Fisheries and Oceans Canada | Pêches et Océans Canada
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**Maritimes, Newfoundland and Labrador, Gulf, and Quebec Regions**

**Canadian Science Advisory Secretariat
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# TOTAL FISHING MORTALITY AFFECTING PORBEAGLE SHARK IN ATLANTIC CANADIAN WATERS

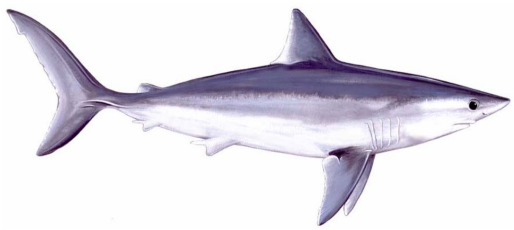

*Photo: Porbeagle Shark (*Lamna nasus*). Source: Species at Risk Public Registry.*

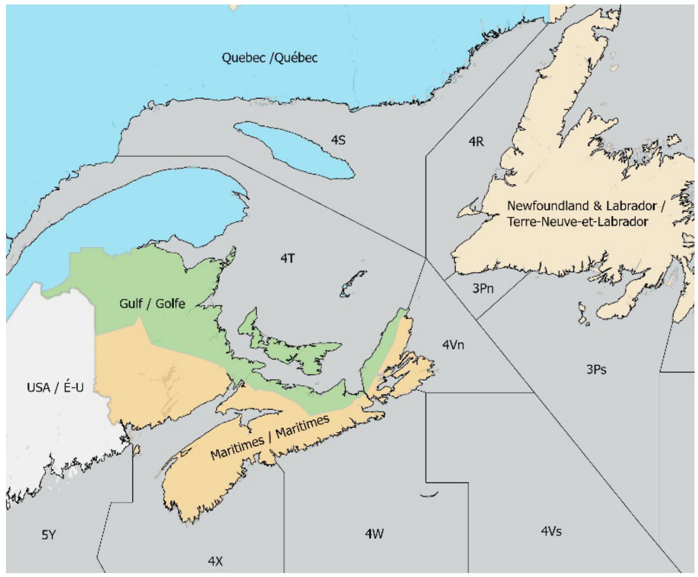


*Figure 1. Map indicating Northwest Atlantic Fisheries Organization (NAFO) divisions and Newfoundland and Labrador (beige), Quebec (blue), Gulf (green) and Maritimes (yellow) Fisheries and Oceans Canada Administrative regions.*

## Context:

*The Northwest Atlantic population of Porbeagle Shark (*Lamna nasus*) is distributed throughout Atlantic Canadian waters. The population was assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada in 2014 and is being considered for listing under the Canadian Species at Risk Act (SARA). A 2015 assessment of allowable harm determined that total mortality must not exceed 185 metric tonnes (mt) annually to allow abundance to increase.*

*The Fisheries and Oceans Canada (DFO) Science Branch was requested to: estimate the total commercial catches of Porbeagle Shark in the Maritimes, Gulf, Newfoundland and Labrador, and Quebec regions; determine the proportion of Porbeagle bycatch attributed to specific fisheries and retained by each; evaluate the spatial and temporal distribution of bycatch and how it has changed over time; estimate post-release mortality for discards from each fishery/gear type; describe uncertainties in the estimates of bycatch and mortality and identify gaps in available data sources; and, explore various methods to address the above objectives, including approaches used in other jurisdictions.*

*Addressing these objectives was difficult due to the diversity of fisheries that catch Porbeagle, and the characteristics of commercial and at-sea observed data collected from these fisheries. Results should be considered highly uncertain and the magnitude of annual Porbeagle mortality in Canadian waters is likely underestimated.*

