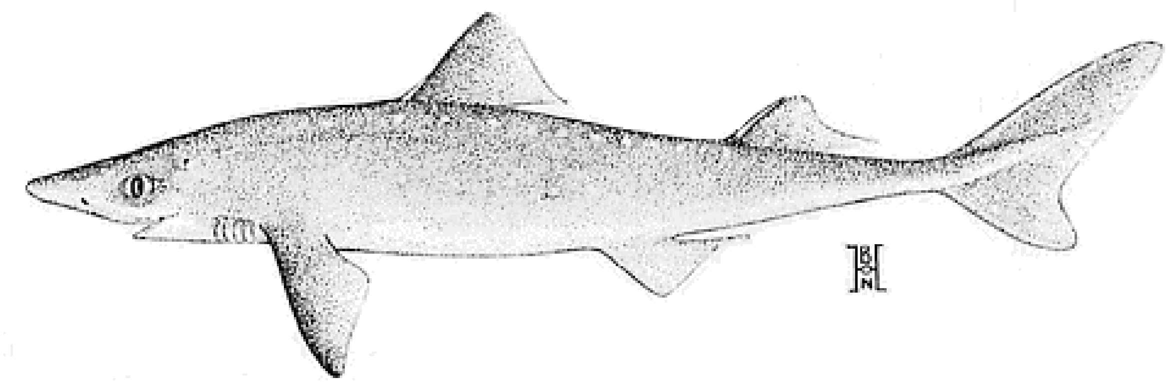
COSEWIC
Assessment and Status Report

on the

North Pacific Spiny Dogfish
Squalus suckleyi

in Canada



SPECIAL CONCERN
2011

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

COSEWIC. 2011. COSEWIC assessment and status report on the North Pacific Spiny Dogfish *Squalus suckleyi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 45 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Production note:
COSEWIC acknowledges Steven Campana, Gordon (Sandy) McFarlane, Scott Wallace and Jacquelynne King for writing the draft report on the Spiny Dogfish (*Squalus acanthias*) in Canada and Scott Wallace for updating the provisional report to focus on the Pacific population. Both reports were prepared under contract with Environment Canada. This report was overseen by Alan Sinclair, Co-chair of the COSEWIC Marine Fishes Species Specialist Subcommittee, and has been reviewed by Peter Shelton, Lou van Guelphen, Carrie Holt, and Bruce Atlinson, members of the Marine Fishes SSC.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur l'Aiguillat commun du Pacifique Nord (*Squalus suckleyi*) au Canada.

Cover illustration/photo:
North Pacific Spiny Dogfish — Illustration by: D.R. (Bon) Harriott. Source: Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada Bulletin 180. 740 pp.

Catalogue No. CW69-14/644-2012E-PDF
ISBN 978-1-100-20217-4

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – November 2011

Common name
North Pacific Spiny Dogfish

Scientific name
Squalus suckleyi

Status
Special Concern

Reason for designation
This small shark is widely distributed in the north Pacific throughout the shelf waters of western Canada. 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, and the age of female sexual maturity (35 years) is one of the oldest. The species is subject to both targeted and bycatch fishing mortality. The species remains relatively abundant in Canadian waters, but low fecundity, long generation time (51 years), uncertainty regarding trends in abundance of mature individuals, reduction in size composition, and demonstrated vulnerability to overfishing are causes for concern.

Occurrence
Pacific Ocean

Status history
Designated Special Concern in November 2011.

COSEWIC
Executive Summary

North Pacific Spiny Dogfish
Squalus suckleyi

Wildlife species information

North Pacific Spiny Dogfish (*Squalus suckleyi*) is an easily identified small shark, with spines in front of both dorsal fins. Until recently, this species was considered to be the same as *Squalus acanthias* in the Atlantic and south Pacific; however, a recent review has reclassified it as a separate species. The colouration is typically grey-brown with irregular white spots on sides and back.

Distribution

Spiny Dogfish occurs on the continental shelf, from the intertidal to the shelf slope, in temperate and boreal waters. Waters off British Columbia comprise a large portion of the core range of Spiny Dogfish in the northeast Pacific with concentrations in the Strait of Georgia, on the continental shelf of west coast Vancouver Island, and in Hecate Strait.

Habitat

The widespread nature of this species both spatially and in depth indicates they can survive in a variety of habitats. They have been observed at surface waters to depths of 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, the longest of any known vertebrate, 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. The age of 50% female maturity is 35 years and the generation time is estimated at 51 years. These life history features make them highly susceptible to overexploitation and stock depletion.

Spiny Dogfish do not have many known predators. In the Pacific, adults are likely preyed upon by large pelagic fishes (other sharks, swordfish), sea lions, Harbour Seals, and Elephant Seals. Pups have been found in the stomach contents of Lingcod and Sablefish. Fishing mortality is the largest known cause of mortality for adult Spiny Dogfish. Spiny Dogfish are opportunistic predators preying upon a wide variety of fish and invertebrate species that change by locality, depth, and season.

Information is limited in the northeast Pacific, but based on tagging studies there appears to be an offshore stock extending from Alaska to Baja California and two coastal stocks, one in the Strait of Georgia and the other in Puget Sound. In this report North Pacific Spiny Dogfish is assessed as a single designatable unit (DU).

Population sizes and trends

Commercial and survey indices for Spiny Dogfish do not provide a clear and coherent picture of how the population has changed over time. Declines can be inferred from some series but this is not consistent across series. Research surveys tend be either of short duration relative to the generation time of Spiny Dogfish, intermittent, variable or cover only parts of the spatial distribution.

The relative percentage of larger Spiny Dogfish throughout Canada’s Pacific waters is much lower at the present time than at earlier time periods (1960s-1980s). A decline in large individuals in a population can be caused by high exploitation rates. Other explanations for reduction in large fish include a possible change in habitat utilization but this has not been demonstrated.

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 (lowest of 26 Pacific shark species analyzed), low fecundity, long life span, and sex-and size-segregated aggregations all contribute toward the Spiny Dogfish’s vulnerability to fishing.

The Spiny Dogfish fishery is managed by Fisheries and Oceans Canada. They consider it unlikely that deleterious or irreversible declines in stock abundance are likely to occur over the next 5 years at the current (2000-2009) level of removals. The fishery is managed by catch quotas and the quota for the offshore stock has been considerably greater than the catch ever since the quota was established. It is therefore not clear that the quota would afford adequate protection should the catch of Spiny Dogfish increase to match an increase in demand.

Special significance of the species

The Spiny Dogfish is an 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 lubricants, lighting, and vitamin A, its flesh for fertilizer, food, 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 International Union for the Conservation of Nature (IUCN) has assessed the Pacific population of Spiny Dogfish as "*vulnerable*". Spiny Dogfish fisheries are managed by setting total allowable catches and associated quotas. The scientific basis for the quota has not been established in the absence of estimates of population size. It is therefore not clear that the quota would afford adequate protection should the market demand increase for the species. Finning, the process of removing and selling only the fins, is prohibited in Canada. However, fins can be sold if the rest of the shark is being sold for meat.

TECHNICAL SUMMARY

Squalus suckleyi
North Pacific Spiny Dogfish — Aiguillat commun du Pacifique Nord
Range of occurrence in Canada:Pacific Ocean

Demographic Information

Generation time (estimated as age of 50% maturity + 1/natural mortality)	51 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? *There are 9 time series of abundance. The most reliable index has a slightly increasing trend over the past 10 years, but 7 of the 9 series indicate declining trends. None of the time series span 1 generation, let alone 3. Most cover only a portion of the species range and have high interannual variability.*	Clear population trends not established
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Clear population trends not established
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Clear population trends not established
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	N/A
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence *Area based on the size of the continental shelf comprising the spatial extent of Spiny Dogfish.*	118,000 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)).	94,000 km²
Is the total population severely fragmented?	No
Number of locations∗ *Overfishing is considered the sole threat to the species. Fisheries for Spiny Dogfish are managed in 2 areas, the Strait of Georgia and the "Outside" waters. Overfishing is not thought to be occurring and the location concept does not currently apply.*	NA
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	Unknown, not likely decreasing

∗ See definition of location.

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?	No
Are there extreme fluctuations in number of locations∗?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Minimum estimate from synoptic trawl surveys	100,000
Total	at least 100,000

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)

Overfishing (directed and as discarded bycatch) is the single largest threat. The fisheries are managed by Fisheries and Oceans Canada and it is unlikely that overfishing is currently occurring.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? USA: NE Pacific (Alaska) – stable, increasing over the last decade	
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?	Yes

Current Status

COSEWIC: Special Concern
IUCN (Pacific): Vulnerable

Status and Reasons for Designation

Status:	**Alpha-numeric Code:**
Special Concern	

Reasons for Designation:
This small shark is widely distributed in the north Pacific throughout the shelf waters of western Canada. 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, and the age of female sexual maturity (35 years) is one of the oldest. The species is subject to both targeted and bycatch fishing mortality. The species remains relatively abundant in Canadian waters, but low fecundity, long generation time (51 years), uncertainty regarding trends in abundance of mature individuals, reduction in size composition, and demonstrated vulnerability to overfishing are causes for concern.

∗ See definition of location.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Does not meet the criterion. While clear population trends have not been established, it is unlikely the population has declined to the extent needed to meet this criterion.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not meet the criterion. The population is widely distributed throughout the marine environment off western Canada.
Criterion C (Small and Declining Number of Mature Individuals): Does not meet this criterion. The minimum estimate of the number of mature individuals is 100,000.
Criterion D (Very Small or Restricted Total Population): Does not meet the criterion. The number of mature individuals and the area of occupancy exceeds the thresholds, and the ‘locations’ concept does not apply.
Criterion E (Quantitative Analysis): Not done

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2011)

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

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

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

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

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

Canada

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

COSEWIC Status Report

on the

North Pacific Spiny Dogfish
Squalus suckleyi

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2011

TABLE OF CONTENTS

List of Figures

List of Tables

WILDLIFE SPECIES INFORMATION

Name and classification

Spiny Dogfish historically constituted two species, *Squalus acanthias* (Linneaus 1758) in the South Pacific and the Atlantic and *Squalus suckleyi* (Girard 1855) in the North Pacific. *S. suckleyi* was then placed in synonymy with *S. acanthias* (Hart 1973). A recent taxonomic re-evaluation of the North Pacific population of Spiny Dogfish clearly reveals that this population has many distinctive traits from the widespread *Squalus acanthias* and it has been reclassified as a separate species, *S. suckleyi* by Ebert *et al.* (2010). For the purposes of this report, the species will be referred to as Spiny Dogfish.

Morphological description

Spiny Dogfish is an easily identified small shark, with spines in front of both dorsal fins (Figure 1). The maximum recorded size is approximately 130 cm total length, which corresponds to an estimated age of 90 years (DFO 2010). 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 the sides and back. These spots may disappear with age. The ventral surface is whitish.

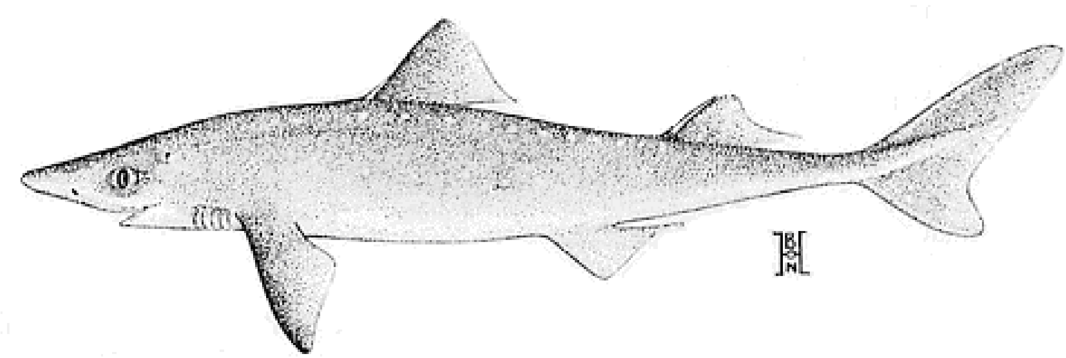


Figure 1. Spiny Dogfish (*Squalus acanthias*). Illustration by: D.R. (Bon) Harriott. Source: Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada Bulletin 180. 740 pp.

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 2009; Ebert *et al.* 2010; Verissimo *et al.* 2010). These genetic differences correspond well to the different life history characteristics observed between the two ocean basins (see **BIOLOGY** section) and morphological differences recently identified by Ebert *et al.* (2010).

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).

Hauser (2009) also considered samples within the northeast Pacific and in this case found no evidence of genetic differentiation (overall F_{ST}=0.000).The study used samples from six locations from California to the Bering Sea. Sample sizes ranged from 25 to 88 individuals and in total 330 Spiny Dogfish were used in the analysis. The inability to detect genetic structure does not necessarily mean that all Spiny Dogfish in the northeast Pacific are from a single self-recruiting population. Tagging data suggests there are in fact discrete stocks.

In British Columbia, there are two stocks of Spiny Dogfish; an outside stock that extends from Baja California to Alaska and an inside stock, in the Strait of Georgia (DFO 2010). McFarlane and King (2003) report that ~ 1% of individuals that have been tagged off BC’s coast were recaptured near Japan. Although extensive migrations (up to 7000 km) and interchange at regional scales have been documented, in some regions tag recaptures were close to their release site indicating the possibility of stock structure at smaller scales. Spiny Dogfish from the Strait of Georgia, based on tagging studies, infrequently leave the semi-enclosed water body (only 10-14% of recaptures were found outside of the region) (Figure 2; Ketchen 1986; McFarlane and King 2003; 2009). Furthermore, Spiny Dogfish tagged in the Strait of Georgia were rarely recaptured in Puget Sound suggesting two discrete coastal or inside stocks. Spiny Dogfish tagged on the outside continental shelf waters demonstrated extensive latitudinal and longitudinal migrations as well as movements into the Strait of Georgia.

