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Canadian Science Advisory Secretariat
Newfoundland and Labrador and Quebec Region **Science Advisory Report 2020/020**

2019 STATUS OF NORTHWEST ATLANTIC HARP SEALS, *PAGOPHILUS GROENLANDICUS*

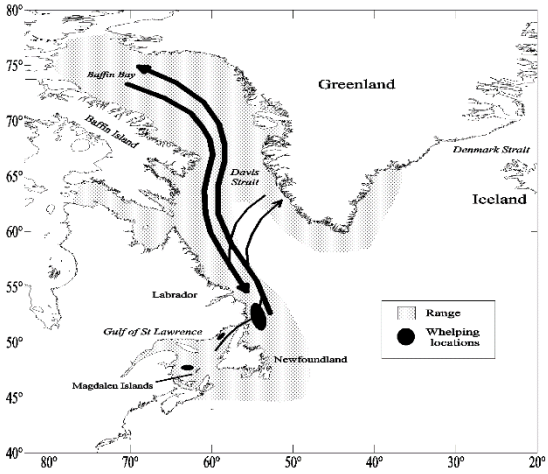

Figure 1. Range, migratory pathways and whelping locations of Harp Seals in the northwest Atlantic.

Context:

The Harp Seal is an abundant, medium-sized seal which migrates annually between Arctic and sub-Arctic regions of the north Atlantic. Three populations are recognized: the White Sea/Barents Sea, the Greenland Sea and the Northwest Atlantic. In the Northwest Atlantic, these seals give birth on the pack ice in the Gulf of St. Lawrence ("Gulf") or off northern Newfoundland ("Front") during late February or March, then return to the north. This population is hunted throughout its range; they are harvested for subsistence purposes by Inuit in Labrador, Arctic Canada and Greenland, and a commercial harvest occurs in the Gulf of St. Lawrence ('Gulf') and off Newfoundland ('Front'). Subsistence harvests are currently not regulated while the commercial harvest is regulated by a five-year management plan.

Harp Seal abundance is estimated using a population model that includes removals, annual reproductive rates and periodic estimates of pup production. The most recent pup production survey was carried out in March 2017. Science was requested to provide an update on the status of the Harp Seal population based upon this survey and current data on removals and reproductive rates. They were also requested to identify the maximum sustainable harvest that meet the management objective (i.e., maintaining an 80% probability of remaining above the Precautionary Reference Level [N70] for the next five years, 2020-2024) assuming catch age structures of 5% adults/95% Young of the Year (YOY), 10% adults/90% YOY and 50% adults/50% YOY. Science was also requested to provide an estimate of the Potential Biological Removal (PBR).

This Science Advisory Report is from the October 21-26, 2019 National Marine Mammal Peer Review Committee meeting held in St. John's, Newfoundland and Labrador. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Northwest Atlantic Harp Seals are harvested in Canadian and Greenland waters. Annual Canadian catches averaged 272,600 between 1996 and 2006. Since then catches have declined, averaging 63,000 between 2009 and 2019. Greenland catches reached a maximum of 100,000 in 2000, but currently average about 60,000 seals annually.
- The Newfoundland Lumpfish fishery is the primary source of bycatch mortality for Harp Seals in Canadian commercial fisheries. Estimated bycatch increased from less than 1,000 in the early 1970s to a peak of 46,400 in 1994, declining to approximately 5,000 by 2003. Lumpfish landings have continued to decline and a bycatch of Harp Seals was estimated to be 555 in 2018. Low numbers of Harp Seals are also caught in U.S. fisheries.
- Over the last decade, the estimated pregnancy rates of mature females have been variable, ranging from 0.2 in 2011 to 0.88 in 2015, due to changes in abundance and the environment. Reproductive rates have remained relatively high in the past five years.
- Harp Seals require stable ice for pupping, nursing and resting. The annual extent of ice cover in Atlantic Canada varies considerably, but overall has declined over the last 44 years, particularly in the Gulf of St. Lawrence (Gulf). Mortality of Young of the Year (YOY) caused by poor ice conditions has been incorporated into the assessment. If the ice cover continues to decline, the fraction of the population breeding in the Gulf is also expected to decline and may result in a permanent redistribution of the breeding population.
- Photographic and visual aerial surveys were flown between March 6 and 18, 2017. The timing of births in the southern Gulf of St. Lawrence was later than normal in 2017 while at the Front it was earlier than usual, suggesting that some females from the Gulf herd moved to the Front due to the lack of ice suitable for pupping.
- The number of pups born in the traditional pupping area of the southern Gulf of St. Lawrence was greatly reduced, with an estimated pup production of only 18,300 (95% CI, 15,400-21,200 rounded to the nearest hundred). Another 13,600 (95% CI, 7,700-19,500) pups were born in the northern Gulf. An estimated 714,600 (95% CI, 538,800-890,400) pups were born off the northeastern coast of Newfoundland (Front); accounting for 96% of all pupping in 2017. Combining the estimates from all areas resulted in an estimated total pup production of 746,500 (95% CI, 570,300-922,700).
- The previous population model formulation did not fit the updated time series of pup production estimates and the reproductive rates as well as in previous assessments. To account for the effects of continued poor ice conditions and other environmental changes, the model was modified to allow juvenile mortality to vary. The impact of broader environmental variability on reproductive rates was also incorporated into the model using a large-scale environmental index.
- The model indicates that the population increased from the 1970s until the mid-1990s. Between the mid-1990s and 2011 the population was relatively stable. Since then it is estimated that the population has begun to increase likely due to reductions in the removals and high reproductive rates.
- The model estimated pup production in 2019 is 1.4 (95% CI, 1.23-1.49) million and a total population size of 7.6 (95% CI, 6.55-8.82) million.
- The Atlantic Seal Management Strategy identifies three reference levels based upon the maximum observed population, which is referred to as N_{max}. Based upon the current model,

