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Canadian Science Advisory Secretariat
Quebec and Maritimes Regions **Science Advisory Report 2017/045**

STOCK ASSESSMENT OF CANADIAN NORTHWEST ATLANTIC GREY SEALS (*HALICHOERUS GRYPUS*)

Photograph by W. D. Bowen.

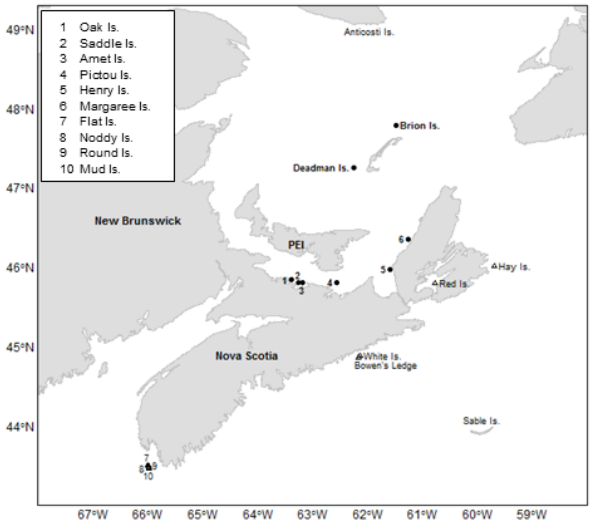

Figure 1. Southern Gulf of St Lawrence and Scotian Shelf showing the locations of Sable Island, coast of Nova Scotia and Gulf of St Lawrence grey seal colonies.

Context:

There is a small commercial hunt for grey seals in the Gulf of St. Lawrence and along the coast of Nova Scotia. Grey seals are managed under the Atlantic Seal Management Strategy (ASM), a precautionary approach for Atlantic seals which was implemented in 2003. The management objective is to maintain an 80% probability (L_{20}) that the population will remain above 70% (N_{70}) of the largest estimated population size. N_{30}, corresponding to 30% of the maximum population size, is the population level below which all harvesting should cease.

The Canadian Northwest Atlantic grey seal population has been increasing since the 1960s. The interaction between a growing grey seal population and fish stocks on the Atlantic Coast has become an issue of considerable interest. Resource Management requested advice on the status of the overall population, harvest scenarios that meet ASM, and risk associated with different levels of harvesting.

This Science Advisory Report is from the October 17-21, 2016, Results of 2016 Northwest Atlantic grey seal pup production survey and sustainable harvest advice. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Grey seals form a single genetic population that is divided into three groups for management purposes based on the location of breeding sites.
- To estimate the number of pups born in 2016, aerial photographic (fixed-winged, helicopter, drone) and visual surveys were completed for all grey seal breeding colonies in Canada. The previous pup production survey was conducted in 2010.
- Pup production on Sable Island was estimated to be 83,600 with 95% confidence interval (CI) of 63,600 to 103,500, an increase of 4% over the 2010 level. Coastal Nova Scotia comprises two main areas of breeding grey seals. Hay Island pup production at 2,500 (95% CI 1,700 to 3,200) was similar to the 2010 level, while the southwest Nova Scotia colonies (Round, Mud, Noddy and Flat) increased to 2,100 pups (95% CI 1,800 to 2,400) compared to an estimate of 417 pups in 2010. A new colony on Red Island in the Bras D'Or lakes had 41 pups in 2016. Pup production in the Gulf of St. Lawrence (GSL) was 10,500 (95% CI=9,000 to 12,200) not significantly different from the 2010 estimate of 11,300 (95% CI=4,000 to 31,800). Total pup production was estimated to be 101,500 (95% CI=80,600 to 121,600)
- The distribution of pup production has changed over time, with a decline in the fraction of the population born in the GSL and continued increases on Sable Island and in southwest Nova Scotia. In 2016, most pups (85%) are born on Sable Island, 11% are born in the GSL and 4% are born along the coast of Nova Scotia.
- In the GSL, the proportion of pups born on the ice has declined from 100% in 2004, to 1% in 2016 due to a decline in winter ice cover. Seals have responded by pupping on nearby islands.
- A mark-resight analysis of individually marked grey seals sighted on Sable Island between 1978 and 2016 was used to estimate age- and sex-specific adult survival. Average adult survival was high (male=0.943, 95% CI 0.937 to 0.948; female=0.976, 95% CI 0.974 to 0.978). Male grey seals had lower survival rates at all ages than females. There is no evidence of a change in survival of adult males or females over time.
- Juvenile survival rate has declined from 76% in early 1990s to 33% in the mid-2000s.
- In previous assessments, it has been assumed that the sex ratio between males and females was 1:1. However, this assumption is not correct due to the different mortality rates observed for males and females. Assuming a stable age distribution, the male to female sex ratio is 0.69:1.
- Information on reproductive rates has been obtained from biological samples collected in the GSL and the mark-resighting program on Sable Island. Both sources of data suggest a decline in reproductive rates at the younger age classes, but also indicate high and stable reproductive rates for older females.
- Population models, incorporating estimates of age-specific reproductive rates, and removals was fitted to pup production estimates to describe the dynamics of the grey seal population in Canada. All three herds continue to increase. The estimated 2016 total population for Sable and Coastal Nova Scotia herd, taking into account the sex ratio, was 380,300 (95% CI 234,000 to 517,200), and 44,100 (95% CL=29,600 to 61,100) for Gulf of St Lawrence herd. The total estimated Canadian grey seal population is 424,300 (95% CI=263,600 to 578,300,

rounded to the nearest 100). This estimate is significantly lower that estimated in 2014, due to changes in the population model.