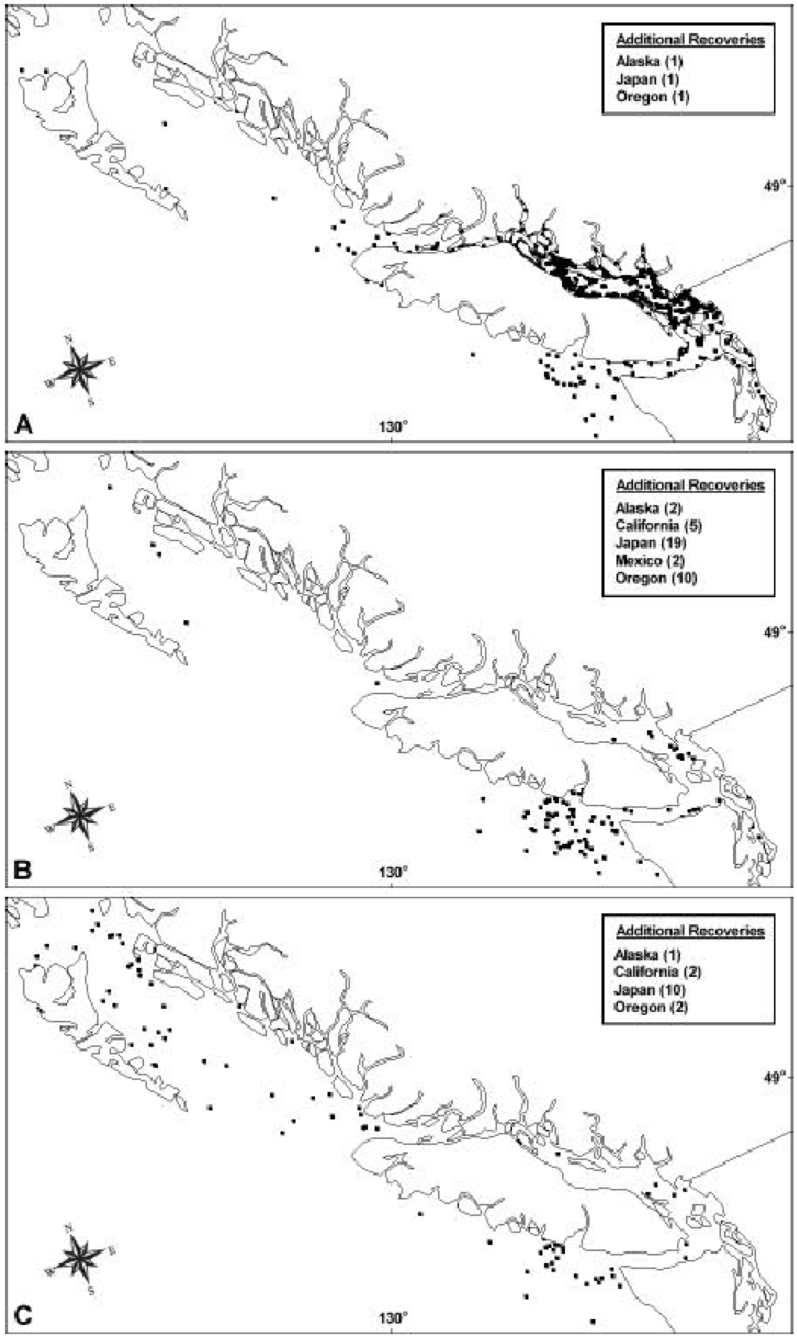


Figure 2. Recapture locations of tagged Spiny Dogfish released from 1978-1988 in: (A) the Strait of Georgia; (B) west coast of Vancouver Island; and (C) northern British Columbia. The number of additional recoveries of tagged Spiny Dogfish that occurred outside the area depicted in each figure is listed by recapture area. Source: McFarlane and King (2003).

Designatable units

The North Pacific Spiny Dogfish, although not likely from a single self-recruiting population, has insufficient known structure to comprise multiple designatable units. Tagging studies and interpretation of some surveys suggest population structuring within Canadian Pacific waters, but more detailed studies are required to confirm this. Therefore, for the purposes of this report, North Pacific Spiny Dogfish is assessed as a single designatable unit (DU).

DISTRIBUTION

Global range

In the North Pacific, Spiny Dogfish occur primarily 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 distribution in the North Pacific is shown in Figure 3 (note that this figure was drawn before *S. suckleyi* was reclassified). The species is most common in coastal waters at 10-100 m although they are found as deep as 730 m. The main populations are found in the northeast and northwest Pacific (including the Sea of Japan) (Germany CITES proposal 2003).

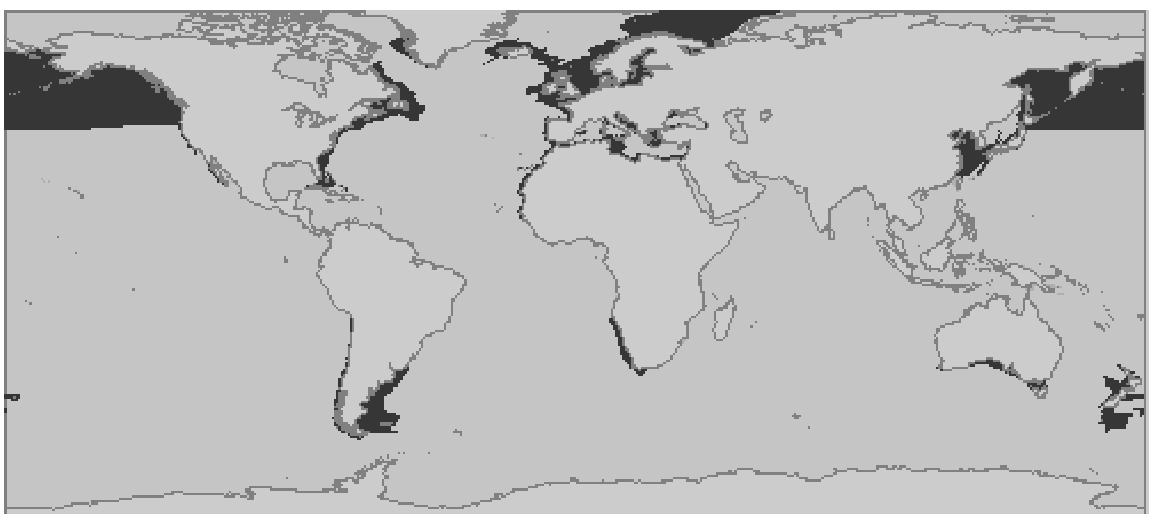


Figure 3. Global distribution of Spiny Dogfish (dark grey). Source: FAO 2004.

Canadian range

Waters off British Columbia comprise a large portion of the core range of Spiny Dogfish in the northeast Pacific. Concentrations have been found in the Strait of Georgia, on the continental shelf of the west coast of Vancouver Island, and in Hecate Strait (Ketchen 1986). The distribution in Canadian waters is best shown from the distribution of catches in the trawl and hook and line fleets (Figure 4). Seasonally there appears to be a shift from deep water in the winter to shallower shelf waters in the summer (Fargo *et al.* 1990). There is also indication that some individuals may make a latitudinal migration between Oregon waters in winter and northern British Columbia waters in summer (Ketchen 1986). There is no information to suggest a contraction or expansion of their range in Canada. The extent of occurrence is basically all shelf and inland waters, which comprises an area of 118,000 km^2; the area of occupancy is ~94,000 km^2 based on captures by the commercial fishing fleet and research surveys (Figure 4). There is some recent evidence that Spiny Dogfish abundance has increased in the Gulf of Alaska since 1990 (Goldman 2001; Courtney *et al.* 2004; Conrath and Foy 2009). This increase is possibly explained by either a northward shift in the core distribution or an increase in abundance throughout the entire northeast Pacific.

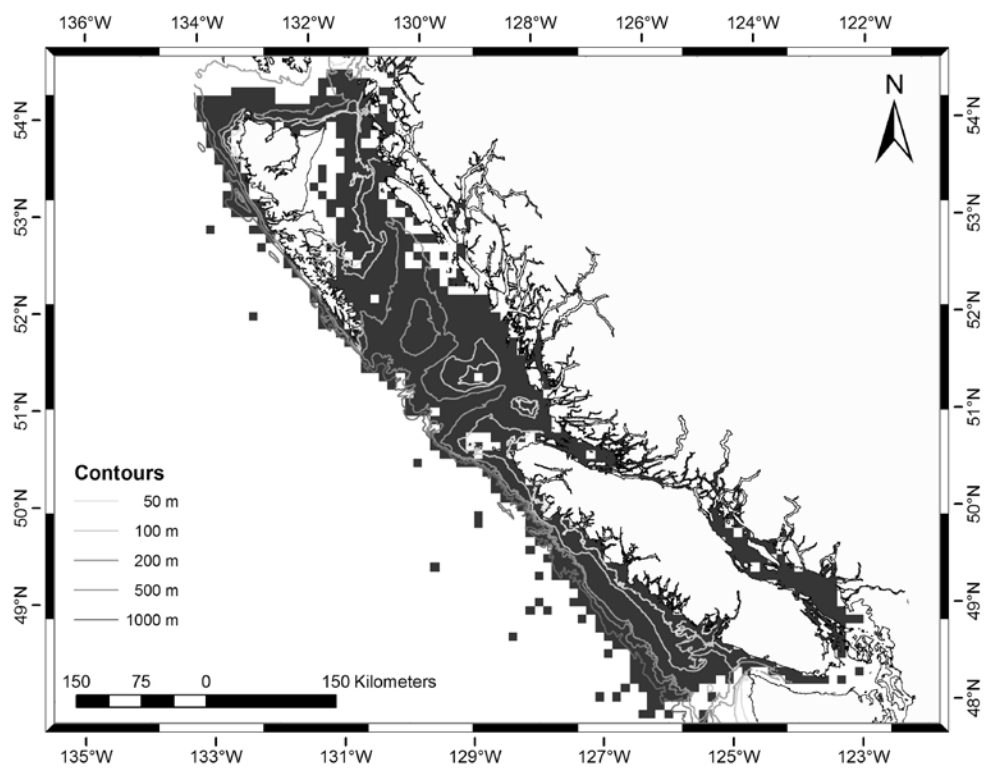


Figure 4. Distribution of Spiny Dogfish in Canada's Pacific waters based on all commercial fishing (1996-2004) and survey records. Shaded area represents presence on a 100 km^2 grid (94,000 km^2). Source: N. Olsen, Fisheries and Oceans, pers. comm.

HABITAT

Habitat requirements

The widespread nature of this species both spatially and in depth indicates they can survive in a variety of habitats. They have been observed at surface waters to depths of 730 m, from intertidal areas to well offshore, and can also tolerate a wide range of salinities including estuarine waters (Compagno 1984).

Habitat requirements have not been well defined but are likely similar to *S. acanthias* found elsewhere. Surveys from the northwest Atlantic indicate *S. acanthias* are associated with 5-15ºC bottom water temperatures throughout the year, with a preference for 6-12ºC (Kulka 2006; Campana *et al.* 2007). 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). Research has shown some size and sex segregation, which may reflect habitat preferences (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 (Campana *et al.* 2008); mating and pupping may occur here. During the summer and fall, the preference is for warmer, shallower shelf waters.

On the Pacific coast, Ketchen (1986) and Fargo *et al.* (1990) describe a seasonal pattern similar to the Atlantic with individuals moving from deep to shallower waters in the spring. The presence or absence at any given time or place is most likely explained by prey distribution (Ketchen 1986). Juvenile Spiny Dogfish on the Pacific coast are typically found in the midwater, and by the age of 18-20 years move closer to the bottom (Beamish *et al.* 1982).

Habitat trends

Numerous threats have been globally 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 a driving factor with respect to population trends.

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 of any known vertebrate. Females typically give birth once every two years.

In Atlantic Canada, mature *S. acanthias* females were found to carry 1-14 embryos with a mode of five (Campana *et al.* 2007). 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). 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).

In the northeast Pacific, the age of 50% maturity of female *S. suckleyi* has been estimated at 35.5 years (93.9 cm) (Saunders and McFarlane 1993; DFO 2010). Reproductive capacity is very low and contributes to one of the lowest population growth rates for any shark species.

Natural mortality of *S. suckleyi* is estimated to be 0.065 yr^{-1} (Smith *et al.* 1998). For this report, the generation time is estimated as the age of 50% maturity plus 1 / natural mortality, i.e. 35.5 + 1 / 0.065 = 51 years. Courtney *et al.* (2004) report generation time of Pacific Spiny Dogfish at 42 years. See Table 1 for a summary of life history parameters.

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

Parameter	Atlantic	Source	Pacific	Source
Longevity (yrs)	35-40	Nammack *et al.* 1985	80-100	McFarlane and Beamish 1987
50% mat. females (yrs)	16	Campana *et al.* 2007	35.5	Saunders and McFarlane 1993
50% maturity males (yrs)	10	"		
50% mat. females (cm)	82	"	93.5	Ketchen 1986
50% maturity males (cm)	63.6	"		
L max-female (cm)	105.7	"	125.3	Ketchen 1975
K	0.106	"	0.048	Ketchen 1975
Rate of increase/yr (%)	4.7;3.4	Heesen 2003; Smith *et al*. 1998	1.7-2.3%	Smith *et al.* 1998
Gestation period (months)	18-24	Compagno 1984	18-24	Ketchen 1986
Natural mortality (adults)	0.15	Campana *et al.* 2007	0.065	Smith *et al.* 1998
Generation time 1	25-40	Germany CITES prop. 2003	25-40	Germany CITES prop. 2003
Generation time 2	23	COSEWIC 2010	51	This report

Predation

There are few records from the Pacific coast regarding predation of Spiny Dogfish, suggesting that very few animals eat them. Pups have been found in the stomachs of Lingcod (*Ophiodon elongatus*) and Sablefish (*Anoplopoma fimbria*) (Ketchen 1986) and adults in the stomachs of Bluntnose Sixgill Shark (*Hexanchus griseus*) (Galluchi and Langseth 2009). Adults are likely eaten by most other large sharks as well as Steller Sea Lion (*Eumetopias jubatus*) and California Sea Lion (*Zalophus californianus*), Elephant Seals (*Mirounga angustirostris*) and possibly Harbour Seals (*Phoca vitulina*) (Compagno 1984; Ketchen 1986; Condit and Le Bouf 1984).

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 are not considered a 'warm-blooded' shark, and therefore would have a relatively low metabolic rate.

Dispersal/migration

Based on tagging studies, it appears that the offshore stock component of Spiny Dogfish undergoes considerable movement with 49-80% of tag recaptures occurring outside the release area (Figure 2, McFarlane and King 2003). Extensive migrations, up to 7000 km, have been observed, with animals that were tagged in Canada being recaptured as far away as Japan and Mexico. However, most of the fish tagged in the Strait of Georgia remain close to the tagging location, and <1% of the recoveries were from Puget Sound. Seasonal migration is described under **Habitat requirements**.

Interspecific interactions

Ketchen (1986) cautions against any attempt to generalize feeding habits as much depends on locality, depth and time of year. At least 60 different food items have been identified (Bonham 1954). Juveniles feed primarily on midwater invertebrates but the diet changes primarily to fish prey as they grow, with Herring being the primary prey source and to a lesser extent Pacific Hake (*Merlucius productis*) and Sardine (*Sardonix sagax*) (Ketchen 1986).

Overall, Spiny Dogfish are considered to be 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 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.

POPULATION SIZES AND TRENDS

There were several fishery-dependent and fishery-independent indices available for the species. These are summarized in Table 2. A qualitative comment is also provided regarding the suitability of each index for determining status.

Table 2. Commercial fisheries and research survey data used to assess trends in Spiny Dogfish abundance in Pacific Canada. The table summarizes the time period covered, the number of years spanned, the number of observations, the slope of a log-linear regression of the time series, the residual standard error and the percent change estimated over the span of the index and an extrapolation to 1 generation (51 years).