N_{max} was estimated to be 7.6 million, resulting in a Precautionary Reference Level N_{70} of 5.3 million animals and a Critical Reference Level, N_{30}=2.3 million animals.

- Sustainable harvest levels that maintained an 80% probability of remaining above N_{70} for the next five years were estimated. The identified annual Canadian Total Allowable Catch (TAC) levels were 425,000, 375,000 and 175,000 animals assuming harvest age structures of 95%, 90% and 50% YOY, respectively.
- The estimated annual Potential Biological Removal (PBR) for the Northwest Atlantic population is 425,600.
- Both reproductive rates and, presumably, YOY mortality have been highly variable in recent years which has made it difficult to fit the model, suggesting that the effects of environmental variability on vital rates are not fully captured by the current model. This variability appears to have played a lesser role in the past.
- The expected decline in ice cover will lead to an increase in YOY mortality and changes in prey availability which influence reproductive rates. This will impact future advice on sustainable levels of harvest.

BACKGROUND

Aerial surveys were carried out in March 2017 to estimate pup production. Data on recent reproductive rates and removals were also available. Using these data, the current status of the Northwest Atlantic Harp Seal population was assessed. The estimates of total population presented here are based upon a population model that incorporates pup production estimates, as well as reproductive rates, Canadian harvest information and ice related mortality up to 2019, and Greenland harvest information up to 2017.

Northwest Atlantic Harp Seals have been managed under the Atlantic Seal Management Strategy. They are a data-rich population and have been managed for the 15 years to maintain an 80 % probability that the population remains above a precautionary reference level (N_{70}) which was defined to be 70% of the maximum estimated population size.

Species Biology

The Northwest Atlantic population of Harp Seals summers in the Canadian Arctic and Greenland. In the fall, most of these seals migrate southward to the Gulf of St. Lawrence ("Gulf"), or to the area off southern Labrador and northern Newfoundland ("Front") where they give birth in late February or March on medium to thick first year pack ice (Fig. 1). Male and female Harp Seals are similar in size with adults averaging 1.6 m in length and 130 kg in weight prior to the breeding season. Females nurse a single pup for about twelve days, after which they mate and then disperse to feed for a short period. The pup, known as a whitecoat, moults its white fur at approximately three weeks of age after which it is referred to as a beater. Older Harp Seals moult later in April and May, forming large concentrations on the sea ice off northeastern Newfoundland and in the northern Gulf of St. Lawrence. Following the moult, seals disperse and eventually migrate northward. Small numbers of Harp Seals may remain in southern waters throughout the summer while a portion of the population remains in the Arctic.

The Hunt

Harp Seals have been hunted commercially since the early 18th century. The largest catches occurred off Newfoundland with catches of over 700,000 animals in the early 1800s. Since then,

the level of Canadian commercial catches has varied considerably with annual catches averaging approximately 288,000 Harp Seals between 1952 and the introduction of quotas in 1972 (Fig. 2). Between 1972 and the demise of the large vessel hunt in 1982, annual catches averaged 166,000 seals. Catches then declined to an annual average of 52,000 until 1995 when interest in the hunt increased significantly. Annual catches, consisting primarily of YOY, increased to an average of 272,600 between 1996 and 2006. Since then catches have declined, averaging 63,000 between 2009 and 2019. YOY seals ('beaters') have made up over 95% of the harvest since 2000.

