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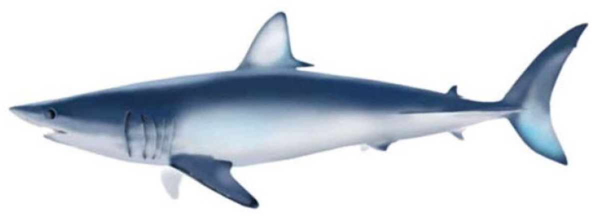
Maritimes, Gulf, Quebec, and Newfoundland and Labrador Regions

Canadian Science Advisory Secretariat
Science Advisory Report 2021/050

RECOVERY POTENTIAL ASSESSMENT FOR SHORTFIN MAKO SHARK (*ISURUS OXYRINCHUS*)



*Shortfin Mako Shark (*Isurus oxyrinchus*)*

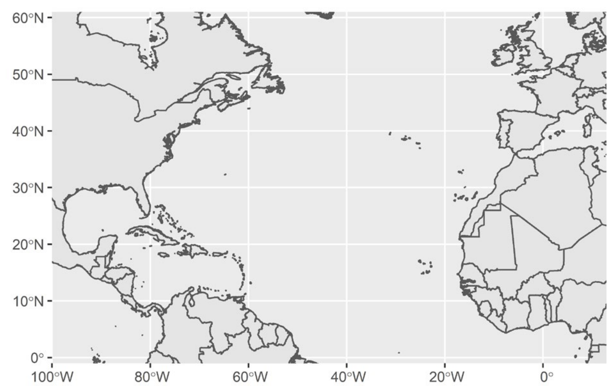


Figure 1. Distribution of the North Atlantic Designatable Unit: 0°–60°N.

Context:

Shortfin Mako Shark (Isurus oxyrinchus) in the North Atlantic Ocean are considered to be a single Designatable Unit (DU) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). In May 2019, the North Atlantic DU was assessed by COSEWIC as Endangered (COSEWIC 2019).

Fisheries and Oceans Canada (DFO) Science Branch was asked to complete a Recovery Potential Assessment (RPA) based on the national RPA guidance to provide scientific advice to inform a listing recommendation for Shortfin Mako Shark under the Species at Risk Act (SARA). The advice in the RPA may be used to inform both scientific and socio-economic aspects of the listing process, development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits or agreements, and the formulation of exemptions and related conditions.

This Science Advisory Report is from the November 17–19, 2020, zonal advisory process on the Recovery Potential Assessment - Shortfin Mako Shark (Isurus oxyrinchus) Atlantic Population. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule] as they become available.

SUMMARY

- The North Atlantic Designatable Unit (DU) of Shortfin Mako Shark is defined as the population that occurs throughout the Northern Hemisphere of the Atlantic Ocean. It was assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Endangered in 2019.
- This Recovery Potential Assessment contains information to support decision-making, develop a recovery strategy, or quantify the impact of a listing decision under the *Species at Risk Act*.
- Shortfin Mako have a broad distribution throughout Canadian waters, encompassing areas from the Bay of Fundy, into the Gulf of St. Lawrence, out to the Grand Banks towards the Flemish Cap, and off the eastern coast of Newfoundland. Tagged sharks spent the majority of their time in waters between 10–25°C, remaining primarily in the top 600 m of the water column.
- Shortfin Mako are vulnerable to fishing pressure given their late age at maturity and relatively slow reproductive rate.
- The 2019 International Commission for the Conservation of Atlantic Tuna (ICCAT) assessment update predicted a decline of approximately 54% in relative abundance from the 1950s until 2018, with the majority of the decline occurring from the 1980s onwards (approximately 39 years; less than two generations).
- Mortality from various directed and bycatch fisheries was the only threat to the North Atlantic DU of Shortfin Mako identified by COSEWIC. Since 1994, total international catches of Shortfin Mako have averaged 3,685 mt in the North Atlantic, with an average of 67 mt coming from Canada.
- In Canada, there has never been a directed fishery for Shortfin Mako. Between 2014–2019, the majority of landings of Shortfin Mako by Canadian fisheries (greater than 99%) come from benthic and pelagic longline fisheries in Maritimes Region.
- The gear types associated with incidental catches of Shortfin Mako include pelagic or drift longline, bottom longline, and otter trawl; with lesser amounts in purse seine, fixed gillnet, handlines, and troll lines. Relative interception probabilities were highest for the pelagic longline fleet, with an average of 48% of observed sets encountering Shortfin Mako.
- Although the risk associated with individual fisheries in Canada is low, mortality is cumulative and each fishery contributes to population decline for the North Atlantic DU.
- An abundance estimate or fisheries assessment specific to Canadian waters is not informative because it would consider a very small component of the entire DU.
- ICCAT assessments use Biomass at Maximum Sustainable Yield (B_{MSY}) or a proxy for B_{MSY} (e.g., Spawning Stock Fecundity at MSY [SSF_{MSY}]) to assess overfished status, which is proposed as the abundance target for Shortfin Mako.
- There is no distribution target proposed in this RPA. The available data do not allow for quantitative predictions on distribution or changes in distribution for the North Atlantic DU of Shortfin Mako.
- Total removals (landings + dead discards + post-release mortality of live releases) of 500 mt or less had a 52% probability of rebuilding the North Atlantic stock to SSF_{MSY} by 2070.