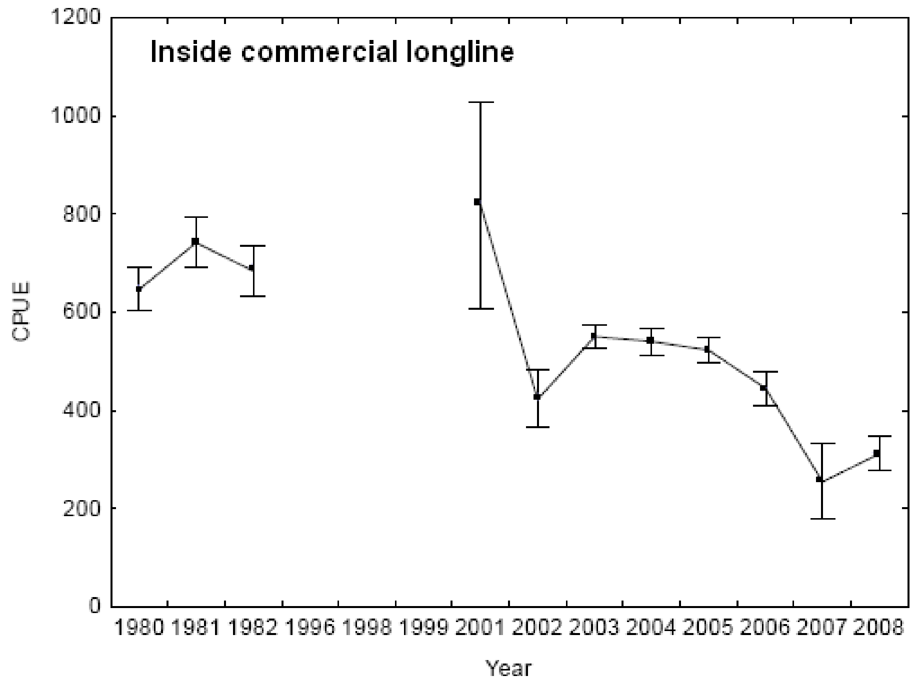
Index	Years	Span	# obs	Slope	SE	Pval	% Span	% Gen	Suitability for Status Report
Commercial Longline CPUE Inside	1980-2008	28	11	-0.0208	0.0082	0.03	-44	-65	Moderate. Years are missing. Fisheries-dependent data.
Commercial Longline CPUE Outside	1996-2008	12	11	-0.0412	0.0323	0.23	-39	-88	Moderate. Fisheries-dependent data.
Longline Survey Index Inside	1986-2008	22	4	0.0165	0.0105	0.26	44	131	Moderate. Long span but very few data points. Independent data.
Hecate Strait Assemblage Survey	1984-2003	19	11	-0.0795	0.0416	0.09	-78	-98	Moderate. Fishery-independent data, long span. Limited coverage.
Queen Charlotte Sound Synoptic Survey	2003-2009	6	5	-0.1807	0.2079	0.45	-66	-100	Poor. Short time period and limited coverage. Good for swept area abundance estimate.
Hecate Strait Synoptic Survey	2005-2009	4	3	-0.3474	0.1293	0.23	-75	-100	Poor. Short time period and limited coverage. Good for swept area abundance estimate.
West Coast Vancouver Island Synoptic Survey	2004-2010	6	4	-0.0876	0.0534	0.24	-41	-99	Poor. Short time period and limited coverage. Good for swept area abundance estimate.
IPHC Longline Survey	1998-2008	10	11	0.0021	0.0167	0.90	2	11	Very good. Coastwide coverage. Fisheries-independent data. Shown to be suitable for indexing Spiny Dogfish.
NMFS Triennial Survey	1980-2001	21	7	-0.0152	0.0336	0.67	-27	-54	Moderate to poor. Limited coverage. Last point is now a decade old. Trend influenced by two large tows.

Commercial catch and effort data

Catch with effort data were available from 1980 onwards. Commercial indices were developed based on trips where landings of Spiny Dogfish comprised at least 60% of total landing, using years with at least 30 trips that met this criterion (DFO 2010). This was done in an attempt to include only targeted fisheries. Longline effort data were sparse. For the inside area, there were only 11 years between 1980 and 2008 that had data adequate to produce CPUE estimates (Table 3 and Figure 5). The commercial longline CPUE inside index exhibits a point-to-point decline of approximately 44% from 1980 to 2008. The commercial longline CPUE for the outside stock (Table 3 and Figure 6) had observations for the period 1996-2008 and also included 12 years. The index exhibits a general decline driven by the low 2006 and 2008 data points. The point-to-point decline from 1996 to 2006 is 39%.

Table 3. Population abundance indices for Pacific Spiny Dogfish (kg/1000 hooks) from longline fishery, Spiny Dogfish longline survey, groundfish Hecate Strait survey, IPHC Longline survey, and NMFS bottom trawl survey.

	Longline CPUE				**Longline survey**		**Groundfish Hecate**		**IPHC Longline**		**NMFS Bottom**	
	Inside		**Outside**				**Strait survey**		**survey**		**trawl survey**	
Year		**SD**		**SD**		**SD**		**SD**		**SD**		**SD**
1980	647	43.35									26759	9900.8
1981	742	51.20										
1982	685	51.38										
1983											44640	16517
1984							148.07	26.69				
1985												
1986					225	14.4						
1987							190.37	52.49				
1988												
1989					301	16.254	102.18	28.81			99040	45558
1990												
1991							45.49	14.5				
1992											38650	8503
1993							87.05	17.73				
1994												
1995							46.07	12.77			14220	3697.2
1996			754	73.89			46.47	9.44				
1997												
1998			689	69.59			229.45	90.37	128	12.416	40219	7641.6
1999			438	60.88					134	12.998		
2000							88.32	21.8	105	10.71		
2001	818	211.04	500	11.50					129	9.546	29321	7037
2002	423	58.37	598	19.14			64.64	17.62	103	7.931		
2003	551	25.35	518	18.13			8.08	1.42	105	11.025		
2004	541	27.05	760	22.80					88	10.912		
2005	523	24.58	785	21.20	411	21.372			125	9.5		
2006	445	34.27	208	24.96					139	8.757		
2007	255	76.50	644	21.90					154	9.394		
2008	312	34.63	339	12.88	312	19.032			106	9.646		
	0.517774		0.724138									



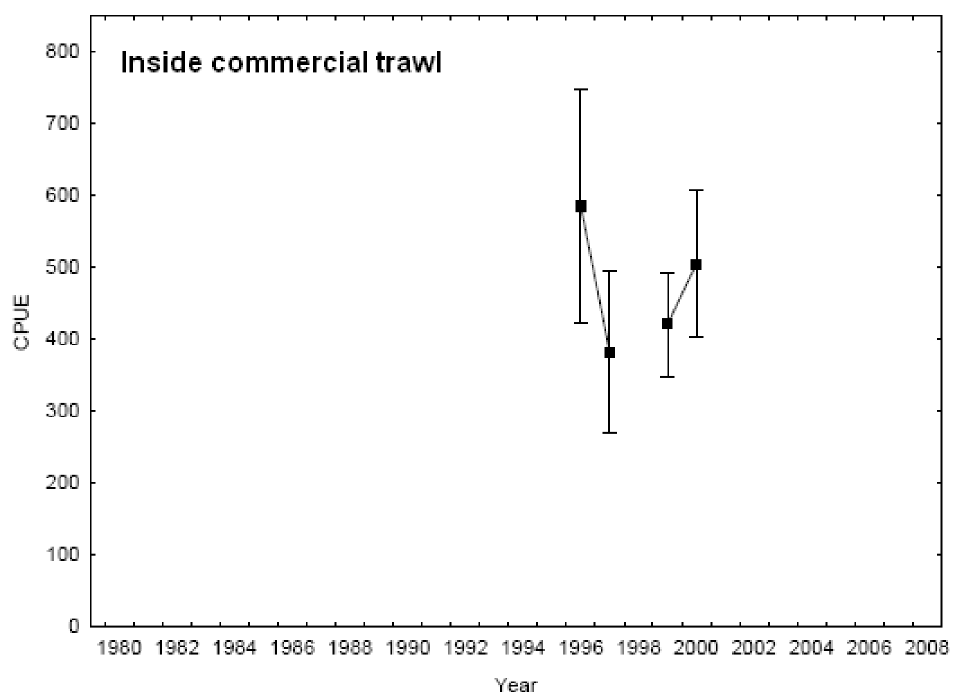


Figure 5. Inside Stock: Mean commercial longline fishery catch per unit effort (CPUE; kg per 1000 hooks; top panel) and mean trawl fishery catch per unit effort (CPUE; kg per hour; bottom panel) and standard deviation. Only trips with 60% or more of the total landings composed of Spiny Dogfish were considered, and years with at least 30 trips that met this criterion were retained. Error bars are ± one standard deviation. Source: DFO 2010.

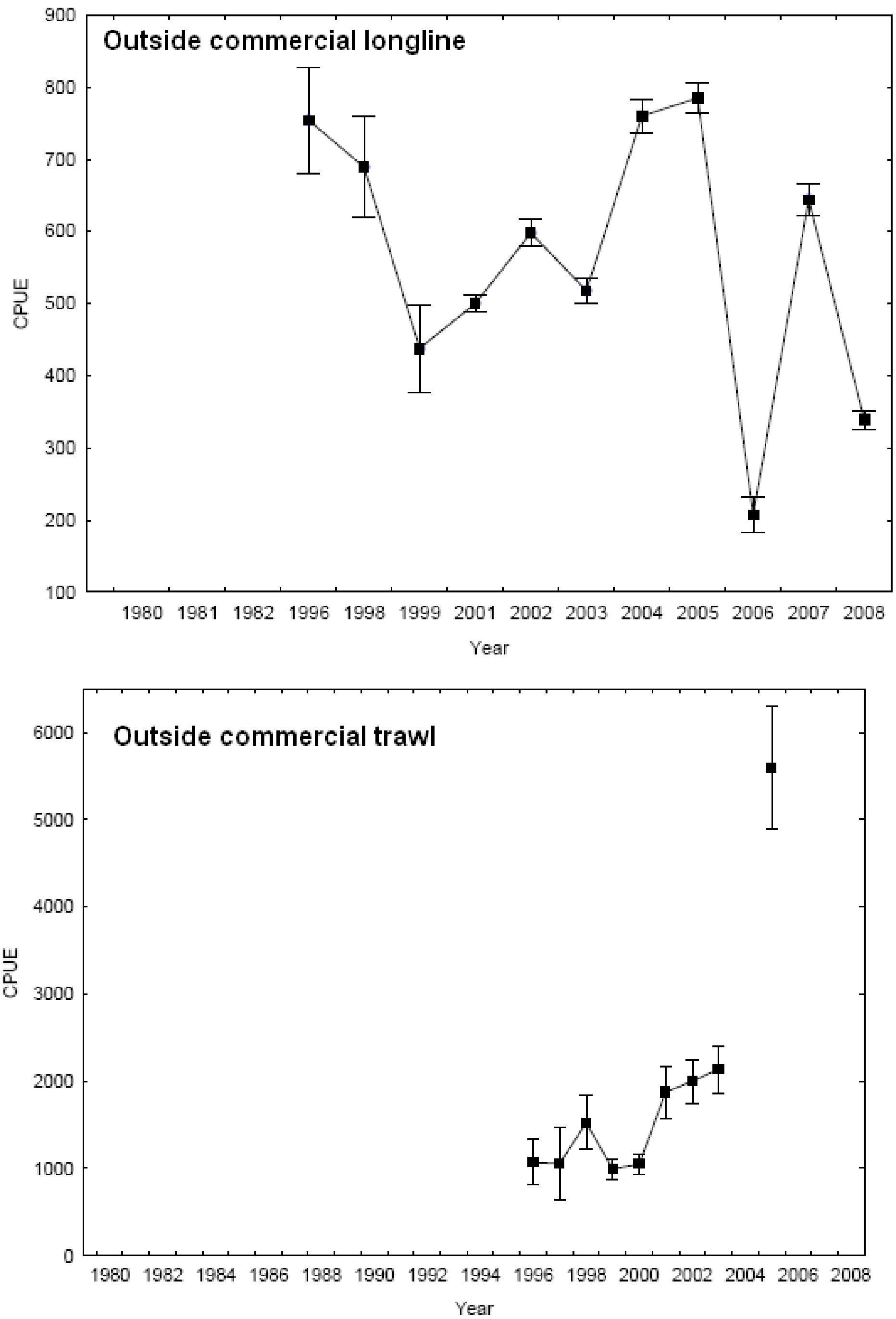


Figure 6. Outside Stock: Mean commercial longline fishery catch per unit effort (CPUE; kg per 1000 hooks; top panel) and mean trawl fishery catch per unit effort (CPUE; kg per hour; bottom panel) and standard deviation. Only trips with 60% or more of the total landings composed of Spiny Dogfish were considered, and years with at least 30 trips that met this criterion were retained. Error bars are ± one standard deviation. Source: DFO 2010.

Although trawl catch rate data by tow are available from 1996 onwards, these data likely do not indicate relative abundances due to low catch rates of Spiny Dogfish and high discard rates (Gallucci *et al.* 2011). Therefore, commercial trawl effort data are not considered here.

Spiny Dogfish longline survey (inside stock)

The DFO Strait of Georgia longline Spiny Dogfish survey has only four data points spread out over more than 20 years, 1986, 1989, 2005, and 2008 (Table 2 and Figure 7). The average of the last two data points is higher than the average of the two data points twenty years previous.

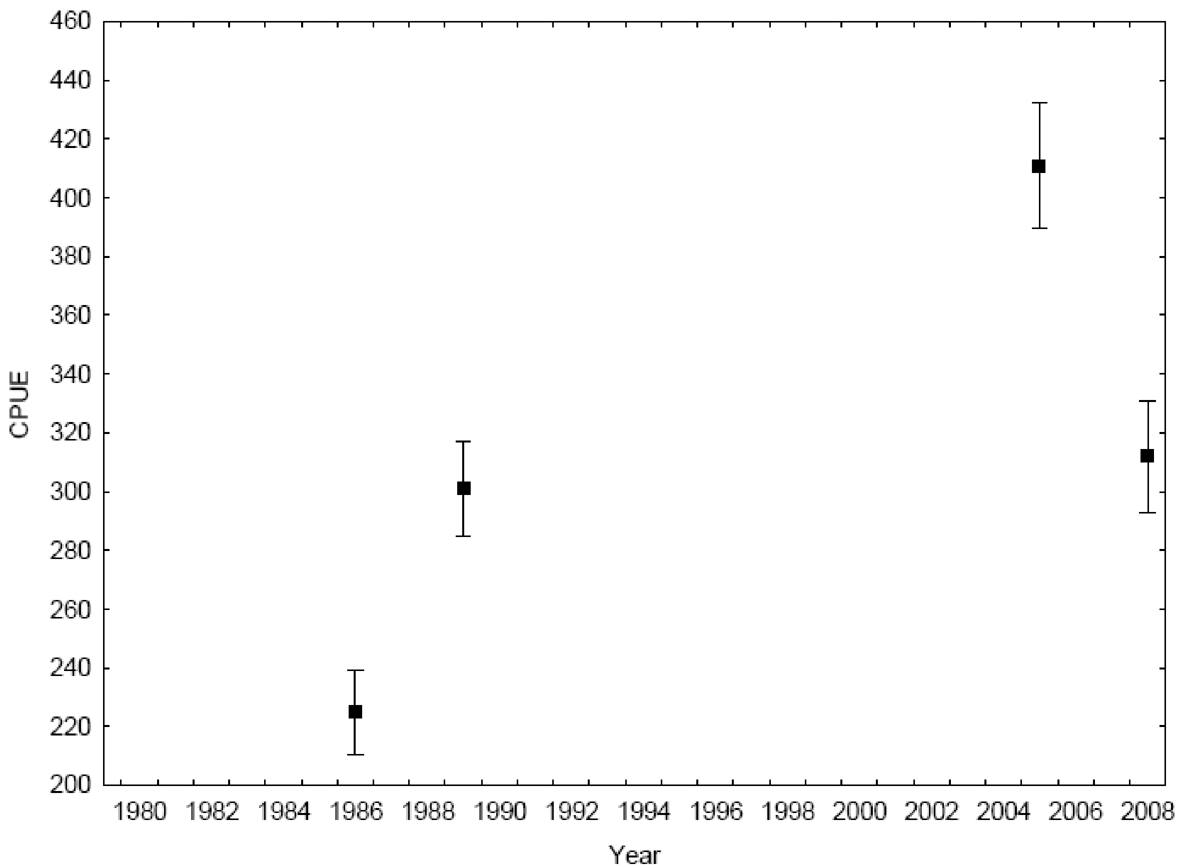


Figure 7. Spiny Dogfish mean catch per unit effort (CPUE; kg per 1000 hooks) and standard deviation for the targeted Spiny Dogfish longline survey conducted for the inside stock. Error bars are ± one standard deviation. Source: DFO 2010.