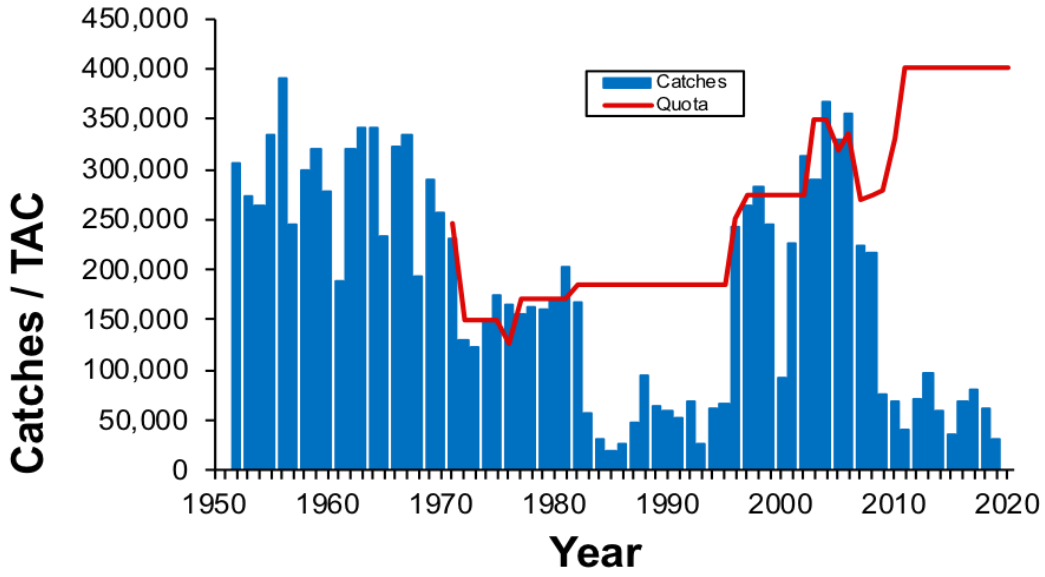

Figure 2. Canadian commercial Catches and Total Allowable Catch (Quota) of Harp Seals *from 1952-2019.*

A large subsistence harvest occurs in Greenland. Greenland catches increased relatively steadily since 1980 to a peak of approximately 100,000 in 2000 (Table 1). Since then, catches have declined and between 2011 and 2017, an average of 60,000 seals were reported. Recent catches in Greenland are similar in magnitude to the Canadian catch.

Table 1. Canadian commercial (and TAC) and Greenland catches of Harp Seals (,000s), 2011-2019. Recent catches in Greenland are not available. TAC was not announced for Harp Seals in 2017, 2018 and 2019.

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Canada									
TAC	400	400	400	400	400	400	-	-	-
Catch	40	71	98	60	35	68	82	61	32
Greenland									
Catch	73	55	65	63	62	57	49	NA	NA

Catches in the Canadian Arctic are not well documented, but are assumed to be small, with likely fewer than 1,000 Harp Seals taken annually in recent years.

Other Sources of Human-Induced Mortality

In addition to reported catches, some seals are killed but not recovered or reported (referred to as 'struck and lost'). Estimates of the additional mortality caused by struck and lost for YOY

during the large vessel whitecoat hunt (prior to 1983) are considered to be low (~1%). Since then, loss rates of YOY seals, which make up the majority of the current harvest in Canada, appear to be 5% (or less) while losses of older seals are higher (assumed to be 50% of those killed). This higher figure is also applied to all catches in the Canadian Arctic and Greenland when estimating total removals (Fig. 3).

Harp Seals are also taken as bycatch in fishing gear. The Newfoundland Lumpfish fishery is thought to be responsible for the largest bycatch mortality of seals. Estimates of bycatch increased from less than 1,000 in the early 1970s to a peak of 46,400 in 1994, declining to approximately 5,000 by 2003. Based on published bycatch rates in the Newfoundland Lumpfish fishery and data on Lumpfish landings, bycatch appears to have increased again in the mid-2000s to approximately 35,000. Since then, Lumpfish landings have declined significantly and bycatch of Harp Seals was estimated to be 555 in 2018. Low numbers of Harp Seals are also caught in United States (U.S.) fisheries (<500/yr).

Combining these various sources of human induced mortality results in estimates of total removals (Fig. 3). Between 1952 and 1982, approximately 395,000 Harp Seals were killed annually. This declined to 177,000 per year between 1983 and 1995. With the renewed interested in hunting in Canada and increased catches in Greenland, the average annual removal from 1996 to 2006 was 476,000. Since 2008, reduced catches, particularly in Canada have lowered the annual total removals to approximately 200,000 Harp Seals per year.

