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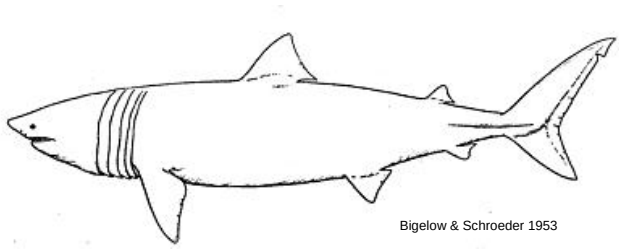
Maritimes Region
Canadian Science Advisory Secretariat
Science Advisory Report 2008/036

STATUS OF BASKING SHARKS IN ATLANTIC CANADA



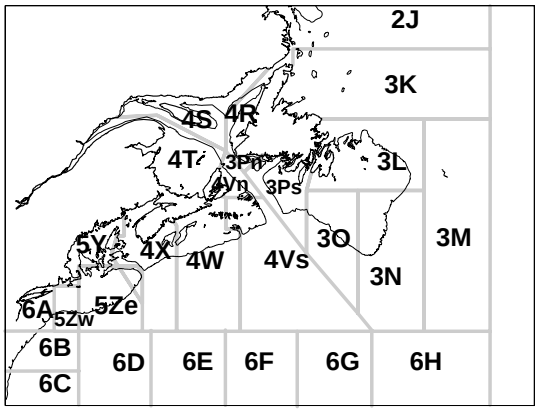


Figure 1. Map of NAFO areas relevant to this assessment.

Context :

Basking sharks are generally distributed throughout the waters of Atlantic Canada south of northern Newfoundland in water temperatures at or above 6-7 °C. Due to their uncommon capture and large size, they are often misidentified as another large, unusual shark, the Greenland shark. Basking sharks appear to be highly migratory, and it is likely that there is only a single population in the waters off of Canada and the U.S.

There is no recreational or commercial fishery for basking sharks in Atlantic Canada, but they are caught incidentally in several fisheries.

The life history characteristics of basking sharks are poorly understood, but the species is believed to be long-lived, with a late age at sexual maturation and low fecundity, and thus is very unproductive and slow to increase in population abundance.

Basking sharks have been listed under Appendix 2 of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The International Union for Conservation of Nature (IUCN) has listed the species as vulnerable globally, and endangered in the northeast Atlantic and in the north Pacific. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has designated the Pacific population of basking sharks as Endangered. The status of the Atlantic population is expected to be assessed in the near future.

This report is an overview of work done to date to better understand the distribution, abundance trends and current state of the Atlantic Canadian portion of the basking shark population. Estimated discard numbers have been put into the context of the estimated population size to determine if the population is in danger of collapse.

SUMMARY

- The life history characteristics of basking sharks are inadequately known, and key parameters such as growth rate, natural mortality and fecundity are assumed rather than measured. However, there is little doubt that the species is relatively unproductive and incapable of sustaining even modest mortality rates.

- Basking shark distribution appears to be restricted to temperatures between 6-16 °C, which implies that observations of basking sharks north of Newfoundland and in cold waters elsewhere are likely to be misidentifications of Greenland sharks.

- There is no directed fishery for basking sharks in Canadian waters. Observed bycatch in foreign fisheries peaked in the 1980s and early 1990s at about 150 mt per year, but has averaged only a few metric tons annually since 2000. Basking sharks are caught incidentally in domestic fisheries, with most observed bycatches having occurred in groundfish and redfish trawl fisheries. When scaled to total landings, total estimated bycatch has averaged 164 mt annually (corresponding to 164 basking sharks) since 1986.

- It is possible that bycatch is somewhat larger than estimated, since there has been little in the way of observer coverage of inshore fishing gear such as gill nets and cod traps.

- Estimates of absolute basking shark abundance from aerial surveys of whales in the Bay of Fundy, the Scotian Shelf/Gulf of St. Lawrence and Newfoundland waters suggest numbers of 4,200, 5,340, and 560, respectively, for a total of 10,100 in the summer of 2007. These estimates are uncertain due to the number of assumptions that were invoked.

