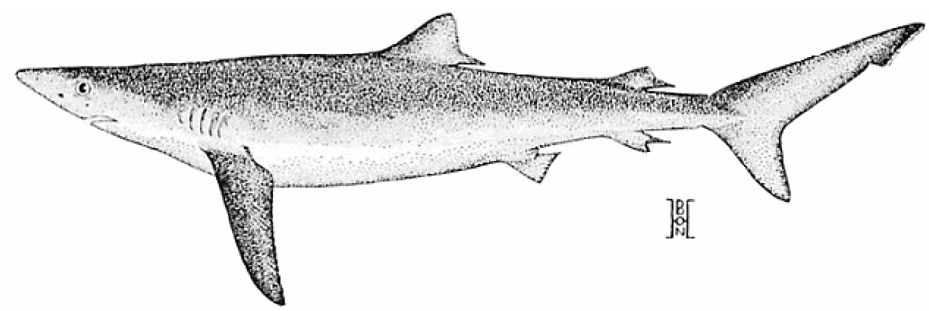
COSEWIC
Assessment and Status Report

on the

Blue Shark
Prionace glauca

Atlantic population
Pacific population

in Canada



ATLANTIC POPULATION – SPECIAL CONCERN
PACIFIC POPULATION – DATA DEFICIENT
2006

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE
IN CANADA

COSEPAC
COMITÉ SUR LA SITUATION
DES ESPÈCES EN PÉRIL
AU CANADA

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

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Production note:

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COSEWIC
Assessment Summary

Assessment Summary – April 2006

Common name
Blue shark – Atlantic population

Scientific name
Prionace glauca

Status
Special Concern

Reason for designation
This species is a relatively productive shark (maximum age 16-20 years, mature at 4-6 years, generation time 8 years, 25-50 pups every two years) but as an elasmobranch, populations are susceptible to increased mortality from all sources including from human activities. The species is considered to have a single highly migratory population in the North Atlantic, of which a portion is present in Canadian waters seasonally. The abundance index which is considered to best represent the whole population has declined 60% 1986-2000 but another index shows no long-term trend for the whole population 1971-2003. Indices of abundance in and near the Canadian waters show variable trends from no decline to 60% decline from the 1980s to early 2000s. There is evidence for a decline in mean length in longline fisheries in Canadian waters 1986-2003. The primary threat is bycatch in pelagic longline fisheries; although the threat is understood and is reversible, it is not being effectively reduced through management. Assessing the impact of bycatch on the population would benefit from better information on proportion of individuals discarded which survive. It appears that recent fishery removals from the North Atlantic have been several tens of thousands of tons annually. Estimated Canadian removals, a small proportion of the total, have been declining since the early 1990s and recently have averaged around 600 t/yr.

Occurrence
Atlantic Ocean

Status history
Designated Special Concern in April 2006. Assessment based on a new status report.

Assessment Summary – April 2006

Common name
Blue shark – Pacific population

Scientific name
Prionace glauca

Status
Data Deficient

Reason for designation
The species is apparently present regularly in Canada's Pacific waters, probably as part of a wider North Pacific population. Catch information and data from the International Pacific Halibut Commission longline survey (1998-2004) suggest the species is widespread on the continental shelf with a concentration at the shelf break. It has also been taken, at times in large numbers, in oceanic waters. No information is available to assess status in Canada, as there have been few records in existing surveys. Pacific-wide indices are of low reliability because of historical misidentification issues, but one recent assessment from United States National Marine Fisheries Service suggests that fishing mortality on this species in the North Pacific is well below the level of maximum sustainable yield. Level of fishery removals (bycatch) in the Canadian Pacific are low, of the order of 20-40 t/yr.

Occurrence
Pacific Ocean

Status history
Species considered in April 2006 and placed in the Data Deficient category. Assessment based on a new status report.

COSEWIC
Executive Summary

Blue Shark
Prionace glauca

Atlantic population
Pacific population

Species information

The blue shark (*Prionace glauca*) is long and slender with distinctive blue coloration on dorsal and lateral surfaces. They are widespread and highly migratory with some evidence of movement between hemispheres although most tagging studies suggest that blue sharks are largely separated by hemispheres. The North Atlantic and North Pacific populations are considered as two designatable units because they are geographically isolated by the continental landmass of North America: there is no evidence of movement between ocean basins. The population structure is not well defined from a genetic point of view. In French this species is known as *requin bleu*.

Distribution

Blue sharks are found worldwide in temperate and tropical oceans, most often in the offshore surface waters. In Atlantic Canada they are regularly found in almost all waters with a peak occurrence in the late summer and fall. Similarly, blue sharks are widespread throughout Canada's Pacific waters with peak occurrences in the late summer and fall. Studies in both Atlantic and Pacific waters indicate large scale latitudinal movements and segregation of the population by sex and size.

Habitat

Blue sharks are most commonly encountered offshore between the surface and 350 m. Water temperature appears to influence their depth and latitudinal distributions as well as size and sex distributions. Canada's waters (Atlantic and Pacific) provide habitat for primarily subadult (immature) individuals although adult (mature) specimens are occasionally encountered. Loss of habitat is not considered a threat for this species.

Biology

Blue sharks have a 9-12 month gestation period and females produce litters approximately every two years. The average litter size is between 25-50 pups and is positively correlated with female length. Maturity is reached between ages 4-6 and maximum age is between 16-20 years. Their generation time is about 8.1 years. Blue sharks are opportunistic feeders and are reported to eat a wide variety of prey including bony fishes, squids, birds and marine mammal carrion. Adult blue sharks have no known predators; however, subadults and juveniles are taken by both shortfin makos and white sharks as well as by sea lions. Blue sharks are the most heavily fished species of sharks in the world and fishing is the single largest source of adult mortality.

Population sizes and trends

Population size and trends of blue sharks in Canada reflect what is happening to populations existing at the scale of hemispheric ocean basins. In Atlantic Canada, on average approximately 600 t of blue shark have recently been killed per year, which is estimated to represent a small fraction of the fishing removals in the North Atlantic. North Atlantic-wide trend assessments are constrained by limited data. Population assessments by an international commission suggest the population is not depleted but the estimates are considered preliminary and extremely uncertain. Two analyses of abundance trends covering large geographical areas indicate either no decline since 1971 or a decline of 60% since 1986. Abundance indices based on catch rates in or near Canadian waters show varying decline rates between near 0 and 53% since the mid-1990s. Biological data indicate a decline in the mean lengths of commercially caught blue sharks in both the Canadian and Japanese fisheries in the northwest Atlantic since 1986.

There are no studies of blue shark trends or abundance in Pacific waters. Canadian fishing vessels occasionally catch blue sharks as bycatch at a level of 20-40 t/yr. The low level of bycatch reflects the methods of fishing rather than the abundance of blue sharks.

Limiting factors and threats

Fishing mortality is the single largest threat to blue shark populations worldwide. Pelagic fisheries regularly catch blue sharks as bycatch. In Canada’s Atlantic waters approximately one third of the biomass of animals caught in the Canadian pelagic fishery (tunas and swordfish) is blue shark, but removals in Canada are probably 1% or less of total North Atlantic removals. A review of published catch rates in the North Atlantic indicates a range of 5.1-40 blue sharks per 1 000 hooks. Overall fishing effort for pelagic species in the North Atlantic has increased substantially since the mid-1950s implying an increase in catch of blue sharks. Fishing mortality of blue sharks in Canada’s Pacific waters accounts for possibly 0.1% of the fishing mortality in the entire North Pacific.

Special significance of the species

This species is one of the most abundant, widespread, fecund, and fast growing shark species worldwide and likely is a significant component of tropical and temperate open ocean ecosystems worldwide. Blue shark has very low value in the marketplace and is often discarded when caught as bycatch. The meat is rarely marketable due to the rapid breakdown of urea in the muscle tissue into ammonia immediately following death thereby tainting the meat. The fins are of low value but may contribute an estimated 50-70% of the international fin market traded through Hong Kong.

Existing protection

There are no jurisdictions that prohibit the capture of blue sharks. In 2004, ICCAT accepted a resolution to prohibit finning in Atlantic high seas pelagic fisheries. Likewise, in Canada finning is prohibited on both coasts and on the Pacific coast blue sharks cannot be landed in the hook and line fishery. The Atlantic recreational shark fishery is catch and release only. The IUCN assessed the blue shark in 2000 and listed it as *lower risk/near threatened* (LR/nt).

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 5th 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 (2006)

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 it 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.

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

COSEWIC Status Report

on the

Blue Shark
Prionace glauca

Atlantic population
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in Canada

2006

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SPECIES INFORMATION

Name and classification

The blue shark (*Prionace glauca*) is the only species in the genus *Prionace* and belongs to the family Carcharhinidae collectively known as requiem sharks (Compagno 1984). The family has 12 genera and 48 species including the tiger shark (*Galeocerdo cuvier*) and commonly encountered reef sharks (*Carcharhinus* sp.). The blue shark is the only species in this family regularly found in temperate waters, the others being largely restricted to tropical environments. In French this species is called *requin bleu*.

Morphological description

The blue shark is easily recognized by its distinctive coloration. The dorsal region is a vibrant dark blue, the sides bright blue, then abruptly white ventrally (Nakano and Seki 2002). The body is long and slender reaching 3.8 m in length with the most obvious anatomical features being a long pointed snout and long sickle-shaped pectoral fins (Figure 1) (Mecklenburg *et al*. 2002). The pectoral fins are as long as the distance between the tip of the snout to the last gill slit. The caudal fin bears a distinctive notch characteristic of carcharhinids just below the end of the upper lobe. The eyes are large with a nictitating lower eyelid (i.e., able to open and close). The spiracle (an opening between the eye and first gill slit) is absent or very small. There are five moderate sized gill openings with the middle one the largest and the last two positioned over the pectoral fin. The teeth on both the lower and upper jaw are triangular with smooth or finely serrated edges with the upper teeth overlapping at the bases (Mecklenburg *et al*. 2002).

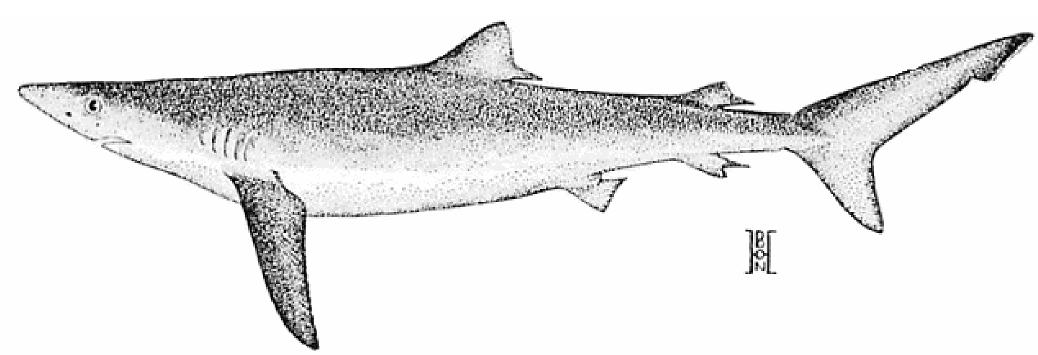

Figure 1. Blue shark (*Prionace glauca*). Source: Hart 1973.

Genetic description

There has been no population genetic work undertaken on blue sharks. There were no differences in morphometric comparisons between blue sharks caught in equatorial western Atlantic and these in the northwestern Atlantic and in the Pacific (Hazin *et al*. 1994).

Blue sharks are the only species out of 33 shark species investigated by the National Marine Fisheries Service (NMFS) Cooperative Shark Tagging Program (Atlantic) to show trans-equatorial movement, but most of the recoveries of tagged individuals were from the hemisphere in which they were released (Kohler *et al*. 1998) suggesting that the populations are largely separated by hemispheres. Tagging studies in the northwestern Atlantic conducted in Canadian, American, and international waters indicate considerable movement with many sharks tagged in Canada being recovered from the central and eastern Atlantic. These studies strongly suggest there are no physical barriers to gene flow throughout the North Atlantic, but that does not rule out the potential for population structuring based on behavioural preferences. Similar to the Atlantic, movement in the North Pacific is widespread with an apparent northward seasonal movement in late spring and summer (Nakano and Nagasawa 1996). Tagging studies undertaken by the California Department of Fish and Game have shown trans-Pacific movements (CDFG 2003).

Models from both the North Atlantic and Pacific suggest that there may be north-south seasonal movements within each hemisphere (Nakano and Seki 2002).

Designatable units

The North Atlantic and North Pacific populations of blue shark occupy two distinct biogeographical units, the Atlantic and Pacific Oceans. They are geographically isolated by the continental landmass of North America: there is no evidence of movement between ocean basins. For the purposes of this report, blue sharks in the North Pacific and North Atlantic are considered to be two designatable units.

DISTRIBUTION

Global range

Blue sharks are found worldwide in temperate and tropical oceans primarily in surface waters and offshore (epipelagic) (Figure 2). There is no evidence of either a reduction or expansion in the global range.

Canadian range

<u>Atlantic</u>

Blue sharks are encountered along the shelf break from northeastern Newfoundland southward including the Gulf of St. Lawrence and the Bay of Fundy (Figure 3). Abundance in Canadian waters varies seasonally with higher catches occurring in the third and fourth quarters. Catch is very low in the first quarter and moderate in the second quarter (Figure 4). Extent of occurrence is approximately 1.2 million km^2 based on the distribution of catch records. Area of occupancy is 0.8 million m^2 based on the area with the most frequent sightings.

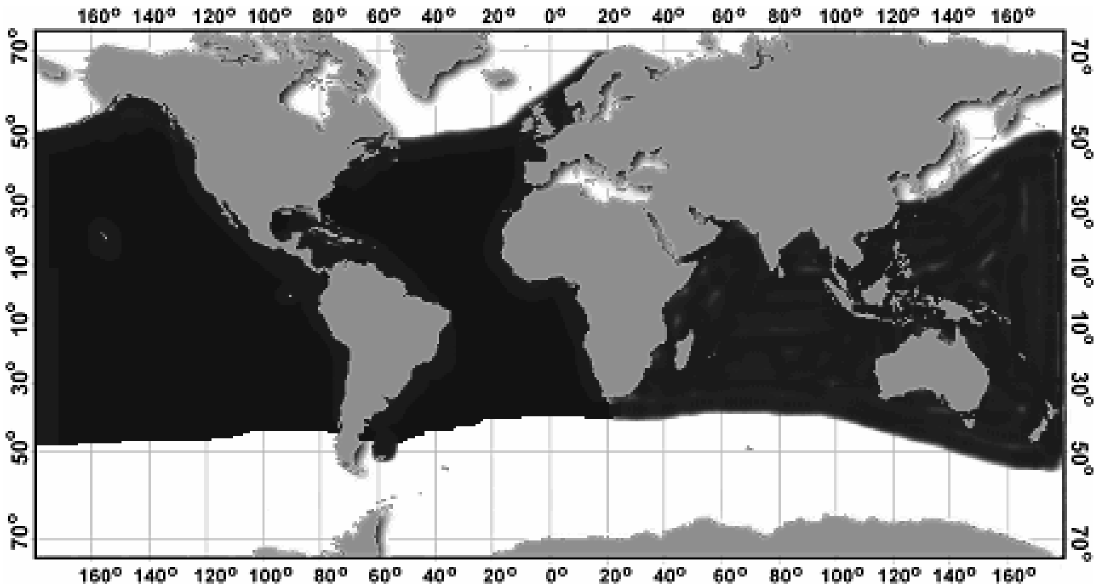

Figure 2. Global distribution of blue shark (Map source: FAO 2004).