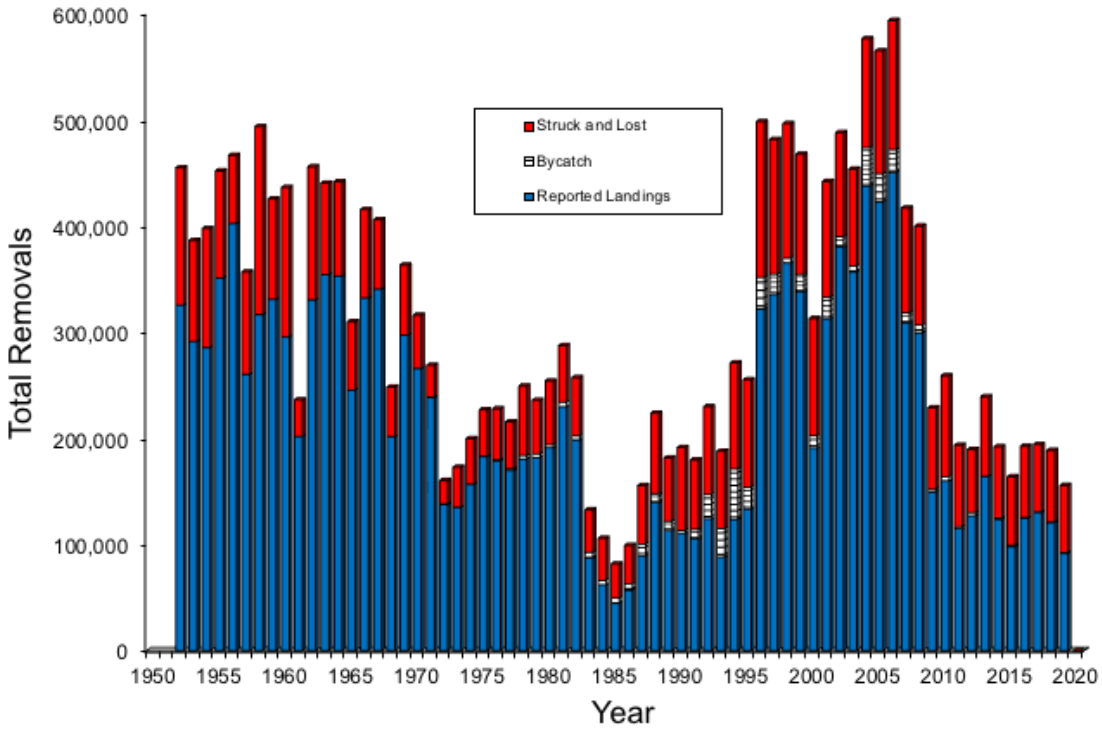

Figure 3. Total removals of Northwest Atlantic Harp Seals, 1952 to 2019.

ASSESSMENT

Resource Status

The number of Harp Seal pups born in a year is estimated periodically from surveys flown in the spring when the seals gather on the ice to have their pups. Estimates of total population size are based on a population model that fits to estimates of pup production and reproductive rates and incorporates information on annual catches in Canada and Greenland, by-catch, struck and lost, and unusual pup mortality due to poor ice conditions. A long-term environmental index is used to indicate changes in the environment that impact reproductive rates and juvenile survival.

Photographic and visual aerial surveys were flown in the Gulf of St. Lawrence, and off Newfoundland, to determine Harp Seal pup production during March 2017. Estimated pup production in the southern Gulf was 18,300 (95% CI, 15,400-21,200) seals; 13,600 (95% CI, 7,700-19,500) in the northern Gulf and 714,600 (95% CI, 538,800-890,400) at the Front, for a total estimated pup production in 2017 of 746,500 (95% CI, 570,300-922,700) (Table 2). This estimate is approximately one half of the number of pups estimated in 2008, but similar to estimates from 1999, 2004 and 2012. Overall, the proportion of pups born in the southern Gulf of St Lawrence has declined from a high of 28% in 1994 to 2% in 2017 (Table 2).

Table 2. Northwest Atlantic Harp Seal pup production estimates from aerial surveys completed since 1990 (with SE) and the proportion of pupping in each component.

Year	Southern Gulf	Northern Gulf	Front	Total
1990	106,000 (23,000)	4,400 (1,300)	467,000 (31,000)	578,000 (39,000)
1994	198,600 (24,200)	57,600 (13,700)	446,700 (57,200)	702,900 (63,600)
1999	176,200 (25,400)	82,600 (22,500)	739,100 (96,300)	997,900 (102,100)
2004	261,000 (25,700)	89,600 (22,500)	640,800 (46,900)	991,400 (58,200)
2008	287,000 (27,600)	172,600 (22,300)	1,185,000 (112,474)	1,644,500 (117,900)
2012	115,500 (15,100)	74,100 (12,400)	626,200 (66,700)	815,900 (69,500)
2017	18,300 (1,500)	13,600 (3,000)	714,600 (89,700)	746,500 (89,800)

Since the 1950s, reproductive rates have shown a declining trend while inter-annual variability has increased (Fig. 4). These highly variable reproductive rates have continued although the very low rates observed in 2010 and 2011 have not occurred again. Relatively high reproductive rates were observed in 2014 and 2015 associated with a period of extensive ice coverage and high capelin abundance (the main prey of Harp Seals) and have remained relatively high for the past five years. The longer-term decline in reproductive rates is a reflection of density-dependent processes associated with increased population size. The large inter-annual variability is due to varying rates of late term abortions which appear to be related to changes in capelin abundance, and mid-winter ice coverage (which reflects environmental conditions that influence a variety of species).

Changing prey availability influenced reproductive rates through changes in body condition. Overall, the average relative condition of pregnant females has been consistently high, whereas that of non-pregnant and immature females has shown a general decline since 2000. Changes in condition affected the rate of late term abortions suggesting that as overall condition in the population declines, females that attain sufficient energy maintain their pregnancy while those that do not, terminate their pregnancy prematurely.

In the short term (i.e., the next two years), capelin biomass is predicted to decline, and this will likely affect reproductive rates. In the long term, there is great uncertainty as to how the

predicted changes in timing of ice formation and retreat will impact capelin, and hence reproductive rates of Harp Seals.

