

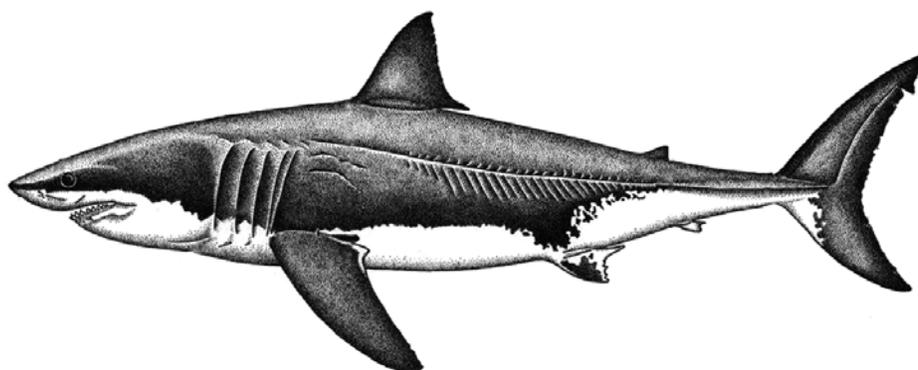
**COSEWIC**  
**Assessment and Status Report**

on the

**White Shark**  
*Carcharodon carcharias*

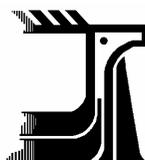
Atlantic population  
Pacific population

**in Canada**



**ATLANTIC POPULATION – ENDANGERED**  
**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:

COSEWIC 2006. COSEWIC assessment and status report on the White Shark *Carcharodon carcharias* (Atlantic and Pacific populations) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 31 pp. ([www.sararegistry.gc.ca/status/status\\_e.cfm](http://www.sararegistry.gc.ca/status/status_e.cfm)).

Production note:

COSEWIC would like to acknowledge R. Aidan Martin and Scott Wallace for writing the status report on the white shark, *Carcharodon carcharias*, (Atlantic and Pacific populations) in Canada, prepared under contract with Environment Canada. The report was overseen and edited by Mart Gross and Paul Bentzen (Co-chairs, COSEWIC Marine Fishes Species Specialist Subcommittee).

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le requin blanc (*Carcharodon carcharias*) populations de l'Atlantique et du Pacifique au Canada.

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White Shark — Provided by R. Aidan Martin.

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## COSEWIC Assessment Summary

### Assessment Summary – April 2006

**Common name**

White shark – Atlantic population

**Scientific name**

*Carcharodon carcharias*

**Status**

Endangered

**Reason for designation**

The species is globally distributed in sub-tropical and temperate waters, but absent from cold polar waters; hence Atlantic and Pacific populations in Canada are isolated from each other and are considered separate designatable units. This very large apex predator is rare in most parts of its range, but particularly so in Canadian waters, which represent the northern fringe of its distribution. There are only 32 records over 132 years for Atlantic Canada. No abundance trend information is available for Atlantic Canada. Numbers have been estimated to have declined by about 80% over 14 years (less than one generation) in areas of the Northwest Atlantic Ocean outside of Canadian waters. The species is highly mobile, and individuals in Atlantic Canada are likely seasonal migrants belonging to a widespread Northwest Atlantic population; hence the status of the Atlantic Canadian population is considered to be the same as that of the broader population. Additional considerations include the long generation time (~23 years) and low reproductive rates (estimated gestation is 14 months and average fecundity is 7 live-born young) of this species, which limit its ability to withstand losses from increase in mortality rates. Bycatch in the pelagic long line fishery is considered to be the primary cause of increased mortality.

**Occurrence**

Atlantic Ocean

**Status history**

Designated Endangered in April 2006. Assessment based on a new status report.

### Assessment Summary – April 2006

**Common name**

White shark – Pacific population

**Scientific name**

*Carcharodon carcharias*

**Status**

Data Deficient

**Reason for designation**

The species is globally distributed in sub-tropical and temperate waters, but absent from cold polar waters; hence Atlantic and Pacific populations in Canada are isolated from each other and are considered separate designatable units. This very large apex predator is rare in most parts of its range, but particularly so in Canadian waters, which represent the northern fringe of its distribution. There are only 14 records over 43 years for the Pacific coast of Canada. No abundance trend information is available for Pacific Canadian waters, or for adjacent waters in the United States that would permit a status designation.

**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**

**White Shark**  
*Carcharodon carcharias*

**Species information**

The (great) white shark (*Carcharodon carcharias* (Linnaeus, 1758)) is the only living species of this genus. In French it is called 'grand requin blanc'. It is recognizable in the field by its conspicuously black iris and a sharp contrast between dorsal and ventral colouration changing from dark (grey or black) to white. Genetic evidence combined with satellite tracking information clearly shows that this species is wide-ranging. Gene flow between Atlantic and Pacific populations is likely restricted but population structure between hemispheres and ocean basins has not been investigated. There is no known genetic structure in Canadian populations. For the purpose of this report, Canada's Atlantic and Pacific populations are treated as two separate designatable units.

**Distribution**

The white shark is widely distributed in sub-polar to tropical seas of both hemispheres, from 60°N to 60°S, but it is most frequently observed and captured in inshore temperate waters over the continental shelves of the western North Atlantic, Mediterranean Sea, southern Africa, southern Australia, New Zealand, and the eastern North Pacific. Worldwide, this species is rare but does occur with some predictability in certain areas. On both the Atlantic and Pacific coast of Canada, white sharks appear to occur sporadically, known from only 46 confirmed or probable records since 1874. White shark records from Pacific Canada consist almost exclusively of strandings on the leeward shores of the Queen Charlotte Islands (Haida Gwaii) during late autumn and early winter months. Off Atlantic Canada, the white shark has been recorded from the Northeast Newfoundland Shelf, the Strait of Belle Isle, the St. Pierre Bank, Sable Island Bank, the Forchu Misaine Bank, in St. Margaret's Bay, off Cape La Have, in Passamaquoddy Bay, in the Bay of Fundy, in the Northumberland Strait, and in the Laurentian Channel as far inland as the Portneuf River Estuary.

**Habitat**

The white shark occurs in both inshore and offshore waters, from the intertidal to the upper continental slope and mesopelagic zone. Known bathymetric range is from

just below the surface to just above the bottom down to a depth of at least 1,280 m. It occurs in the breakers off sandy beaches, off rocky shores, and readily enters enclosed bays, lagoons, harbours, and estuaries, but does not penetrate brackish or fresh waters to any extent.

## **Biology**

Reproductive mode is ovoviviparous. Gestation period is unknown, but may be about 14 months, inferred from the estimated gestation of the closely related shortfin mako. Litter size varies from 2 to 10 and possibly to 17 with an average of 7, with fecundity increasing with size of the female. Length at birth is assumed to be between 109 and 165 cm, with known length of the smallest free-swimming neonates 109 to 129 cm. Possible white shark pupping areas on the west and east coasts of North America include off southern California and the Mid-Atlantic Bight, respectively. Length of reproductive cycle in the white shark is unknown, but may be more than three years as post-partum females may take a year or more off between pregnancies to rebuild energy stores. Maximum lifetime reproductive output of a female white shark has been estimated to be 45 pups with pup survival considered to be low.

Age and size at maturity in white sharks varies regionally. Males reach sexual maturity at an age of 8 to 10 years and a length of 3.5 to 4.1 m while females reach maturity at an age of 12 to 18 years and a length of 4 to 5 m. Longevity in this species is estimated to be 23-60 years. Generation time has been estimated at 23 years and natural mortality at  $0.077 \text{ year}^{-1}$  and  $0.125 \text{ year}^{-1}$ . Intrinsic rate of population increase is estimated at 0.04-0.056.

White sharks are an apex predator with a wide prey base feeding primarily on teleosts, elasmobranchs, and marine mammals, as well as cephalopods, other molluscs, decapods, marine birds, and reptiles.

Biological information from Canadian waters is limited.

## **Population sizes and trends**

There are no estimates of population size in Canadian waters or elsewhere in the world. The species is apparently rare in Canada with only 32 records in the Atlantic since 1874 (and only one in the last decade) and only 14 records since 1961 in the Pacific. Given the low encounter rate in commercial and recreational fisheries in Canada, abundance in Canada has likely always been much lower than in adjacent southern U.S. waters. White shark population trend information is unknown in North American waters. However, there are several locations throughout the world with documented declines in population.

## **Limiting factors and threats**

Humans are the most significant predators of white sharks, taking them as sport fish, commercial bycatch, and for international trade of their valuable body parts. In the Northwest Atlantic, white sharks are taken as bycatch by pelagic longlining operations. In Atlantic Canada there are only two records of white sharks captured in fishing gear since 1990. In Pacific Canada, there are no confirmed records of white sharks caught by fishing activities. Several stranded white sharks on the Queen Charlotte Islands had markings that may have resulted from fishing gear. The white shark's tendency to investigate boats and other floating objects often brings them to the surface, where they can be easily hooked, shot, or harpooned.

## **Special significance of the species**

The white shark is the quintessential shark species due to its large size, predatory nature and reputation for occasionally attacking humans. The celebrated cultural status of the white shark makes its jaws and teeth particularly sought-after as curios and its fins for Asian delicacies and traditional medicines. Even in the face of protective legislation, the high prices some individuals are willing to pay for white shark parts is an incentive likely sufficiently powerful to stimulate and maintain a clandestine black market trading in such goods.

## **Existing protection**

In the fall of 2004, CITES listed white shark in Appendix II. In 2000, the International World Conservation Union listed white shark globally as 'vulnerable'. No federal or provincial laws explicitly protect white sharks in Canadian waters. On Canada's Pacific coast, hook and line fisheries are prohibited from keeping any species of shark except dogfish, and therefore white shark receives some protection by this regulation.



## 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<sup>th</sup> 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

## **White Shark** *Carcharodon carcharias*

Atlantic population  
Pacific population

**in Canada**

2006

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## SPECIES INFORMATION

### Name and classification

The (great) white shark (*Carcharodon carcharias* (Linnaeus, 1758)) is the only living species of this genus. Over the years there have been proposals to name separate regional populations, but to date morphometry, meristics, colouration and skeletal anatomy from different 'centres of abundance' are not recognizably separable. The accepted French name for white shark is 'grand requin blanc'.

### Morphological description

The following description is taken primarily from Compagno (2001). The snout is bluntly conical (Figure 1a). The interior teeth are enlarged and the anterior, intermediate and lateral teeth are compressed and form a continuous cutting edge. The intermediate teeth are enlarged and are over two-thirds the height of adjacent anteriors. The total tooth count is 44 to 52.