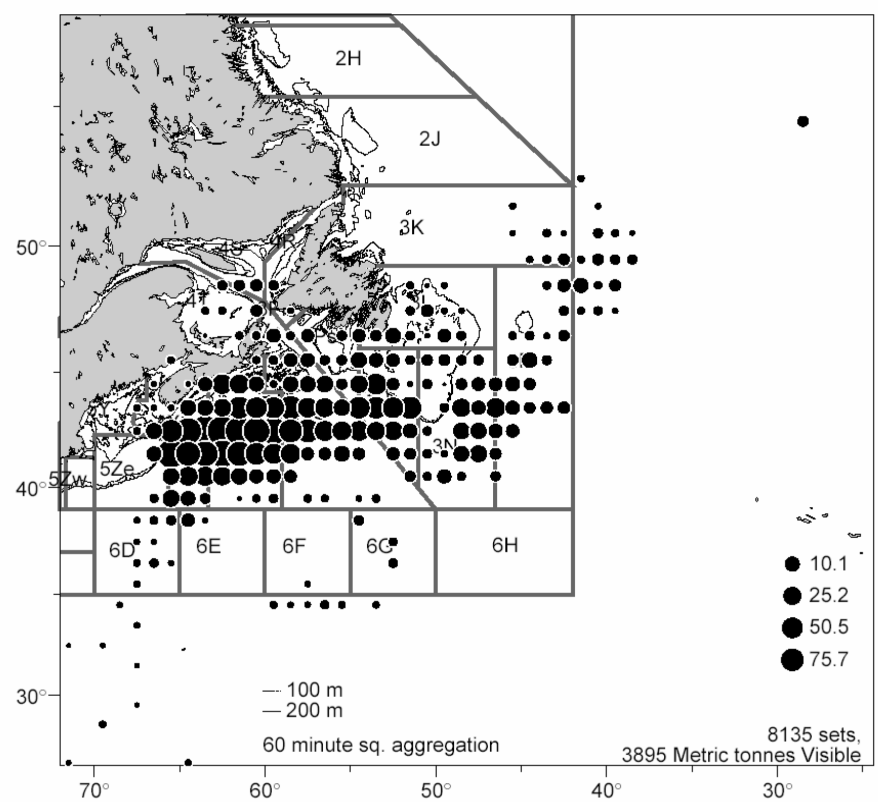

Figure 3. Distribution of blue sharks in Canada's Atlantic region based on all known commercial catch records between 1986-2004.

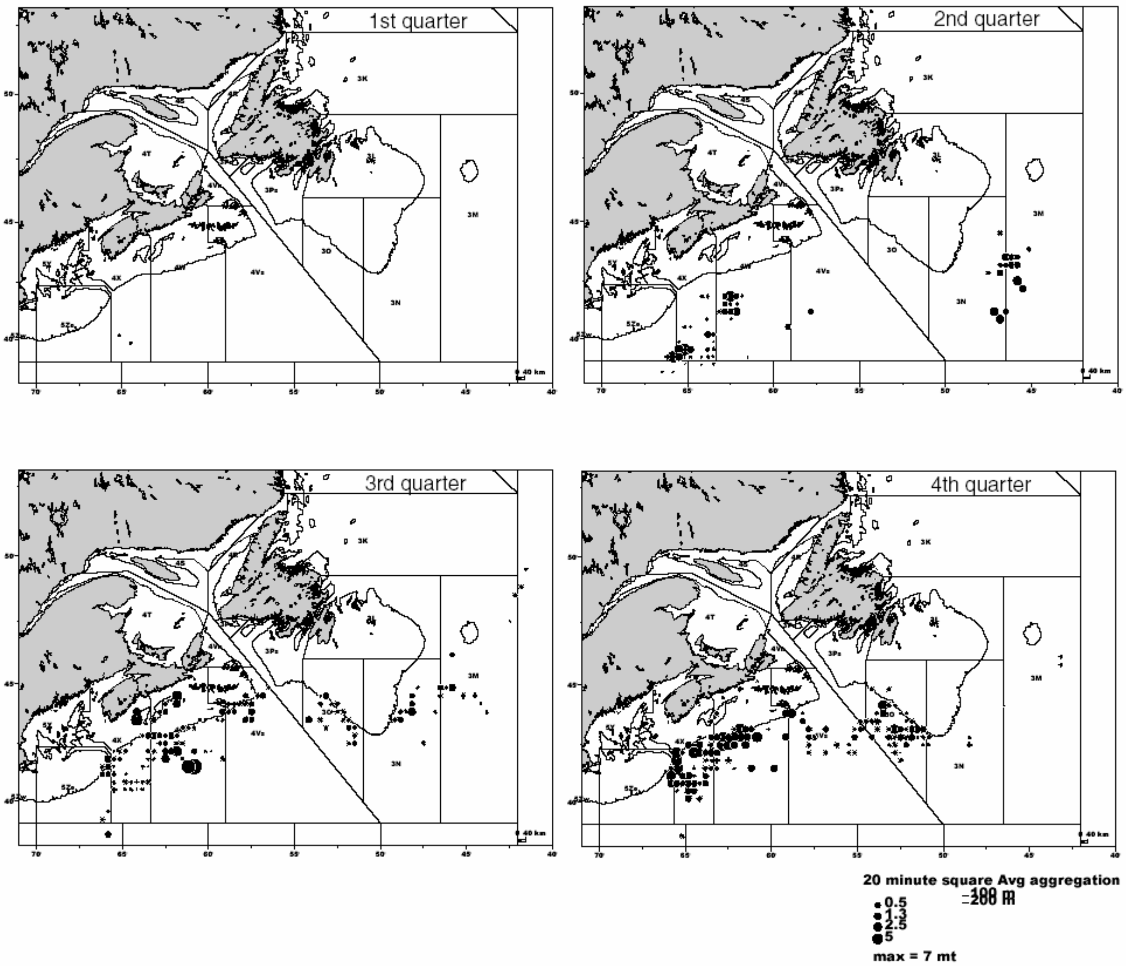

Figure 4. Blue shark catch location by season observed by the International Observer Program on Canadian vessels fishing swordfish or tuna between 1986-2001 (From Campana *et al*. 2004). Note that most blue sharks are caught in the 3rd and 4th quarters.

Pacific

Blue sharks are encountered in trawl and hook and line fisheries along the west coast of Vancouver Island and the Queen Charlotte Islands, as well as in Hecate Strait (Figure 5). Surveys conducted throughout most of the continental shelf by the International Pacific Halibut Commission (IPHC) from 1998-2004 using longline gear show a similar encounter pattern as the commercial fishery (Figure 6). There is also an increase in hook and line commercial catches of blue sharks during summer which reflects a seasonal increase in blue shark abundance (Figure 7) as catch per unit effort in the third and fourth quarters is nearly fifty times that in the first and second quarters (Appendix 1).

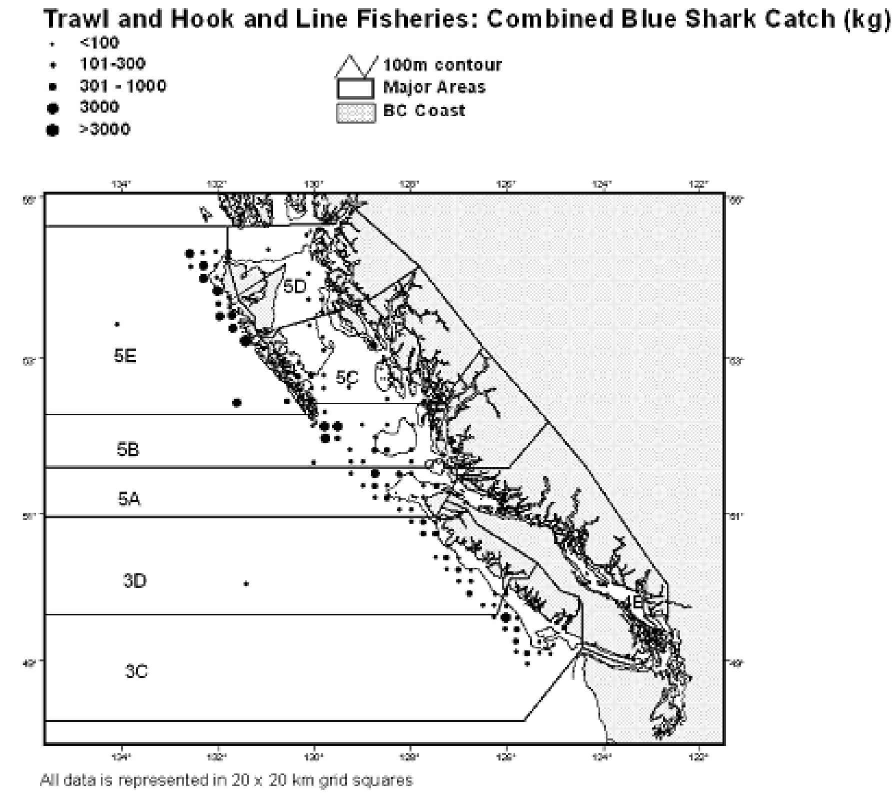

Figure 5. Distribution of blue shark catch off British Columbia based on records from all commercial fisheries between 1996-2004 (23.5 t visible). Source: DFO PacHarvHL and PacHarvTrawl databases.

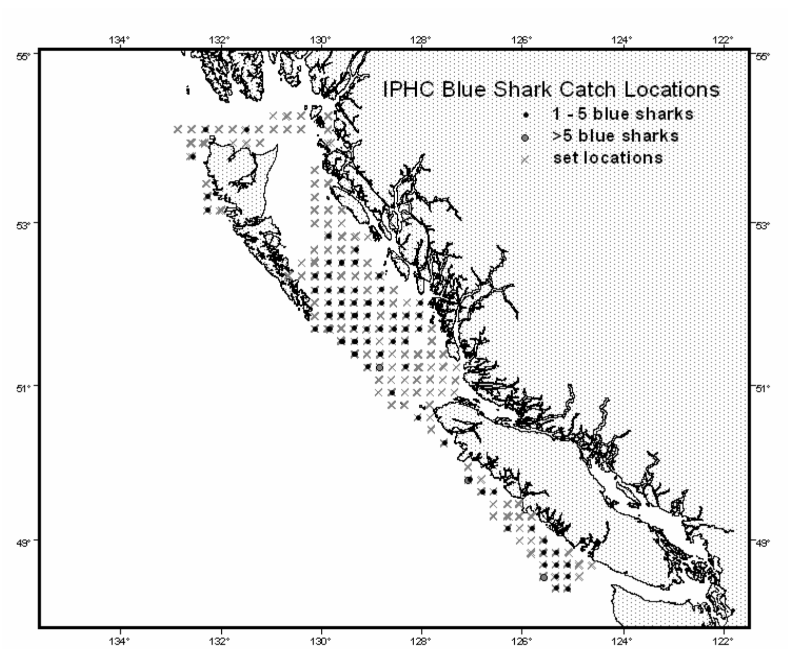

Figure 6. Catch location of blue sharks (n=170) in the International Pacific Halibut Commission set surveys in Area 2B between 1998-2004. Data from IPHC.

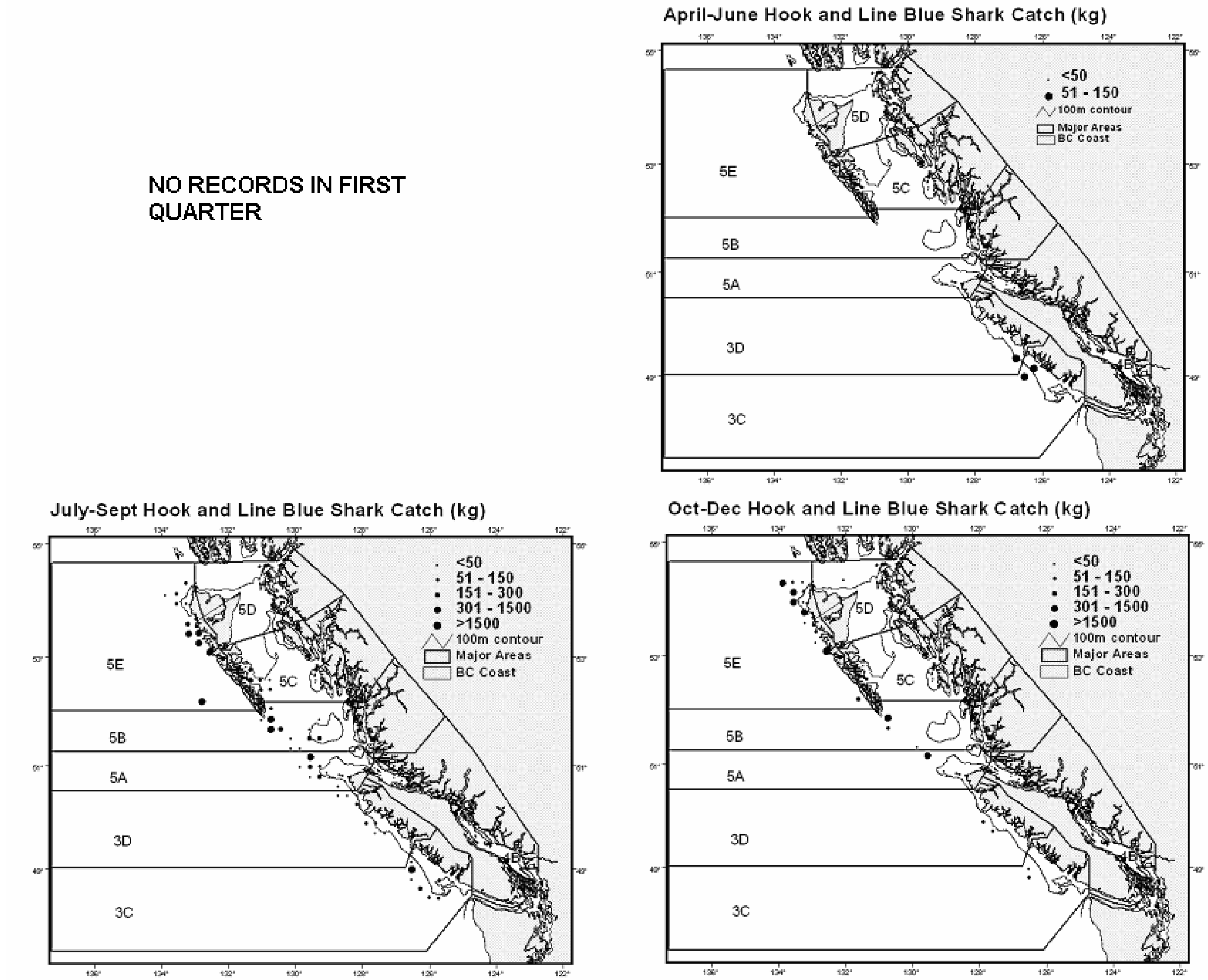

Figure 7. Distribution of blue shark caught by British Columbia's commercial hook and line fleet by season between 1998-2004. Source: DFO, PacHarHL database.

Based on known movement patterns (Nakano and Seki 2002), it is unlikely that blue sharks have extended residency in Pacific Canadian waters and at any time only a small portion of the overall North Pacific population is likely utilizing Canada's waters. There are few data available to detect changes in range in Canadian waters. The extent of occurrence is approximately 117 000 km^2 based on the area within polygons encompassing catch records (Appendix 2). Being a pelagic species, their distribution likely extends from depths of 200 m offshore to the limits of Canada's international boundary, an area of 450 000 km^2.