- The population model was updated to incorporate the new estimates of adult female survival, and input data including removals and pup production estimates. Based on the new sex-specific estimates of adult survival, the estimated total abundance also used the estimated male:female sex ratio of 0.69:1 instead of the 1:1 ratio assumed in previous assessments.
- Removals from the population during the last five years include animals taken in the commercial harvest, for scientific collections, nuisance seals (seals removed for damaging gear and catches), and incidental catches in commercial fisheries. Estimates of the number of seals killed as nuisance seals are incomplete and poorly known. There is no data available on incidental catches, but the numbers are thought to be small.
- Projections from the model were used to investigate the consequences of a range of harvest strategies. In the GSL, harvests of 4,500 and 2,400 animals comprising 95% young of the year (YOY) and 70% YOY, respectively, would respect the current management objective of remaining above N_{70}. For the combined Sable and Coastal Nova Scotia (Scotian Shelf) herds, harvests of 30,000 and 17,000 animals comprising 95% YOY and 70% YOY, respectively, would have an 80% probability of remaining above N_{70}.
- In the GSL, harvests of 6,800 and 4,000 animals comprising 95% YOY and 70% YOY, respectively, would have a 50% probability of remaining above N_{70}. For the Scotian Shelf herd, harvests of 51,000 and 31,000 animals comprising 95% YOY and 70% YOY, respectively, would have a 50% probability of remaining above N_{70}.
- The probability of exceeding N_{70} and N_{50} for total allowable catches of 60,000, 70,000 and 90,000, 100,000, 120,000 150,000 and 200,000, assuming catches taken in proportion to pup production, and age composition of 95% YOY and 70% YOY were estimated.
- For a total catch of 60,000, the probabilities of exceeding N_{70} for Scotian Shelf is 53% (95% YOY) and 83% (70% YOY) and exceeding N_{50} is 48% (95% YOY) and 80% (70% YOY). The probabilities of exceeding N_{70} for the Gulf is 46% (95% YOY) and 94% (70% YOY) and exceeding N_{50} is 30% (95% YOY) and 96% (70% YOY). Higher harvest levels reduce the probabilities of remaining above N_{70} and N_{50}.
- The number of grey seals foraging throughout Atlantic Canada varies seasonally. Model estimates of the number of seals in the population and estimated locations from satellite telemetry were used to calculate the seasonal abundance of grey seals in the GSL. These estimates were very uncertain, and should only be used for illustration. The results suggest that the population of grey seals foraging in the GSL can more than double between January to March and July to September.

BACKGROUND

The status of the Canadian Atlantic grey seal population was re-assessed. The dynamics of the population were described using an age-structured model that incorporates data on reproductive rates, removals and estimates of ice-related mortality. Canadian Atlantic grey seals have been managed under the Atlantic Seal Management Strategy. As a data-rich population, the management objective has been to maintain an 80% probability that the population remains above a precautionary reference level (N_{70}), which is defined to be 70% of the maximum estimated population size.

Resource Management requested advice on the status of the overall population, as well as changes in the status of the three herds. The following specific questions were addressed:

1. For the next five years (2017-2021) what would be the maximum sustainable harvest with an 80% confidence of remaining above N_{70}?
2. What is the risk that the grey seal population will drop below 50% and 70% of N_{max} at a total allowable catch of 60,000, 70,000 and 90,000, 100,000, 120,000 150,000 and 200,000 animals with a composition of 30% adults / 70% beaters, and 5% adults / 95% beaters?
3. If a target population was set at N_{70} (e.g. 70% of maximum population observed) what would be the total annual removals required to maintain that target over a range of 5 and 10 years?
4. Estimate the number of grey seals foraging in the Southern Gulf of St. Lawrence (4T).

Species biology

The grey seal is a member of the family Phocidae. In Canada, they are sometimes referred to as horse-head seals owing to the elongated snout of adult males. Males may reach a length of 231 cm and weigh as much as 350 kg. Females are smaller, reaching 201 cm in length and weigh up to 250 kg. Breeding occurs on islands, isolated beaches, or on pack ice. Pupping occurs between late December and mid February; females nurse a single pup for about 17 days. Mating occurs during late lactation after which adults return to sea to feed. 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. There is a single population of grey seals in Atlantic Canada that is divided into three components, Sable Island, Gulf of St. Lawrence (GSL) and Coastal Nova Scotia, for management considerations based on the locations of the major pupping concentrations (Figure 1).

