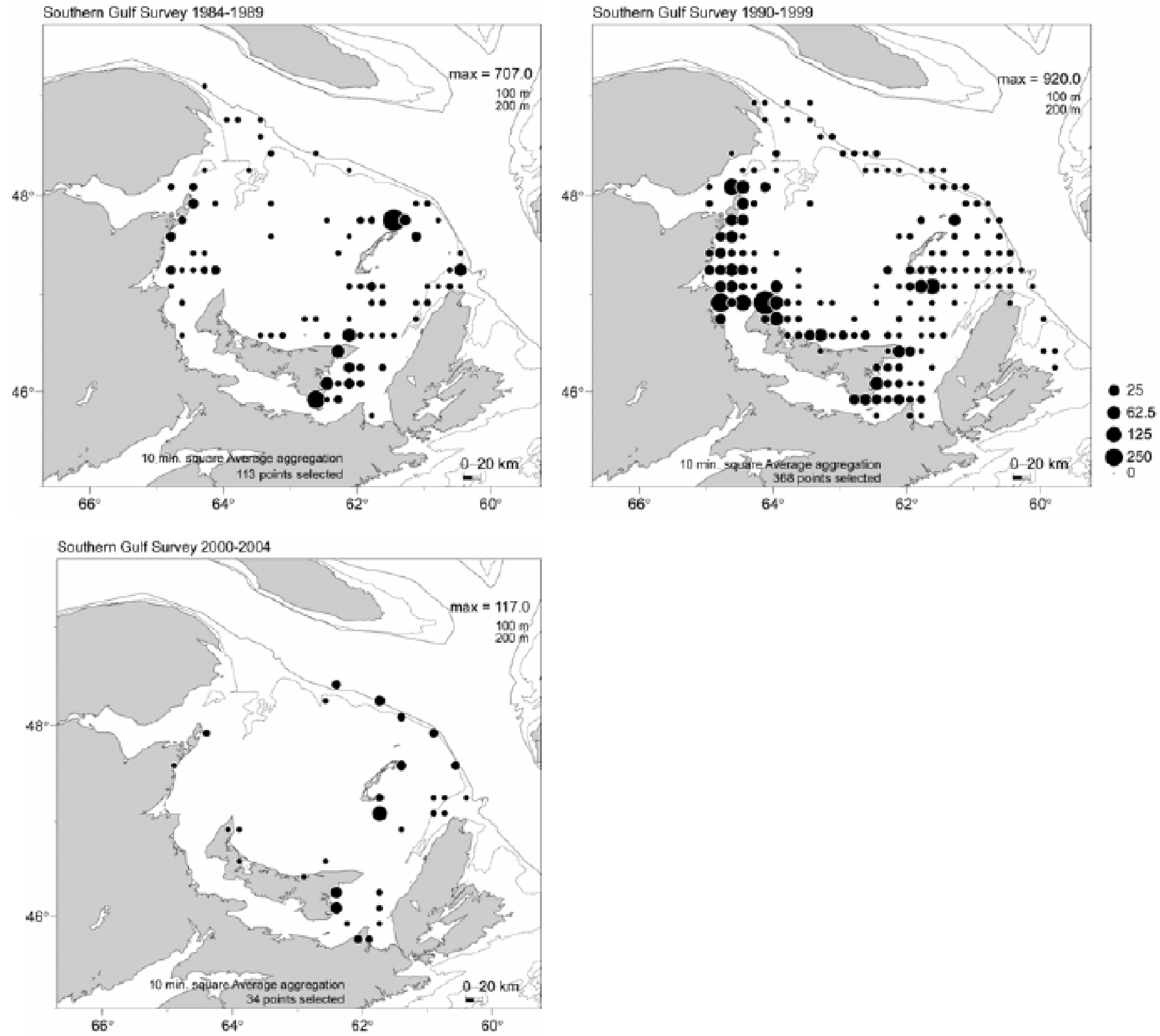

Figure 14. Southern Gulf of St. Lawrence (Div. 4T) summer stratified random groundfish survey 1971-2006; set locations and abundance of Spiny Dogfish (numbers) by aggregated years. Source: Campana *et al*. 2007.

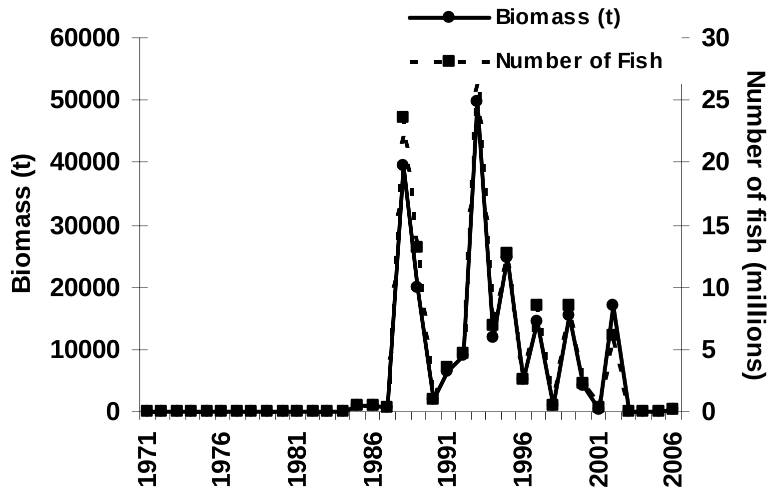

Figure 15. Trend in swept area biomass (t) and number of Spiny Dogfish (millions) estimated from the southern Gulf of St. Lawrence (Div. 4T September) survey between 1971 and 2006. Figure compiled from data tables in Campana *et al*. 2007.

Since their appearance in the survey area in 1984, estimates of Spiny Dogfish abundance have been highly variable with pronounced spikes in abundance occurring every 4-5 years. The last four years of data show a virtual disappearance of Spiny Dogfish from the region. Campana *et al*. (2007) suggest that this area was colonized in 1984, resulting in a non-self-sustaining “sink” population. Their hypothesis is partly validated by a progressive increase in the mean size over this period, suggesting little new recruitment.

Dogfish are also occasionally taken in the northern Gulf of St. Lawrence during research surveys. However, analysis of these data indicated that there were substantial numbers of records for dogfish < 20 cm TL, which is below the birth length. Since Black Dogfish (*Centroscyllium fabricii*) are common in the northern Gulf, it appears likely that at least some of the Spiny Dogfish records are actually black dogfish.

Spring (February-May) demersal research surveys off southern Newfoundland 1972-2005 (Div. 3LNOP)

Surveys in this region have been carried out on an annual basis since 1972. This survey overlaps Canada’s 200 mile limit, but Kulka (2006) found that on average, only 0.22% of the abundance of dogfish in that area, the Grand Banks, occurred outside of Canadian waters (a minute fraction of total dogfish in all Canadian waters). There, Spiny Dogfish distribution at that time of year is concentrated in the deeper waters at the edge of the Laurentian Channel and continental shelf, southwest slope of the grand Banks (Figure 16). Relative abundance during 1972-2005 was highly variable, increasing in recent years or without trend (Figure 17). However, the area occupied did show a decline over that period as dogfish became more concentrated in the northern portion of the Laurentian Channel directly south of Newfoundland (Figures 3 and 7 in Kulka 2006). Dogfish are presently almost absent from other parts of the Grand Bank.