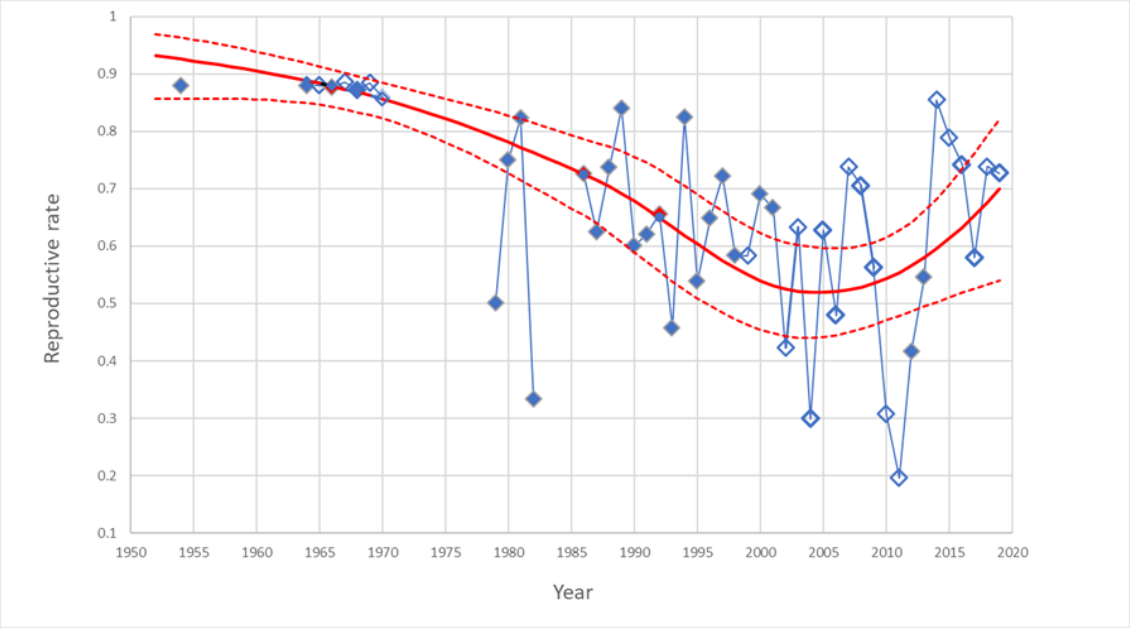

Figure 4. Age-specific pregnancy rates of Northwest Atlantic Harp Seal females aged 8+ years from 1952 to 2013. Open symbols represent samples of 50 or more. Solid symbols represent samples with less than 50 animals.

Harp Seals require stable ice for pupping, nursing and as a platform for young to rest. The annual extent of ice cover in Atlantic Canada has varied considerably over the last 50 years, particularly in the Gulf, where overall total ice cover has declined (Fig. 5). This decline reduces early YOY survival, and mortality of young seals associated with very poor ice conditions has been incorporated into the assessment since 2003. If the frequency of winters with poor ice cover continues or increases, pup production in the Gulf will likely decline and may result in a redistribution of pupping to areas with better ice.

