COSEWIC
Assessment and Status Report

on the

Tope
Galeorhinus galeus

in Canada

SPECIAL CONCERN
2021

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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Previous report(s):

COSEWIC 2007. COSEWIC assessment and status report on the tope *Galeorhinus galeus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 29 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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COSEWIC
Assessment Summary

Assessment Summary – April 2021

Common name
Tope

Scientific name
Galeorhinus galeus

Status
Special Concern

Reason for designation
This Pacific coast shark is considered to be a single migratory population off the west coast of North America. More than 800,000 individuals, primarily large adults, were killed for their livers between 1937 and 1949. In 2012, the coastwide population was estimated at about 10% of historical abundance. Commercial fishery catch rates and research vessel surveys suggest greater abundance in Canadian waters from 2012 to 2018 compared with 2003 to 2011. The main ongoing threat is bycatch in commercial trawl and longline groundfish fisheries, which continues at low levels in Canada and the United States. Targeting and retention of this shark has been prohibited in Canada, although mortality rates upon release are unknown. Population recovery is further limited by its slow growth rate and low fecundity.

Occurrence
Pacific Ocean, British Columbia

Status history
Designated Special Concern in April 2007. Status re-examined and confirmed in May 2021.

COSEWIC
Executive Summary

Tope
Galeorhinus galeus

Wildlife Species Description and Significance

Tope (*Galeorhinus galeus*), also commonly referred to as Soupfin Shark and Milandre in French, is one of 46 species belonging to the family Triakidae (the houndsharks) and is the only representative of this family on Canada's Pacific coast.

The population structure of Tope is largely unknown, although gene flow among individuals from the northeastern Pacific Ocean indicates that it constitutes a single population. Tope are considered migratory, moving north along the northeast Pacific coast during summer and south into deeper waters during winter. Tope in Canada's Pacific waters is considered as a single designatable unit with Tope in waters off the west coast of North America.

Distribution

Tope are widespread, occurring in coastal seas between 68°N and 55°S latitude in the north and south Pacific and Atlantic oceans. Tope are found in the northeastern Pacific from northern British Columbia (only one record in the Gulf of Alaska off the United States) to the Gulf of California as well as waters off Peru and Chile.

Habitat

Tope prefer cooler, continental shelf waters, where they range from close inshore to offshore waters up to 471 m deep. They occur near the bottom but switch between pelagic and benthic habitats over periods of months, as reflected by their capture by both pelagic floating longlines and bottom trawls. Pups and juveniles utilize shallow nearshore habitats for one to two years before moving offshore. There is no direct protection of Tope habitat in Canada except in the Hecate Strait Glass Sponge Reef Marine Protected Area and Strait of Georgia and Howe Sound Glass Sponge Reef Conservation Initiatives, which are small in comparison to Tope distribution in Canada and not situated in their primary habitat.

Biology

The reproductive cycle has been reported as one to three years with a gestation period of one year. Tope are ovoviviparous, with females carrying between six and 52 pups, released between March and July. Pups are an average 24–37 cm TL (total length) long at birth. Little is known about the breeding behaviour of Tope.

Tope are slow growing and reach a maximum age of at least 40 years. Age of maturity in females is about 13–17 years and for males about 12–17 years. Generation time is estimated at 23 yr. In the eastern Pacific, females are mature at 150 cm and males at 135 cm. In the northeast Pacific, maximum length is 195 cm for females and 175 cm for males.

Limited tagging studies suggest that at least some individuals migrate between California and Hecate Strait and can travel long distances over a short time. Movement is limited across deep ocean basins.

Population Sizes and Trends

Research surveys indicate a positive population trend off California from 1994 to 2018 and off British Columbia for 2012-2018 compared to 1994-2011. However, none of these data provide robust indices of abundance and cover a short time series for a long-lived species. An increase in area of occupancy into Hecate Strait east of Haida Gwaii may reflect population growth as well as improved reporting, or latitudinal range shifts in response to recent warming events. Low catches in research surveys and a slow intrinsic growth rate suggest substantial depletion persists relative to presumed higher abundance in the 1930s.

Threats and Limiting Factors

The intensive fishery for primarily adult Tope took place between 1937 and 1949 throughout their migratory range in the northeast Pacific. This directed fishery likely caused a substantial depletion in the adult biomass. Fisheries and Oceans Canada introduced Codes of Conduct for handling and release of sharks in incidental catch in 2014, but the effectiveness of these measures awaits research on release mortality in Canada.

Protection, Status and Ranks

Tope was designated as globally Vulnerable by the IUCN (International Union for the Conservation of Nature) in 2006, based upon criteria A2bd+3d+4bd, although this did not include Canada. Prior to the current assessment, Tope was previously designated as Special Concern by COSEWIC in 2007 and was listed under the *Species at Risk Act*, Schedule 1 as Special Concern in 2009.

In 2011, targeting and retention of Tope in commercial and recreational fisheries was prohibited in British Columbia, with the added requirement that these sharks be released alive and with as little harm as possible.

TECHNICAL SUMMARY

Galeorhinus galeus

Tope

Milandre

Range of occurrence in Canada (province/territory/ocean): Pacific Ocean, British Columbia

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2011) is being used)	23 years (see **Biology: Life Cycle and Reproduction**)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Not considered to be in decline
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a.clearly reversible and b.understood and c. ceased?	a. Yes b. Yes c. Yes, although mortality from incidental catch still occurring in low numbers
Are there extreme fluctuations in number of mature individuals?	Unlikely

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	Estimated EOO in Canadian waters is 171,591 km²; 113,142 km² (excluding land masses); see **Distribution: Canadian Range**).
Index of area of occupancy (IAO) (Always report 2x2 grid value).	Estimated at ~ 19,300 km² (see **Distribution: Canadian Range**).

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. Unlikely b. Unlikely
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	Location concept does not apply
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Unknown, unlikely
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Unknown, unlikely (see **Distribution**).
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Unknown whether northeast Pacific population has regional or subpopulations, but unlikely (see **Wildlife Species Description and Significance.**).
Is there an [observed, inferred, or projected] decline in number of "locations"*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Unknown, unlikely (see **Habitat**).
Are there extreme fluctuations in number of subpopulations?	Unknown
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	Unknown, unlikely
Are there extreme fluctuations in index of area of occupancy?	Unknown, unlikely

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Unknown (all northeast Pacific)	Estimated 89,000 females
Total	

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Unknown. No quantitative analysis available.

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes. i. IUCN 5. Biological Resource Use (Low) a. Unintentional bycatch in trawl and longline fisheries (Low) What additional limiting factors are relevant? A late age of maturity leads to a long generation time; low fecundity.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Most likely source of immigrants is from US waters, part of the same DU hence the same status
Is immigration known or possible?	Immigration from the USA is likely as tagging and genetic evidence indicates it is the same population connected by gene flow (see Species Information: **Wildlife Species Description and Significance.**).
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Likely
Are conditions deteriorating in Canada?+	Unknown
Are conditions for the source population deteriorating?+	Unknown
Is the Canadian population considered to be a sink?+	No
Is rescue from outside populations likely?	Yes

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Special Concern in April 2007. Status re-examined and confirmed in May 2021.

Status and Reasons for Designation:

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

+ See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Reasons for designation:
This Pacific coast shark is considered to be a single migratory population off the west coast of North America. More than 800,000 individuals, primarily large adults, were killed for their livers between 1937 and 1949. In 2012, the coastwide population was estimated at about 10% of historical abundance. Commercial fishery catch rates and research vessel surveys suggest greater abundance in Canadian waters from 2012 to 2018 compared with 2003 to 2011. The main ongoing threat is bycatch in commercial trawl and longline groundfish fisheries, which continues at low levels in Canada and the United States. Targeting and retention of this shark has been prohibited in Canada, although mortality rates upon release are unknown. Population recovery is further limited by its slow growth rate and low fecundity.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. After a substantial inferred reduction during the 1937-1949 period, significant exploitation ceased in 1949. During the most recent three generations, there are insufficient data to reliably infer, project, or suspect population reduction and the threat leading to historical reduction has ceased. While there is evidence of increased abundance in Canadian waters from commercial catch rates and research vessel surveys, the available data cover only a small portion of three generations.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. EOO of 113,142 km^2 and IAO of 19,300 km^2 exceed thresholds.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Number of mature individuals > 1000; no indication of continuing decline.
Criterion D (Very Small or Restricted Population): Not applicable. Number of mature individuals > 1000.
Criterion E (Quantitative Analysis): Not applicable. Analyses not done.

PREFACE

Tope in the northeast Pacific was last assessed by COSEWIC in 2007. Two recent global population genetic analyses indicate that the northeast Pacific population in North America is a discrete population with low gene flow between it and populations in South America, Africa, the north Atlantic, and Australia. These genetic analyses have also revealed that the major barriers to dispersal for Tope, which were not well understood at the time of the last Status Report, include large ocean basins and warm water.

Recent trends in population abundance are interpreted from surveys and commercial fisheries data. There are some indications of increasing abundance since the last Status Report based on a California set net survey, the International Pacific Halibut Commission (IPHC) set line survey (for which modelled mean Tope catch at a station increased by seven times from 2003 to 2018), and from incidental catch reported in commercial fisheries. It is still unclear how much these increases reflect population growth, as better reporting or distributional shifts caused by ocean warming events may be partially responsible. The index of area of occupancy has also likely increased based on a wider spatial distribution of catch in commercial fisheries and research surveys, particularly in Hecate Strait. Consistent historical and continuing fishing effort in the region support this increase in area of occupancy.

There is still not enough population information to develop an index of relative abundance for Tope or to assess its population size, although the IPHC set line survey is a candidate for an index of relative abundance in the future.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2021)

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

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

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

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

Environment and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
Service canadien de la faune
Canada

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Tope (*Galeorhinus galeus*) is one of 46 species belonging to the family Triakidae or houndsharks. In Canada, Tope is more commonly referred to as Soupfin Shark, but it is recognized by the American Fisheries Society as Tope (Nelson *et al.* 2004). The genus *Galeorhinus* is derived from the Greek words "galeos" meaning a shark and "rhinos" which means nose. Tope is the only representative of the family Triakidae on Canada's Pacific coast. It has many common names. Countries in the southern hemisphere, in particular, Australia, New Zealand, and South Africa refer to Tope as 'School Shark'. Other common names include Eastern School Shark, Flake, Greyboy, Greyshark, Penny's Dog, Schnapper Shark, Sharpie Shark, Sweet William Shark, Tope Oil Shark, Tope School Shark, Tope Soupfin Shark, and Vitamin Shark (Florida Museum 2020). In French, this species is referred to as *Milandre*.

Morphological Description

Tope are a dark bluish grey on the dorsal side, which shades to white on the underside (Mecklenburg *et al.* 2002). They are reported to grow up to 195 cm total length (TL) for females and 175 cm for males (Compagno 1984). They have two dorsal fins, with the first dorsal fin well ahead of the pelvic fins and the second dorsal fin similar in size to the anal fin (Figure 1). The caudal fin has a large subterminal lobe which is nearly as long as the lower lobe (Ebert 2003). Their snout is long and pointed and they have a large mouth. The eyes are horizontally oval with conspicuous spiracles behind each eye.

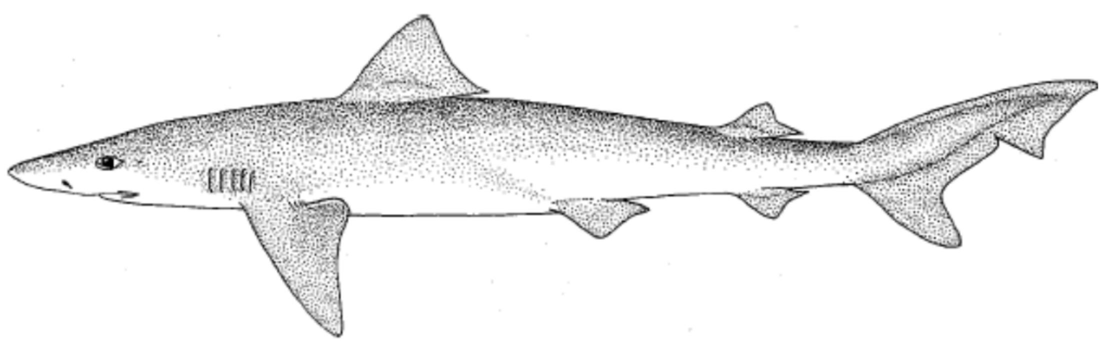

Figure 1. Biological illustration of the Tope. Source: Compagno 1984.

Population Structure and Variability

Mid-ocean ridges, cold currents, gyres, and large ocean basins and bights form barriers to gene flow for Tope (Chabot 2015; Bester-van der Merwe *et al.* 2017). The main factor restricting gene flow is the species' thermal preference and consequent avoidance of warm tropical waters (Chabot and Allen 2009) leading to separation of northern and southern hemisphere populations. Avoidance of tropical (equatorial) waters is responsible for genetic difference between populations in North and South America (F_{ST} = 0.09, P<0.001) and between western Europe versus Africa (F_{ST} = 0.21, P<0.001) (Chabot 2015).

On a broader scale, a global genetic analysis using mitochondrial DNA (mtDNA) found significant population structure for Tope (Φ_{ST} = 0.84; P < 0.000001) across six geographically distinct areas: Australia, North America (northeast Pacific), South Africa, South America (Argentina and Peru), and the United Kingdom, with estimates of less than one individual (Nm = 0.05–0.97) migrating per generation across those populations (Chabot and Allen 2009).There is a higher degree of similarity of populations between North America and the United Kingdom (Φ_{ST} = 0.61, P < 0.000001) in the northern hemisphere than between North and South America (Φ_{ST} = 0.67, P < 0.000001), the former not separated by warm equatorial water (Chabot and Allen 2009). This low gene flow particularly across the hemispheres is evidence of distinct regional populations. However, analyses with mtDNA are inconclusive in terms of significance because sharks are known to have high female philopatry, which may produce high levels of population differentiation for maternally inherited mtDNA markers, and which do not reflect population differentiation across the genome when males mediate dispersal. However, satellite tracking indicates Tope rarely cross ocean basins and have high site philopatry in all populations studied.

Within hemispheres, high genetic connectivity (i.e., gene flow) has been found in populations over large scales in the Australian Bight, the southern coast of South Africa, and the Brazilian coastline, suggesting that Tope in general has a high dispersal ability, (Bitalo *et al.* 2015; Hernández *et al.* 2015; Bester-van der Merwe *et al.* 2017; Jaureguizar *et al.* 2018). There is also evidence of relatively high gene flow between Australia and South Africa, and across the Atlantic-Indian boundary on the South African coastline suggesting the potential for strong dispersal ability, even across some of those barriers (Bitalo *et al.* 2015; Bester-van der Merwe *et al.* 2017).

Tope within the northeast Pacific (southeast Alaska to northern Mexico) likely form a discrete population (F_{ST} = 0.09–0.21, P<0.001) (Chabot 2015) but the degree of subpopulation structuring within the northeast Pacific Ocean is uncertain. Movement and gene flow between the United States and Canada is possible given the continuity in distribution and lack of barriers to dispersal. However, the precise extent of population mixing and movement is unknown (See **Dispersal and Migration**).

Designatable Units

Tope in Canada's Pacific waters and in the waters to the south off the west coast of North America are considered as a single DU (designatable unit) due to genetic homogeneity (Chabot and Allen 2009), a lack of evidence for any population structure or heterogeneity in habitat that could create it, as well as tagging information showing movement from as far south as Baja California north to Washington, and from California into Canada.