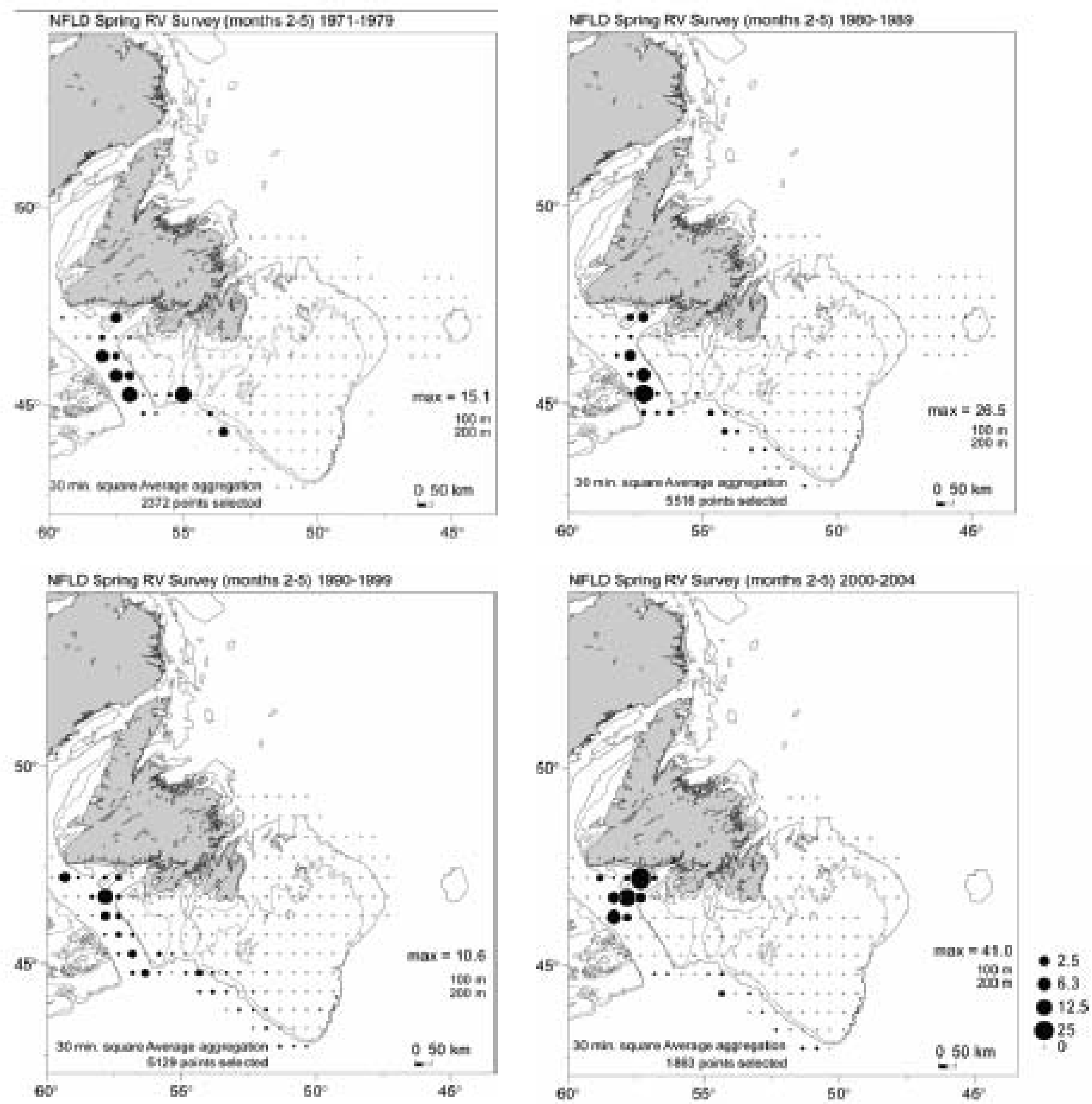

Figure 16. Distribution of Spiny Dogfish in the spring demersal research surveys off southern Newfoundland (Div, 3LNOP). Source: Campana *et al*. (2007).

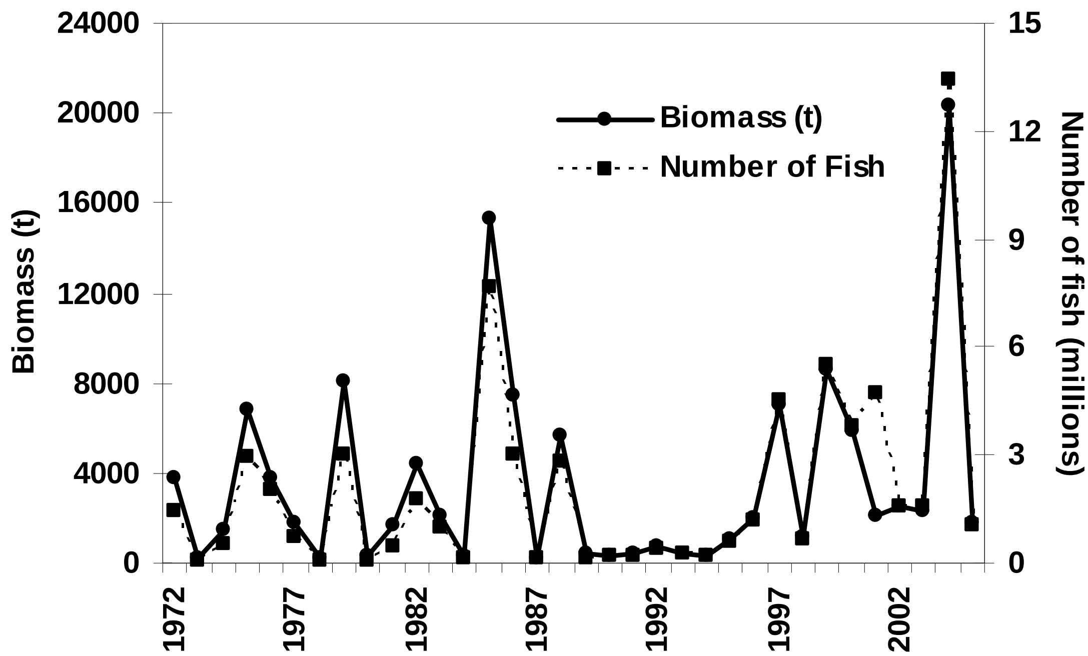

Figure 17. Trend in swept area biomass (t) and number of Spiny Dogfish (millions) estimated from the spring (Feb-May) demersal research surveys off southern Newfoundland (Div. 3LNOP) between 1972 and 2005. Figure compiled from data tables in Campana *et al*. 2007.

Sentinel longline lurvey (Sept.-Oct.) 1995-2005 NAFO (4VsW)

The 4VsW cod sentinel longline survey operated each fall (Sept-Oct) between 1995 and 2005. Spiny Dogfish were caught throughout the survey area, although they tended to be uncommon on the shallower portions of the offshore banks, concentrating in troughs between the banks (Figure 18). The estimate of relative abundance was very high in 1995, about 10 times higher than subsequent values, likely an anomaly. From 1996, the mean weight per tow fluctuated or possibly declined through the time series (Figure 19). Given the variation in the estimates and the short time series, whether the trend actually reflects changes in abundance is uncertain.