- Landings prohibitions are expected to be the most effective mitigation measure to reduce fishing mortality, and these were introduced for Canadian fisheries starting in 2020.
- The efficacy of other types of bycatch mitigation measures (gear or bait modifications, time-area closures, effort restrictions, and shark deterrents) are unclear and would need to be tested following implementation.
- Current practices of using monofilament leaders, corrodible hooks, and releasing sharks in the water by cutting the line as close as possible to the hook should be maintained.
- At-Sea-Observer coverage is very low or non-existent in some fisheries, which leads to higher uncertainty in the catch rates, discards, and status of Shortfin Mako, especially when scaling limited information up to entire fisheries. There continues to be unreported bycatch in many fisheries, both in Canadian and international waters.
- Even if Canadian fisheries removals became zero, total international removals would remain well above 500 mt under current management, representing a Persistent Limitation to recovery.
- While there is scope for Allowable Harm, efforts should be made to keep future removals from all threats occurring in Canada below approximately 59 mt until a Canadian threshold for Allowable Harm can be developed.

INTRODUCTION

The North Atlantic Designatable Unit (DU) of Shortfin Mako Shark (*Isurus oxyrinchus*) is defined as the population that occurs throughout the Northern Hemisphere of the Atlantic Ocean (Figure 1). It was assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Endangered in 2019 (COSEWIC 2019). Shortly after a COSEWIC assessment of Threatened, Endangered, or Extirpated, Fisheries and Oceans Canada (DFO) provides scientific information on the current status of the wildlife species, threats to its survival and recovery, and the feasibility of recovery through a Recovery Potential Assessment (RPA). An RPA summarizes the life history, population status, threats, mitigation options, and potential for Allowable Harm for a wildlife species. The information presented may be used to support decision-making, development of a recovery strategy, or quantification of the impact of a listing decision under the *Species at Risk Act*. This Science Advisory Report summarizes the RPA Research Document (Bowlby et al. 2020[1]), and readers should consult the Research Document for additional supporting references, analyses, and information.

ASSESSMENT

Elements 1 and 3: Biology and Life History Parameters

Shortfin Mako is a circumglobal, generalist predator (Compagno 2001) that exhibits seasonal variations in abundance in Canadian waters. They are slow growing, relatively late to mature, and sexually dimorphic, with females growing larger than males (Natanson et al. 2006). Compared to other fishes, they experience low rates of natural mortality and have a

[1] Bowlby, H.D., Coates, P.J., Joyce, W.N., and Simpson, M.R. (2020). Recovery potential assessment for the North Atlantic designatable unit of Shortfin Mako Shark (*Isurus oxyrinchus*). Manuscript in preparation

correspondingly low intrinsic rate of population increase (Table 1; Cortés 2016). Estimated generation time is approximately 25 years (Rigby et al. 2019).

Table 1. Basic biology and current life-history parameters for the North Atlantic Designatable Unit of Shortfin Mako Shark.

	Life history parameter	Female	Male
Growth and Aging	Parturition size (cm)	60–70 up to 88.7 cm	60–70 up to 81.2 cm
	Growth rate (k) ($year^{-1}$)	0.087	0.125
	Maximum length (cm)	336 cm	253 cm
	Longevity (years)	38 years	21 years
Maturity	Age (A_{50})	18 years	8 years
	Length (L_{50})	280 cm	182 cm
	Weight (W_{50})	275 kg	64 kg
Reproduction	Gestation (Months)	19–20 months	
	Parturition	winter–spring, possibly into summer	-
	Number of Pups	4–16	-
	Reproductive cycle	2–3 years	-
Diet	Teleost fish, cephalopods, marine mammals, elasmobranchs. With increasing size, a trophic shift to larger prey likely occurs. Unlikely any sex specific diet, with the exception of possible size dependent diet shifts in mature females.		
Distribution and habitat	Circumglobal in all tropical to temperate seas. Resides between 60°N and the equator in North Atlantic. Preferred temperature range: 17–22°C. Majority of time spent in mixed layer with periodic dives in excess of 900 m. Some age/size dependent habitat use is possible. Sex-specific distribution likely with males undertaking infrequent long migrations between ocean basins and females likely remaining within one basin		

Element 2: Abundance Trajectory and Number of Populations

A single Catch-Per-Unit-Effort (CPUE) index from Canadian waters is unlikely to represent abundance trends for the entire North Atlantic DU and was not developed for this assessment. The 2019 ICCAT assessment update incorporated several CPUE indices and predicted a decline of approximately 54% in relative abundance from the 1950s until 2018, with the majority of the decline occurring from the 1980s onwards (approximately 39 years; less than two generations; Anon 2020). There was no indication that population decline had slowed or ceased.

Shortfin Mako are distributed throughout the North Atlantic (Natanson et al. 2020), and genetic evaluation supports that there is only one population (Heist et al. 1996).

