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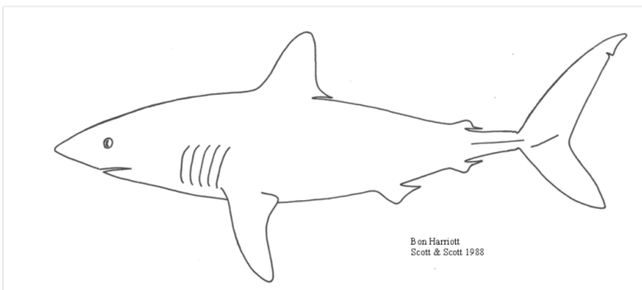
Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Maritimes & Newfoundland and Labrador Regions

Canadian Science Advisory Secretariat
Science Advisory Report 2015/048

RECOVERY POTENTIAL ASSESSMENT FOR PORBEAGLE (*LAMNA NASUS*) IN ATLANTIC CANADA



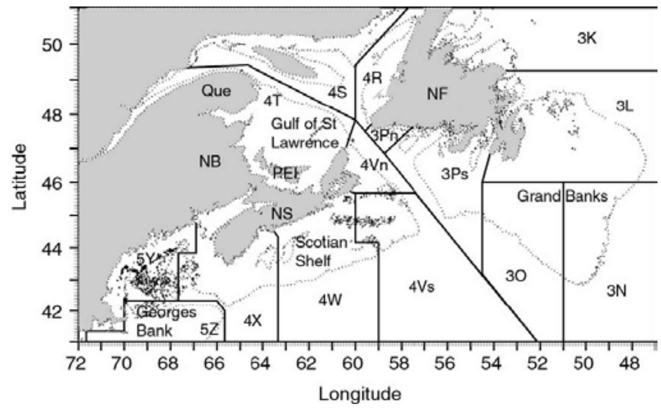


Figure 1. Map of eastern Canada showing NAFO Divisions and fishing banks.

Context:

In May 2014, Porbeagle (Lamna nasus) was reassessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The rationale provided for this designation was that "the abundance of this shark declined greatly in the 1960s after fisheries began targeting this species. A partial recovery during the 1980s was followed by another collapse in the 1990s. Numbers have remained low but stable in the last decade, since catch has decreased. Directed fisheries have been suspended since 2013, though there is still bycatch of unknown magnitude in Canadian waters and unrecorded mortality in international waters. This species' life history characteristics, including late maturity and low fecundity, render it particularly vulnerable to overexploitation."

DFO Science was asked to complete a Recovery Potential Assessment (RPA) to provide science advice to inform a listing recommendation for the addition of Porbeagle to Schedule 1 of the Species at Risk Act (SARA). The advice in the RPA may be used to inform both scientific and socio-economic elements of the listing decision, as well as development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions, as per section 73, 74, 75, 77 and 78 of SARA should the species be listed.

This Science Advisory Report was generated by the 19-20 February 2015, zonal Recovery Potential Assessment – Porbeagle (Lamna nasus). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Porbeagle (*Lamna nasus*) is a species of mackerel shark in the family Lamnidae. This species is widely distributed in the Northwest (NW) Atlantic, occurring in Canadian waters; the Gulf of St. Lawrence, around Newfoundland and Labrador, on the Scotian Shelf, and in the Bay of Fundy.

- Porbeagle was originally assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Endangered in 2004. As per section 24 of *Species at Risk Act* (SARA), COSEWIC reviewed the classification of Porbeagle in May 2014. The status of Porbeagle was confirmed as Endangered.
- The life span of Porbeagle is estimated to be between 25 and 46 years and generation time is about 18 years. The species has low fecundity (approximately 4 pups per year) and a late age of sexual maturation.
- All modeled runs indicated that abundance of Porbeagle in the NW Atlantic declined during the 1960s, increased slightly during the late 1970s and early 1980s, and decreased again during the late 1990s. Estimates of the population size in 2009 ranged from 196,911 to 206,956 sharks or approximately 22% to 27% of its size in 1961. Female spawner abundance was estimated to be approximately 16% of what it was in 1961.
- Porbeagle appear to occupy relatively cool water temperatures throughout the year, with 50% being caught between 5-10°C (gear depth). Temperature at depth is a significant predictor of catch rate, while sea surface temperature is not. Results from Pop-up Satellite Archival Tags indicate that Porbeagle can reside in slightly warmer temperatures than those suggested by fishery captures, with 50% of their time being spent between 8-13°C.
- Fishing is the only known source of human-induced mortality on Porbeagle in Atlantic Canada. With closure of the Canadian Porbeagle directed fishery in 2013, the only remaining source of fishing mortality in Canada's exclusive economic zone (EEZ) is bycatch. There are unknown and unregulated catches outside of Canadian waters.
- In Canadian waters, Porbeagle bycatch mortality from all sources (capture + post release + landing) has averaged 110 metric tonnes (mt) annually since 2010.
- The swordfish and other tuna longline, offshore tuna longline, groundfish longline, groundfish gillnet and otter trawl are considered the greatest current threats based on landings records and discard estimates. Although the threat risk of each fishery independently is considered low/medium, the cumulative impacts of all fishing-related mortality would represent a higher threat risk.
- Anthropogenic activities that could pose a potential threat to Porbeagle habitat necessary for population viability (e.g. mating grounds and areas of high population density) include: noise associated with offshore petroleum exploratory seismic surveys, marine pollution associated with a catastrophic offshore petroleum exploration or development spills, and large scale marine development projects such as pipelines and submarine cables.
- A recovery target for the Northwest Atlantic Porbeagle population is proposed as achieving 80% of female spawning stock numbers (SSN) at Maximum Sustainable Yield (MSY), or $SSN_{80\%}$, within three generations (or approximately 54 years). Across the four productivity models examined, this would equate to 24,000 to 32,000 mature females.
- Under what is considered the most realistic of the four productivity models that were examined (Model 3), recovery to $SSN_{80\%}$ in the absence of fishing would occur around 2033, while recovery under recent fishing mortality rates (approximately 110 mt or 2%) would occur around 2042.
- The current 2% mortality rate from all sources (based on 110 mt bycatch mortality since 2010) would allow the population to recover under all scenarios and at a faster rate than the 4% total allowable catch (185 mt) mortality rate. Total harm to the population (from all sources, including capture mortality, post release mortality, and landings) should not exceed a 4% mortality rate to allow the population to continue to increase and move towards the recovery targets.