Multispecies trawl surveys

Hecate Strait trawl survey (1984-2003)

The Hecate Strait trawl survey is a systematic stratified survey typically carried out on an annual or biannual basis. All sets used in this analysis were taken between May 25 and June 26, but the exact timing changed for each year presented. The relative distribution of Spiny Dogfish and survey location is shown in Figure 8. The mean catch rate of Spiny Dogfish in 2003, the last year in the time series, measured as CPUE (kg/hr) was the lowest in the time series at 8.9 kg/hr (Table 2 and Figure 9). The timing of the Hecate Strait survey straddles the period in which Spiny Dogfish move from deeper to shallower waters, and therefore it is possible that the variability in the survey reflects the timing of Dogfish movement onto the banks relative to the survey timing (Fargo pers. comm. 2005).

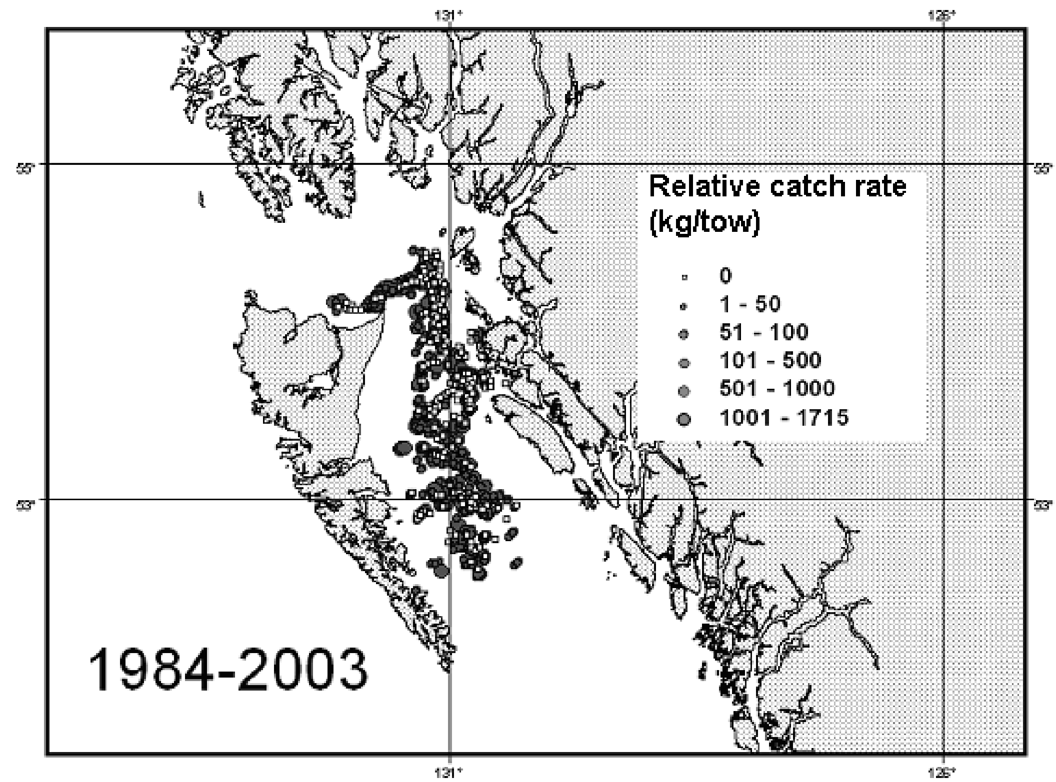


Figure 8. Distribution and relative catch rate of Spiny Dogfish in the Hecate Strait assemblage survey from 1984-2003.

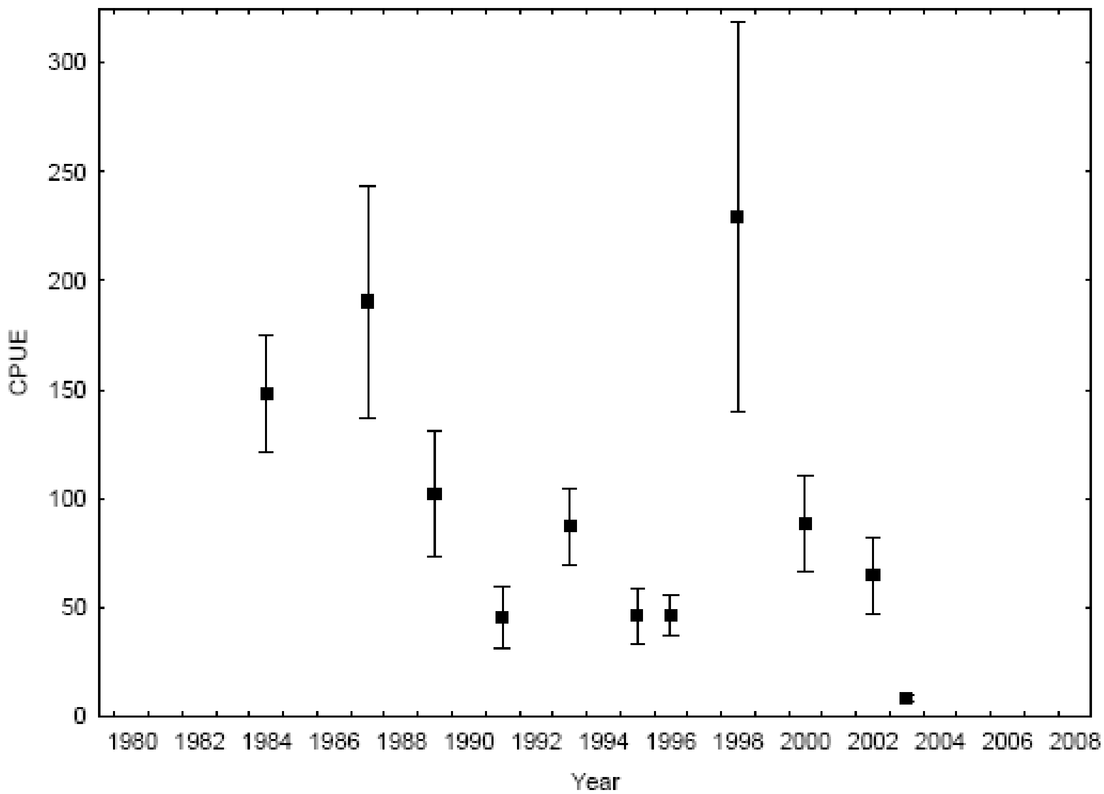


Figure 9. Spiny Dogfish mean catch per unit effort (CPUE; kg per hour) and standard deviation for the groundfish Hecate Strait (outside stock) trawl research surveys from 1982-2003. Note that the survey was discontinued in 2003. Error bars are ± one standard deviation. Source: DFO 2010.

Groundfish synoptic survey (2003-2009)

Since 2003, four different synoptic surveys have been conducted covering the outside waters of Hecate Strait, the west coast of Vancouver Island, Queen Charlotte Sound, and the west coast of Haida Gwaii. The latter survey catches very few dogfish and is not considered useful as an index for the species in that area. The remaining 3 survey time series are short, making it difficult to infer trends in population abundances over time frames of interest for COSEWIC listings (3 generations). However, the surveys have been used to develop estimates of minimum biomass and population size (Figure 10, Table 4). Combined estimates of total biomass and abundance in the 3 survey areas is 24,000 t or 19.3 million individuals based on the average values in each area (Table 4). Abundance is greatest off the west coast of Vancouver Island.

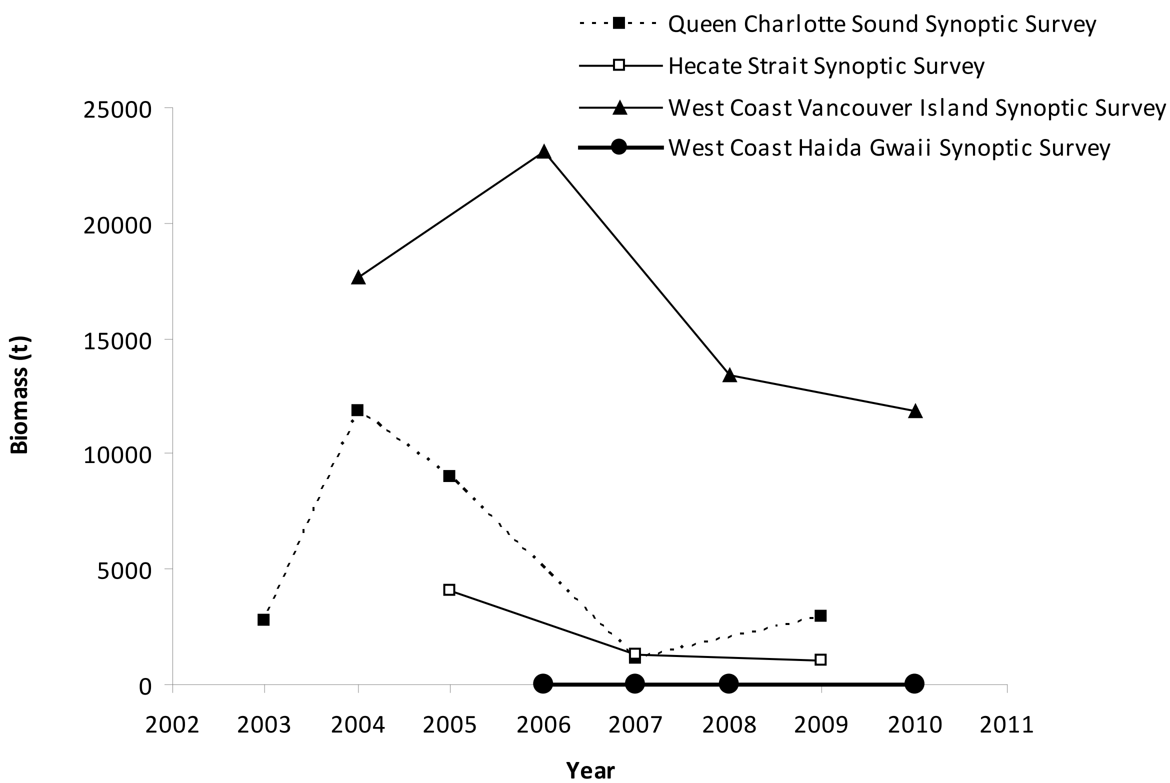


Figure10. Mean swept area biomass estimates (t) of Spiny Dogfish, all age classes, from four multispecies synoptic trawl surveys (see Table 4 for error estimates). Data source: N. Olsen, DFO Pacific Biological Station, March 2011.

Table 4. Summary of Spiny Dogfish biomass and population bootstrap estimates from the Queen Charlotte Sound, Hecate Strait, West Coast Vancouver Island, and West Coast Haida Gwaii multispecies synoptic surveys (N. Olsen, DFO Pacific Biological Station, March 2011).

Survey	Year	Catch (kg)	# sets	Non-zero sets	Biomass (t)	Median (t)	Lower 95% (t)	Upper 95% (t)	Population Size
QCS	2003	2,161	233	125	2810	2686	1218	6963	2,166,351
QCS	2004	13,790	230	89	11858	11713	917	54731	11,038,411
QCS	2005	7,187	224	122	9013	8317	3566	30819	6,101,045
QCS	2007	1,405	257	118	1084	1077	702	1740	829,869
QCS	2009	2,926	233	155	2932	2875	1674	5438	2,148,488
HS	2005	6,969	203	144	4025	3966	2216	9159	2,189,992
HS	2007	1,492	134	107	1284	1278	990	1746	835,657
HS	2009	1,307	156	111	1003	983	752	1732	746,330
WCVI	2004	11,728	90	64	17687	16775	9591	42220	11,706,484
WCVI	2006	29,466	166	139	23106	22659	11222	68547	20,827,699
WCVI	2008	18,757	163	131	13414	12767	6728	30959	12,340,034
WCVI	2010	25,573	138	116	11825	11596	7220	18733	9,280,960
WCHG	2006	40	110	7	7	7	3	16	
WCHG	2007	106	112	21	22	21	12	40	
WCHG	2008	15	118	6	2	2	1	4	
WCHG	2010	82	129	28	9	9	6	16	

IPHC standardized stock assessment survey (1998-2008)

The International Pacific Halibut Commission (IPHC) survey is the only survey presented in this report that is conducted on an annual basis and occurs coast-wide. The survey is probably the best index of abundance for the species in Canadian waters. The survey methodology and applicability to non-halibut species, including Spiny Dogfish is reviewed in Kronlund (2001) and was determined to be a suitable index of abundance for the outside stock of Spiny Dogfish. Catch rates of Spiny Dogfish in all survey years are actually greater than Pacific Halibut, the target species of the survey. A maximum of 172 stations are typically surveyed between May and September, with most of the survey effort taking place in June, July, and August when Spiny Dogfish have largely completed their seasonal migrations.

The distribution of Spiny Dogfish based on relative catch rates by station from 1998-2004 data was consistent with commercial catch and other survey data. Catch rates were greatest along the southwest coast of Vancouver Island and Hecate Strait and often exceeded 40 Spiny Dogfish per 100 hooks (Figure 11 upper panel).

In Figure 11 (lower panel), the mean catch rates (Spiny Dogfish per 1000 hooks) by station are presented for each survey year between 1998 and 2008. Throughout the entire survey area 2B, mean catch rates of Spiny Dogfish steadily declined from 1997 to 2004, but increased from 2005-2007, and declined again in 2008.

A.

B.