HABITAT

Habitat requirements

Blue sharks are considered epipelagic, meaning they are associated with the surface layer of the ocean. There are indications that there are latitudinal variations in depth preference but they are typically found between the surface and 350 m (Nakano and Seki 2002). They prefer offshore habitats but have been observed on occasion inshore. Blue sharks are known to occur in waters between 5.6-28º C. Their preferred temperature has been estimated based on associated catch rates and varies considerably by both region and study (Nakano and Seki 2002). Strasburg (1958) reported that 99% of blue sharks in the Pacific were caught in the water temperature range of 5.6-18.9º C. There is evidence of a latitudinal trend in depth preference. In tropical latitudes (20ºS-20ºN) there appears to be a preference for deeper waters (80-220 m) and no apparent seasonal shift in abundance (Nakano and Seki 2002). In northern latitudes, the blue shark is found in shallower waters and there is evidence for a seasonal shift in abundance as animals move to higher latitudes in the summer (Nakano and Seki 2002). Water temperature is likely the principal factor determining the depth and latitudinal distributions of blue sharks.

Habitat preference by sex and size has been described from research surveys in the North Pacific (Nakano and Nagasawa 1996). Females were caught between 8-21º C whereas males were caught between 12-21 ºC. Larger females (>90 cm) tend to occur in cooler waters than similar-sized males (Females 8-21º C, Males 14-21º C). Nakano (1994) proposed a general model based on temperature preferences, later supported by McKinnell and Seki (1998), describing sex and size segregation in the North Pacific. The band between 35-45º N was identified as a parturition area, and a slightly wider band as the nursery (68-134 cm total length). Subadult females (134-199 cm TL) are typically found north of the parturition grounds while subadult males occupied waters south of the parturition grounds. Nakano's model predicts that most of the blue sharks in Canada's Pacific waters would be subadult females. A single study on Canada's Pacific coast lends support to this hypothesis with 93% (n=134) of the observations being immature females (IEC Collaborative Marine Research and Development Limited 1992).

Sex and size segregation in the northwest Atlantic has also been observed (Pratt 1979; Campana *et al*. 2004; Beerkircher 2005). All studies have indicated the absence of mature females from the waters off the northeastern U.S. and Canada. Campana *et al*. (2004) examined length frequency data from summer observations in the commercial and recreational fisheries (Figure 8). These data suggest that mature males comprise a small component of the commercial catch (considered more representative) but comprise a large portion of the recreational derby fishery due to targeting of large individuals. Immature blue sharks of both sexes were found in equal proportions (Campana *et al*. 2004; Beerkircher 2005). Based on analyses of U.S. pelagic longline observer data from 1992-2003, Beerkircher (2005) found that mean fork length decreased with increasing latitude and as a general trend the largest mean lengths were found in areas south of 35° north latitude. Mean fork lengths in the northeast distant (NED) ICCAT region (including waters around Newfoundland) were found to be 139 cm (n=11174) and 133 cm (n=11172) for males and females respectively. Northern waters may be important nursery areas based on the higher proportion of smaller individuals (Beerkircher 2005). Across the Atlantic in the English Channel, Vas (1990) reports that only one of 73 captured sharks was male, which is similar to Stevens (1976) who reports that only 6% of the catch was composed of males.

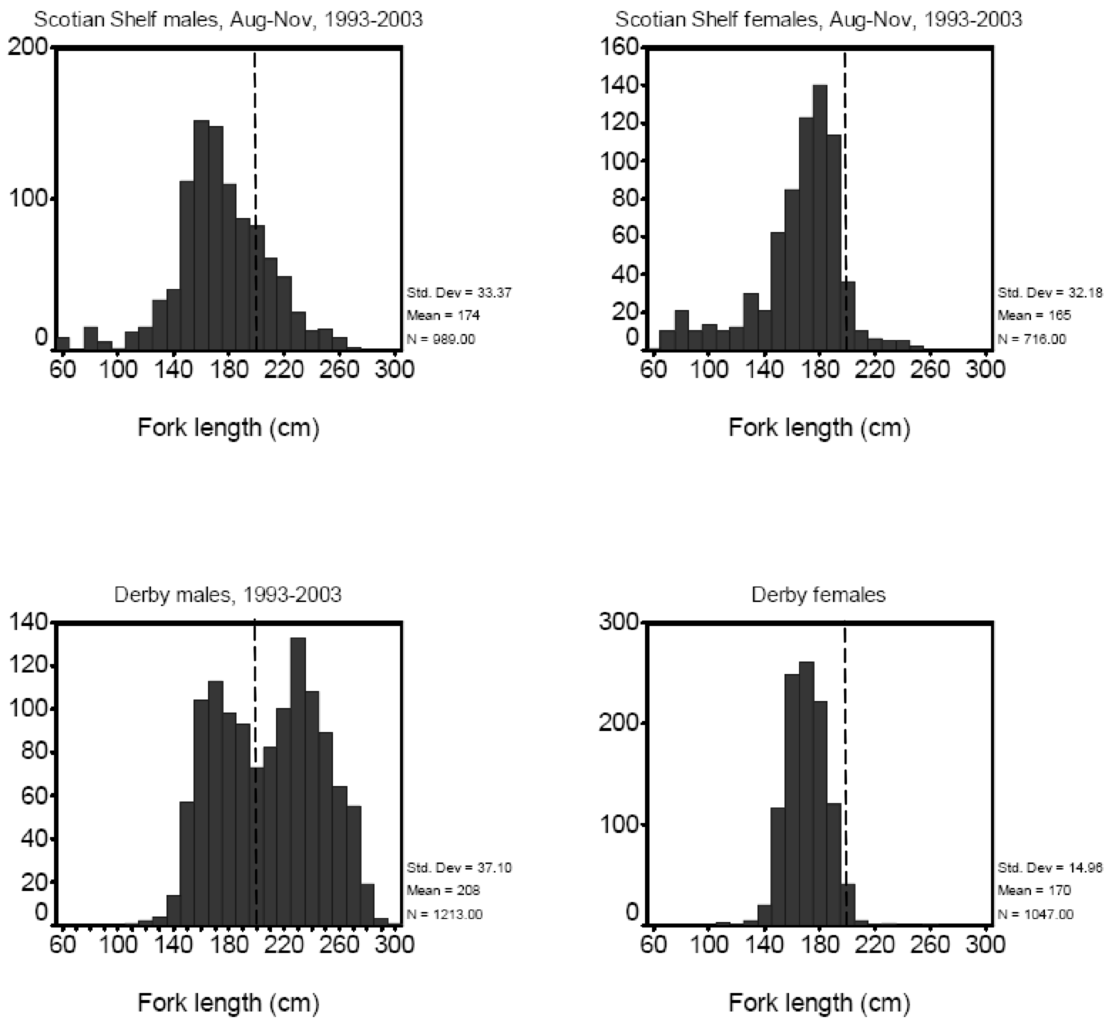

Figure 8. Length frequency distributions of blue sharks examined at shark derbies and measured by observers in the commercial catch on the Scotian Shelf between 1993-2003 over the same range of months and years. Vertical dash line represents the size at 50% maturity. Source: Campana *et al*. 2004.

Habitat trends

There has been no research investigating trends of habitat availability for blue sharks in Canada. Based on anecdotal evidence, it appears that warm water events (i.e., El Niño) in Canada’s Pacific waters results in an increase in the abundance of blue sharks but this has not been confirmed. Commercial catch rates of blue sharks in the North Pacific have been shown to decline considerably in sea surface temperatures less than 16°C and in latitudes greater than 40°N (Bigelow *et al*. 1999).

Habitat protection/ownership

Protection of habitat for blue sharks has not been considered in Canada. The loss of blue shark habitat (i.e., global epipelagic environments) is not thought to be a conservation concern at present time. Note, for the purposes of this report, fisheries interactions are not considered to be a threat to habitat.

BIOLOGY

In Canada's Atlantic waters, there has been some effort to collect biological information including length/frequencies by sex, diet, age and patterns of movement. There has been insufficient biological research done on blue sharks in Canada's Pacific waters to derive any meaningful conclusions. The global occurrence of this species along with known large migration patterns suggests that biological information derived from outside of Canada is applicable to sharks utilizing Canada's waters.

Life cycle and reproduction

Mating and Parturition

Blue sharks are viviparous with an average litter size of 25.6 (Range 1-62, n=600) in the North Pacific (Nakano 1994). In the northwest Atlantic, litter size has not been well investigated. Bigelow and Schroeder (1948) report an average of 41 based on a sample size of two individuals. In European waters, a mean litter size of 36.6 was derived based on eleven individuals. Although there is considerable individual variation, average litter size is likely between 25 and 50. The sex ratio of embryos is on average 1:1. There is a positive correlation between female length and litter size (Nakano and Seki 2002).

Mating appears to be most frequent in the spring to early summer season. After copulation, there is evidence that females may store spermatozoa for periods of months or years waiting for ovulation (Pratt 1979). After fertilization, gestation is between 9-12 months. Birth has been observed over a wide seasonal range from spring to fall suggesting considerable variation amongst individuals. Pratt (1979) estimated that blue sharks off New England produce a litter about every two years.

Growth and Maturity

Length of newborn pups is typically considered to be 40-50 cm, although a range of 35 to 60 cm has been reported in the literature (Nakano and Seki 2002). Several growth models have been published from around the world with similar results. Models from the Atlantic predict a slightly faster and larger growth when compared to Pacific populations but none of these models is considered to provide precise age estimates. Two recent growth models from the northwest Atlantic using vertebral sections (Skomal and Natanson 2003) and whole vertebrae (MacNeil and Campana 2003) to estimate age showed similar trends in length at age for the first four years of age but then varied after that age. The whole vertebrae technique predicts faster growth (~15-20%) than does the sectioned vertebrae technique. The differences in the models have implications for understanding the mortality rates (see Mortality and Productivity section) since a faster growth rate translates into a higher estimated total mortality rate (Z).

Length at maturity has been examined in numerous studies in various regions reviewed in Nakano and Seki (2002). In the North Pacific, length at 50% maturity for males and females respectively is 203 cm (total length) and 186-212 cm (TL) which corresponds to the ages of 4-5 years and 5-6 years respectively (Nakano 1994). Campana *et al* (2004) estimated length at maturity for male sharks caught in Atlantic Canadian waters to be between 193 to 210 cm (fork length) and Pratt (1979) reports maturity for females in the North Atlantic to be between 145 to 185 cm (FL). Age of maturity is between 4 to 6 years. Maximum age is between 16 to 20 years (Skomal and Natanson 2003).

Mortality and Productivity

Natural mortality has never been directly estimated in blue sharks. There are various published estimates of natural mortality (M) reported in the literature, which vary from as low as 0.07 to a high of 0.48 with a mean of 0.23 (i.e., approximately 23% of the population is dying from natural causes each year) (Campana *et al*. 2004).

Intrinsic rate of population growth at maximum sustained yield (r_{2M}) for Pacific populations was estimated by Smith *et al*. (1998) to be 0.061. Compared to other elasmobranchs, blue sharks are productive. Campana *et al*. (2004), using data from the North Atlantic, found the intrinsic population growth rate to be 0.36, which translates into an annual increase in the population (i.e., growth rate) of ~43%. Such high population growth rates may help explain why blue sharks have been slow to decline in the face of what appears to be very high overall catch mortality.

Campana *et al*. (2004) estimated that the generation time of blue sharks in the North Atlantic is 8.1 years using life table analysis. Overall, blue sharks have a high natural mortality and high intrinsic population growth rate in comparison to other sharks.

Predation

There are no known predators of adult blue sharks (Nakano and Seki 2002). Sub-adults and juveniles are taken by both shortfin mako (*Isurus oxyrinchus*) and white shark (*Carcharodon carcharias*). In addition, California sea lions (*Zalophus californianus*) are reported to eat blue sharks (Lowry *et al*. 1990, Froese and Pauly 2004). The high level of natural mortality (described above) suggests that predation on juveniles must be high but the nature of the predation is poorly understood. Blue sharks are the most heavily fished species of shark in the world, and given there are no known predators of adult blue sharks, humans are likely the most significant predator.

Physiology

Blue sharks can tolerate a wide range of temperatures 5.6-28º C but prefer temperatures in the middle of this range (8-16º C). This tolerance range allows for a wide distribution assuming that temperature is the primary factor affecting distribution.

Dispersal/migration

Blue sharks actively move throughout North Atlantic and Pacific waters as indicated from tagging. There are two tagging studies applicable to populations in Canada's North Atlantic waters. A Canadian study carried out between 1961 and 1980 tagged 2 017 individuals of which 17 were recaptured. This study indicated that the blue sharks move in and out of Canadian waters as well as exhibit movement between offshore and inshore habitats (Burnett *et al*. 1987). The National Marine Fisheries Service (NMFS) conducted a long-term tagging study (1971-2002) where thousands of blue sharks (n=60 856) were tagged in U.S, international, and Canadian waters. Of the sharks tagged in Canada (n=916), most were recaptured in the central and eastern Atlantic, but some were captured off western Africa (Figure 9A). Blue sharks tagged in the NMFS tagging program outside of Canada (U.S. and international waters) between 1974-2002 resulted in 188 recaptures in Canadian waters (Figure 9B, Campana *et al*. 2004). There was no obvious difference in migration pattern between males and females, or between small and large blue sharks. In the northeast Atlantic, tag recapture information suggests a seasonal migration between 30-50° N with some gender and size differences in movement (Stevens 1976). The Central Fisheries Board of Ireland monitors a volunteer-based tagging program (Central Fisheries Board, www.cfb.ie/fisheries_research/tagging/blueshark.htm). The starting year of the program is not reported. By the end of 1998 15 037 blue sharks around the Irish coast had been tagged of which 490 have been returned (3.25%). Several of the recaptures were from the western North Atlantic with two records from waters south of Newfoundland. Most recaptures were from the northeastern Atlantic around the Azores.

There have been no tags applied to blue sharks in Canada's Pacific waters. The California Department of Fish and Wildlife has tagged 7 925 blue sharks off California of which 141 have been recaptured (CDFG 2003). The overall results of the tagging program have not been published but at least three of these sharks were caught near the coast of Japan between 1.5 and 2 years after tagging (CDFG 2003). Nakano and Seki (2002) suggest a large scale, sex and size segregated Pacific migration described in the 'Habitat' section of this report.