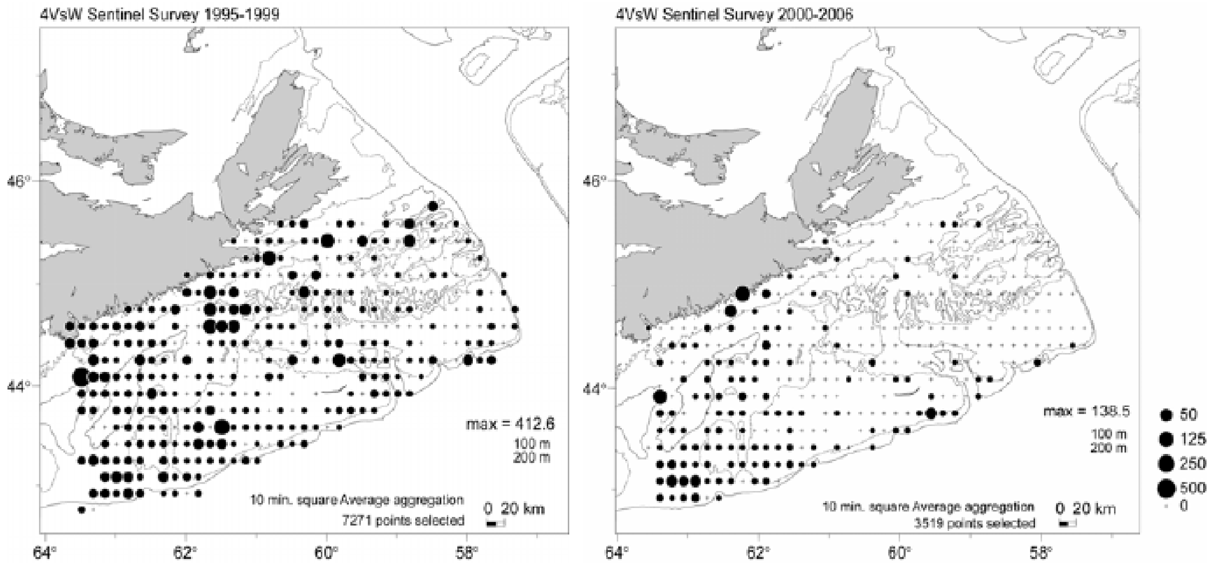

Figure 18. Distribution of Spiny Dogfish by relative abundance and aggregated years in the Sept-Oct sentinel longline surveys for Div. 4VsW cod on the Scotian Shelf. Source: Campana *et al*. 2007.

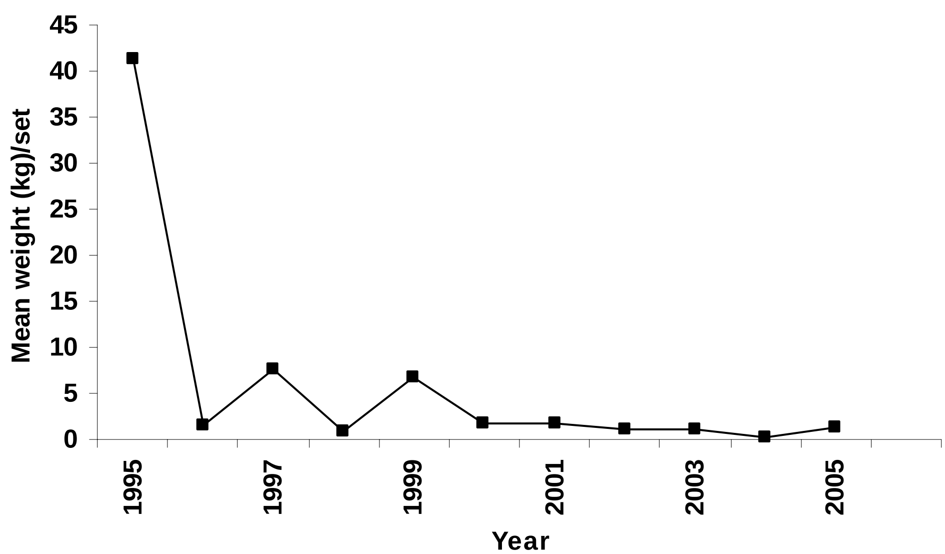

Figure 19. Trend in abundance of Spiny Dogfish (kg/set) from the sentinel longline survey for NAFO Div. 4VsW cod between 1995 and 2005. Figure compiled from data tables in Campana *et al*. 2007.

4Vn sentinel longline 1994-95, 1998-2001   NAFO (4Vn)

Longline surveys for cod were carried out in 4Vn in September each year between 1994 and 2001 with the exceptions of 1996-97. Spiny Dogfish were collected throughout the survey area (Figure 20). Relative abundance declined steeply after the initial survey in 1994 and remained low for the remainder of the time series (Figure 21). However, that apparent decline is based on two points only. Given the short time series, few locations surveyed each year and the small portion of the overall population surveyed, whether the trend actually reflects changes in abundance is uncertain. It likely represents a change in local density.

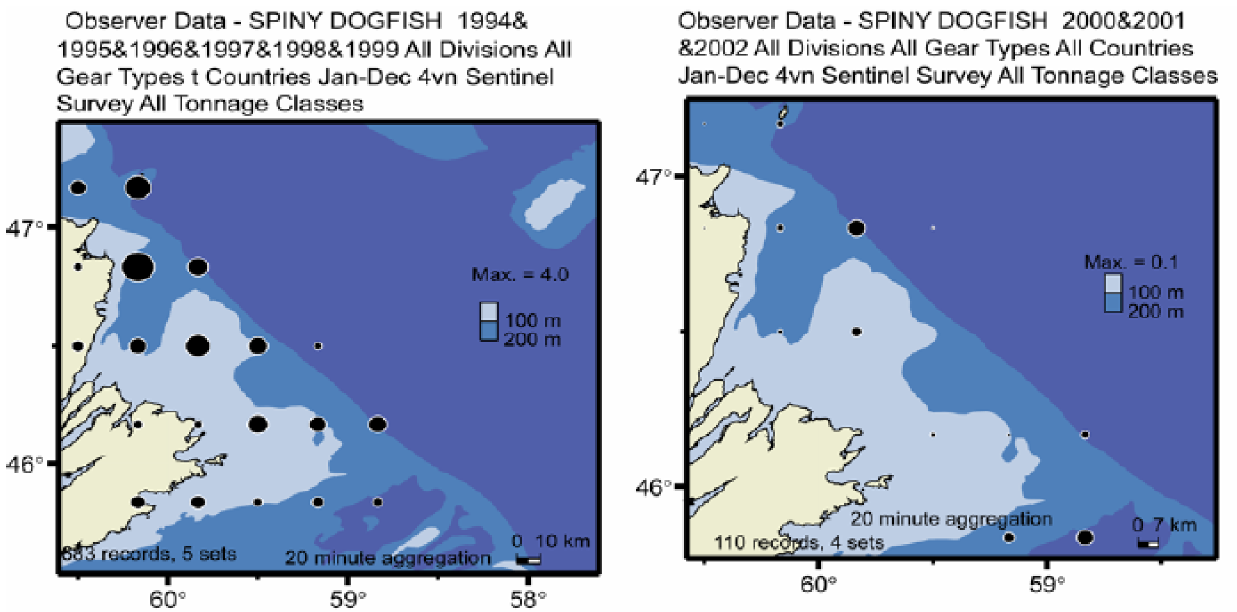

Figure 20. Distribution of Spiny Dogfish by relative abundance and aggregated years in the September sentinel longline cod surveys in NAFO Subdiv. 4Vn on northern end of the Scotian Shelf. Source: Campana *et al*. 2007.

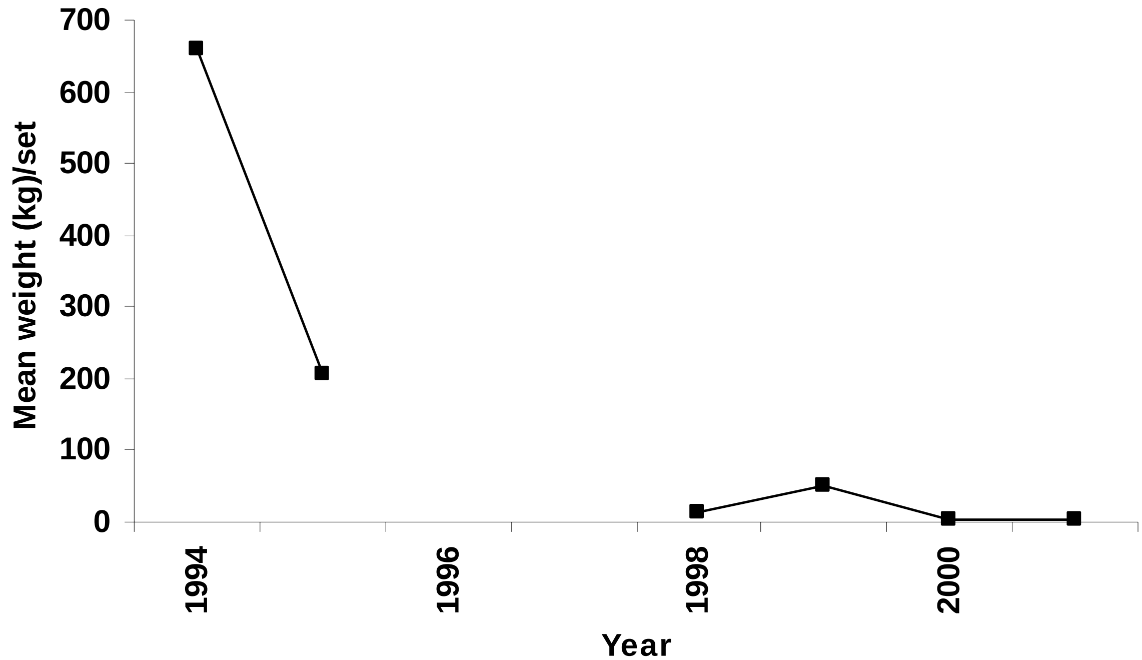

Figure 21. Trend in abundance of Spiny Dogfish (kg/set) from the sentinel longline survey for NAFO Subdiv. 4Vn cod between 1994 and 2001. Figure compiled from data tables in Campana *et al*. 2007.