Elements 4 and 5: Distribution and Habitat

Atlantic Canadian waters represent the most northern extent of the DU's range. Shortfin Mako are most commonly found in warm waters along the continental shelf and in offshore waters near or within the Gulf Stream (Campana et al. 2005). Individuals tagged with archival satellite tags exhibited cyclical daily-diving behaviour, remaining primarily in the top 600 m of the water column but with the potential to dive in excess of 900 m. From June to December, tagged sharks spent the majority of their time in waters between 10–25°C, only making brief forays into surficial or deep waters less than 10°C. These behaviours are consistent with the hypothesis that Shortfin Mako congregate in areas of warm and cold water mixing where productivity is high (Bigelow et al. 1999).

Commercial landings of Shortfin Mako are a more complete representation of their distribution in Canadian waters as compared to more sparse (and potentially biased) At-Sea-Observer (ASO) data. Combining records from Newfoundland and Labrador Region and Maritimes Region from 2001 to 2019 shows Shortfin Mako have a broad distribution throughout Canadian waters, encompassing areas from the Bay of Fundy, into the Gulf of St Lawrence, out to the Grand Banks towards the Flemish Cap, and off the eastern coast of Newfoundland (Figure 2). There are no distinct seasonal patterns, although distribution may not extend as far north in the winter and spring. Previously, habitats critical for mating and pupping were believed to take place outside of Canadian waters (Campana et al. 2006, Showell et al. 2017). New research shows a widespread distribution of neonates and Young-Of-the-Year (YOY), suggesting that pupping is widespread and occurs throughout the continental shelf (Natanson et al. 2020).

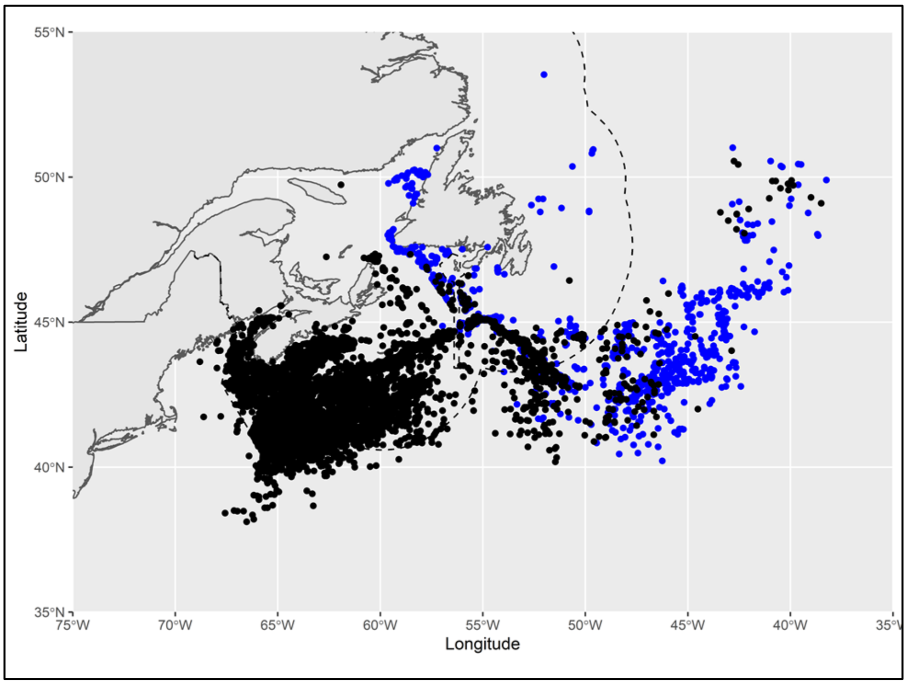


Figure 2. Commercial captures of Shortfin Mako Shark in Maritimes (black points) and Newfoundland and Labrador (blue points) regions from 2001–2019.

Elements 6 and 7 pertain to spatial configuration constraints and species' residence, and are not relevant to Shortfin Mako. This species moves freely, inhabiting a wide vertical distribution in the water column as well as a broad spatial distribution in the North Atlantic. The concept of a residence (a dwelling-place, such as a den, nest, or other similar area or place that is occupied or habitually occupied by one or more individuals during all or part of their life cycles) does not apply to the life history of Shortfin Mako.

Element 8: Threats

Shortfin Mako are vulnerable to fishing pressure given their late age at maturity and relatively slow reproductive rate (COSEWIC 2019, Rigby et al. 2019). Mortality from various directed and bycatch fisheries was the only threat to the North Atlantic DU of Shortfin Mako identified by COSEWIC. To date, other large-scale changes to North Atlantic ecosystems such as underwater noise, marine pollution, ocean acidification, or climate change may present potential threats but have not yet been demonstrated to threaten Shortfin Mako survival, influence life history characteristics, or restrict available habitat.

Landings

Throughout the time series, international catches (landings plus dead discards; Task I data from ICCAT) of Shortfin Mako in the North Atlantic are dominated by European fleets. Catches from all countries peaked in 1995 and 1996, exceeding 5,000 mt in both of those years. Since 1994, annual catches of Shortfin Mako have averaged 3,685 mt in the North Atlantic, with an average of 67 mt coming from Canada. Until 2017, there was no systematic trend over time, but catches declined in 2018 and 2019 coincident with management changes.