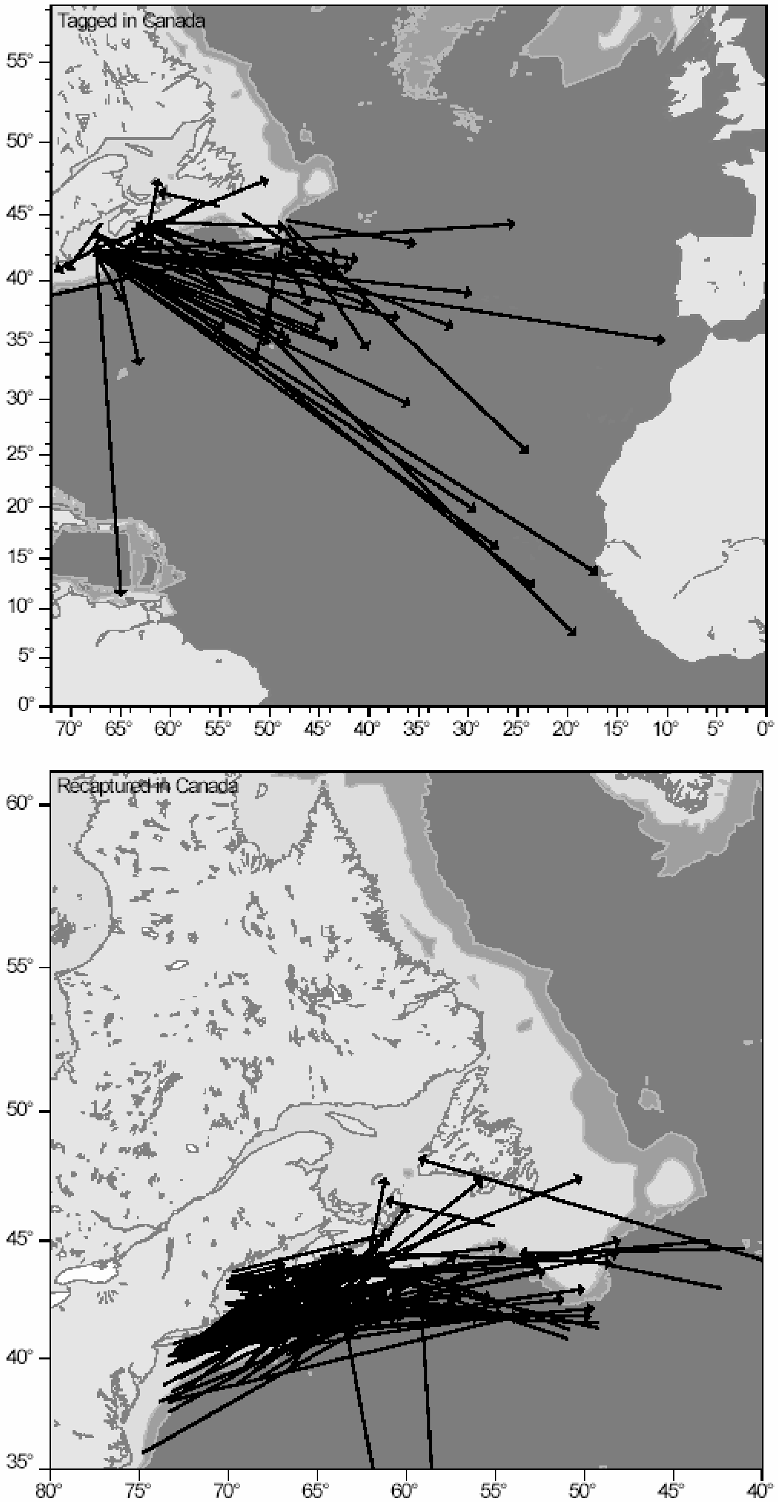

Figure 9. Movements of blue sharks A.) tagged in Canada or B.) recaptured in Canada between 1971-2002 under the NMFS tagging program. From Campana *et al*. (2004).

In September of 1991 a private company conducted the only blue shark research done in Canada's Pacific waters (IEC Collaborative Marine Research and Development Limited 1992). The four-day longlining trip was conducted off the west coast of Vancouver Island with the intention of capturing blue sharks. In this period 134 sharks were captured, all immature with an average length of 147 cm and with pronounced sex segregation (124 females and 10 males), which is consistent with Nakano's model described earlier (see Habitat section). Two separate samples in an experimental Canadian high seas driftnet fishery in the eastern North Pacific (1987) found significantly more males in one sample (males 26, females 13) and significantly more females in another (males 7, females 34-none with pups) (McKinnell and Seki 1998).

Overall, the tagging studies are consistent the view that blue sharks are highly migratory, with no evidence of extended residency in Canadian waters. The observation that few of the sharks tagged off Atlantic Canada were later recaptured in U.S. waters supports the hypothesis that many blue sharks migrate in a clockwise gyre across the North Atlantic.

The hemispheric distribution of blue shark, their apparent migration through Canadian waters, the absence of reproduction occurring in Canadian waters (i.e., few mature individuals), the low fishing mortality in Canadian waters relative to the entire Atlantic population, and the composition of the Canadian catch (mostly immature individuals (Figure 8)) all suggest that blue shark abundance in Canadian waters is dependent entirely on the abundance of the hemispheric populations.

Interspecific interactions

Blue sharks have been reported to eat a wide variety of prey consisting of an assortment of bony fishes, squid, birds, and marine mammal carrion. They are capable of pursuing and capturing numerous prey sources and are generally considered to be opportunistic feeders. There has been only one diet study in Canadian waters (McCord and Campana 2003). This study was undertaken on 'derby-caught' blue sharks off Nova Scotia in August and September (1999-2001). Pelagic and demersal teleost (bony) fish comprised the primary prey sources but an assortment of other prey sources was also found. There were also differences observed depending on size and sex of the sharks which is likely a reflection of either depth segregation and/or size selectivity of prey depending on the shark size. Overall, blue sharks eat a wide variety of prey and are capable of prey switching to take advantage of locally and seasonally abundant prey. The abundance and distribution of this species is not considered to be limited by caloric or nutrient intake.

Adaptability

Blue sharks are the most widely distributed and most abundant pelagic shark species in the world (Nakano and Seki 2002) which, combined with their wide prey base, lack of known fine scale population structure, a huge habitat (all temperate and tropical oceans), and no known dependence on other ecosystem components that may themselves be at risk, suggests that blue sharks would be resilient to many natural changes.

FISHERIES (BYCATCH)

Atlantic

Catch Mortality of Blue Sharks in Atlantic Waters

Campana *et al*. (2004) estimated the catch mortality of blue sharks in Canadian waters to be on average 1 000 t per year since 1986 based on the combination of *reported landings*, *observed bycatch*, estimated *non-observed bycatch*, and estimated *hooking mortality*.

Reported landings includes landing data from recreational and commercial fisheries (including foreign vessels) but since most blue sharks are caught as bycatch and discarded, reported landings do not provide much insight into the actual catch and mortality. *Observed bycatch* is the amount of blue shark caught (landings and discards) reported by the International Observer Program (IOP) which has 100% observer coverage on foreign vessels and ~5% coverage for Canadian vessels. To account for the non-observed Canadian fishery, the encounter rate of blue sharks observed in the foreign fishery was extrapolated to Canadian vessels to estimate the minimum *non-observed bycatch*. The proportion of blue sharks comprising the *non-observed bycatch* varies depending on season and fishery type and therefore a unique bycatch proportion was attributed by season and fishery. Furthermore, known under-reporting of blue sharks within the observer program was accounted for by using only datasets with at least one blue shark resulting in a maximum *non-observed bycatch* proportion. The average of the minimum and maximum proportions was used to calculate the overall *non-observed bycatch*.

Virtually all the catch of blue shark is bycatch and therefore calculating the survival rate after release is critical for understanding the *hooking mortality*. Hooking mortality has been estimated based on a small study (n=105) that categorized the state of the animal upon retrieval as healthy (38%), injured (44%), or dead (18%) (Campana *et al*. 2004). It was arbitrarily assumed that half of the injured animals died and therefore the overall hooking mortality was assumed to be 40%. Note there was no accounting for “drop off” mortality (animals that were caught but fell off the hook before being brought on board). Figure 10 shows the overall mortality in Canadian waters, which on average is approximately 1 000 t per year (1986-2003). Annual catch mortality from 1996 to 2003 has been relatively stable averaging less than 700 t per year. The decline in catch mortality from 1996 onwards has resulted from a decrease in foreign fishing combined with a decrease in Canadian catch for swordfish (Campana *et al*. 2004).

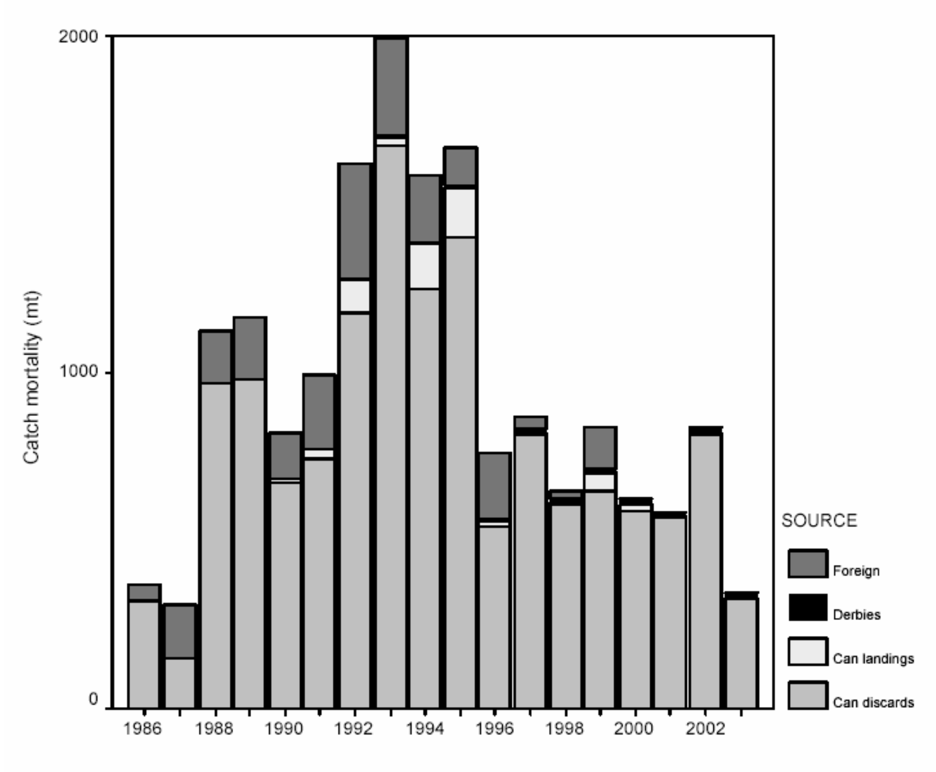

Figure 10. Total catch by source for blue sharks caught in Atlantic Canadian waters (From Campana *et al*. 2004).

Campana *et al*. (2004) extended the analysis described above to account for catch mortality in the entire North Atlantic. Based on international data from 2000, they conservatively estimated that more than 100 000 t of blue shark were caught which resulted in an approximate catch mortality of 37 000 t in that year.

An alternative and totally independent technique from the one described previously was also applied to calculate North Atlantic mortality. Using exploitation rates from tagging studies and fishing mortality rates from catch curve analysis, overall North Atlantic catch mortality was estimated to be 26 000 t/yr (Campana *et al*. 2004).

Given the widespread and migratory nature of this species, it is clear that mortality due to fishing in Canadian waters is a small fraction of the overall mortality. Furthermore, as inferred from the age and maturity of animals in the Canadian catch, it is very unlikely that the Canadian fishery has a disproportionate impact on a critical population component such as mature females.

<u>Exploitation Rates from Tagging-Atlantic</u>

Tagging studies (described above in the *Dispersal/Migration* section) have been used to estimate exploitation rates in Canadian waters (Campana *et al*. 2004). In the

Canadian study (1961-1980), annual exploitation rates were always less than 1%. Similarly, the NMFS tagging study resulted in a mean annual exploitation rate in Canadian waters of 0.78% for the years 1992-2002. Most (93%) of the Canadian tags were applied before 1972. As a crude comparison between the two tagging periods (1961-1972 and 1992-2002), Campana *et al*. (2004) compared overall tag return ratios and found that exploitation rates increased from a mean of 0.009 to 0.089 (~tenfold) under the assumption of similar reporting rates. This increase in apparent exploitation was similar in magnitude to the approximate tenfold increase in North Atlantic longline effort (Figure 11; ICCAT 2005).

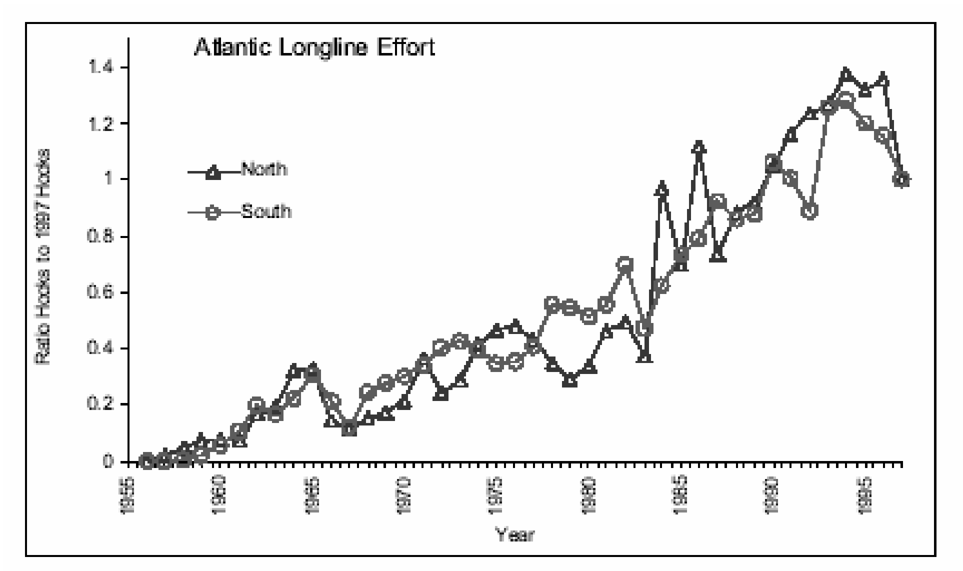

Figure 11. Trend in effort for the North and South Atlantic longline fleet (1956-1997). Figure from ICCAT 2005. North and South refer to hemispheres.

Campana *et al*. (2004) also compared the proportion of tags recaptured in Canada with those caught elsewhere in the Atlantic. This comparison found that about 1/3 of the total fishing mortality occurred in Canada, but this is likely an overestimate due to better tag reporting occurring in Canadian waters than in international waters.

Overall, it appears that the annual exploitation rate in Canadian waters is probably less than 1% per year.

Pacific

Canadian Fishery Data-Pacific

Since 1996 there has been 100% observer coverage in the "Option A" groundfish trawl fishery, which accounts for the majority of the groundfish landings on British Columbia's coast. From 1996-2004 there have been a total of 5 737 kg of blue sharks caught by the trawl fleet resulting in a mean of 637 kg/year. The catch is concentrated along the west coast of Vancouver Island and off the south end of the Queen Charlotte Islands (Figure 12A). Actual mortality rate (i.e., survival after discarding) of trawl caught sharks is unknown.