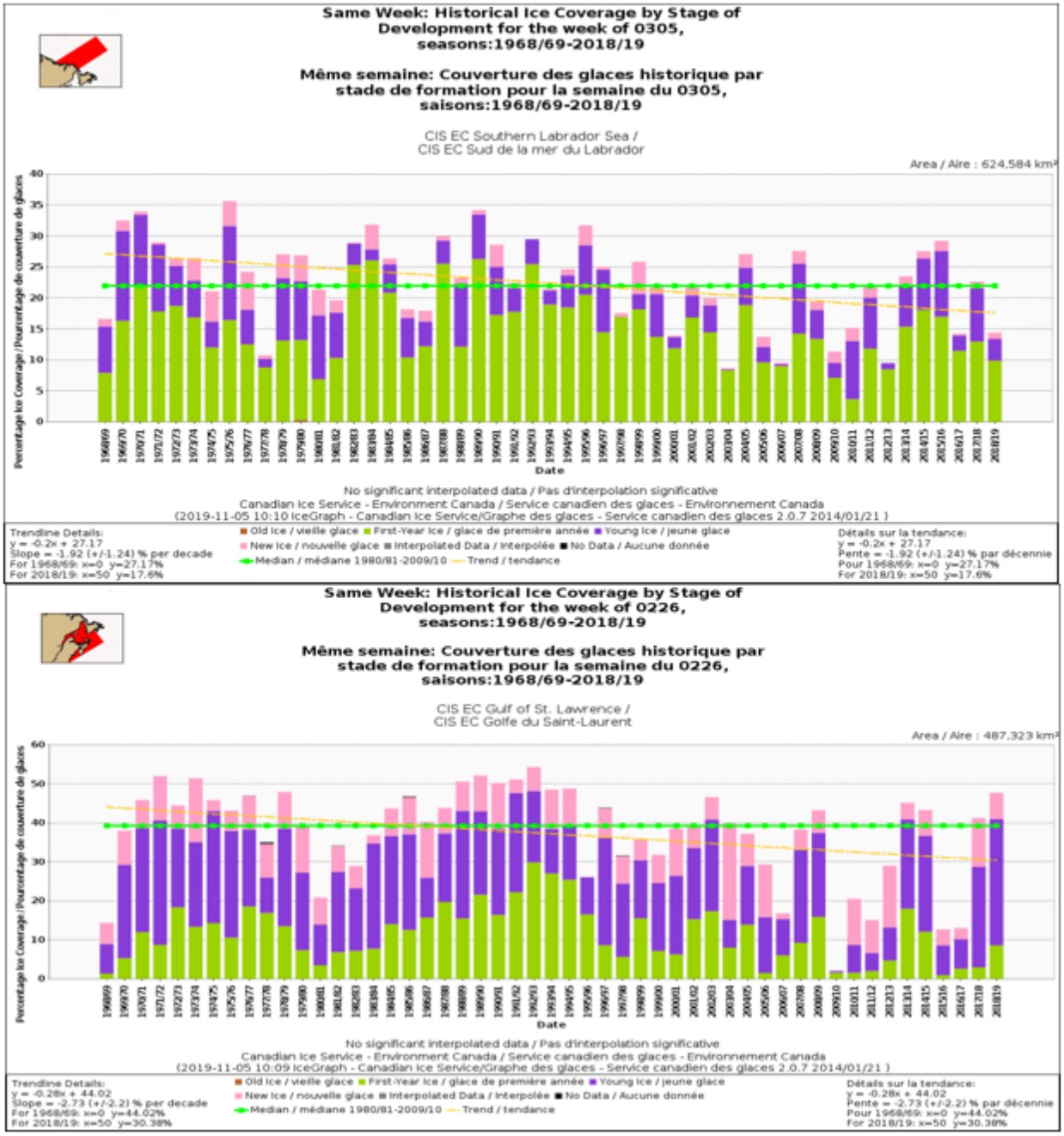

Figure 5. Changes in the amount of first year, young, new ice and total ice cover off southeast Labrador (Front, top) and in the Gulf of St. Lawrence (bottom) 1969-2019. Harp Seals primarily utilize first year (green) ice (Canadian Ice Service 2019).

The Northwest Atlantic Harp Seal population has increased significantly over the past five decades. The general decline in reproductive rates over this period, as well as a decline in size at age suggests that the population is approaching its environmental carrying capacity (K). These density dependent changes are affecting the dynamics of this population although it is very difficult to determine the exact relationship between the current population and the carrying-capacity. Attempts to estimate K are further complicated by periodic large harvests,

interannual variability in reproductive rates which affect the dynamics of the population, and the time interval of four to five years between pup production surveys.

Ecological changes are variable and will impact the carrying capacity (K) through changes in reproductive rates and juvenile survival. In this assessment, a Comprehensive Environmental Index was incorporated into the population model and used to adjust the annual estimate of K to account for differences in the quality of the environment (Fig. 6). Furthermore, regional climate models are predicting that winter ice cover will decline and the area is likely to be ice-free by the end of the century. These models were used to predict future ice related mortality.

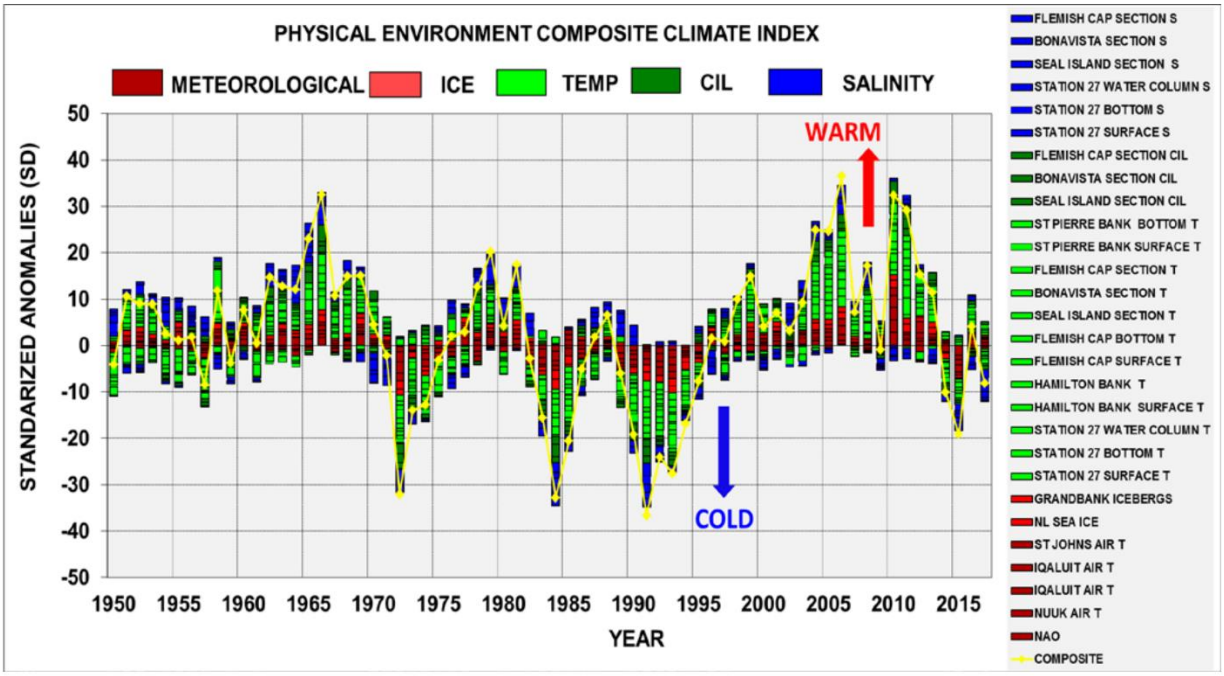

Figure 6. Variability in the Comprehensive Environmental Index between 1950 and 2018.

