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

Photograph by W. D. Bowen

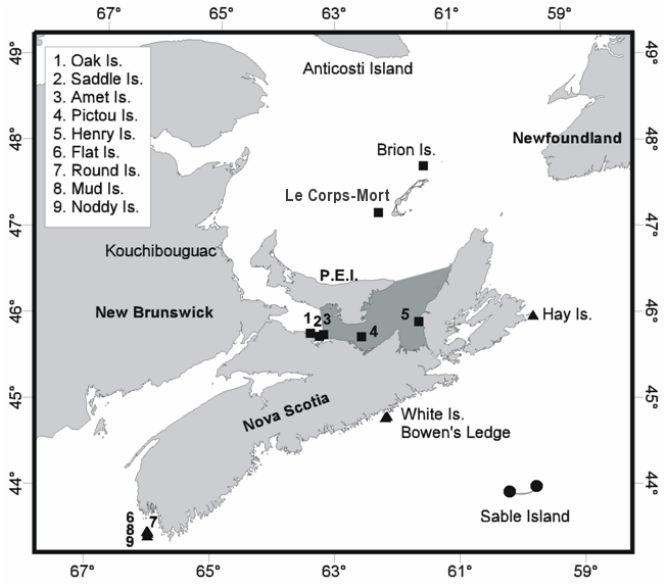

Figure 1. Southern gulf of St Lawrence and Scotian Shelf showing location of Sable Island (●), coast of Nova Scotia (▲), Gulf (■) grey seal colonies and general location of ice-breeding animals (dark grey area).

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 Objective Based Fisheries Management (OBFM) approach for Atlantic seals which was implemented in 2003. The management objective is to maintain an 80% probability (L20) that the population will remain above 70% (N70) of the largest population seen. For example, for a grey seal population of 300,000 animals, N70 is 210,000 animals.

The interaction between a growing grey seal population and fish stocks on the Atlantic Coast has become an issue of considerable interest, as cod stocks, in particular, continue to decline and fisheries become severely restricted or closed altogether. If seal management actions are to be considered by the Department, it is important to understand the long-term impacts on the population. A new population survey of grey seals was conducted in early 2010 to provide new estimates of population parameters.

SUMMARY

- Grey seals form a single genetic population that can be divided into three groups for management purposes based on the location of breeding sites. Most pups (81%) are born on Sable Island, 15% are born in the Gulf and 4% are born along the coast of Nova Scotia. This distribution has changed over time, with a decline in the fraction of the population born on the ice compared to on small islands, and an increase in the proportion of animals born on the coast of Nova Scotia, compared to the Gulf.

- Total pup production of Northwest Atlantic grey seals in 2010 was 76,300 (SE=6,500). This includes 62,000 (SE=600) pups born on Sable Island, 3,000 (SE=100) along the coast of Nova Scotia, and 11,300 (SE=6,400) in the Gulf of St. Lawrence.

- Pup production on Sable Island increased at an exponential rate of 12.8% per year between the 1970s and 1997. However, since 1997 surveys indicate that there has been a decline in the rate of increase to about 4% per year between 2007 and 2010. Pup production along the coast of Nova Scotia has increased from a few hundred in the early 1990s to about 3,000 in 2007 and 2010. However, the number of pups born at small breeding colonies in southwest Nova Scotia doubled between 2007 and 2010 and colonies have expanded to adjacent islands. Pup production in the Gulf has been more variable. It has increased from roughly 7,000 animals in 1984 to 11,000 in 1996, but has fluctuated between 6,100 and 15,600 since then.

- On Sable Island there has been an increase in the age at first birth and a reduction in apparent survival of juveniles over the last decade. For example, the proportion of animals aged 5 years old appearing for the first time with a pup has declined from 30% during the period 1985-1989 to 12% during 1998-2002. In the Gulf herd of the population, the mean age at first birth is 5 years old. This has not changed since the late 1960s, nor have changes been observed over time in age-specific pregnancy rates. There are no data on age-specific pregnancy rates for the coast of Nova Scotia.

- Removals from the population during the last five years include animals taken in the commercial harvest, scientific collections, nuisance seals, and incidental catches in commercial fisheries. Estimates of the number of seals killed as nuisance seals are incomplete. There is no data available on incidental catches, but the numbers are thought to be small.

- Pup surveys completed approximately every 4 years combined with estimates of age-specific reproductive rates and removals are incorporated into a Bayesian population model to determine total abundance. The variability associated with model parameters, as well as potential changes in natural mortality rates due to changes in environmental conditions add uncertainty to the Gulf population estimates. Additional uncertainty is associated with the application of reproductive rate data from the Gulf to the Sable Island herd.