- A life table analysis indicated that the intrinsic rate of basking shark population growth (*r*) in an unfished population is 0.040, which is near the maximum sustainable bycatch mortality. With F_{crit}= 0.043, and the annual mean number of discards being 164, and assuming 100% mortality of discards, this would suggest that the average population size which could support the estimated number of discards N_{crit} would be about 4,800. The best available estimate of population size for 2007 is above N_{crit}.

- A Monte Carlo analysis based on the life history of basking sharks and discard data was used to evaluate recent trends in abundance. The results of this population model, which are consistent with the results of the life table analysis, suggest a 23% probability (about a 1-in-5 chance) that the population is decreasing, although the uncertainty associated with the model inputs is large. This result is more or less consistent with SPUE indices in U.S. waters that show no evidence of a decline since 1979.

- Given the life history characteristics of the basking shark, high discard mortality associated with bycatch could lead to population collapse. Therefore it is important that basking shark bycatch continue to be monitored. Measures to improve species identification accuracy in the observer program, record the numbers of individuals and sex in the bycatch, and to reduce discard mortality would be useful.

BACKGROUND

Species Biology

Basking sharks are found circumglobally in temperate coastal shelf waters but are patchy in distribution. Canadian records from both Atlantic and Pacific waters indicate they utilize virtually all coastal temperate waters where temperatures exceed 6 or 7 °C.

The life cycle and reproduction of basking sharks are poorly understood. They are believed to be ovoviviparous, giving birth to 6 live pups of 1.5 to 2 meters in length during the summer after a gestation period of 3 (2.5-3.5) years. It is believed males mature at a length of 4.6 to 6.1 m, but the length of female maturity is unknown. There is only one record of a pregnant female (containing 6 young), and only one observation of a free-living juvenile. Longevity is presumed to be approximately 50 years, but the basis for age estimation in this species is weak. Basking shark age at maturity has been tentatively estimated at 14 (12 to 16 years) for males and 18 (16 to 20 years) for females, but the problems with age estimation noted above mean that these estimates are uncertain.

The intrinsic rate of population growth (*r*) calculated in this review was about 0.04 based on the average life history values shown above, which is very low. Pauly (2002) calculated the natural mortality (M) to be 0.068. Based on an age of maturity of 18 years for females, the generation time can be estimated as 18+(1/0.068)=33 years.

The population structure of basking sharks is currently being studied using genetic techniques, but nothing has been published to date. Preliminary satellite tagging suggests that a single population exists in the northwest Atlantic, based on movements from Cape Cod to the Caribbean. COSEWIC has designated the Atlantic and Pacific populations of basking sharks as separate Designatable Units.

Distribution and Habitat

Aerial and ship-based surface observations indicate that basking sharks are widely distributed in the Gulf of St. Lawrence, off southern Newfoundland, on the Scotian Shelf and in the Gulf of Maine, at least during the summer months. Water temperature may set a limit for the distributional range of the basking shark, with 6-7 °C being the lower limit for suitable habitat. In general, such a water temperature would limit the range of basking sharks to the waters south of the northern tip of Newfoundland, although the capture of a single basking shark in a Newfoundland groundfish research vessel (RV) survey at a latitude of 55.3°N (NAFO Div. 2J) indicates that the distribution of basking sharks can occasionally extend north of Newfoundland.