## SUMMARY


- Porbeagle Shark (*Lamna nasus*) are intercepted as bycatch from numerous fisheries in the Maritimes (MAR), Newfoundland and Labrador (NL), Gulf (GULF), and Quebec (QC) regions.
- From 2015 onwards, Porbeagle Sharks have been considered bycatch as there has been little incentive to land the species due to its low economic value. Given changes in fishing practices, these analyses considered data from 2015–2021.
- The three components of fishing mortality were considered: landings, at-vessel mortality (AVM), and post-release mortality (PRM) of discards. AVM represents animals that are dead upon gear retrieval, PRM represents animals that die following release.
- Most Porbeagle landings came from MAR, and landings were sporadic from all other regions. Within MAR, the majority was from benthic longline. However, landings make up a small component of total fishing mortality, as the majority of Porbeagle are discarded.
- Discard information was obtained from Canadian at-sea observer (ASO) data. Discards from observed trips represent a proportion of fishery-wide bycatch; therefore, they must be scaled up to represent fishery-wide values.
- Total discard weights from observed trips were highest in MAR, lower in NL, and lowest in GULF and QC. Fishery-wide estimates will be substantially higher due to low ASO coverage in numerous fisheries.
- Numerous statistical methods to estimate fishery-wide bycatch were identified and examined for ASO data from pelagic longline, given that this gear type was used historically to target Porbeagle. However, the quality and characteristics of the data precluded the use of these methods.
- For fisheries in MAR, total Porbeagle bycatch (kg) on observed trips was scaled up to fishery-wide estimates based on the proportion of trips that were observed.
- For fisheries in NL, total Porbeagle bycatch (kg) on observed trips was scaled up to fishery-wide estimates based on the proportion of target species landings that were observed.
- Bycatch weight on observed trips from fisheries in QC and GULF was not scaled up due to the lack of information on observer coverage levels and low levels of bycatch.
- There was information on AVM and PRM rates from few fisheries. Example scenarios applied different assumed AVM and PRM rates for fisheries in MAR and NL to estimate fishery-wide dead discards. The annual estimates varied by 6–20% among scenarios.
- Given demonstrated challenges and limitations of the available data, it is not possible to derive meaningful estimates of total annual fishing mortality of Porbeagle.
- Interpretation of the implications or impacts of observed increases or decreases in annual fishing mortality is not possible without information on underlying abundance and status of infrequently observed, discarded bycatch species (such as Porbeagle). This limits the utility of estimates of fishing mortality to address conservation or management goals, and warrants consideration of an alternate framework to quantify threats to bycatch species from fisheries.

# BACKGROUND

Commercial fishing on Porbeagle Sharks in the Northwest Atlantic began in 1961. Canadian participation in the fishery started in 1991 and continued until the directed fishery closed in 2013. In 2014, the population was designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada, and international trade was restricted under the Convention on International Trade in Endangered Species of Wild Fauna and Flora. From 2015 onwards, Porbeagle Sharks were considered incidental catch or bycatch. The 2015 assessment of allowable harm determined that total fishing mortality must not exceed 185 mt annually, which corresponded to slightly less than 4% harvest rate from estimated population size in 2009, to allow abundance to increase (Campana et al. 2015).

Fishing mortality consists of landings, as well as at-vessel and post-release mortality (AVM and PRM) of discards. AVM represents the number or weight of animals dead upon retrieval of fishing gear. PRM occurs when animals are discarded alive yet subsequently die due to injuries sustained during the capture process. Quantifying mortality of discards relies on two components: (1) fishery-wide estimates of the magnitude of discarded catches and (2) gear-specific estimates of AVM and PRM rates. Other sources of human-induced and natural mortality were not considered in this assessment.

# ASSESSMENT

## Landings

Landings of Porbeagle Shark were extracted from the regional Zonal Interchange File Format (ZIFF) database, which contains all commercial logbook reports by Canadian fisheries. Landings are reported in weight (kg) rather than number of animals, and round (whole fish) weights were extracted. Round weights may incorporate conversion factors if fish were landed dressed (gutted).

Throughout 2015–2021, total landings have remained extremely low from Atlantic Canadian fisheries, dropping from approximately 4 mt in 2015 to less than 200 kg in 2021 (Table 1). Most Porbeagle landings came from MAR, and landings were sporadic from all other Fisheries and Oceans Canada (DFO) Administrative Regions. Within MAR, the majority of landed weight was from benthic longline. However, landings make up a small component of total fishing mortality as the majority of Porbeagle are discarded.

*Table 1. Porbeagle Shark landings (kg) by gear type in the Gulf (GULF), Newfoundland and Labrador (NL), Quebec (QC) and Maritimes (MAR) Fisheries and Oceans Canada Administrative regions, 2015–2021.*

| Region | Gear | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|
| GULF | Longline* | 0 | 107 | 0 | 0 | 0 | 0 | 0 |
| NL | Longline* | 167 | 0 | 0 | 0 | 0 | 0 | 0 |
| NL | Handline | 0 | 0 | 0 | 10 | 0 | 0 | 0 |
| QC | Longline* | 0 | 0 | 0 | 0 | 0 | 108 | 0 |
| QC | Not reported | 0 | 227 | 0 | 0 | 0 | 0 | 0 |
| MAR | Otter trawl | 351 | 210 | 127 | 92 | 0 | 0 | 0 |
| MAR | Set gillnet | 741 | 199 | 391 | 30 | 202 | 0 | 0 |
| MAR | Pelagic longline | 503 | 107 | 27 | 0 | 0 | 0 | 0 |
| MAR | Benthic longline | 2,004 | 967 | 927 | 506 | 102 | 126 | 198 |
| MAR | Handline | 0 | 169 | 39 | 42 | 0 | 0 | 0 |

* Type of longline not specified.