- Total estimated population size at the end of the 2010 breeding season (i.e., including pups) was 348,900 (95% CI 291,300-414,900). This is 4% higher than the equivalent estimate for 2009 of 335,200 (95%CI 292,000-395,100) and an order of magnitude higher than the estimate for 1977 of 35,800 (95%CI 24,700-53,100). Estimates of average annual rates of population increase from the model were 6% in the 1980s, 9% in the 1990s, and 6% in the 2000s.

- Outputs from the population dynamics model were used to investigate the consequences of a range of harvest strategies. The management objective was to find harvest levels that have an 80% probability of maintaining the population at or above 70% of the largest estimate to date, i.e., above 244,200.

- The management objective could be achieved with harvests as high as 70,000 and 45,000 animals per year over a 3-year and 5-year period, respectively, given a harvest that was 50% young-of-the-year and 50% older animals, and assuming that mortality was distributed among ages, sexes and regions in proportion to relative abundance in the population. This objective could also be achieved with harvests of 50% young-of-the-year and 50% older animals as high as 30,000 animals per year over a 20-year period.

- Removals of 95% young-of-the-year and 5% older animals could achieve higher total harvest levels, up to 70,000 animals per year, and still meet the management objective over 20 years. This is possible because adult females have such long reproductive lives. However at the end of the 20-year period such high harvest levels would result in a population collapse. Higher quotas could be sustained over shorter time periods, but for a long-lived species such as grey seal, more work is needed to determine if 20 years is a long enough time window to judge long-term sustainability.

INTRODUCTION

Resource Management requests Science to provide an update on the status of this population. Advice should include information on the status of the overall population, as well as changes in the status of the three herds generally known by sub-areas as Sable Island, coastal Nova Scotia (formerly referred to as Eastern Shore) and the Gulf of St. Lawrence. Advice is being requested to evaluate the maximum number of animals that can be removed over a three-year period that will still respect the management plan over the long term, assuming harvests that are comprised of 95% young of the year, 5% animals aged 1+ and a second composition of the catch consisting of 50% young of the year and 50% animals aged 1+ years. A second scenario examined how many animals would need to be removed if the population were to be reduced to N70 within 3 and 5 years assuming the above age-structure compositions of the harvest.

The assessment will provide managers with the information required to evaluate the proposed harvest levels and ensure their compliance with the principles and objectives of the upcoming 2011-2015 Integrated Fisheries Management Plan (IFMP) for seals, including compliance with the Precautionary Approach. Advice will be considered in the development of any grey seal population management actions (e.g. population reduction and/or targeted removals).

Species Biology

The grey seal is a member of the family Phocidae that was first described by Fabricius (1791). Its name *Halichoerus* comes from the Greek meaning “sea pig”, and *grypus* from the Latin meaning hook-nosed. In Canada, they are sometimes referred to as horse-head seals owing to the elongated snout of adult males. Males tend to be darker than females, in some cases almost black. They 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 227 kg. Breeding occurs on islands, isolated beaches or on the pack ice. Pups are born with a white lanugo,

which they begin to shed approximately 15 days after birth and is completely replaced with a black spotted, silver coat by the time pups are 25 days old.

An examination of mitochondrial DNA variation in samples from Canada, Norway and the Baltic Sea supports the hypothesis that seals from these areas represent three distinct populations. Eastern and western Atlantic grey seals diverged first, possibly 1.0 - 1.2 million years ago, while the Baltic Sea animals diverged much later. Historically, the Northwest Atlantic population has been divided into two components (Gulf and Sable Island), for management considerations based on the locations of the major pupping concentrations. However, recent increases in coastal colonies indicate that the population could be further separated into animals born in the Gulf of St. Lawrence (Gulf), Sable Island and coast of Nova Scotia (previously referred to as Eastern Shore) herds, the latter including colonies mainly along the eastern shore of Nova Scotia.

Grey seals are a coastal or continental shelf species. They haul out on exposed reefs or on beaches of undisturbed islands. Historically grey seals were abundant, and widely distributed along the Canadian east coast, and in the Gulf of St Lawrence where they were first hunted by Amerindians. Extensive hunting by Europeans, particularly after the disappearance of the Walrus (*Odobenus rosmarus*) in the Gulf and on Sable Island, resulted in the depletion of the grey seal population by the mid-1800s. Up to the 1950s, the grey seal was considered uncommon or rare, but they continued to be hunted. Some grey seals were taken in a bounty program focused on harbour seals (*Phoca vitulina*). A grey seal culling program at the breeding sites in the Gulf of St. Lawrence and along the Eastern Shore occurred between 1967 and 1984, removing from 114 to 2,375 animals per year. From 1978 until 1990, a bounty was paid to licenced fishermen who submitted lower jaws from grey seals, and information on date and location of capture. A total of 4,379 individuals was taken during this program. Captures were initially quite high, but with the exception of a large number of returns in 1987 (753), they declined steadily until 1990, when only 79 returns were received.