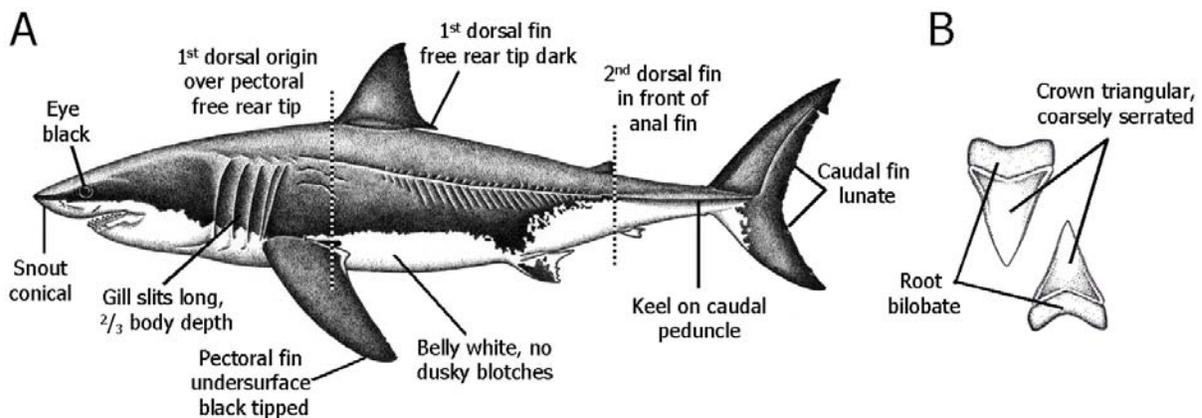


Figure 1. Field characters useful for identifying the white shark (*Carcharodon carcharias*), A. Lateral view, B. detail of upper and lower anterior teeth. Diagrams by R. Aidan Martin.

The body is usually stout with the dorsal fin origin usually over the pectoral inner margins. The origin of the anal fin is under or slightly posterior to second dorsal fin insertion. The total vertebral count is between 170 and 187 with total length of adults between 3.8-6 m and possibly longer. Typically there is a black axillary spot at the insertion point of the pectoral fin; and the pectoral fin tips are usually abruptly black on their ventral surfaces.

Field Marks: Heavy spindle-shaped body with a moderately long conical snout. The teeth are large, flat, and triangular with blade-like serrations. The gill slits are long. The first dorsal fin is large with a dark, free rear tip; the second dorsal is minute; and the caudal fin is large and crescentic.

The dorsal surface is a grey or brownish-grey to blackish above and the ventral surface of body is white. The margin between the dark dorsal and white ventral surfaces is sharply delimited. The iris of the eye is conspicuously black.

### **Genetic description**

There has been no genetic, tagging, or other population work conducted on white sharks in Canadian waters. Satellite tracking information from other jurisdictions suggests this species is highly migratory (Pardini *et al.* 2001, Boustany *et al.* 2002—see Dispersal and Migration for detailed description). Population structuring between hemispheres and oceans basins has not been investigated. Genetic structure within Canada's Atlantic and Pacific populations does not likely exist, but has not been investigated.

### **Designatable units**

White sharks in Canada's Atlantic and Pacific oceans occupy two distinct biogeographic units with no interchange through the Arctic, and likely limited interchange between ocean basins from dispersal around the southern tip of South America. For the purpose of this report, Canada's Atlantic and Pacific populations are treated as two separate designatable units.

## **DISTRIBUTION**

### **Global range**

The white shark is widely distributed in sub-polar to tropical seas of both hemispheres, from 60°N to 60°S, but it is most frequently observed and captured in inshore temperate waters over the continental shelves of the western North Atlantic, Mediterranean Sea, southern Africa, southern Australia, New Zealand, and the eastern North Pacific (Figure 2, Compagno 2001). In the western North Atlantic, the white shark ranges from Hare Bay, Newfoundland, to northern Brazil (Templeman 1963, Gadig and Rosa 1996). In the eastern North Pacific, it ranges from the central Bering Sea to Mazatlan, Mexico (Kato 1965, Cook pers. comm. 1987). This species occurs sporadically in Canadian waters, known from only 47 confirmed or probable records since 1874 (Table 1, Figure 3).

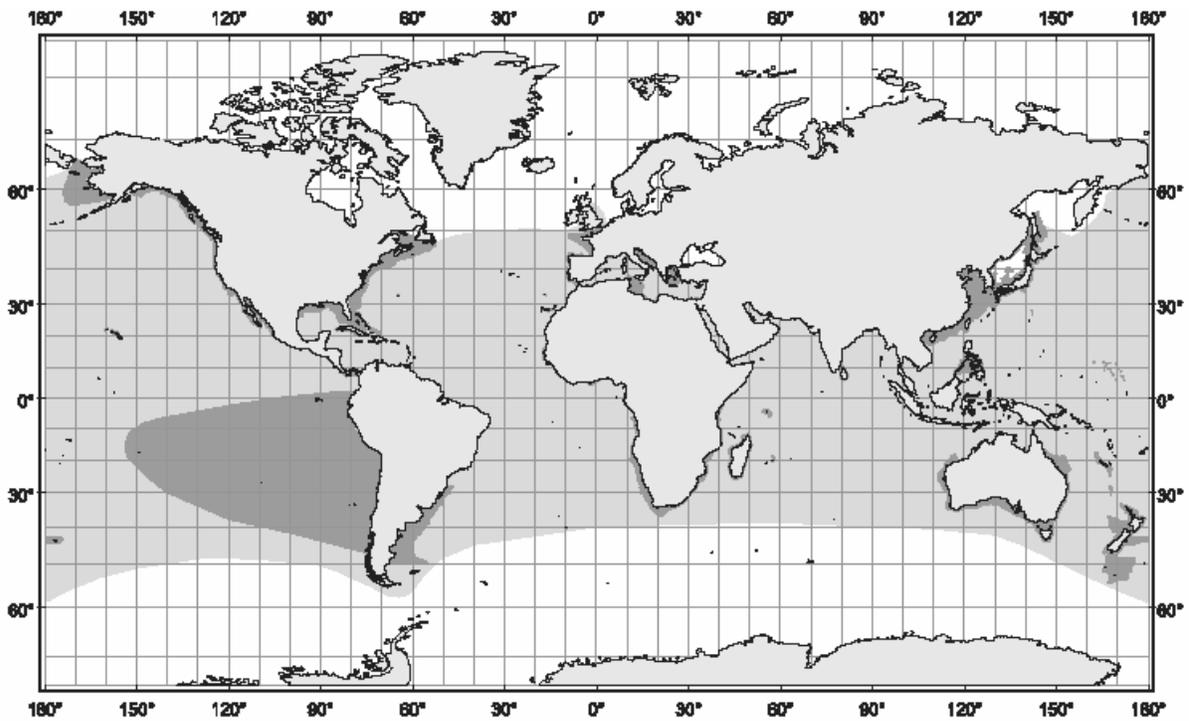


Figure 2. Global distribution of white sharks. Map source: Compagno 2001.

**Table 1. Chronological list of white shark records from Canada. \* = not authenticated; UNK=unknown, +=possibly the same shark.**

Locality	Date	Length (m)	Sex	Remarks	Reference
<b>Atlantic Ocean</b>					
Pig Island, Northumberland Strait, NS	1000-2000 years bp	UNK	UNK	Tooth in oyster stratum	Gilhen (1998)
St. Pierre Bank, NS	1873 or 1874	3.9	UNK	Teeth in attacked dory	Putnam (1874)
Off Hubbard Cove, St. Margaret's Bay, NS	June 27, 1920	4.6	UNK	Tooth scarpes on attacked dory	Piers (1934)
White Head Island, near Grand Manan, NB	June (mid), 1930	11.3*	UNK	Trapped in herring weir	Vladykov & McKenzie (1935)
16 km NW of Digby Gut, NS	July 2, 1932	4.6	UNK	Tooth in attacked motorboat	Piers (1933)
Harbour de Loutre, Campobello Island, NB	November 22, 1932	7.9*	UNK	Trapped in herring weir	Piers (1933)
Wedgeport, NS	August, 1938	2.6	M	Caught on rod & line by Ms. Michael Lerner; mass 196 kg	Anon (1940) in Templeman (1963)
Whale Head, N shore, St. Lawrence River	August, 1938	UNK	UNK		Vladykov & McAllister (1961)
Isle Caribou, N shore, St. Lawrence River	August, 1942	2.7	UNK		Vladykov & McAllister (1961)
Isle Caribou, N shore, St. Lawrence River	August, 1943	3	UNK		Vladykov & McAllister (1961)
Deer Island, NB	August 24, 1949	3.87	F	Trapped in herring weir; immature, mass 590 kg	Scattergood <i>et al.</i> (1951)
Portneuf River estuary, N shore, St. Lawrence River	August 27, 1949	4.6	UNK	Shot by W.B. Scott	Templeman (1963)

Locality	Date	Length (m)	Sex	Remarks	Reference
Between Passamaquoddy Bay & Grand Manan, NB	August 20, 1952	4.3	UNK	Observed attack on porpoise	Day & Fisher (1954)
Off Fourchu, Cape Breton Island, NS	July 9, 1953	3.7	UNK	Teeth in attacked dory	Day & Fisher (1954)
Wedgeport, NS	July 9-10, 1953	2.4	M	Caught on rod & line (tuna fisherman)	Day & Fisher (1954)
La Have Islands, NS	August 12, 1953	4.7	UNK	Caught in herring trap	Day & Fisher (1954)
St. Croix River, near Dochet Island between ME & NB	August 25, 1953	UNK	UNK	Observed attack on seal	Day & Fisher (1954)
Mace's Bay, Bay of Fundy, NB	August 3, 1954	2.6	UNK	Trapped in herring weir	Leim & Day (1959)
Maces Bay, NB	September 10, 1954	4.87	F	Caught in herring weir	Hogans & Dadswell (1985)
Ireland Bight, Hare Bay; depth 26 m	August 10, 1956	3.7	UNK	Teeth in codtrap leader	Templeman (1963)
SE Grand Bank (44°30'N, 50°12'W)	August, 1956	3.7-4.6	UNK	Spanish otter trawl Santa Ines	Templeman (1963)
Northumberland Strait, 13 km off Wallace, NS	July 30, 1962	3	UNK	Caught in hake gillnet; tooth examined by L.R. Day	Templeman (1963)
Northumberland Strait, 13 km off Wallace, NS	August (1st week), 1962	2.7	UNK	Caught in hake gillnet; ID by W.G. Smith, fishery officer	Templeman (1963)
Wallace, NS	August, 1962 <sup>+</sup>	6	UNK	Observed in hake gillnets, escaped	Templeman (1963)
Wallace, NS	September, 1962 <sup>+</sup>	6	UNK	Observed in hake gillnets, escaped	Templeman (1963)
Passamaquoddy Bay, between ME & NB	1969	UNK	UNK	Observed attack on porpoise	Arnold (1972)
Passamaquoddy Bay off Leonardville, Deer Island, NB	August 13-14, 1971	4.3	F	Caught in otter trawl	Scott & Scott (1988)
Letite Passage, NB	August 8, 1977 <sup>+</sup>	5.05	F	Caught in herring weir	Hogans & Dadswell (1985)
Passamaquoddy Bay, off Mascarene Shore, NB	August 8-9, 1977 <sup>+</sup>	5.2	UNK	Tarped in herring weir	Scott & Scott (1988)
Gulf of St. Lawrence, off Alberton, PEI	August 4, 1983	5.2	M	Caught in cod gillnet	Scott & Scott (1988)
Off Tiverton, PEI	July, 1988	4.5	UNK	Caught in gillnet	Connors Bros. Ltd. In Mollomo (1998)
Southern Scotian Shelf	November, 1989	UNK	UNK	Japanese longliner (200 kg)	Scotia-Fundy Observer database
Sable Island	Late 1980s	UNK	UNK	Tooth recovered from seal carcass	Campana, pers. comm. (2004)
Bay of Fundy	Early 1990s	4.2	UNK	Caught in gillnet	Campana, pers. comm. (2004)
Scotian Shelf	December, 1999	UNK	UNK	Japanese longliner (65 kg)	Scotia-Fundy Observer database
<b>Pacific Ocean</b>					
Esperanza Inlet, Vancouver Island	August 17, 1961	4-6	UNK	Teeth in float bag of salmon troller	Collier <i>et al.</i> (1996)
Creek Mouth, Island Bay, QCI	October 24, 1961	3.4	UNK	Stranded on beach	Pike (1962)
Lawn Point, Graham Island, QCI	September (late), 1977	3-4	UNK	Stranded on beach, in advanced state of decomposition	RAM data