In Canada, there has never been a directed fishery for Shortfin Mako (Campana et al. 2005, Showell et al. 2017). The majority of landings come from fisheries in Maritimes Region. The Quebec and Gulf regions contribute minimally to the total in any year. Landings from Newfoundland and Labrador Region were as high as 44% of those in Maritimes Region (in 2000), but they were more often 10% or less, and were zero for 2018 and 2019. Overall, landings from Canadian waters declined from approximately 70 mt in the early 2000s to the series minimum of approximately 30 mt in 2012. In 2017, landings increased to a high of 96 mt yet dropped to approximately 54 mt for 2019. Between 2014–2019, the majority of landings of Shortfin Mako (greater than 99%) came from benthic and pelagic longline. The length-frequency distribution of the landings indicates that the pelagic longline fishery almost exclusively catches juvenile animals. This gear type does not effectively retain larger animals.

Discards

For Maritimes Region, the gear types associated with incidental catches of Shortfin Mako include pelagic or drift longline, bottom longline, and otter trawl, with minimal amounts in purse seine, fixed gillnet, handlines, and troll lines. From 2017–2019, discards have only been observed from otter trawl and pelagic longline, primarily representing the otter trawl fishery targeting Haddock and the pelagic longline fishery for Swordfish and Other Tunas. Discard amounts are low, below 5 mt since 2008, and were < 1 mt in 2019. ASO coverage rates are high (up to 100%) in groundfish otter trawl fisheries operating on Georges Bank and in the annual benthic longline survey for Atlantic Halibut. Coverage targets are 10% for pelagic longline. ASO coverage for fisheries associated with sporadic interactions (e.g., set gillnet, purse seine, other otter trawl and bottom longline) are extremely low relative to other groundfish fisheries or pelagic longline. Relative interception probabilities were highest for the pelagic longline fleet, with an average of 48% of observed sets encountering Shortfin Mako. Also, approximately 45% of animals would be expected to die as a result being caught; approximately 23% of catches are dead upon retrieval of the gear, and approximately 28% of live releases would be expected to subsequently die. No other fishery had an annual interception probability higher than 1%, and most were consistently below 0.5%. Differences in sample size owing to variation in observer-coverage levels would impact the precision of interception probability estimates. There were few observed captures of Shortfin Mako in Quarter 1 (Jan–Mar), followed by the majority of catches in Quarter 2 (Apr–Jun) and 3 (Jul–Sep), and a decrease in Quarter 4 (Oct–Dec). This seasonal pattern likely reflects patterns in fishing effort as well as the thermal preferences of Shortfin Mako.

Newfoundland and Labrador Region ASO data indicated that Shortfin Mako was predominantly caught by gillnets in the Subdivision 3Ps Cod fishery, the Divisions 3OPs Monkfish/White Hake/skate mixed fishery, and the Division 3L Greenland Halibut fishery. Historically, Shortfin Mako bycatch was observed in the Division 3MNO longline Swordfish/tuna and Division 3LNO Porbeagle fisheries. More recently, bycatch of this species was observed in the Subdivision 3Ps

Atlantic Halibut longline fishery. It must be noted that ASO coverage of fisheries in Subdivision 3Ps has been almost non-existent since 2012, hence the near-absence of recorded Shortfin Mako bycatch in an area where this species (and other large shark species) continued to be incidentally caught by gillnets. In bottom (otter) trawl fisheries, Shortfin Mako bycatch was observed mainly in the Division 3NO Yellowtail Flounder fishery and in the Subdivision 3Ps Atlantic Cod fishery. Since 2016, recorded catches (kept catch + discards) in the ASO database were < 1.5 mt, but data collection was constrained by the very low to non-existent annual ASO coverage in the majority of fisheries in recent years.

Currently, all recreational shark fisheries in Gulf, Quebec, Newfoundland and Labrador, and Maritimes regions are catch and release for Shortfin Mako. Post-release survival from rod-and-reel capture has not been quantified in the North Atlantic but was estimated to be approximately 90% in the Pacific. Recreational shark fisheries in Canada are unlikely to be causing significant mortality of Shortfin Mako in the North Atlantic. There are no records of Shortfin Mako being caught in Food, Social, and Ceremonial (FSC) fisheries occurring in Maritimes (MAR), Newfoundland and Labrador (NL), Gulf, or Quebec (QC) regions.

Threats Summary

Threats were categorized at the level of the DU (Table 2). The only activity where the level of impact could be quantified to estimate overall risk was from fisheries. To aid in prioritization, the risk from individual fisheries was also assessed (Table 3), while recognizing mortality is cumulative and each fishery contributes to population decline for the North Atlantic DU. International fisheries are by far the greatest threat, both in terms of recorded landings as well as discards.

Table 2. Assessment of threats affecting the entire DU

Activity	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Occurrence	Threat Frequency	Threat Extent	Overall Risk
Fisheries	Known	Extreme	Very High (1)	Historical, Current, Anticipatory	Continuous	Extensive	High (1)
Underwater Noise	Known	Unknown	Very Low (5)	Unknown	Unassessed	Unassessed	Unknown
Marine Pollution*	Known	Unknown	Low (4)	Unknown	Unassessed	Unassessed	Unknown
Ocean Acidification	Known	Unknown	Very Low (5)	Unknown	Unassessed	Unassessed	Unknown
Climate Change	Known	Unknown	Very Low (5)	Unknown	Unassessed	Unassessed	Unknown

Table 3. Threat assessment of individual fisheries.