Human induced mortality

There is a small commercial harvest for grey seals (Table 1). Harvests occur in the GSL and along the Eastern Shore of Nova Scotia. Animals are also taken under scientific permits, under the nuisance seal permit provision of the Marine Mammal Regulations, and as incidental catch in commercial fisheries. There is limited information on the magnitude of this latter mortality. Nuisance seal licenses are issued to fishermen that report seals causing damage to fishing gear or catches. They are required to report the number of seals they have removed, but most fishermen do not provide this information.

Table 1. Reported removals from the NW Atlantic grey seal population over the last 5 years.

	2012	2013	2014	2015	2016
Commercial harvest 1+	0	243	82	1381	1588
Science collections	159	58	83	42	30
Nuisance seals[1]	5428	3757	3732	3732	3732

[1]*the nuisance seal estimate is based on the number of seals reported removed, divided by the reporting rate.*

ASSESSMENT

The total number of grey seals in the Northwest Atlantic cannot be counted directly. The number of seal pups born is estimated from aerial surveys and ground counts conducted at pupping

colonies. Estimates of total population are based on a population model that incorporates estimates of pup production with data on reproductive rates (age-specific, late-term pregnancy rates), mortality rates, and removals, including seals struck and lost.

Adult and juvenile survival

A mark-resight analysis of individually marked grey seals sighted on Sable Island between 1978 and 2016 was used to estimate age- and sex-specific adult survival. Average adult survival was high (male=0.943, 95% CI 0.937 to 0.948; female=0.976, 95% CI 0.974 to 0978). Male grey seals had lower survival at all ages. There has been no change in survival of adult males or females over time. Another mark-resight analysis of marked females on Sable Island found that the 1998-2002 cohorts had their first pup almost a year later than the 1985-1989 cohorts and that the 1998-2002 survival rate (0.33) was almost half the survival rate of the 1985-1989 cohorts (0.76). These estimates of juvenile and adult survival were incorporated into the model by setting a higher ratio of first year mortality to adult mortality, and allowing the model to estimate lower adult mortality.

Reproductive rates

Age-specific reproductive rates were estimated from samples in the GSL. There appears to have been a decline in the pregnancy rates for 5-7 year-old females since the early 2000s, but samples sizes are too small for these age classes (as evidenced by large confidence intervals) to draw firm conclusions (Figure 2). Overall, pregnancy rates for age 8 years and older were high throughout most of the time-series. Similar results were obtained from a mark-resight analysis of females sighted between 1992 and 2016 on Sable Island. This analysis showed that, although there was interannual variation, the probability of breeding was high and that there was no trend.

Pup Production

Pup production on Sable Island was 83,600 with 95% confidence interval (CI) of 63,600 to 103,500. Coastal Nova Scotia comprises two main areas of breeding grey seals. Hay Island pup production at 2,500 (95% CI 1,700 to 3,200) was similar to the 2010 level, while the southwest Nova Scotia colonies (Round, Mud, Noddy and Flat) increased rapidly to 2,100 pups (95% CI 1,800 to 2,400) compared to an estimate of 417 pups in 2010. A new colony on Red Island in the Bras D'Or lakes first discovered in 2015 had 41 pups in 2016. Pup production in the GSL was 10,500 (95% CI=9,000 to 12,200), which is not significantly different from the 2010 estimate of 11,300 (CI=4,000 to 31,800). Sable Island production accounts for 85% of the estimated total number of pups born. The GSL accounts for 11% and Coastal Nova Scotia 4%.