Special Significance

Tope occupy a high trophic level and prey upon almost any pelagic and demersal fish, and they can also be prey for larger sharks and marine mammals, suggesting they are an important species structuring marine food webs (Ebert 2003). Tope liver has the highest known concentration of vitamin A of any fish species on Canada's Pacific coast (Bailey 1952) and the meat has market value for its quality (Holts 1988), factors that historically made it a sought-after species in fisheries in the eastern Pacific.

DISTRIBUTION

Global Range

Tope occur in coastal waters between 68°N and 55°S latitude globally but in the eastern Pacific from only northern British Columbia to the Gulf of California, as well as in waters off Peru and Chile (Figure 2). There is only one record from the Gulf of Alaska defining its northern extent in the Pacific (King *et al.* 2017). Tope are also distributed in the southwestern Pacific Ocean in waters off Australia and New Zealand. In the western Atlantic Ocean, its range is limited from southern Brazil to Argentina while in the eastern Atlantic it can be found from Iceland to South Africa, including the Mediterranean Sea. In the western Indian Ocean region, Tope can be found in waters off South Africa (Compagno 1984 IUCN 2012). Tagging studies in Australia have shown that Tope prefer midwater depths between 50–100 m (Rogers *et al.* 2017), but they can go as deep as 532 m (West and Stevens 2001). Trawlers in Brazil catch Tope in waters 50–350 m deep (Peres and Vooren 1991).

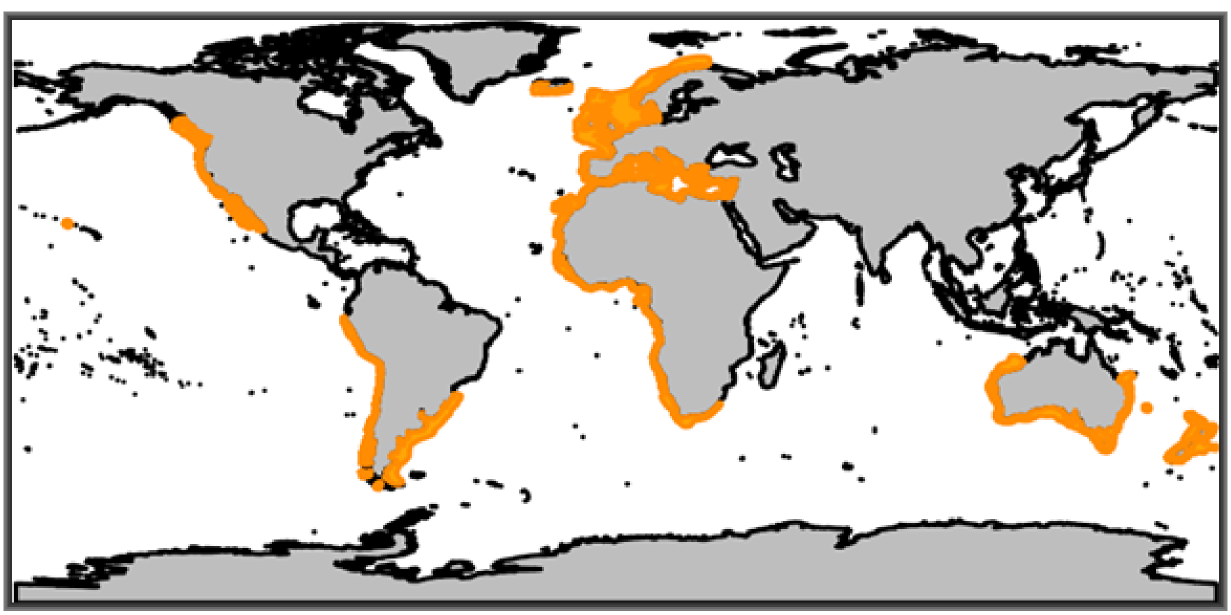

Figure 2. Global distribution of Tope (orange shaded areas). Source: IUCN Red List (IUCN 2012).

Canadian Range

In Canada, Tope occur primarily from the continental shelf along Vancouver Island, Queen Charlotte Sound, and into northern Hecate Strait (Table 1, Figure 3). There is a single commercial fishing record of Tope being taken in the Strait of Georgia along with two records of deceased Tope that washed ashore (Table 1, Figure 3). Based on recent research hook and line and trawl surveys (2003-2018) and commercial hook and line (2005-2018) and trawl (2003-2018) catch, 95% of the records (N=854 sets with Tope) fall between the depths of 10–280 m (Figure 4); additionally, 74% of Tope observations since 1996 from commercial catch and research surveys, and by staff in Pacific Rim National Park Reserve (PRNPR), occur in waters 20–500 m deep (Figure 5).

Table 1. Confirmed observations of Tope in Canada by the public. WCVI=west coast Vancouver Island; PRNPR=Pacific Rim National Park Reserve. Source: Parks Canada (PRNPR encounters), DFO Shark Sightings Network (all other encounters).

Year	Month	Sex	Location	Comments
1990	10	Unknown	PRNPR	Washed ashore
1996	8	Unknown	WCVI	Live at surface
1998	7	Unknown	WCVI	Live at surface
1998	7	Unknown	WCVI	Live at surface
1998	7	Unknown	WCVI	Live at surface
1998	7	Unknown	WCVI	Live at surface
1998	7	Unknown	WCVI	Live at surface
1998	7	Unknown	WCVI	Live at surface
1999	8	Unknown	WCVI	Live at surface
1999	9	Unknown	WCVI	Live at surface
1999	9	Unknown	PRNPR	Live at surface
2000	10	Male	PRNPR	Washed ashore
2007	10	Male	PRNPR	Washed ashore
2004	10	Male	PRNPR	Washed ashore
2004	10	Male	PRNPR	Washed ashore
2007	11	Female	PRNPR	Washed ashore
2013	10	Male	Southern Hecate Strait	Washed ashore
2014	8	Male	Northern Hecate Strait	Washed ashore
2014	9	Unknown	Northern Hecate Strait	Swimming near dock
2015	7	Male	Northern WCVI	Recreational fishing
2016	10	Male	Strait of Georgia	Washed ashore
2016	10	Male	Strait of Georgia	Washed ashore

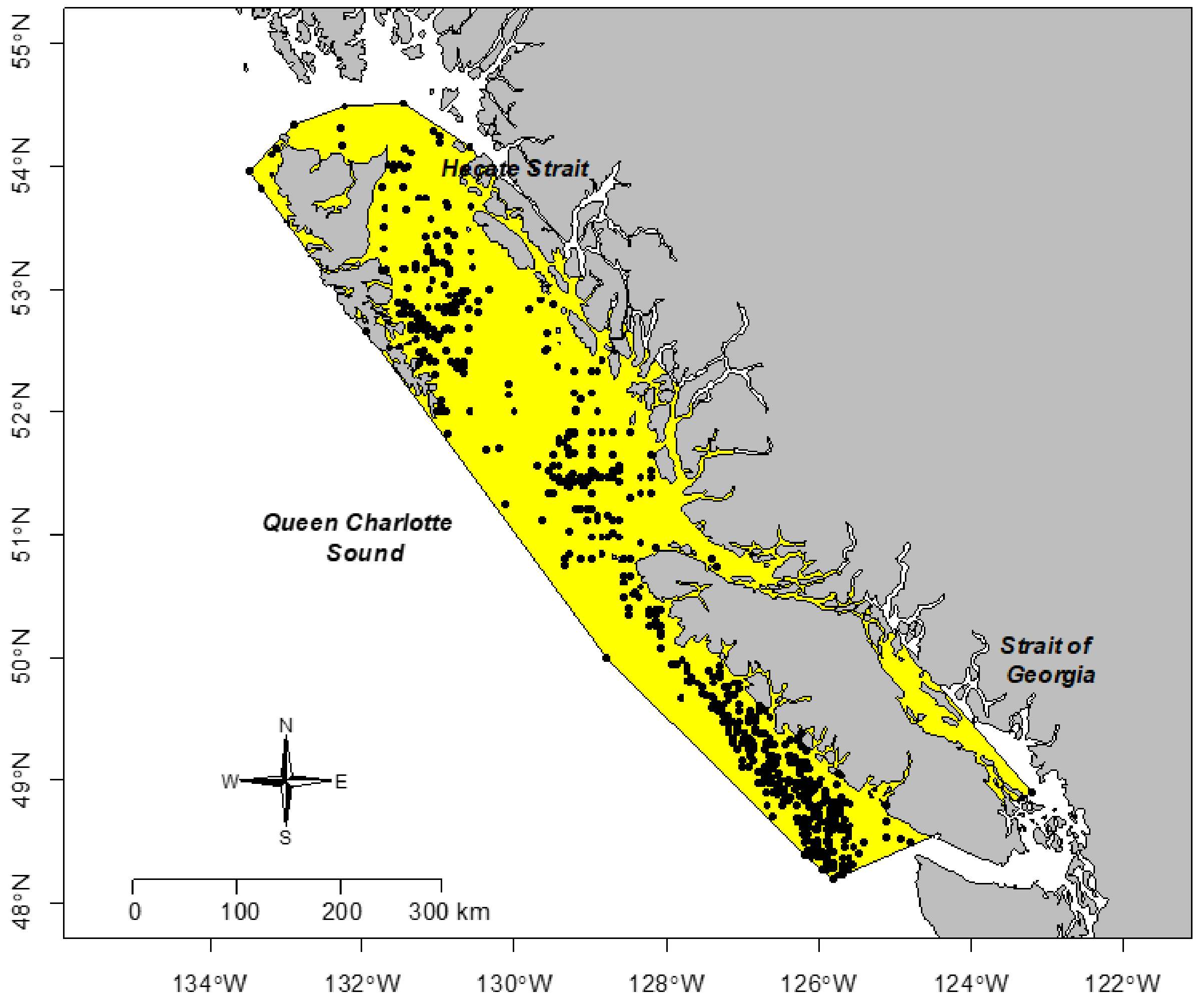

Figure 3. Canadian range and extent of occurrence (yellow polygon) of Tope based on observations in research surveys and the commercial trawl and hook and line fisheries between 1996 and 2018, including IPHC set line survey data from 1998-2018 and observations of live Tope by staff of PRNPR from 1996-1999. Each point based on fisheries catches up to 2016 represents the centre of a 5 km by 5 km square in which catch is reported. Source: PacHarv database, PacHarvTrawl, GFFOS, GFBio, PacharvHL, PacharvSable, IPHC set line survey, WCVI High Seas Salmon research survey, WCVI Pelagics survey, Integrated Pelagic Ecosystems Survey, and PRNPR sightings databases.

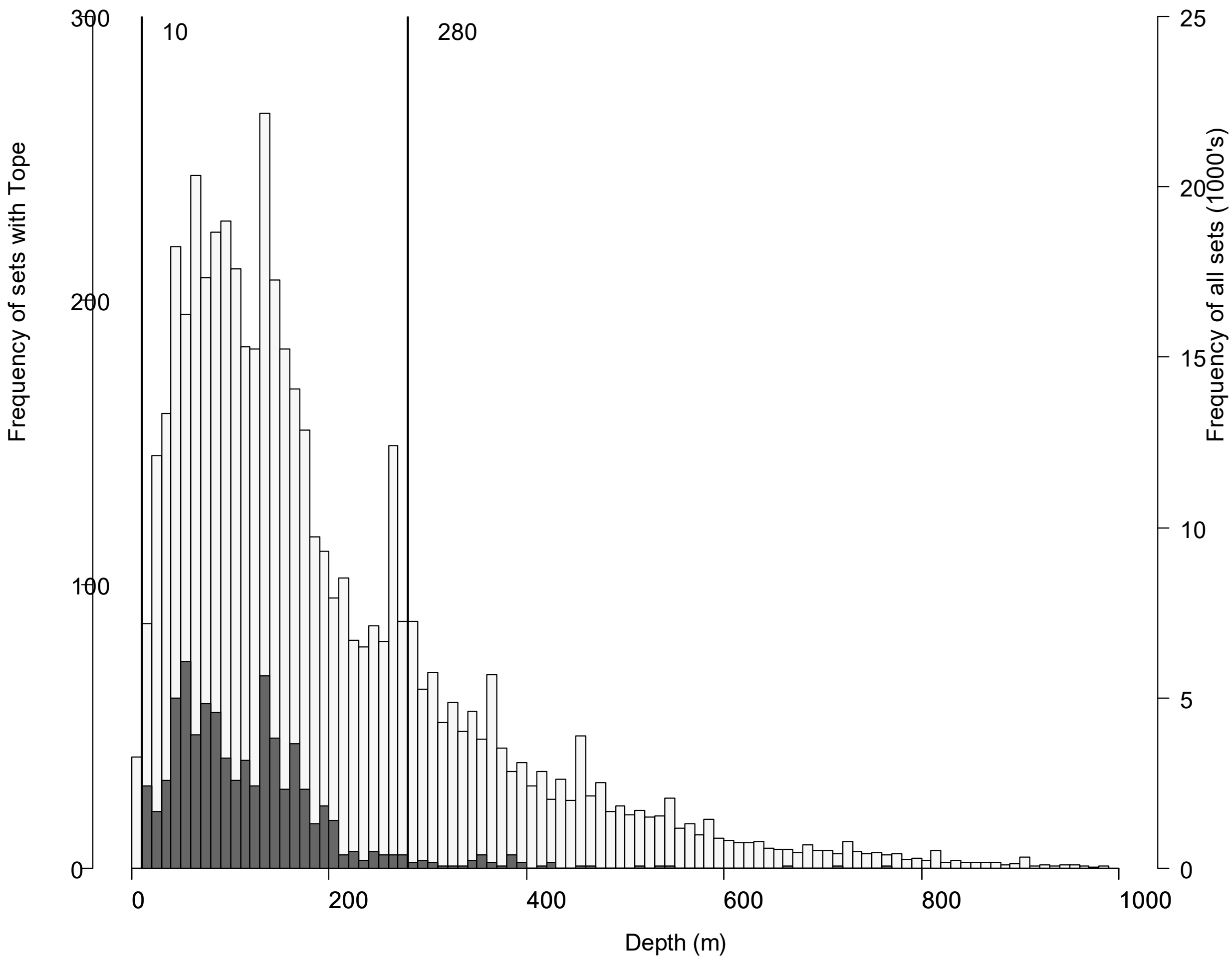

Figure 4 Depth distribution of commercial groundfish trawl tows and line sets and research trawl tows and line sets coastwide between 2003 and 2018 with records of Tope (dark grey) compared with the total trawl effort by depth (light grey). Records between the vertical lines represent the depth interval accounting for 95% of the sightings. Source: PacHarv database, PacHarvTrawl, GFFOS, GFBio, PacharvHL, PacharvSable, and IPHC set line survey data bases.