Region (Activity)	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Occurrence	Threat Frequency	Threat Extent	Overall Risk
International fisheries (pelagic longline + other surface gear)	Known	Extreme	Very High (1)	Historical, Current, Anticipatory	Continuous	Extensive	High (1)
Canada: MAR (pelagic longline)	Known (100%)	Low	Very High (1)	Historical, Current, Anticipatory	Recurrent	Broad	Low (1)
Canada: MAR (otter trawl)	Known (100%)	Low*	Very High (1)	Historical, Current, Anticipatory	Recurrent	Narrow	Low (1)*
Canada: MAR (bottom longline)	Likely (80%)	Low*	Very High (1)	Historical, Current, Anticipatory	Recurrent	Narrow	Low (1)*
Canada: MAR (purse seine)	Remote (20%)	Low**	Very High (1)	Historical, Current, Anticipatory	Single	Restricted	Low (1)**
Canada: MAR (fixed gillnet)	Remote (20%)	Low**	Very High (1)	Historical, Current, Anticipatory	Single	Restricted	Low (1)**
Canada: MAR (handlines)	Unknown (0% currently)	Low **	Very High (1)	Historical	Single	Restricted	Low (1)**
Canada: MAR (troll lines)	Unknown (0% currently)	Low **	Very High (1)	Historical	Single	Restricted	Low (1)**
Canada: NL (commercial)	-	Low*	Very High (1)	Historical, Current, Anticipatory	Recurrent	Narrow	Low (1)*
Canada: GULF (commercial)	-	Low**	Very High (1)	Historical, Current, Anticipatory	Single	Restricted	Low (1)**
Canada: QC (commercial)	-	Low**	Very High (1)	Historical, Current, Anticipatory	Single	Restricted	Low (1)**
Canada: MAR, NL, Gulf, QC (recreational: rod and reel)	Known	Low	Very High (1)	Historical, Current, Anticipatory	Single	Broad	Low (1)*
Canada: MAR, NL, Gulf, QC (FSC fisheries)	Remote	Low**	Very High (1)	Historical, Current, Anticipatory	Unknown	Unknown	Low(1) **

**Very Low: No measurable change to population, or threat is extremely unlikely to jeopardize survival or recovery*
***Negligible: No measurable change to population; threat is not expected to measurably impact survival or recovery*

Elements 10 and 11: Natural and Ecosystem Factors

Despite Shortfin Mako having few natural predators and being able to tolerate a wide variety of ocean conditions, the species remains vulnerable to fishing pressure given their late age at maturity and relatively slow reproductive rate (Compagno 2001). Demographic analyses and ecological risk assessment demonstrate that Shortfin Mako are more at risk from exploitation as compared to other shark species (Mollet et al. 2000, Au et al. 2015). Additionally, there is recent evidence that fishing mortality rates may be substantially higher than previously thought, which has increased global concern about the status of the species (Byrne et al. 2017).

Further work on bycatch is required to understand and quantify the ecosystem impacts of the fisheries that interact with Shortfin Mako. The three main gear types that interact with Shortfin Mako (pelagic and benthic longline, and otter trawl) are non-selective in the sense that they do not exclude non-target organisms from the catch. The most comprehensive assessment of bycatch from fisheries in Maritimes Region (2002–2006) demonstrated that the pelagic longline fleet was associated with catches of approximately 22 different species, including several sharks, birds, marine mammals, turtles, and other pelagic fishes (Gavaris et al. 2010). The groundfish otter trawl fleet as well as the bottom longline fishery for Atlantic Halibut were associated with catches of an even larger suite of species, including teleost fishes, various skates, invertebrates, and pelagic fishes.

Element 9 pertains to threats to habitat properties and is not relevant for Shortfin Mako. Large-scale oceanographic changes affecting habitat are diffuse, systemic, and result from essentially all activities that contribute to industrialization, both in Canada and internationally.

Element 12: Abundance and Distribution Targets

An abundance estimate or fisheries assessment specific to Canadian waters is not informative because it would consider a very small component of the entire DU. ICCAT assessments of Shortfin Mako in the North Atlantic were used in this RPA to define the abundance target and assess status (Anon 2018, Anon 2020). ICCAT assessments use a variety of modeling approaches, which means that there is no single value (in biomass or in numbers of individuals) that can be defined as the abundance target. Overfished status is determined relative to Biomass at Maximum Sustainable Yield (B_{MSY}) or a proxy for B_{MSY} (e.g., Spawning Stock Fecundity at MSY [SSF_{MSY}]), which is proposed as the abundance target for Shortfin Mako.

There is no quantitative distribution target proposed in this RPA. Shortfin Mako are generalist predators and are able to use a wide variety of water conditions (Compagno 2001). It is anticipated that the population will continue to make use of waters throughout the Canadian Exclusive Economic Zone. Future understanding of distribution will come from a combination of fishery-independent and fishery-dependent data. Further work is required to understand how informative these two data sources will be when quantifying distribution patterns and changes in distribution.