Locality	Date	Length (m)	Sex	Remarks	Reference
Un-named beach, Moresby Island, QCI	October, 1977	4.5	UNK	Stranded on beach	RAM data
Cape Ball, Graham Island, QCI	October 20, 1977	5.5	F	Stranded on beach	RAM data
Un-named beach, Lyell Island, QCI	November 25, 1977	4.5	UNK	Stranded on beach	RAM data
Cape Ball, Graham Island, QCI	Autumn (early), 1983	4	UNK	Stranded on beach	RAM data
Long Inlet, Graham Island, QCI	December 16, 1986	5	UNK	Stranded on beach	RAM data
near Queen Charlotte City, Graham Island, QCI	Autumn (early), 1987	5	UNK	Stranded on beach	RAM data
Long Inlet, Graham Island, QCI	December 16, 1987	5.2	UNK	Stranded on beach	RAM data
East Beach, near Cape Ball, Graham Island, QCI	Autumn, 1988	5	UNK	Stranded on beach	RAM data
Skidegate Inlet, Graham Island, QCI	Autumn, 1988	4-5	UNK	Stranded on beach	RAM data
North side of Goose Island, Queen Charlotte Sound, BC	September, 2004	2.5	UNK	Vertebrae found on beach	Found by Jane Watson ID by RAM
Cape Ball, Graham Island, QCI, BC	25 Oct 2004	4.6	UNK	25 vertebrae, bits of cartilage (including left Meckel's cartilage), chondrocranium, teeth and patches of skin	RAM data

RAM=R. Aidan Martin

The northernmost record of a white shark in the eastern North Pacific is a single white shark approximately 4 m in total length observed feeding on salmon in the spring of 1985 off Cordova, Alaska (latitude 60°17'N). Species confirmation is supported by the carcass of a sockeye salmon (*Oncorhynchus nerka*) bearing distinctive bites of a white shark (R.A. Martin-author, unpublished data). At least 15 other specimens have been reported from Washington, British Columbia, and Alaska (Bonham 1942; LeMier 1951; Pike 1962; Royce 1963; Karinen *et al.* 1985; Coad 1995; Collier *et al.* 1996).

The northernmost record for a white shark in the western North Atlantic is a 3.7 m specimen caught in August 1956 on a cod trap leader set at a depth of 25 m off Ireland Bight, Hare Bay, Newfoundland (latitude 51°18'N) (Templeman 1963). Mollomo (1998) gives 44 other records of this species from Maine and Atlantic Canada waters.

### Canadian range

In Canada's Pacific waters, the white shark has been recorded from Esperanza Inlet and Hecate Strait (Pike 1962; R.A. Martin-author, unpublished data). White shark records from British Columbia consist almost exclusively of strandings on the leeward shores of the Queen Charlotte Islands (Haida Gwaii) during late autumn and early winter months (Figure 3a, Table 1), plus a single attack on commercial fishing gear (Collier *et al.* 1996). Lack of strandings from seaward shores of the Queen Charlottes may reflect sparse human settlement rather than distributional or stranding bias of white sharks.

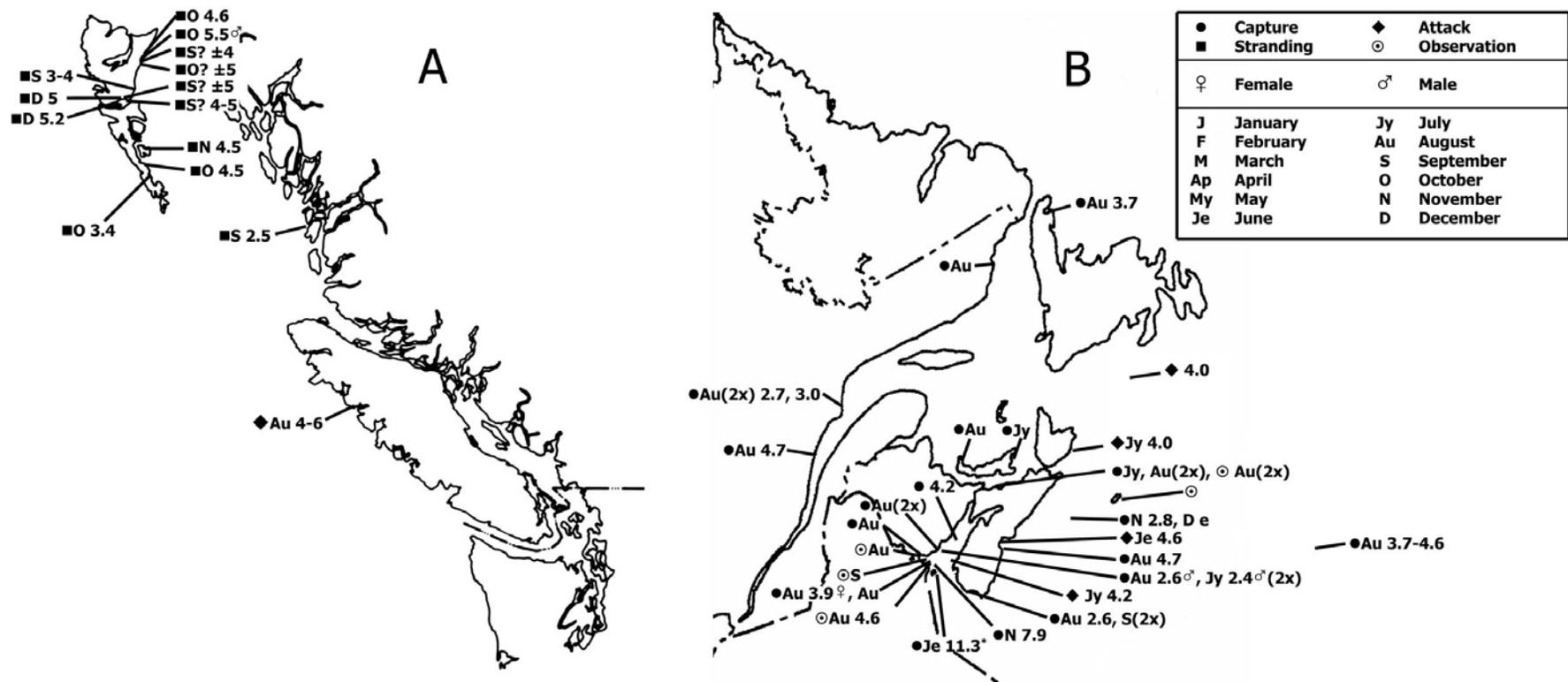


Figure 3. Locality, month, and total length of white shark (*Carcharodon carcharias*) captures, strandings, attacks, and reports from Canadian waters. A. British Columbia. B. Atlantic Canada.

Off Atlantic Canada, the white shark has been recorded from the northeast Newfoundland Shelf, the Strait of Belle Isle, the St. Pierre Bank, Sable Island Bank, the Forchu Misaine Bank, in St. Margaret's Bay, off Cape La Have, in Passamaquoddy Bay, in the Bay of Fundy, in the Northumberland Strait, and in the Laurentian Channel as far inland as the Portneuf River Estuary (Putnam 1874; Piers 1934; Vladykov and McKenzie 1935; Day and Fisher 1954; Leim and Day 1959; Vladykov and McAllister 1961; Templeman 1963; Arnold 1972; Molomo 1998). White shark records from Atlantic Canada (Figure 3b, Table 1) consist primarily of incidental captures plus four cases of attacks on boats (Templeman 1963; Mollomo 1998). Of 30 Atlantic Canada records for which the month is known, 20 occurred during the month of August, the remainder occurred during June, July, or September with an additional record in November and one in December. Clustering of white shark records in Atlantic Canada during late summer months suggests they may be correlated with the seasonal shift of the warm Gulf Stream toward the coast (Hogg 1992).

Collectively, the foregoing suggests that the Canadian component of this species distribution represents the northern fringe of their distribution.

## **HABITAT**

### **Habitat requirements**

The white shark occurs in both inshore and offshore waters, from the intertidal to the upper continental slope and mesopelagic zone. Known bathymetric range is from just below the surface to just above the bottom down to a depth of at least 1,280 m (Bigelow and Schroeder 1948). It occurs in the breakers off sandy beaches, off rocky shores, and readily enters enclosed bays, lagoons, harbours, and estuaries, but does not penetrate brackish or fresh waters to any extent (Compagno 2001). Known temperatures from which the white shark has been recorded range from 5 to 27°C (Nakaya 1994; Boustany *et al.* 2002). Off California this species seems more abundant at temperatures of 14-15°C than at 11°C or below (Compagno 2001). The white shark is a wide-ranging, nomadic species capable of crossing ocean basins as it occurs sporadically off oceanic islands such as Hawaii (Taylor 1985) and the Azores (Compagno *et al.* 1997). Movement of this species from coastal waters into oceanic waters far offshore is further supported by a recent satellite tracking study (Boustany *et al.* 2002).

### **Habitat trends**

It is unknown to what degree habitat deterioration has contributed to the apparent global decline of this species. The Australia and Madagascar CITES Proposal (2004) makes the case that inshore coastal feeding and breeding habitats of white sharks have deteriorated due to increased fishing pressure, pollution resulting in bioaccumulation, and possible prey depletion (Australia and Madagascar CITES Proposal 2004). In Canadian waters, both Atlantic and Pacific, there are no known activities altering the habitat and hence abundance or distribution of white sharks. For the purpose of this report, fisheries interactions are a cause of mortality and not a habitat issue.

## Habitat protection/ownership

There are some marine protected areas in California that overlap with known important white shark areas. Generally, there has been little effort to protect white shark habitat.

## BIOLOGY

### Life cycle and reproduction

Due to the rarity of this species, knowledge of the reproduction and life history of the white shark is incomplete. In some cases inferences are drawn from other closely related species. Reproductive mode is ovoviviparous (aplacentally viviparous), with yolk sac reserves augmented at late term via oophagy (Gilmore 1983; Francis 1996; Uchida *et al.* 1996). Gestation period may be similar to that of its close relative, the shortfin mako (*Isurus oxyrinchus*), in which gestation has been estimated to last 14 months (Mollet *et al.* 2000). Litter size varies from 2 to 10 and possibly to 17 with an average of 7 (Compagno 2001; Cliff *et al.* 2000), with fecundity increasing with size of the female. Length at birth is assumed to be between 1.09-1.65 m (Compagno 2001). Possible white shark pupping areas on the west and east coasts of North America include off southern California (Klimley 1985) and the Mid-Atlantic Bight (Casey and Pratt 1985), respectively. The length of the reproductive cycle in the white shark may be more than three years as post-partum females may require a year or more between pregnancies to rebuild energy stores (Compagno 1991). Maximum lifetime reproductive output of a female white shark has been estimated to be 45 pups (Compagno 1991). Pup survival is thought to be low (Australia and Madagascar CITES Proposal 2004).