<u>Scotian Shelf summer halibut longline survey 1998-2006 NAFO (4VWX)</u>

Longline surveys for halibut have been conducted on the Scotian Shelf (NAFO 4VWX) each June since 1998. Spiny Dogfish are caught throughout the survey area, but are much more concentrated off central and southern Nova Scotia, in 4X (Figure 22). Relative abundance in this series has increased or possibly fluctuated without trend or over the short series (Figure 23).

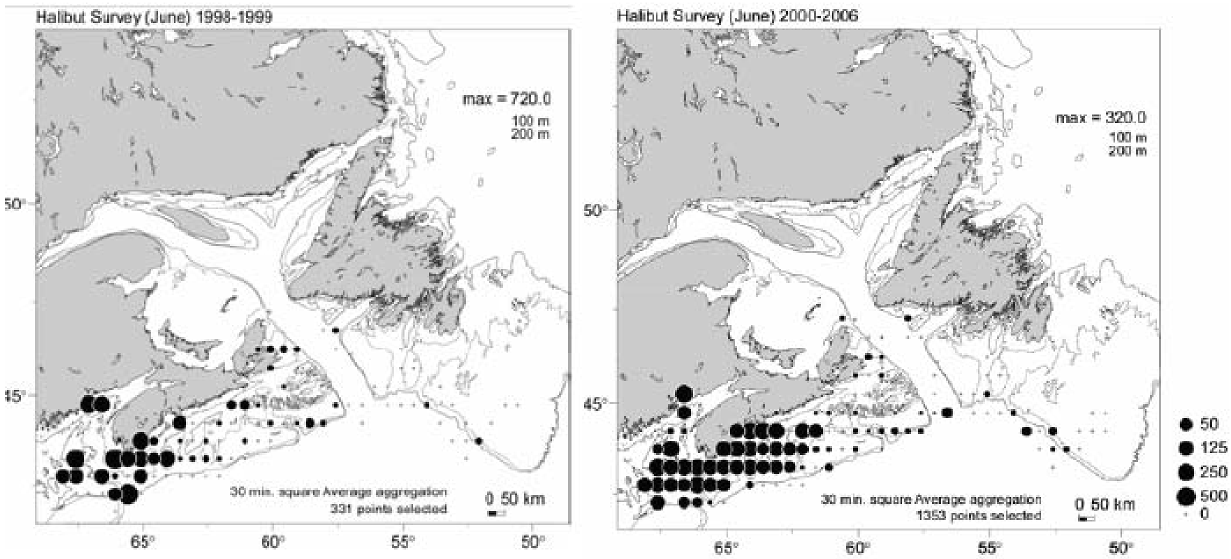

Figure 22. Distribution of Spiny Dogfish (numbers per tow), 1998-1999 and 2000-2006 from the Scotian Shelf summer halibut longline survey. Source: Campana *et al*. 2007.

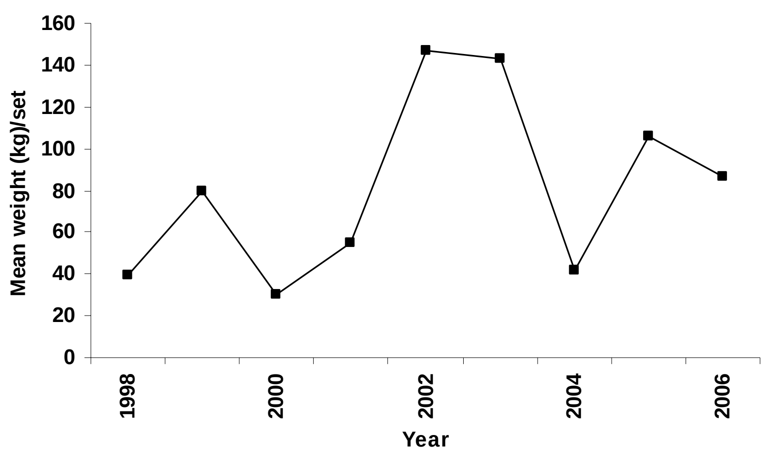

Figure 23. Trend in abundance of Spiny Dogfish (kg/set) from the Scotian Shelf Summer Halibut Longline Survey between 1998 and 2006. Figure compiled from data tables in Campana *et al*. 2007.

Summary of trends in Canadian Atlantic waters

Ninety-five percent of the survey biomass, primarily juveniles within the area surveyed in the summer, was taken in 4X. In the summer 4VWX survey, between 1970 and 2006, all survey catches are highly variable, estimates of relative biomass and abundance often fluctuating 300% among years.

Understanding the overall abundance trend in Canadian waters is hampered by the absence of any long-running survey in 4X in the spring when adult females are offshore and accessible to the survey gear. Div. 4X accounts for most of the Spiny Dogfish in Atlantic Canada; thus the summer 4VWX survey encompasses most of the Canadian juvenile biomass and is longest running. However, this survey does not sample nearshore waters in 4X, where, based on commercial returns, mature females are thought to concentrate during the summer (Campana *et al*. 2007), and thus misses an important component of the population. At least, the increase in juvenile abundance observed in the 4VWX survey reflects good recruitment in recent years.

As well, demersal research surveys consistently catch significantly more mature females in the spring compared to summer; summer surveys typically have <5% mature females. The summer commercial fisheries that typically operate in inshore shallow waters, not accessible to research surveys, catch a high proportion of mature females (~45%) (Campana *et al*. 2007, Wallace *et al*. 2009). This suggests that although mature females make up a relatively small proportion of the summer survey catch in Div. 4X, they are actually present in substantial numbers in that area, but outside of the survey footprint. Summer surveys have shown a long-term steady increase in 4VWX, with 95% of that abundance located in 4X. Assuming a seasonal movement pattern from nearshore to offshore as described elsewhere in this document, it is expected that spring surveys in 4X would show a similar trend.

Between 1979 and 1984 there were both spring and summer surveys in 4X. Campana *et al*. (2007) used these six years of data to derive a biomass conversion factor between the two seasons. On average, spring 4X biomass exceeded summer 4X biomass by a factor of 3.8. If this trend observed in the early 1980s holds true for 2007, then the spring biomass on the Scotian Shelf, if it were to be sampled, might be 3.8 times greater than the summer minimum abundance estimate or 1.3 million t. Campana *et al*. (2007) suggest the summer 4X biomass can be used as a conservative proxy for the estimate of total spring biomass.

A minimum trawlable biomass for spring and summer surveys is shown in Figure 24. A comparison of minimum trawlable biomasses from all Atlantic Canadian RV surveys gives a relative indication of the stock proportion present in each area (Figure 24a). Given the large differences in RV catchability between spring and summer, it is appropriate to compare trawlable biomass only within a given season. The comparison of the various summer/fall RV surveys (summer 4VWX5Z, fall 4VWX and 4T) indicates that the fall and summer trawlable biomasses are roughly comparable, and show similar trends. However, the trawlable biomass in the southern Gulf of St Lawrence is roughly 10% of that on the Scotian Shelf, and thus is small by comparison.