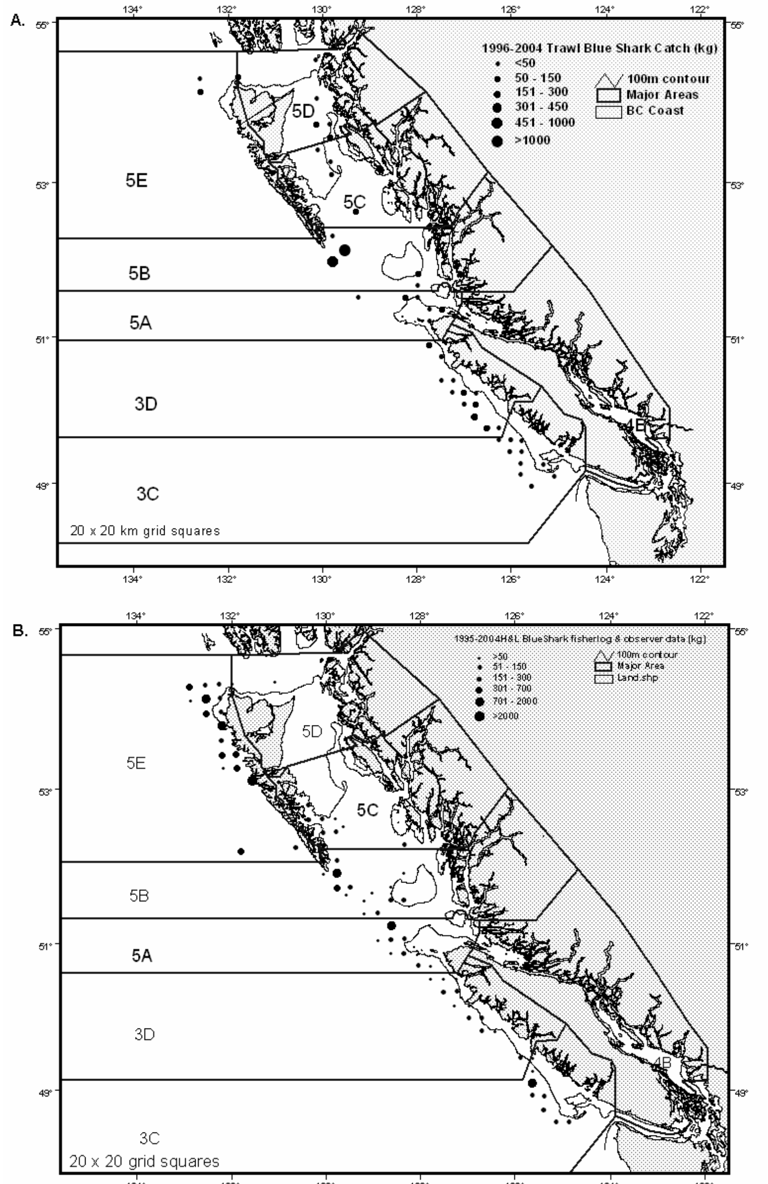

Figure 12. Distribution of blue shark catches between 1996-2004 in commercial (a) groundfish trawl and (b) hook and line fisheries. Source: DFO PacHarvHL and PacHarvTrawl databases.

The hook and line fleets (i.e., halibut, sablefish, dogfish, lingcod, and rockfish) are not permitted to fish for or retain blue sharks and therefore all catch records are from either logbook data filled out by fishers or in recent years from the observer program. The observer program began in 2001 with a maximum coverage of 15% in the hook and line fisheries. Voluntary reporting of bycatch species in logbooks is of limited use for understanding the actual catch. The implementation of the observer program, even with limited coverage, has provided a means to estimate actual catch. From 2001 to 2003 there has been a sharp increase in blue shark records (Figure 13). Prior to 2001, reported blue shark annual catch ranged from 0-0.84 t. From 2001-2003 reported catches range from 3.8-7.7 t which is conservatively a five to tenfold increase from pre-observer years. Given that observed trips account for only ~10-15% of the overall fishing effort, annual catches are likely conservatively five times greater than presently reported or about 20-40 t per year. There is no basis for estimating mortality. The sablefish fishery catch database has only two records of blue sharks since 1996 indicating that there are likely few encounters with blue sharks in this fishery (DFO PacHarSable database).

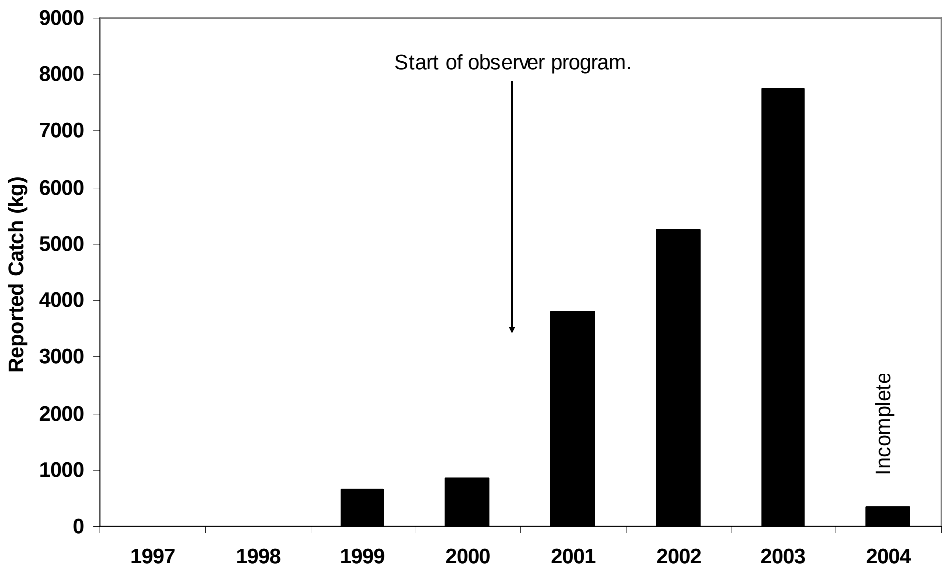

Figure 13. Reported catch of blue shark by British Columbia's hook and line fleet between 1997-2004. Note that the increase after 2000 is due to the implementation of a partial observer program covering approximately 10-15% of the trips whereas prior to 2001 data was voluntarily recorded in logbooks. Source: DFO PacHarvHL Database.

Blue sharks are also reported caught in small numbers by the salmon troll fleet. Since 2001, some segments of the salmon troll fishery have operated year-round, but blue shark encounters, as reported in logbooks, are confined to the months of July to early October. From 2001-2004, a total of 42 blue sharks were reported as caught and released in the salmon troll fishery. Furthermore the recreational fisheries for salmon and groundfish likely encounter blue shark but catches of sharks in those fisheries are unknown.

Estimated mortality from fishing in Canadian waters is small in comparison to estimated catch throughout the North Pacific. Bonfil (1994) estimated annual blue shark catch in the North Pacific is approximately 2 million individuals or 39 000 metric tons.

Information pertaining to blue shark distribution and migration supports the notion that sharks caught in Canada are part of a much larger North Pacific hemispheric population. Canada's Pacific waters are part of this species' normal range but current domestic fisheries are seemingly having a negligible impact on the population and account for perhaps 0.1% of the population's mortality (assuming 100% discard mortality). Furthermore, limited evidence suggests that animals encountered in Pacific Canadian waters are primarily immature individuals.

POPULATION SIZES AND TRENDS

There is no region in the world where blue shark abundance and trends are well understood. Trends in the abundance can only be inferred through catch rate information and limited biological information taken from catches. Internationally there are only a few published accounts of blue shark abundance trends. Due to the highly migratory behaviour of this species, its status in Canadian waters is probably dependent on ocean basin-wide population trends.

Information sources

Atlantic

There are no surveys specifically designed to estimate abundance of blue sharks. Information on abundance, trends, and biological information in Canada is derived from commercial catch data verified through the Maritime and Newfoundland International Observer Programs (IOP) (1978-2003) and from recreational fisheries in the form of shark derbies. Given that blue sharks found in Canadian waters are part of a much larger Atlantic population, international assessments from NMFS and International Commission for the Conservation of Atlantic Tuna (ICCAT) are also important in determining the status of blue shark in Canada.

Pacific

Although anecdotal information from fishers and other mariners indicates that blue sharks are common in waters off British Columbia, there are no indicators of abundance. There has been only one directed investigation into blue sharks in Canada's Pacific waters. Catch databases including trawl and hook and line were examined for records as well as all Canadian groundfish surveys from 1979-present. International surveys that occur in Canadian waters, including the IPHC survey and U.S. NMFS Triennial groundfish survey, were examined for Canadian records of blue sharks. International surveys and assessments occurring adjacent to Canadian waters were also examined.

Atlantic Population Abundance and Trends

Atlantic Population Abundance

There are no reliable estimates of the number of mature blue sharks in Canadian waters. Mature females are rarely observed, which is thought to be due to a natural age/sex segregation. There are no defensible methods for estimating absolute abundance in Canadian waters.

Atlantic Population Trends-International Waters

The existence of international high-seas fisheries coupled with the wide-ranging nature of the blue shark makes it difficult to acquire reliable data suitable for determining trends. Specifically, the under-reporting, misreporting, and non-reporting of shark bycatch by several international fleets has hampered the ability to conduct accurate stock assessments (ICCAT 2005). Furthermore, the lack of biological data, including age and length frequencies, sex ratios, breeding periodicity, and estimates of natural mortality further constrain the possibility for accurate assessments. However, there appears to be no disputing that total fishing effort on pelagic species in the North Atlantic has increased approximately tenfold over the last fifty years (Figure 11). Since those fisheries unavoidably capture blue sharks as bycatch, it is highly probable that total fishing mortality of blue shark in the North Atlantic has increased correspondingly.

Large scale abundance indices of blue sharks rely primarily on catch rates (catch per unit of effort or CPUE) reported from a sub-sample of the international fishery. Two international blue shark assessments are presented; one from ICCAT and the other from an analysis published by researchers at Dalhousie University in Halifax (Baum *et al*. 2003). Both of these assessments use components of the same datasets.

International Commission for Conservation of Atlantic Tunas (ICCAT) Blue Shark Assessment

In 2004 the ICCAT subcommittee on bycatch undertook a review of available blue shark information throughout the Atlantic (north and south) for the purposes of deriving an overall assessment (ICCAT 2005). The incomplete nature of shark catch reporting necessitated the estimation of blue shark catch and mortality using ratios of shark to tuna landings from fleets reporting both to ICCAT. A catch history for blue shark by major gear type was reconstructed using these ratios. The assessments described below use this catch reconstruction. Additional uncertainties include uncertainty on frequency of reproduction (which affects intrinsic rate of increase), and uncertainty about initial carrying capacity of the species. Because of uncertainties in input data the results of the assessments were considered “preliminary and extremely uncertain” by ICCAT, and were used mainly to provide a tentative basis for assessment models which utilize catch, effort and biological information. Models for the North Atlantic were based on what were considered to be the best available data; (1) Japanese longline logbook and (2) the U.S. longline logbook (Figure 14). Three models were explored; a Bayesian surplus production model, an age-structured model, and a ‘catch-free’ model.

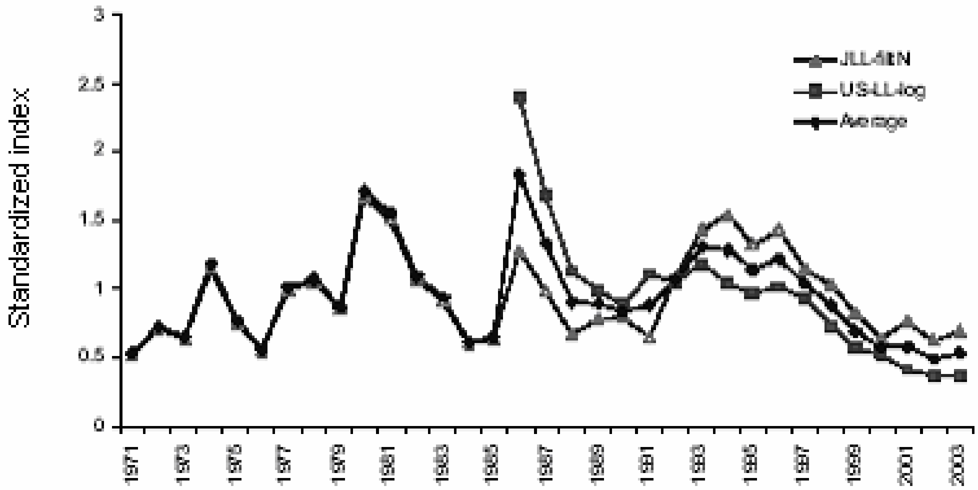

Figure 14. Indexed CPUE of blue shark in the North Atlantic from the Japanese longline fleet (JLL) and United States longline fleet (USLL) from 1971-2003. Index achieved by identifying the years common to all indices, calculating the mean within each series for those common years, and expressing all values in each series as a proportion of the calculated mean for that series. Figure from ICCAT 2005.

The Bayesian surplus production model involved 10 runs of which the three which converged showed an average current biomass around 85% of the unfished biomass.

The age structured model was run using the complete CPUE series from the U.S. longline logbook CPUE series and the CPUE series from the Japanese longline fleet without the first three values (1971-1973) (Figure 15). The model was run using two different weightings of the CPUE series; equal weighting (Run 1) and catch dependent weighting (Run 2). The model was also run assuming a biannual or annual reproduction cycle (Run 3). The probability density functions for population depletion of all three runs indicated depletion of about 50% but also suggested that the ratio of the current stock size to virgin stock size is close to 1 (i.e., no depletion).

The catch-free model consisted of three scenarios using the averaged CPUE index (Figure 14). The results from the original assessment produced implausible results and were corrected in a later ICCAT document (Brooks 2005). The results of the re-assessment are the same as those made during the assessment meeting, namely that blue shark do not appear to be overfished.

ICCAT (2005) and a subsequent peer-review (Simpfendorfer 2005) concluded that the assessments showed that North Atlantic blue shark population is above the biomass at maximum sustained yield, but stated that results should be considered “preliminary and extremely uncertain”. One critical assumption for all of the assessments described above is the initial blue shark carrying capacity: if the assumed value was correct, then current biomass is well above MSY levels; if underestimated, then the current biomass could be

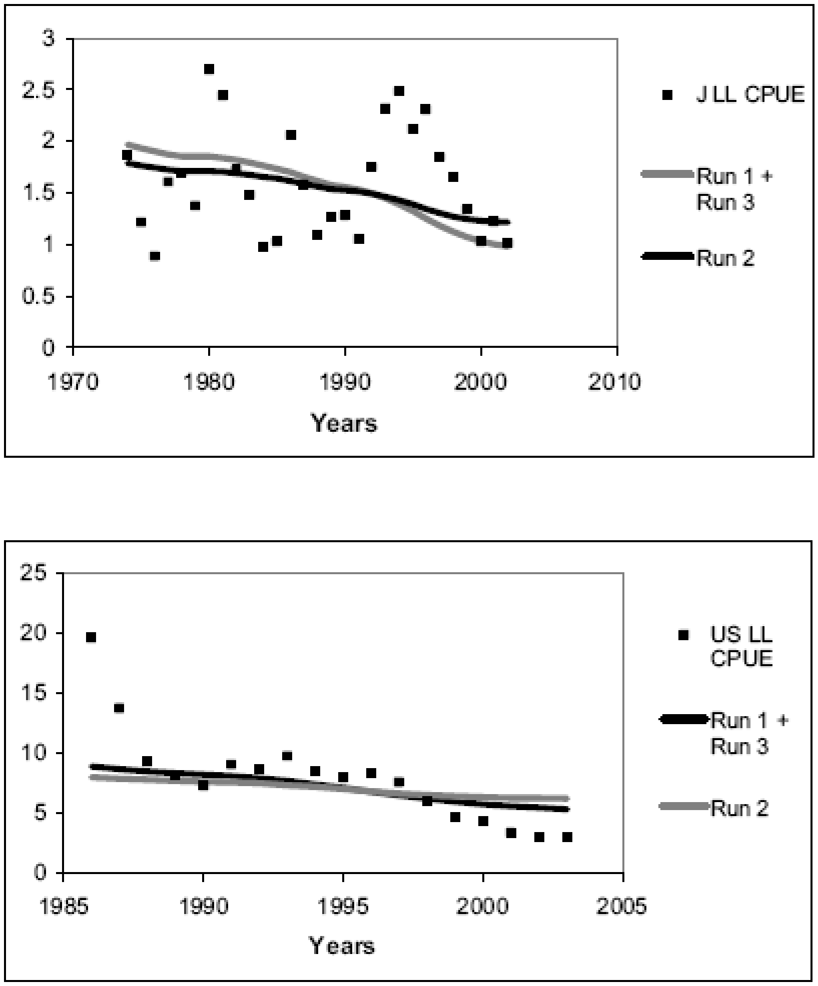

Figure 15. Fit of the age structured model for North Atlantic blue shark for each of the runs considered using Japanese (above) and U.S. CPUE data (below). Figure from ICCAT 2005.

below MSY levels. Overall, the ICCAT document provides a very useful data summary but does not offer any strong conclusions one way or the other about the status of North Atlantic blue shark.