Males reach sexual maturity at an age of 8 to 10 years and a length of 3.5 to 4.1 m (Pratt 1996; Compagno 2001) while females reach maturity at an age of 12 to 18 years and a length of 4 to 5 m (Francis 1996; Compagno 2001; Australia and Madagascar CITES Proposal 2004).

Longevity in this species is estimated to be 23-60 years (Cailliet *et al.* 1985; Mollet and Cailliet 2002; Australia and Madagascar CITES Proposal 2004). Generation time has been estimated at 23 years and instantaneous natural mortality (M) between 0.077 and 0.125 (Smith *et al.* 1998; Mollet and Cailliet 2002). Intrinsic rate of population growth (i.e., annual population increase) is estimated at 4-5.6% (Smith *et al.* 1998).

The maximum size of the white shark is unknown, with length and especially mass of large individuals notoriously difficult to validate (see Mollet *et al.* 1996). The largest captured specimens measured between 5-5.8 m in total length. Reports of white sharks reaching total lengths greater than 7 m have been reliably reported but have not been verified (Compagno 2001).

## Life history information from Canadian waters

There have been no scientific studies or surveys of white sharks in Canadian waters. Opportunistic data from strandings or bycatch have shown that reproductively mature white sharks of both sexes have been recorded from Pacific and Atlantic Coasts of Canada (Figure 3, Table 1).

The largest verified white sharks from Canadian waters are a 5.2 m individual found stranded at Long Inlet, Graham Island, Queen Charlotte Islands, British Columbia, on 16 December 1986 (Coad 1995), and another of the same length and 907 kg in mass captured between Bliss and Whitehorse Islands, southern New Brunswick, in August 1971 (Arnold 1972).

## Behaviour

In cool temperate waters, this species is often observed scavenging on floating cetacean carcasses, either with aggregates of conspecifics (Pratt *et al.* 1982; Fallows pers. comm. 2000) or with other large sharks (Dudley *et al.* 2000). Natural predation by white sharks on pinnipeds is observed seasonally at the Farallon Islands, California (Klimley 1994; Klimley *et al.* 1992, 1996), and off the Western and Eastern Cape, South Africa (Stewardson and Brett 2000, Fallows and le Sueur 2001). A single case of possible white shark courtship and mating has been reported (Francis 1996). Recent studies reveal that the white shark exhibits a variety of social behaviours and may travel in small but stable groups (Compagno 2001; Collier pers. comm. 1986; Fallows pers. comm. 2000).

The white shark is a highly visual creature with a duplex retina featuring a low rod-to-cone ratio (about 4:1) that is well adapted to acute, and possibly full-colour vision (Gruber and Cohen 1995). This species will visually investigate virtually any object at the surface, from boats and surfboards to floating kelp and rubbish (Strong 1996; Collier pers. comm. 1986; Fallows pers. comm. 2000). The white shark's curiosity about novel objects and activities at the surface often brings it into contact with humans (Miller and Collier 1981; Burgess and Callahan 1996; Collier pers. comm. 1986; Fallows pers. comm. 2000).

## Herbivory/predation

White sharks are born at a total length of 1.09-1.65 m. Their large size at birth precludes predation from most marine animals. Humans have been identified as the single largest cause of mortality to adult sharks (Compagno 2001). Newborns are likely taken by other shark species and possibly marine mammals but there is no evidence of this. There is one reported attack of an orca whale (*Orcinus orca*) on a white shark off California.

## Physiology

White sharks can tolerate a wide range of temperatures and therefore have been observed from sub-polar to tropical waters (5-27°C). There is some evidence that white sharks have a temperature preference around 14-15°C, but they are regularly found in warmer temperatures.

The ability for white sharks to perform as agile predators in colder water is in part attributable to countercurrent vascular heat exchangers which allow them to maintain a body temperature higher than the ambient water (Compagno 2001).

## Dispersal/migration

White sharks are able to swim long distances over extended periods with an average cruising speed of 3.2 kph (Compagno 2001). Seasonal and size-class distribution of 109 white sharks captured along the West Coast of North America suggests pregnant individuals may migrate south to southern California waters to give birth (Klimley 1985), but this remains to be demonstrated. Sonic telemetry studies conducted at the Farallon Islands, California, suggest that larger white sharks concentrate predatory effort in relatively small areas, while smaller individuals cruise larger areas (Goldman and Anderson 1999). Size-based differences in white shark activity space at the Farallon Islands may reflect learning in larger sharks to concentrate predatory effort in areas that have proved successful in previous years and/or displacement of smaller sharks by larger conspecifics. A satellite telemetry study revealed that four of six white sharks tagged off the Farallon Islands travelled at depths of 300 to 500 m far into the open Pacific – in one case, a 4.7-m male, travelled from the Farallon Islands to off Kahoolawe, Hawaii, a distance of 3,800 km; the two other sharks remained close to the Farallons (Boustany *et al.* 2002).

Of 36 white sharks tagged in the western North Atlantic through the National Marine Fisheries Service (NMFS) Cooperative Shark Tagging Program, only two were recaptured, both female (Kohler *et al.* 1998). Of these, one travelled north from off Assateague Island National Seashore, Virginia, to off Gloucester, Massachusetts, the other south from off Moriches, Long Island, New York, to Charleston, South Carolina.

A study of mitochondrial and nuclear DNA of 95 white sharks from South Africa, Australia and New Zealand suggests sex-biased dispersal of this species: males migrate long distances (up to and including crossing entire ocean basins) while females occupy relatively small ranges (Pardini *et al.* 2001). Based on the non-coding 'control' region of the maternally inherited mitochondrial genome, two divergent genetic lineages were revealed. Populations from Australia and New Zealand are not significantly different, but these individuals are significantly different from South African sharks ( $P < 0.0001$  for each). This result was further supported by an analysis of restriction-fragment-length polymorphisms in mitochondrial DNA that found only 1 of the 95 animals to be out of place (a South African haplotype male captured in Australia). In contrast, an analysis of five polymorphic nuclear encoded microsatellite loci revealed no

significant difference. Pardini *et al.* (2001) concluded that there is sufficient male mediated gene flow to homogenize allele frequencies and that dispersal of individuals is more extensive than previously thought. This differential dispersal may reflect sex differences in parental investment between males and females, allowing the latter to conserve energy stores toward nourishment of pups. In a recent oral presentation, unpublished data were presented that showed satellite tracking of a female white shark (3.8 m total length) that travelled from Gansbaai, South Africa, to Exmouth, Western Australia – a distance of approximately 10,000 km – in three months; possibly disproving Pardini *et al.*'s (2001) hypothesis of female philopatry in this species (Bonfil pers. comm. 2004). It is worth noting that the observed movement of this individual does not necessarily indicate gene flow.

No tagging or telemetry studies have been published on white sharks in Canadian waters and available data (Table 1) are inadequate to draw any meaningful conclusions about dispersal in Canadian waters.

### **Interspecific interactions**

The white shark is an apex predator exploiting a very broad prey spectrum. Teleosts, elasmobranchs, and marine mammals are the main prey categories, but it also takes cephalopods, other molluscs, decapods, marine birds, and reptiles (Cortéz 1999). The white shark also scavenges marine mammal carcasses, fisheries offal, and fishes caught on lines (Compagno 2001). Its dentition broadens with growth and it has been suggested that, at a length of about 300 cm, this species undergoes an ontogenetic dietary shift from bottom-dwelling fishes to marine mammals (Tricas and McCosker 1984). Smaller white sharks (<2.5 m total length) tend to consume relatively small demersal prey, including teleosts, small elasmobranchs, and invertebrates, while larger individuals tend to take larger nektonic prey, including pinnipeds, odontocetes, and large elasmobranchs (Klimley 1985; Cliff *et al.* 1989; Bruce 1992). However, at every growth stage, the white shark is highly opportunistic and apparently can capture and kill a wide variety of prey. For example, LeMier (1951) reported that the stomach of a 4.4 m white shark captured in Willapa Harbor, Washington, September 1950 contained four partly digested salmon (*Oncorhynchus* sp.), vertebral columns of Pacific hake (*Merluccius productus*) and rockfish (*Sebastes* sp.), the hides of two harbour seals (*Phoca vitulina*), and 150 crabs, primarily Dungeness crabs (*Cancer magister*) with the remainder rock crabs (*C. productus*). Feeding periodicity in an adult white shark (~ 4.5 m total length), based on calculated metabolic rate and calorie content of blubber-rich food, has been estimated to be between 45 and 90 days (Carey *et al.* 1982; Klimley *et al.* 2001).

In Canada, diet and feeding behaviour of the white shark in Canadian waters have only been reported from the Atlantic coast. In August 1953, between Passamaquoddy Bay and Grand Manan Island, a pale grey shark more than 4.3 m long – believed to be a white shark – was observed to bite a full-grown harbour porpoise (*Phocoena phocoena*) in half and consume the posterior part while the anterior part was retrieved by a fisherman with a gaff (Day and Fisher 1954). In August 1953, an adult male

harbour seal was shot near Docet Island, in the St. Croix River between Maine and New Brunswick; its tail was severed and bore fresh tooth slashes of a size that strongly suggested they were made by a white shark (Day and Fisher 1954). In July 1962, a 3 m white shark caught near Wallace, Nova Scotia, had a “small porpoise” (probably *P. phocoena*) in its stomach. In September 1969, near the mouth of Passamaquoddy Bay, New Brunswick, two specimen collectors lost a harbour porpoise to a shark at least 4 m long (Arnold 1972). In August 1971, a 5.2 m white shark was caught between Bliss and Whitehorse islands, New Brunswick; its stomach contained three harbour porpoises, estimated to have been between 1.2 to 1.5 m long, in variable stages of digestion and with their tail stalks severed (Arnold 1972). The white shark has also been implicated in attacks on grey seals (*Halichoerus grypus*) off eastern Canada (Brodie and Beck 1983). In Atlantic Canada, the white shark probably also feeds on a wide variety of fish and invertebrate prey, but this remains to be documented.

Based on reports from Washington State (Bonham 1942; LeMier 1951) and southeastern Alaska (R.A. Martin-author, unpublished data), diet of white sharks in Canada’s Pacific waters probably includes green sturgeon (*Acipenser medirostris*), sockeye salmon (*Oncorhynchus nerka*) and other Pacific salmonids, rockfishes, hakes, Pacific halibut (*Hippoglossus stenolepis*), harbour seal, and Steller sea lion (*Eumetopias jubatus*).

### **Adaptability**

The life history of the white shark suggests that it is unable to withstand high anthropogenic mortality. The widespread distribution combined with an opportunistic feeding strategy may allow for the species to adapt by dispersing from localized catastrophic events and changing prey sources.

## **POPULATION SIZES AND TRENDS**

### **Search effort**

There are no surveys for white sharks in Canadian waters. Most records in Canadian waters come from opportunistic stranding reports, published historical observations, investigative work by the authors, and the occasional reported incidental catch. Observer databases from both coasts were examined for records as were all available fisheries surveys. Effort was made to examine surveys in adjacent jurisdictions.