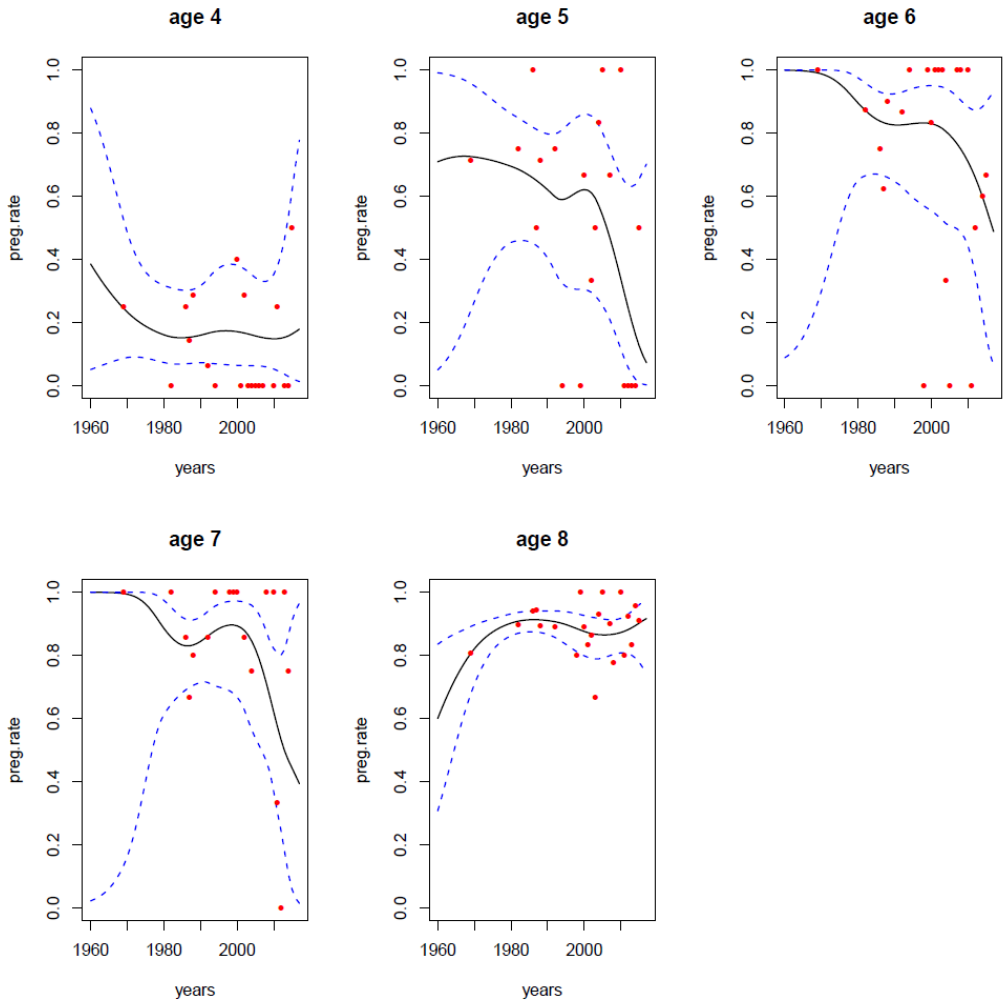

Figure 2. Age-specific pregnancy rates (red circles) and non-parametric smoothed rates (solid line) of females sampled in the Gulf of St. Lawrence for the period 1969-2016 for ages 4-8+ years. Dotted lines represent 95% confidence interval.

Population Model

The age-structured model, based on the model formulation used to describe the dynamics of the Northwest Atlantic harp seal, is fitted to the time series of estimated pup production by adjusting the model estimates of initial population size, adult mortality rate, and carrying capacity. The model assumes that the male to female sex ratio is 1:1. We have updated the model used in previous assessments in the following ways. First, the Sable Island and CNS pup production and removals data were combined and a single Scotian Shelf population model was run for these two groups. We continue to run a separate population model that includes the impact of varying ice conditions for the GSL. Second, based on the new mark-recapture estimates of adult survival, the ratio of adult to juvenile mortality in the population models was increased from 3, 5, and 6 for Sable, CNS and GSL respectively to 15 for both GSL and Scotian Shelf models. Third, based on the adult mortality rates estimated from the mark-resight study on Sable Island, estimates of adult mortality in the model were restricted to values within a range of 0.01 to 0.07, instead of the range of 0.01 and 0.1 used in the previous assessment. Fourth, the

total population estimates from the sum of the two models was adjusted based on sex ratio (0.69:1 male:female) calculated from the new estimates of female and male adult survival, instead of the 1:1 sex ratio used in the 2014 assessment.

The models predict that the overall population has continued to increase, driven primarily by increases of the Scotian Shelf colonies (Figure 3). The population model estimate of pup production in 2016 for the Scotian Shelf colonies was 87,100 (95% CI=70,200-103,300). The total estimated population in 2016 is 380,300 (95% CI=234,000 to 517,200). In the GSL, the model estimated a 2016 pup production of 14,200 (95% CL=10,500-18,300) and a total population in 2016 of 44,100 (95% CI=29,600 to 61,100). The model estimate of total Canadian grey seal pup production is 101,500 (95% CI 80,600 to 121,600) and the total estimated population is 424,300 (95% CI=263,600-578,300) (rounded to the nearest 100, and adjusted for sex ratio of 0.69:1.

The current estimate of abundance is less than that estimated in 2014 due to changes in model assumptions concerning the adult sex ratio and first year and adult mortality rates. The change in sex ratio assumed for the population has the greatest impact in estimates of total population size. Estimates of adult mortality from the model decreased from values 0.07 and 0.08 from the 2014 assessment, to values 0.039 and 0.032 for the Sable Island and the Gulf colonies respectively. With a higher ratio of first year to adult mortality there are fewer immature females in the population and a smaller total population is needed to produce the observed number of pups. The difference does not represent a decrease in abundance, but rather a change in the scale of estimated total population as new biological information is incorporated into the population model. Using this new model formulation, the 2014 estimate is reduced to 394,400 from the previous estimate of 505,400.