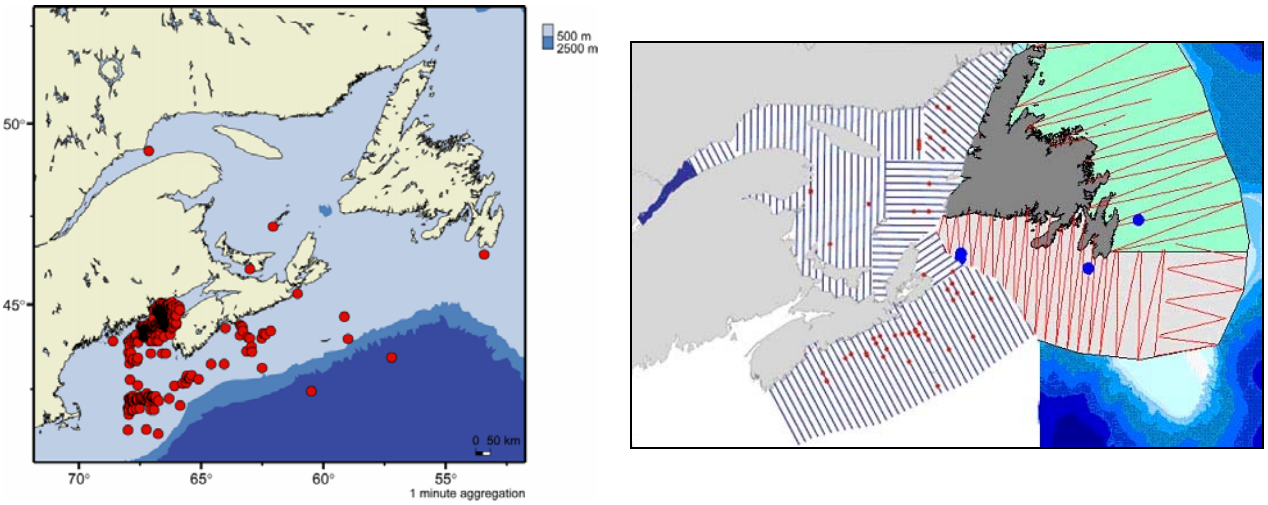


Figure 2. Confirmed basking shark distribution as recorded in: (left) Aerial and ship-based surveys of right whales combined with reports phoned in to BIO between 1997 and 2007; (right) aerial surveys for marine mammals.

In principle, observations by fisheries observers should provide a reliable source of information on basking shark occurrence in fisheries catches in Atlantic Canada. In practice, it appears that basking shark identifications are sometimes confused with those of Greenland sharks. Observer records from the Newfoundland and Maritimes Observer Programs suggest that basking sharks are often caught not only in the Gulf of St Lawrence, off the coast of Newfoundland and on the Scotian Shelf, but along the edge of the continental shelf and well up into Labrador. The distribution of some of these catches reflects those of Greenland sharks recorded by observers, which tend to occur in deep, cold waters along the shelf edge and into the Arctic. As a result, it appears likely that at least some of the observer records of basking sharks are actually Greenland sharks, especially those north of Newfoundland and those collected at the shelf edge and in water temperatures < 6 °C.

The water depths occupied by basking sharks are relevant to the use of aerial surveys for estimating abundance. In the northeast Atlantic, 4 basking sharks spent an average of 36% of their time in surface waters between June-August, although the time varied greatly with the abundance of zooplankton prey (Sims et al. 2003).

The Emerald Basin on the Scotian Shelf is suspected to be a mating area for the population, but the pupping area remains unknown.

ASSESSMENT

Abundance

The only assessment of abundance in U.S. waters estimated basking shark numbers at 6,700-14,300 off the New England Coast and in the Gulf of Maine in the early 1980s (Owen 1984).

A time series of relative abundance for basking sharks in the Maritimes was developed by using catch-per-unit-effort (CPUE) in those fleets most likely to catch basking sharks – groundfish and redfish bottom trawls in the Scotia-Fundy observer database. The data were sparse and variable, and this time series likely reflects changes in distribution rather than changes in overall abundance. Therefore the index was not used.

Trends in the relative abundance of basking sharks in the Bay of Fundy were assessed by using the number of observations of basking sharks seen during aerial surveys and shipboard surveys looking for right whales as collated by the North Atlantic Right Whale Consortium (NARWC). Relative abundance was quantified in terms of sightings per unit effort (SPUE). Although the basking shark SPUE index showed a relatively clear peak in abundance in 1998 followed by a rapid decline to near-zero levels in recent years, the changes were too abrupt to be explicable by changes in overall population abundance, and were more likely attributable to changes in distribution due to oceanographic factors.