INTRODUCTION

Rationale for Assessment

After the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses an aquatic species as Threatened, Endangered or Extirpated, Fisheries and Oceans Canada (DFO), as the responsible jurisdiction for aquatic species under the *Species at Risk Act* (SARA), undertakes a number of actions to support implementation of the *Act*. Many of these actions require scientific information on the current status of the species, threats to its survival and recovery, and the species potential for recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted shortly after the COSEWIC assessment. This timing allows for the consideration of peer-reviewed scientific analyses into SARA processes, including the decision whether or not to list a species on Schedule 1 and during recovery planning if the species is listed.

Porbeagle (*Lamna nasus*) is a species of mackerel shark in the family Lamnidae. Porbeagle in the Northwest Atlantic Ocean is considered one population. The Northwest Atlantic population ranges from northern Newfoundland and Labrador to New Jersey, and possibly South Carolina, with mature females ranging farther south to the Sargasso Sea. This species is widely distributed in the Canadian Atlantic, occurring in the Gulf of St. Lawrence, around Newfoundland and Labrador, on the Scotian Shelf, and in the Bay of Fundy. Most of the Northwest Atlantic population is found within Canadian waters at some point in its life history (Figure 1).

Porbeagle was originally assessed by COSEWIC as Endangered in 2004. As per section 24 of SARA, COSEWIC reviewed the classification of Porbeagle in May 2014 (COSEWIC 2014). The status of Porbeagle was confirmed as Endangered. The reasons for designation were: "The abundance of this shark declined greatly in the 1960s after fisheries began targeting this species. A partial recovery during the 1980s was followed by another collapse in the 1990s. Numbers have remained low but stable in the last decade, since catch has decreased. Directed fisheries have been suspended since 2013, though there is still bycatch of unknown magnitude in Canadian waters and unrecorded mortality in international waters. This species' life history characteristics, including late maturity and low fecundity, render it particularly vulnerable to overexploitation."

Following the first assessment of Porbeagle in 2004, the Governor in Council decided not to add Porbeagle to the List of Wildlife Species at Risk set out in Schedule 1 of SARA. In support of a new listing recommendation for Porbeagle by the Minister of Fisheries and Oceans, DFO Science has been asked to undertake an RPA, based on the national RPA Guidance (DFO 2007). The advice in the RPA may be used to inform both scientific and socio-economic aspects of the listing decision, 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, as per sections 73, 74, 75, 77, 78 and 83(4) of SARA. It may also be used to prepare for the reporting requirements of SARA section 55. The advice generated via this process will update and/or consolidate any existing advice regarding this species.

Biology, Life History, Distribution, and Abundance

Biology

There are two populations of Porbeagle in the North Atlantic: one in the Northwest (NW) and one in the Northeast (NE) Atlantic, with no appreciable mixing between the two. Monthly shifts in the location of the NW Atlantic Porbeagle-directed fishery suggest that these sharks carry out extensive annual migrations up and down the east coast of Canada, with no indication of population substructure within the NW Atlantic. Porbeagle eat primarily fish and squid; marine mammals are not part of the diet.

Life History

The life span of Porbeagle is estimated to be between 25 and 46 years and generation time is about 18 years. Natural mortality is estimated to be 0.10 for immature Porbeagle, 0.15 for mature males, and 0.20 for mature females. The species has low fecundity (approximately 4 pups per year) and a late age of sexual maturation, with males maturing at approximately 174 cm (Age 8), and females maturing at approximately 217 cm (Age 13). Satellite tracking results indicate that pupping occurs in late winter or spring in deeper waters of the Sargasso Sea after an 8-9 month gestation period.

Distribution

Tagging studies carried out by Norway, Canada and the U.S. document extensive annual migrations within the NW Atlantic, especially between the Grand Banks, Scotian Shelf and Gulf of Maine. Recent research using Pop-up Satellite Archival Tags (PSATs) demonstrated that most Porbeagles remained within the Canadian and American Exclusive Economic Zone (EEZ), although there was significant movement by some individuals into the high seas (Figure 2). All mature females whose tags popped off in the spring were found in the Sargasso Sea between Cuba and Bermuda, indicating that the Sargasso Sea is a major pupping ground for the NW Atlantic population (Campana et al. 2010a).

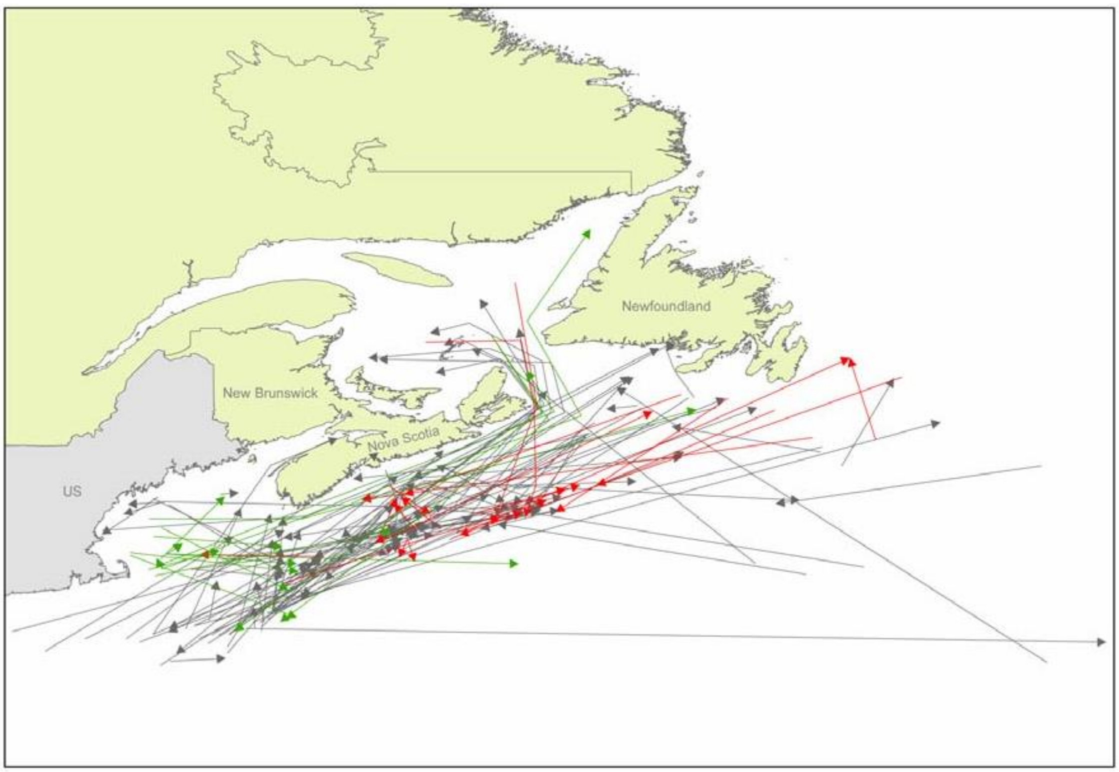


Figure 2. Summary of Porbeagle tag movements from tagging location (line origin) to recapture location (arrowhead) between 1961 and 2008. Norwegian tags in green; Canadian tags in red; U.S. tags in grey.