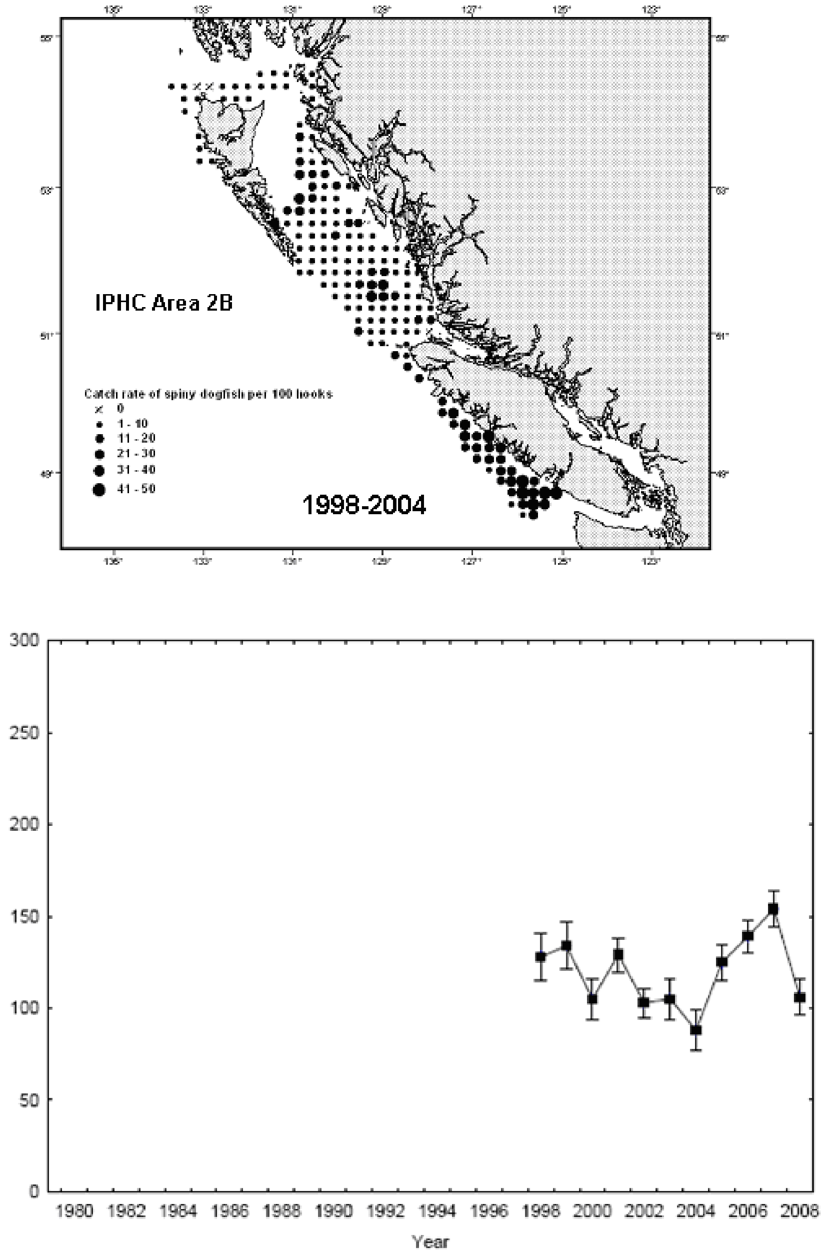


Figure 11. (A) Distribution of Spiny Dogfish in IPHC Area 2B (outside stock) shown by relative catch rates from 1998-2004 at IPHC survey stations; and (B) mean catch rate by year (1998-2008) expressed as number of fish per 1000 hooks. Data provided from the International Pacific Halibut Commission standardized stock assessment survey 1993-2008. Error bars are ± one standard deviation. DFO 2010.

U.S. National Marine Fisheries Service groundfish bottom trawl survey (1980-2001)

For over twenty years, the National Marine Fisheries Service (NMFS) conducted surveys on a triennial basis along the west coast of North America (survey described in Weinberg *et al.* 2002). Most of the survey took place in U.S. waters with only a small northerly extension into the Canadian waters off the southwest coast of Vancouver Island (Figure 12). Abundance estimates based on swept area biomass extrapolations from the survey data of Spiny Dogfish (outside stock) in the International North Pacific Fisheries Commission (INPFC) Vancouver area were provided to the authors by NMFS.

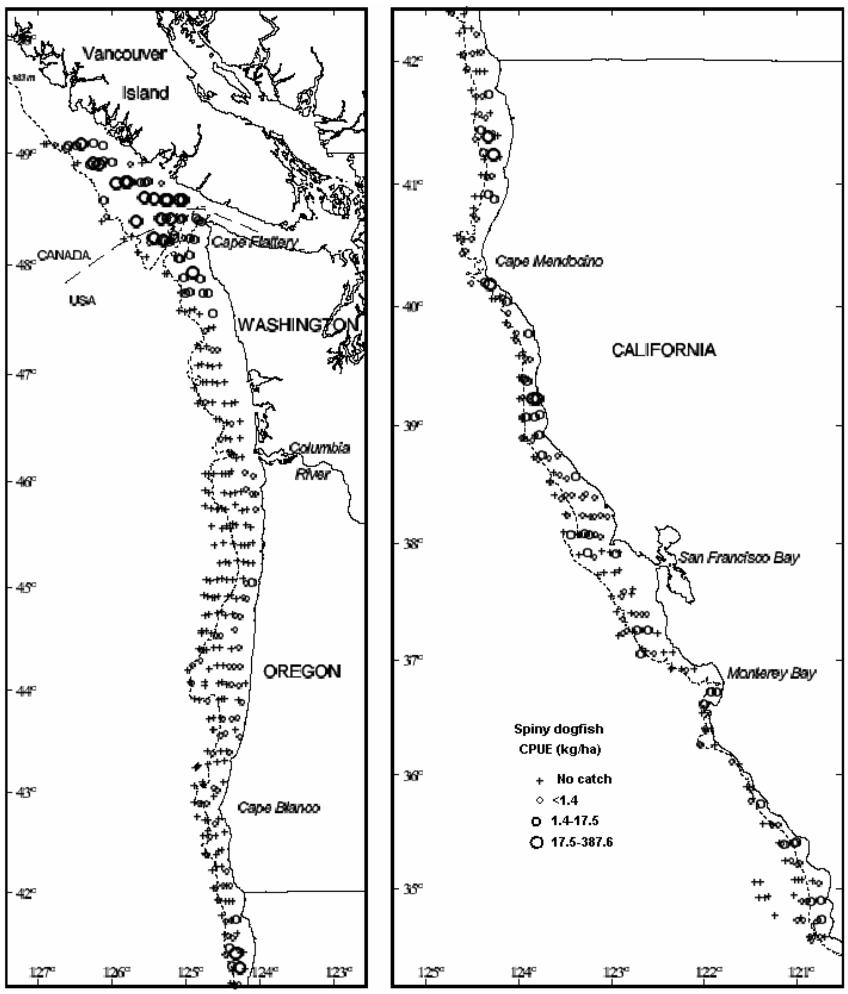


Figure 12. Spiny Dogfish distribution and relative abundance measured by catch rates (kg/ha) from the West Coast Triennial Bottom Trawl Survey. Source: Weinberg *et al.* 2002.

Any trends in abundance inferred from the survey estimates (Figure 13) are largely influenced by a single year (1989) which in turn was caused by the two largest Spiny Dogfish sets in the survey's history. It should be noted that the last data point was over ten years ago.

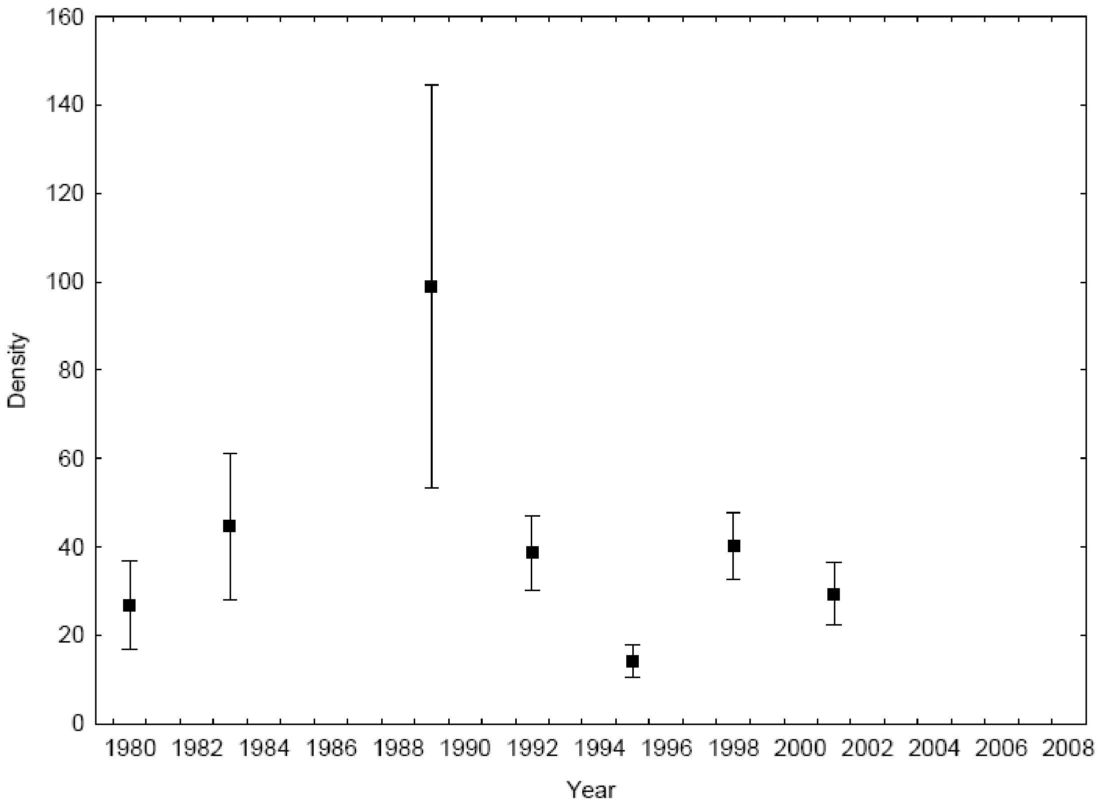


Figure 13. Spiny Dogfish mean biomass density estimates (thousand kg per km^2) and standard deviation for the National Marine Fisheries Service groundfish bottom trawl survey that extends into Canadian waters (Area 3CD outside stock). Error bars are ± one standard deviation. Source: DFO 2010.

Statistical analysis of trends in the abundance indices

The rate of change of each index was estimated from the slope of the linear regression of $\log_e$ abundance index (I_t) versus time (t, in years). The resulting regression equation is $\ln(I_t) = \alpha + \beta * t$. The percentage change over *t* years can be calculated as $(e^{\beta t} - 1) * 100$. *t* was set equal to the number of years between the first data point and the last data point in each series (the span). To compare between series the calculation was also extrapolated to 51 years (*t* = 51 years, one generation) for each series. The index values applied in the analysis are given in Tables 3 and 4 and the results are summarized in Table 2. Slopes fitted to the log index values are plotted in Figure 14.

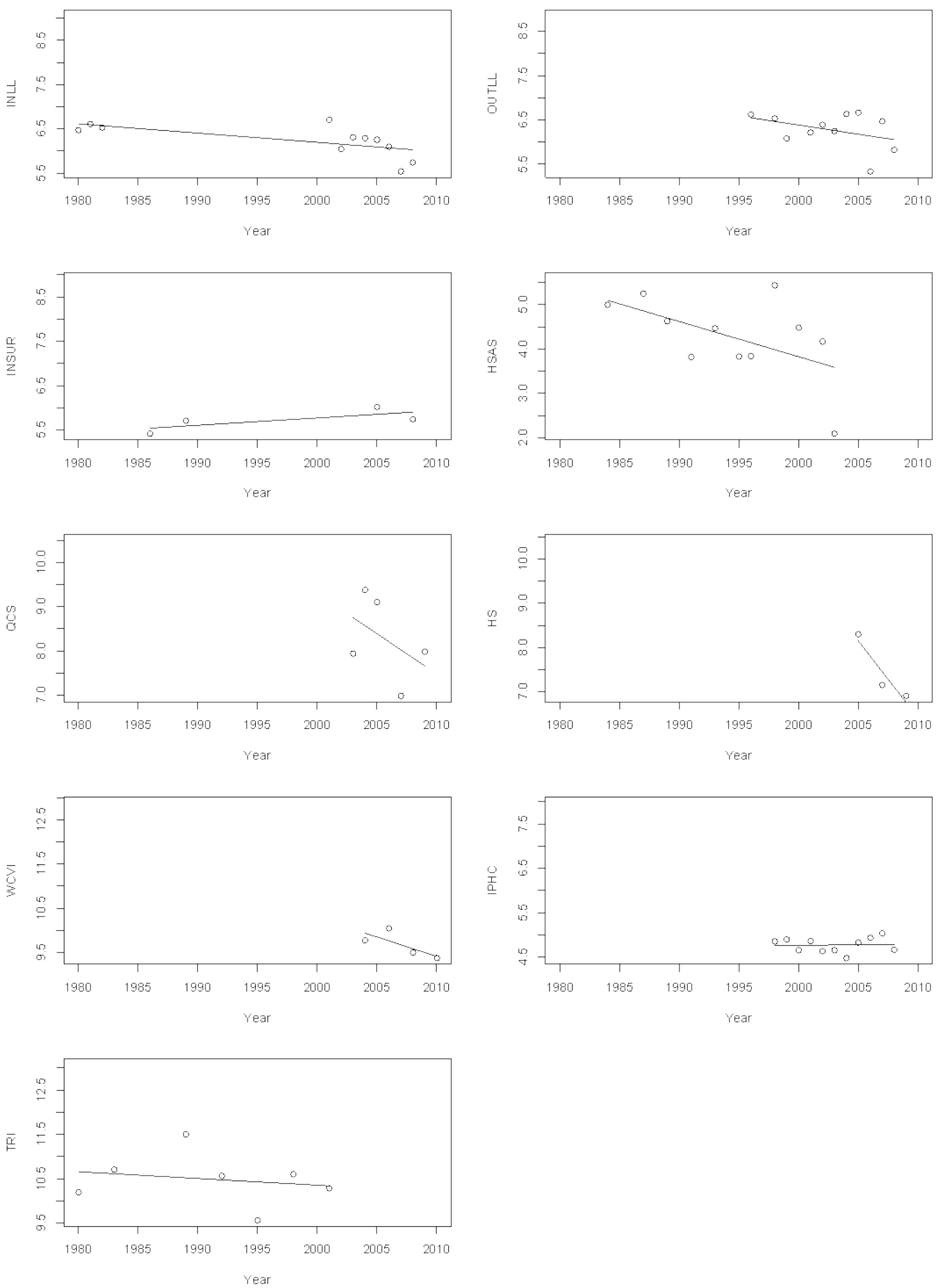


Figure 14. Log linear regressions of the various time series of Spiny Dogfish abundance. The y-axis is the natural log of the index. The y-axis labels indicate the index name: INLL=Commercial longline CPUE inside, OUTLL=Commercial longline CPUE outside, INSUR=Longline survey index inside, HSAS=Hecate Strait Assemblage Survey, QCS=Queen Charlotte Sound synoptic survey, HS=Hecate Strait synoptic survey, WCVI=west coast Vancouver Island survey, IPHC=IPHC longline survey, TRI=NMFS triennial survey.