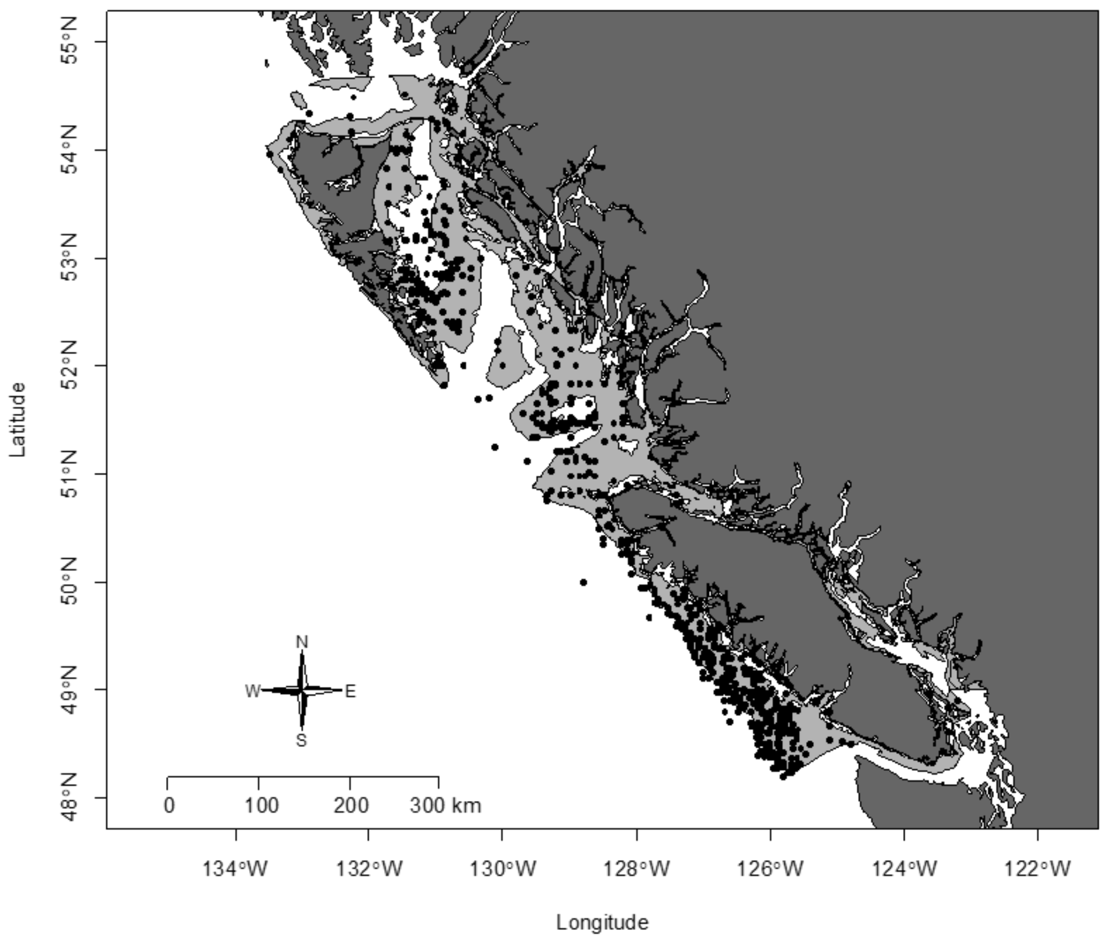

Figure 5. Distribution of Tope observations in relation to likely preferred shallow and mid-water (lighter grey area: 20–500m) depths in Canada's Pacific waters based on captures in the commercial trawl and hook and line fisheries and research trawl and hook and line surveys from 1996 to 2018. Observations include IPHC set line survey data from 1998 to 2018 and observations of live Tope by staff of PRNPR from 1996 to 1999. Each point based on fisheries catches up to 2016 represents the centre of a 5 km by 5 km square in which catch is reported. Source: PacHarv database, PacHarvTrawl, GFFOS, GFBio, PacharvHL, PacharvSable, IPHC set line survey, WCVI High Seas Salmon research survey, WCVI Pelagics survey, Integrated Pelagic Ecosystems Survey, and PRNPR sightings databases.

Extent of Occurrence and Area of Occupancy

Based on all observations from commercial and research surveys, and staff observations of live sharks from Parks Canada, the extent of occurrence in Canadian waters is 171,591 km² (land masses included); 113,142 km² (land masses excluded) (Figure 3; calculations by writers using COSEWIC guidelines). Documented occurrences in Canadian waters from commercial trawl and hook and line fisheries catches are reported in 5X5 km grid squares for data prior to 2016. Combining these grid cells with point data for research and commercial catch up to and including 2016 and then finding the intersection of these data with the 2X2 km grid cells used by COSEWIC to estimate the index of area of occupancy (IAO) estimates an IAO of 19,300 km². This new estimate is much higher than the ~2000 km² estimated in the previous report (COSEWIC 2007), but the previous estimate was based on a sum of 5X5 km grid cells rather than on the overlap of these 5X5 km grid cells with set 2X2 km grid cells as is the standard now. The IAO calculated using the previous approach is 11,175 km², which suggests a real expansion of the Tope's IAO in Canada. There have been some new occurrences in Hecate Strait in both the IPHC set line survey and commercial catch, particularly off the eastern coast of Haida Gwaii (Figures 3, 6), including observations in what was historical fishing ground for Tope. The previous report discussed the absence of occurrences in this historical fishing ground despite considerable trawling effort (COSEWIC 2007).

Search Effort

Tope were first recorded in BC waters in 1891 by Ashdown Green who reported it to be rather common along the coast (Clemens and Wilby 1946). There have been active commercial groundfish fisheries in Canadian waters that caught Tope for over a century, and currently there are active fisheries for Pacific Halibut (*Hippoglossus stenolepis*), Sablefish (*Anoplopoma fimbria*), rockfish (*Sebastes* spp.), Lingcod (*Ophiodon elongatus*), and Pacific Spiny Dogfish (*Squalus acanthias*) all throughout the Tope's range in Canada (Figures 6, 7). Of >450,000 sets in the trawl and hook and line fisheries that could catch Tope since 2003, only 0.001% (665 sets) encountered at least one individual.

In addition to commercial fisheries data, there are surveys that record Tope (Appendix 1 lists surveys), two of which are of note. The National Marine Fisheries Service (NMFS) US West Coast Groundfish Bottom Trawl Survey (1977–2017) has conducted 1275 tows (705 hours) over 27 years north of 48º (NMFS US West Coast Groundfish Bottom Trawl Survey unpubl. data). The IPHC set 1690 skates of longline over 123–167 different stations in 1996–1997 and a total of 23,136 skates over approximately 170 (296 in 2018) different stations covering the range of Tope in Canada since 1998 (Figure 6). The characteristics, duration, and gear used for additional surveys conducted in Canada are summarized in Appendix 1.

Appendix 2 indicates that 80% of commercial captures (not adjusted to effort) were from summer, June-Aug. Of 18 surveys examined (Appendix 1), only the IPHC survey using set line (longline) gear captured significant numbers of Tope. Almost no Tope were captured in bottom trawl surveys.

Tope sightings by the public, including divers and fishers, have been reported to the DFO Shark Sightings Network established in accordance with the Management Plan for Tope (DFO 2012) since 2013. Sightings from Parks Canada staff have been reported in the PRNPR since 1990 (Table 1).

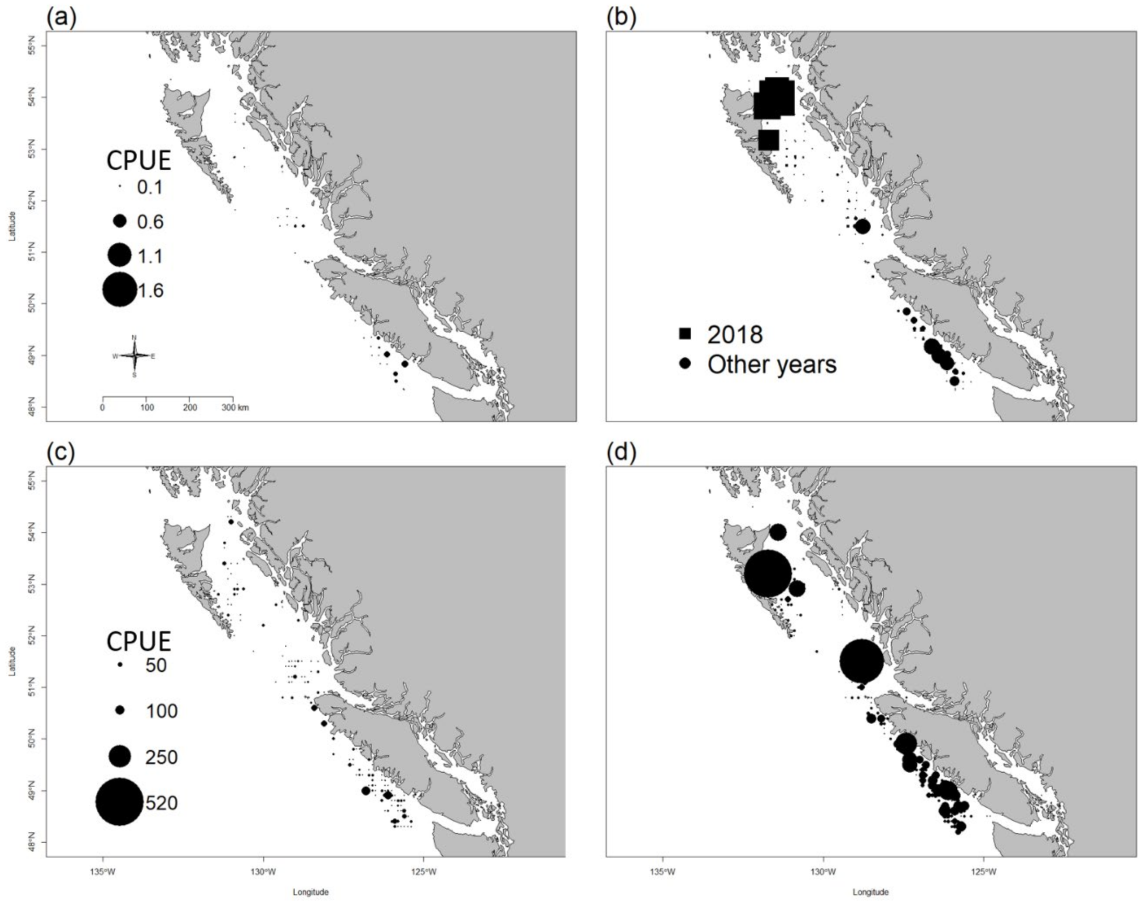

Figure 6. Catch per unit effort (Tope catch in kg per number of sets) along the BC coast based on catch in the IPHC set line survey (a) 1998–2008 and (b) 2009–2018, and catch in the commercial trawl and hook and line fisheries (c) 2003–2011 and (d) 2012–2018. Source: PacHarv database, PacHarvTrawl, GFFOS, GFBio, PacharvHL, PacharvSable, IPHC set line survey databases.

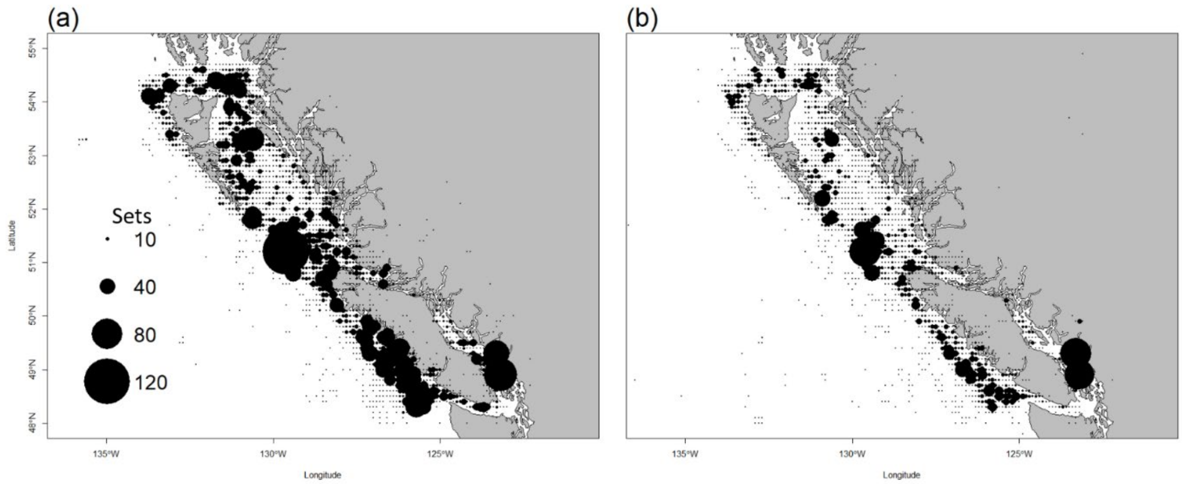

Figure 7. Number of sets along the BC coast in the commercial trawl and hook and line fisheries (a) 2003–2012 and (b) 2012–2018. Source: PacHarv database, PacHarvTrawl, GFFOS, GFBio, PacharvHL, PacharvSable databases.

HABITAT

Habitat Requirements

Compagno (1984) described the habitat of Tope as coastal pelagic, often well offshore but not oceanic. Genetic analyses indicate Tope stay coastal and rarely cross open ocean basins (Chabot 2015; Bester-van der Merwe *et al.* 2017). Ebert (2003) described Tope habitat as temperate continental shelf waters from close inshore, including shallow bays, to offshore waters up to 471 m deep often near the bottom. Tope have been found in the surfline, bays, and submarine canyons. They are generally thought to occur near the bottom but have been captured by pelagic floating longlines in deep waters (Compagno 1984), and are known to switch between pelagic and benthic habitats over periods of months (West and Stevens 2001). They have a preference for relatively cooler (between 12–21°C) and low salinity waters (between 33–34 ppt; Cuevas *et al.* 2014; Kippel *et al.* 2016; Jaurequizar *et al.* 2018) hence their avoidance of equatorial waters. Pups and juveniles utilize shallow nearshore habitats for one to two years before moving offshore.

Habitat Trends

It is not known whether suitable habitat for Tope has decreased or become less available, but as temperature is a major limiting factor to their distribution, warming sea surface temperatures in the northeast Pacific could lead to an expansion of suitable habitat (temperatures between 12-21°C), particularly in Hecate Strait (BC Ministry of Environment 2016; Kaschner *et al.* 2016; Morley *et al.* 2018).

BIOLOGY

There has been no research on Tope in Canadian waters. Information from US waters is limited to research undertaken following extensive fisheries during the late 1930s and early 1940s (Ripley 1946) and from an ongoing tagging study out of La Jolla, California on females (Nosal pers. comm. 2018). The most recent and comprehensive biological information on Tope is from populations around Australia and New Zealand that are targeted by commercial fisheries and to a lesser degree from populations in the northeast and southwest Atlantic. It should be noted that life history characteristics between ocean basins and/or hemispheres may not be comparable.

Life Cycle and Reproduction

In the northeast Pacific, a single study indicated that few females have unfertilized eggs by May, suggesting that fertilization occurs primarily in the spring (Ripley 1946). The reproductive cycle for Tope is variable by regions but globally is thought to be 12 months (Ripley 1946; Last and Stevens 1994; Capape *et al.* 2005). Similarly, the breeding and pupping seasons of Tope vary among regions (Elias *et al.* 2004; Capape *et al.* 2005; McMillan *et al.* 2018). Tope are ovoviviparous, with females carrying between six and 52 pups near term depending on the size of the female (Ripley 1946; Compagno 1984; Ebert 2003; Capape *et al.* 2005). However, in Argentina, fecundity and fertility were not strongly related to female size (Lucifora *et al.* 2004). Genetic data for Tope in New Zealand showed that two of five litters had multiple paternity, suggesting sperm storage could be occurring (Hernandez *et al.* 2015). Parturition in the northeast Pacific is thought to occur between March and July with pups being on average 35–37 cm long (Ripley 1946). Estimates of length at birth range from 24 to 32 cm TL in the northeast Atlantic and Mediterranean (Capape *et al.* 2005; Dureuil and Worm 2015).

Tope from Brazil, Australia, and New Zealand exhibit rapid growth during the first three years followed by steady growth until about 10 years of age and then slow continued growth through maturity (Peres and Vooren 1991; Moulton *et al.* 1992; Francis and Mulligan 1998). In the northeast Pacific maximum length of females is 195 cm TL and 175 cm TL for males (Compagno 1984).