A comparison of the spring RV surveys shows that the spring 4VWX, spring 4VW and the February Georges Bank trawlable biomasses are all comparable, although the spring 4VWX survey does not overlap in time with any other spring survey (Figure 24a). Interestingly, the abrupt decline in the 4VW spring survey in 1993 occurred one year after an abrupt increase in the Georges Bank survey, but 1-2 yr before the abrupt decline on Georges. Thus there was no obvious link between areas in the changing abundances. Biomass increased in 4X in the 1980s and decreased in 4VW, but there was no apparent change in the summer 4X biomass in or around 1993, indicating that the 4VW dogfish did not migrate to 4X. The relative biomass in Newfoundland waters was negligible compared to the other regions prior to 1997, but the biomass in the other regions except 4X subsequently declined so that the Newfoundland biomass is now comparable. Short time series sentinel surveys in various parts of 4VW have largely fluctuated without trend (Figure 24b).

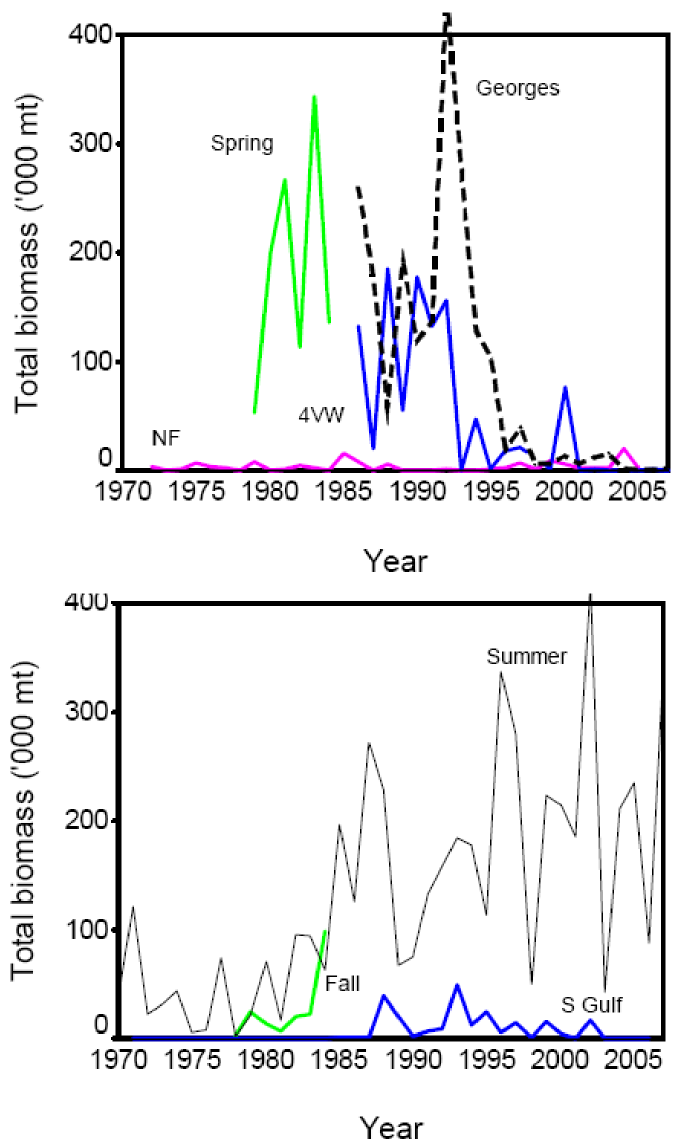

Figure 24a. Canadian time series of minimum trawlable biomass of Spiny Dogfish in spring (top) and summer/fall (bottom) RV surveys off Atlantic Canada, 1970-2007. Spring=Mar RV of Scotian Shelf; 4VW=Mar RV of 4VW; NF=spring RV of southern Newfoundland; Georges=Feb RV of Georges Bank; Summer=July RV of Scotian Shelf; Fall=Nov RV of Scotian Shelf; S Gulf=Sept RV of southern Gulf of St Lawrence (after Campana *et al*. 2007).

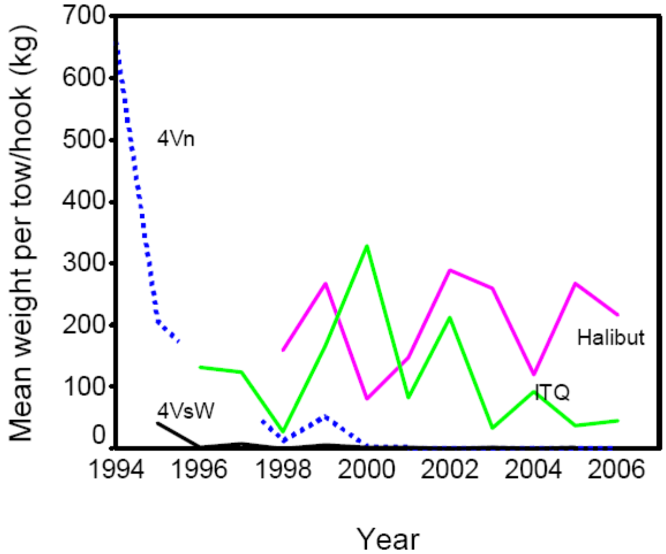

Figure 24b. Canadian time series of relative biomass of Spiny Dogfish in sentinel (summer/fall) surveys off Atlantic Canada, 1994-2006. 4Vn=Sept 4Vn cod longline survey; 4VsW=Sept/Oct longline survey for 4VsW cod; ITQ=July trawl survey in 4X; Halibut=June longline survey in 4VWX (after Campana *et al*. 2007).

Under the assumption that most of the biomass of Spiny Dogfish occurs in 4X and the abundance in the missing area of 4X in the spring survey is at least as great as the summer abundance, then Spiny Dogfish in Canadian waters are likely to be healthy and not in decline in Canadian waters.

U.S. research surveys (Atlantic)

The following section deals with surveys that largely fall outside of Canada's territory but are presented to provide a wider picture of dogfish abundance and distribution.

The Northeast Fisheries Science Center (NEFSC) has conducted both spring and autumn annual trawl surveys off the U.S. continental shelf since 1968; coverage extends from the Gulf of Maine to Cape Hatteras (North Carolina) and includes both the U.S. and Canadian portion of the Georges Bank. The spring survey is considered to provide the best representative sample of the total abundance in U.S. waters (NEFSC 2006). Following an increase through much of the time series (1968-early 1990s), there was a gradual decline in total swept area biomass in the spring R/V trawl survey beginning in the early 1990s until 2005 (Figure 25). A rapid upturn in total abundance driven primarily by increases in mature female abundance was first observed in 2006 and has continued to 2008 (Figure 26). Abundance of mature females declined in the mid-1990s and continued until 2005 (Figure 26). The rapid decline in mature female abundance coincided directly with the time period of the large U.S. fishery that preferentially targeted mature females (see section on commercial fishing). Mature female biomass has returned to levels found in the early 1990s.