## Observed discards

Information on the species composition and weight of discards from Canadian fisheries comes from at-sea observer (ASO) programs (Beauchamp et al. 2019). Typically, shark catches are reported by species, and kept or discarded weights (kg). Weights are estimated because crew do not have the ability to weigh individual sharks at sea. The condition of discards (healthy, injured, dead) is assessed visually.

Depending on the fishery, observers may not be able to watch every set on an observed trip (e.g., while sleeping). In advance of this assessment, it was not possible to prorate the observed weight of Porbeagle by the proportion of the sets that were monitored due to the diversity and amount of data considered. This means some of the ASO data were transcribed from industry logbooks and likely underestimate bycatch. Nearly 100% of benthic and pelagic longline sets were monitored on an observed trip, but Porbeagle bycatch weights from other gear types were underestimated by an unknown degree.

Discards of Porbeagle on ASO monitored trips were highest in MAR (Table 2). Of Maritimes fisheries, only the Cod/Haddock/Pollock fishery in Northwest Atlantic Fisheries Organization (NAFO) Division 5Z had observer coverage greater than 25% annually; therefore, observed discard totals were substantially lower than the amount of bycatch occurring across the whole fishery. Discards were observed from diverse fisheries using a variety of gear types, including benthic and pelagic longline, otter trawl, gillnet and purse seine. There was a substantial amount of fishing effort (e.g., multispecies flatfish, small pelagics) that had no ASO coverage or no observed Porbeagle discards on observed trips.

In the NL region, discards of Porbeagle from ASO monitored trips were typically an order of magnitude lower than in MAR from 2015–2021 (Table 2). Annual ASO coverage varies in NL commercial fisheries, with the majority in the range of 0–5%, yet there are examples of very high coverage (e.g., 3LNO Yellowtail with nearly 100%). Similar to MAR, observed discard totals of Porbeagle Shark were substantially lower than fishery-wide bycatch when ASO coverage was low.

In the Gulf and QC regions, ASO data indicated very low levels of Porbeagle Shark discards in any year from 2015–2021 (Table 2). Due to the scarcity of data, the fisheries associated with these discards was not determined so ASO coverage levels were unknown.

*Table 2. Discards (kg) of Porbeagle Shark on trips monitored by at-sea observers in Maritimes (MAR), Gulf (GULF) and Quebec (QC), and Newfoundland and Labrador (NL) regions, considering all fisheries and gear types from each region.*

| Region | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|
| MAR | 21,251 | 25,136 | 24,861 | 28,105 | 23,961 | 11,706 | 4,588 |
| NL | 1,089 | 1,294 | 2,092 | 1,998 | 1,599 | 6,266 | 7,617 |
| QC + GULF | 0 | 90 | 285 | 300 | 75 | 868 | 650 |

## Fishery-wide discard estimates

A suite of analytical approaches was identified that could be applied to set-level data and used to estimate fishery-wide bycatch (Hastie et al. 2009, Gavaris et al. 2010, Themelis and den Heyer 2015, Stock et al. 2019). These included simple approaches such as means, stratified means and catch ratios, as well as more complex methods such as nearest neighbor interpolation, random forests, generalized linear mixed models, and spatiotemporal models. Previous evaluations of bycatch from Canadian fisheries tended to use catch ratios (e.g., Gavaris et al. 2010, Themelis and den Heyer 2015), yet more complex methodologies are increasingly being applied in Canada and elsewhere (e.g., Stock et al. 2019, Jubinville et al. 2021).

The directed fishery (1991–2013) for Porbeagle Shark used pelagic longline gear, so preliminary model evaluation was conducted using ASO data from the Swordfish and Other Tunas fishery which also uses pelagic longline gear. To increase the amount of information available, nearly all years following the implementation of an expanded ASO shark monitoring protocol were included (2011–2020). Data from 2021 were too limited to be informative and so were not considered.

The number of sets observed each year (51–155) was small relative to the spatial region used by the commercial fishery. In addition, greater than 75% of observed sets in each year did not catch Porbeagle. These two characteristics indicate extremely limited and highly zero-inflated data. Meaningful predictions of bycatch magnitude and spatial distribution might be expected when:

- Interaction rates are high with the bycatch species of interest (i.e., the species is caught on the majority of observed trips).
- The majority of commercial sets are observed.
- Observed sets are known to be representative of the commercial fishery.
- There is relatively low spatial and/or temporal variability in bycatch events (high signal-to-noise ratio).
- Correlations between bycatch and target species catches are high (for catch ratio methods).
- Bycatch magnitude is related to measured covariates (for complex modeling approaches).
- Independent data exist for comparison (e.g., fishery-independent sampling).