Estimation of ages and lifespan is constrained by the difficulty in reading vertebral sections. The aging technique used in Brazil involving X-rays (Peres and Vooren 1991) is considered more reliable than the Australian technique using alizarin staining of the whole centrum (Moulton *et al.* 1992). Ferreira and Vooren (1991) found Brazilian Tope to be slow growing and to reach a maximum age of 40 years, whereas Moulton *et al.* (1992) reported a faster growth rate and a maximum age of 20 years in Australia. In contrast, the lifespan of Australian Tope for a tagged individual at liberty for 35 years is estimated to be at least 45 years (Moulton *et al.* 1989). Tag recapture data in the northeast Atlantic was used to assess growth and James' weighted least-squares approach to the von Bertalanffy equation was selected as most accurate (Dureuil and Worm 2015). Dureuil and Worm (2015) also estimated slow growth and longer lifespan, between 43 and 59 years, similar to the populations in Brazil with asymptotic total length of 200 cm for females and 177 cm for males, higher than populations at lower latitudes.

Age of maturity based on a study from New Zealand, found females to mature at about 13–15 years (and males at about 12–17 years) (Francis and Mulligan 1998). In the northeast Atlantic, age at 50% maturity is 17 years in females and 12 years in males (Dureuil and Worm 2015). Male Tope in both Argentina and the northeast Atlantic mature at smaller sizes than females (Lucifora *et al.* 2004; Dureuil and Worm 2015). In northeastern Pacific waters, females and males mature at 150 cm TL and 135 cm TL, respectively (COSEWIC 2007).

Generation time is estimated from the age at which 50% of the females are mature (F) and the instantaneous rate of natural mortality (M):

$$Generation\ time = F + \frac{1}{M}$$

For northeastern Pacific Tope, proxies were chosen for instantaneous natural mortality, 0.113 (Smith *et al.* 1998), and age at 50% maturity, 14 (Francis and Mulligan 1998). Generation time is estimated as:

$$14 + \frac{1}{0.113} = 23\ years$$

Physiology and Adaptability

Tope are found in waters between 12–21°C (Cuevas *et al.* 2014; Kippel *et al.* 2016; Rogers *et al.* 2017; Jaurequizar *et al.* 2018). In South Africa aggregations occur in autumn and spring, when water is relatively cooler (McCord 2005). The warming of the northwestern Atlantic after the creation of the Isthmus of Panama may explain the extirpation of Tope in that region (Haug and Tiedeman 1998; Musick *et al.* 2004). There is also some evidence for a preference for salinity between 33–34 ppt (Jaurequizar *et al.* 2018), but Tope have effective ion transporters in their gills, and mechanisms for regulating urea in their blood that allow them to adapt easily to higher salinities (Tunnah *et al.* 2016). Tope can also effectively reduce the physiological impacts of mercury consumption and accumulation likely using detoxification mechanisms involving selenium in their livers (Storelli and Marcotrigiano 2002; Torres *et al.* 2014). For fishery captures, when hooks are small, soak-times moderate, and sharks are healthy (few injuries), Tope show high survival post capture and release (Rogers *et al.* 2017).

Dispersal and Migration

Tope are considered highly migratory, moving north during the summer and south into deeper waters during the winter (Ebert 2003). Two recaptures of female sharks tagged in California were made ~1,600 km away in Canadian waters in Hecate Strait and off the west coast of Vancouver Island after ~3 and 26 months at large, respectively (Table 2). Four other recaptures were made between 121– 306 km from their tagging site. Additionally, ongoing tagging research out of La Jolla, California has found high dispersal for females between Vizcaino Bay, Mexico and Willapa Bay and Grays Harbor, Washington State

(Nosal pers. comm. 2018). These results indicate that Tope can travel long distances, including between Canada and the US, over a short period of time. The migration rate between Canada and the US is unknown and, as with all tagging studies, conclusions should be viewed in light of the distribution of recovery effort.

Table 2. Summary of Tope tag returns in the northeast Pacific. Source: Herald and Ripley (1951).

Date Tagged (m/d/y)	Sex	Study	Approximate tagging location	Recovery date (m/d/y)	Time/distance at large	Location of recovery
07/18/1943	F	CA Fish & Game	Ventura, CA	09/11/1945	26 months/ 1600 km N	Nootka Sound, BC
01/20/1949	M	CA fishers	Baja, CA	07/05/1949	5.5 months/ 160 km N	San Diego, CA
05/18/1949	F	CA fishers	Pt. Mugu, CA	08/29/1949	3.3 months/ 1760 km N	Hecate Strait, BC
05/23/1949	F	CA fishers	Malibu Pt., CA	05/27/1949	4 days/ 150 km S	Encinitas, CA
05/07/1949	M	Oregon fishers	Point Sur, CA	08/28/1949	2.7 months/ 144 km N	Halfmoon Bay, CA
08/05/1949	M	Oregon fishers	Cape Scott, BC	08/07/1949	2 days/ 120 km E	Queen Charlotte Sound, BC

Tope may be seasonal visitors to Canadian waters (Ebert 2003). Commercial catch data indicate that they can be caught year-round, but are caught more frequently, at higher catch per unit effort, and further north in the summer (Figure 8, Appendix 2, McFarlane *et al.* 2010). The distribution of commercial trawl and hook and line fishing effort is consistent across areas but variable by seasons (Figure 9), which influences conclusions about seasonality of occurrence. In other areas of the world, Tope are known to make large latitudinal seasonal migrations and they are capable of large-scale migration on the order of hundreds to thousands of kilometres (Stevens 1990, Rogers *et al.* 2017; see review by Walker 1999), suggesting the same may occur in the northeast Pacific.

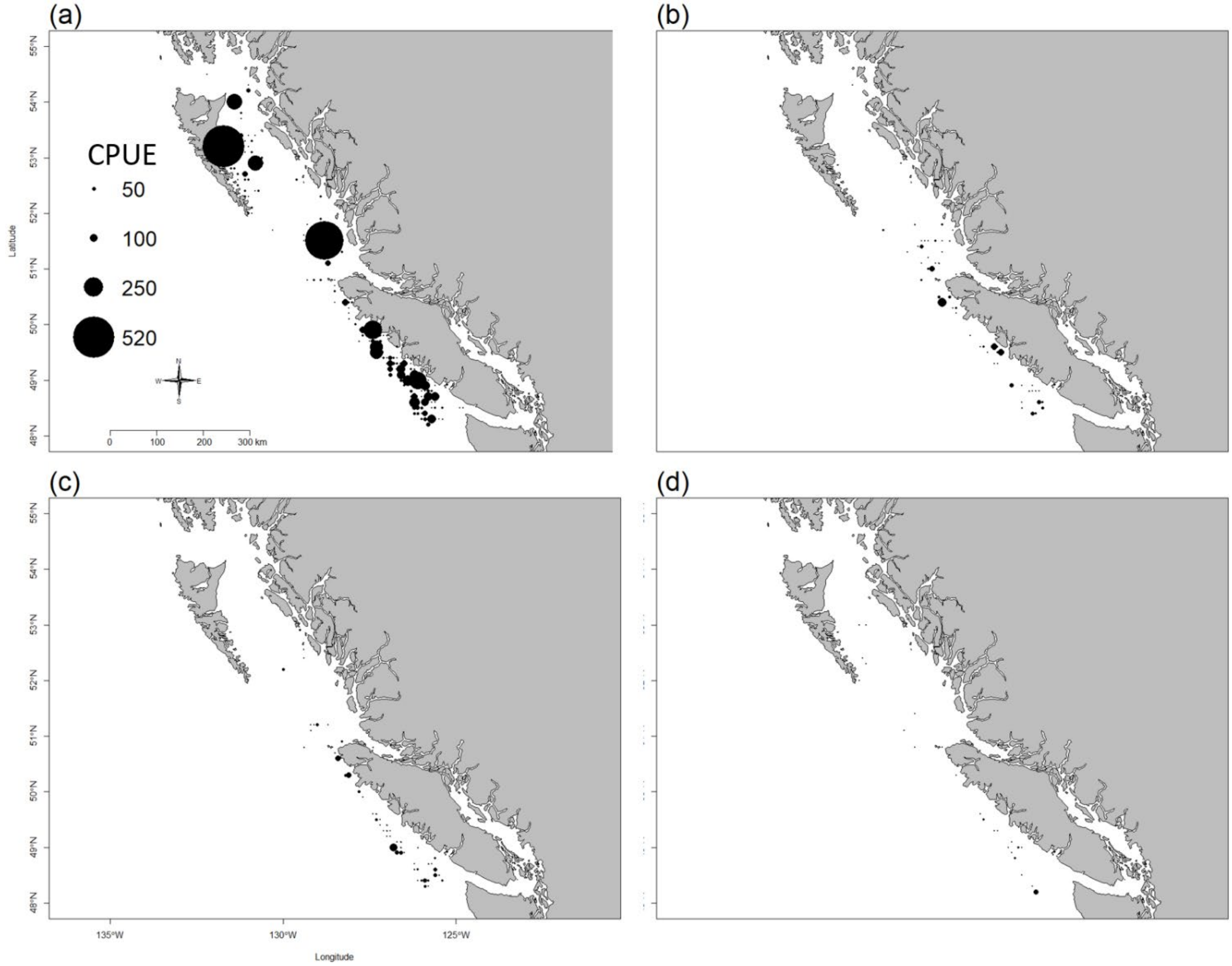

Figure 8. Catch per unit effort (Tope catch in kg per number of sets) along the BC coast based on catch in the commercial trawl and hook and line fisheries from 2003–2018 in (a) summer (June–August), (b) fall (September–November), (c) winter (December–February), and (d) spring (March–May). Source: PacHarv database, PacHarvTrawl, GFFOS, GFBio, PacharvHL, PacharvSable databases.

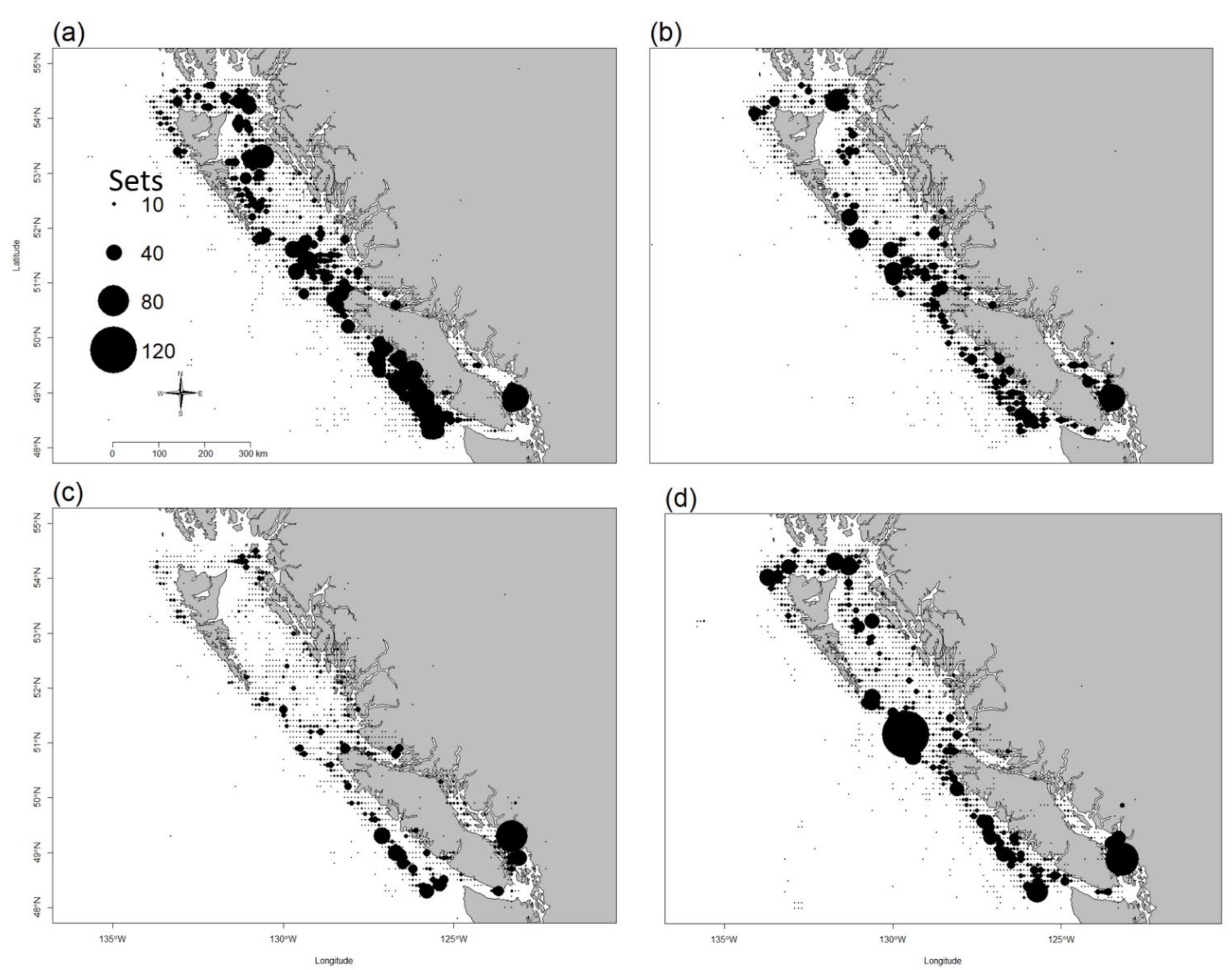

Figure 9. Number of sets along the BC coast in the commercial trawl and hook and line fisheries from 2003–2018 in (a) summer (June–August), (b) fall (September–November), (c) winter (December–February), and (d) spring (March–May). Source: PacHarv database, PacHarvTrawl, GFFOS, GFBio, PacharvHL, PacharvSable databases.

Further inferences about movement are mostly limited to patterns observed in the California commercial fisheries from 1941–1944 and from a small number of Tope found in Canadian research surveys. Overall, there appear to be both bathymetric and latitudinal movements that vary by sex and season (Ripley 1946). Off the northern California coast, Ripley (1946) found that 97.5% of the catch was composed of males (n=5,724) and mostly in deep water (>37 m), whereas off the southern coast 97.8% of the catch were female (n=5020) and mostly in shallow water (<18 m). Off the mid-California coast, the ratios were approximately equal. Observations from Canadian research surveys between 2002 and 2018 found 92% (n=68 of 74) of Tope captured were male (DFO 2012, GFBio Database, Integrated Pelagic Ecosystem Survey), as well as all sexed dead sharks found washed ashore since 2004 (n=9) in Hecate Strait and Vancouver Island (source: DFO Sightings Network, Parks Canada). The 43 males captured in the 2017-2018 Integrated Pelagic

Ecosystem Surveys were likely mostly mature given their total length (>140 cm). This predominance of males in Canada, supported by the lack of tag returns for females in Canada in the ongoing tagging work (Nosal pers. comm. 2018), suggests that Tope in Canada are part of a larger population.

Female philopatry and male dispersal in Tope are supported by global genetic analysis showing a lower nuclear-derived (F_{ST} =0.09–0.21, P<0.001) than mitochondrial-derived F_{st} (F_{ST} =0.15–0.29, P<0.001) (Chabot 2015).

In other jurisdictions, tagging studies have been more extensive (Walker *et al.* 1997; Rogers *et al.* 2017) and indicate movements of >500 km, up to a longest recorded movement of 3016 km.

Interspecific Interactions

Tope are preyed upon by other elasmobranchs including White Shark (*Carcharodon carcharias*), and Broadnose Seven Gill Shark (*Notorynchus cepedianus*), and possibly by marine mammals (Ebert 2003; Rogers *et al.* 2017). In New Zealand, Killer Whale (*Orcinus orca*) has been reported taking hooked Tope off commercial longlines (Visser 2000).