### **Abundance**

Information on the global population size of white sharks is sparse, but most sources agree the species is relatively rare compared with sympatric shark species. As an apex predator occupying a mean trophic level of 4.5, population size in a given region is necessarily low (Cortez 1999). Based on a low encounter rate, it is suspected

that abundance of white sharks in Canadian waters is less than in neighbouring southern regions.

### Pacific

Off Pacific Canada between 1961 and 2004, 14 white shark records have been collected (Table 1). Most of these records are from stranded animals. Given the low frequency of sightings in Canada's Pacific waters, it is not possible to estimate a population but it is assumed to be very low. For the eastern North Pacific, from northern Washington to central Mexico, between 1936 and 1984, 116 white sharks were documented (Klimley 1985). In Monterey Bay, California, white sharks were sighted during spotter aircraft surveys between 1948 and 1950; 104 white sharks were seen in 445 flights (average 0.23 per flight); a maximum of 27 white sharks were recorded in any one month (Squire 1967). There are no indicators of abundance anywhere in the North Pacific at present time.

### Atlantic

Off Atlantic Canada between 1874 and 2004, 32 white shark observations have been recorded, with only one record over the last decade (Table 1). There are only two records from the Scotia Fundy Observer Program which indicates that white sharks are not regularly caught in Atlantic Canadian waters. In U.S. Atlantic waters, longlining has resulted in significant catches. Baum *et al.* (2003) reported 6,087 records of white shark in the U.S. pelagic longline database from 1986-2000 extracted from over 200,000 sets. Most of these records (80%) were from areas south of Florida (Areas 2-4; Figure 4). In northern waters adjacent to Canada's 200 mile limit (Areas 6 and 7; Figure 4), there have been no reported white sharks since the early 1990s. There are no estimates of white shark abundance in Canadian waters but given the low encounter rate in commercial and recreational fisheries, the abundance is likely much lower than in adjacent U.S. waters, particularly in southern latitudes.

## **Fluctuations and trends**

### Recent North American Trends

There is a general lack of white shark population trend information worldwide, reflecting their rarity. International longline fishing effort for pelagic species occurring outside of Canada has increased exponentially in the North and South Atlantic over much of the last fifty years but uncertainty remains about the extent of the impact on white shark (Figure 5). The only published study examining trends in white shark abundance is that of Baum *et al.* (2003), which covers only 14 years (less than one generation) in the northwest Atlantic Ocean.

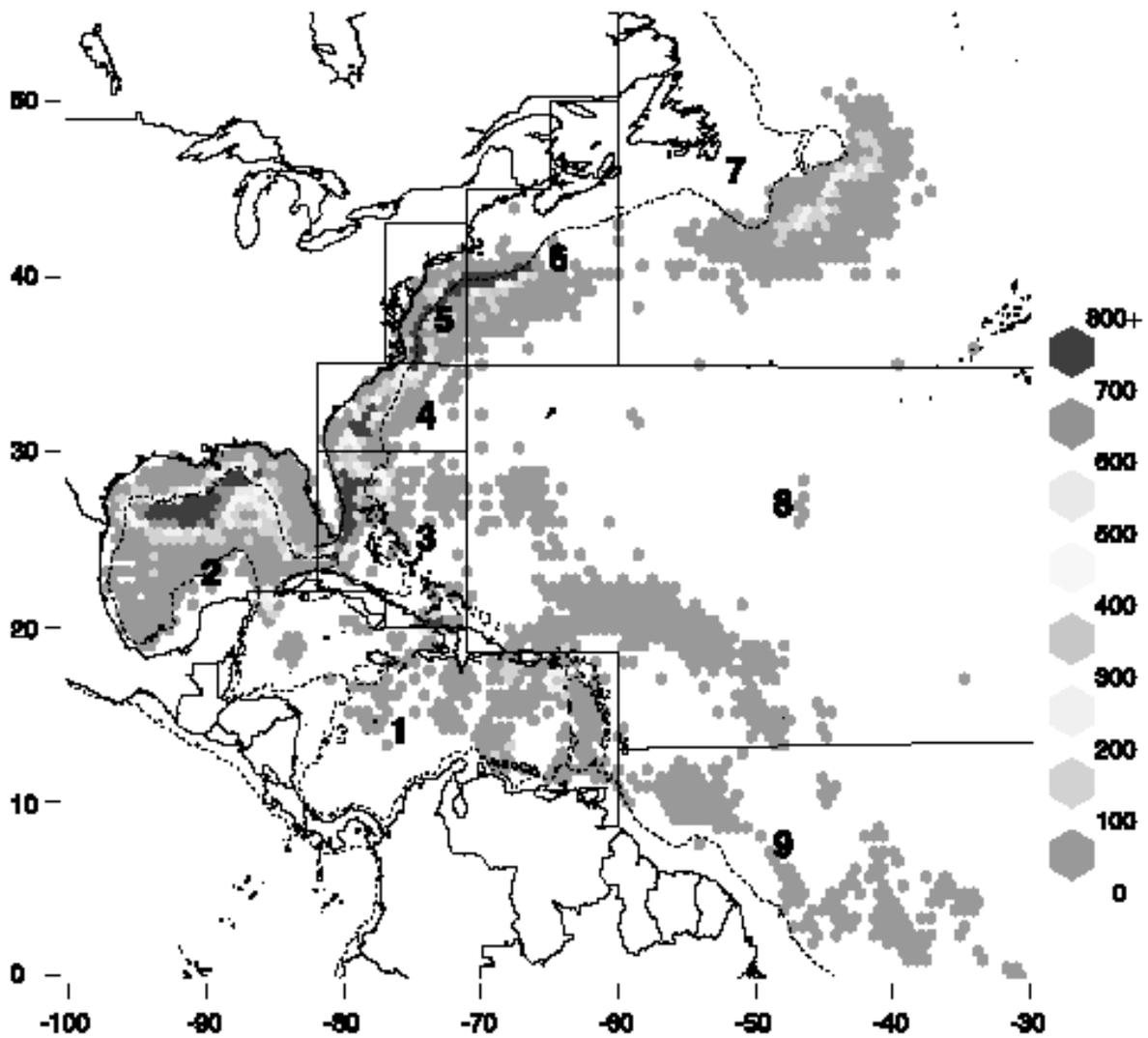


Figure 4. Map of the Northwest Atlantic showing the distribution of effort in the U.S. pelagic longline fishery between 1986 and 2000, categorized by number of sets (0 to 800+), within the nine areas assessed: 1, Caribbean; 2, Gulf of Mexico; 3, Florida East Coast; 4, South Atlantic Bight; 5, Mid Atlantic 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 1,000-m coastal isobath (dotted line) is given for reference. From Baum *et al.* 2003.

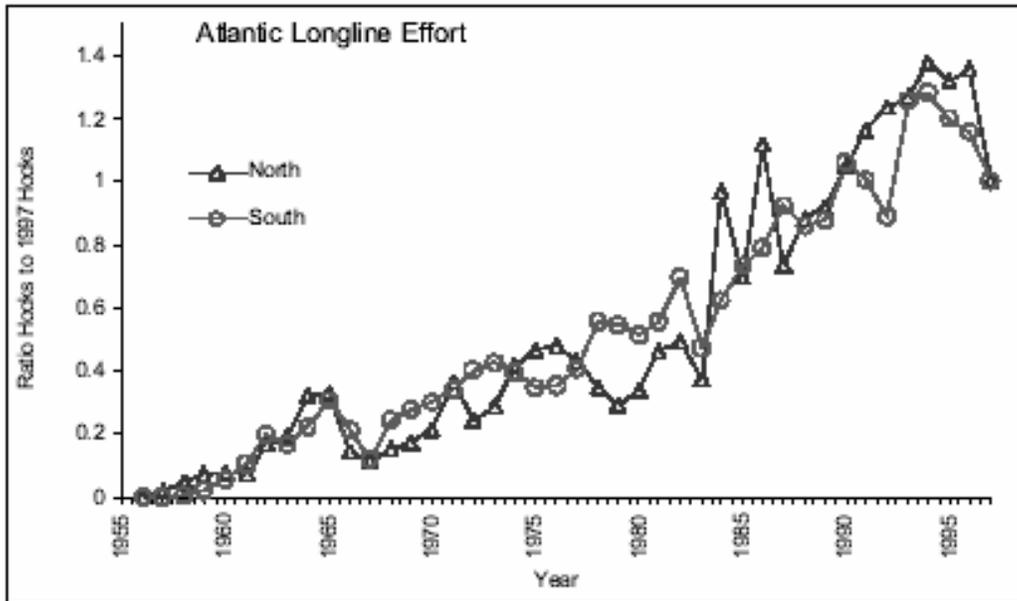


Figure 5. Trend in effort for the North Atlantic longline fleet (1956-1997). Source: ICCAT 2005.

Baum *et al.* (2003) calculated trend information based on catch per unit of effort (CPUE) logbook data from the U.S. pelagic longline swordfish and tuna fleets in the Northwest Atlantic from 1986 to 2000 (Figure 6). They estimated a decline of 79% in CPUE during this period (95% CI: 59 to 89%) which was based on 6,087 records primarily from the southeastern seaboard of the United States and Caribbean (Areas 1-4; see Figure 4).

The white shark analysis by Baum *et al.* (2003) has been challenged recently by ten shark biologists in the U.S. (Burgess *et al.* 2005). Burgess *et al.* (2005) criticized the Baum *et al.* (2003) analysis on the basis of several potential shortcomings of the longline data set for estimating trends in shark abundance; however, in a reply Baum *et al.* (2005) rebutted the main points of the critique and concluded that their trend estimate was robust. For example, a major concern of Burgess *et al.* (2005) was that that “white sharks” in the pelagic longline logbooks may have included misidentified oceanic whitetip sharks (*Carcharhinus longimanus*) or any other light-coloured sharks; however, Baum *et al.* (2005) noted that if the southern area where the mis-identifications were most likely to have occurred was omitted from the analysis, the magnitude of the estimated decline in white shark abundance would actually increase. Burgess *et al.* (2005) further suggested that pelagic longlining does not adequately sample coastal shark species such as the white shark. Contrary to this statement, Boustany *et al.* (2002) found that white sharks are more pelagic than was previously thought.