Porbeagle are widely distributed in offshore waters in Atlantic Canada, although most landed Porbeagle have been caught on the shelf edge and in the deep basins of the Scotian Shelf since the Total Allowable Catch (TAC) was significantly reduced in 2006 (Figure 3). The majority of commercial Porbeagle catches in Newfoundland waters occurred on the Grand Banks in NAFO Div. 3LNO

(Figure 3). Catch quantities and locations of Porbeagle by the international fleet on the high seas are poorly documented, but some Porbeagle have been caught south of Iceland.

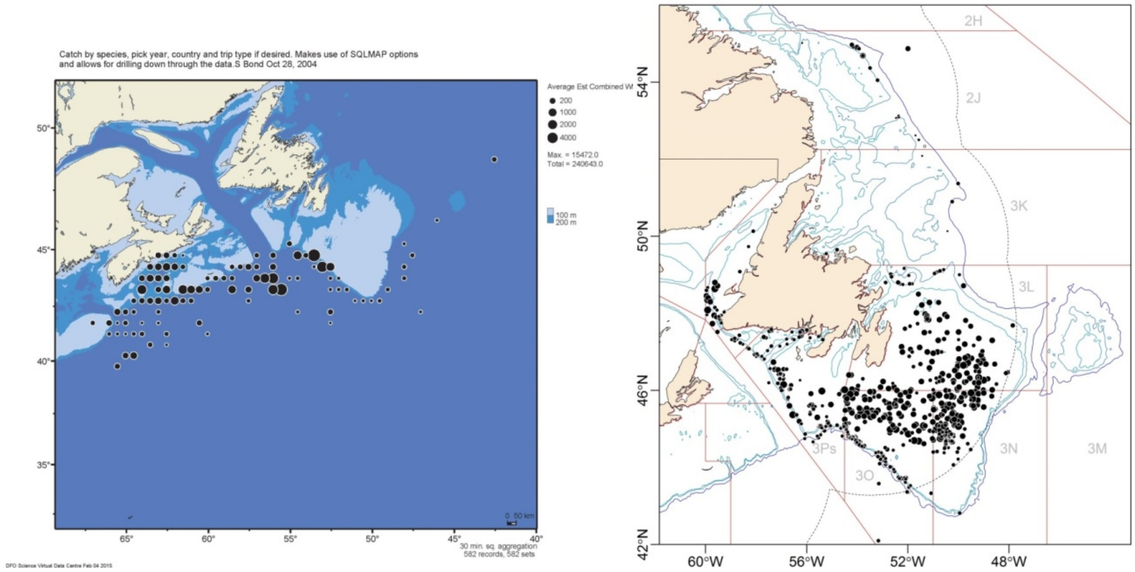


Figure 3. Porbeagle catch locations in all pelagic longline fisheries as recorded by at-sea Maritimes Observers, 1998-2014 (Left Panel). Porbeagle distribution based on at-sea Newfoundland Fisheries Observer data, 1995-2013 (Right Panel).

Abundance and Trends

Porbeagle abundance in the NW Atlantic population was estimated with a forward-projecting age- and sex-structured population dynamics model (Campana et al. 2010b). Within this model, the population was projected forward from an equilibrium starting abundance and age distribution by adding recruitment and removing catches. A key assumption of the model is that Porbeagle abundance was at an unfished equilibrium at the beginning of 1961, when the directed commercial fisheries for Porbeagle began. Model parameter estimates were obtained by fitting the model to catch, Catch Per Unit Effort (CPUE), length frequency, and tagging datasets using maximum likelihood. Four model variants were produced, differing only in their assumptions of population productivity.

All modeled runs indicated that abundance of Porbeagle in the NW Atlantic declined during the 1960s, increased slightly during the late 1970s and early 1980s, and decreased again during the late 1990s (Figure 4). Estimates of the population size in 2009 ranged from 196,911 to 206,956 sharks, or approximately 22% to 27% of its size in 1961. Female spawner abundance was estimated to be approximately 16% of what it was in 1961. Total Porbeagle biomass was estimated to be around 10,000 metric tonnes (mt) in 2009; this places the 2009 value at between 20-24% of its value in 1961 and 4-22% higher than it was in the year 2001. Assuming Shelf-Edge selectivity, the models placed vulnerable biomass in 2009 (mid-year) for the entire population at approximately 4,700-5,100 mt.

The decline in total and spawner abundance appears to have halted sometime after the quota reductions in 2002. Although Porbeagle abundance has been relatively stable since 2002, there has been a very slight increase in abundance of both spawners and recruits since 2006. This upturn in abundance suggests that the population may have entered the initial stages of recovery. Population size is expected to increase now that exploitation rates have been lowered, although recovery times are expected to be slow. A challenge in estimating population abundance in the future will be reliable data for fishing mortality (e.g. accurate bycatch data and landings outside Canada's EEZ) and the absence of data from a directed fishery, which were major inputs to the population model.