This shark is an opportunistic predator feeding upon several fish species in both pelagic and demersal environments (Ebert 2003; Domi *et al.* 2005). Items include fish (Clupeidae-herring, Pleuronectiformes-flatfish, Scorpaenidae-rockfishes, Scombridae-mackerel, and Embiotocidae-perches), as well as cephalopods (Teuthoidea) (Ripley 1946).

In Peru, Tope has a unique isotopic niche, less than 2% overlap with other sharks, such as *Alopias* spp. and *Sphyrna zygaena,* suggesting a generalized diet adaptable to niche partitioning (Alfaro-Cordova *et al.* 2018).

A study in the northeast Atlantic found the diet of adult Tope highly generalized, but consisting almost entirely of fish (98.8% by weight) (Morato *et al.* 2003). A similar predominance of fish (~96.5%) in the diet was found for Tope in New Zealand, along with crustaceans (~0.2%) and cephalopods (3.6%) (Dunn *et al.* 2010). In Australia teleosts comprised 47% of the diet by weight followed by cephalopods (37%) (Walker 1989). Diet likely varies considerably by season and size of the shark. In Argentina, although teleosts still comprise 98.5% of the diet by index of relative abundance, Tope diet shifts with ontogeny and season; juveniles prey more on benthic invertebrates, such as octopus; during the summer, adult Tope are less opportunistic, increasing benthic teleost consumption (from December to January) and squid consumption (from March to April) (Lucifora *et al.* 2006). Ontogenetic differences in diet are likely due to shifts in habitat to deeper water as well as growth of Tope (Lucifora *et al.* 2006).

POPULATION SIZE AND TRENDS

Abundance and Trends

In the United States, NMFS groundfish bottom trawl survey (1977–2017) had only 51 Tope captures between California and waters off southern Vancouver Island (NMFS west coast groundfish bottom trawl survey, unpubl. data) and thus is not a reliable source pertaining to abundance or trends.

In the Southern California Bight, an increase in abundance was evident over the short term from a set net survey (1995–2004), and this increase was attributed to the California gillnet ban (Pondella and Allen 2008).

In Canada, only one of 18 surveys examined captured significant numbers of Tope (Appendix 1). The IPHC annual set line survey in BC waters recorded only 45 records of Tope between 1996 and 2004 (COSEWIC 2007), but this number has since increased to 551 occurrences as of 2018 (Figure 10, Appendix 3). The survey uses longline gear, covers most of the geographic and depth range of Tope in Canada and occurs in the summer, so is a good candidate for an index of relative abundance. Tope are not caught consistently by this survey as the data contain years where no Tope were caught (Appendix 3, 95% of stations with zero catch overall) and there is a large coefficient of variation (CV=8.7 overall) (Figure 10, 89% of stations with zeros and CV=5.6 since 2014).

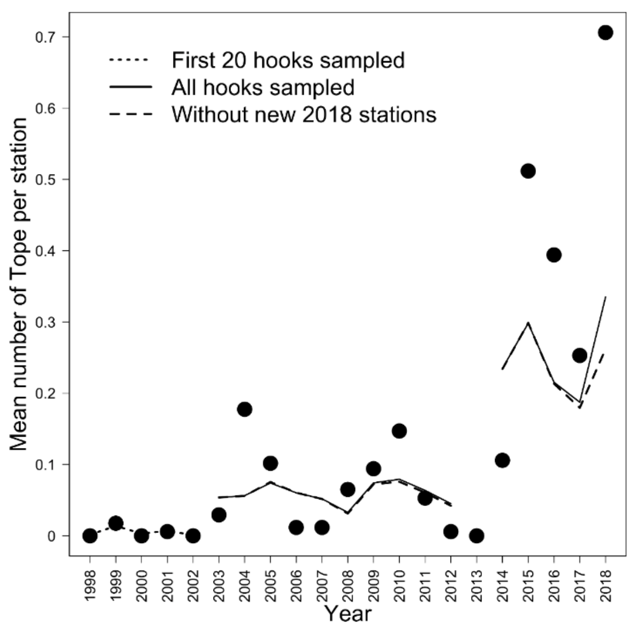

Figure 10. The mean number of Tope captured per station from May to August each year in IPHC set line surveys along the BC coast and the mean predicted values per year from a General Linear Model (GLM) of Tope catch on year, depth, soak time, and PDO index with number of hooks as an offset. The mean predicted values from a GLM run on a subset of the data without subsampled sets (sets prior to 2003) and from a GLM on data without the additional stations added in 2018 are included for comparison (see Appendix 4).

Set line catches were analyzed using two zero-inflated generalized linear models with a negative binomial distribution, with year, depth, Pacific Decadal Oscillation (PDO) index, and soak time as explanatory variables; number of hooks in a set was used as an offset. One model used data from 1998 to 2002, when only the first 20 hooks of a set were enumerated for non-halibut catch. The second model used data from 2003 to 2018 when all hooks were enumerated; however, 2013 was excluded as only the first 20 hooks were again enumerated in that year. While controlling for effort, depth, and the PDO, the fitted mean Tope catch per station did not increase significantly from 1998-2002 but increased approximately 7-fold from 2003 to 2018 based on the year coefficient from the model ($P<0.0001$) (Figure 10, Appendix 4). In 2018, an additional 126 stations were sampled. The trend was also robust to this sampling change (Figure 10), as subsampling the 2018 catch to include only previously sampled stations preserved the estimated increase at approximately 7-fold from 2003 (Appendix 4).

Although there are still insufficient commercial catch data to develop a useful index of abundance (only 0.0018% of sets with Tope records overall, 0.0023% since 2014), total commercial catch and CPUE of Tope in British Columbia has increased in the last seven years, with a total catch between 2012 and 2018 of 23,534 kg (mean per year = 3,362 kg), compared to a total of only 3,589 kg (mean per year = 449 kg) caught from 1994–2004 (no data for 1995–1997) (Figure 11a). However, these increases are not monotonic and have high variation. Observer coverage has been complete since 1996 in the trawl fisheries but has only been complete in the hook and line fisheries since 2006, so better reporting, in combination with efforts to improve shark identification (DFO 2012), could be partially responsible for the changes in catch. Similarly, research surveys have had a slight increase in catch but have still only captured 2632.6 kg (mean 125.4 kg/yr) of Tope since 1977 with trawl gear, and 14698.4 kg (mean 699.9 kg/yr) since 1982 with hook and line gear (including the IPHC set line survey) (Figure 11b).

Both commercial and research catch has increased in the area east of Haida Gwaii, which was heavily fished during the historical fishery (Figure 6, Barraclough 1948). Up until 2005, no records of Tope were found in this region of BC, despite considerable fishing effort (7,243 hours of trawl effort and 1,632 sets with hook and line gear, COSEWIC 2007). Since then there have been at least 30 occurrences from commercial and research data (Figure 3, 6), of which 18 are from the 2017–2018 IPHC set line survey. The increase in Hecate Strait in the IPHC surveys could be attributed to the new stations added in 2018 (Figure 6ab), but the increase was also observed in the commercial records (Figure 6cd), suggesting some expansion or population growth has occurred.

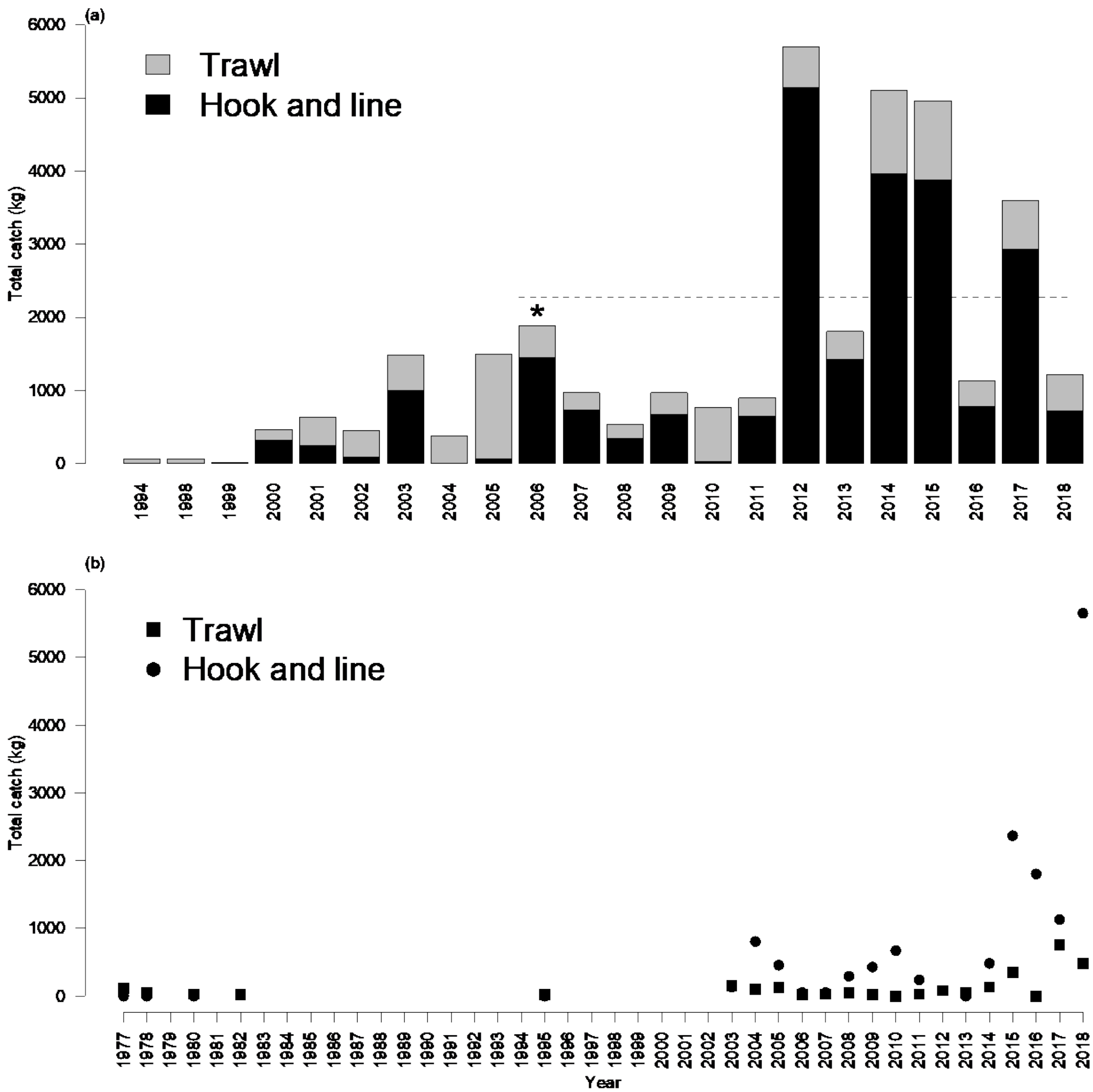

Figure 11. Observed catches of Tope in Canada's Pacific (a) commercial groundfish trawl and longline fisheries between 1994 and 2018 and (b) in research surveys between 1977 and 2018. Dashed line represents average catch from 2006 to 2018. Comprehensive at-sea electronic monitoring in the longline fishery began in 2006 (*). Totals in the hook and line fishery include discards of individuals converted to weight based on mean weight 26.92kg/individual from Canadian survey data. Source: PacHarv database, PacHarvTrawl, GFFOS, GFBio, PacharvHL, PacharvSable, IPHC set line survey, WCVI High Seas Salmon research survey, Integrated Pelagic Ecosystem Survey, and WCVI Pelagics survey databases.

The observed increase in research and commercial Tope catch and the expansion of area of occupancy in Hecate Strait could result from population growth, but may also reflect distributional changes in response to recent warming events, such as the "warm blob" related to the PDO from 2013-2016 and the subsequent 2015/2016 El Niño (Tseng *et al.* 2017), in addition to improved reporting. As temperature is an important barrier to dispersal (see **Population Structure and Variability**), the observed increases here, and any observed in the future, could be the result, at least in part, of latitudinal range shifts. However, neither the IPHC set line data nor commercial catch data provide strong evidence of latitudinal range shifts in Canada (Figure 6). The mean latitude of catch in the IPHC survey has not increased with year (mean latitude of catch = 50.5°N from 2003–2012, mean = 50.1 from 2013–2018); neither has the mean latitude of commercial catch in the hook and line and trawl fisheries (mean latitude of catch = 50.1°N from 2003–2012, mean = 50.0 from 2013–2018). IPHC survey and commercial catch have also both increased in the southern portion of Tope range west of Vancouver Island since 2012 (Figure 6).

A genetic analysis estimated breeding female population size at 89,545 for the entire northeast Pacific (Chabot and Allen 2009). In the seven years between 1938 and 1944 approximately 15,600 t of Tope may have been removed from waters along the west coast of North America. This catch can be used as a surrogate for a minimum historical population. DFO (2012) estimates that, given 60 years of no targeted fishing, minimal bycatch, and its life history, it is reasonable to assume a recovery of Tope to at least 10% of the historical level in these waters, i.e., approximately 1500 t.

Overall abundance and population trends in Canadian waters are unknown; available data suggest there has been some increase in longline surveys since 2014 but the exact magnitude is unknown due to the high variability in the data. It is unlikely that Tope abundance has returned to levels presumed in the 1930s, prior to the peak of the directed fisheries.

Rescue Effect

British Columbia represents the northern extent of Tope range in the northeast Pacific. The DU extends throughout the west coast of North America but the Canadian population could be rescued by Tope from U.S. waters. Tagging and genetic data indicate regular interchange of Tope between Canadian and U.S. waters.

THREATS AND LIMITING FACTORS

Threats

The IUCN Threats Calculator was used to assess the scope and severity of risk to the population from current and imminent threats (Master *et al.* 2012). Scope of a threat is defined as the percentage of the population expected to be impacted by the threat within 10 years if current circumstances and trends continue. Severity is the level of damage (percent population loss) to the population within the scope identified for the threat that can reasonably be expected if current circumstances and trends continue over the next 10 years or three generations, whichever is longer. Timing is defined as whether the threat is occurring now or only expected in the future. An IUCN Threat Calculator is provided for the Tope DU (Appendix 6).

IUCN 5. Biological Resource Use – Low Impact

Currently, the main threat to Tope in Canadian waters is continued incidental catch in the commercial groundfish fishery, where Tope are caught in low numbers by both trawling and hook and line gear. The assigned overall threat impact is Low (Appendix 6).

In the early 1930s, Tope fisheries in the northeast Pacific were composed of a small fresh fillet market in California and a dried fin Asian export market (Ripley 1946; Appendix 5). Beginning in 1937, Tope became the target of a brief but extensive fishery throughout their northeast Pacific range for their liver (King *et al.* 2017). In early catch statistics, only liver weight was reported. The liver comprises approximately 10% of the weight of adult male Tope (Bailey 1952). Number of individuals is estimated using the average length of Tope in the catch (160 cm TL) (Ripley 1946) and the length-weight relationship Wt_{kg}=3.89x 10^{-6} $(TL)^{3.02}$ (Froese *et al.* 2013) for an average weight per individual of 18 kg. The fishery began in California and then followed in British Columbia, Oregon, and Washington in the early 1940s (Figure 12). Shark landings in California peaked in 1939 (2,209 t) but the fishery collapsed by 1945. Tope landings were higher than reported, as much of the post-1941 catch was still being recorded as unidentified shark (Ripley 1946).