Elements 13 and 15: Population Projections

During assessments, population projections are used to assess the probability of stock rebuilding under various levels of fishing mortality. The most recent ICCAT assessment evaluated removals from 0–1,100 mt in 100 mt Total Allowable Catch (TAC) increments (Anon 2020). A length-based (age structured) model incorporating up-to-date life-history parameters projected the population forward until 2070 (approximately two generations). Results were summarized in 5-year time increments as the probability of the population being at or above B_{MSY}.

Total removals (landings + dead discards + post-release mortality of live releases) of 500 mt or less had a 52% probability of rebuilding the stock to SSF_{MSY} by 2070. This probability only increased to 81% if total removals were zero. At 1,100 mt, there was a 10% probability that the stock could rebuild to SSF_{MSY} by 2070 (Anon 2020). For comparison, total international fisheries removals were 1,863 mt in 2019, with 63 mt coming from Canadian fisheries. The projections predict continued population decline to 2035 under any removal scenario because international catches are predominantly juveniles. Juvenile females would take approximately 10 years to contribute to reproductive output, thus enabling population increase.

Projections assuming higher productivity were not developed. There have been no measurable changes in key reproductive parameters such as length or weight at maturity over the last 50 years (Natanson et al. 2020). Large variations in survival over ontogeny are not expected for a long-lived top predator. Because population-dynamics parameters are relatively fixed, it is very unlikely that changes to life-history rates would increase future productivity.

Element 14 pertains to the supply of suitable habitat and is not relevant to Shortfin Mako because abundance is not limited by the amount of habitat available, even if the population increases substantially in size.

Persistent Limitation

A Persistent Limitation is defined as a constraint on the ability to return a species to its natural condition (Government of Canada 2019). The current level of fishing mortality in the North Atlantic will not allow recovery even though recovery remains biologically feasible. Fishing mortality must decline to 500 mt or less to have a greater than 50% probability of achieving recovery within two generations. For a species assessed as Endangered, using a probability threshold higher than 50% may be desirable. Over the last 20 years, Canadian catches in the North Atlantic have been a fraction of those from other nations, only exceeding 100 mt in three years. Even if Canadian fisheries removals became zero, total international removals would remain well above 500 mt under current management (Anon 2020). To promote recovery, Canada must continue to work internationally to reduce total fishing mortality in the North Atlantic, while also minimizing mortality from Canadian fisheries affecting this DU.

Elements 16 and 19: Scenarios For and Effectiveness of Mitigation

Bycatch mitigation measures either prevent capture or minimize mortality after capture. Preventing capture is optimal to reduce mortality in addition to any detrimental impacts to industry participants (Gilman et al. 2008). As soon as a Shortfin Mako does interact with fishing gear, mitigation measures can reduce at-vessel mortality, mortality during handling, and/or post-release mortality (Gilman et al. 2016, Gilman et al. 2019). From the identified suite of mitigation options, landings prohibitions are expected to be the most effective mitigation measure to reduce fishing mortality, and these were introduced for Canadian fisheries starting in 2020.

There are three main factors to keep in mind when discussing the effectiveness of mitigation: (1) how the measure affects capture probability; (2) how the measure affects at-vessel and post-release mortality rates; and (3) how the measure may influence the catch of the target species or other components of the ecosystem (e.g., other pelagic species). It is important to note that none of the mitigation measures identified in this document are known to optimize all three simultaneously (Gilman et al. 2016, Gilman et al. 2019). It is also worth considering whether specific mitigation options can be effectively enforced, given that they are unlikely to achieve their desired outcome if not.

The efficacy of other types of bycatch mitigation measures (Table 4) are unclear, primarily due to challenges in controlling for covariates when a specific mitigation measure is assessed. We consider the potential to reduce mortality from gear modifications to be very low in comparison with landings restrictions, particularly over the short term. The effectiveness of various spatial or temporal management strategies would need to be tested following their development from future spatio-temporal analyses of fleetwide catches. Similarly, the efficacy of effort restrictions in achieving a specified level of bycatch reduction or post-release mortality rate would need to be tested following implementation, given that catch rates of Shortfin Mako are not expected to be a linear function of effort.

Table 4. A summary of the strengths and weaknesses of mitigation measures considered for Shortfin Mako in the North Atlantic DU.

Mitigation Type	Specific Measure	Strengths	Weaknesses
Hook Type	circle hook	Increases probability of mouth-hooking	Likely longer retention times in sharks following release
		Reduces mortality for other species at risk (sea turtles)	Likely increases capture probability of Shortfin Mako
	J hook	Likely lower catch rates for Shortfin Mako	Increases probability of gut hooking
		Hooks likely expelled more quickly	Detrimental to other species at risk
	corrodible	Shorter retention times in sharks	Need replacement more frequently (cost)
	weak hooks	Permit larger animals to escape the gear	Not tested/developed Likely would reduce target species catch rates
Leader Type	monofilament	Increases probability of escape from the gear	Hook and trailing line are retrained
	steel	Provides opportunity to remove hooks/trailing line	Increases retention time on the gear Escaped animals have more substantial retained gear (weights, steel, hook, line)
Bait Type	small pelagic fish	Reduces bycatch of other species at risk	May increase gut-hooking Increases catchability
	squid	Reduced catchability	Increases bycatch of other species at risk
	artificial	Lower ecosystem impact	May reduce target species catch rates Unknown effects on shark bycatch rates
Handling Practices	onboard	Facilitates removal of hooks/trailing line	Physiological damage from lifting shark and animal’s inability to support its weight