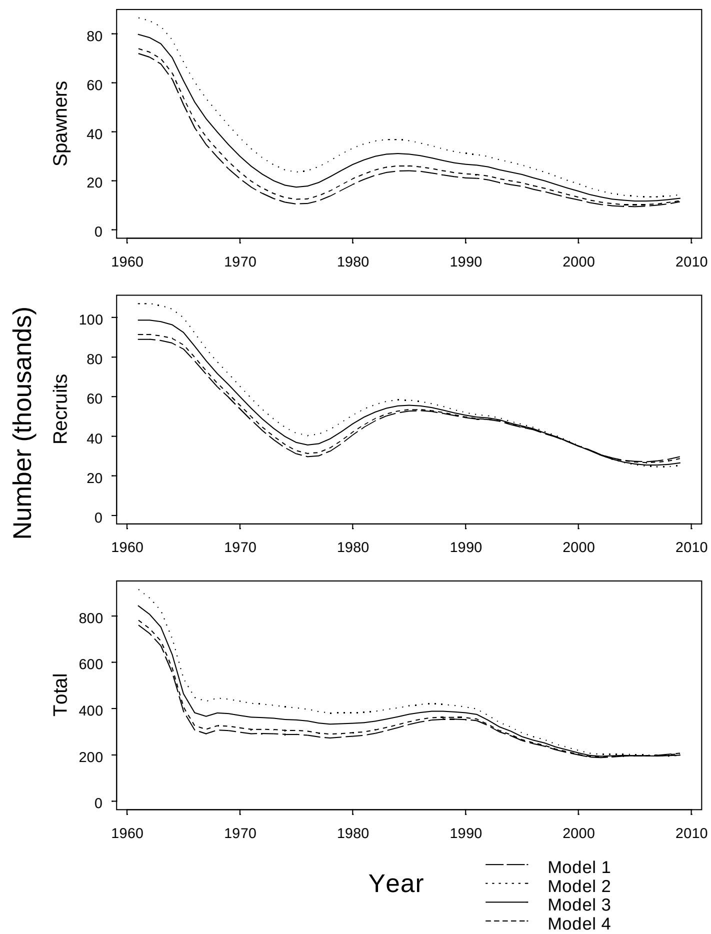


Figure 4. Comparison of the predicted time series for female spawner abundance (spawners), recruitment at age-1 (recruits) and total number (total) from each of the four population models. The line styles indicate differing incidental harm rates.

Fishery-independent surveys of Porbeagle shark abundance were carried out by Atlantic Canadian fishermen working in conjunction with DFO scientists in 2007 and 2009. The objective of the surveys was to provide a baseline for monitoring population health and abundance of Porbeagle found off of Atlantic Canada. The surveys covered 50 fixed stations in Atlantic Canada that extended from the Canada-U.S. border of Georges Bank to southern Newfoundland and Labrador. Station spacing was not uniform throughout the survey area and tended to be denser on the Scotian Shelf. Pelagic longline gear fit with #8 or #9 J-hooks and baited with squid was fished from the surface to the bottom and back, at repeating intervals. A total of 600 hooks were fished each set, with a total soak time of about 6 hours. Scientific staff were present on the survey boats throughout the survey.

Porbeagle were caught throughout the survey area (n_{2007}=865; n_{2009}=488), but were most common around the deep basins and edge of the continental shelf (Figure 5). Mature female Porbeagle were only caught on the shelf edge. No appreciable change in Porbeagle abundance would be expected between 2007 and 2009 given the low commercial catches during that period and the low intrinsic population productivity. Thus, the real value of the shark survey will become apparent if the 2007 and 2009 survey results (which are calibrated against the most recent year of the population model abundance estimate) can be compared to results of future survey years, by which time more change in population abundance might be expected.

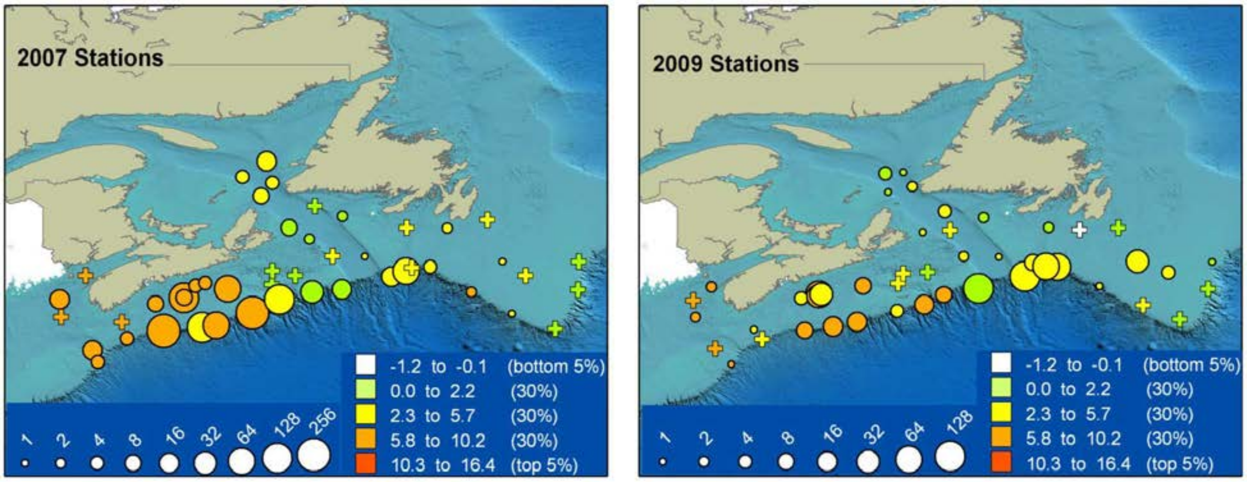


Figure 5. A comparison of Porbeagle survey abundance in 2007 and in 2009. Circles indicate Porbeagle catch while crosses indicate nulls. Catch abundance per survey station is represented by a graduated symbology, whereas average temperature at the depth of the gear is represented by a colour ramp.

ASSESSMENT

Habitat and Residence Requirements

Porbeagle are pelagic sharks, and thus have no affinity for the ocean bottom. They are widely distributed in inshore and offshore waters throughout Atlantic Canada, and their distribution appears limited only by salinity and temperature. Salinity is limiting only in that Porbeagle require saltwater, although they appear tolerant to temporary exposure to estuarine waters. Water depth is not limiting since satellite tags have recorded Porbeagle anywhere between the surface and a depth of 1360 m.

Porbeagle appear to occupy relatively cool water temperatures throughout the year, with 50% being caught between 5-10°C (based on temperature at the depth of the gear). Temperature at depth is a significant predictor of catch rate, while sea surface temperature is not. There is no significant seasonal pattern in temperature, suggesting that Porbeagle adjust their location to occupy the preferred temperature range. Catch rates in the 2007 and 2009 surveys were highest in water temperatures of 6°C (at the depth of the fishing gear) and at depths of 100 m, with very low catch rates observed in waters colder than 2°C and warmer than 10°C. In contrast, results from PSATs indicate that Porbeagle can reside in slightly warmer temperatures than those suggested by fishery captures, with 50% of their time being spent between 8-13°C. For much of the spring commercial fishery, Porbeagle were caught most frequently in waters immediately adjacent to the frontal edge separating cool Shelf waters from warmer offshore waters. Porbeagle were not associated with fronts in the fall fishery, although the temperature occupied was similar to that observed in the spring (5-10°C). Porbeagle captured in the June shark surveys were caught most frequently in water temperatures (at the depth of the hook) of 2-11°C.

There are only two life history stages of the Porbeagle that appear to be spatially concentrated: pupping stage and mating stage. Based on satellite tags, all pupping appears to take place in spring in and around international waters of the Sargasso Sea at depths of around 500 m. Since the Sargasso Sea pupping grounds are well outside of Canadian waters the habitat characteristics of the pupping grounds have not been considered here. Research and observations of mature females and early-stage pregnancies identified a mating ground on Grand Banks in the offshore of southern Newfoundland and at the entrance to the Gulf of St. Lawrence (Jensen et al. 2002). Similar mature female aggregations suggest a second mating ground on Georges Bank.