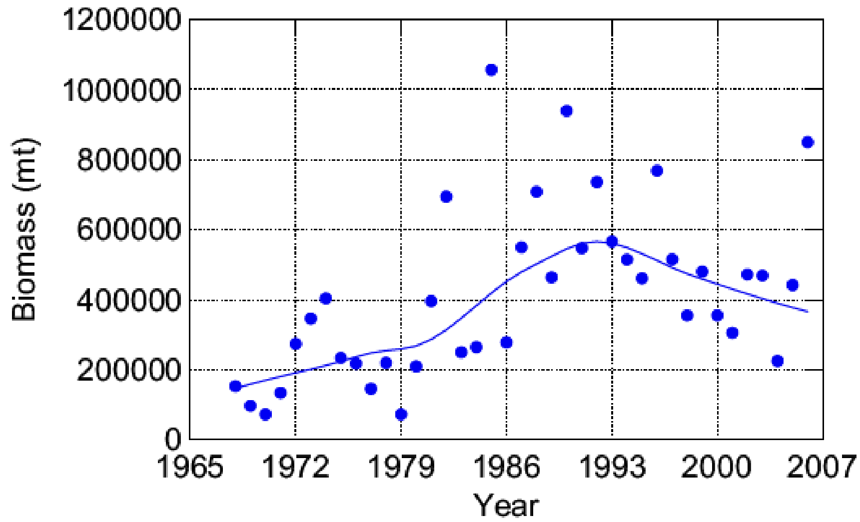

Figure 25. Swept area biomass estimate of all Spiny Dogfish (metric tonnes-mt) in the U.S. spring R/V trawl survey, 1968-2006, from Cape Hatteras to Gulf of Maine. Source: NEFSC 2006.

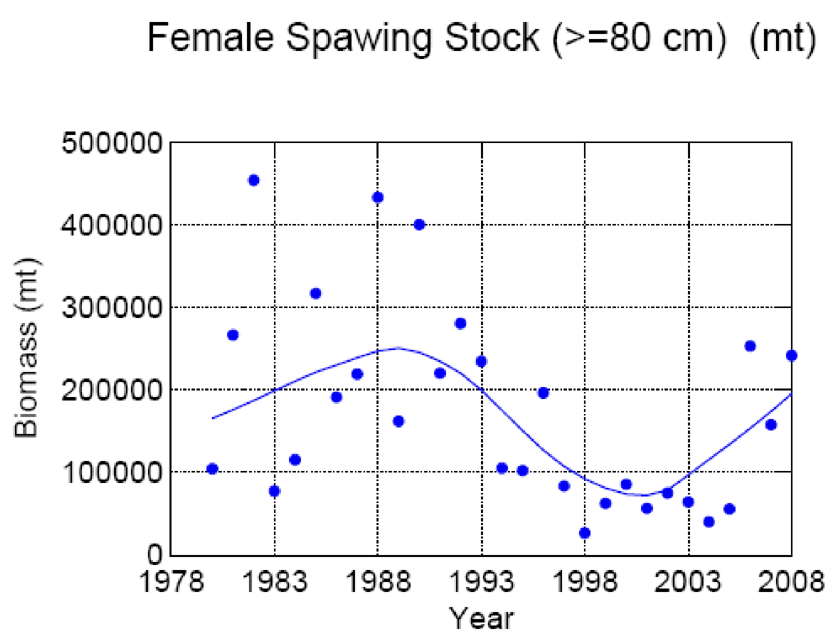

Figure 26. Swept area biomass estimate of mature female Spiny Dogfish (>=80cm) (metric tonnes-mt) in the U.S. spring R/V trawl survey, 1968-2006, from Cape Hatteras to Gulf of Maine. Source: NEFSC 2006, Rago and Sosebee 2008.

In 1998 the National Marine Fisheries Service declared Spiny Dogfish in U.S. waters as “overfished” resulting in a complete closure of the fishery between 2001 and 2003. Based on the recent data, this stock is now considered to be above the target rebuilding threshold and increases in allowable catch will likely ensue (Rago and Sosebee, 2008).

The decrease in the spawning biomass (i.e., mature females) observed in the late 1990s may have been responsible for the apparent recruitment failure shown in Figure 27; furthermore, the mean length of mature females and recruits has declined during this same time period (NEFSC 2006). Both fecundity and pup length have shown to be positively correlated with female length. The combination of reduced biomass of mature females, diminished mean length of mature females, and a decline in average size and numbers of pups are considered the reasons behind the observed recruitment failure (NEFSC 2003).

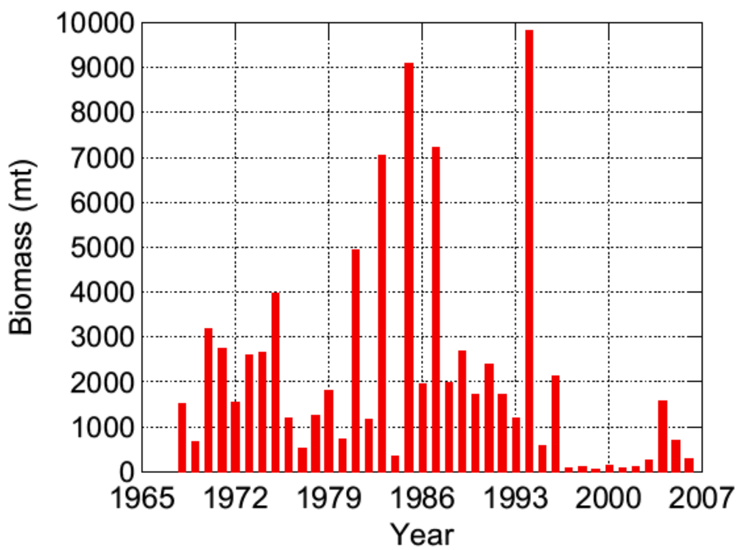

Figure 27. Swept area estimate of Spiny Dogfish biomass (000 mt) recruits (pups) in the U.S. spring R/V trawl survey,1968 – 2006. Source: NEFSC 2006.

<u>Relationship between Canadian and U.S. stocks (Atlantic)</u>

As described elsewhere in this document (see *Population Structure*), Spiny Dogfish occupying the waters along the east coast of North America exhibit characteristics of a metapopulation (Campana *et al*. 2007). A metapopulation implies that there are several “groups” of Spiny Dogfish (i.e., southern Gulf of St. Lawrence, around Newfoundland, the eastern and central Scotian Shelf, Bay of Fundy and Southwest Nova Scotia, Massachusetts and North Carolina). Under this hypothesis the groups remain largely separate, and migrate primarily between onshore and offshore on a seasonal basis. Some groups may undertake seasonal north-south migrations, particularly those in the south.

Rescue effect

Both the Canadian Atlantic and Pacific populations of Spiny Dogfish have varying, but largely unquantified interchange with adjacent U.S. populations (see previous sections). On the Atlantic coast of North America, the centre of abundance for this species is shared between Canadian and U.S. waters (see Figure 4). The Georges Bank component of the population appears to be strongly linked to the U.S. Gulf of Maine component and both appear to have been reduced in numbers. A rescue effect from the Scotian Shelf to Georges Bank depends on the rate of exchange between these two components of the population, which at present is thought to be 10-20% based on tag returns. The extent of interchange with more northerly components (i.e., north of Halifax) is probably much lower.

LIMITING FACTORS AND THREATS

Globally, overfishing is considered the only proximate threat to Spiny Dogfish at a population level (Germany CITES Proposal 2003). Life history characteristics of long gestation, slow growth rate, late age of maturity, low intrinsic rate of increase, low fecundity, long life span, and dense sex- and size-segregated aggregations all contribute towards the Spiny Dogfish’s vulnerability to overfishing (Ketchen 1986). Compounding the problem is the preference of some commercial fisheries to target the larger reproductively mature females, and high, unreported discard rates although that issue is better controlled in recent years through the placement of fishery observers and video monitoring systems. On the other hand, Spiny Dogfish are widely distributed, have few predators, exhibit density-dependent growth and are opportunistic generalist predators, which are traits that may aid in the rebuilding of depleted populations providing the human mortality is greatly reduced or removed (Wood *et al*. 1979; Ketchen 1986). Furthermore, in the Pacific, it is thought that juvenile Spiny Dogfish are less susceptible to fishing pressure than adults due to a primarily midwater existence, whereas the majority of the directed fishing is benthic. This segregation may help explain how Spiny Dogfish recovered faster than was expected after being over-exploited in the 1940s.

Mature females on the Scotian Shelf move inshore to warmer waters in summer, and it is at this time that they may be susceptible to target and bycatch fisheries (Campana *et al*. 2008). Both Georges Bank (Canada) and adjacent U.S. waters, over-fishing of Spiny Dogfish had considerable impact on the abundance and altered the size structure of the population. Recent evidence suggests this population is showing strong signs of rebuilding. Fishing for Spiny Dogfish in Canadian waters does not appear to be having any detectable impact on the populations.