The population model estimates the starting population size, juvenile mortality rate (M) and population carrying capacity (K). It incorporates a time series of pup production estimates up to 2017, as well as reproductive rates (1952-2019), ice-related mortality and harvest information up to 2019 to predict 2019 pup production and total population size. The model indicates that the population has been relatively stable since 1995, declined in 2010 and 2011, but has increased since then. The model provides a 2017 estimated pup production of 1,000,000 (95% CI, 927,000-1,100,000), and a total population of 6,800,000 (95% CI, 5,800,000-8,000,000). Projecting to 2019, resulted in an estimated pup production of 1,400,000 (95% CI, 1,200,000-1,500,000) and a total population of 7,600,000 (95% CI, 6,600,000-8,800,000) seals (Figs 7, 8).

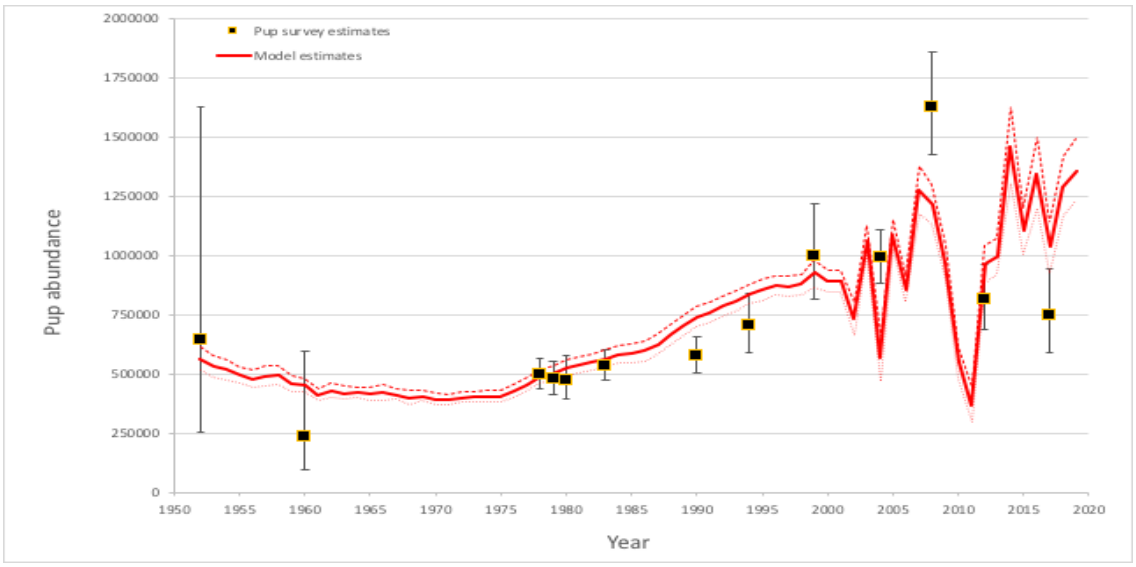

Figure 7. Independent survey (square symbols) (±95% CI) and model (line, ±95% CI, dotted lines) estimates of pup production 1952 to 2019

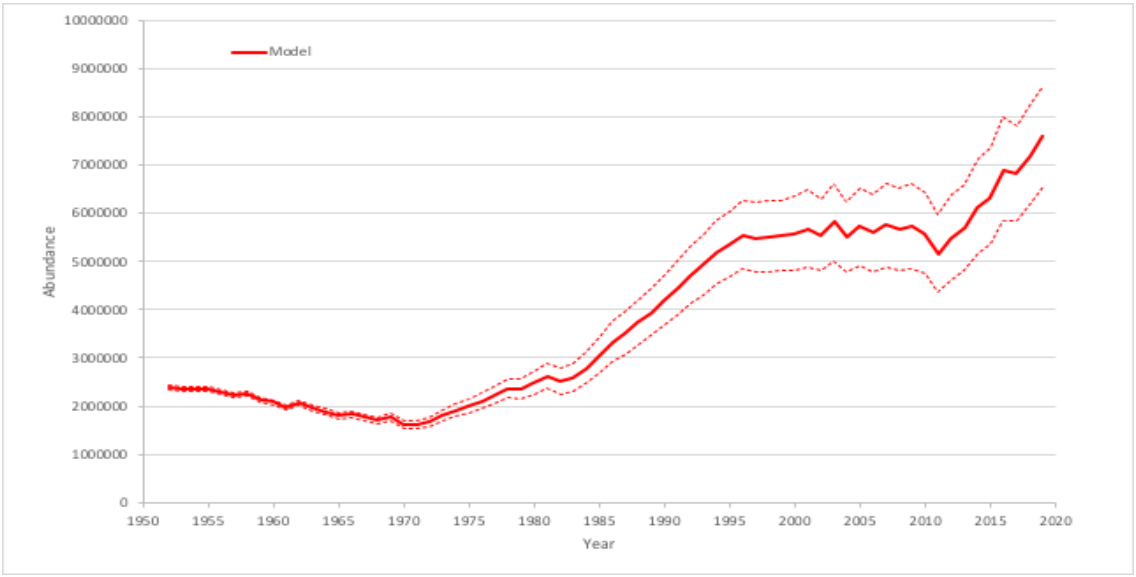

Figure 8. Estimates of total population size (±95% CI, dotted lines) for Northwest Atlantic Harp Seals 1952 to 2019

Removals

Science was requested to identify the maximum sustainable harvest that meets the management objective (i.e., maintaining an 80% probability of remaining above N_{70} for the next five years, 2020-2024) assuming catch age structures of 5% adults/95% YOY, 10% adults/ 90% YOY and 50% adults/50% YOY. The Atlantic Seal Management Strategy identifies three reference levels as a proportion of the maximum population size estimated (N_{max}). Based upon the population model, N_{max} was estimated to be 7.6 million seals, with the precautionary level, N_{70}=5.3 million, a secondary precautionary level, N_{50}=3.8 million and the critical reference level, N_{30}=2.3 million animals.