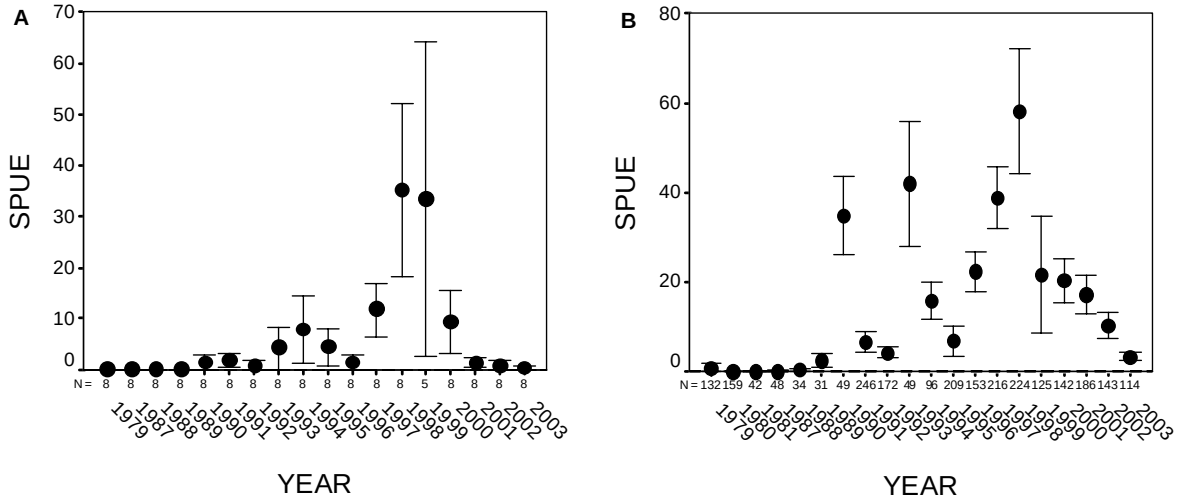


Figure 3. Trend in relative abundance of basking sharks in the Bay of Fundy based on sightings per unit effort (SPUE) during aerial and ship-based surveys for right whales. Note: there are missing years on x axis. (A) Relative abundance based on a subset of strata common to all years and (B) relative abundance based on all strata. SPUE=sharks per 1,000 km of qualifying effort on a 5-minute lat/long grid, by year (n = 2570).

Comparable SPUE indices in U.S. waters between 1979-2006 showed no significant trends in three of the sub-regions, and significant increases in the southern Gulf of Maine and the southeastern U.S., albeit with high inter-annual variability. There was no obvious inverse relationship between the SPUE indices in the Gulf of Maine and those in the Bay of Fundy.

As an alternate measure of relative abundance, the number of basking shark observations in the NARWC database relative to the number of right whales observed (which is known to consist of an annual average of 123 uniquely-identified whales in the Bay of Fundy in 1987-2004) were analyzed. The relative index (mean of 0.17 sharks per whale) can be converted to an absolute index if the factors affecting the relative visibility of basking sharks compared to right whales can be quantified. Those factors would include the proportion of time spent at or near the surface (assumed to be equal in right whales and basking sharks), any recording bias towards right whales by individual observers (assumed to be a factor of 2), and the relative visibility of the two species once at the surface (assumed to be a factor of 100 due to the greater visibility of breaching and spouting whales). This calculation suggests an average of 4,200 basking sharks in the Bay of Fundy.

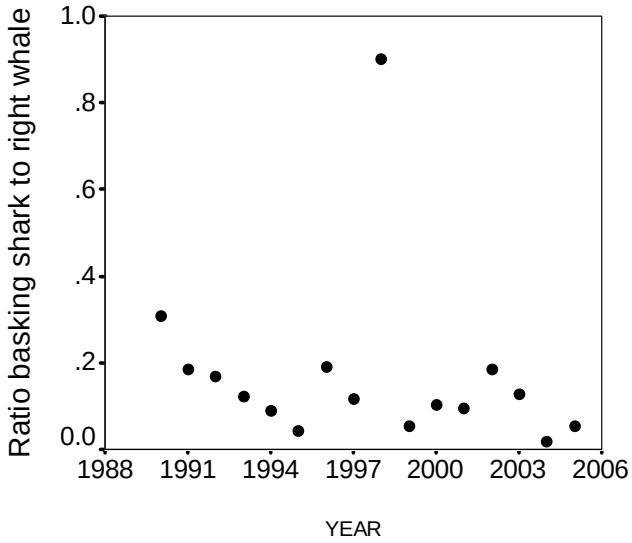


Figure 4. Ratio of basking sharks to right whales observed in right whale aerial and ship-based surveys of the Bay of Fundy and approaches.