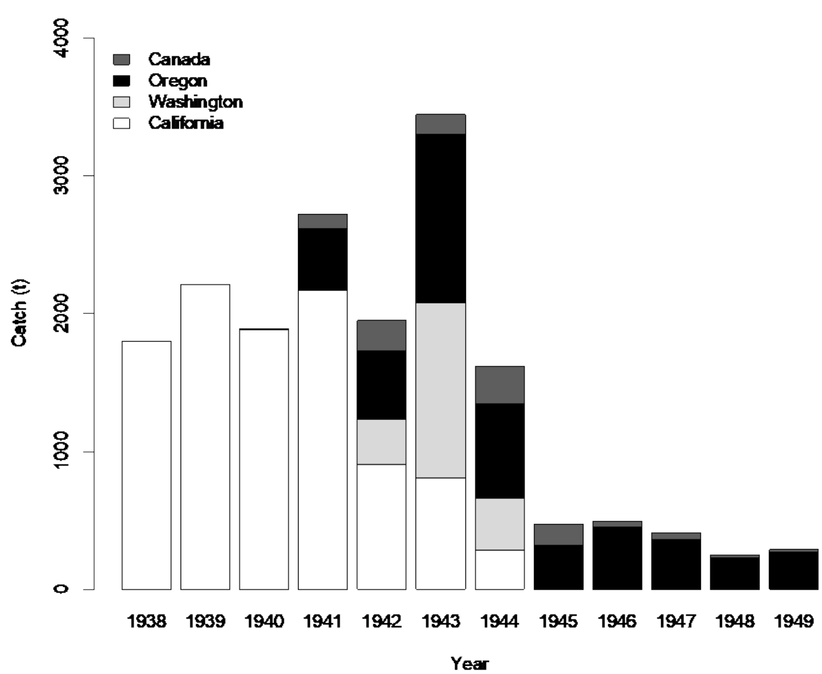

Figure 12. Estimated catch of Tope along the west coast of North America from 1938 to 1949 when the fishery collapsed. Data sources: California-Ripley (1946), Canada-Barraclough (1946) and Bailey (1952), Oregon (Westrheim 1950), Washington (Department of the Interior Information Service). California landings pre-1941 based on proportion (52.9%) of total shark landings. Canadian, Washington, and Oregon landings converted to whole weights based on 10:1 conversion from Bailey (1952). See Appendix 5 for values.

The Canadian Tope fishery began in 1940 mostly off the west coast of Vancouver Island and in Hecate Strait with longlines, trawls, sunken gillnets, and driftnets (Barraclough 1948). It peaked in 1944 at 278 t of livers landed or approximately 13,200 individuals. From 1930 to 1949, approximately 975,833 Tope were taken from the northeast Pacific population of which about 58,300 were landed in Canadian ports and an unknown amount caught in Canadian waters (Appendix 5). Then in 1947 vitamin A was first synthesized removing the demand on natural sources. By 1949 the Canadian fishery for Tope had ended (Figure 12, Appendix 5).

The intensive fishery between 1938 and 1949 caused a rapid depletion in the adult biomass, resulting in the collapse of the fishery (Walker 1999; Ebert 2003). Walker (1999) argues that Tope targeted during this brief period were relatively large in size and because the smaller juveniles were only lightly fished the stocks should recover after fishing ceased. However, there are no data to support this hypothesis.

Subsequently, commercial catches of Tope in the US between 1976 and 1994 varied between 100–380 t round weight and in California and from 1995 to 1999 between 30–68 t (Walker 1999). During 2000–2009, landings averaged 27 t per year, mostly from California. Since 2010, landings in the US have averaged 2.5 t/year (NMFS 2018). Incidental catches in Canada are released.

Reported Canadian incidental catch has averaged 527 kg/year and 1,748 kg/year since 2006 in the trawl and hook and line fisheries, respectively, for an overall average of 2,275 kg/year (Figure 11); assuming an average of 26.9 kg/shark (as observed in Canadian research surveys) 85 individual sharks were caught per year on average. Since 2012, when the DFO management plan for Tope was put in place (DFO 2012), a total of approximately 23,533 kg, or ~875 individuals have been caught as incidental catch. Most of the catch is from Pacific States Marine Fisheries Commission (PSMFC) areas 3C/D west of Vancouver Island (Table 3, 4). Tope have been captured in all months of the year, but greatest catch is in January-February and June-August (Figure 8, Appendix 2). Overall, the observer data indicate that the incidental catch of Tope in Canadian waters is small compared to total fishing effort, but the significance of the incidental catch relative to the total population is unknown, as release mortality is unknown.

Table 3. Commercial trawl catch (kg) of Tope by year and Pacific States Marine Fisheries Commission area in Canada's Pacific waters based on at-sea observer coverage from 1994 to 2018. The mean was calculated for 2001-2018, when data were considered complete. Estimated number of sharks based on a mean weight of 26.92 kg from Canadian survey data. Source: PacHarvTrawl, GFFOS, and GFBio databases.

	Catch (kg)										
Year	Area 4B	Area 3C	Area 3D	Area 5A	Area 5B	Area 5C	Area 5D	Area 5E	Area unknown	Total	Estimated number of sharks
1994	0.0	0.0	0.0	0.0	66.7	0.0	0.0	0.0	0.0	66.7	2
1998	0.0	0.0	23.6	45.4	0.0	0.0	0.0	0.0	0.0	68.9	3

Year	Catch (kg)										Estimated number of sharks
	Area 4B	Area 3C	Area 3D	Area 5A	Area 5B	Area 5C	Area 5D	Area 5E	Area unknown	Total	
1999	0.0	0.0	0.0	0.0	0.0	18.1	0.0	0.0	0.0	18.1	1
2000	0.0	93.9	0.0	36.3	0.0	18.1	0.0	0.0	0.0	148.3	6
2001	0.0	99.0	45.4	58.1	67.6	29.5	82.5	0.0	0.0	381.9	14
2002	0.0	117.9	36.3	99.8	45.4	36.3	27.2	0.0	0.0	362.8	13
2003	0.0	74.8	97.5	163.3	100.7	54.4	0.0	0.0	0.0	490.8	18
2004	0.0	213.2	13.6	124.7	0.0	31.8	0.0	0.0	0.0	383.3	14
2005	0.0	754.3	337.9	78.5	168.3	72.6	0.0	0.0	23.1	1434.7	53
2006	0.0	265.4	106.6	22.7	0.0	34.0	0.0	0.0	0.0	428.7	16
2007	0.0	134.7	0.0	88.9	11.3	0.0	0.0	0.0	0.0	235.0	9
2008	0.0	68.1	22.7	0.0	0.0	56.7	39.5	0.0	0.0	186.9	7
2009	0.0	92.5	0.0	31.8	138.4	36.3	0.0	0.0	0.0	298.9	11
2010	0.0	421.9	256.3	0.0	54.4	0.0	15.9	0.0	0.0	748.5	28
2011	0.0	163.3	22.7	0.0	25.0	0.0	45.4	0.0	0.0	256.3	10
2012	0.0	387.8	34.0	0.0	140.6	0.0	0.0	0.0	0.0	562.5	21
2013	0.0	152.0	49.0	36.3	147.4	0.0	0.0	0.0	0.0	384.6	14
2014	0.0	447.7	68.5	68.0	480.8	0.0	54.4	0.0	24.5	1143.9	42
2015	0.0	595.9	374.2	77.1	18.1	0.0	0.0	0.0	20.9	1086.2	40
2016	0.0	154.2	142.0	0.0	0.0	31.8	0.0	0.0	23.6	351.5	13
2017	22.7	458.6	186.5	0.0	0.0	0.0	0.0	0.0	0.0	667.7	25
2018	0.0	381.5	32.6	0.0	81.7	0.0	0.0	0.0	0.0	495.8	18
Total	22.7	5076.5	1849.4	930.8	1546.3	419.6	264.9	0.0	92.0	10202.1	379
Mean (2001-2018)	1.3	276.8	101.4	47.2	82.2	21.3	14.7	0.0	5.1	550.0	20

Table 4. Commercial catch (kg) of Tope by year and Pacific States Marine Fisheries Commission area in Canada's Pacific waters by hook and line from observer and logbook programs. Total includes individuals, reported caught and discards, converted to round weight. The mean was calculated for 2006-2018, when data and observer coverage were considered complete. Estimated number of sharks based on a mean weight of 26.92 kg from Canadian survey data. Source: PacHarvHL, PacharvSable, and GFFOS databases.

	Catch (kg)										
Year	**Area 4B**	**Area 3C**	**Area 3D**	**Area 5A**	**Area 5B**	**Area 5C**	**Area 5D**	**Area 5E**	**Area unknown**	**Total**	**Estimated number of sharks**
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	322.5	322.5	12
2001	0.0	0.0	0.0	0.0	106.6	143.8	0.0	0.0	0.0	250.4	9
2002	0.0	0.0	9.10	34.0	0.0	49.0	0.0	0.0	0.0	92.1	3
2003	0.0	253.4	54.4	0.0	285.7	305.3	0.0	102.0	0.0	1000.8	37
2004	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1
2005	0.0	35.0	7.70	0.0	0.0	0.0	0.0	0.0	20.0	62.7	2
2006	0.0	969.1	0.0	0.0	0.0	269.2	188.4	26.9	0.0	1453.7	54
2007	0.0	161.5	430.7	54.1	0.0	93.0	0.0	0.0	0.0	739.4	27
2008	0.0	26.9	0.0	26.9	26.9	269.2	0.0	0.0	0.0	350.0	13
2009	0.0	511.5	26.9	0.0	134.6	0.00	0.0	0.0	0.0	673.0	25
2010	0.0	0.0	26.9	0.0	0.0	0.0	0.0	0.0	0.0	26.9	1
2011	0.0	350.0	53.8	161.52	53.8	26.9	0.0	0.0	0.0	646.1	24
2012	0.0	1076.8	2422.8	188.44	26.9	1426.8	0.0	0.0	0.0	5141.7	191
2013	0.0	457.6	457.6	26.92	26.9	457.6	0.0	0.0	0.0	1426.8	53
2014	0.0	2099.8	619.2	188.44	134.6	915.3	0.0	0.0	0.0	3957.2	147
2015	0.0	1319.1	1453.7	161.52	673.0	242.3	26.9	24.6	0.0	3874.2	144
2016	0.0	80.8	376.9	0.00	0.0	296.1	0.00	26.9	0.0	780.7	29
2017	0.0	1749.8	0.00	0.00	53.8	26.92	1103.7	0.0	0.0	2934.3	109
2018	0.0	484.6	161.5	0.00	0.0	80.8	0.0	0.0	0.0	726.8	27
Total	0.0	9577.9	6101.3	841.90	1522.9	4602.2	1319.1	180.5	342.5	24461.3	908
Mean (2006-2018)	0.0	714.4	463.9	62.1	87.0	315.7	101.5	6.0	0.00	1748.5	65

Landings of Tope by commercial fisheries in Mexico are poorly documented. Regulations to protect sharks and rays from overexploitation in Mexico were introduced in 2020 but their effectiveness is unknown. Tope in inshore bays, particularly where females may be pupping, may be most vulnerable to Mexican fisheries and the threat to Tope from commercial fisheries may be higher than can be determined with available information.

Climate change may lead to warmer temperatures in northern waters and may shift the centre of distribution of this cool-water species in the eastern Pacific to the north.

Limiting Factors

The degree to which the Tope population has recovered or remained depressed since the 1940s is unknown. The main factor limiting recovery of Tope following the collapse of the directed fishery is the species' late age of maturity and low fecundity (Smith 1998; Lucifora *et al.* 2004, Dureil and Worm 2016).

Number of Locations

All individuals within Canada likely form a single population and the primary threat is incidental bycatch, which applies throughout the range in Canadian waters. However, the Tope in the DU are wide-roaming and the threat of mortality is random and ephemeral, therefore the Locations concept does not apply.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Prior to the current assessment, Tope was previously designated as Special Concern by COSEWIC in 2007 and was listed under the *Species at Risk Act*, Schedule 1 as Special Concern in 2009.

Since 2006, both the commercial longline and trawl groundfish fisheries have received 100% observer coverage either at-sea or with electronic monitoring. In 2011, targeting and retention of Tope in commercial and recreational fisheries was prohibited and all Tope must be released alive with least possible harm (DFO 2012). A Tope management plan created by DFO in 2012 called for more research on the species' ecology and biology in Canadian waters and development of an index of relative abundance by 2017. In the six years since the plan was created there has been no research on Tope in Canadian waters, or an index of relative abundance developed. However, the Code of Conduct (CoC) for shark handling (DFO 2014) and a sightings database where divers and fishers are encouraged to report sightings of Tope were developed as part of the plan (DFO 2012). A species identification sheet for sharks in British Columbia was established in 2011 and updated in 2017 to meet requirements of improved monitoring accuracy for incidental catch (DFO 2011).

Tope was designated globally as Vulnerable by the IUCN in 2006 based upon criteria A2bd+3d+4bd (population reduction observed and predicted in the future based on exploitation levels and an index of abundance, although this did not include Canada) (Walker *et al.* 2006). In 2020, Tope was listed on Appendix II of the Convention on Migratory Species (CMS), which obligates Parties to work regionally toward conservation, specifically through the CMS Memorandum of Understanding for Migratory Sharks. Tope was assessed as Critically Endangered in 2020 under criteria A2bd by the IUCN (Walker *et al.* 2020). It should also be noted that the IUCN assessment used a global generation time of 26.3 years.

Tope is not yet ranked on the global scale by NatureServe (2018), although in Canada, it is ranked as Vulnerable (N3), indicating a moderate risk of extirpation due to recent or widespread declines for the non-breeding (N3N) and migratory population (N3M) in Canada.

Non-Legal Status and Ranks

Since 1996, the Canadian commercial groundfish trawl fleet has been monitored with 100% at-sea observer coverage. In 2001, the Canadian government promoted the correct identification of sharks to improve reporting of shark discards, and this subsequently increased reported discards for some species, although not Tope (King *et al.* 2017). Since 2006, Canada's Pacific groundfish longline fisheries (i.e., Pacific Halibut, Rockfishes, Lingcod, and Pacific Spiny Dogfish) have adopted at-sea catch monitoring through a system of video monitoring combined with auditing of logbooks, where fishers are required to report all shark catch (DFO 2012). DFO developed CoC for shark encounters, including entanglement in fishing gear, providing handling and release guidelines for commercial and recreational fishers (DFO 2014). The intention of the CoC is to reduce fishing mortality, but despite improved monitoring, the mortality associated with incidental catch is not well understood.

Habitat Protection/Ownership

There is no direct protection of Tope habitat in Canada. There is potential, albeit limited, protection by the Hecate Strait/ Queen Charlotte Sound Glass Sponge Reef MPAs, and there could be minor protection from restrictions to hook and line fishing in Rockfish Conservation Areas, particularly on the west coast of Vancouver Island. Tope occur in both the PRNPR and the Gwaii Haanas National Marine Conservation Area Reserve (Table 1). PRNPR does not extend deep enough to protect primary Tope habitat (Yakimishyn, pers. comm. 2018), and some commercial fishing occurs within parts of the park reserve. Tope habitat is protected in nearly half of Gwaii Haanas waters, where restricted access and strict protection zones exclude commercial fishing (2018 Management Plan (https://www.pc.gc.ca/en/pn-np/bc/gwaiihaanas/info/consultations/gestion-management-2018).

There are additional closures for groundfish fishing on glass sponge reefs in the Strait of Georgia and Howe Sound. However, Tope are rarely caught in the Strait, so these protections are not on optimal habitat. Overall, habitat protection is minimal.

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Authorities Contacted

In addition to those acknowledged above, the following authorities were contacted:

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INFORMATION SOURCES

Alfaro-Cordova, E., A. Del Solar, A. Gonzalez-Pestana, N. Acuña-Perales, J. Coasaca, F. Cordova-Zavaleta, J. Alfaro-Shigueto, and J.C. Mangel. 2018. Isotopic niches of four commercially important pelagic elasmobranch species captured by the small-scale driftnet fishery of northern Peru. Latin American Journal of Aquatic Research 46:482-488.