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 pelagic life history of Porbeagle.

Threats and Limiting Factors to Survival and Recovery

Threats to Population

Fishing is the only known source of human-induced mortality on Porbeagle in Atlantic Canada (Table 1). Overfishing, both directed and as bycatch, was identified as the most important threat to Porbeagle in the 2014 COSEWIC status report, although it was acknowledged that most of the population decline occurred due to overfishing in the 1960s. With closure of the Canadian Porbeagle directed fishery in 2013, the only remaining source of fishing mortality in Canada's exclusive economic zone (EEZ) is bycatch. There are unknown and unregulated catches outside of Canadian waters.

Historically, Porbeagle landings in Canada's EEZ increased from about 1,900 mt in 1961 to more than 9,000 mt by 1964, and then subsequently declined to less than 1,000 mt in 1970 as a result of the collapse of the fishery. Reported landings remained less than 500 mt until 1989, and then increased to a high of about 2000 mt in 1992. Landings since 1998 have been restricted by quota, and have been less than the 185 mt quota since 2007 (Table 1). The directed fishery was closed in 2013, and landings have decreased in recent years and been less than 100 mt since 2009. Most of the recent landings have been bycatch from the groundfish and pelagic longline fisheries. Porbeagle landings in Newfoundland waters peaked in the mid-1990s, and have remained relatively low in recent years. With the exception of a few metric tonnes reported from groundfish gillnets, all of the landings in Newfoundland waters were from Porbeagle-directed pelagic longline fisheries. Very few Porbeagle are taken in the Atlantic Canadian recreational shark fishery.

Some Porbeagle are alive at the time of retrieval to the boat and continue to remain alive following release. However, some sharks die (capture mortality) while on the fishing gear, with a further percentage of the live releases subsequently dying due to stress or injury (post-release mortality). Capture mortality can be measured directly by onboard observers and has been assessed particularly carefully since 2010. From 2010-2014, capture mortality due to hooking estimated by Observers onboard pelagic longline fishing vessels ranged between 23-67%, with an overall mean of 44%. However, there was significant variation in mortality within the pelagic longline category when disaggregated by species sought: hooking mortality was 65% when bluefin tuna was the target species sought, whereas it was 30% when the target species was swordfish. The hooking mortality rate of 20% for other tuna species was based on few observations. Injury rates of 13-18% did not differ significantly with the target species. The observed capture mortality of 235 Porbeagle caught with otter trawlers over the same time period was 7%, while 24% were reported as injured.

Post-release mortality rates of Porbeagle have never previously been reported. Preliminary analysis of 53 PSAT-tagged Porbeagles tagged from 2005-2013 provided 40 records where the PSAT transmitted successfully. All 40 of these sharks were tagged on board the fishing vessel, either by scientists, observers or the fishermen themselves. All four sharks caught and tagged on commercial otter trawlers fishing Georges Bank survived post-release. Five sharks caught in short-duration research sets all survived. Of the 31 Porbeagles caught on pelagic longline trips directing for sharks, swordfish or tunas, 6 of the 29 (21%) healthy sharks died post-release, while the two injured sharks died. Since different fishing gear and methods are used for targeting different species (sharks, swordfish or tunas), there may be differences across fishing gears in the resulting mortality of released Porbeagle.

Table 1. Estimated discards (live and dead) of Porbeagle by DFO Maritimes Region (Scotia-Fundy) fisheries (upper section of the table). Estimated mortality (hooking + post-release) of Porbeagle discards in Canadian waters from all sources (lower section of the table). All values in metric tonnes (mt).

Category	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Porbeagle Discards by Fishery (mt):[a]																			
Swordfish and Tuna LL[b]	9	13	10	11	20	20	31	34	38	41	40	35	31	27	52	60	61	62	61
Porbeagle LL	8	11	10	10	9	7	2	1	2	2	1	1	1	0	0	0	0	0	0
Groundfish LL	0	0	0	0	2	3	2	2	2	3	2	2	2	2	1	9	9	8	8
Groundfish Gillnet	2	5	4	3	5	4	4	5	4	1	1	1	1	1	11	6	5	4	5
Groundfish OTB	1	1	2	1	9	11	10	9	10	35	30	32	32	34	121	100	106	71	81
Total	21	30	25	26	53	45	56	53	56	83	75	70	67	64	194	176	181	146	155
Porbeagle Discards by Source (mt):[a]																			
Reported Landings	1014	1223	916	951	884	497	225	139	219	203	190	93	125	62	83	31	34	19	9
Estimated Total Porbeagle Catch[c]	1046	1260	949	984	946	554	294	220	302	334	314	207	232	157	281	219	232	180	181
Hooking/capture Mortality[d]	10	16	13	13	20	19	20	24	25	26	24	21	19	17	52	49	48	45	46
Estimated Porbeagle Discards (live + dead)	21	30	25	26	45	45	49	53	56	83	75	70	67	64	194	176	181	146	155
Estimated Discard Mortality (hooking + post-release)	15	21	18	18	28	28	30	34	36	41	38	34	31	28	82	77	77	69	72
Sum of Landings and All Discard Mortality	1029	1245	934	969	912	524	255	173	255	244	228	127	156	90	164	108	111	88	81

[a] Discard ratios calculated by five-year blocks.
[b] Hooking and post-release mortality calculated separately for each gear type, as indicated in text.
[c] The sum of total discards + landings does not necessarily equal the estimated total catch, since landings were measured and discards were estimated.
[d] Discards have been calculated for all pelagic longline bycatch and not separated between target species.

For the pelagic longline fishery, applying the 21% PSAT-based mortality rate to the 41% healthy rate (as recorded by observers), and the 100% PSAT-based mortality rate to the 15% observer-based injury rates, implies that the overall post-release mortality rate of live Porbeagles is 42%. When combined with a 44% hooking mortality, and assuming that no Porbeagles were retained, and given that only 56% of the Porbeagles are still alive after capture and before release, the overall non-landed fishing mortality of Porbeagles in the fishery is estimated at 68%.

Although the post-release mortality of healthy sharks caught on otter trawlers was found to be zero, injured sharks were not satellite tagged, and thus mortality is assumed to be 50%. Post-release mortality of all sharks caught in groundfish longlines and gillnets was assumed to be 100%.