The absolute abundance of basking sharks on the south, east and north coast of Newfoundland out to the edge of the continental shelf was estimated from DFO's Trans North Atlantic Sightings Survey (TNASS) aerial survey of marine mammals in 2007. Five basking sharks were sighted. Based on this admittedly sparse information, effective strip width was estimated at 442 m with a CV of 93%. The overall estimate of basking sharks in the survey area was 201, with a 95% confidence interval of 42-970 animals. Assuming that basking sharks spend an average of 36% of their time at the surface, the total number of basking sharks in the Newfoundland area was 558.

The absolute abundance of basking sharks on the Scotian Shelf and in the Gulf of St. Lawrence was estimated from DFO's TNASS aerial survey of marine mammals in 2007, carried out in tandem with the Newfoundland aerial survey. A total of 17 basking sharks was observed in the Gulf, and a further 36 sharks on the Scotian Shelf, along transects separated by 10 nm (= 18.5 km). The effective strip width of 250 m (CV=0.26, 95% CI: 202-308) was estimated from the overall sighting distribution. The overall abundance estimate for the Gulf and Scotian Shelf was 1,923 (CV=0.20, 95% CI: 1303-2836). For the Scotian Shelf, the estimate was 1,254 (CV=0.24, 95%CI: 781-2,012). Assuming that basking sharks spend an average of 36% of their time at the surface, the total number of basking sharks present on the Scotian Shelf and in the Gulf of St. Lawrence during the summer of 2007 was 5,342.

A visual estimate of basking shark numbers in the Bay of Fundy during the summer of 2007 is not available. Assuming that the Bay of Fundy and Scotian Shelf numbers are independent (which they are probably not), the total number of basking sharks in Atlantic Canadian waters in 2007 was estimated to be 4,200 + 558 + 5,342 = 10,100. This number is subject to a number of assumptions, and thus is highly uncertain.

Bycatch

There is no directed fishery for basking sharks in Canadian waters. However, there are observer records of basking sharks caught in commercial fisheries. The observer program has maintained 100% coverage of foreign vessels in Canadian waters since 1987, allowing a straight forward determination of foreign basking shark discards. However, observer coverage is typically less than 5% of the domestic fishery, thus requiring that the observer data be scaled

to reported landings. Therefore, the observer coverage was stratified by fishery, region, season and year to estimate the total discards of basking shark.

Most of the observed foreign catch of basking sharks came from vessels fishing for silver hake, and to a lesser extent, redfish. Basking shark catch peaked in the 1980s and early 1990s at about 150 mt per year, but has averaged only a few mt annually since 2000 as a result of the near-exclusion of foreign vessels fishing in the Canadian Exclusive Economic Zone (EEZ).

Observed domestic catches of basking sharks also peaked in the 1980s and 1990s, averaging about 10 mt per year across all fleets. When scaled to total landings, estimated basking shark discards averaged 122 mt annually in the Scotian Shelf groundfish trawl fishery between 1986-1996, and considerably less in the other fisheries. Estimated discards in Newfoundland waters were considerably smaller than those in Scotia-Fundy once the records suspected of being Greenland sharks were excluded. Considering all regions and fisheries, estimated basking shark discards peaked at 741 mt in 1990 and have averaged 164 mt annually since 1986. In general, most of the basking sharks have been caught in Scotia-Fundy domestic fisheries.

It is possible that bycatch is somewhat larger than estimated, since there has been little in the way of observer coverage of inshore fishing gear such as gill nets and fish traps. Estimates from fishers participating in a voluntary reporting network indicate that about 370 basking sharks were captured by inshore fishing gear in coastal waters of Newfoundland from 1980-1983 (Lien and Fawcett 1986). Inshore fishing effort in coastal Newfoundland has declined substantially since the 1990s. However, inshore fisheries remain important throughout eastern Canada and few of these fisheries are observed.

Using the median weight of 1,000 kg (25^{th}-75^{th} percentiles = 465-2,500 kg) calculated from both the Scotia-Fundy and Newfoundland observer data, total estimated discard numbers averaged 164 basking sharks annually since 1986.