Evaluation of the Porbeagle data from pelagic longline captures and preliminary model fits from each analytical approach did not meet any of these criteria, so statistical modeling was not pursued.

As an alternative, the simplest metric that can be used to estimate fishery-wide bycatch scales up the summed discarded weights on all observed trips by the proportion of observed effort. For fisheries in MAR, Porbeagle bycatch on observed trips ($N_{obs}$) was scaled up to a fishery-wide estimate ($N_{fishery}$) based on the proportion of observed trips ($p_{obs}$).

$$N_{fishery} = N_{obs}/p_{obs} \quad (1)$$

The proportion of observed trips could not be calculated for fisheries in NL because commercial data stored in ZIFF-NL does not have a variable that identifies unique trips. For fisheries in NL, $p_{obs}$ represented the weight of target species kept for processing on observed trips divided by total commercial landings of the target species from the ZIFF database (representing trips that landed their catches in the Newfoundland region). This provides a fraction of how much of the target species' catch was observed by an ASO.

Bycatch weight on observed trips from fisheries in QC and GULF were not scaled up to fishery-wide totals due to the scarcity of data and unknown ASO coverage.

## Total Fishing Mortality

The condition of kept catches (alive, dead) or discards (dead, injured, healthy, sharkbit or unknown) was recorded from ASO data in the Swordfish and Other Tunas pelagic longline fishery (n = 277) and the mobile gear otter trawl fishery for Cod/Haddock/Pollock (n = 809) in MAR. Shark condition was not available from other fisheries in MAR, or any NL, GULF or QC fishery for this assessment.

### At-vessel mortality

The proportion of captures released alive was calculated as the sum of all healthy and injured releases, divided by the total number released from all condition categories, excluding 'unknown'. During 2015–2021, values averaged 64% released alive from pelagic longline and 80% released alive from otter trawl. Anecdotal information from NL supports the conclusion that survival is high following capture by otter trawl. The corresponding AVM rates were 36% for pelagic longline and 20% for otter trawl.

### Post-release mortality

Quantifying post-release mortality from fish released alive requires tagging with pop-up archival satellite tags (PSATs) to determine the fate of each released fish. If the tagging includes both healthy and injured animals, the mortality rate of healthy and injured animals is weighted by the proportion of each injury category in the captures when calculating overall PRM. PRM has only been estimated from captures by pelagic longline in the Swordfish and Other Tunas fishery.

PRM estimates were 0.06 (CI = 0.02, 0.17) for healthy and 0.40 (CI = 0.19, 0.65) for injured animals. Accounting for the relative frequency of the condition categories in the commercial catches gave a weighted mean PRM mortality rate of 15% (Bowlby et al. 2019).

### Mortality of discards

Mortality of discards (i.e., dead discards) becomes the sum of AVM and PRM from all fisheries. Two mortality scenarios were compared in this assessment.

The first scenario incorporated an AVM rate of 36% for all types of longline, 20% for all types of otter trawl, and 100% from gillnet. The PRM rate of 15% was applied to releases from all types of longline. PRM from gillnet was zero because AVM was 100%. All other captures were from otter trawl, and the condition monitoring from otter trawl in the Cod/Haddock/Pollock fishery suggested that 80% of releases were healthy and 20% were injured. To approximate PRM for all otter trawl fisheries, the condition-specific PRM rates of 6% for healthy and 40% for injured were applied to the proportion of discards that were healthy and injured, respectively. The weighted mean PRM rate applied to discards from otter trawl was 16%.

The second mortality scenario used the 75$^{th}$ quantile of the estimates of AVM rather than the mean value, which was 49% from pelagic longline in the Swordfish and Other Tunas fishery and 24% from otter trawl in the Cod/Haddock/Pollock fishery. All PRM rates were the same as described in the first scenario. The decision was made to vary AVM because this component of mortality contributes more than PRM to the total and there were observed data that could be used to calculate variability.

The combined annual estimates of dead discards from MAR and NL were 6–20% higher in scenario 2 compared to scenario 1 (Table 3).