In the projections to evaluate the impact of different levels of harvest it was assumed that the Greenland harvest and reproductive rates remained within the range of values observed over the last decade. Based upon a regional climate change model, ice cover was predicted to decline with the area becoming ice-free during winter by the end of the century. The estimated probabilities of remaining above N_{70}, are affected by the age composition of the harvest, herd productivity and the amount of suitable ice available for breeding. A catch that respects the management objectives would be 425,000, 375,000 and 175,000 animals for a harvest composition of 95%, 90% and 50% YOY, respectively.

Science was also requested to estimate Potential Biological Removals (PBR).

PBR is defined as $PBR=F_R*R_{max}*0.5*N_{min}$, where R_{max} is the maximum rate of population increase, F_R is a recovery factor (between 0.1 and 1.0) and N_{min} is the estimated population size using the 20-percentile of the log-normal distribution of the most recent population estimate. Assuming a $F_r=1$ and an estimate population of 7,600,000 (95% CI, 6,337,800-8,862,200) Harp Seals in 2019, N_{min} is 7,100,000 and the estimated PBR is 425,600. This estimate includes all removals from the Northwest Atlantic Harp Seal population and therefore is not equivalent to the Canadian TAC.

Sources of Uncertainty

The annual reproductive rate data have a significant impact on our ability to fit the model to the observed data. As well, assumptions about future rates have a significant impact on modelled population trajectories and impacts of different harvest levels. Animals aged 8+ years of age contribute the most to the total pup production, and therefore it is important to have adequate numbers of samples from this age class to describe the productivity of the herd. Identifying variation in age of first reproduction also requires increased samples sizes of younger seals.

The Greenland harvest has an important impact on the population dynamics of Northwest Atlantic Harp Seals. There is considerable uncertainty as to the level and age structure of the subsistence catches, as well as the number that are killed, but not recovered or reported (Struck and Lost) in the Canadian Arctic and Greenland.

Estimates of seals caught in fishing gear are not well known, but may have an impact on our estimates of abundance.

Although reduced ice cover and quality are known to result in increased YOY mortality, the nature of that relationship is not known. It is also not known how ice cover and quality will change in the future. Nevertheless, as further reductions in ice coverage are predicted, poor ice conditions are likely to have an increased impact on YOY mortality. Reduced ice cover may also affect food availability and body condition of Harp Seals which, in turn, could impact reproductive rates. Again, the nature of these relationships is poorly understood and thus difficult to account for in the population assessment.

Regional ice models predict declines in ice cover and the timing of ice formation and retreat which would increase ice related mortality. However, this assumption may be conservative because some animals may move to areas where more suitable ice occurs. At the same time, a northward expansion in the whelping areas may increase exposure to other sources of mortality such as predation by polar bears or alter access to seasonal food resources. Changes in the timing of ice formation and retreat may also impact prey availability, and hence, reproductive rates of Harp Seals.

Since 1990, Harp Seals have been assessed every four to fiveyears when new pup production survey results became available. The harvest targets YOY primarily but the majority of females

are not reproductively mature until they are 7 to 9 years old. Therefore, changes in pup production, resulting from high removal rates or unusual mortality will not be detected for a minimum of 15 to 20 years. If the frequency of surveys is reduced, it will result in increased uncertainty and may require more conservative harvest levels to ensure the population remains viable.

CONCLUSION

The estimated population of Northwest Atlantic Harp Seals was 7.6 million in 2019 based upon a population model that included pup production estimates up to 2017, annual estimates of age-specific reproductive rates, removals and ice related mortality up to 2019. The population appears to have been relatively stable since the mid-1990s, but has been increasing in recent years likely due to higher reproductive rates and lower removals.

Inter-annual fluctuations in reproductive rates of Harp Seals have increased over the last decade. This change can be explained by density dependent (i.e., population size approaching carrying capacity) and density independent (e.g., ice conditions and/or prey availability affecting reproductive rates) factors which are predicted to remain variable and will have an important impact on our advice.

The impact of different harvest scenarios was examined. Population trajectories and the impact of different levels of removals on the population are very sensitive to assumptions concerning future productivity of the herd, and the probability that harvests will meet the management objectives.

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SOURCES OF INFORMATION

This Science Advisory Report is from the October 21-26, 2019 meeting of the National Marine Mammal Peer Review Committee. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2010. Canadian Atlantic Seal Management Strategy. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/089.

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Wade, P. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Mar. Mamm. Sci. 14:1-37.

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