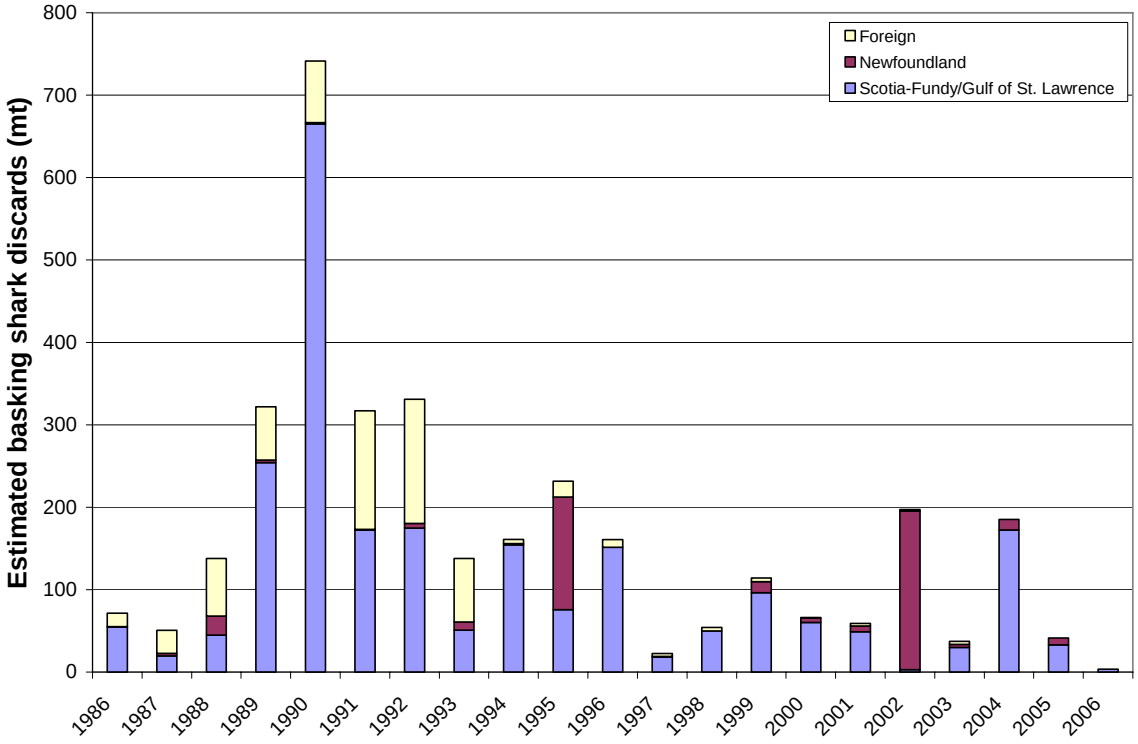


Figure 5. Estimated (domestic) and known (foreign) basking shark discards from domestic and foreign fisheries from all regions.

Sustainable Mortality Rate

The life table results indicated that the intrinsic rate of population growth (*r*) in an unfished basking shark population is 0.040. Based on this rate of population growth and assuming that fishing selectivity is knife-edged at Age 2, the fishing mortality rate which would drive the population to extinction (F_{crit}) is estimated to be 0.043. Given an annual mean number of discards of 164, and assuming 100% mortality of discards and no human-induced mortality on Ages 0-1, this would suggest that the average population size which could support the estimated number of discards (N_{crit}) would be about 4,800. If discard mortality was less than 100%, N_{crit} could be smaller. If there were sources of mortality, such as inshore fishery sectors, not captured in the discard analysis, the required population size would have to be larger. The best available estimate of population size for 2007 is about 10,100, which has a high level of uncertainty, but is still above N_{crit}.

Population Trends

A population dynamics model was used to assess recent (1986-2007) trends in basking shark abundance. Assuming exponential growth, the population size in one year equals the population size in the previous year multiplied by the intrinsic rate of population growth (*r*) minus the number of human-induced mortalities in the previous year. Because an abundance estimate exists for the year 2007, and the discards are known for this time period, the population trajectory can be estimated for these years.