*Table 3. A comparison of two mortality scenarios of discards from the Maritimes and Newfoundland and Labrador regions, representing the summed weight in kg of at-vessel and post-release mortality from all fisheries in each year. The fishery-wide estimate of total bycatch (kg) and the percentage that mortality differs between the scenarios are also shown.*

| Year | Total bycatch | Scenario 1 | Scenario 2 | Difference |
|---|---|---|---|---|
| 2015 | 195,173 | 79,409 | 92,928 | 17% |
| 2016 | 95,744 | 43,612 | 49,664 | 14% |
| 2017 | 201,764 | 124,918 | 135,312 | 8% |
| 2018 | 187,368 | 72,791 | 87,277 | 20% |
| 2019 | 199,530 | 104,128 | 110,614 | 6% |
| 2020 | 73,571 | 24,789 | 28,613 | 15% |
| 2021 | 31,614 | 10,715 | 12,390 | 16% |

### Total Fishing Mortality

Total annual mortality was calculated as the sum of landings, plus AVM and PRM from the two scenarios described above, applied to: (1) the fishery-wide estimate of discards for MAR and NL, and (2) observed discards in GULF and QC. Mortality associated with a fishery-independent Porbeagle survey in 2017 was also included. When gear type was not specified for discards in GULF and QC, AVM was assumed to be 0.36 and 0.49 in the two scenarios, respectively (the values used for longline). For scenario 1, total fishing mortality ranged between 11.1 mt and 136.9 mt. For scenario 2, total fishing mortality ranged between 12.9 mt and 147.3 mt.

## Sources of Uncertainty

Several limitations inherent to data collection prevent rigorous science advice on total fishing mortality for Porbeagle Sharks.

At capture, observers use a visual assessment of shark length to approximate its weight. Accuracy depends on how long the shark was visible, how close it was to the vessel (if discarded in the water), and the estimation ability of the individual observer.

When data are subsequently archived in catch databases, conversion factors are embedded in ZIFF to calculate round (whole) weight from sharks that are landed dressed (gutted). These were developed in the early 2000s and cannot be updated because Porbeagle are now rarely landed (developing this conversion factor necessitates killing the sharks).

The assessed condition of shark captures was much more variable from pelagic longline than from otter trawl, likely because animals were assessed while in the water rather than while onboard. Lower certainty in AVM for pelagic longline also affected fisheries using benthic longline when calculating fishery-wide mortality.

AVM and PRM rates would vary among fisheries, even those using the same gear general type (e.g., Gilman et al. 2022). The amount of variability in AVM from captures on different types of otter trawl or longline could not be determined, which is why assumed rates were used in the mortality scenarios.

It was computationally simple to scale up observed bycatch to fishery-wide totals using the proportion of observed effort, but discard estimates were extremely variable (chance captures of Porbeagle on one or two observed trips could scale up to multiple tonnes of discards). Discards for the majority of fisheries were zero in several years because of small sample sizes (i.e., low ASO coverage). It is unlikely that discards vary so widely among years.

### Factors contributing to bias

There were several fisheries or components of fisheries identified in this assessment that did not have any ASO coverage, but used gear types that would be expected to catch Porbeagle. Total bycatch was underestimated from those fisheries.

Observed bycatch in GULF and QC was not scaled up to fishery-wide estimates, and was thus underestimated.

All ASO data records from a trip were summed with no consideration of whether each set was witnessed by the observer. Several fleets fish over a 24-hour period or set multiple nets at the same time, yet only a single observer is on the vessel. Porbeagle bycatch was therefore underestimated for fleets in which it was logistically impossible to monitor all sets (e.g., while an observer was sleeping), such as otter trawl fisheries for groundfish.

In MAR, the method used to scale up observed discards to fishery-wide estimates relied on being able to accurately calculate ASO coverage by fishery. However, commercial trips in MAR were difficult to uniquely assign to specific fisheries because licenses are multispecies (i.e., multispecies groundfish) rather than specific to a target (e.g., Atlantic Halibut). Duplicated trips were removed, after making somewhat subjective determinations of the target species. If specific trips were wrongly ascribed to a specific fishery, ASO coverage would be overestimated, and bycatch underestimated.

In NL, the method used to scale up observed Porbeagle discards to fishery-wide estimates relied on being able to appropriately quantify the amount of target landings that were observed relative to the total target species landings from commercial fisheries. However, this proportion could exhibit extreme variability among years (e.g., changing from 0.64 in 2016 to 0.023 in 2017 for Redfish in NAFO Subdivision 3Ps) and there were several instances where the estimate was greater than 1 (suggesting more was observed than was landed in a particular year). For NL fisheries with low ASO coverage targets (0–5%), it is likely that total landings of the target species in ZIFF-NL are underestimated when proportions are greater than 0.05. As with data from MAR, underestimating commercial effort means that bycatch is also underestimated.