The abundance index for the years 1971-2003 based on catch per unit effort in the US and Japanese longline fleets used by ICCAT (Figure 14) can be used to explore abundance trends. This index shows no long-term change since 1971, although there was an increase to the mid-1980s followed by a decrease.

Dalhousie University Blue Shark Assessment

Analyses by Baum (2002) and Baum *et al*. (2003) use the same U.S. longline logbook data as ICCAT but restrict their analysis to catch rates in the period 1986-2001 when species identification was considered relatively reliable. The author/s examined data from nine assessment regions covering the western Atlantic from South America to the Grand Banks of Canada (Figure 16). The dataset analyzed consists of 214 234 longline sets between 1986 and 2000 with a mean of 550 hooks per set. A total of 1 044 788 records of blue sharks are found in the database.

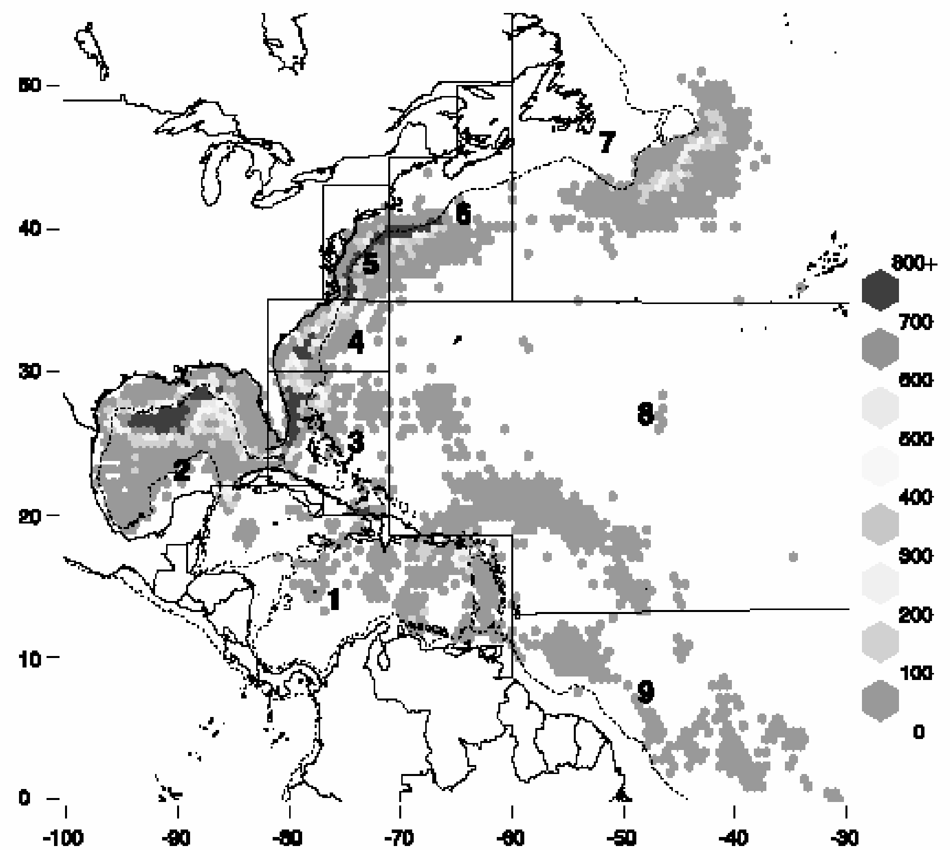

Figure 16. Map of the Northwest Atlantic showing the distribution of effort in the U.S. pelagic longline fishery between 1986 and 2000, categorized by number of sets (0 to 800+), within the nine areas assessed: 1, Caribbean; 2, Gulf of Mexico; 3, Florida East Coast; 4, South Atlantic Bight; 5, Mid Atlantic Bight; 6, Northeast Coastal; 7, Northeast Distant; 8, Sargasso/North Central Atlantic; 9, Tuna North/Tuna South. Areas were modified from the U.S. National Marine Fisheries Service classification for longline fisheries. The 1000-m coastal isobath (dotted line) is given for reference. From Baum *et al*. 2003. Note, it is difficult to discern the 100 hexagon from the 700 hexagon in the grey scale presented. With the exception of a few hexagons in close proximity to high density areas (darkest grey), the majority are low density (0-100).

For international waters adjacent to the Scotian Shelf (Area 6) and the Grand Banks (Area 7) declines in CPUE of 63.8% and 9.6% respectively were estimated for the years between 1986-2000 (Figure 17, Baum 2002). The overall trend in blue shark CPUE in the entire northwest Atlantic reported by Baum *et al*. (2003) showed a gradual and constant decline of 60% (95% CI: 58 to 63%) over the period 1986-2000, equivalent to a decline rate of 6.4% per year (Figure 18).

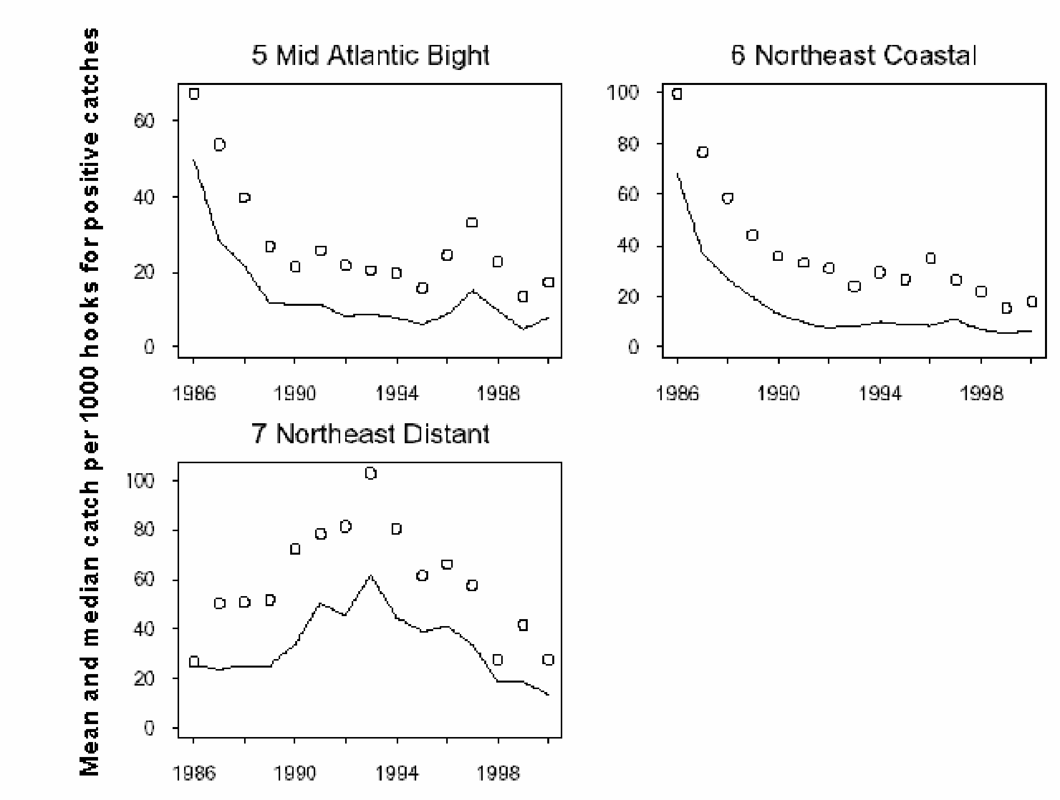

Figure 17. Catch rate of blue sharks in three assessment regions in the northwest Atlantic expressed as a mean (full circles) and median (solid line). Figures reprinted from Baum 2002. Note these areas are the same as those found in Figure 15.

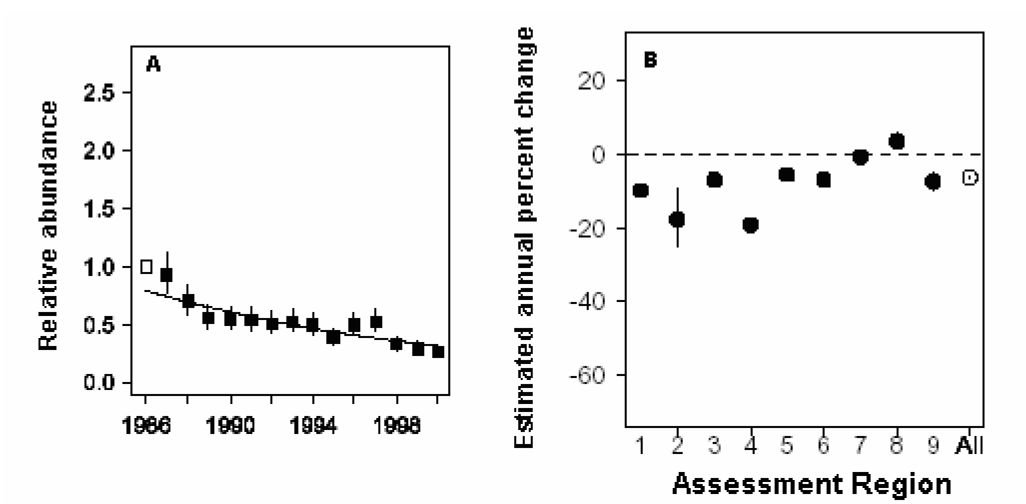

Figure 18. A. Relative abundance of blue sharks in the entire West Atlantic indicated by an analysis of U.S. commercial longline fishery logbook (60% decline) from 1986-2000; (B) estimated annual rate of change for each assessment region and total. Note the areas in (B) are shown in Figure 16. Source: Baum *et al*. 2003.

The findings by Baum *et al*. (2003) are supported by similar findings by Brooks *et al*. (2005) who analyzed standardized catch rates for blue sharks using U.S. pelagic logbook data (1986-2003) from the entire North Atlantic. Brooks *et al*. (2005) found that the overall relative decline in catch rates between 1989 and 2003 dropped from a relative value of about 0.9 to 0.3. Similarly, Simpfendorfer *et al*. (2002), using catch and effort data from a fishery-independent longline survey in the western North Atlantic found that male blue sharks showed an approximately 80% decline between the mid-1980s and the early 1990s, while a significant change in female catch rates could not be demonstrated.

On the other hand, Burgess *et al*. (2005) challenged some aspects of the analysis by Baum *et al*. (2003) and argued that the trend observed for the blue shark should be considered preliminary without the full benefit of data from multiple international sources and a complete stock assessment.

Atlantic Population Trends-Canadian Waters

Population trends observed in Canadian waters have been reported in Campana *et al*. (2004) based on catch rates in the commercial fishery and fishing derbies and inferences from biological data. Campana *et al*. (2004) used a general linear model (GLM) to analyze standardized commercial catch rates from Canadian and Japanese vessels with year, region, season, target species and vessel (CFV) as factors. The analysis was restricted to fall and winter and the regions Newfoundland and Scotian Shelf, for the period after 1994. The GLM trends in swordfish and bigyeye tuna fisheries were similar and were analyzed together whereas the trend for bluefin tuna fisheries necessitated a separate analysis. The GLM of blue shark catch rate based on bigeye tuna and swordfish fisheries data indicated that all factors but season and target species were significant. The marginal catch rate based on significant factors indicated that catch rates have declined significantly since 1995 (Figure 19). The decline is estimated to be 53% (6.6%/yr) from 1995-2003 with the year term in the model being highly significant ($P<0.001$) (Figure 19). The GLM based on bluefin tuna fisheries was significant with respect to all factors. However, the significant interaction terms necessitated that the marginal trends be plotted separately by region (Figure 20). The trend based on the Scotian Shelf fishery showed a significant decline for the first three years of the time series, but with relative stability in recent years. The trend based on the Newfoundland fishery suggested a modest increase since 1995, although there were few significant differences among years.

Catch rates from the recreational derby fisheries were also used as an index of blue shark abundance (Campana *et al*. 2004). Estimation is complicated by the presence of multiple fishers per boat, discarding of undersized sharks, and difficulties in assigning catches to specific fishers on the boat. A coarser approximation of fishing success (percentage of fishers catching sharks) at each derby suggests that catch rates across derbies (i.e., different regions) within a year are often synchronous and have declined slightly between 1998 and 2003.

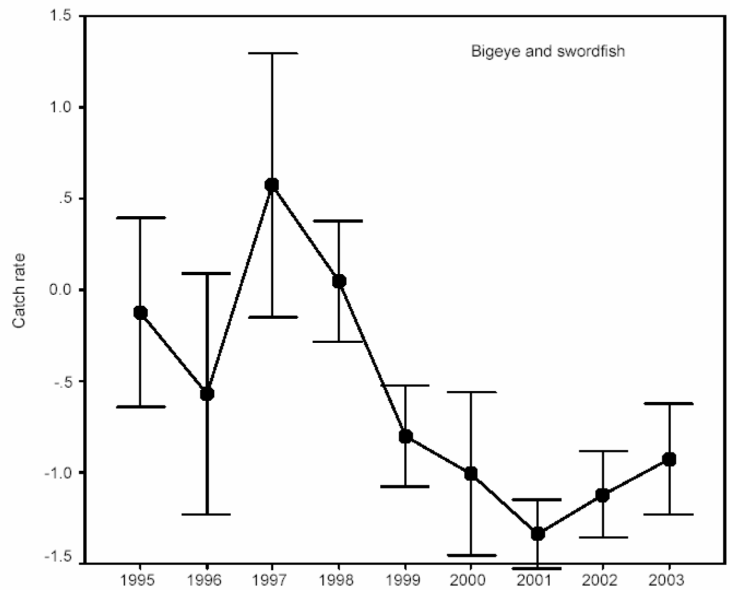

Figure 19. Standardized commercial catch rate (ln-transformed kg/hook ± 95% CI) of blue shark in Canadian and Japanese large pelagic fisheries targeting bigeye tuna and swordfish (From Campana *et al*. 2004).

Analysis of SST (sea surface temperature) in relation to recreational catch rate suggests a relationship with temperature, since the year with the highest catch rate (1999) was also among the warmest, while the year with the poorest catch rate (2001) was among the coldest. Anecdotal comments by fishers also supported the view that there was a correspondence between warm water conditions and higher catch rates for blue sharks. Records maintained by a charter operator indicate that blue sharks were caught at temperatures between 10-20°C; however, most were caught between 14-18°C (Campana *et al*. 2004). A more rigorous statistical analysis of these data was not carried out.