Generally the amount of variation in the index data explained by the regression model is low (Table 2). Seven out of the nine indices have negative slopes. Of these only one is significant at the 0.05 level (commercial longline CPUE for the inside component). The Hecate Strait assemblage survey index for the outside component is significant at the 0.1 level. The decline in these two indices is 44% and 78% respectively over their span, and 65% and 98% respectively over one generation.

Summary of abundance indices

Commercial and research indices for Spiny Dogfish do not provide a clear and coherent picture of how the population has changed over time. The time series tend to be either of short duration relative to Spiny Dogfish generation time, intermittent, variable, or cover only parts of the spatial distribution. The annual IPHC Area 2B longline survey (outside stock) covers the years 1998 to 2008 and may be the most reliable index available based on the extensive spatial coverage and fishing gear used. It shows a slight (non-significant) increasing trend over the span. The inside longline survey, which spans 22 years but with only 4 annual surveys, also indicates an increasing trend. The Hecate Strait assemblage survey (outside stock) shows a declining trend (non-significant) from 1984 to 2003 when the survey was discontinued. The decline in the commercial longline CPUE series for the inside is significant at the $\alpha = 0.05$ level and corresponds to a 44% decline over the span of the time series (or 65% if extrapolated to 1 generation). The remaining commercial and research indices all have non-significant negative slopes in the log-linear analysis but they cover only portions of the species distribution in Canada.

Surplus production models based on catch and survey indices have been fitted separately for the inside and outside components of Pacific Spiny Dogfish off the west coast of Canada (Gallucci *et al.* 2011); however, the results are not considered adequate for determining stock status and the latest assessment advice is based on general considerations of the catch and survey indices (DFO 2010). This assessment draws the conclusion that it is unlikely that deleterious or irreversible declines in stock abundance will occur over a five year time frame established for the next assessment.

Trends in length frequency distributions

<u>Hecate Strait survey data 1984-2002: Outside stock</u>

Length frequency distributions of female Spiny Dogfish from 1984-2002 taken from the Hecate Strait survey indicate a striking decrease in the proportion of larger size classes (Figure 15). Although there was a survey conducted in 2003, catches of Spiny Dogfish were insufficient to generate a meaningful length frequency distribution. The percentage of females >900 mm declined from 30.5% in 1984 to only 0.9% in 2002 (Figure 16) (Wallace *et al.* 2009). These changes are likely to reflect true changes in size composition in the survey area because comparable fishing gear and sampling protocols were used throughout the survey.

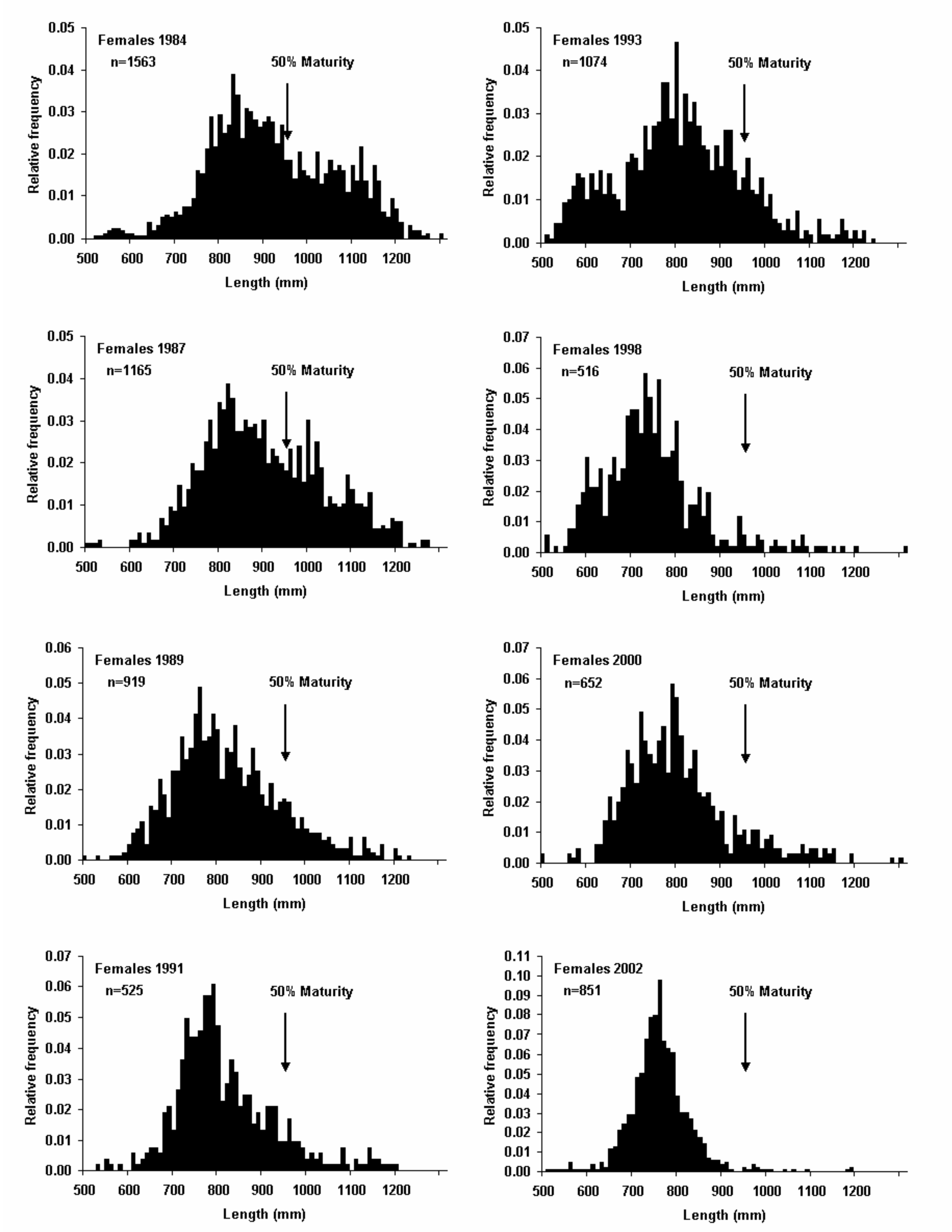


Figure 15. Relative length-frequencies of female Spiny Dogfish sampled in the Hecate Strait trawl survey between 1984 and 2002. Source Wallace *et al.* 2009.

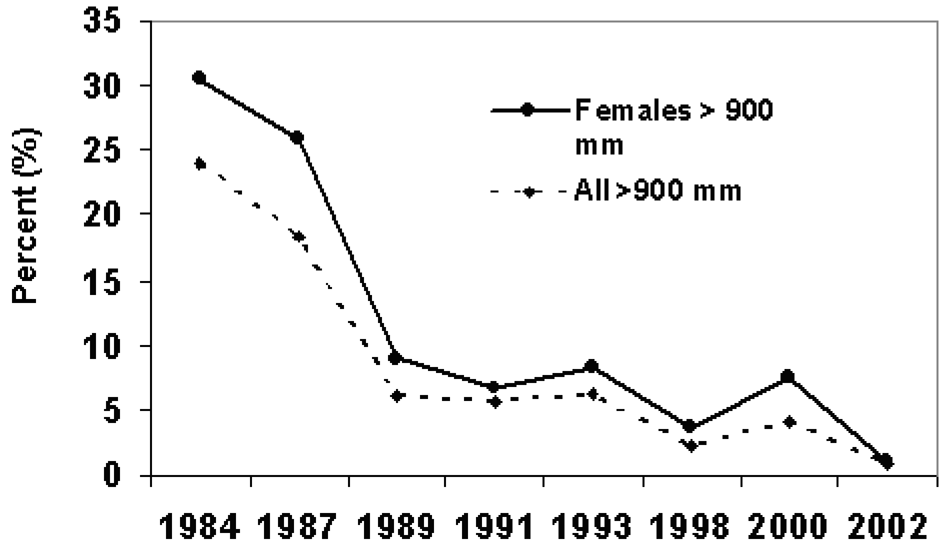


Figure 16. Percentage of Spiny Dogfish (>900mm) found in Hecate Strait trawl survey from 1984-2002. Note female size at 50% maturity is ~940 mm. Source: Wallace *et al.* 2009.

Groundfish synoptic survey (2003-2009): Outside stock

Extrapolated survey length-abundance estimates for all (male and female) Spiny Dogfish sampled in the Hecate Strait (2005, 2007, 2009), West Coast Vancouver Island (2004, 2006, 2008, 2010), and Queen Charlotte Sound (2003, 2004, 2005, 2007, 2009) synoptic surveys are presented in Figure 17. The mean lengths of Spiny Dogfish are 70 cm, 69 cm, and 68 cm and the proportion of the sampled populations greater than the length of maturity is 5.4%, 0.2%, and 0.1% for the Hecate Strait, West Coast Vancouver Island, and Queen Charlotte Sound populations respectively. Based on the population abundance estimates in Table 3 and these proportions mature, a minimum estimate of the number of mature individuals is approximately 100,000. This is a minimum estimate because it is likely that adult dogfish are under sampled by bottom trawl gear.

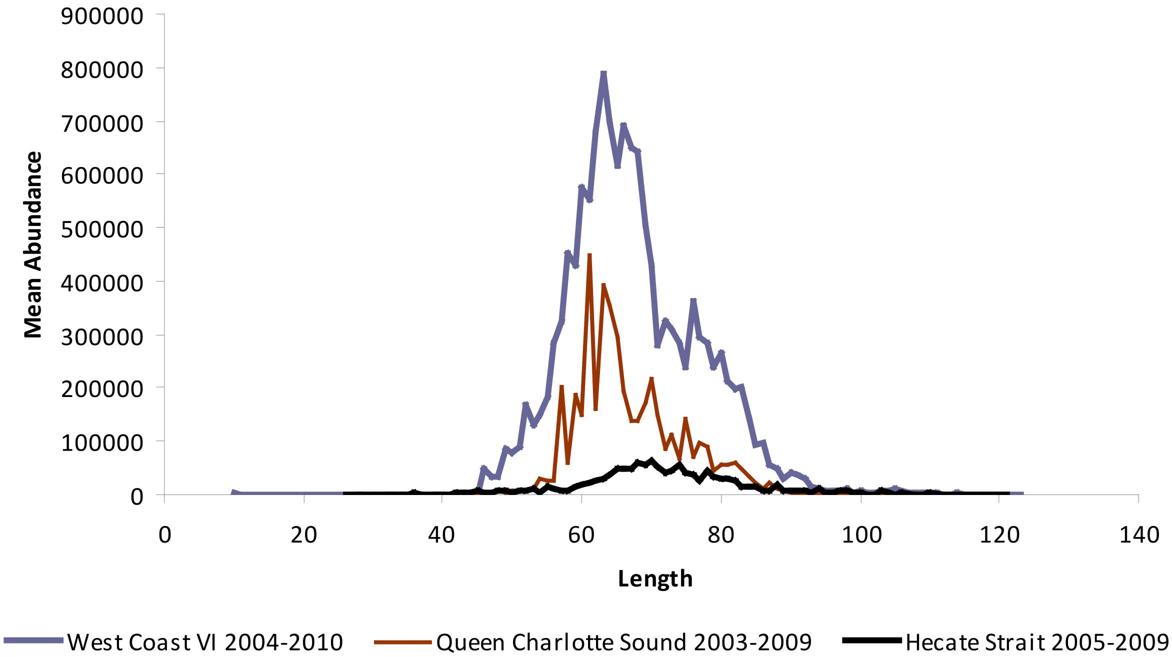
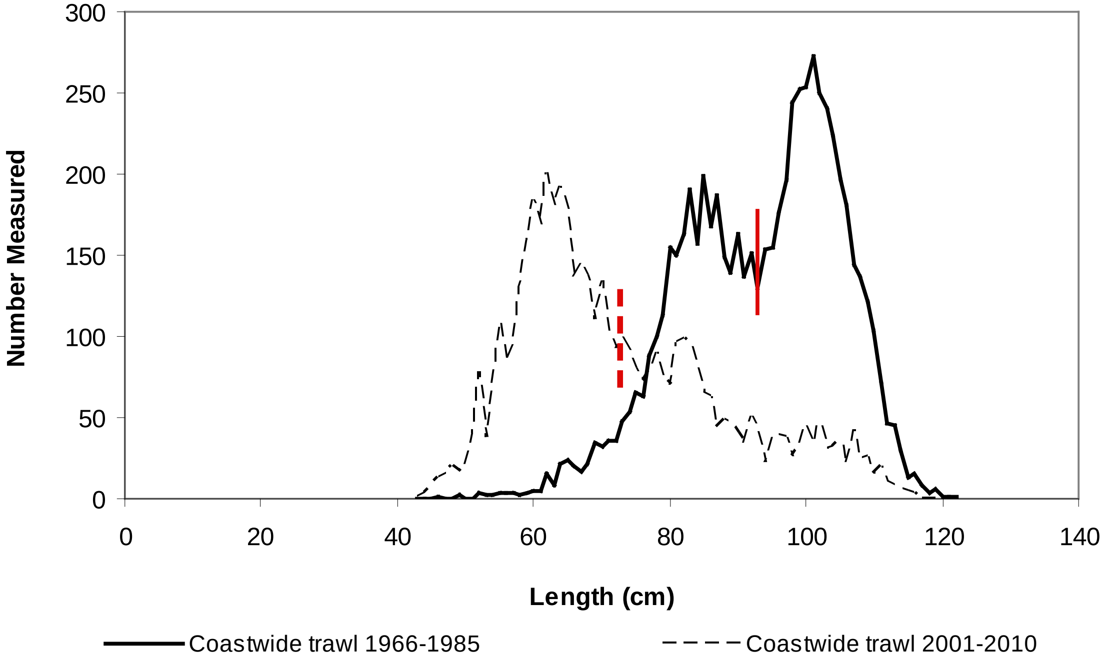


Figure 17. Extrapolated abundance at length estimates of Spiny Dogfish from West Coast Vancouver Island, Queen Charlotte Sound, and Hecate Strait synoptic surveys. Data source: DFO Pacific region GFBio database.

<u>Coast-wide commercial longline and trawl fishery</u>

Commercial length-frequency distributions from both longline and trawl fisheries taken between 1966 and 2010 indicate a reduction in the abundance of large individuals in the samples between earlier data and present time (Figure 18). The mean length in the trawl fishery declined from 93 cm (1966-1985) to 73 cm (2001-2010). This is at least partially due to the high incidence of at-sea sampling of the trawl catch in the later period before smaller fish could be discarded. The sampling in the earlier period was on shore and therefore only of the landed portion of the catch. Nevertheless, there was a noticeable absence of large mature dogfish in the trawl catches in the later time period, similar to the pattern seen in the research survey catches. The mean length in longline samples declined from 93 cm (1973-1995) to 85cm (2001-2009) (Figure 18). The proportion of individuals larger than 94 cm decreased from 54% to 12% for the trawl fishery and from 49% to 20% in the longline fishery. All of these samples were collected from landings.