## CONCLUSIONS AND ADVICE

It is not possible to derive estimates of total annual fishing mortality of Porbeagle Shark from Canadian fisheries with sufficient precision to manage relative to the estimate of allowable harm (185 mt). The available data allow for a limited understanding of the magnitude of mortality attributable to specific fisheries in a given year, largely due to limited ASO monitoring, low data quality, and challenges related to describing the extent of commercial fishing activity. ASO coverage across fleets would need to increase substantially, and in advance of future analyses, in order to generate sufficient data to obtain reliable estimates of fishing mortality.

### TOR 1: Estimate the total commercial catches of Porbeagle Shark in the Maritimes, Gulf, Newfoundland and Labrador, and Quebec regions, in both tonnage and number of animals

The annual estimates of total commercial catches of Porbeagle Shark in MAR, GULF, QC, and NL could only be derived as a tonnage. Catch number is an optional field in ASO data and there is no representative length-frequency information from Porbeagle commercial catches that could be used to transform tonnage into a number of animals.

For the years considered in this assessment (2015–2021), recorded data led to commercial catch estimates that were imprecise and underestimated by an unknown degree due to:

- Partial reliance on industry self-reporting in both the commercial landings data and ASO records (commercial data in logbooks are not always verified by dockside monitoring, and logbook records are used by an ASO when a specific set could not be monitored on an observed trip).
- Low and/or non-existent ASO coverage in numerous fisheries that have the potential to intercept Porbeagle.
- Annual Porbeagle discards from specific fisheries are extremely variable with a high number of zeros; interception rates on observed trips are similarly variable.
- Relative to other years in this assessment, ASO coverage in 2021 tended to be particularly low. Starting in 2020, restrictions related to the COVID 19 pandemic would have influenced data collection. Data from 2021 were not comparable to other years.

Total commercial catches include all landings and discards from all regions, without consideration of whether the animal was alive or dead at capture or release (i.e., these values represent all bycatch from fisheries, not only the proportion contributing to total mortality estimates). For each year, the fishery-wide discard estimates from MAR and NL (Total bycatch; Table 3), the observed discards from QC and GULF (GC+GULF; Table 2) and all landings (Table 1) were summed to get an annual estimate. Captures from the fishery-independent shark survey in 2017 were not included, because these are not from commercial fisheries. Note that the survey was included in the annual mortality estimates under TOR 4. Excluding 2021, values ranged between 74.7 mt (2020) and 203.3 mt (2017) per year and these should be considered minimum estimates given the caveats above.

### TOR 2: Determine the proportion of Porbeagle bycatch attributed to specific fisheries and retained by each

Similar to the outcomes of TOR 1, it was difficult to accurately attribute the proportion of annual Porbeagle bycatch to specific fisheries, due to:

- Landings could only be evaluated by gear type rather than fishery given the structure of the national ZIFF database.
- There was no objective way to assign commercial trips to specific fisheries for multispecies groundfish licences in MAR that used the same gear, yet interception rates for Porbeagle differed among them.
- There were examples of fleets with landings but no observed discards, due to low/non-existent ASO coverage.
- Observed catches (landings or discards) of Porbeagle were sporadic from numerous regions (particularly GULF and QC) and from different fisheries in MAR and NL.

Porbeagle bycatch was consistently observed in the majority of years from the Atlantic Halibut fishery (benthic longline) and the Swordfish and Other Tunas fishery (pelagic longline) in MAR. From 2015–2021, benthic longline used in the Atlantic Halibut fishery was associated with the highest bycatch of Porbeagle Shark, considering both landings and discard information. High amounts of observed bycatch in the otter trawl component of the Cod/Haddock/Pollock fishery were associated with substantially higher ASO coverage in comparison with other fisheries, resulting in fishery-wide discard estimates that were more similar to observed bycatch. Conversely, there was a notable absence of monitoring or limited monitoring in fisheries using gear types that would be expected to have high mortality for Porbeagle Shark (e.g., set or drift gillnets) in both MAR and NL regions.

### TOR 3: Evaluate the spatial and temporal distribution of bycatch and estimate how it has changed over time

It was not possible to address this TOR with the data available.

The reporting accuracy of set-level positional data in commercial logbooks can be poor (Bowlby et al. *in press*). Points on land were excluded from the data used in this assessment, but other types of positional errors remained (e.g., incorrect NAFO Divisions, points outside Canadian waters). These types of errors can only be corrected by comparisons with paper copies of logbooks, which was a quality control exercise that was into possible to undertake for all fisheries contributing to this assessment, particularly across regions.