Mitigation Type	Specific Measure	Strengths	Weaknesses
		Better species identification and characterization of shark condition	
	in-water release	Minimizes time on the line Minimizes physiological damage	Animals released with trailing gear Less accurate condition assessment and species ID
Deterrents	magnets/electrical acoustic/chemical	Species-specific and situation-specific potential to deter shark bycatch	Effectiveness may be short-lived Unknown effects on catch rates of target species
Gear Placement	deep sets	Potential reduction in interaction rate with longline gear	Increased bycatch rates of other pelagic shark species
Gear Substitutions	replace non-selective with more selective gear types (e.g., harpoon, rod and reel)	Eliminate potential for bycatch Potential shift in temporal and/or spatial distribution of effort	May reduce target species catch rate Potential shift in temporal and/or spatial distribution of effort
Prohibitions	Complete Landings Prohibition	Ensures all live and live but injured animals are released (minimizes population-level mortality) May change interception probability by fleets Simple to enforce	Without changes to interception probability, doesn’t influence at-vessel mortality Loss of opportunity for biological sampling and reduced data quality on fishery interactions Higher discarding rates (live + dead)
	Mandatory Live Release	Lower discarding rates (only dead) relative to a landings prohibition	No anticipated change in interception probability Affects integrity of data collection (Proportion dead at vessel increased in ASO data when allowed to land dead animals)

Mitigation Type	Specific Measure	Strengths	Weaknesses
			Difficult to enforce because categorizing condition is subjective
Restricting Effort	soak time	Likely reduces at-vessel mortality (magnitude unknown) Less opportunity for depreciation of retained catch Less dissipation of the scent from the bait	Unknown effects on target species catch rates
	total number of hooks	Potential to spatially-constrain fishing effort Potential to reduce interaction rates with the gear	Unknown effects on target species catch rates
Time-area Closures	-	Possibly reduces potential for interaction with gear Can possibly protect vulnerable life stages	Species biology and available data doesn't suggest these will be easily developed Static temporal or spatial closures unlikely to be effective
Bycatch Reduction Device (BRD)	-	May prevent capture of shark bycatch in trawls	Requires development and testing for Canadian gear types and efficacy for reducing bycatch of Shortfin Mako

Element 17 pertains to the development of an inventory of activities to increase productivity or survivorship parameters, and is not relevant for Shortfin Mako. There has been no indication of changes to key life-history parameters or the ecosystem that would markedly influence natural mortality rates over ontogeny (Natanson et al. 2020). It is highly unlikely that survivorship or productivity parameters could be influenced by mitigation.

Element 18 pertains to the provision of advice on the feasibility of restoring the habitat to higher values, and is not relevant for Shortfin Mako. Restoring oceanographic conditions to their previous state is not an outcome that could realistically be expected from comparatively small-scale remediation activities occurring in Canada. It is also possible that threats like climate change could increase Shortfin Mako habitat use in Canadian waters, although it is unknown whether any redistribution would also result in population increase for the North Atlantic DU.

Element 20: Projections and Exploration of Additional Scenarios

At present, we cannot quantitatively link the levels of individual threats in Canada to an expected level of population response for Shortfin Mako in the North Atlantic. Until total fisheries removals approach a level that may allow population increase, incremental changes to variables such as interception probabilities, mortality rates, or the amount of bycatch will not be measurable.

With the 2020–2021 regulations to prohibit landings of Shortfin Mako from Canadian fisheries, the major components of fishing mortality in the future will be at-vessel and post-release. Approximately 45% of Shortfin Mako captures would be expected to die following interaction with the Canadian pelagic longline fishery, and a rough approximation of total mortality from Canadian fleets is approximately18–59 mt annually.

Element 21 pertains to the recommendation of specialized features of population models that would allow exploration of socioeconomic impacts. This element was not addressed in this RPA. Although a risk-based evaluation method exists (Booth et al. 2020), it is complex and would require implementation through an international assessment body such as ICCAT to successfully define and reach recovery goals.

Element 22: Allowable Harm Assessment

For the entire DU, total fishery removals (landings + dead discards + post-release mortality of live discards) of 500 mt or less have a 52% probability that the population will rebuild to MSY by 2070 (two generations; Table 5). For an Endangered species, the group recommended that higher probabilities be considered when setting the threshold for Allowable Harm. International removals were 1863 mt in 2019 and are expected to remain high because catch limits have not been implemented. Under the 2020–2021 landings prohibition and current fishing effort, total mortality from Canadian fisheries is estimated to remain below 100 mt annually (approximately 18–59 mt). At 100 mt for total removals, the DU would be expected to reach the recovery target by 2045 (approximately one generation). Even if Canadian fisheries removals became zero, total international removals would remain well above 500 mt under current management, representing a Persistent Limitation to recovery. While there is scope for Allowable Harm, efforts should be made to keep future removals from all threats occurring in Canada below the upper estimated value (approximately 59 mt) until a Canadian threshold for Allowable Harm can be developed.

Table 5. Probability that Spawning Stock Fecundity (SSF) is greater than SSF at Maximum Sustainable Yield. Reprinted from Anon 2020.