A standardized catch rate for the recreational fishery was prepared by Campana *et al*. (2004) using a binomial dependent variable (successful/unsuccessful) and derby location as a fixed factor in a GLM. The model was not statistically significant. A final GLM was based on the overall fishing success at the 5 shark fishing derbies carried out annually since 1998. Individual catch rates were not available, so an index based on the percentage of fishers successful in catching a shark at each derby was used. This model was less than ideal, since the derbies represented fixed factors, and thus year X derby interaction terms could not be assessed. With these deficiencies in mind, the model suggested a significant decline since 1999 of 27% (Figure 21). When scaled to the same scale as the standardized bigeye/swordfish model (Figure 19), the trend across years was similar in the two models. These results suggest that the derbies and the offshore commercial fishery are samples from the same population, and that the catch rate from 1999 to 2003 was significantly lower than in the period 1995 to 1998.

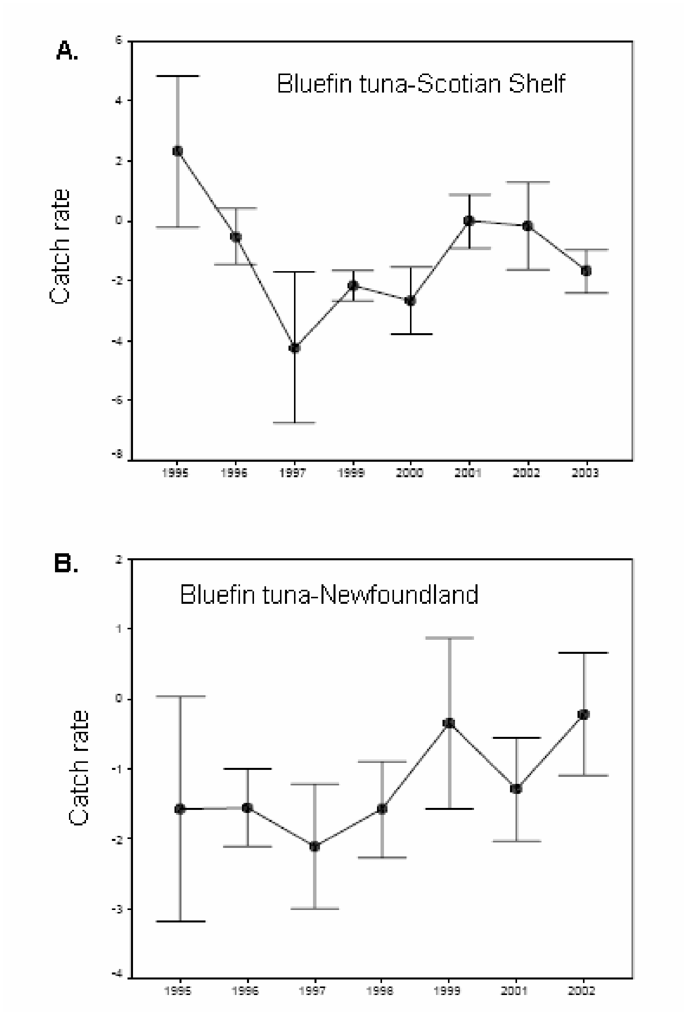

Figure 20. Standardized commercial catch rate (ln-transformed kg/hook ± 95% CI) of blue shark by region in Canadian and Japanese large pelagic fisheries targeting bluefin tuna on (A) the Scotian Shelf and (B) waters off Newfoundland. Source: Campana *et al*. 2004.

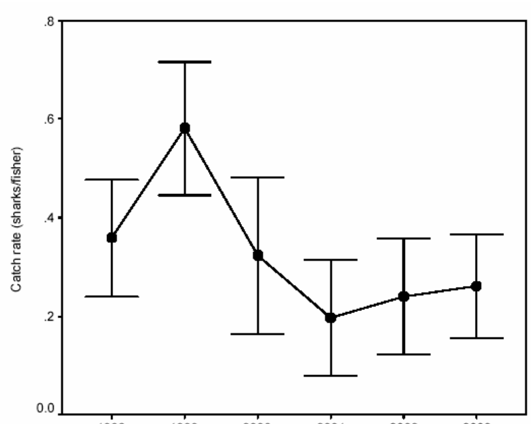

Figure 21. Standardized catch rate (sharks/fisher, ± 95% CI) of blue sharks at recreational shark derbies (From Campana *et al*. 2004).

Biological data from long-term changes in mean length can be used as an indicator of exploitation intensity. Since 1986 there has been a significant decline in the mean lengths of commercially caught blue sharks in both the Canadian and Japanese fisheries (Figure 22). The analysis was restricted to the fall and winter seasons in order to minimize seasonal differences. The difference between the Canadian and Japanese fisheries is most likely due to differences in depth fished (Campana *et al*. 2002). There was no apparent trend from the recreational fishery, presumably due to targeting of the largest individuals.

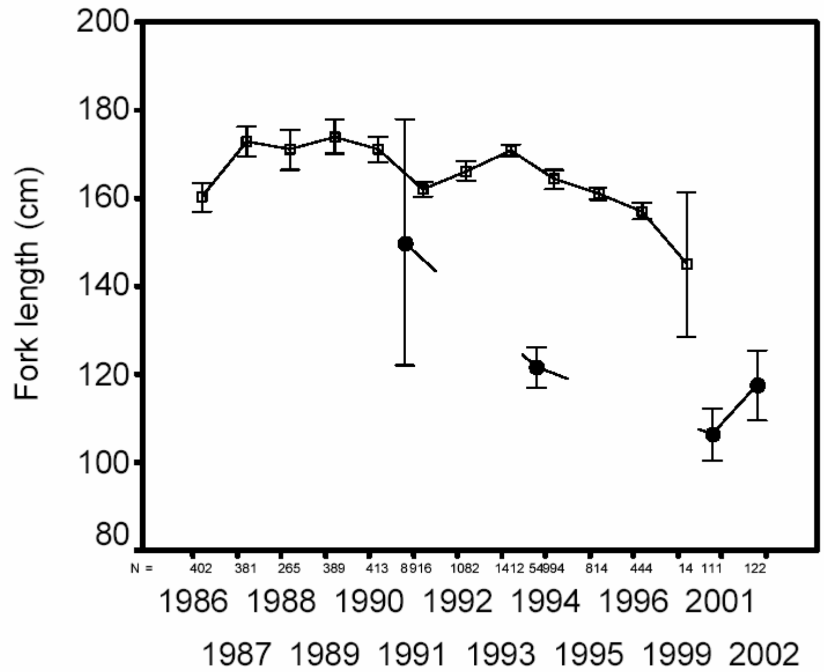

Figure 22. Trend in mean fork length (± 95% CI) of blue sharks caught in fall and winter in Japanese (open square-top series) and Canadian (closed circle-bottom series) pelagic longline fisheries, as observed by the International Observer Program (From Campana *et al*. 2004).

Summary of Atlantic Trends

Overall there appears to be a decline in blue shark abundance in the northwest Atlantic based on several indices (see Table 1 for summary). All of the indices examined have shortcomings. The Canadian Atlantic population of blue sharks is part of a population occupying the entire North Atlantic. Studies that cover large geographic areas are necessary for understanding the overall status of this population. Results from regional studies may be influenced by local environmental conditions and demographic partitioning of the hemisphere-wide population. With respect to geographical coverage, the ICCAT population assessments cover the entire North Atlantic range of the population. However, the input data are considered to be highly uncertain and the results are inconclusive. The ICCAT CPUE series is based on uncertain identification to species in the earlier years. The Baum *et al*. (2003) analysis covers only the northwest Atlantic and a single fleet, which probably represents the best large-scale dataset presently available, but the data quality has been called into question due to the fact that it was derived from fishermen's logbooks. The indices presented by Campana *et al*. (2004) cover a smaller area but are in or near Canadian waters and use the most reliable data (observer data). The abundance indices presented by both Campana *et al*. (2004) and Baum *et al*. (2003) were consistent with one another despite coverage of only the northwest Atlantic. Overall, the Baum *et al*. (2003) and Campana *et al*. (2004) indices are the most representative of the status in Canadian waters.

Table 1. Population trend indices for blue shark in Canadian and northwest Atlantic waters.

Study	Years	Area	Overall Trend	Comments
ICCAT 2005	1971-2003 (32 yrs)	NW Atlantic	No overall trend 1971-2003 (increase then decrease) Up to 60% decline 1987-2003	US and Japanese longline logbook CPUE data. Early years uncertain because of identification issues (Figure 14)
Baum *et al*. 2003	1986-2000	NW Atlantic	60% decline	CPUE from US longline logbook data (Figures 17,18B)
Baum *et al*. 2003	1986-2000 (14 yrs)	Area 6, adjacent to Scotian shelf	64% decline	(Figure 18A)
Baum *et al*. 2003	1986-2000	Area 7, adjacent to Grand Banks	No overall trend (increase, then decrease - 9.6% decline start to end)	(Figures 17,18B)
Campana *et al*. (2004)	1995-2003 (8 yrs)	Newfoundland and Scotian shelf	53% decline	Commercial catch rates (Figure 19)
Campana *et al*. (2004)	1998-2003 (5 yrs)	Canadian waters	27% decline	Recreational catch rate (Figure 21)

Pacific Population Abundance and Trends

There has been little research on blue sharks in Canada's Pacific waters. There are two Canadian-based studies; one which involved assessing bycatch of blue sharks in an experimental Canadian high seas squid driftnet fishery (1985-1987) (McKinnell and Seki 1998) and the other consisting of a single four-day research trip done through a private company in 1991 (IEC Collaborative Marine Research and Development Limited 1992). Neither of these studies provided information on trends or abundance, but some limited biological information was obtained. All other blue shark data in Canada's Pacific waters are from catch databases and from observations recorded during various research surveys. The low encounter rate found in fishery operations and research surveys does not provide sufficient data to allow for analysis of population trends.

Pacific Population Trends-International Waters

Blue sharks are commonly caught by international pelagic fisheries throughout the North Pacific, but there have been few attempts to assess trends. Assessments in the North Pacific are constrained by under-reporting of catches and/or grouping of all sharks together as a single category. Nakano (1996) used standardized shark CPUE (~70% assumed to be blue shark) from Japanese commercial logbooks (1971-1993) and concluded that there was a 20% decline of CPUE in the North Pacific. The most comprehensive assessment for blue shark in the North Pacific was undertaken by Klieber *et al*. (2001) who reported that the MSY for blue sharks in the Pacific was 1.8-4 times greater than current estimated fishing mortality in the North Pacific and concluded that the blue shark population appears to be in no danger of collapse.

Pacific Population Trends-Canadian Waters

There are numerous ongoing research surveys undertaken in Canadian waters. These surveys are not designed for sampling pelagic species and consequently only provide limited data. Since 1993, the International Pacific Halibut Commission (IPHC) has been recording non-halibut species in their annual surveys along the west coast of North America. Data are available for blue sharks from 1998 to 2004 as prior to this all sharks were aggregated into a single category. The IPHC changed their survey protocol beginning in 2003 and therefore inter-annual comparisons for rarely caught species require some interpretation. From 1998-2004 a total of 170 blue sharks were recorded in the Canadian portion of the IPHC survey. Of the 171 survey stations in Canadian waters, 68 have a record of a blue shark since 1998 (Figure 7). These surveys clearly show that most of the encounters take place in the southern portion of Hecate Strait. Blue shark catch rates since 1998 have varied between 0.06-0.93 sharks/1 000 hooks (Figure 23). Catch rates in the 2004 survey were the highest on record which also coincides with anecdotal reports from tourism and other marine operators of more encounters of blue sharks possibly in response to an El Niño event.

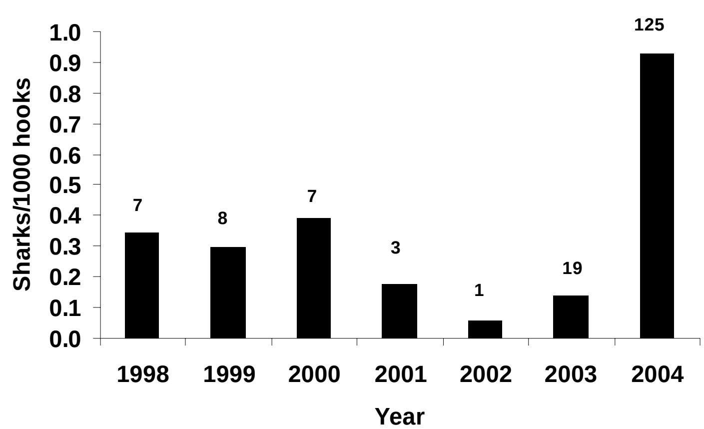

Figure 23. Catch rate of blue shark in IPHC set surveys in Area 2B (Canada) from 1998-2004. Numbers above bars represent the number of blue sharks caught. Data source: IPHC set survey database.

The NMFS Triennial trawl survey has conducted tows off southwest Vancouver Island on a triennial basis since 1981. There are no records of blue shark from Canadian waters and only four records in total from U.S. waters (database accessed by authors).

A variety of groundfish and shrimp survey databases undertaken by DFO from 1979 to present were examined for blue shark records. In total 12 records consisting of 14 blue sharks were found (Appendix 3).

The Canadian experimental high seas flying squid driftnet fishery occurred between 1979-1987 but blue shark data were only collected for three years (1985-1987) and biological data for only 1987 (McKinnell and Seki 1998). It should be noted that most of the fishery took place in the eastern North Pacific outside of Canada's Exclusive Economic Zone (EEZ). An important finding from this study was that the CPUE was nearly tenfold greater than that observed in the Japanese central North Pacific driftnet fishery (McKinnell and Seki 1998) indicating that blue sharks are relatively abundant in high seas waters near Canada.

In summary, there is insufficient information to estimate abundance or trends in Canada's Pacific waters. The hook and line fleet appears to be the largest source of blue shark mortality on Canada's Pacific coast although catch mortality is low (see Fishery section above). The distribution of the catch and the IPHC survey records indicate that blue sharks appear to be found throughout the continental shelf with a concentration closer to the slope break (Figures 6&7). A single research trip conducted in 1991 caught 134 sharks in a period of four days which suggests that blue sharks can be caught quite readily in Canadian waters if they are targeted (IEC Collaborative Marine Research and Development Limited 1992).

Rescue effect

Canadian waters represent a small portion of blue shark habitat in both the Pacific and Atlantic oceans, reproduction does not occur in Canadian waters and there is good evidence that blue sharks are highly migratory. Thus, the population status of blue shark and the potential for rescue in Canadian waters is completely dependent on the status of the hemispheric populations. If the ocean basin-wide population increases, so should the relative abundance in Canadian waters.

LIMITING FACTORS AND THREATS

Fishing mortality is the single largest threat to blue shark populations worldwide. Pelagic fisheries regularly catch blue sharks as bycatch. Campana *et al*. (2004) examined six pelagic fisheries occurring in Canada's Atlantic waters and found that, mean blue shark bycatch accounted for 26-152% of the total directed large pelagic catch, with an overall mean of 34%. A review of published catch rates in North Atlantic pelagic fisheries found catch rates ranged from 5.1-40.0 blue sharks per 1 000 hooks

(Campana *et al*. 2004). Blue sharks have little value and are therefore released at sea. Campana *et al*. (2004) estimated that 60% of blue sharks would survive after being captured. Current catch of blue sharks in Canadian waters between 1996 and 2002 has been less than 1 000 t/yr which is a decline from the early 1990s when catches were often greater than 1 500t. Annual removals in Canadian waters probably represent a small fraction (perhaps 1% or less) of total removals in the North Atlantic.