Assessment of Population Consequences of Harvest Strategies

The population dynamics model was used to investigate the consequences of a range of harvest strategies on the future population trends. Harvest advice was provided for each herd separately by allocating catches to each herd relative to its size. The total catch that would respect the management objectives is determined by summing the catches from the GSL and the Scotian Shelf herds (Figure 4).

In the GSL, harvests of 4,500 and 2,400 animals comprising 95% YOY and 70% YOY respectively would have an 80% probability of remaining above N_{70} (Figure 4, Table 2). The likelihood the population will be at N_{70} (i.e. 50% probability of falling below or being above N_{70}). A harvest of 6,800 would result in the population declining to N_{70} if the harvest comprised 95% YOY (Figure 4, Table 3). If the harvest comprised 70% YOY, then a harvest of 4,000 would result in a decline to the thresholds of N_{70} (Figure 4, Table 3). Harvests at these levels would maintain the Gulf population at N_{70} over 5 and 10 years.

Table 2. The maximum sustainable harvest with an 80% probability of remaining above N_{70} for catches with a composition of 30% adults / 70% beaters (70% YOY) and 5% adults / 95% beaters (95% YOY).

Herd	95% YOY	70% YOY
Gulf of St. Lawrence	4500	2400
Scotian Shelf	30000	17000

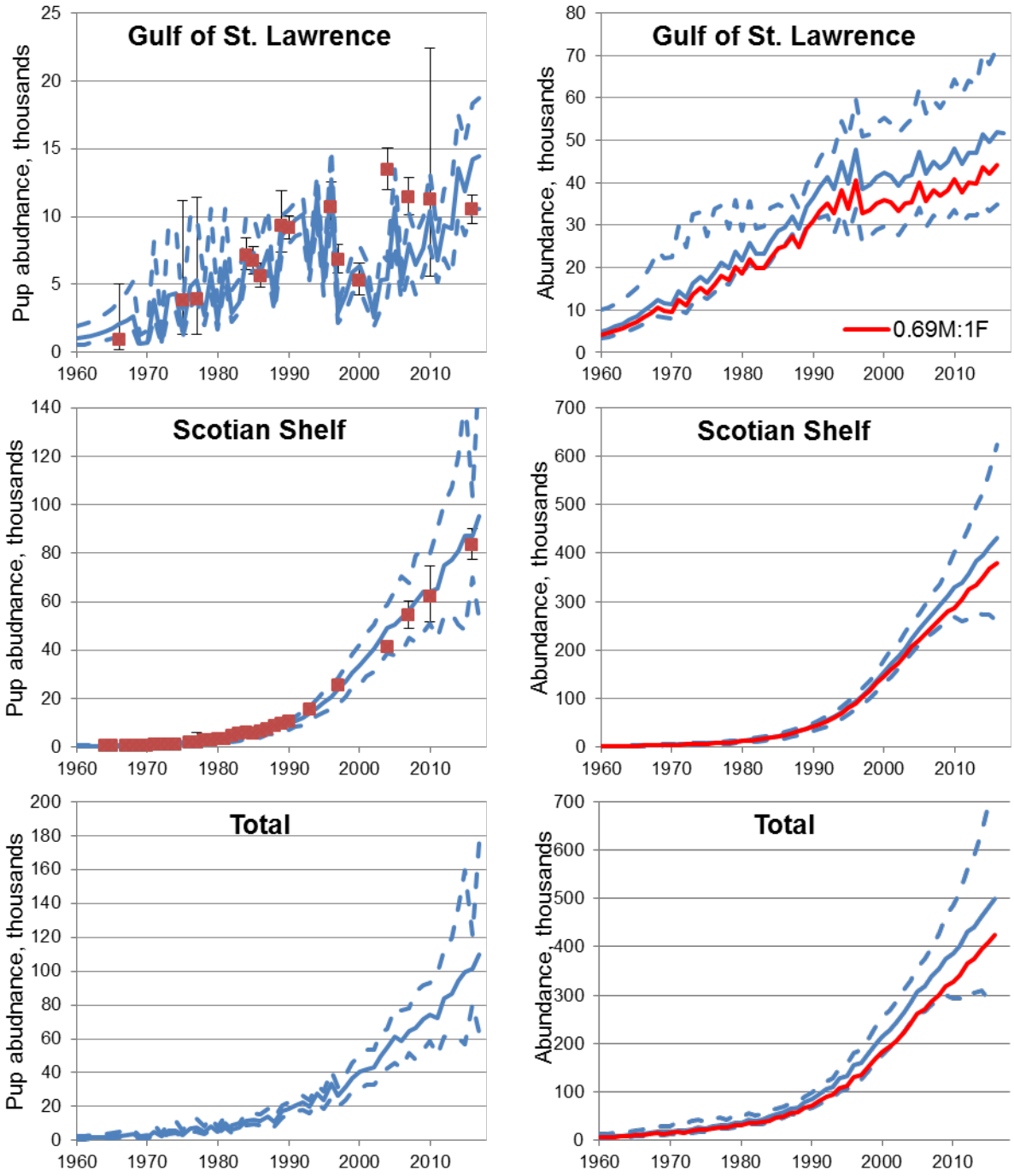

Figure 3. Estimated trajectories (mean ±95% confidence interval) of pup production (left), the total population (right) for the Gulf of St. Lawrence (top), the Scotian Shelf (middle) and the entire Canadian Atlantic population (bottom). The blue line shows the estimated abundance assuming a 1:1 male:female sex ratio. The red line shows the estimated abundance assuming a sex ratio of 0.69:1 male:female.