Anonymous. 1942. Canadian fishes: Twenty third in a series of non-technical articles with reference to various Canadian fish and shellfish and their place in the nation's fisheries. Fisheries News Bulletin. Volume 16 Number 190. p. 2.

Anonymous. 1944a. Soupfin sharks becoming scarce through overfishing. Canadian Fisherman, April 1944, p. 25.

Anonymous. 1944b. Money in shark livers. Canadian Fisherman, March 1944, p. 17.

Baeyaert, J., D. Abecasis, P. Afonso, G. Graça, K. Erzini and J. Fontes. 2018. Solo datasets': unexpected behavioural patterns uncovered by acoustic monitoring of single individuals. Marine and Freshwater Behaviour and Physiology 51:183-201.

Bailey, B.E. 1952. Marine oils with particular reference to those in Canada. Fisheries Research Board of Canada Bulletin No. 89. 413 pp.

Barraclough, W.E. 1948. The decline of the soupfin shark fishery in British Columbia. Fisheries Research Board of Canada Progress Reports 77:91-94.

Byers, R.D. 1940. The California shark fishery. California Fish and Game Fish Bulletin 26:23–38.

Bester-van der Merwe, A.E., D. Bitalo, J.M. Cuevas, J. Ovenden, S. Hernández, C. da Silva, M. McCord, and R. Roodt-Wilding. 2017. Population genetics of Southern Hemisphere tope shark (*Galeorhinus galeus*): Intercontinental divergence and constrained gene flow at different geographical scales. PloS one 12(9): e0184481.

Bitalo, D.N., S.N. Maduna, C. da Silva, R. Roodt-Wilding, and A.E. Bester-van der Merwe. 2015. Differential gene flow patterns for two commercially exploited shark species, tope (*Galeorhinus galeus*) and common smoothhound (Mustelus mustelus) along the south–west coast of South Africa. Fisheries Research 172:190-196.

British Columbia Ministry of Environment. 2016. Indicators of Climate Change for British Columbia 2016 Update. 61 pages.

California Department of Fish and Wildlife (CDFW). 2019. 2019-2020 Ocean Sport Fishing Regulations. https://www.wildlife.ca.gov/Fishing/Ocean/Regulations/Sport-Fishing . Downloaded 30 May 2019.

Capapé, C., J.B. Souissi, H. Méjri, O. Guélorget, and F. Hemida. 2005. The reproductive biology of the school shark, *Galeorhinus galeus* Linnaeus 1758 (Chondrichthyes: Triakidae), from the Maghreb shore (southern Mediterranean). Acta Adriatica: International Journal of Marine Sciences 46(2):109-124.

Chabot, C.L. 2015. Microsatellite loci confirm a lack of population connectivity among globally distributed populations of the tope shark *Galeorhinus galeus* (Triakidae). Journal of Fish Biology 87(2):371-385.

Chabot, C.L., and L.G. Allen. 2009. Global population structure of the tope (*Galeorhinus galeus*) inferred by mitochondrial control region sequence data. Molecular Ecology 18(3):545-552.

Clemens, W.A. and G.V. Wilby. 1946. Fishes of the Pacific coast of Canada. 1st ed. Fisheries Research Board of Canada Bulletin. 68. 368 pp.

COSEWIC. 2007. COSEWIC assessment and status report on the soupfin shark (*Galeorhinus galeus*) in Canada. COSEWIC, Ottawa, Canada.

Compagno, L.J.V., 1984. FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2 - Carcharhiniformes. FAO Fisheries Synopsis 125(4/2):251-655.

Cuevas, J.M., M. García, and E. Di Giacomo. 2014. Diving behaviour of the critically endangered tope shark *Galeorhinus galeus* in the Natural Reserve of Bahia San Blas, northern Patagonia. Animal Biotelemetry 2(1):11.

Domi, N., J.M. Bouquegneau, and K. Das. 2005. Feeding ecology of five commercial shark species of the Celtic Sea through stable isotope and trace metal analysis. Marine Environmental Research 60(5):551-569.

Dunn, M.R., A.Szabo, M.S. McVeagh, and P.J. Smith. 2010. The diet of deepwater sharks and the benefits of using DNA identification of prey. Deep Sea Research Part I: Oceanographic Research Papers 57(7): 923-930.

Dureuil, M. and B. Worm. 2015. Estimating growth from tagging data: an application to north-east Atlantic tope shark *Galeorhinus galeus*. Journal of Fish Biology 87(6):1389-1410.

Ebert, D.A. 2001. Soupfin shark. Pp. 255-256. in W.S. Leet, C.M. Dewees, R. Klingbeil, and E.J. Larson (eds.). California's Living Marine Resources Status Report. California Department of Fish and Game, Sacremento, California.

Ebert, D.A. 2003. Sharks, rays and chimaeras of California. University of California Press: Berkeley, California. 284 p.

Elías, I., A. Rodriguez, E. Hasan, M. V. Reyna, and R. Amoroso. 2004. Biological observations of the tope shark, *Galeorhinus galeus*, in the northern Patagonian gulfs of Argentina. Journal of Northwest Atlantic Fishery Science 37:261-265.

Ferreira, B.P., C.M. Vooren. 1991: Age, growth, and structure of vertebra in the school shark *Galeorhinus galeus* (Linnaeus, 1758) from southern Brazil. Fishery Bulletin 89:19-31.

Fisheries and Oceans Canada (DFO). 2011. Sharks of British Columbia. Department of Fisheries and Oceans, Ottawa, Canada.

Fisheries and Oceans Canada (DFO). 2012. Management Plan for the Bluntnose Sixgill Shark (*Hexanchus griseus*) and Tope Shark (*Galeorhinus galeus*) in Canada. Species at Risk Act Management Plan Series. Fisheries and Oceans Canada, Ottawa. iv + 37 pp.

Fisheries and Oceans Canada (DFO). 2014. Codes of Conduct: shark encounters. Department of Fisheries and Oceans, Ottawa, Canada.

Florida Museum. 2020. Discover Fishes: Tope. (https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/galeorhinus-galeus/) .

Francis, M.P. and K.P. Mulligan. 1998: Age and growth of New Zealand school shark, *Galeorhinus galeus*. New Zealand Journal of Marine and Freshwater Research 32: 427-440.

Froese, R., J. Thorson and R.B. Reyes Jr., 2013. A Bayesian approach for estimating length-weight relationships in fishes. Journal of Applied Ichthyology 30(1):78-85.

Haug, G.H. and R. Tiedemann. 1998. Effect of the formation of the Isthmus of Panama on Atlantic Ocean thermohaline circulation. Nature 393:673-676.

Herald, E.S. and W.E. Ripley 1951. The relative abundance of sharks and bat stingrays in San Francisco Bay. California Fish and Game Fish Bulletin 37:315–329.

Hernández, S., R. Daley, T. Walker, M. Braccini, A. Varela, M.P. Francis, and P.A. Ritchie. 2015. Demographic history and the South Pacific dispersal barrier for school shark (*Galeorhinus galeus*) inferred by mitochondrial DNA and microsatellite DNA mark. Fisheries research 167:132-142.

Holts, D.B. 1988. Review of US west coast commercial shark fisheries. Marine Fisheries Review 50(1):1-8.

International Union for the Conservation of Nature (IUCN) 2012. *Galeorhinus galeus*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1. http://www.iucnredlist.org. Downloaded on 04 October 2018.

Jaureguizar, A.J., F. Argemi, G. Trobbiani, E.D. Palma, and A.J. Irigoyen. 2018. Large-scale migration of a school shark, *Galeorhinus galeus*, in the Southwestern Atlantic. Neotropical Ichthyology 16(1): e170050.

Kaschner, K., K. Kesner-Reyes, C. Garilao, J. Rius-Barile, T. Rees, and R. Froese, 2016. AquaMaps: predicted range maps for aquatic species. World wide web electronic publication, www.aquamaps.org, Version 08/2016. Accessed 17 Oct. 2018.

King, J., McFarlane, G.A., Gertseva, V., Gasper, J., Matson, S., and Tribuzio, C.A. 2017. Shark interactions with directed and incidental fisheries in the Northeast Pacific ocean: historic and current encounters, and challenges for shark conservation. In Advances in marine biology (Vol. 78, pp. 9-44). Academic Press.

Klippel, S., S. Amaral, and L. Vinhas. 2016. Development and evaluation of species distribution models for five endangered elasmobranchs in southwestern Atlantic. Hydrobiologia 779:11-33.

Last, P.R. and J.D. Stevens. 1994. Sharks and rays of Australia. CSIRO, Australia.

Lucifora, L., R. Menni, and A. Escalante. 2004. Reproductive biology of the school shark, Galeorhinus galeus, off Argentina: support for a single south western Atlantic population with synchronized migratory movements. Environmental Biology of Fishes 71:199-209.

Lucifora, L.O., V.B. García, R.C. Menni, and A.H. Escalante. 2006. Food habits, selectivity, and foraging modes of the school shark *Galeorhinus galeus*. Marine Ecology Progress Series 315:259-270.

McCord, M. E. 2005. Aspects of the ecology and management of the soupfin shark (*Galeorhinus galeus*) in South Africa (Masters dissertation, Rhodes University).

McFarlane, G.A., R.P. McPhie and J.R. King. 2010. Distribution and life history parameters of elasmobranch species in British Columbia waters. Canadian Technical Report of Fisheries and Aquatic Sciences 2908: ix + 143 p.

McMillan, M. N., C. Huveneers, J.M. Semmens, and B.M. Gillanders. 2018. Natural tags reveal populations of Conservation Dependent school shark use different pupping areas. Marine Ecology Progress Series 599:147-156.

Mecklenburg, C.W., T.A. Mecklenburg, and L.K. Thorsteinson 2002. Fishes of Alaska. American Fisheries Society, Bethesda, Maryland. 1037 p.

Morato, T., E. Solà, M.P. Grós, and G. Menezes. 2003. Diets of thornback ray (Raja clavata) and tope shark (*Galeorhinus galeus*) in the bottom longline fishery of the Azores, Northeastern Atlantic Fish Bulletin 101:590-602.

Morley, J.W., R.L. Selden, R.J. Latour, T.L. Frölicher, R.J. Seagraves, and M.L. Pinsky. 2018. Projecting shifts in thermal habitat for 686 species on the North American continental shelf. PloS one 13(5): e0196127.

Moulton, P.L., S.R. Saddlier, and I.A. Knuckey. 1989. New time-at-liberty record set by school shark *Galeorhinus galeus* caught off southern Australia. North American Journal of Fisheries Management 9:254–255.

Moulton, P. L., T.I. Walker, and S.R. Saddlier. 1992. Age and growth studies of gummy shark, *Mustelus antarcticus* Giinther, and school shark, *Galeorhinus galeus* (Linnaeus), from southern Australian waters. Australian Journal of Marine and Freshwater Research 43:1241-1267.

Musick, J.A., M.M. Harbin, and L.J.V. Compagno. 2004. Historical Zoogeography of the Selachii. pp. 33–77 *in*: J.C. Carrier, J.A. Musick, and M.R. Heithaus (eds.). Biology of Sharks and Their Relatives. CRC Press, Boca Raton, Florida.

Natureserve. 2018. NatureServe Web Service. Arlington, VA. U.S.A. Available http://services.natureserve.org . (Accessed: October 31, 2018).

Nelson, J.S., E.J. Crossman, H. Espinosa-Pérez, L.T. Findley, C.R. Gilbert, R.N. Lea, and J.D. Williams. Common and scientific names of fishes from the United States, Canada, and Mexico. American Fisheries Society, Special Publication 29, Bethesda, Maryland.

Nosal, A., pers. comm. 2018. *Email correspondence with G. Osgood*. October 2018. Research scientist, Scripps Institution of Oceanography, UC San Diego, La Jolla, California.

Olsen, A.M. 1954. The biology, migration, and growth rate of the school shark, *Galeorhinus australis* (Macleay) (Carcharhinidae) in southeastern Australian waters. Australian Journal of Marine and Freshwater Research 5:353–410.

Peres, M.B. and C.M. Vooren. 1991. Sexual development, reproductive cycle and fecundity of the school shark *Galeorhinus galeus* off southern Brazil. Fishery Bulletin (U.S.) 89:655-667.

Pondella, D.J., and L.G. Allen. 2008. The decline and recovery of four predatory fishes from the Southern California Bight. Marine Biology 154:307-313.

Ripley, E., 1946. The soupfin shark and the fishery. California Fish and Game Fish Bulletin 64:7-37.

Rogers, P.J., I. Knuckey, R.J. Hudson, A.D. Lowther, and L. Guida. 2017. Post-release survival, movement, and habitat use of school shark *Galeorhinus galeus* in the Great Australian Bight, southern Australia. Fisheries Research 187:188-198.

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.

Stevens, J.D. 1990. Further results from a tagging study of pelagic sharks in the north-east Atlantic. Journal of the Marine Biological Association of the United Kingdom 70:707-720.

Storelli, M. M. and G.O. Marcotrigiano. 2002. Mercury speciation and relationship between mercury and selenium in liver of *Galeus melastomus* from the Mediterranean Sea. Bulletin of Environmental Contamination and Toxicology 69:516-522.

Torres, P., R.T. da Cunha, and A. dos Santos Rodrigues. 2017. Mid-Atlantic elasmobranchs: Suitable metal scouts? Marine Pollution Bulletin 117:203-213.

Tseng, Y.-H., R. Ding, and X.-Meng Huang. 2017. The warm Blob in the northeast Pacific—The bridge leading to the 2015/16 El Niño. Environmental Research Letters 12:054019.

Tunnah, L., S.R.C MacKellar, D.A. Barnett, T.J. MacCormack, K.M. Stehfest, A.J. Morash, J.M. Semmens, and S. Currie. 2016. Physiological responses to hypersalinity correspond to nursery ground usage in two inshore shark species (*Mustelus antarcticus* and *Galeorhinus galeus*). Journal of Experimental Biology: jeb-139964.

Visser, I.N. 2000. Killer whale (Orcinus orca) interactions with longline fisheries in New Zealand waters. Aquatic Mammals. 26:241-252.

Walker, T.I. 1989. Stomach contents of gummy shark, Mustelus antarcticus Gunther and school shark, Galeorhinus galeus (Linnaeus) from south-eastern Australia. In Southern Shark Assessment Project- Final FIRTA Report: March 1989. pp. 24. (Marine and Freshwater Resources Institute: Queenscliff, Victoria, Australia)

Walker, T.I., L.P. Brown, and N.F. Bridge 1997. Southern Shark Tagging Project. Final report to Fisheries Research and Development Corporation. November 1997. (Marine and Freshwater Resources Institute: Queenscliff, Victoria, Australia).

Walker, T.I. 1999. *Galeorhinus galeus* fisheries of the world. In Case Studies of Management of Elasmobranch Fisheries. FAO Fisheries Technical Paper 378/2, 728-773.

Walker, T.I., R.D. Cavanagh, J.D. Stevens, A.B. Carlisle, G.E. Chiaramonte, A. Domingo, D.A. Ebert, C.M. Mancusi, A. Massa, M. McCord, G. Morey, L.J. Paul, F. Serena, and C.M. Vooren. 2006. *Galeorhinus galeus*. The IUCN Red List of Threatened Species 2006: e.T39352A10212764. http://dx.doi.org/10.2305/IUCN.UK.2006.RLTS.T39352A10212764.en. Downloaded on 29 October 2018.

Walker, T.I., Rigby, C.L., Pacoureau, N., Ellis, J., Kulka, D.W., Chiaramonte, G.E. & Herman, K.2020. *Galeorhinus galeus*. *The IUCN Red List of Threatened Species* 2020: e.T39352A2907336. https://dx.doi.org/10.2305/IUCN.UK.2020-2.RLTS.T39352A2907336.en.