Positional errors influence our understanding of the spatial distribution of effort in particular fisheries, by including locations that are not actually being fished. If bycatch at these erroneous locations were to be predicted from a statistical model, positional errors would also influence the spatial distribution of bycatch. This is why our assessment did not show the spatial distribution of observed Porbeagle bycatch relative to the extent of each commercial fishery.

Statistical models must be fit to observed data to predict bycatch magnitude at unobserved locations. These models can be spatially implicit (e.g., stratified means, nearest neighbour interpolation) or spatially explicit (e.g., spatiotemporal models). Combining predictions with the locations of the observed catches gives information on the spatial distribution of bycatch throughout a commercial fishery. For this assessment, statistical modeling could only be explored for one fishery.

None of the identified analytical approaches were pursued, due to:

- High spatial and temporal variability in Porbeagle catches in the pelagic longline data coupled with low sampling and a very high proportion of zeros.
- Poor data quality, in that Porbeagle weights are estimated from the approximate length of each animal and then summed to a total discard weight per set.

- No correlation between Porbeagle bycatch and target species catches, invalidating catch ratio methods.
- Preliminary comparison of multiple modeling frameworks demonstrated similar predictive power from simple and complex approaches, suggesting weak/non-existent relationships with covariate predictors.

Other research has combined all observed data on a particular species to describe spatial patterns in bycatch, irrespective of fishery that it came from (e.g., Jubinville et al. 2021). This assessment showed distinct differences in Porbeagle catchability by different fisheries using the same general gear type (e.g., high interception rates from benthic longline for Atlantic Halibut in comparison with benthic longline for groundfish). These differences in catchability would bias spatial patterns in a combined analysis, overestimating density in the areas targeted by fisheries with high catchability. Thus, combining all data is not appropriate unless differences in relative catchability can be accounted for.

The trends in annual bycatch were not meaningful because of the predominance of zeros in the ASO data. Porbeagle were captured sporadically on observed trips from the majority of fisheries, and it is not possible to scale up a zero. Fishery-wide estimates of Porbeagle bycatch could go from zero to multiple tonnes and back to zero over the course of three years. Such high variability resulted from low ASO coverage as well as the methods used to scale up observed catches to fishery-wide totals in MAR and NL.

Even if a trend could have been described, there was no clear interpretation of what it may have indicated for the status of Porbeagle. There is a tendency to view positive trends in bycatch as a negative characteristic (indicating increased mortality on a population), yet increased bycatch might signify increased abundance and thus be a positive instead of a negative sign (Minami et al. 2007). On the other hand, the magnitude of discarded bycatch is expected to be related to fishery characteristics that influence catchability. If operational characteristics of the fisheries (e.g., spatial distribution, seasonality) and/or changes in the abundance of the target species (via hook exclusion) lead to lower catchability, bycatch can decline without a change in the underlying abundance of Porbeagle.

## TOR 4: When bycatch is discarded, estimate post-release mortality for each fishery/gear type

Mortality during capture and release of bycatch has been estimated in some but not all commercial fisheries. Therefore, assumed AVM and PRM rates were applied to captures by the same general gear type (longline, otter trawl, gillnet, etc.) when fishery-specific data were unavailable. This meant that the magnitude of annual discard mortality was highly uncertain for the majority of fisheries. Condition monitoring to assess AVM occurred in two fisheries in MAR; rates were assumed for 18 other fisheries in MAR and NL plus all observed discards in QC and GULF. PRM has been estimated for one fishery in MAR; rates were assumed for all others. It is critical to consider the number of assumptions contributing to information from a specific fishery in future work.

Annual estimates of dead discards from MAR and NL varied by 6–20% between the two mortality scenarios considered (Table 3). The higher scenario would be more precautionary. If the same mortality assumptions (AVM and PRM rates for each gear type) were applied to observed discards in GULF and QC (Table 2) and added to the values in Table 3, total dead discards ranged from 10.9–125.0 mt in Scenario 1 and 12.7–135.4 mt in Scenario 2. These totals represent the sum of AVM and PRM mortality (dead discards) for all regions. The lowest values in both scenarios were in 2021 and the highest in 2017.

### TOR 5: Describe uncertainties in the estimates of bycatch and mortality and identify gaps in available data sources

Correctly propagating the numerous sources of uncertainty and bias affecting these analyses was not possible from the available data. There is cumulative variability associated with all aspects of this assessment. Most often, the magnitude of uncertainty was unknown and logistically impractical to estimate. For example, there would be the potential to explore the influence of conversion factors (i.e., constant values vs. a length-based relationship) when going from dressed to round weight when evaluating the magnitude of observed Porbeagle discards or when summing commercial landings. However, without current morphological monitoring (from landings or lethal sampling), it would be difficult to determine which option would generate more accurate values.