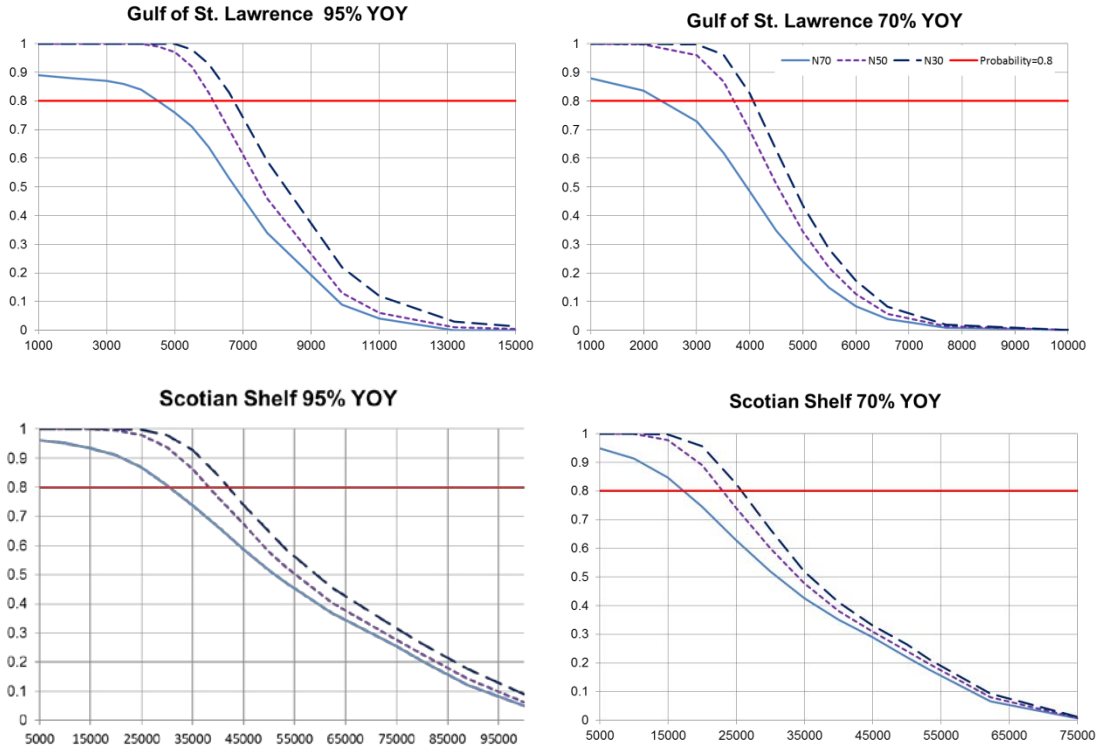

Figure 4. The probability (Y-axis) that different levels of harvest (x-axis) from the Gulf of St. Lawrence (top) and Scotian Shelf (bottom) herds would decline below N_{70}, N_{50} and N_{30} depending on the age composition of the harvest. The two options were 95% Young of the year (left) (YOY) or 70% YOY (right).

Table 3. The maximum sustainable harvest with a 50% probability of remaining above N_{70} for catches with a composition of 30% adults / 70% beaters (70% YOY) and 5% adults / 95% beaters (95% YOY).

Herd	95% YOY	70% YOY
Gulf of St. Lawrence	6800	4000
Scotian Shelf	51000	31000

For the Scotian Shelf herd, harvests of 30,000 and 17,000 animals comprising 95% YOY and 70% YOY, respectively, would have an 80% probability of remaining above N_{70} (Figure 4, Table 2). The risk that the population declines below N_{70} is that harvest that has a 50% probability of falling below those thresholds. A harvest of 51,000 would result in the population declining to N_{70} if the harvest comprised 95% YOY (Figure 4, Table 3). If the harvest comprised 70% YOY, then a harvest of 31,000 would result in a decline to the thresholds of N_{70} (Figure 4, Table 3). Harvests at these levels would maintain the Scotian Shelf population at N_{70} over 5 and 10 years.