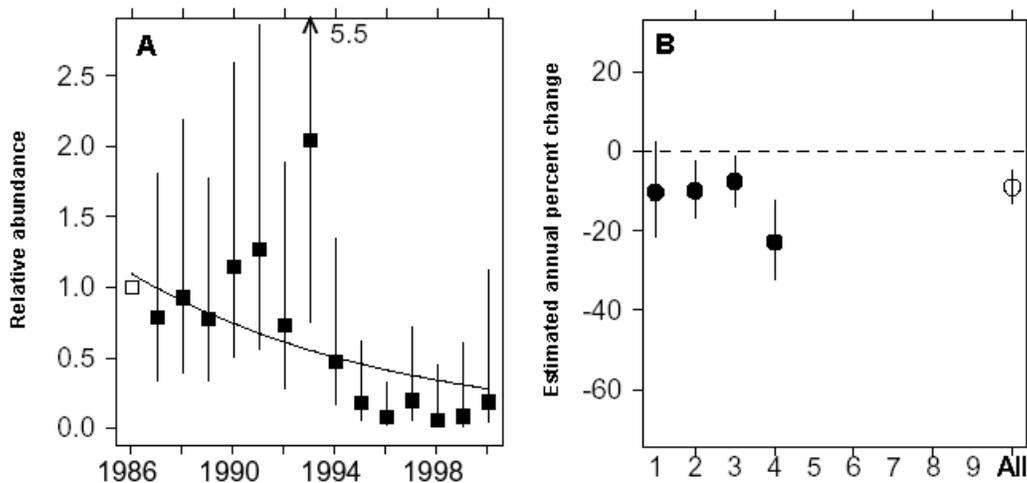


Figure 6. (A) Relative abundance of white shark from 1986-2000 in the entire Northwest Atlantic indicated by an analysis of U.S. commercial longline fishery logbook (decline of 79%); (B) estimated annual rate of change for nine assessment areas and total. From Baum et al. 2003.

## Global Trends

White shark populations in several regions show marked reduction from historical abundance. Catches of white sharks in the protective beach meshing program off New South Wales, Australia, show an almost unbroken decline since the commencement of meshing in 1937; CPUE over all meshed regions dropping over 80% between 1950 and 1990 (Reid and Krogh 1992). Pepperell (1992) expressed concern at the disappearance of white sharks from game fishing catches off southeastern Australia in the 1980s and Bruce (1992) noted a decline in white shark numbers in some areas off South Australia. A tagging-resighting study of white shark population in South Australia during five expeditions over 2.5 years revealed a low estimated probability of survival between samples of 0.20 (Strong *et al.* 1996). Catches in the beach meshing program off Natal, South Africa, are among the highest in the world and CPUE data show a long-term, irregular decline between 1974 and 1988 (Cliff *et al.* 1989). Finally, the killing of four white sharks off Southeast Farallon Island, California in 1982 resulted in a drastic reduction in shark sightings by researchers stationed at the Island during 1983, 1984, and 1985 (Ainley *et al.* 1985; Pyle *et al.* 1996). These results suggest that there may be small localized populations which are less migratory and consequently removal of only a few individuals may have a noticeable effect on local populations.

## Rescue effect

The relationship between white sharks found in Canadian waters with those found in adjacent jurisdictions is unknown. It is suspected that Canadian waters comprise part of the range of North Pacific and North Atlantic populations and, as such, an increase in the total population will likely result in increased abundance of white sharks in Canadian waters.

## LIMITING FACTORS AND THREATS

Humans are the most significant predators of white sharks, taking largely unmonitored numbers as sport fish and commercial bycatch as well as targeting them for their lucrative jaws, teeth, and fins (Compagno *et al.* 1997). Markings found on stranded white sharks in the Queen Charlotte Islands, British Columbia (Figure 3a), suggest that mortality may have resulted from fisheries bycatch (R.A. Martin-author, unpublished data), but there are no confirmed records of any white shark being caught by fishing gear in Canada's Pacific waters.

Sixteen of 32 (50%) of white shark records from Atlantic Canada are accidental captures as bycatch (present study). The white sharks' tendency to investigate boats and other floating objects often brings them to the surface, where they can be easily hooked, shot, or harpooned.

As long-lived, apex predators, one would expect white sharks to bioaccumulate pollutants in their tissues. Zitko *et al.* (1972) found that muscle and liver tissue from white sharks taken in the Bay of Fundy-Gulf of Maine area had higher levels of PCBs and chlorinated hydrocarbon pesticides than other fishes. Note, the health impacts of these toxins have not been investigated in elasmobranchs, however – given the fragility of spermatozoa and the well-documented feminizing influence of organochlorides – it seems likely to negatively impact reproductive fitness of males, possibly via compromised gametogenesis or impaired sperm motility (Cadbury 1997).

## SPECIAL SIGNIFICANCE OF THE SPECIES

The white shark is the largest predatory fish and the only shark that regularly preys upon marine mammals (Compagno 2001). The species has apparently been known to the Mi'kmaq people of Atlantic Canada for thousands of years: a tooth has been found in an oyster midden dated 1,000 to 2,000 years B.P. at Pig Island, Northumberland Strait, Nova Scotia (Gilhen 1988).

The white shark is notorious for its attacks on humans and boats (Miller and Collier 1981; Burgess and Callahan 1996). Five attacks by white sharks on boats or fishing gear are known from Canadian waters (Figure 3): 1) in 1873 or 1874 a 4 m white shark attacked a dory off the St. Pierre Bank, Newfoundland; it was identified by tooth fragments embedded in the hull (Putnam 1874); 2) in June 1920, a 4.6 m white shark attacked a boat off Hubbard Cove, St. Margaret's Bay, Nova Scotia; it was identified from scars on the boat and description of a tooth embedded in it (Piers 1934); 3) in July 1932, a 4.6-m white shark attacked a boat 16 km NW of Digby Gut, Nova Scotia; it was identified from a tooth embedded in the hull (Piers 1934); 4) on 9 July 1953, a 3.7 m white shark attacked and sank a dory off Forchu, Cape Breton Island, Nova Scotia, neither of the fishermen was attacked but one of them drowned; the attacker was identified from teeth embedded in the hull (Day and Fisher 1954); and 5) in August 1961, a 4-6 m white shark attacked the canvas float bag of a Pacific coast salmon

troller; it was identified from a tooth and several fragments removed from the bag (Collier *et al.* 1996).

Due to its large size, striking appearance, predatory prowess, and potential dangerousness, the white shark has assumed an almost hagiographic status in popular culture (Ellis 1994). The celebrated cultural status of the white shark makes its jaws and teeth particularly sought-after as curios and its fins as a food additive, the latter especially in markets catering to Asian delicacies and traditional medicines. Even in the face of protective legislation, the high prices some individuals are willing to pay for white shark parts is an incentive likely sufficiently powerful to stimulate and maintain a clandestine black market trading in such goods. However, there is some debate on whether white sharks are targeted for high-value body parts, or whether these enter trade once the animals have been killed in fishery bycatch or a sports fishery.

### **EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS**

In the fall of 2004, the Convention on International Trade in Endangered Species of Flora and Fauna (CITES) listed white shark in Appendix II. The World Conservation Union (IUCN 2000) listed white shark globally as 'vulnerable'. In California, the white shark has been protected since 1997, making it illegal to attract or harass a white shark in any way as well as to possess or sell a specimen in whole or in part; any vessel containing white shark material is refused landing in State ports. The species has also been protected along U.S. Atlantic and Gulf Coasts under the federal Fisheries Management Plan since 1997, but recreational catch and release is permitted with a marine sport angling licence. The white shark is also listed in Appendices I and II of the Convention on Migratory Species (<http://www.wcmc.org.uk/cms/>), a United Nations Treaty Organization.

No federal or provincial laws explicitly protect white sharks in Canadian waters. On Canada's Pacific coast, hook and line fisheries are prohibited from keeping any shark except dogfish and therefore white shark receives some protection by this regulation. In Atlantic Canada, shark fishing regulations prohibit the retention of any recreationally caught sharks other than dogfish.

## TECHNICAL SUMMARY Atlantic Population

### ***Carcharodon carcharias***

White shark – Atlantic population

Range of Occurrence in Canada: Atlantic Ocean

Grand requin blanc

<b>Extent and Area Information</b>	
<ul style="list-style-type: none"> <li>Extent of occurrence (EO)(km<sup>2</sup>) <b>Insufficient data for a calculation</b></li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Specify trend in EO</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in EO?</li> </ul>	Unlikely
<ul style="list-style-type: none"> <li>Area of occupancy (AO) (km<sup>2</sup>) <b>[explain source of information and calculation]</b></li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Specify trend in AO</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in AO?</li> </ul>	Unlikely, possibly seasonal
<ul style="list-style-type: none"> <li>Number of known or inferred current locations</li> </ul>	Unknown (rare in Canadian waters, no records found north of Newfoundland)
<ul style="list-style-type: none"> <li>Specify trend in #</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in number of locations?</li> </ul>	Unlikely
<ul style="list-style-type: none"> <li>Specify trend in area, extent or quality of habitat</li> </ul>	Unknown
<b>Population Information</b>	
<ul style="list-style-type: none"> <li>Generation time (average age of parents in the population)</li> </ul>	23 yrs (est.)
<ul style="list-style-type: none"> <li>Number of mature individuals</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Total population trend:</li> </ul>	Declining
<ul style="list-style-type: none"> <li>% decline over the last 14 years (~0.6 generations)</li> </ul>	Unknown (Canada) 79% (North America) <sup>1</sup>
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in number of mature individuals?</li> </ul>	Unlikely
<ul style="list-style-type: none"> <li>Is the total population severely fragmented?</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Specify trend in number of populations</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in number of populations?</li> </ul>	Unlikely
<ul style="list-style-type: none"> <li>List populations with number of mature individuals in each: No data available</li> </ul>	
<b>Threats (actual or imminent threats to populations or habitats)</b>	
Commercial fishery bycatch worldwide, but only 13 recorded gear interactions from Atlantic Canada in 130 years; market for jaws, teeth, and fins; sport angling (not in Canada); coastal habitat modification, pollution.	
<b>Rescue Effect (immigration from an outside source)</b>	
<ul style="list-style-type: none"> <li>Status of outside population(s)? <b>USA: Unknown</b></li> </ul>	
<ul style="list-style-type: none"> <li>Is immigration known or possible?</li> </ul>	Possible
<ul style="list-style-type: none"> <li>Would immigrants be adapted to survive in Canada?</li> </ul>	Yes
<ul style="list-style-type: none"> <li>Is there sufficient habitat for immigrants in Canada?</li> </ul>	Yes
<ul style="list-style-type: none"> <li>Is rescue from outside populations likely?</li> </ul>	Possible
<b>Quantitative Analysis</b>	
Not done	
<b>Current Status</b>	
COSEWIC: Endangered (April 2006); CITES Appendix II (October 2004), IUCN - Vulnerable	

<sup>1</sup> The abundance trend estimate for the Northwest Atlantic (Baum *et al.* 2003) has been disputed (Burgess *et al.* 2005); however, the Marine Fishes Species Specialist Subcommittee considered the Burgess *et al.* (2005) critique to have been convincingly rebutted by Baum *et al.* (2005)

### Status and Reasons for Designation

<b>Status:</b> Endangered	<b>Alpha-numeric code:</b> A2b
<p><b>Reasons for Designation:</b></p> <p>The species is globally distributed in sub-tropical and temperate waters, but absent from cold polar waters; hence Atlantic and Pacific populations in Canada are isolated from each other and are considered separate designatable units. This very large apex predator is rare in most parts of its range, but particularly so in Canadian waters, which represent the northern fringe of its distribution. There are only 32 records over 132 years for Atlantic Canada. No abundance trend information is available for Atlantic Canada. Numbers have been estimated to have declined by about 80% over 14 years (less than one generation) in areas of the Northwest Atlantic Ocean outside of Canadian waters. The species is highly mobile, and individuals in Atlantic Canada are likely seasonal migrants belonging to a widespread Northwest Atlantic population; hence the status of the Atlantic Canadian population is considered to be the same as that of the broader population. Additional considerations include the long generation time (~23 years) and low reproductive rates (estimated gestation is 14 months and average fecundity is 7 live-born young) of this species, which limit its ability to withstand losses from increases in mortality rates. Bycatch in the pelagic long line fishery is considered to be the primary cause of increased mortality.</p>	
<p><b>Applicability of Criteria</b></p>	
<p><b>Criterion A:</b> (Declining Total Population): Meets Endangered, A2b (population declines &gt; 50% over the past 3 generations, using an index of abundance appropriate for the taxon, where the reduction or its causes may not have ceased or may not be understood).</p> <p><b>Criterion B:</b> (Small Distribution, and Decline or Fluctuation): Not met</p> <p><b>Criterion C:</b> (Small Total Population Size and Decline): Not met</p> <p><b>Criterion D:</b> (Very small Population or Restricted Distribution): Not met</p> <p><b>Criterion E:</b> (Quantitative Analysis): Not available.</p>	