Human Induced Mortality

There is a small commercial harvest for grey seals (Table 1). Over the last five years, an average of 655 animals has been removed from the population each year. Harvests occur in the Gulf of St. Lawrence and along the Eastern Shore of Nova Scotia. Some grey seals have been killed under a nuisance seal permit provision of the Marine Mammal Regulations. Reports on the numbers of seals removed under the nuisance seal program are limited by the low number of license holders reporting. In 2008, 422 licenses were issued; 31 holders reported that 218 grey seals were killed for an average of 7 seals per report. In 2009, 428 licenses were issued, 14 holders reported killing 122 seals for an average of 8.7 seals per report. Together this results in an average of 7.9 seals (SE 0.6) per reporting holder in the two years. This removal rate was extrapolated to the total number of permits issued to derive an estimate of seals removed under the nuisance seal program. Since these permits have largely been issued by Maritimes region, removals were applied only against the Sable population. Some animals are removed as part of Department of Fisheries and Oceans scientific sampling programs to study diet, growth and reproductive rates. This program has removed 127 seals in the last 5 years. Grey seals may also be taken as incidental catch in commercial fisheries, but no data are available on the magnitude of this mortality.

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

	2005	2006	2007	2008	2009	2010
Commercial harvest 1+	1073	1857	1747	1471	263	58
Science collections	12	28	87	0	0	0
Nuisance seals	3105	3437	3373	3334	3381	2933

ASSESSMENT

The total number of grey seals in the northwest Atlantic cannot be counted directly. Surveys of the total population are impractical because animals are distributed widely across the Atlantic seaboard during the summer and, even though they congregate during the whelping and moulting periods, not all of the population is present on land at any one time and place. However, the number of seal pups born in a year can be 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 pregnancy rates), mortality rates, and removals, including seals struck and lost.

2010 Pup Production

The Northwest Atlantic grey seal population gives birth on Sable Island, on the pack ice in the Gulf of St. Lawrence and on small islands in the Gulf and along the east coast of Nova Scotia. Visual strip transect surveys were flown over the whelping patches on the ice in the Gulf of St. Lawrence and multiple counts were completed at islands in the Gulf and along the coast of Nova Scotia. Where possible, counts were corrected for the proportion of pupping completed at the time of the survey. Pup production in the Gulf has been more variable. It has increased from roughly 7,000 animals in 1984 to 11,000 in 1996, but has fluctuated between 6,100 and 15,600 since then (Table 2). Prior to 1996, 95% of the non-Sable Island pups were born on the ice, while the remainder was born on islands within and outside of the Gulf of St. Lawrence.

Due to a series of winters with poor ice conditions, particularly since 1997, the proportion of pups born on the ice declined to approximately 80% of production during the assessments of 1997, 2000, and 2004, then declined further to approximately 30% of total non-Sable Island production in 2007. Pup production along the coast of Nova Scotia has increased from a few hundred in the early 1990s to about 3,000 in 2007 and 2010. However, the number of pups born at small breeding colonies in southwest Nova Scotia doubled between 2007 and 2010 and have expanded to adjacent islands. Pup production along the coast of Nova Scotia accounted for approximately 18% of the non-Sable Island pup production in 2010.

Table 2. Estimates of Non-Sable grey seal pup production, from mark-recapture (M-R) and aerial surveys, rounded to the nearest 100. The mark-recapture method was replaced after 1990 by aerial survey methods. Standard errors are in brackets.

Year	Mark-recapture estimates	Aerial survey estimates
1984	7,200 (900)	
1985	6,700 (800)	
1986	5,600 (700)	
1989	9,700 (900)	
1990	9,000 (600)	
1996		11,100 (1,300)
1997		7,300 (800)
2000		6,100 (900)
2004		15,600 (1,200)
2007		13,000 (600)
2010		14,200 (6,400)

On Sable Island, the numbers of pups born were assessed using an aerial digital-photographic census. A total of 58,000 pups was counted on the digital imagery. Given the high quality of the imagery, no correction for missed pups was necessary after analysis of ground truthing plots. Once corrected for proportion of pups that died prior to the survey and the proportion of pups born before the survey, estimated total pup production was 62,000 (SE=600). Pup production on Sable Island increased at an exponential rate of 12.8% per year between the 1970s and 1997. However, since 1997 surveys indicate that there has been a decline in the rate of increase to about 4% per year between 2007 and 2010 (Table 3).