These estimates must be considered to be preliminary until a more thorough analysis is completed. For both the pelagic longline (LL) and the Otter bottom trawl (OTB) fisheries, the estimated total discards and discard mortalities can be refined for future assessments. For example, almost all of the Porbeagles caught by OTB were caught during haddock fishing on Georges Bank. As such, observer discard ratios should probably be based on Georges Bank haddock alone, rather than OTB catches of all groundfish in 4X and 5Y, which would almost certainly result in lower total discard quantities. Similarly, pelagic longline discards could be disaggregated into those targeting swordfish and other tunas, for which hooking mortalities are lower, and those targeting Bluefin Tuna, where hooking mortalities are higher. Given the higher observer coverage on bluefin longline vessels, it is possible that the resulting sum of discard mortalities for pelagic longlines would be lower than has been calculated here. The fact that the Porbeagles were brought on board for tagging could conceivably influence their post-release mortality rate. However, the 100% survival rate of both OTB-caught and short duration longline-caught Porbeagles suggests that any boarding effect was small.

Estimates of shark discards by DFO Maritimes Region (Scotia-Fundy) fisheries indicate that about 170 mt (range of 146-194 mt) Porbeagle has been discarded annually by all fisheries combined since 2010 (Table 1). The pelagic longline fishery for swordfish/tuna and the otter trawl groundfish fishery accounted for most of the Porbeagle discards in recent years. Pelagic longline discards of approximately 60 mt per year were greatest in and around Emerald and La Have basins from August through October. Pelagic longline mortalities due to hooking and discarding have exceeded landings each year since 2011.

The groundfish OTB fishery has discarded an average of about 96 mt of Porbeagle annually since 2010, with almost all of that being observed on and around Georges Bank in June and July. There is no other documented location in the NW Atlantic where such a high proportion of mature females have been observed in the catch of any fishery.

In contrast to the pelagic longline and OTB fisheries, Porbeagle bycatch and discards in the groundfish longline and gillnet fisheries have been relatively small (<10 mt each) and dispersed across the Scotian Shelf. Anecdotal evidence suggests that actual Porbeagle bycatch in these fisheries is much larger, and has been underestimated because of very low observer coverage. Catches and discards in Newfoundland and Labrador waters occurred mainly in the Swordfish-directed longline fisheries, and gillnet fisheries directing for White Hake, Atlantic Cod, Monkfish, and Greenland Halibut. Porbeagles are also caught in Yellowtail Flounder-directed otter trawls. Finally, Porbeagle discards by the international high seas fleets are unknown, unregulated, and seldom recorded.

In Canadian waters, Porbeagle bycatch mortality from all sources (capture + post release + landing) has averaged 110 mt annually since 2010.

Threats to Habitat

Given the widespread distribution of Porbeagle in Atlantic Canada, it is unlikely that any anthropogenic event could significantly alter the habitat of the entire population, at least in the short term. However, there are anthropogenic activities that could pose a potential threat to Porbeagle habitat necessary for population viability (e.g. mating grounds and areas of high population density), including noise associated with offshore petroleum exploratory seismic surveys, marine pollution associated with a catastrophic offshore petroleum exploration or development spills, and large scale marine development projects such as pipelines and submarine cables.

Sharks have acute hearing at low frequencies, which they use to locate prey. There has been no research on the effects of seismic sound on sharks to date, but seismic surveys could potentially have behavioural impacts on large pelagic sharks: e.g., a seismic survey in a shark mating area during mating season may lead to a cessation of mating behaviours. This remains an unknown threat, but numerous seismic surveys on the Scotian Shelf and on Porbeagle mating grounds off of southern Newfoundland in recent years are of concern.

A second potential impact is that of catastrophic failure of offshore petroleum operations on or around Porbeagle mating or feeding grounds. Offshore petroleum production operations around both Newfoundland and Sable Island are particularly noted here, as well as the exploratory drilling being discussed for the Gulf of St. Lawrence.

Threats Assessment

Threats were prioritized in a threats table prepared for the single population of Porbeagle, following the requirements laid out by DFO (DFO 2014) (Table 2). The population-level threat risk (PTR) is calculated using rankings for level of impact and likelihood of occurrence and plotting them in the Threat Risk Matrix (DFO 2014) to derive an overall threat risk. The impact of commercial fisheries on the Porbeagle population is related to whether Porbeagle are found in the area where the fishery occurs, the likelihood that the gear will capture Porbeagle, and the level of effort. In areas where there is little or no Porbeagle, the fishery will have no impact on the Porbeagle population. The swordfish and other tuna longline, offshore tuna longline, groundfish long line, groundfish gillnet and otter trawl are considered the greatest current threats based on landings records and discard estimates. Although the threat risk of each fishery independently is considered low/medium (Table 2), the cumulative impacts of all fishing-related mortality would represent a higher threat risk.

Table 2. Prioritized threats table for Porbeagle.

Threat	Likelihood of Occurrence of Threat	Level of Impact of Threat	Causal Certainty of Threat	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Swordfish & Other Tuna Longline	**Known**	**Low/Medium**	**High** There is bycatch, can quantify it	**Low/Medium**	**Current** but at low level, bycatch	**Recurrent**	**Broad/Extensive** potential, can effect throughout the range in Canada, but at low level
Offshore Tuna Longline	**Known**	**Low/Medium**	**High** There is bycatch, can quantify it	**Low/Medium**	**Current** but at low level, bycatch	**Recurrent**	**Broad/Extensive** potential, can effect throughout the range in Canada, but at low level
Directed Porbeagle Longline	**Known**	**Low/Medium**	**High** is not occurring	**Low/Medium**	**Historical**	**Recurrent** was recurrent in the past	**Extensive**
Groundfish Longline	**Known**	**Low/Medium** uncertainty due to low observer coverage	**High** There is bycatch, can quantify it	**Low/Medium**	**Current** but at low level, bycatch	**Recurrent**	**Extensive** potential, can effect throughout the range in Canada, but at low level
Pelagic Gillnet	**Known**	**Low**	**High** There is bycatch, can quantify it	**Low**	**Current** but at low level, bycatch	**Recurrent**	**Narrow** potential, can effect throughout the range in Canada, but at low level
Groundfish Gillnet	**Known**	**Low/Medium** uncertainty due to low observer coverage	**High** There is bycatch, can quantify it	**Low/Medium**	**Current** but at low level, bycatch	**Recurrent**	**Broad** potential, can effect throughout the range in Canada, but at low level
Purse Seine	**Known**	**Low** sharks released alive	**Medium**	**Low** sharks released alive	**Current** but at low level, bycatch	**Recurrent**	**Restricted**
Herring Weir	**Known**	**Low** sharks released alive	**Medium**	**Low** sharks released alive	**Current** but at low level, bycatch	**Recurrent**	**Restricted**
Otter Trawl	**Known**	**Low/Medium**	**High** There is bycatch, can quantify it	**Low/Medium**	**Current** but at low level, bycatch	**Recurrent**	**Extensive** potential, can effect throughout the range in Canada, but at low level
Bluefin Rod & Reel	**Known**	**Low**	**High** There is bycatch, can quantify it	**Low**	**Current** but at low level, bycatch	**Recurrent**	**Restricted**
Recreational and Derby	**Known**	**Low**	**Medium**	**Low**	**Current** but at low level	**Recurrent**	**Restricted**