In jurisdictions outside of North America, Spiny Dogfish have also been shown to be vulnerable to overfishing. In the northeastern Atlantic, populations are below 5% of their former abundance (Heesen 2003). The depletion of northeast Atlantic populations opened up European markets to North America, which is in part responsible for the rapid development of the U.S. northwest Atlantic fishery (Germany CITES Proposal 2003).

Bioaccumulation of toxins, such as mercury, has been demonstrated to occur in Spiny Dogfish in Canadian waters but the long-term effects at a population level are unknown (Ketchen 1986).

SPECIAL SIGNIFICANCE OF THE SPECIES

The Spiny Dogfish is the world's most abundant shark species and consequently plays an important role in both natural and human systems (Compagno 1984). Its role in the ecosystem as an apex predator is not well understood; however, its perception as a direct predator or competitor of commercial species is well entrenched in fisheries lore (Ketchen 1986). This species has been killed for more varied purposes than any other fish in Canada. Its body oils have been used for industrial lubricants, lighting (including lighthouses), and vitamin A; its flesh for fertilizer, meat and fishmeal; and its fins enter the international shark fin trade. Finally, they have been the subject of directed eradication programs due to their "nuisance" factor in commercial fisheries (Ketchen 1986). The reputation amongst the fishing community as a pest is from its ability to prey upon target species that are entangled or hooked or from Spiny Dogfish themselves being incidentally caught and thereby taking the bait or damaging fishing nets.

The reputation of the Spiny Dogfish is partly responsible for the lack of proper management worldwide. Their biology clearly shows they are highly vulnerable to human-induced mortality. The gestation period of the Spiny Dogfish (18-24 months) is the longest known of any animal, with the possible exception of the basking shark, which is in part responsible for their intrinsic rate of increase being the slowest of 26 Pacific shark species analyzed (Smith *et al*. 1998).

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The IUCN has assessed the Spiny Dogfish as *near threatened* on a global basis. Populations in the northwest and northeast Atlantic are currently assessed as *vulnerable* and *endangered* respectively (Fordham 2000, 2003a,b). The Pacific population has not been assessed by the IUCN.

In 1998 the National Marine Fisheries Service declared Spiny Dogfish in the northwest Atlantic as *overfished*. Since that time, a fisheries management plan has been developed and Spiny Dogfish abundance has increased and the species is no longer considered *overfished* (NEFSC 2006).

In January of 2004, Germany put forward a proposal to the Regional Representatives Meeting of European CITES member states to list Spiny Dogfish under Appendix II of CITES, which would help control the trade of dogfish from depleted populations (Germany CITES Proposal 2003). This proposal was rejected by the European member states in May 2004 and therefore not considered by CITES.

Canadian populations are managed by setting total allowable catches and associated quotas. On the Atlantic coast, the current quotas are 2500 t for fixed gear, and individual vessel quotas of 10 t and 25 t for trawl vessels >65 feet and <65 respectively. On the Pacific coast, there is a coast-wide quota of 14 940 t of which only 3000 t can be taken from the Strait of Georgia. Finning, the process of removing and selling only the fins is prohibited in Canada.

TECHNICAL SUMMARY

Squalus acanthias
Spiny Dogfish, Atlantic Population — Aiguillat commun, population de l'Atlantique
Range of occurrence in Canada: Atlantic Ocean

Demographic Information

Generation time (estimated as age of 50% maturity + 1/natural mortality)	23 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? 1. US survey index for mature females 2. Canadian indices showing overall stability, with increases and decreases in specific areas, increasing in Div. 4X where 95% of the Canadian abundance resides	1. 70% decline from early 1980s to early 2005, 2006-2008 rapid increase in survey abundance 2. Stable, or increasing
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	No evidence of continuing decline
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Some decline likely over 3 generations, but no estimate because no long-term survey covers 3 generations; only long-term survey shows no decline
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	N/A
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	N/A
Are the causes of the decline clearly reversible and understood and ceased?	Partially understood. Past declines in some parts of range (U.S.) due to overfishing, but this trend has now been reversed. Other apparent declines or fluctuations may be due to shifts in distribution, a non-reproducing sink population (Gulf of St. Lawrence), or high sampling variance.
Are there extreme fluctuations in number of mature individuals?	Unlikely in the absence of fishing due to the low reproductive potential

Extent and Occupancy Information

Estimated extent of occurrence **Area based on the size of the continental shelf comprising the spatial extent of Spiny Dogfish.**	425 000 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value; other values may also be listed if they are clearly indicated (e.g., 1x1 grid, biological AO)).	Same as EO
Is the total population severely fragmented?	No
Number of locations*	Unknown
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	Unknown, not likely decreasing
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	No
Are there extreme fluctuations in number of populations?	Not likely
Are there extreme fluctuations in number of locations*?	Unknown
Are there extreme fluctuations in extent of occurrence?	Not likely
Are there extreme fluctuations in index of area of occupancy?	Not likely

Number of Mature Individuals (in each population)

Population	**N Mature Individuals**
Total	Unknown > 7.5 million females

Quantitative Analysis

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

Threats (actual or imminent, to populations or habitats)

Fishing mortality (directed and as discarded bycatch) is the single largest threat.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? USA: NW Atlantic – not overfished USA: NE Pacific – stable UK: severely depleted (-5% of historical biomass)	
Is immigration known or possible?	Yes
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	**Possible**

*See definition of location.

Current Status

COSEWIC: Special Concern (April 2010) IUCN (globally): Near Threatened IUCN (NE Atlantic): Endangered IUCN (NW Atlantic): Vulnerable

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric Code:** Not applicable.
Reasons for Designation: This small shark is widely distributed in temperate regions of the world's oceans and appears to be a habitat generalist. The Atlantic population occurs from Labrador to Cape Hatteras; in Canadian waters the species is most abundant in southwest Nova Scotia. An average of six pups are born every two years; the gestation period of 18-24 months is one of the longest known for any vertebrate. The species has few natural predators, but is subject to both targeted and bycatch fishing mortality. The species remains relatively abundant in Canadian waters, but low fecundity, long generation time (23 years), uncertainty regarding abundance of mature females, and demonstrated vulnerability to overfishing in adjacent U.S. waters are causes for concern.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable.
Criterion D (Very Small or Restricted Total Population): Not applicable.
Criterion E (Quantitative Analysis): Not applicable.

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There are numerous people who assisted in the writing of this report. On the Atlantic coast, Linda Marks and Warren Joyce assisted in the mapping and data preparation. The report writers also thank Paul Rago of the National Marine Fisheries Service for providing the U.S. data and assessments.

INFORMATION SOURCES

Annand, C. and D. Beanlands. 1986. A genetic stock structure study of dogfish in the Northwest Atlantic. NAFO SCR Doc. 86/102 Ser. No. N1229.

ASMFC (Atlantic States Marine Fisheries Commission). 2002. Interstate Fishery Management Plan for Spiny Dogfish. Fishery Management Report No. 40 of the Atlantic States Marine Fisheries Commission (ASMFC), Washington DC, USA, November 2002. 107 pp.

Bowman, R., R. Eppi and M. Grosslein. 1984. Diet and Consumption of Spiny Dogfish in the Northwest Atlantic . NOAA, NMFS, NEFSC, Woods Hole, MA. 16 pp.

Campana, S.E., A.J.F. Gibson, L. Marks, W. Joyce, R. Rulifson and M. Dadswell. 2007. Stock structure, life history, fishery and abundance indices for Spiny Dogfish (*Squalus acanthias*) in Atlantic Canada Canadian Science Advisory Secretariat Research Document 2007/089.

Compagno, L.J.V. 1984. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 1. Hexanchiformes to Lamniformes. FAO Fish Synop. 125:1-249.