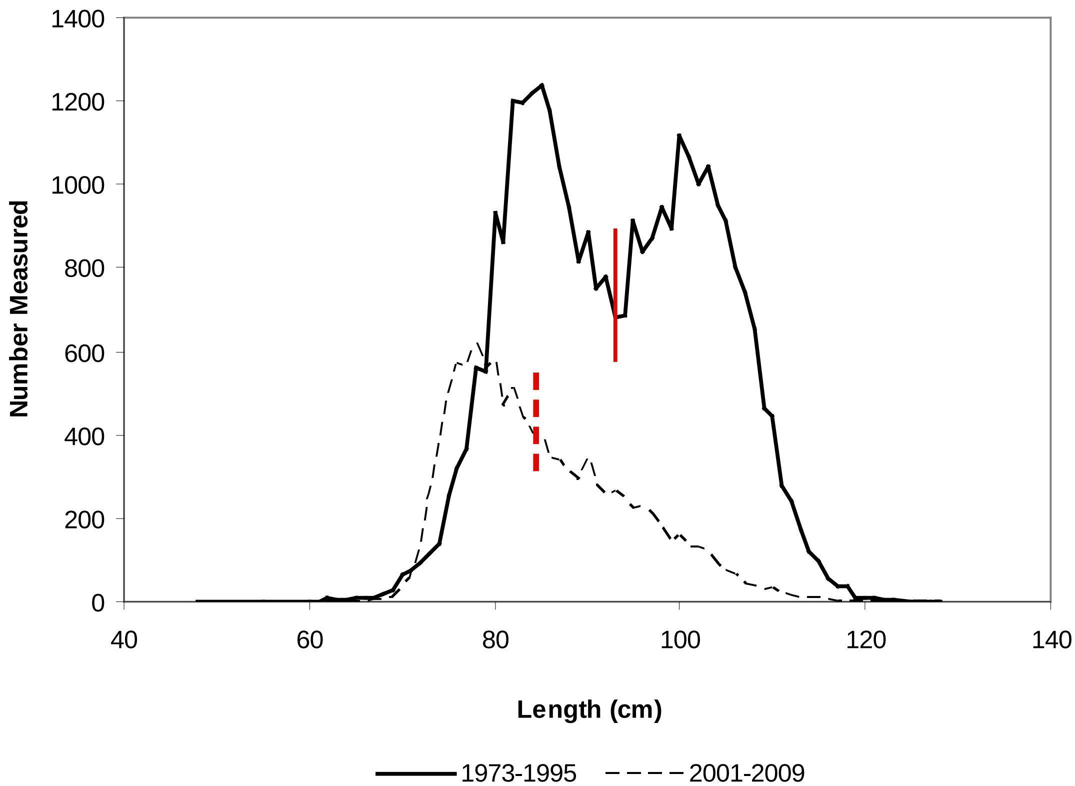


Figure 18. Historical and present length-frequency distributions of Spiny Dogfish taken from ‘unsorted’ commercial trawl fisheries (upper panel) and ‘shore sampled’ longline fisheries (bottom panel). Vertical lines intersect with the mean in each series. Source: DFO Pacific region GFBio database.

Inside waters commercial fishery and survey data

For the period 1974-2004, there was a decline in the mean size of females in the commercial longline fishery data from 124 cm (1975-1979) to 80 cm (2000-2004) (DFO 2010). For survey data, the modal length interval for males shifted from the 80-85 cm interval observed in 1986 and 1989 to the 75-80 cm interval observed in 2005 and 2006; modal length for females was not as pronounced (Figure 19; DFO 2010). The frequency distribution of female Spiny Dogfish exhibited three characteristics over time: (1) a decrease in the number of large-sized fish (>100 cm); 2) an increase in the abundance of females >90cm; (3) an increase in the number of small-sized fish (55-85 cm) (Figure 19). Large, mature fish are still present in the size composition. Given that the recent average abundance index of the inside stock (Figure 7) is higher than 20 years ago, this shift in the size distribution might reflect increased numbers of juvenile fish in bottom habitat (King and McFarlane 2009).

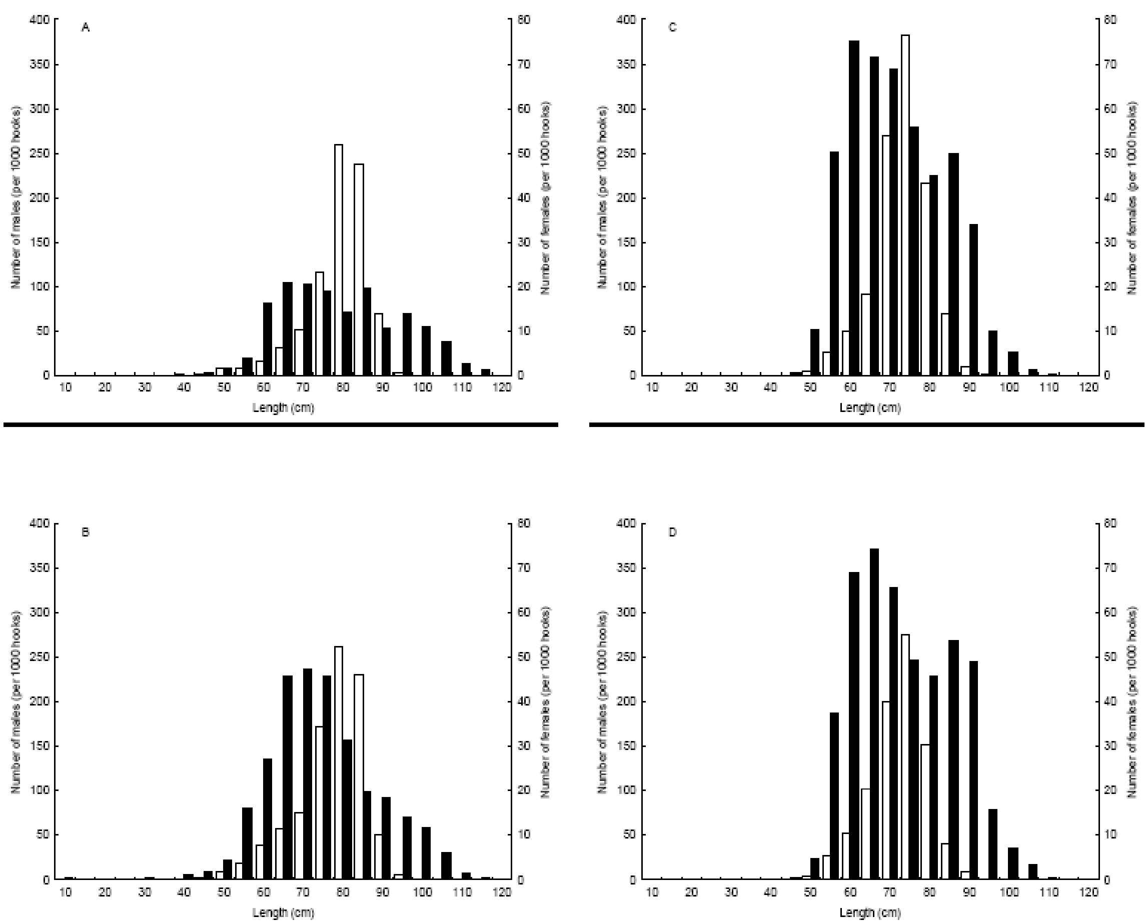


Figure 19. Inside stock frequency (number of fish) distributions of male (open bars; left axes) and female (closed bars; right axes) Spiny Dogfish captured in longline survey in A) 1986; B) 1989; C) 2005 and D) 2008 per thousand hooks. The frequencies for the 2005 and 2008 surveys were corrected for differences in gear catchability by depth as per King and McFarlane (2009). Source DFO 2010.

National Marine Fisheries Service: Outside stock

The NMFS collected length-frequency data for Spiny Dogfish from 1980-2004; however, sex was only recorded in the later part of the time series. In general very few large individuals are represented in the length frequency distributions (Figure 20). Mature females represent less than 0.5% of the individuals recorded (Figure 20 lower panel). Spiny Dogfish are known to travel in size- and sex-segregated schools, and therefore the virtual absence of large individuals from the NMFS database (all years) suggests that some form of size or sex segregation may occur in the Vancouver region (Ketchen 1986).

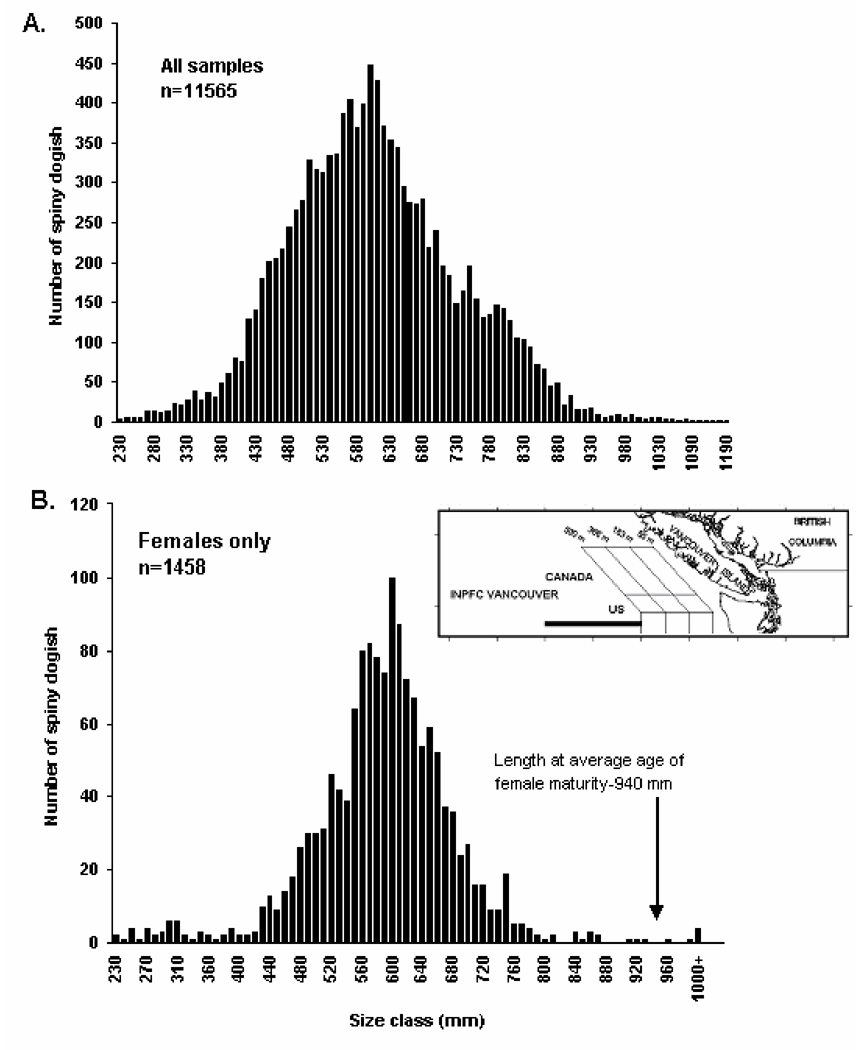


Figure 20. Length-frequency distributions of Spiny Dogfish in the INPFC Vancouver region from the National Marine Fisheries Service trawl survey database for (A) all Spiny Dogfish in database from 1986-2004; and (B) females from 1999-2004. Note: Prior to 1999 the sex of animals was not identified with the exception of a small sample in 1986.

Summary of length-frequency distributions

The proportion of large individuals has declined in both commercial and research samples over the last four decades. It is suspected that part of the decline in mean commercial size in the commercial samples can be attributed to more at-sea sampling before smaller fish can be discarded. It may also reflect market conditions favouring smaller dogfish that developed in the mid-1990s that would have likely led to the retention of smaller fish (DFO 2010). However, it is considered that this also reflects a substantial decline in large individuals in the population.

The shift in size composition was also found in the inside stock longline survey data and outside stock synoptic trawl survey data. Individuals larger the 94 cm are virtually absent from recent synoptic surveys (Figure 17) despite being present in greater proportions in earlier survey time series (Figures 15 and 16).

A decline in large individuals in a population can be caused by high exploitation rates. Other explanations for reduction in large fish include a possible change in habitat utilization but this has not been demonstrated.

Population trends in adjacent U.S. Pacific waters

There are two reliable current and published surveys adjacent to Canadian waters and both are from Alaskan waters. One survey is undertaken by the NMFS Alaska Fisheries Science Center (AFSC) every two years and the other by the IPHC on an annual basis. Aspects of these surveys relevant to Spiny Dogfish are summarized in Tribuzio *et al.* (2010). The NMFS survey indicates an increasing trend from 1983 to 2007 but then a large decline in 2009 (Figure 21). Rodgveller *et al.* (2007) report that the 2007 swept area biomass estimate for the Gulf of Alaska had increased to 161,965 mt, a series maximum. The IPHC survey data is only shown as a distribution of catch rates over the survey area (Figure 22). While insufficient to infer trend, the survey does clearly show that Spiny Dogfish are caught in large quantities throughout the survey area. Overall, both surveys indicate that Spiny Dogfish abundance is stable and possibly increasing in adjacent Gulf of Alaska waters.

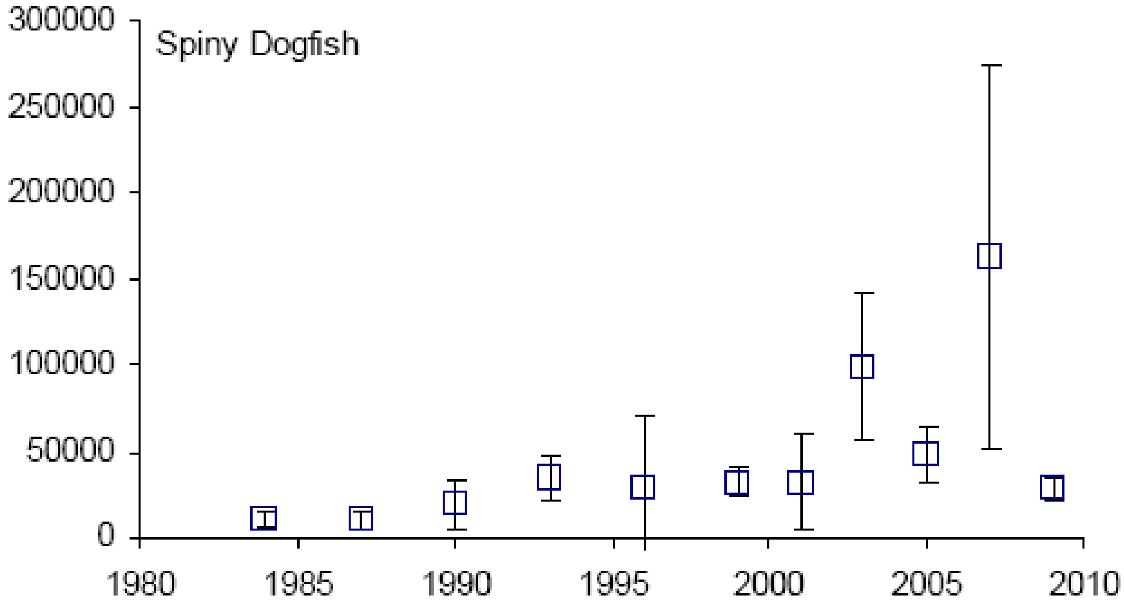


Figure 21. Trends in Gulf of Alaska AFSC bottom trawl survey estimates of Spiny Dogfish total biomass (t) reported as an index of relative abundance. Error bars are 95% confidence intervals. Source: Tribuzio *et al.* 2010.