Threat	Likelihood of Occurrence of Threat	Level of Impact of Threat	Causal Certainty of Threat	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Aboriginal Food, Social, Ceremonial	**Remote**	**Low**	**Very low** no records of Porbeagle being caught	**Low**	**Current**	**Recurrent**	**Restricted**
Offshore Petroleum Seismic	**Known**	**Unknown**	**Very Low** no evidence threat leading to population decline	**Unknown**	**Current**	**Recurrent**	**Broad**
Offshore Petroleum Spill	**Remote**	**Unknown**	**Very Low** no evidence threat leading to population decline	**Unknown**	**Anticipatory**	**Single**	**Broad**
Large Scale Marine Construction	**Unknown**	**Unknown**	**Very Low** no evidence threat leading to population decline	**Unknown**	**Anticipatory**	**Single**	**Restricted**
Scientific Research	**Known**	**Low**	**High**	**Low**	**Current**	**Recurrent**	**Narrow** potential, can effect throughout the range in Canada, but at low level

Recovery Targets and Timeframe for Recovery

Recovery Target

There are no accepted recovery or fishing reference points for Porbeagle. For species managed by the International Commission for the Conservation of Atlantic Tuna (ICCAT), MSY is usually used as a fishing target reference point. An Upper Stock Reference Point of 80% of female spawning stock numbers (SSN) at MSY, $SSN_{80\%}$, is proposed as the population recovery target. Across the four productivity models examined, this would equate to 24,000 to 32,000 mature females (Figure 6). Under model three, which is considered the most realistic productivity model, approximately 27,700 mature females would be required to meet this target.

A generational timeframe for Porbeagle is about 18 years. Using the same recovery timeframe used by COSEWIC, a recovery target for the NW Atlantic Porbeagle population is proposed as achieving $SSN_{80\%}$ at MSY within three generations (or approximately 54 years).

With respect to distribution targets for recovery, there is no evidence for a reduction in the area occupied by Porbeagle. A reasonable recovery target would be to maintain current distribution.

Timeframe for Recovery

In the last complete Porbeagle stock assessment (Campana et al. 2010b), population viability analysis (PVA) was used to evaluate recovery potential, recovery trajectories and recovery times. The base year for the model predictions is 2009. At the time, recovery targets had not yet been established for Porbeagle, so how differing levels of incidental harm (mortality associated with bycatch in fisheries not targeting Porbeagle) affected the recovery timelines relative to two commonly used fishery reference points $SSN_{20\%}$ and SSN_{MSY} was assessed. These are not recovery targets, but are reference points against which population growth can be evaluated. The recovery target proposed here ($SSN_{80\%}$) was not considered at the time, and therefore has not been shown on Figure 6.

All four model scenarios indicated that the NW Atlantic Porbeagle population could recover if levels of human induced mortality were to be kept low (Figure 6). Estimated recovery times to SSN_{msy} (shown) and $SSN_{80\%}$ (not shown) varied depending on the assumed productivity and harvest rate. Based on lower productivity Models 2 and 3, in the absence of human-induced mortality, recovery to $SSN_{80\%}$ was expected to occur between 2030 and 2045, whereas higher productivity Models 1 and 4 predicted recovery as early as 2022. An incidental harm rate of 4% of the vulnerable biomass was expected to delay recovery to $SSN_{80\%}$ to somewhere between 2030 (Model 1, best case scenario) and the 22^{nd} century (Model 2, worst case scenario).

Under what is considered the most realistic of the four productivity models that were examined (Model 3), recovery to $SSN_{80\%}$ in the absence of fishing would occur around 2033, while recovery under recent fishing mortality rates (approximately 110 mt or 2%) would occur around 2042. For purposes of the modeling analysis, Porbeagle fishing mortality outside of Canada’s EEZ is assumed to remain low and constant.