Longline effort in the entire Atlantic has rapidly increased since 1955 (Figure 11), and fishing mortality is probably increasing in direct proportion to the fishing effort (although this information is not directly relevant to individuals in Canadian waters it is considered a good indication of fishing effort on the wider population). Decreasing fishing mortality on this species is only possible with a decrease in fishing effort for pelagic species worldwide. In 2004, ICCAT adopted the resolution to prohibit shark finning, which is anticipated to decrease fishing mortality. However, the amount of blue shark fins removed on an annual basis is unknown (see next section). The impact on blue shark populations from this change in fishing practice depends on the proportion of blue sharks which are currently being finned and by the compliance rate of the various international fisheries involved.

SPECIAL SIGNIFICANCE OF THE SPECIES

This species is one of the most abundant, widespread, fecund, and fast growing shark species worldwide and likely is a very significant component of pelagic oceanic ecosystems throughout the tropical and temperate oceans worldwide. Blue shark has very low value in the marketplace and is often discarded when caught as bycatch. The meat is rarely marketable due to the rapid breakdown of urea in the muscle tissue into ammonia immediately following death thereby tainting the meat. The fins are of low value but may contribute an estimated 50-70% of the international fin market traded through Hong Kong (Nakano and Seki 2002). It is thought that most of these fins originate from high seas North Pacific waters and are captured by Japanese, Taiwanese, and Korean vessels.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

There are no jurisdictions that prohibit the capture of blue sharks. In Canada finning is prohibited on both coasts and blue sharks cannot be landed in the hook and line fishery (Pacific) or recreational fishery (Atlantic). Fisheries management plans for blue sharks in Atlantic Canada consist of a nonrestrictive catch guideline of 250t. Finning has been prohibited in the U.S. Atlantic since 1993 and since 2000, the U.S. Shark Finning Prohibition Act has prohibited finning in all federal waters. In 2004, ICCAT accepted a resolution to prohibit finning in Atlantic pelagic fisheries. Finally, the IUCN assessed the blue shark in 2000 and listed it as *lower risk/near threatened* (LR/nt).

TECHNICAL SUMMARY

Prionace glauca
Blue shark - Atlantic population — Requin bleu
Range of Occurrence in Canada: Atlantic Ocean

Extent and Area Information	
• *Extent of occurrence (EO)(km²)* Sum across the annual distributional range determined from catches.	1,200,000 km²
• *Specify trend in EO*	Unknown
• *Are there extreme fluctuations in EO?*	Unlikely
• *Area of occupancy (AO) (km²)* **Represents area of frequent and regular sightings (catches).**	800,000 km²
• *Specify trend in AO*	Unknown
• *Are there extreme fluctuations in AO?*	Unlikely
• *Number of known or inferred current locations*	Widespread, non localized.
• *Specify trend in #*	Not Applicable
• *Are there extreme fluctuations in number of locations?*	Not Applicable
• *Specify trend in area, extent or quality of habitat*	Habitat not considered to have changed.
Population Information	
• *Generation time (average age of parents in the population)*	8 years (approximate)
• *Number of mature individuals*	Unknown
• *Total population trend:*	Possible decline
• *% decline over the last/next 10 years or 3 generations.* 1. Northwest Atlantic longline CPUE (Baum)(1986-2000) 2. ICCAT longline CPUE (ICCAT)(1971-2000) 3. Scotian shelf longline CPUE (Baum)(1986-2000) 4. Grand Banks longline (Baum) (1986-2000) 5. Canadian bigeye swordfish fleet CPUE (Campana)(1995-2003) 6. Canadian bluefin fleet longline CPUE (Campana)(1995-2003)	 1. 60% decline 2. No overall trend 3. 64% decline 4. No overall trend 5. 50% decline 6. No overall trend
• *Are there extreme fluctuations in number of mature individuals?*	No
• *Is the total population severely fragmented?*	No
• *Specify trend in number of populations*	Considered a single ocean basin-wide population
• *Are there extreme fluctuations in number of populations?*	N/A
• List populations with number of mature individuals in each: Not Available	
Threats (actual or imminent threats to populations or habitats)	
The primary threat is fishing, especially mortality from pelagic longline fishing operations where blue sharks are regularly caught as bycatch. Fishing in Canada's Atlantic waters contributes a small fraction of the overall removals in the North Atlantic	
Rescue Effect (immigration from an outside source)	
• *Status of outside population(s)?* Blue sharks are highly migratory and status in Canada is a reflection of the population as a whole.	
• *Is immigration known or possible?*	Yes (seasonal)
• *Would immigrants be adapted to survive in Canada?*	Yes (seasonal)
• *Is there sufficient habitat for immigrants in Canada?*	Yes
• *Is rescue from outside populations likely?*	Yes

Quantitative Analysis	
Quantitative Analysis [provide details on calculation, source(s) of data, models, etc]	Not undertaken
Current Status COSEWIC: Special Concern, April 2006 IUCN: lower risk/ near threatened	

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code**: Not applicable

Reasons for Designation:
This species is a relatively productive shark (maximum age 16-20 years, mature at 4-6 years, generation time 8 years, 25-50 pups every two years) but as an elasmobranch, populations are susceptible to increased mortality from all sources including from human activities. The species is considered to have a single highly migratory population in the North Atlantic, of which a portion is present in Canadian waters seasonally. The abundance index which is considered to best represent the whole population has declined 60% 1986-2000 but another index shows no long-term trend for the whole population 1971-2003. Indices of abundance in and near the Canadian waters show variable trends from no decline to 60% decline from the 1980s to early 2000s. There is evidence for a decline in mean length in longline fisheries in Canadian waters 1986-2003. The primary threat is bycatch in pelagic longline fisheries; although the threat is understood and is reversible, it is not being effectively reduced through management. Assessing the impact of bycatch on the population would benefit from better information on proportion of individuals discarded which survive. It appears that recent fishery removals from the North Atlantic have been several tens of thousands of tons annually. Estimated Canadian removals, a small proportion of the total, have been declining since the early 1990s and recently have averaged around 600 t/yr.

Applicability of Criteria

Criterion A: (Declining Total Population): Not applicable.

Criterion B: (Small Distribution, and Decline or Fluctuation): Not applicable.

Criterion C: (Small Total Population Size and Decline): Not applicable.

Criterion D: (Very Small Population or Restricted Distribution): Not applicable.

Criterion E: (Quantitative Analysis): Not applicable.

TECHNICAL SUMMARY

Prionace glauca
Blue shark - Pacific population — Requin bleu
Range of Occurrence in Canada: Pacific Ocean

Extent and Area Information	
• *Extent of occurrence (EO)(km²)* **Sum across the annual distributional range determined from catches.**	117,000 km²
• *Specify trend in EO*	Unknown
• *Are there extreme fluctuations in EO?*	Unlikely
• *Area of occupancy (AO) (km²)*	Unknown
• *Specify trend in AO*	Unknown
• *Are there extreme fluctuations in AO?*	Unlikely
• *Number of known or inferred current locations*	Widespread, non localized.
• *Specify trend in #*	Not Applicable
• *Are there extreme fluctuations in number of locations?*	Not Applicable
• *Specify trend in area, extent or quality of habitat*	Habitat not considered to have changed.
Population Information	
• *Generation time (average age of parents in the population)*	8 years (approximate)
• *Number of mature individuals*	Unknown
• *Total population trend:*	Unknown
• *% decline over the last/next 10 years or 3 generations.*	Unknown
• *Are there extreme fluctuations in number of mature individuals?*	Unlikely
• *Is the total population severely fragmented?*	No
• *Specify trend in number of populations*	Considered a single ocean basin-wide population
• *Are there extreme fluctuations in number of populations?*	No
• List populations with number of mature individuals in each: Not Applicable	
Threats (actual or imminent threats to populations or habitats)	
The primary threat is fishing - blue sharks are caught as bycatch. Fishing in Canada's Pacific waters accounts for an insignificant proportion of the total annual catch in the North Pacific (20-40 t of the estimated total 39,000 t/yr.)	
Rescue Effect (immigration from an outside source)	
• *Status of outside population(s)?* Blue sharks are highly migratory and status in Canada is a reflection of the population as a whole. The overall status in the Pacific is unknown.	
• *Is immigration known or possible?*	Yes (seasonal)
• *Would immigrants be adapted to survive in Canada?*	Yes (seasonal)
• *Is there sufficient habitat for immigrants in Canada?*	Yes
• *Is rescue from outside populations likely?*	Yes

Quantitative Analysis [provide details on calculation, source(s) of data, models, etc]	Not undertaken
Current Status COSEWIC: Data deficient, April 2006 IUCN: lower risk/ near threatened	

Status and Reasons for Designation

Status: Data deficient	**Alpha-numeric code**: Not applicable
Reasons for Designation: The species is apparently present regularly in Canada's Pacific waters, probably as part of a wider North Pacific population. Catch information and data from the International Pacific Halibut Commission longline survey (1998-2004) suggest the species is widespread on the continental shelf with a concentration at the shelf break. It has also been taken, at times in large numbers, in oceanic waters. No information is available to assess status in Canada, as there have been few records in existing surveys. Pacific-wide indices are of low reliability because of historical misidentification issues, but one recent assessment from United States National Marine Fisheries Service suggests that fishing mortality on this species in the North Pacific is well below the level of maximum sustainable yield. Level of fishery removals (bycatch) in the Canadian Pacific are low, of the order of 20-40 t/yr.	
Applicability of Criteria **Criterion A**: (Declining Total Population): Not Applicable. **Criterion B**: (Small Distribution, and Decline or Fluctuation): Not Applicable. **Criterion C**: (Small Total Population Size and Decline): Not Applicable. **Criterion D**: (Very Small Population or Restricted Distribution): Not Applicable. **Criterion E**: (Quantitative Analysis): Not Applicable.	

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

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This report was handled for COSEWIC by Mart Gross and Howard Powles (Co-chairs Marine Fishes) and Blair Holtby (SSC Member).

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Dr. Pierre Kleiber, National Marine Fisheries Service, Hawaii
Dr. Robin Allen, Inter-American Tropical Tuna Commission, Scripps Institution of Oceanography

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LIST OF ACRONYMS

Acronym	Full Text	Comments
CPUE	Catch Per Unit of Effort	
DFO	Department of Fisheries and Oceans	
GFBIO	Groundfish Biological Database	Database of biological information on Pacific groundfish species.
ICCAT	International Commission for the Conservation of Atlantic Tuna	
IOP	International Observer Program	Atlantic Canada Observer Program
IPHC	International Pacific Halibut Commission	
NMFS	National Marine Fisheries Service	
PacHarv	Pacific Harvest	catch database used by DFO Pacific Region
PacHarvHL	Pacific Harvest Handline.	fisheries include halibut, rockfish, sablefish, dogfish, and lingcod licences
PacHarvTrawl	Pacific Harvest Trawl	All groundfish trawl

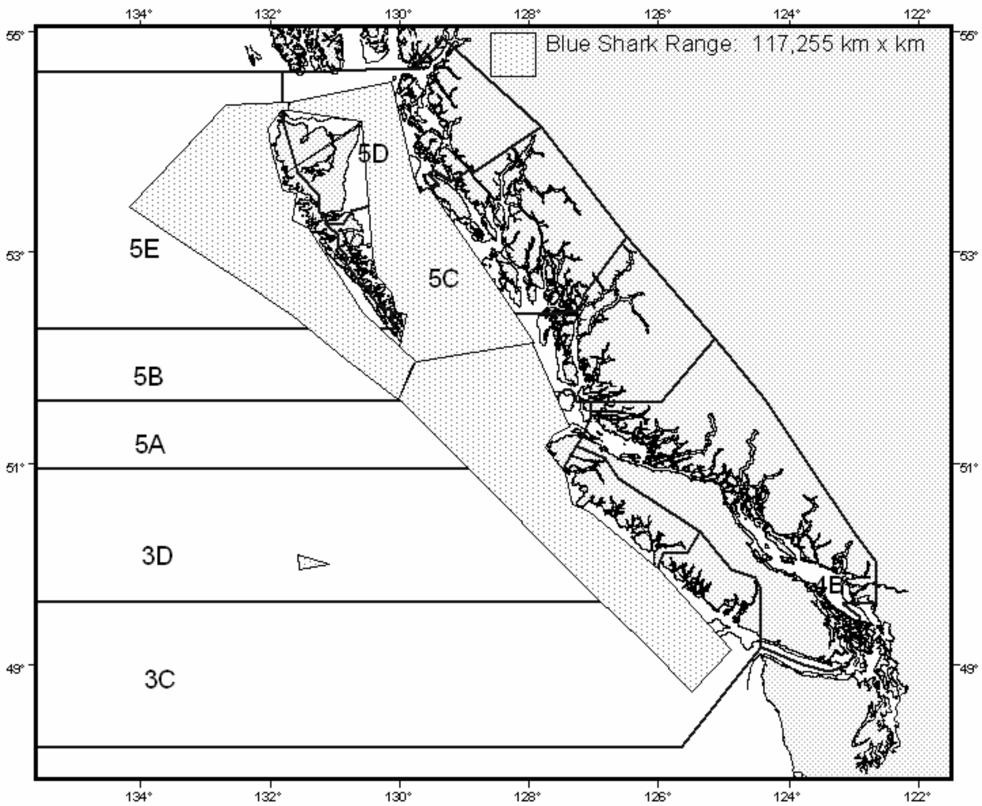
BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Dr. Scott Wallace is an independent fisheries scientist (PhD UBC Fisheries Centre) and owner of Blue Planet Research and Education on Vancouver Island, BC. His interests are best management practices and the sustainability of Pacific fisheries. Dr. Steven Campana is a DFO Senior Scientist at the Bedford Institute of Oceanography, Nova Scotia where he studies Canada's Atlantic sharks. Dr. Gordon (Sandy) McFarlane is a DFO scientist at the Pacific Biological Station, BC where he studies the biology and distribution of sharks and skates. Dr. Jacquelynne King is a DFO scientist at the Pacific Biological Station, BC where she studies age and growth parameters for big and longnose skates, ageing methodology for sixgill sharks, and distribution and migration of spiny dogfish.

Appendix 1. Catch per unit of effort of blue shark (kg/1 000 hooks) broken down by season (quarter) in British Columbia's hook and line fleet. Data from observer logs (2001-2003).

Quarter	Hooks	Catch (kg)	kg/1000hooks
1	6437655	45	0.01
2	20907429	158	0.01
3	13899962	12389	0.89
4	7150534	4216	0.59

Appendix 2. Polygon area used to determine extent of occurrence in Pacific waters. Polygon surrounds all known catch records from 1996-2004.



Appendix 3. Blue shark observations on Canada's Pacific coast from groundfish research surveys summarized from published data reports and the groundfish biological (GFBIO) database.

Year	Area	# Sharks	Weight (kg)	Sex	Fork Length (mm)	Total Length (mm)	Source
1979	5E	3	~20 kg each	?			Carter and Leaman
1981	5E	1		?			McCarter
1999	3C	1		F		1330	GFBIO
1999	3C	1		M		980	GFBIO
1999	3C	1		M		1040	GFBIO
2000	5E	1		F		2180	GFBIO
2000	5E	1		F		1640	GFBIO
2001	3D	1		M	1590		GFBIO
2001	3D	1		F		1030	GFBIO
2001	3D	1	7.12	F	1260		GFBIO
2001	5A	1		F	1550		GFBIO
2004	3C	1	11.1	?		1440	GFBIO