West, G.J., and J.D. Stevens. 2001. Archival tagging of school shark, *Galeorhinus galeus*, in Australia: initial results. In The behavior and sensory biology of elasmobranch fishes: an anthology in memory of Donald Richard Nelson. Springer: Dordrecht. pp. 283-298.

Westrheim, S.J. 1950. The 1949 soupfin shark fishery of Oregon. Fish Commission Research Briefs 3:39-49.

Yakimishyn, J., pers. comm. 2018. *Email correspondence with G. Osgood*. October 2018. Resource Management Officer, Pacific Rim National Park Reserve of Canada, Parks Canada, Ucluelet, British Columbia.

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Geoffrey Osgood completed his Bachelor's of Science, Honours in Ecology and Zoology at the University of Calgary in 2014 and since then has been working on his PhD in Biology at the University of Victoria studying the use of marine protected areas for shark conservation.

Julia K. Baum is Associate Professor of Biology at the University of Victoria in British Columbia, Canada and a 2017 Pew Fellow in Marine Conservation. She earned her BSc from McGill University (1999; Montréal), and her MSc (2002) and PhD (2007) from Dalhousie University (Halifax), all in Biology. Julia subsequently held a David H. Smith Conservation Research Fellowship at Scripps Institution of Oceanography, University of California (UC) San Diego, followed by a Schmidt Ocean Institute Postdoctoral Fellowship at the National Center for Ecological Analysis and Synthesis, UC Santa Barbara. Amongst other foci, Julia's research has documented precipitous declines in shark populations and the cascading effects of the loss of apex predators.

Appendix 1. Information on the research surveys conducted in Canadian Pacific waters that could capture Tope. VI = Vancouver Island.

Survey	Years	Frequency	Spatial coverage (Canada)	Design	Gear	Number of years with Tope
AFSC Triennial	1977-2001	Every 3 years	Canada-US border (1977-1979, 1986); West Coast of VI	Shelf transects perpendicular to coast stratified by depth	Bottom trawl	1
NWFSC Triennial	2004	Once	Canada-US border	Shelf transects perpendicular to coast stratified by depth	Bottom trawl	0
NWFSC West Coast Groundfish Bottom Trawl	2003-2018	Twice per year	Canada-US border	Stratified random sampling across geographic area and depth	Bottom trawl	0
Hecate Strait Synoptic Bottom Trawl Survey	2005-Present	Every 2 years	Hecate Strait	Stratified random sampling across depth 2km by 2km blocks	Bottom trawl	1
Queen Charlotte Sound Synoptic Bottom Trawl	2003-Present	Every 2 years	Queen Charlotte Sound	Stratified random sampling across depth 2km by 2km blocks	Bottom trawl	0
Strait of Georgia Synoptic Bottom Trawl	2012, 2015		Strait of Georgia	Stratified random sampling across depth 2km by 2km blocks	Bottom trawl	0
West Coast Haida Gwaii Synoptic Bottom Trawl	2006, 2007, 2008, 2010-Present	Every 2 years from 2010	West Coast of Haida Gwaii	Stratified random sampling across depth 2km by 2km blocks	Bottom trawl	0
West Coast VI Synoptic Bottom Trawl	2004-Present	Every 2 years	West coast of VI	Stratified random sampling across depth 2km by 2km blocks	Bottom trawl	0
Hard Bottom Longline Hook Surveys, Outside	North: 2006-Present South: 2007-Present	Every 2 years except 2013	North and west VI, entire coast north of VI	Stratified random sampling across depth 2km by 2km blocks	Snap and swivel longline	1
Hard Bottom Longline Hook, Inside	North: 2004-Present, South: 2003-Present	Every 2 years except 2006	Waters east of VI	Stratified random sampling across depth 2km by 2km blocks	Snap and swivel longline	0
Joint Canada-US Hake Acoustic	2003-Present	Every 2 years plus 2012	Entire BC coast north and west of VI		Midwater trawl	2
Strait of Georgia Dogfish Longline	1986, 1989, 2005, 2008, 2011		Strait of Georgia	Ten representative sites through Strait of Georgia	Longline	0
IPHC Fishery Independent Setline	1996-2018	Annual	Coast of BC north and west of VI	Fixed-hook skates at regular, systematically placed stations	Longline	19
Hecate Strait Multispecies Trawl	1984-1986, 1987, 1991, 1993, 1995, 1996, 1998, 2000, 2002		Hecate Strait	Sampling area divided into 10 by 10 nm cells with depth strata sampled	Bottom trawl	1
Miscellaneous historical	1977-1982				Trawl, longline	
West coast VI Pelagics	1997-Present	Annual	Offshore west coast of VI	Line transects spaced from north to south VI	Surface trawl	7

Survey	Years	Frequency	Spatial coverage (Canada)	Design	Gear	Number of years with Tope
High Seas Salmon Research	1998-Present	Annual	West coast VI, Queen Charlotte Sound, Hecate Strait, west coast Haida Gwaii	Line transects	Midwater trawl	2
Integrated Pelagic Ecosystem	2017-2018		West coast VI	Random sampling	Midwater trawl	2

Appendix 2. Total and mean catch (kg) of Tope by month in Canada's Pacific waters based on at-sea observer and electronic monitoring coverage in commercial trawl (1996–2018) and hook and line fisheries (2003–2018). Source: PacHarvTrawl, GFFOS, GFBio, PacharvHL, and PacharvSable databases.

	Total catch (kg)		Mean catch (kg)	
Month	Trawl	Hook and line	Trawl	Hook and line
January	2746	27	119	2
February	1401	81	61	6
March	266	0	12	0
April	27	27	1	2
May	219	270	9	21
June	2030	7161	88	551
July	2344	7268	102	559
August	1610	4711	70	362
September	833	727	36	56
October	312	1023	14	79
November	79	108	3	8
December	429	0	19	0

Appendix 3. Total numbers of stations, skates (100 hooks/skate) hauled, and stations with confirmed Tope observed, and total numbers of Tope observed in Canada's Pacific waters (IPHC Survey Area 2B) from the IPHC set line survey. From 1998 to 2002 and again in 2013, only the first 20 hooks of each set were enumerated for non-halibut catch. Source: IPHC set line database.

Year	Total Number of Stations	Total Number of Skates Hauled	Number of Stations with Tope	Number of Tope observed
1996	123		2	3
1997	167		3	3
1998	128	1019.8	0	0
1999	170	1356.8	2	3
2000	129	896.7	0	0
2001	170	850.0	1	1
2002	170	849.9	0	0
2003	170	1358.1	2	5
2004	169	1345.5	15	30
2005	167	1185.6	11	17
2006	170	1018.5	2	2
2007	170	849.9	2	2
2008	169	847.9	6	11
2009	170	1186.0	12	16
2010	170	1359.2	14	25
2011	170	1019.3	8	9
2012	170	680.0	1	1
2013	170	1019.9	0	0
2014	170	1189.8	13	18
2015	170	1190.0	23	87
2016	170	1016.7	13	67
2017	166	826.7	19	42
2018	296	2070.3	40	209
Total	**3894**	**23 136.6**	**189**	**551**

Appendix 4. Results of the negative binomial zero-inflated generalized linear mixed models on the IPHC data of Tope catches. Scaled continuous variables representing depth, soak time, and PDO were included in each model. Log of the number of hooks observed was an offset. Three models were run: one for years 1998 to 2002 since only the first 20 hooks were enumerated for non-halibut catch during this time; one for data 2003 to 2018, excluding 2013, during which all hooks were enumerated; and one from 2003 to 2018 excluding new stations sampled in 2018. Coefficients are on the log scale. Predicted change is calculated as Tope count predicted using the year coefficient for the end of the time series divided by the predicted count for the start of the time series. Source: IPHC set line database.

Model	Year coefficient (p-value)	Predicted change	Depth coefficient (p-value)	Soak time coefficient (p-value)	PDO coefficient (p-value)
1998-2002	-0.154 (0.83)	0.08-fold	-3.61 (0.10)	0.658 (0.45)	-0.899 (0.22)
2003-2018 all stations	0.123 (<0.001)	7.2-fold	-1.61 (<0.001)	0.147 (<0.14)	0.349 (<0.001)
2003-2018 no new stations	0.121 (<0.001)	6.9-fold	-1.25 (<0.001)	0.174 (<0.08)	0.384 (<0.001)

Appendix 5. Estimated historical catch (t) of Tope along the west coast of North America. Data sources: California-Ripley (1946), Canada-Barraclough (1946) and Bailey (1952), Oregon (Westrheim 1950), Washington (Department of the Interior Information Service). California landings 1938–1940 are based on proportion (52.9%) of total shark landings found in Ripley (1946). Canadian, Washington, and Oregon liver landings converted to whole weights based on 10:1 conversion from Bailey (1952). Estimated number of sharks based on mean weight of 18 kg from length-weight regression (Froese *et al.* 2013) of average total length of 160 cm caught in California at that time (Ripley 1946).

Year	California Total Sharks (t)	California Estimated Catch (t) of Tope	Washington Estimated Catch (t) of Tope	Oregon Estimated Catch (t) of Tope	Canada Estimated Catch (t) of Tope	Total Catch (t) of Tope	Estimated number of sharks
1930	293						
1931	270						
1932	385						
1933	213						
1934	238						
1935	251						
1936	214						
1937	414						
1938	3400	1799				1799	99944
1939	4176	2209				2209	122722
1940	3557	1881			12	1893	105167
1941		2168		452	105	2725	151389
1942		903	303	498	221	1952	108444
1943		810	1271	1222	144	3447	191500
1944		286	379	679	278	1622	90111
1945				317	160	477	26500
1946				452	41	493	27389
1947				362	47	409	22722
1948				226	24	251	13944
1949				271	18	290	16111
Total (t)		**10056**	**1980**	**4479**	**1050**	**17565**	**975833**

Appendix 6. Threats Calculator for the Tope DU.

THREATS ASSESSMENT WORKSHEET

Species or Ecosystem Scientific Name	*Galeorhinus galeus*			
Element ID			**Elcode**	
Date	16/12/2019			
Assessor(s)	D. Fraser (facilitator), J. Neilson (Co-Chair), G. Osgood, J. Baum (report writers), B. Leaman, D. Kulka, A. McNeil, J. Yakimishyn			
	Overall Threat Impact Calculation Help:		**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	0	0
	D	Low	1	1
	Calculated Overall Threat Impact:		Low	Low
Assigned Overall Threat Impact:	**D = Low**			
Impact Adjustment Reasons:				
Overall Threat Comments	Generation time 23 years; low fecundity. It is considered to be highly migratory, moving along the coast of North America during summer and south into deeper waters during winter. The major ongoing threat is resource use resulting in bycatch in non-directed fisheries. Demand for vitamin A during World War II led to a large fishery that quickly collapsed due to over-exploitation. More than 800,000 individuals, primarily large adults, were killed for their livers between 1937 and 1949 throughout its migratory range. There is evidence from commercial fishery catch rates and research vessel surveys that this species is more abundant in Canadian waters in 2012 to 2018 compared with 2003 to 2011, although those these data cover only a portion of the 23-yr generation time. While fishery bycatch continues in Canada and the US, targeting and retention of these sharks in commercial and recreational fisheries has been prohibited in British Columbia and they must be released alive and as unharmed as possible.			

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development						
1.1	Housing & urban areas						Not relevant for this DU
1.2	Commercial & industrial areas						Not relevant for this DU
1.3	Tourism & recreation areas						Not relevant for this DU
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						Not relevant for this DU
2.2	Wood & pulp plantations						Not relevant for this DU
2.3	Livestock farming & ranching						Not relevant for this DU

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.4	Marine & freshwater aquaculture						It is not clear whether future aquaculture site would have any impact on Tope, but no current evidence suggesting a concern or interaction. Not relevant to this DU.
3	Energy production & mining						
3.1	Oil & gas drilling						Current moratorium on drilling and exploration in BC waters; unknown in future
3.2	Mining & quarrying						Not relevant for this DU
3.3	Renewable energy						No current developments of renewable energy affecting this DU
4	Transportation & service corridors						
4.1	Roads & railroads						Not relevant for this DU
4.2	Utility & service lines						Current windfarm development on hold; future uncertain; while some impacts of the EMF from undersea windfarm cables seen elsewhere, no studies in Tope in BC waters
4.3	Shipping lanes						Not relevant for this DU because Tope occur at depths greater than shipping
4.4	Flight paths						Not relevant for this DU
5	B iological resource use	D	Low	Pervasive (71 100%)	Slight (1-10%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						Not relevant for this DU
5.2	Gathering terrestrial plants						Not relevant for this DU
5.3	Logging & wood harvesting						Not relevant for this DU
5.4	Fishing & harvesting aquatic resources	D	Low	Pervasive (71 100%)	Slight (1-10%)	High (Continuing)	Main threat to Tope is incidental capture in commercial fisheries, estimated at approx. 2.275 t (85 individuals) per year. Catches in Canada reported to be mainly males but both sexes affected in more southerly waters. Code of Conduct management aims to minimize mortality, the fisheries are well monitored. The release mortality for Tope is unknown but believed to be low. The scope is pervasive but the impact over the next three generations thought to be slight. Also note that there are different management regimes in place for the US, Canada, and Mexico with different measures. Regulations protecting sharks have recently been introduced in Mexico but their effectiveness is unknown. Information on species-specific landings is likewise unknown but Tope in inshore bays may be vulnerable.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6	Human intrusions & disturbance						
6.1	Recreational activities						Not relevant for this DU
6.2	War, civil unrest & military exercises						Not relevant for this DU
6.3	Work & other activities						Not relevant for this DU
7	Natural system modifications						
7.1	Fire & fire suppression						Not relevant for this DU
7.2	Dams & water management/use						Not relevant for this DU
7.3	Other ecosystem modifications						Unknown
8	I nvasive & other problematic species & genes						
8.1	Invasive non-native/alien species						Not relevant for this DU
8.2	Problematic native species						Not relevant for this DU
8.3	Introduced genetic material						Not relevant for this DU
9	P ollution		Unknown	Pervasive l (71-100%)	Unknown	High (Continuing)	
9.1	Household sewage & urban waste water						Not relevant for this DU
9.2	Industrial & military effluents		Unknown	Pervasive (71 100%)	Unknown	High (Continuing)	Trace metals can bioaccumulate (Domi *et al.* 2005, Torres *et al.* 2014) but physiological mechanisms (such as mitigation by selenium) likely reduce toxicity. Possible impacts of shipping/industrial discharges but magnitude small
9.3	Agricultural & forestry effluents						Not relevant for this DU
9.4	Garbage & solid waste						While some prey may ingest microplastics, no evidence of higher trophic levels effects on Tope.
9.5	Air-borne pollutants						Not relevant for this DU
9.6	Excess energy						Not relevant for this DU
10	Geological events						
10.1	Volcanoes						Not relevant for this DU
10.2	Earthquakes/tsunamis						Not relevant for this DU
10.3	Avalanches/landslides						Not relevant for this DU
11	Climate change & severe weather		Not a Threat	Pervasive (71 100%)	Neutral or Potential Benefit	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.1	Habitat shifting & alteration		Not a Threat	Pervasive (71 100%)	Neutral or Potential Benefit	High (Continuing)	Long-term warming may shift the centre of distribution for this species to the north, increasing exposure to incidental capture in BC but decreasing in southern waters. Climate change may result in ecosystem changes in primary productivity and resulting prey base for Tope.
11.2	Droughts						Not relevant for this DU
11.3	Temperature extremes						
11.4	Storms & flooding						Not relevant for this DU

Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).