TAC (t)	2019	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070
0	46	42	24	14	11	33	53	60	63	67	72	81
100	46	42	24	13	10	29	49	56	59	61	66	73
200	46	42	24	13	9	26	47	54	55	57	61	66
300	46	42	24	12	9	22	42	50	52	53	56	60
400	46	42	24	12	8	19	39	47	49	50	52	55
500	46	42	24	12	7	17	34	42	45	47	49	52
600	46	42	24	12	7	14	28	37	40	41	43	47
700	46	42	24	11	6	11	23	31	34	35	37	41
800	46	42	23	11	6	10	19	26	27	28	30	32
900	46	42	23	11	5	8	16	20	21	21	23	24
1,000	46	42	23	11	5	7	12	16	16	15	15	17
1,100	46	42	23	10	5	6	10	12	12	11	10	10

Sources of Uncertainty

Fisheries removals by international fleets are intended to include dead discards when reported to ICCAT, but this requirement is rarely met and the majority of Task I data represent landings. Also, Task I data do not include mortality from many non-ICCAT and small-scale artisanal fisheries. In the reported data, many sampling programs are not extrapolated to the entire fleet, and post-release mortality is not incorporated into dead-discard estimates. This is why Task 1 data are considered to be a minimum estimate of fisheries removals during stock assessment (Anon 2018, Anon 2020). This means that population status and the potential for future recovery is likely worse than reported here.

The majority of information on Shortfin Mako habitat use, threats, or potential mitigation measures provided in this report characterizes either the Canadian pelagic longline fleet or pelagic longline fisheries in general. Although it is likely that pelagic longline has the highest potential for interaction, there is limited ability to estimate the contribution to bycatch and the characteristics of that bycatch (e.g., alive/dead) from other fleets and gear types in Atlantic Canada due to data deficiencies (i.e., lack of ASO coverage).

At-sea-observer coverage is variable among different regions, as well as among different fleets operating within these regions. It is also disproportionately low or absent in some of the fisheries considered in this RPA. This leads to higher uncertainty in the catch rates, discards, and status of Shortfin Mako, especially when scaling limited information up to entire fisheries. There continues to be unreported bycatch in many fisheries, both in Canadian and international waters.

The main information on status, recovery targets, and projections for Shortfin Mako comes from fisheries assessments conducted by ICCAT. ICCAT uses slightly different latitudinal bounds to define the North Atlantic population (5–70°N) as compared to the DU assessed by COSEWIC (0–60°N). This difference should have very little influence on the results of this RPA, if any.

Research Recommendations

To better characterize threats and allow a more meaningful evaluation of Allowable Harm, quantifying encounter rates between individual Canadian fisheries and Shortfin Mako is recommended. The group recommends future research to determine at-sea-observer coverage levels for each individual fleet intercepting Shortfin Mako so that observed encounter rates and bycatch amounts can be scaled up to fleetwide estimates.

The available data do not allow for quantitative predictions on distribution or changes in distribution for the North Atlantic DU of Shortfin Mako. A better understanding may require more comprehensive data collection (fishery-dependent or -independent) or new types of information (e.g., eDNA or close kin mark-recapture).

CONCLUSIONS

Shortfin Mako is a circumglobal, generalist predator that exhibits seasonal variations in abundance in Canadian waters. Their general life-history characteristics result in a low intrinsic rate of population increase and relatively long generation time. Low productivity makes the population highly susceptible to fishing pressure, the main threat identified in the North Atlantic.

There is no directed fishing for Shortfin Mako in Canada, although they are caught as bycatch in several Canadian fisheries, predominantly in Maritimes Region. Interception probabilities are highest from pelagic longline. Compared to international fisheries, the level of threat posed by individual Canadian fisheries is low.

Reliable physical or biochemical deterrents that reduce interaction rates between Shortfin Mako and fishing gear have yet to be developed. Other changes to the manner of gear deployment are likely to negatively affect catch rates of Swordfish (e.g., deep-set longlines), increase bycatch of other pelagic species (e.g., switching to squid bait), or require dedicated experimentation to test (e.g., effort restrictions).

There are strengths and weaknesses identified from all of the mitigation options identified in this RPA. The new landings prohibition is expected to lead to the greatest reduction in total mortality resulting from Canadian fisheries. On the balance of available evidence, the current practices of using monofilament leaders, corrodible hooks, and releasing sharks in the water by cutting the line as close as possible to the hook should be maintained.

Under the 2020–2021 landings prohibition and current fishing effort, total mortality from Canadian fisheries is estimated to remain below 100 mt annually (approximately 18–59 mt). At 100 mt for total removals, the DU would be expected to reach the recovery target by 2045 (approximately one generation; Anon 2020). Even if Canadian fisheries removals became zero, total international removals would remain well above 500 mt under current management, representing a Persistent Limitation to recovery. While there is scope for Allowable Harm, efforts should be made to keep future removals from all threats occurring in Canada below the upper estimated value (approximately 59 mt) until a Canadian threshold for Allowable Harm can be developed.

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This Science Advisory Report is from the November 17–19, 2020 Recovery Potential Assessment – Shortfin Mako Shark (*Isurus oxyrinchus*) Atlantic Population. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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