## TECHNICAL SUMMARY Pacific Population

### ***Carcharodon carcharias***

White shark – Pacific population

Range of Occurrence in Canada: Pacific Ocean

Grand requin blanc

<b>Extent and Area Information</b>	
<ul style="list-style-type: none"> <li>Extent of occurrence (EO)(km<sup>2</sup>)</li> </ul> <b>Insufficient data for a calculation</b>	Likely continental shelves.
<ul style="list-style-type: none"> <li>Specify trend in EO</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in EO?</li> </ul>	Unlikely
<ul style="list-style-type: none"> <li>Area of occupancy (AO) (km<sup>2</sup>)</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Specify trend in AO</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in AO?</li> </ul>	Unknown, possibly seasonal
<ul style="list-style-type: none"> <li>Number of known or inferred current locations</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Specify trend in #</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in number of locations?</li> </ul>	Unlikely
<ul style="list-style-type: none"> <li>Specify trend in area, extent or quality of habitat</li> </ul>	Unknown
<b>Population Information</b>	
<ul style="list-style-type: none"> <li>Generation time (average age of parents in the population)</li> </ul>	23 yrs (est.)
<ul style="list-style-type: none"> <li>Number of mature individuals</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Total population trend:</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>% decline over the last/next 10 years or 3 generations.</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in number of mature individuals?</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Is the total population severely fragmented?</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Specify trend in number of populations</li> </ul>	Unknown
<ul style="list-style-type: none"> <li>Are there extreme fluctuations in number of populations?</li> </ul>	Unlikely
<ul style="list-style-type: none"> <li>List populations with number of mature individuals in each: No data available</li> </ul>	
<b>Threats (actual or imminent threats to populations or habitats)</b>	
Commercial fishery bycatch worldwide (no confirmed records from Canada); market for jaws, teeth, and fins; sport angling; coastal habitat modification, pollution.	
<b>Rescue Effect (immigration from an outside source)</b>	
<ul style="list-style-type: none"> <li>Status of outside population(s)</li> <li><b>USA: Unknown</b></li> </ul>	
<ul style="list-style-type: none"> <li>Is immigration known or possible?</li> </ul>	Possible
<ul style="list-style-type: none"> <li>Would immigrants be adapted to survive in Canada?</li> </ul>	Yes
<ul style="list-style-type: none"> <li>Is there sufficient habitat for immigrants in Canada?</li> </ul>	Yes
<ul style="list-style-type: none"> <li>Is rescue from outside populations likely?</li> </ul>	Possible
<b>Quantitative Analysis</b>	
Not done	
<b>Current Status</b>	
COSEWIC: Data Deficient (April 2006); CITES Appendix II (October 2004), IUCN- Vulnerable	

### Status and Reasons for Designation

<b>Status:</b> Data deficient	<b>Alpha-numeric code:</b> Not available
<b>Reasons for Designation:</b> The species is globally distributed in sub-tropical and temperate waters, but absent from cold polar waters; hence Atlantic and Pacific populations in Canada are isolated from each other and are considered separate designatable units. This very large apex predator is rare in most parts of its range, but particularly so in Canadian waters, which represent the northern fringe of its distribution. There are only 14 records over 43 years for the Pacific coast of Canada. No abundance trend information is available for Pacific Canadian waters, or for adjacent waters in the United States that would permit a status designation.	
<b>Applicability of Criteria</b>	
<b>Criterion A:</b> (Declining Total Population): Information is not available.	
<b>Criterion B:</b> (Small Distribution, and Decline or Fluctuation): Not met	
<b>Criterion C:</b> (Small Total Population Size and Decline): Not met	
<b>Criterion D:</b> (Very small Population or Restricted Distribution): Not met	
<b>Criterion E:</b> (Quantitative Analysis): Not available.	

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## INFORMATION SOURCES

- Ainley, D.G., R.P. Henderson, H.R. Huber, R.J. Boekelheide, S.G. Allen, and T.L. McElroy. 1985. Dynamics of white shark/pinniped interactions in the Gulf of the Farallones. *Memoirs of the Southern California Academy of Sciences* 9:109-122.
- Arnold, P.W. 1972. Predation on harbour porpoise, *Phocoena phocoena*, by a white shark, *Carcharodon carcharias*. *Journal of the Fisheries Research Board of Canada* 29(8):1213-1214
- Australia and Madagascar CITES Proposal. 2004. Inclusion of *Carcharodon carcharias* in Appendix II with a zero annual export quota. Thirteenth meeting of the Conference of the Parties, Bangkok, Thailand, Proposal 32.  
<http://www.cites.org/eng/cop/13/prop/E13-P32.pdf>
- Baum, J.K., R.A. Myers, D.G. Kehler, B. Worm, S.J. Harley, and P.A. Doherty. 2003. Collapse and conservation of shark populations in the northwest Atlantic. *Science* 299:389-392.
- Baum, J.K., D. Kehler, and R.A. Myers. 2005. Robust estimates of decline for pelagic shark populations in the northwest Atlantic and Gulf of Mexico. *Fisheries* 30(10):27-29.
- Bigelow, W.C. and W.C. Schroeder. 1948. Sharks. In *Fishes of the Western North Atlantic*. *Memoirs of the Sears Foundation for Marine Research* 1(1):56-576.
- Bonfil, R. pers. comm. 2004. *Oral presentation*. October 2004 VIII Annual meetings of the European Elasmobranch Association.
- Bonham, K. 1942. Records of three sharks on the Washington coast. *Copeia*, 1942(4): 264-266.
- Boustany, A.M., S.F. Davis, P. Pyle, S.D. Anderson, B.J. Le Boeuf, and B.A. Block. 2002. Expanded niche for white sharks. *Nature* 415:35-36.
- Brodie, P. and B. Beck. 1983. Predation by sharks on the grey seal (*Halichoerus grypus*) in eastern Canada. *Canadian Journal of Fisheries and Aquatic Sciences* 40(3):267-271.

- Bruce, B.D. 1992. Preliminary observations on the biology of the white shark, *Carcharodon carcharias*, in South Australian waters. *Australian Journal of Marine and Freshwater Research* 43:1-11.
- Burgess, G.H., L.R. Beerkircher, G.M. Cailliet, J.K. Carlson, E. Cortés, K.J. Goldman, R.D. Grubbs, J.A. Musick, M.K. Musyl, and C.A. Simpfendorfer. 2005. Is the collapse of shark populations in the Northwest Atlantic Ocean and Gulf of Mexico real? *Fisheries Research* 30(10): 19-26.
- Burgess, G.H., and M. Callahan. 1996. Worldwide patterns of white shark attacks on humans. Pp. 457-469. *in* A.P. Klimley and D.G. Ainley (eds.). *Great white sharks: the Biology of Carcharodon carcharias*. Academic Press, San Diego.
- Cadbury, D. 1997. *The Feminization of Nature*. Penguin Books, London.
- Cailliet, G.M., L.J. Natanson, B.A. Welden, and D.A. Ebert. 1985. Preliminary age and growth of the white shark, *Carcharodon carcharias*, using vertebral bands. *Memoirs of the Southern California Academy of Sciences* 9:49-60.
- Campana, S.E. pers. comm. 2004. *Email correspondence with Scott Wallace*. November 2004. Senior Scientist at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia.
- Carey, F.G., J.W. Kanwisher, O. Brazier, G. Gabrielson, J.G. Casey, and H.L. Pratt, Jr. 1982. Temperature and Activities of a White Shark, *Carcharodon carcharias*. *Copeia* 1982(2): 254-260.
- Casey, J.G., H.L. Pratt, Jr., and C. Stillwell. 1985. Distribution of the white shark, *Carcharodon carcharias*, in the western North Atlantic. *Memoirs of the Southern California Academy of Sciences*, 9: 2-14.
- Cliff, G., L.J.V. Compagno, M.J. Smale, R.P. van der Elst, and S.P. Wintner. 2000. First records of white sharks, *Carcharodon carcharias*, from Mauritius, Zanzibar, Madagascar and Kenya. *South African Journal of Science* 96(7):365-367.
- Cliff, G., S.F.J. Dudley, and B. Davis. 1989. Sharks caught in the protective nets off Natal, South Africa. 2. The great white shark *Carcharodon carcharias* (Linnaeus). *South African Journal of Marine Science* 8:131-144.
- Coad, B.W. 1995. *Encyclopedia of Canadian Fishes*. Canadian Museum of Nature, Ottawa.
- Collier, R.S., M. Marks, and R.A. Warner. 1996. White shark attacks on inanimate objects along the Pacific Coast of North America. Pp. 217-222. *In* A.P. Klimley and D.G. Ainley (eds.). *Great White Sharks: the Biology of Carcharodon carcharias*. Academic Press, San Diego.
- Collier, R.S., pers. comm. 1986. *Interview by R.A. Martin*. November 1986. Shark Research Committee, Van Nuys, California.
- Compagno, L.J.V. 1991. A review of the general biology and conservation of the white shark (*Carcharodon carcharias*). Pp. 30-31. *In* T. Condon (ed.). *Great White Sharks – Carcharodon carcharias – a Perspective*. Underwater, Special Edition, 17.
- Compagno, L.J.V. 2001. *Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Volume 2. Bullhead, mackerel and carpet sharks (Heterodontiformes, Lamniformes and Orectolobiformes)*. United Nations Food and Agricultural Organization Species Catalogue for Fishery Purposes 1(2) Rome, FAO. 269 pp.