All of the inputs into this model are highly uncertain, and therefore a Monte Carlo simulation model was used to aid in addressing this uncertainty. A range of plausible values for population size in 2007, *r*, litter size, age-at-maturity, gestation period, lag between parturition and the next

pregnancy, maximum age, age) mortality and natural mortality were chosen. Values were then drawn randomly from uniform distributions of each parameter and used to first calculate *r* and then to back-calculate abundance. Simulations in which *r* was greater than 0.057 were considered unrealistically high and were deleted from the results. This limit was selected based on a review of published values of *r* for sharks (the *r* that was selected was the median value of *r* from 21 species of sharks with maximum lengths greater than 2 meters). This procedure was used until 1000 simulations were obtained. The resulting histograms for the population size in 1986, the population size in 2007, *r* and the instantaneous rate of change in the population size show the uncertainty in both past and present population sizes as well as the uncertainty in *r*. This uncertainty carried over into the analysis of trends, where 23% of the simulations showed a decline between 1986-2007. Several alternate population runs were carried out to examine the robustness of this conclusion to the model inputs. For example, if the number of discards were doubled, the proportion of populations that were decreasing increased to 64%. Additionally, the model output is sensitive to the range of values assumed for the population size in 2007; when lower values are used, a larger proportion of simulated populations show a decline.

Inputs for the simulation model;

Parameter	Minimum	Maximum
Estimated population size in 2007:	5,000	20,000
Estimated age at maturity (assumed knife edge):	16 yr	20 yr
Estimated female litter_size (thought to be 3):	2	4
Estimated gestation_period (thought to be 3 yr):	2 yr	4 yr
Lag between parturition and next pregnancy	0 yr	1 yr
Maximum age	40 yr	60 yr
Estimated natural mortality (thought to be 0.068)	0.058	0.078
Ratio of age-0 mortality to mortality of older fish	1.5	2.5