The greatest source of potential variability would arise from the method used to extrapolate from observed Porbeagle discards to fishery-wide total estimates. This was apparent in the annual estimates of fishery-wide discards from MAR and NL, where small catch amounts (10s of kg) could become multiple tonnes of discards when the effort ratio was low (e.g., multispecies flatfish in MAR), or observed discards could remain similar to fishery-wide estimates if the effort ratio was high (e.g., the NAFO 3OPs Witch Flounder fishery in NL).

There weremajor gaps in available data sources related to ASO monitoring, which was low or non-existent for several components of several fisheries, particularly those using gear types that would be expected to cause higher Porbeagle mortality (e.g., gillnets). Another major gap resulted from the inconsistencies in databases and data archival. Considerably more progress could have been made if the format of data were standardized among regions. It was difficult to extract and summarize all commercial and ASO records used in this assessment, leading to inconsistencies in results. For example, landings from all regions could only be partitioned relative to gear type rather than assigned to a particular fishery.

### TOR 6: Explore various methods to address the above objectives, including approaches used in other jurisdictions

An attempt was made to address this TOR by identifying and evaluating multiple statistical modeling approaches to estimate bycatch magnitude on unobserved commercial sets in the Swordfish and Other Tunas pelagic longline fishery. These methods represented a range of approaches that varied in complexity, used previously in Canadian assessments of bycatch (e.g., Gavaris et al. 2010) or used internationally (e.g., Stock et al. 2019). However, the quality and characteristics of the data precluded the use of statistical models.

## OTHER CONSIDERATIONS

### Relevance of Maximum Level (185 mt)

The simulation model that was used to evaluate allowable harm parameterized future fishing mortality as an exploitation rate, not as a tonnage or number of animals being removed (Campana et al. 2015). The projection that was chosen as the basis for the allowable harm threshold used an exploitation rate of 4%, which equated to approximately 185 mt given the 2009 terminal year biomass prediction from the assessment model. In other words, 4% of the biomass estimate in 2009 was used as the threshold for allowable harm, yet Porbeagle abundance has not been estimated more recently. If abundance is currently lower than the 2009 estimate, the 185 mt threshold for total mortality represents a higher exploitation rate than 4% and thus could be too high relative to the assessment of allowable harm, and *vice versa* if abundance is currently greater. Thus, it is not possible to determine how well 185 mt approximates a 4% exploitation rate, and whether it is still an appropriate threshold for allowable harm.

Without the ability to estimate the current population size of Porbeagle, it is not possible to advise on the ability of the population to recover if annual fishing mortality is in excess of 185 mt, nor is it possible to advise on an allowable harm threshold of 185 mt (Campana et al. 2015) as a maximum acceptable amount of mortality.

## RESEARCH RECOMMENDATIONS

The way that fishing data are collected and archived in Atlantic Canada complicated these analyses. In situations where model-based estimators of bycatch might be appropriate, they may become logistically impossible to implement because they require set-level data (including positional information) from all commercial trips and all ASO trips. From a practical standpoint, statistical model development would only be possible for a limited number of fisheries on an annual basis, given complexities related to development and optimization. It would be beneficial to improve standardization among the data sources contributing to assessments of bycatch for wide-ranging species that inhabit multiple regions. An initial step could be to incorporate an identifier for unique trips in the ZIFF-NL database. This would allow ASO coverage to be calculated at a trip level, similar to the method used in MAR for this assessment.

Identifying fisheries and scaling up observed discards by the proportion of commercial effort that was observed represented a large amount of work. For ASO data from MAR, substantial effort was expended to assign specific trips to unique fisheries. This was done to ensure that observer coverage could be calculated reliably and Porbeagle bycatch could be ascribed to the correct fishery. The reason this took so much time is that multiple fisheries (e.g., small pelagics, flatfishes, redfish) have not been assessed recently, so there is limited knowledge about their characteristics (e.g., number of trips, spatial distribution of effort). Other errors in data (e.g., impossible geographical locations) could not be corrected in advance of this assessment, as this would require comparison of thousands of catch records with paper copies of logbooks. Numerous other species assessment units who were not directly involved in preparation for this peer-review process also contributed their time and input in support of these analyses. It is recommended that these logistical considerations and the issues with data quality and representativity be addressed prior to future analyses to address questions on bycatch. The results of the peer-review process demonstrated the limitations to addressing the request for advice, even after the significant effort and examination of multiple potential approaches that were employed.

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## SOURCES OF INFORMATION

This Science Advisory Report is from the May 30–31, 2023, zonal peer review on Science Advice on Methods for Estimating Fishing Mortality for Porbeagle. 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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