Campana, S.E., W. Joyce, and D.W. Kulka 2009. Growth and reproduction of spiny dogfish off the eastern coast of Canada, including inferences on stock structure. pp. 195-208. In: Gallucci, V.F., McFarlane, G.A., and Bargmann, G.G. [eds]. Biology and management of dogfish sharks. American Fisheries Society. Bethesda, Maryland.

FAO. 2004. Fisheries Global Information System. United Nations Food and Agriculture Organization. Web site: http://www.fao.org/figis/servlet.htm Accessed December 2004.

Fogarty, M.J., and S.A. Murawski. 1998. Large-scale disturbance and the structure of marine systems: fishery impacts on Georges Bank. Ecological Applications 8(S1):S6–S22.

Fordham, S. 2000. *Squalus acanthias*. In: IUCN 2004. *2004 IUCN Red List of Threatened Species.* Website: www.redlist.org. accessed March 2005.

Fordham, S. 2003. *Squalus acanthias* (Northeast Atlantic subpopulation). In: IUCN 2004. *2004 IUCN Red List of Threatened Species.* Website: www.redlist.org. accessed March 2005.

Fordham, S. 2003. *Squalus acanthias* (Northwest Atlantic subpopulation). In: IUCN 2004. *2004 IUCN Red List of Threatened Species.* Website: www.redlist.org. accessed March 2005.

Germany CITES Proposal. 2003. Proposal to include the Spiny Dogfish (*Squalus acanthias*) in Appendix II CITES. Prepared for the Thirteenth meeting of the Conference of the Parties, Bangkok, Thailand.

Hammond, T.R., and J.R. Ellis. 2005. Bayesian Assessment of Northeast Atlantic Spurdog Using a Stock Production Model, with Prior for Intrinsic Population Growth Rate Set by Demographic Methods. J. Northw. Atl. Fish. Sci., 35: 299-308. doi:10.2960/J.v35.m486

Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada Bulletin 180. 740 pp.

Hauser, L., J.H. Franks, N. Vega and V. Gallucci pers. 2007. Potential for sustainable expansion of the dogfish (*Squalus acanthias*) fishery in the northeast Pacific. Final Report to NOAA SK. 37 pp. http://www.nmfs.noaa.gov/mb/sk/pdf/Report_2.pdf

Heessen, H.J.L. 2003. Development of elasmobranch assessments DELASS. European Commission DG Fish Study Contract 99/055, Final Report, January 2003.

Jensen, A.C. 1965. Life history of the Spiny Dogfish. Fisheries Bulletin 65:527-554.

Ketchen, K.S. 1975. Age and growth of dogfish (*Squalus acanthias*) in British Columbia waters. Journal of the Fisheries Research Board of Canada 32: 43-59

Ketchen, K.S. 1986. The Spiny Dogfish (*Squalus acanthias*) in the northeast Pacific and a history of its utilization. Canadian Special Publication of Fisheries and Aquatic Sciences. 88, 78 pp.

Kulka, D.W. 2006. Abundance and distribution of demersal sharks on the Grand Banks with particular reference to the NAFO regulatory area. NAFO SCR Doc. 06/20, Ser. No. N5237.

McCauley, L., C. Goecker, P. Parker, T.O.M. Rudolph, F. Goetz, and G. Gerlach. 2004. Characterization and isolation of DNA microsatellite primers in the Spiny Dogfish (*Squalus acanthias*). Molecular Ecology Notes 4, 494-496.

McMillan, D.G. and W.W. Morse. 1999. Essential Fish Habitat Source Document: Spiny Dogfish, *Squalus acanthias*, Life History and Habitat Characteristics. NOAA Technical Memorandum NMFS – NE 150.

Nammack, M.F., J.A. Musick and J.A. Colvocoresses. 1985. Life history of Spiny Dogfish off the northeastern United States. Transactions of the American Fisheries Society. 114: 367-376.

NEFSC 2003. Spiny Dogfish. Report of the 37th Northeast Fisheries Science Center Stock Assessment Workshop. Northeast Fisheries Center. May 12-14, 2003, Woods Hole, Massachusetts. 151 pp.

NEFSC 2006. Spiny Dogfish. pp 12-30 in 43rd Northeast Regional Stock Assessment Workshop, Summary Report. Northeast Fisheries Science Center Reference Document 06-14. US Department of Commerce, National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, Massachusetts. (available at http://www.nefsc.noaa.gov/nefsc/saw/)

Rago, P. and K. Sosebee. 2008. Update on the status of Spiny Dogfish in 2008 and Initial evaluation of alternative harvest strategies. Northeast Fisheries Science Center, National Marine Fisheries Service, Atlantic States Marine Fisheries Commission, Providence, RI

Smith, S.E., D.W. Au, and C. Show. 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. Marine and Freshwater Research 49: 663-678.

Soldat, V.T. 1979. Biology, Distribution, and abundance of the Spiny Dogfish in the Northwest Atlantic. ICNAF Research Document 79/VI/102. Serial No. 5467. 9 pp.

Templeman, W. 1976. Transatlantic migration of Spiny Dogfish (*Squalus acanthias*). Journal of the Fisheries Research Board of Canada 33:2605-2609.

Templeman, W. 1984. Migrations of Spiny Dogfish, *Squalus acanthias*, and recapture success from tagging in the Newfoundland area, 1963-65. Journal of Northwest Atlantic Fisheries Science 5:47-53.

Weinberg, K.L., M.E. Wilkins, F.R. Shaw, and M. Zimmerman. 2002. The 2001 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. NOAA Technical Memorandum NMFS-AFSC-128. 140 pp.

BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Provisional report

Scott Wallace's research focuses on the sustainability of marine fisheries, conservation of marine biological diversity, and ecosystem-based approaches to fisheries management. He is active in the conservation community where he is currently a Science Advisor to the Sierra Club of Canada, BC Chapter. In this capacity he reviews current fisheries practices, writes status reports, and sits on numerous subcommittees under the umbrella organization of the Pacific Marine Conservation Caucus. Subcommittees include marine mammals, lingcod and rockfish, and species at risk. Current research is focused on the sustainability and current management practices within the Pacific groundfish fishery. He holds a Ph.D. from the University of British Columbia's Fisheries Centre.

Dr. Steven Campana is a Senior Scientist at the Bedford Institute of Oceanography in Canada. There he directs an active research program in fish population dynamics, with particular emphasis on Canadian sharks and the development of new otolith-based technologies in support of age determination and stock discrimination. He currently heads both the Otolith Research Laboratory and the Shark Research Laboratory, chairs the Stock Assessment Working Group, and leads a number of interdisciplinary multinational projects.

Gordon (Sandy) McFarlane

Gordon (Sandy) McFarlane's research centers on determining and refining biological parameters used in stock assessments; examining climatic and oceanic factors influencing the dynamics of marine fish; and the physical, biological and fisheries oceanographic linkages of large marine ecosystems. In addition he has for many years studied the biology and distribution of sharks and skates off Canada's west coast. Previously, he was head of the Marine Fish Population Dynamics Section (1992-2000) and the Groundfish Research Section (1985-1991) at PBS. In addition, he has authored over 90 primary publications concerning the biology and assessment of marine resources as well as over 100 technical publications directly related to stock assessments of Pacific marine fishes.

Jacquelynne King

Jacquelynne King's research in fisheries stock assessment focuses on the impacts of climatic and oceanographic variability on marine fish population dynamics and the implications for fisheries management. Dr. King has published on a suite of disciplines including life history strategies, statistical methodology, climate impacts on ecosystems, ageing methodology, stock assessment, fish population dynamics and behavioural ecology. Current biological research in stock assessment has included refinement of age and growth parameters for big and longnose skates, ageing methodology for sixgill sharks, distribution and migration of Spiny Dogfish, and seasonal behaviour, including spawning, of lingcod. Dr. King is currently the head of the lingcod stock assessment research program; co-investigator for elasmobranch stock assessment research; co-investigator for incorporating climate variability into the assessment of marine fishes.