The probability of falling below N_{70} and N_{50} for total allowable catches of 60,000, 70,000 and 90,000, 100,000, 120,000 150,000 and 200,000 animals with a composition of 95% YOY and 70% YOY were estimated (Table 4). For a total catch of 60,000 with 89% and 11% of the catch allocated to Scotian Shelf and GSL respectively (i.e. proportional to the populations), the probabilities of the population falling below N_{70} for Sable - CNS is 53% (95% YOY) and 83% (70% YOY) and falling below N_{50} is 48% (95% YOY) and 80% (70% YOY). The probabilities of falling below N_{70} for the GSL is 46% (95% YOY) and 94% (70% YOY) and falling below N_{50} is

30% (95% YOY) and 96% (70% YOY). Higher harvest levels increase the probabilities of falling below N_{70} and N_{50}.

Table 4. Probabilities that the Gulf of St Lawrence and Scotian Shelf grey seal herds will be below 50% and 70% of N_{max} at different total allowable catches with a catch compositions of 95% YOY and 70% YOY.

Total Catch 95% YOY	Gulf of St. Lawrence			Scotian Shelf		
	Catch	50% N_{max}	70% N_{max}	Catch	50% N_{max}	70% N_{max}
60000	6600	30%	46%	53400	48%	53%
70000	7700	44%	66%	62300	60%	63%
90000	9900	88%	91%	80100	77%	80%
100000	11000	94%	96%	89000	86%	88%
120000	13200	99%	100%	106800	97%	98%
150000	16500	100%	100%	133500	100%	100%
200000	22000	100%	100%	178000	100%	100%

Total Catch 70% YOY	Gulf of St. Lawrence			Scotian Shelf		
	Catch	50% N_{max}	70% N_{max}	Catch	50% N_{max}	70% N_{max}
60000	6600	96%	94%	53400	80%	83%
70000	7700	99%	98%	62300	91%	92%
90000	9900	100%	100%	80100	100%	100%
100000	11000	100%	100%	89000	100%	100%
120000	13200	100%	100%	106800	100%	100%
150000	16500	100%	100%	133500	100%	100%
200000	22000	100%	100%	178000	100%	100%

Seasonal abundance in the Gulf of St. Lawrence

The number of grey seals in different areas of Atlantic Canada varies seasonally. Model estimates of the number of seals in the population, not accounting for mortality within the year, and estimated locations from satellite telemetry were used to provide an idea of the seasonal abundance of grey seals in the GSL. These data suggest that the number of seals in the southern Gulf of St Lawrence (NAFO 4T) can vary seasonally, with abundance of grey seals in the summer being more than double that present during the winter (Table 5).

These estimates are highly uncertain, and should be considered only for illustrative purposes. Not all age groups or components of the grey seals population have been tagged, and the numbers of tagged seals is small for some seasons. Tags were also deployed over a number of years prior 2010 and, therefore, may not fully represent current seasonal distribution in the Gulf.

Table 5. To illustrate the possible seasonal changes in the distribution of grey seals, estimated number of seals (95% confidence interval in brackets) from the Scotian Shelf and GSL herds in NAFO zones throughout the year. Total numbers have been adjusted for sex ratio assuming that there are 0.69:1 male:female, based on the survival estimated from mark-recapture analysis on Sable Island.

NAFO Area	Jan - Mar	Apr -Jun	Jul - Sep	Oct - Dec
3PsPnLK	3400 (2400-4400)	2900 (1800-4000)	14400 (9800-191000)	1400 (1000-1800)
4RS	1800 (1100-2500)	15600 (11100-20200)	38100 (28400-47800)	12700 (9400-16100)
4T	30500 (24000-36900)	40100 (30500-49600)	73100 (56300-89900)	61000 (46200-75800)
4Vn	20300 (14600-25900)	13100 (8400-17900)	18300 (13100-23400)	6400 (4500-8300)
4VsW	307200 (194700-419600)	319100 (215200-423000)	270100 (184500-355800)	323700 (209200-438300)
4X	27500 (16700-38000)	17500 (10600-24300)	5600 (3300-7800)	11400 (6900-15900)
5Z	29300 (17600-41100)	11900 (7100-16600)	0	4800 (2900-6700)
Other	1900 (1400-2300)	1700 (1200-2100)	2200 (1400-3000)	400 (300-600)
Total	**421800**	**421800**	**421800**	**421800**

Sources of Uncertainty

In the past, the population and projection models assumed a 1:1 male:female sex ratio in the population. We now have estimates of adult male and female survival which indicate that this overestimates the size of the population. While we have used this new information to correct the estimate of total population, changes in the population growth rate or harvest levels will result in a change in the age structure and the sex ratio. A change in sex ratio will change our total population estimates and the assessment of the risk associated with harvest. To fully account for the differences in male and female survival we would have to include these changes in sex ratio directly in the model.

We have assumed that all females in the population have the same reproductive rates as those that forage in the GSL. Uncertainty in reproductive rates has a large impact on population estimates, particularly for grey seals where the total population is estimated based on pup production.

Estimates of pup production in the GSL have been quite variable. This may be due to a number of issues associated with ice breeding. First, pup mortality on the ice can be quite variable depending on ice conditions and this can have an important impact on survey estimates. When ice is not available, grey seals in the GSL pup on small islands. In recent years, new colonies have developed (e.g., Brion Island, Anticosti Island). Some new or temporary colonies might not be identified in some of the surveys. Finally, at the new and smaller colonies, only single counts are completed and these counts are not corrected for births after the survey date.