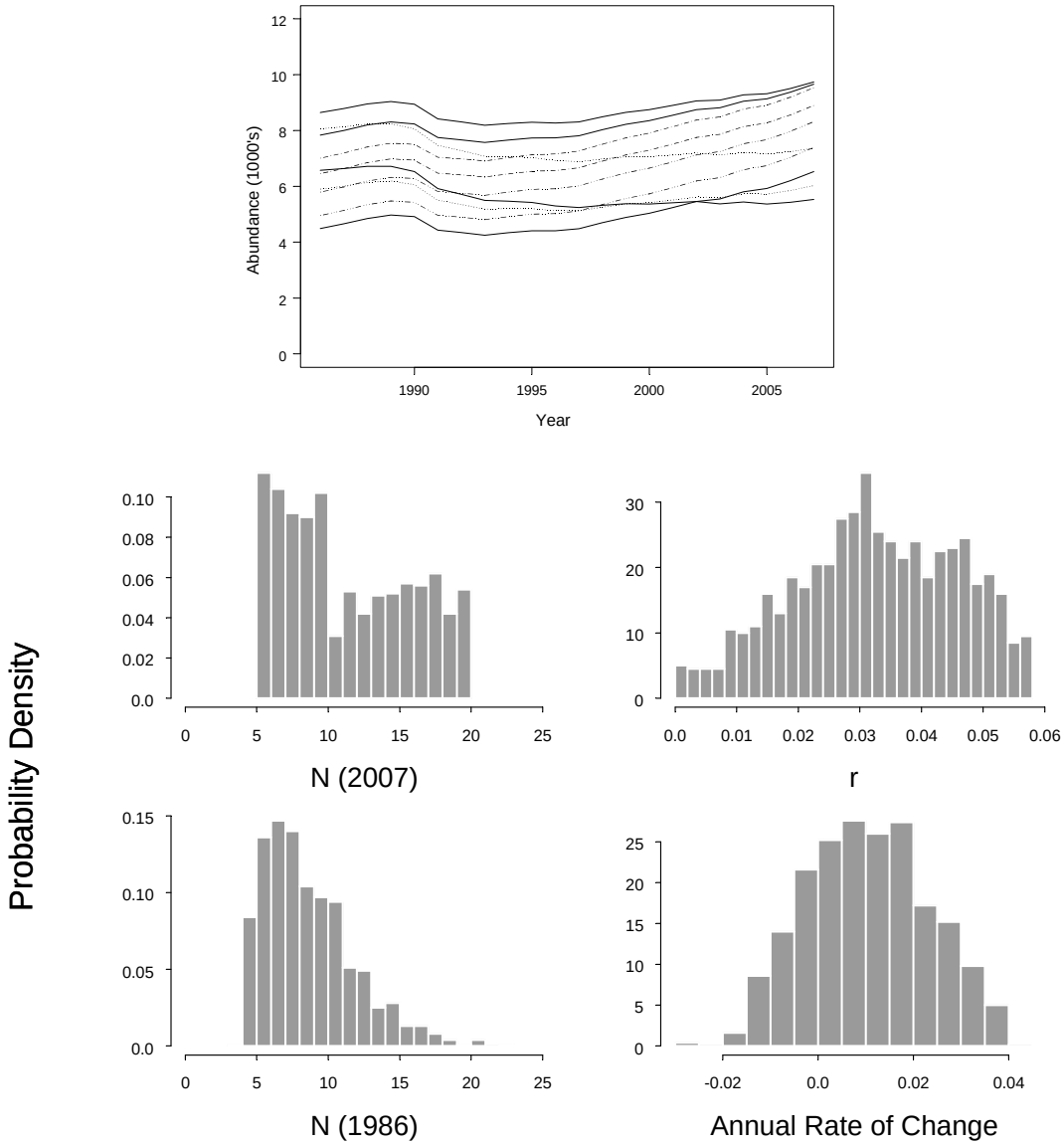


Figure 6. Simulation results from the base model. The top panel shows 10 simulated population trajectories, while the bottom panel shows the histograms of the population size in 2007, the population size in 1986, r and rate of change in population size (positive values indicate an increasing population).

Sources of Uncertainty

Almost all of the life history parameter estimates are uncertain. These estimates are influential in estimating *r* and N_{crit}.

There is uncertainty around the bycatch estimates associated with low coverage in observed fisheries, misidentification of Greenland sharks, mortality of discards, and bycatch in unobserved fisheries.

Any tendency for females to preferentially be observed at the surface during aerial surveys would serve to underestimate population size.

There is sparse information on basking shark abundance and bycatch in the U.S., including mixing rates between Canada and the U.S.

There is uncertainty associated with the population estimates from the aerial surveys, particularly the estimate of proportion of time at surface. There is even more uncertainty associated with the relative visibility of basking sharks compared to right whales, which was used to estimate basking shark abundance in the Bay of Fundy. In addition, there was uncertainty if the Bay of Fundy abundance should be added to that on the Scotian Shelf, since oceanographic features might promote movement from one region to another.

It was uncertain if a density-dependent term should be included in the population model, and if so, at what level.

In all of the above issues, the direction of potential bias could not be identified.

CONCLUSIONS AND ADVICE

The life history characteristics of basking sharks are inadequately known, and key parameters such as growth rate, natural mortality and fecundity are assumed rather than known. However, there is little doubt that the species is relatively unproductive and incapable of sustaining even modest mortality rates.

The average population size which could support the estimated number of discards (N_{crit}) would be about 4,800. The best available estimate of population size for 2007 is about 10,100, which has a high level of uncertainty, but is still above N_{crit}. Based on the model simulations, there is a 23% probability that the population declined, while 77% of the simulated populations increased between 1986 and 2007. SPUE indices in U.S. waters show no evidence of a decline since 1979.

Given the life history characteristics of the basking shark, high discard mortality associated with bycatch could lead to population collapse. Therefore it is important that basking shark bycatch continue to be monitored. Measures to improve species identification accuracy in the observer program, record the numbers of individuals and sex in the bycatch, and to reduce discard mortality would be useful.

OTHER CONSIDERATIONS

Aerial surveys of the Bay of Fundy and/or Scotian Shelf were conducted by the National Marine Fisheries Service (NMFS) on six occasions since 1995. Analysis of these data, along with any bycatch and abundance estimates, would improve the estimates of population size.

Biological sampling of fish taken as bycatch and associated research to better estimate the biological characteristics of basking sharks (i.e., age at maturity, longevity, fecundity) would allow more realistic values to be used.

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