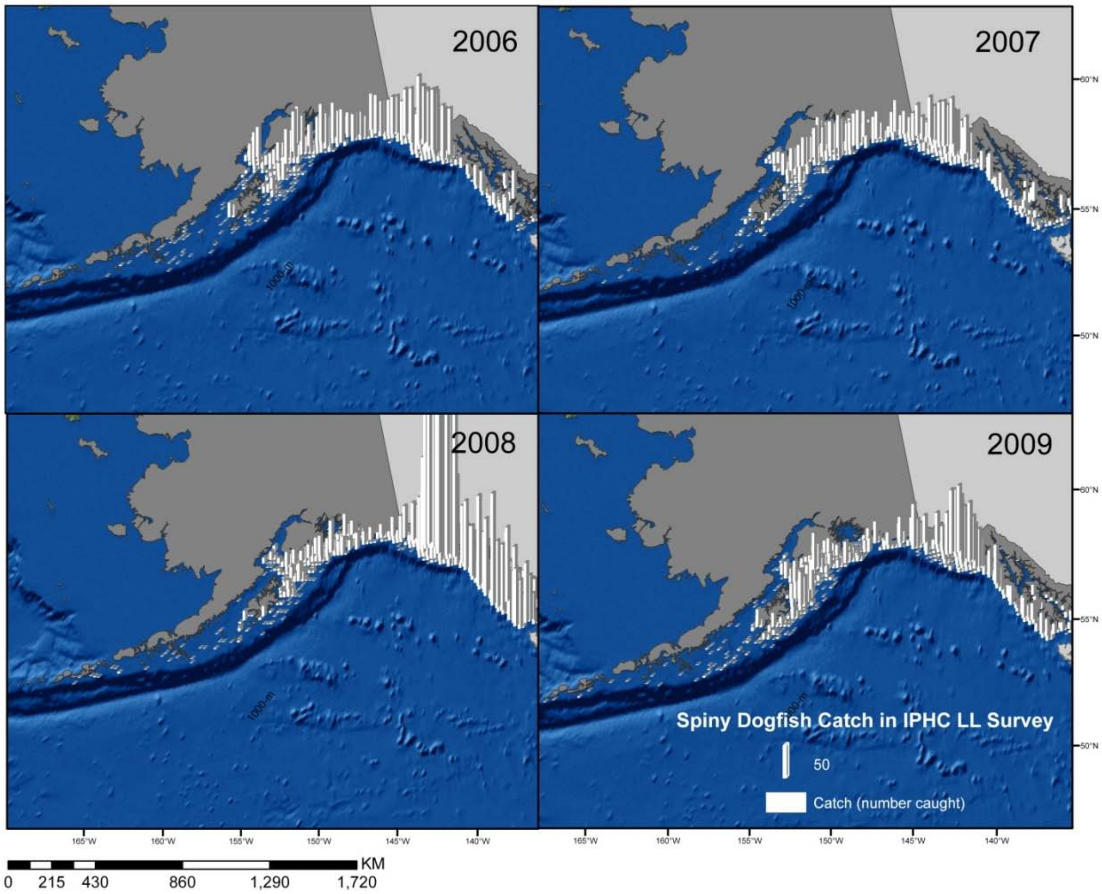


Figure 22. Spatial distribution of the catch of Spiny Dogfish during the 2006-2009 IPHC longline surveys in U.S. waters. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity. Source: Tribuzio *et al.* 2010.

Overall trend in Northeast Pacific waters: Canada and U.S.

In Canadian and adjacent U.S. waters, a variety of abundance and biological data were examined to understand the status of the Pacific Spiny Dogfish: (1) commercial catch and effort data; (2) Spiny Dogfish longline survey (inside stock); (3) historical and current multispecies groundfish trawl surveys; (4) IPHC standardized stock assessment survey; (5) National Marine Fisheries Service groundfish bottom trawl survey; and (6) length frequency information collected from various survey and commercial catch data. Overall from these data there are no obvious consistent upward or downward long-term trends. The best index of abundance, the IPHC set line survey, indicates a stable trend in Canadian waters (Figure 11) as well as a historical maximum in 2007. Similarly, the Gulf of Alaska survey (Figure 22) shows that Spiny Dogfish are widely abundant in that area. However, other less reliable surveys suggest there has possibly been a recent decline in abundance. Consequently, it is not clear what the trend in abundance has been.

The major concern around this population is indicated by the length-frequency data where there has been a decrease in the relative abundance of larger individuals sampled from Hecate Strait, commercial fisheries, and the inside longline survey. This decline does not appear to be explained by fishing effort, as it is generally accepted that the offshore stock is lightly fished and the inside stock shows an increase in abundance based on the best available survey data (DFO 2010). The change in length frequencies therefore might reflect a change in the seasonal availability of larger individuals. Overall the trend needs further investigation and continued monitoring.

Rescue effect

The rate of exchange between Canadian and U.S. waters is partly known (McFarlane and King 2003). The available evidence suggests that there is considerable interchange between Spiny Dogfish found off Canada's southwest coast with those found in adjacent U.S. waters to the south, little exchange between the Strait of Georgia and Puget Sound stocks, and little exchange between northern British Columbia Spiny Dogfish with those found in U.S waters to the south (Figure 2).

The Strait of Georgia stock would not likely receive any rescue effect from the adjacent Puget Sound stock. Palsson (2009) reports that the Puget Sound stock is at a low level of abundance, and based on tagging evidence it is not expected that the Puget Sound stock will contribute much of a rescue effect to Canadian stocks (McFarlane and King 2003).

Movement of Spiny Dogfish into and out of Alaskan waters is unknown. Recent surveys in Alaskan waters (Figures 17 and 18) show that Spiny Dogfish are widespread, abundant, and increasing (Conrath and Foy 2009). It is likely that there is some exchange between the outside stock in Canada and Alaska and these likely belong to the same population.

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, sex and size segregation, and dense aggregations all contribute toward the Spiny Dogfish's vulnerability to overfishing (Ketchen 1986). 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 fishing mortality is greatly reduced or removed (Wood *et al.* 1979; Ketchen 1986).

The commercial fishery for Spiny Dogfish in Canada's Pacific waters has a long and varied history dating back to 1870 (see reviews in Ketchen 1986; Bonfil 1999). Catches peaked at over 12,000 t for the inside stock and over 25,000 t for the outside stock during the liver fishery in the early 1940s (Figure 23). Landings reached low levels in the 1960s. Since the late 1970s, Spiny Dogfish has been fished as a source of food using longline and trawl gear, with total annual landings averaging approximately 1,500 t for the inside stock, and 1,600 t for the outside stock.

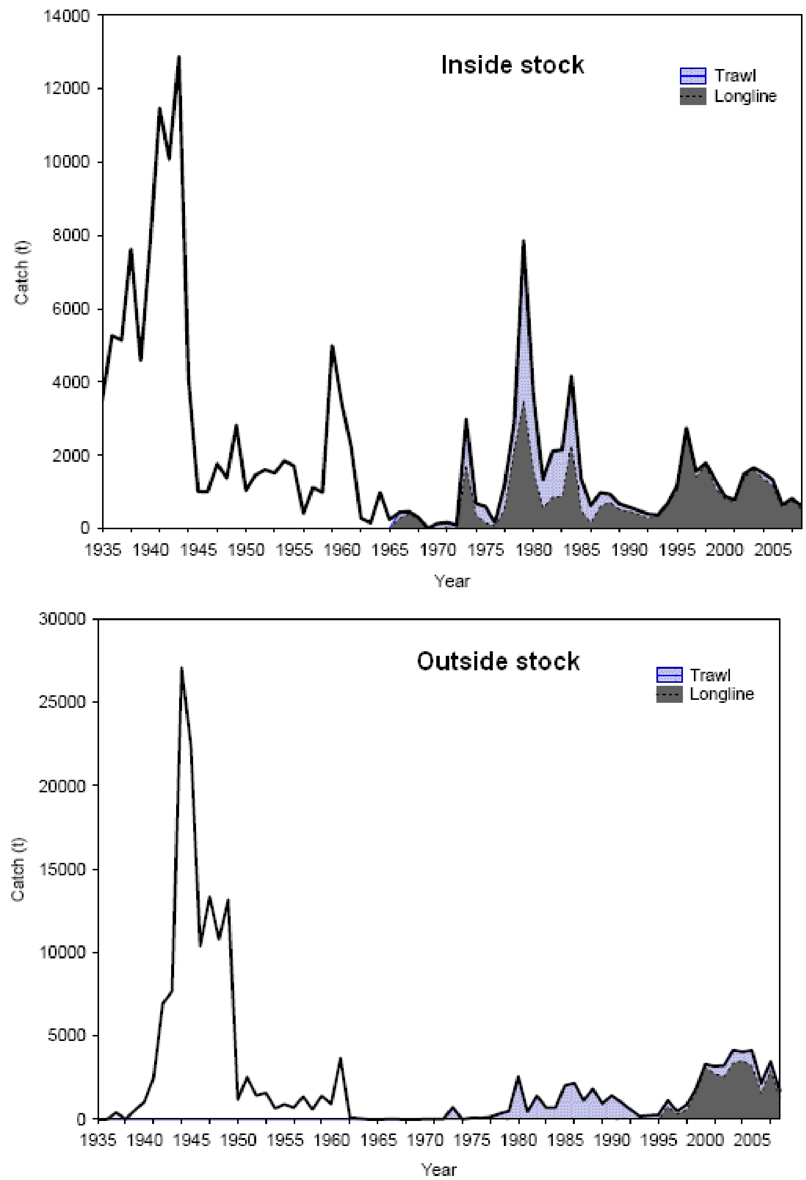


Figure 23. Total Canadian landings and discards (tonnes) of Spiny Dogfish in the inside stock (top panel) and the outside stock (bottom panel) from 1935-2008. From 1966 onwards, total mortality is estimated separately for trawl (hatched area) and longline (solid area) gear. Solid black line is total mortality for all gear types combined. Source: DFO 2010.

Spiny Dogfish in British Columbia are managed with annual quotas for the inside and outside stocks that were first recommended in 1980, based on a population model. The TAC for the outside stock was initially set at 15,000 t and was decreased to 12,000 t in 1994. The TAC for the inside stock was initially set at 3,000 t, decreased to 2,500 t in 1994-1995, increased to 5000 t in 1996-2004, and decreased again to 3,000 t in 2005 and reduced to 2,000 t in 2011.

Twenty years ago Saunders (1989) estimated the coast-wide biomass, including U.S. waters, to be 280,000 t, of which one half to two-thirds likely resided in Canada (i.e., 150,000-200,000 t). Subsequent Canadian catch estimates, including discards are low in comparison.

A more recent stock assessment (Galluci *et al.* 2011) was unsuccessful in producing quantitative estimates of stock size suitable for establishing catch quotas. Nevertheless, and based on qualitative evidence, DFO (2010) concluded that there is no immediate conservation concern for either the inside or outside stocks of Pacific Spiny Dogfish and that, given the perceptions of the current stock status, it is unlikely that deleterious or irreversible declines in stock abundance are likely to occur over the next 5 years at the current (2000-2009) level of removals. Currently, neither the trawl nor hook and line fisheries fulfill their combined annual quotas. Discards have been recorded by a 100%-coverage observer program in the Option B trawl fleet since 1996 and a combination of a logbook program (since 2001) and video monitoring in the hook and line fleet since 2006. Nevertheless it is likely that the discard rates are underestimates and, as such, the total deaths due to fishing is underestimated (DFO 2010). In the absence of population estimates for either the inshore or offshore components it is not possible to directly infer the impact of the current fishery on the population. Nevertheless, the marked decrease in size composition remains a major concern and the role of the fishery in this regard had not been ruled out.

In jurisdictions outside of North America, Spiny Dogfish have been shown to be vulnerable to overfishing (Heesen 2003) but also appear able to recover if fishing pressure is diminished (Rago and Sosbee 2008). The depletion of northeast Atlantic populations opened up European markets to North America, which was 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 an abundant shark and consequently plays an important role in both natural and human systems (Compagno 1984). Its role in the ecosystem 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, and its flesh for fertilizer, food and fishmeal, and its fins enter the international shark fin trade. Finally, they have been the object 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, 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

Under the former single species designation, the IUCN has assessed the Spiny Dogfish as near threatened on a global basis. The Pacific population has been assessed as vulnerable by the IUCN (Fordham *et al.* 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. More recently, the Spiny Dogfish was proposed for inclusion under Appendix II of CITES at the 14th Conference of Parties (CoP14) in 2007 by Germany (on behalf of the European Community Member States acting in the interest of the European Community) and again at the 15th Conference of Parties (CoP15) in 2010 by Sweden and Palau (on behalf of the European Community Member States acting in the interest of the European Community). At both conferences, the proposal was refused and therefore was not listed under CITES. For more detailed information on considerations for the decisions, see: http://www.cites.org/eng/cop/index.shtml.

The Canadian fishery is managed under quota but the scientific basis for the quota has not been established in the absence of estimates of population size. The quota for the offshore stock has been considerably greater than the catch ever since the quota was established. It is therefore not clear that the quota would afford adequate protection should the catch of Spiny Dogfish increase to match an increase in demand.

Finning, the process of removing and selling only the fins, is prohibited in Canada. However, fins can be sold if the rest of the shark is being sold for meat.

ACKNOWLEDGEMENTS AND AUTHORITIES CONSULTED

There are numerous people who assisted in the writing of this report. Vanessa Hodes at the Department of Fisheries and Oceans was extremely helpful in the preparation of data and creation of maps. Thank you to Claude Dykstra at the International Pacific Halibut Commission for preparing and providing relevant databases. Mark Wilkins at the National Marine Fisheries Services prepared and provided the west coast Triennial Trawl database. Assistance with the Hecate Strait trawl data was provided by Jeff Fargo at the Pacific Biological Station of DFO. Norm Olsen at the Pacific Biological Station provided data from the synoptic trawl surveys and commercial fishery size composition.

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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 fisheries analyst with the David Suzuki Foundation. In this capacity he reviews current fisheries practices both nationally and internationally and sits on numerous government advisory committees. He holds a Ph.D. from the University of British Columbia's Fisheries Centre.

Draft report

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's research centres 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'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, aging 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, aging 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.