Estimates of pup production along at the breeding colonies CNS are increasing more rapidly than in other areas and new colonies continue to be established (e.g., Red Island). This rapid population growth appears to be enhanced by immigration from other colonies. As in GSL, small new or temporary colonies might not be identified in some of the surveys and at these locations the counts are not always corrected for births after the survey date.

There are no estimates of when the pups leave the breeding colonies other than Sable Island. Pup production estimates from small islands in CNS and GSL may be underestimated by assuming that there has been no departure of pups from a breeding colony prior to the survey.

A large number of nuisance seal licences have been issued, particularly in Nova Scotia. However, there is very low reporting on removals under the nuisance seal permit program. Also, we do not always have information on species, and it is not possible to identify the herd for removals other than those taken on a breeding colony.

There is uncertainty in the ratio of first year mortality to adult mortality. All estimates of survival are from the Sable breeding colony and may not be appropriate for all breeding colonies. Also, we use the mark-resight estimate of survival from weaning to first pupping at age 4 or older as an estimate of first year survival. If first year mortality is underestimated then the size of the population, and harvest advice, is overestimated. However, if mortality is overestimated the population size is underestimated and the harvest advice is conservative.

CONCLUSIONS AND ADVICE

The total grey seal population in Atlantic Canada continues to increase. While there are no changes in adult survival or reproductive rates, juvenile mortality doubled between the early 1990s and the mid-2000s. Pup production has stabilized in the GSL, and the population associated with breeding in the GSL appears to be levelling off. The Sable and CNS pup production is increasing at an annual rate of 5%. This is a lower rate of growth than observed on Sable prior to 1997.

The increase in pup production for the CNS herd is driven primarily by pup counts from southwest Nova Scotia. The number of pups born on Hay Island has stabilized likely because breeding habitat is fully used. In the GSL, appears to be considerable variability pup production. Pup mortality is considered to be high in this area, owing to changes in ice conditions.

Projections from the model were used to investigate the consequences of a range of harvest strategies on the grey seal herds. In the GSL, harvests of 4,500 and 2,400 animals comprising 95% young of the year (YOY) and 70% YOY, respectively, would respect the current management objective of remaining above N_{70}. For the Scotian Shelf herd, harvests of 30,000 and 17,000 animals comprising 95% YOY and 70% YOY, respectively, would have an 80% probability of remaining above N_{70}.

In the GSL, harvests of 6,800 and 4,000 animals comprising 95% YOY and 70%YOY, respectively, would have a 50% probability of remaining above N_{70}. For the Scotian Shelf herd, harvests of 51,000 and 31,000 animals comprising 95% YOY and 70% YOY, respectively, would have a 50% probability of remaining above N_{70}.

The probability of population declining below N_{70} and N_{50} for total allowable catches of 60,000, 70,000 and 90,000, 100,000, 120,000 150,000 and 200,000 were estimated assuming catches taken from each herd in proportion to pup production. For a total catch of 60,000, the probabilities of falling below N_{70} for Scotian Shelf is 53% (95% YOY) and 83% (70% YOY) and exceeding N_{50} is 48% (95% YOY) and 80% (70% YOY) and the probabilities of falling below N_{70} for the Gulf is 46% (95% YOY) and 94% (70% YOY) and falling below N_{50} is 30% (95% YOY) and 96% (70% YOY). Higher harvest levels increase the probabilities of falling below N_{70} and N_{50}.

The number of grey seals foraging in different areas of Atlantic Canada varies seasonally. The population of grey seals foraging in the GSL can more than double between winter (January to March) and summer (July to September).

OTHER CONSIDERATIONS

Grey seals are considered by the commercial fishing industry as an important factor limiting the recovery of groundfish stocks in eastern Canada. Grey seals are also important hosts for the nematode parasite, *Pseudoterranova decipiens,* which are a cosmetic nuisance and increase costs associated with processing of fish. Grey seals also take baits from lobster traps and fish from gill nets and longlines and are known to break fishing gear. The value of this damage throughout Atlantic Canada has not been quantified in recent years.

Some of the annual harvest scenarios that were requested would eliminate pup production and result in empty cohorts.

SOURCES OF INFORMATION

This Science Advisory Report is from the October 17-21, 2016 Results of 2016 Northwest Atlantic grey seal pup production survey and sustainable harvest advice. 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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Hammill, M.O., den Heyer, C.E., Bowen, W.D., and Lang, S.L.C. 2017. Grey Seal Population Trends in Canadian Waters, 1960-2016 and harvest advice. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/052. v + 30 p.

Hammill, H.O., Gosselin, J.-F., and Stenson, G.B. 2017. Pup production of Northwest Atlantic grey seals in the Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/043. iv + 14 p.

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