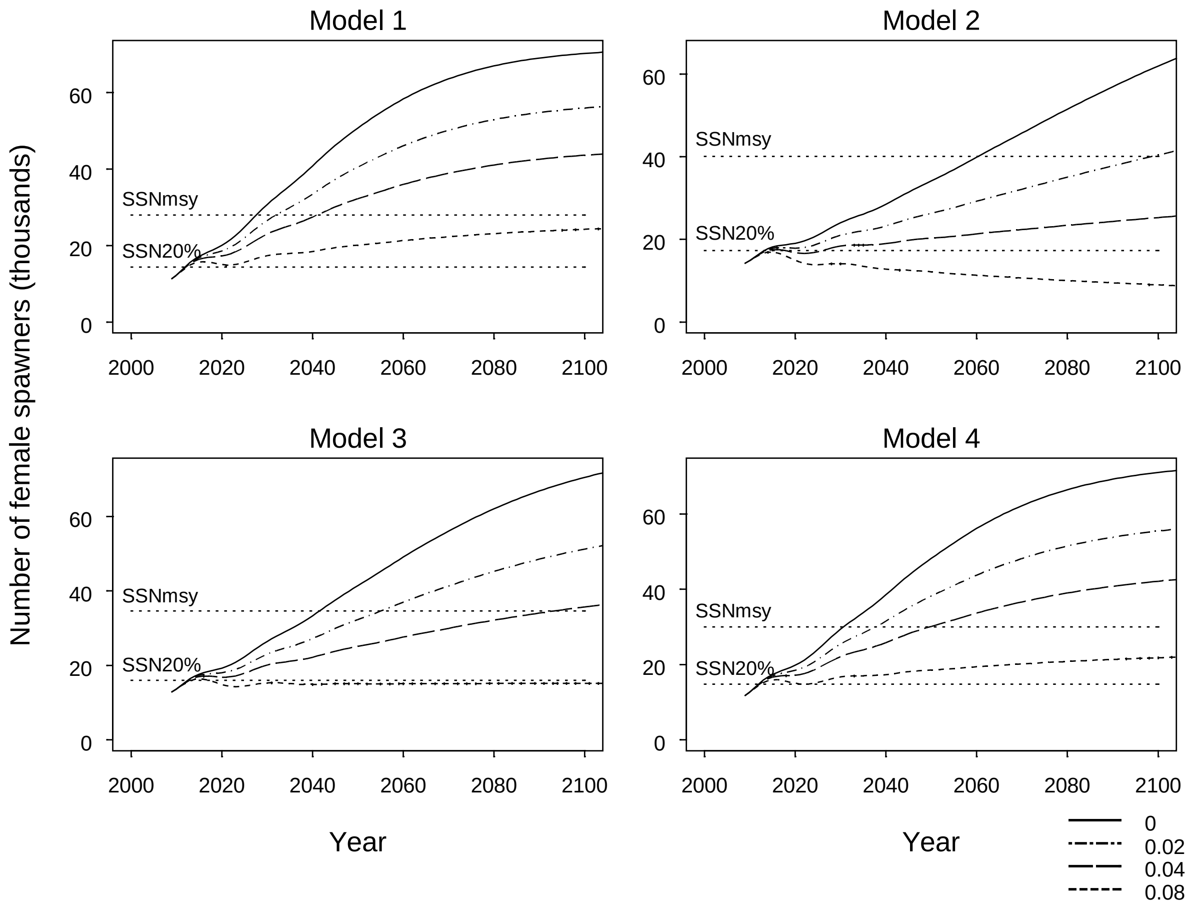


Figure 6. Comparison of recovery trajectories obtained from each of the four modeled scenarios presented in Campana et al. (2010b). Population projections begin in 2009 from the abundance by age and sex predicted by the model, which are projected deterministically using the life history parameters obtained from the model and the assumed exploitation rate. The line styles indicate differing incidental harm rates.

Mitigation Measures and Alternatives

Threats to Porbeagle have already been significantly reduced in Canada from the suspension of the Porbeagle directed fishery and from reduced market demand for the shark, resulting in lower landings. The 185 mt TAC, set at a level to allow for slow recovery of the species remains in place. The main threat to Porbeagle in Canadian waters continues to be mortality from fishery interactions. Porbeagle mortality has decreased to lower levels in recent years (Table 1). With the cessation of a directed fishery, bycatch interactions are having the biggest impact on Porbeagle survival and recovery.

Further mitigation measures to reduce Porbeagle mortality could include:

- No authorization for any harvest of Porbeagle in any commercial, recreational or derby fishery. Although this option is easy to introduce, the landings in Canadian waters are already at low levels, and further reductions would not have an impact on fishery interactions where the Porbeagle may already be dead when retrieved to the boat. Nevertheless, release of all live Porbeagle would improve recovery probability.

- Spatial or temporal area closures to avoid sensitive life history aggregations (e.g. mating areas and pregnant females off southern Newfoundland and on Georges Bank in summer) and areas of high density (e.g. Emerald Basin in fall).
- Develop a best practice for handling and release protocol to support increased survivability of Porbeagle from fishery interactions.
- Increase observer coverage, particularly where there is no or very low observer coverage, to ensure that Porbeagle mortality remains within acceptable limits and to improve estimation of Porbeagle bycatch, either through traditional observer program or through alternate methods such as video monitoring.

This is not considered to be an exhaustive list of possible mitigation measures. Given the fact that the population model is now five years old and that the selectivity of the various mitigation scenarios is so different, it was not possible to project population trajectories under the various scenarios.

Allowable Harm

Estimates of vulnerable biomass in 2009 (assuming Shelf-Edge selectivity) varied from 4700-5100 mt (Campana et al. 2010b). The current TAC in Canadian waters for Porbeagle of 185 mt corresponds to slightly less than a 4% harvest rate, and would allow slow population recovery. The current 2% mortality rate from all sources (based on 110 mt bycatch mortality since 2010) would allow the population to recover under all scenarios and at a faster rate than the 4% total allowable catch (185 mt) mortality rate. Total harm to the population (from all sources, including capture mortality, post release mortality, and landings) should not exceed a 4% mortality rate to allow the population to continue to increase and move towards the recovery targets. Mortality rates beyond 4% (Figure 6) did not reach the recovery targets in all modeled scenarios.

Sources of Uncertainty

- There are no current monitoring programs for Porbeagle abundance or population status. The population model used to assess population status to date requires directed CPUE and length frequency data as input, and thus provides no useful information in the absence of a directed fishery. While anecdotal comments have been made about increases in Porbeagle abundance, there is no current monitoring program to corroborate this. A fishery-independent survey is the best method for monitoring Porbeagle population status in the absence of a directed fishery, but no such survey is currently planned.
- The observer-based reporting level of Porbeagle condition has declined in recent years, which affects the precision of the post-release mortality estimates.
- Observer coverage is very low or nonexistent in some fisheries, which leads to higher uncertainty in the catch rates, discards, and status of Porbeagle, 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 post-release mortality of injured Porbeagle is uncertain because of the small sample size. Further investigation is needed to reduce the uncertainty in these estimates. Furthermore, post-release mortality was only studied in the pelagic longline and otter trawl fisheries. The post-release mortality of Porbeagle in all other fisheries is unknown.
- The impact of anthropogenic activities in the marine environment (e.g. seismic, marine development projects, etc.) on Porbeagle is unknown but could be significant.

Research Recommendations

- Update trends and status of Porbeagle:
  - There are no existing monitoring programs for Porbeagle abundance or population status. The population model used to assess population status to date requires directed CPUE and length frequency data as input, and thus provides no useful information in the absence of a directed fishery. CPUE based on landings would provide too little data to be useful. It is likely that Porbeagle bycatch CPUE in the pelagic longline fishery could be used to provide an index of abundance, but the current at-sea Observer coverage is too low to provide a useful index. Substantially higher observer coverage of the pelagic longline fleet, especially around Emerald Basin and near the edge of the Scotian Shelf, is the most useful source of information for a Porbeagle abundance index.
  - There have been two fishery-independent Porbeagle surveys conducted in the past. These surveys were conducted near the end of the population model time series, and thus could be scaled to the terminal population estimates from the model. With this scaling in place, periodic surveys (e.g., at 5-year intervals) would be a useful way to monitor Porbeagle population recovery status.
- Increase observer coverage in fleets with high sources of uncertainty to improve the accuracy of the total bycatch and discard amounts.
- Investigate capture mortality for all gear types that have not been investigated yet and incorporate into population models.
- Study site fidelity of mature female Porbeagle in Canadian waters to determine if those mating off of Georges Bank use the same pupping ground as those mating off of southern Newfoundland.

SOURCES OF INFORMATION

This Science Advisory Report is from the 19-20 February 2015, zonal peer review on “Recovery Potential Assessment – Porbeagle (*Lamna nasus*)” to update and support specific processes with regards to recovery targets, allowable harm, and other related aspects of SARA. Additional publications from this process will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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