- Compagno, L.J.V., M.A. Marks, and I.K. Fergusson. 1997. Threatened fishes of the world: *Carcharodon carcharias* (Linnaeus, 1758) (Lamnidae). *Environmental Biology of Fishes* 50:61-62.
- Cook, S.F., pers. comm. 1987. *Letter to R.A. Martin*. April 1987. Argus Mariner Consulting Scientists, Corvallis, Oregon.
- Cortéz, E. 1999. Standardized diet compositions and trophic levels of sharks. *ICES Journal of Marine Science* 56:707-717.
- Day, L.R., and H.D. Fisher. 1954. Notes on the great white shark in Canadian Atlantic waters. *Copeia* 4:295-296.
- Dudley, S.F.J., M.D. Anderson-Reade, G.S. Thompson, and P.B. McMullen. 2000. Concurrent scavenging off a whale carcass by great white sharks, *Carcharodon carcharias*, and tiger sharks, *Galeocerdo cuvier*. *Fisheries Bulletin* 98:646-649.
- Ellis, R. 1994. *Monsters of the Sea*. Alfred A. Knopf, New York.
- Fallows, C., and M. le Sueur. 2001. Depth chargers. *BBC Wildlife* 19(4): 48-55.
- Fallows, C., pers. comm. 2000. *Interview by R.A. Martin*. August 2000. African Shark Eco-Charters, Capetown, South Africa.
- Francis, M.P. 1996. Observations on a pregnant white shark with a review of reproductive biology. Pp. 157-172. In A.P. Klimley and D.G. Ainley (eds.). *Great White Sharks: the Biology of Carcharodon carcharias*. Academic Press, San Diego.
- Gadig, O.B.F., and R.S. Rosa. 1996. Occurrence of the white shark along the Brazilian coast. Pp. 347-350. In A.P. Klimley and D.G. Ainley (eds.). *Great White Sharks: the Biology of Carcharodon carcharias*. Academic Press, San Diego.
- Gallucci, V. pers. comm. 2005. *Email correspondence with S.S. Wallace*. September 2005. Wakefield Professor of Ocean and Fishery Sciences, School of Aquatic & Fishery Sciences, Seattle, Washington.
- Garrick, J.A.F., and L.P. Schultz. 1963. A guide to potentially dangerous kinds of sharks. In P.W. Gilbert (ed.). *Sharks and Survival*. D.C. Heath Company, Lexington.
- Gilhen, J. 1998. Fishes of Nova Scotia: species reported in the accession books of Henry Piers, Curator of the Provincial Museum, Halifax, from 1899-1940. Curatorial Report, Nova Scotia Museum of Natural History, Halifax.
- Gilmore, R.G. 1993. Reproductive biology of lamnoid sharks. *Environmental Biology of Fishes* 38(1-3):95-114.
- Goldman, K.J., and S.D. Anderson. 1999. Space utilization and swimming depth of white sharks, *Carcharodon carcharias*, at the South Farallon Islands. *Environmental Biology of Fishes* 56:351-364.
- Gruber, S.H., and J.L. Cohen. 1985. Visual system of the white shark, *Carcharodon carcharias*, with emphasis on retinal structure. *Memoirs of the Southern California Academy of Sciences* 9:61-72.
- Hogg, N. 1992. The Gulf Stream and its recirculations. *Oceanus* 35(2):18-24.
- Hogans, W.E. and M.J. Dadswell. 1985. Parasitic copepods of the white shark (*Carcharodon carcharius* L.) from the Bay of Fundy. *Canadian Journal of Zoology* 63(3):740-741.
- ICCAT. 2005. Report of the 2004 inter-sessional meeting of the ICCAT sub-committee on by-catches: shark stock assessment. Col. Vol. Sci. Pap. ICCAT, 57: in press.

- Karinen, J.F., B.L. Wing, and R.R. Straty. 1985. Records and sighting of fish and invertebrates in the eastern Gulf of Alaska and oceanic phenomenon related to the 1983 El Niño event. Pp. 253-267. *In* W.S. Wooster and D.L. Fluharty (eds.). El Niño North: Niño Effects in the Eastern Subarctic Pacific Ocean. Washington Sea Grant Program, University of Washington, Seattle.
- Kato, S. 1965. White shark, *Carcharodon carcharias*, from the Gulf of California with a list of sharks seen in Mazatlan, Mexico. *Copeia* 1965(3):384.
- Kohler, N.E., J.G. Casey and P.A. Turner. 1998. NMFS Cooperative Shark Tagging Program, 1962-1993: an atlas of shark tag and recapture data. *Marine Fisheries Review* 60(2):1-87.
- Klimley, A.P. 1985. The areal distribution and autoecology of the white shark, *Carcharodon carcharias*, off the west coast of North America. *Memoirs of the Southern California Academy of Sciences* 9:15-40.
- Klimley, A.P. 1994. The predatory behavior of the white shark. *American Scientist* 82(2):122-133.
- Klimley, A.P., S.D. Anderson, P. Pyle, and R.P. Henderson. 1992. Spatiotemporal patterns of white shark (*Carcharodon carcharias*) predation at the South Farallon Islands, California. *Copeia* 1992(3):680-690.
- Klimley, A.P., P. Pyle, and S.D. Anderson. 1996. The behavior of white sharks and their pinniped prey during predatory attacks. Pp. 175-191. *In* A.P. Klimley and D.G. Ainley (eds.). *Great White Sharks: the Biology of Carcharodon carcharias*. Academic Press, San Diego.
- Leim, A.H. and L.R. Day. 1959. Records of uncommon and unusual fishes from eastern Canadian waters, 1950-1958. *Journal of the Fisheries Research Board of Canada* 16(4):503-514.
- LeMier, E.H. 1951. Recent records of the great white shark, *Carcharodon carcharias*, on the Washington coast. *Copeia* 1951(3):259.
- Miller, D.J., and R.S. Collier. 1981. Shark attacks in California and Oregon, 1926-1979. *California Fish and Game* 67(2):76-104.
- Mollet, H.F. and G.M. Cailliet. 2002. Comparative population demography of elasmobranchs using life history tables, Leslie matrices and stage-based matrix models. *Marine and Freshwater Research* 53:503-516.
- Mollet, H.F., G. Cliff, H.L. Pratt, Jr., and J.D. Stevens. 2000. Reproductive biology of the female shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810, with comments on the embryonic development of lamnoids. *Fisheries Bulletin* 98:299-318.
- Mollet, H.F., D.A. Ebert, G.M. Cailliet, A.D. Testi, A.P. Klimley, and L.J.V. Compagno. 1996. A review of length validation methods and protocols to measure large white sharks. Pp. 91-108. *In* A.P. Klimley and D.G. Ainley (eds.). *Great White Sharks: the Biology of Carcharodon carcharias*. Academic Press, San Diego.
- Mollomo, P. 1998. The white shark in Maine and Canadian Atlantic waters. *Northeastern Naturalist* 5(3):207-214.
- Nakaya, K. 1994. Distribution of white shark in Japanese waters. *Fisheries Science*, 60(5): 515-518.
- Pardini, A.T., C.S. Jones, L.R. Noble, B. Kreiser, H. Malcolm, B.D. Bruce, J.D. Stevens, G. Cliff., M.C. Scholl, M. Francis, C.A.J. Duffy, and A.P. Martin. 2001. Sex-biased dispersal of great white sharks. *Nature* 412:139-140.

- Pepperell, J.G. 1992. Trends in the distribution, species composition and size of sharks caught by gamefish anglers off south-eastern Australia, 1961-90. *Australian Journal of Marine and Freshwater Research* 43:213-225.
- Piers, H. 1934. Accidental occurrence of the man-eater or great white shark, *Carcharodon carcharias* (Linn.) in Nova Scotian waters. *Proceedings of the Nova Scotian Institute of Science* 18(3):192-203.
- Pike, G.C. 1962. First record of the great white shark (*Carcharodon carcharias*) from British Columbia. *Journal of the Fisheries Research Board of Canada* 19(2):363.
- Pratt, H.L., Jr. 1996. Reproduction in the male white shark. Pp. 131-138. *In* A.P. Klimley and D.G. Ainley (eds.). *Great White Sharks: the Biology of Carcharodon carcharias*. Academic Press, San Diego.
- Pratt, H.L., J.G. Casey, and R.B. Conklin. 1982. Observations on Large White Sharks, *Carcharodon carcharias*, off Long Island, New York. *Fish Bulletin* 80(1): 153-156.
- Putnam, F.W. 1874. Tooth of a man-eater that attacked a dory near St. Pierre Bank. *Bulletin of the Essex Institute, Salem* 6(4):72.
- Pyle, P., S.D. Anderson, and D.G. Ainley. 1996. Trends in White Shark Predation at the South Farallon Islands, 1968-1993. Pp. 375-379. *In* A.P. Klimley and D.G. Ainley (eds.). *Great White Sharks: the Biology of Carcharodon carcharias*. Academic Press, San Diego.
- Reid, D.D. and M. Krough. 1992. Assessment of catches from protective shark meshing off New South Wales beaches between 1950 and 1990. *Australian Journal of Marine and Freshwater Research* 43:283-296.
- Royce, W.F. 1963. First record of white shark (*Carcharodon carcharias*) from southeastern Alaska. *Copeia* 1963(1):179.
- Scott, W.B. and M.G. Scott. 1988. Atlantic Fishes of Canada. *Canadian Bulletin of Fisheries and Aquatic Sciences* 219: 731 p.
- Smith, S.E., D.W. Au, and C. Show. 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. *Marine and Freshwater Research* 49:663-678.
- Squire, J.L. 1967. Observations of basking sharks and great white sharks in Monterey Bay, 1948-50. *Copeia* 1:247-250.
- Stewardson, C.L. and M. Brett. 2000. Aggressive behaviour of an adult male Cape fur seal (*Arctocephalus pusillus pusillus*) towards a great white shark (*Carcharodon carcharias*). *African Zoology* 35(1):147-150.
- Strong, W.R., Jr. 1996. Shape discrimination and visual predatory tactics in white sharks. Pp. 229-240. *In* A.P. Klimley and D.G. Ainley (eds.). *Great White Sharks: the Biology of Carcharodon carcharias*. Academic Press, San Diego.
- Strong, W.R., Jr., B.D. Bruce, D.R. Nelson, and R.C. Murphy. 1996. Population dynamics of white sharks in Spencer Gulf, South Australia. Pp. 401-414. *In* A. Peter Klimley and David G. Ainley (eds.). *Great White Sharks: the Biology of Carcharodon carcharias*. Academic Press, San Diego.
- Taylor, L.R. 1985. White sharks In Hawaii: historical and contemporary records. *Memoirs of the Southern California Academy of Sciences* 9:41-48.
- Templeman, W. 1963. Distribution of sharks in the Canadian Atlantic (with special reference to Newfoundland waters). *Bulletin of the Fisheries Research Board of Canada* 140:1-77.

- Tricas, T.C. and J.E. McCosker. 1984. Predatory behavior of the white shark (*Carcharodon carcharias*), with notes on its biology. *Proceedings of the California Academy of Science* 43(14):221-238.
- Uchida, S., M. Toda, K. Teshima, and K. Yano. 1996. Pregnant white sharks and full-term embryos from Japan. Pp. 139-155. *In* A.P. Klimley and D.G. Ainley (eds.). *Great White Sharks: the Biology of Carcharodon carcharias*. Academic Press, San Diego.
- Vladykov, V.D., and D.E. McAllister. 1961. Preliminary list of marine fishes of Quebec. *Le Nature Canadien* 88(3):53-78.
- Vladykov, V.D., and R.A. McKenzie. 1935. The marine fishes of Nova Scotia. *Proceedings of the Nova Scotian Institute of Science* 19(1):17-113.
- Wintner, S.P. and G. Cliff. 1999. Age and growth determination of the white shark, *Carcharodon carcharias*, from the east coast of South Africa. *Fisheries Bulletin* 97(1):153-169.
- Zitko, V., O. Huntzinger, and P.M.K. Choi. 1972. Contamination of the Bay of Fundy-Gulf of Maine area with polychlorinated biphenyls, polychlorinated terphenyls, chlorinated dibenzodioxins, and dibenzofurans. *Environmental Health Perspectives* 4:47-50.

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