Table 3. Estimates of Sable grey seal pup production, total count and aerial surveys. Standard errors are in brackets.

Year	Total counts	Aerial survey estimates
1984	5,900 (300)	
1985	5,600 (300)	
1986	6,300 (300)	
1987	7,400 (300)	
1988	8,600 (300)	
1989	9,700 (400)	11,200
1990	10,500 (600)	10,450 (550)
1993		15,500 (500)
1997		25,400 (800)
2004		41,500 (4,400)
2007		54,500 (1,300)
2010		62,000 (600)

Total pup production of Northwest Atlantic grey seals in 2010 was 76,300 (SE=6,500). This includes 62,000 (SE=600) pups born on Sable Island, 3,000 (SE=100) along the coast of Nova Scotia, and 11,300 (SE=6,400) in the Gulf of St. Lawrence. Most pups (81%) are born on Sable Island, 15% are born in the Gulf and 4% are born along the coast of Nova Scotia. This distribution has changed over time, with a decline in the fraction of the population born on the ice compared to on small islands, and an increase in the proportion of animals born on the coast of Nova Scotia, compared to the Gulf.

On Sable Island there has been an increase in the age at first birth and a reduction in apparent survival of juveniles over the last decade. For example, the proportion of animals aged 5 years old appearing for the first time with a pup has declined from 30% during the period 1985-1989 to 12% during 1998-2002. The reduction in the rate of increase in pup production and observed changes in age of first birth provide evidence of changes in the vital rates of this population. In the Gulf herd, the mean age at first birth is 5 years old. This has not changed since the late 1960s, nor have changes been observed over time in age-specific pregnancy rates. There are no data on age-specific pregnancy rates for the coast of Nova Scotia.

Population Model

A stochastic discrete-time modelling framework called a state-space model was used to estimate total population size from pup production data from 1977-2010. The model was used to estimate Northwest Atlantic grey seal population size in 2007. The population was divided into three breeding regions: Sable Island, Gulf of St Lawrence, and coast of Nova Scotia. Pup surveys completed approximately every 4 years combined with estimates of age-specific reproductive rates and removals are incorporated into a Bayesian population model to determine total abundance. Females are allowed to move from their natal area to a new region to breed, but once they start breeding they do not move. A Bayesian computer-intensive method was used to fit the model, with informative priors on model parameters. The posterior estimates for some parameters were close to their priors indicating that there was little information about these parameters in the pup production data. Other parameters were far from the prior: in particular the posterior estimates of carrying capacity were far higher than the prior values. These results indicate little evidence of density-dependent population regulation at current levels of pup production for the Sable and Gulf herds. Model results suggest strong density dependence for the coastal Nova Scotia herd, dominated by the pupping colony on Hay Island. The variability associated with model parameters, as well as potential changes in natural mortality rates due to changes in environmental conditions add uncertainty to the non-Sable Island population estimates. Additional uncertainty is associated with the application of reproductive rate data from the Gulf to the Sable Island herd.

The total estimated population size at the end of the 2010 breeding season (i.e., including pups) was 348,900 (95% CI 291,300-414,900; Figure 2). This is 4% higher than the equivalent estimate for 2009 of 335,200 (95%CI 292,000-395,100) and an order of magnitude higher than the estimate for 1977 of 35,800 (95%CI 24,700-53,100). Estimates of average annual rates of population increase from the model were 6% in the 1980s, 9% in the 1990s, and 6% in the 2000s.

Assessment of Population Consequences of Harvest Strategies

The outputs of the population dynamics model were used to investigate the consequences of a range of harvest strategies. Populations were simulated using the posterior distribution of model states and parameters from the fitted model, and then projected forward stochastically for up to 20 years under different harvest regimes. The management objective was to find harvest levels that have an 80% probability of maintaining the population at or above 70% of the largest estimate to date, i.e., above 244,200. This objective could be achieved with harvests as high as 70,000 and 45,000 animals per year over a 3-year and 5-year period, respectively, given a harvest that was 50% young-of-the-year and 50% older animals, and assuming that mortality was distributed among ages, sexes and regions in proportion to relative abundance in the

population (Table 4). This objective could also be achieved with harvests of 50% young-of-the-year and 50% older animals as high as 30,000 animals per year over a 20-year period.

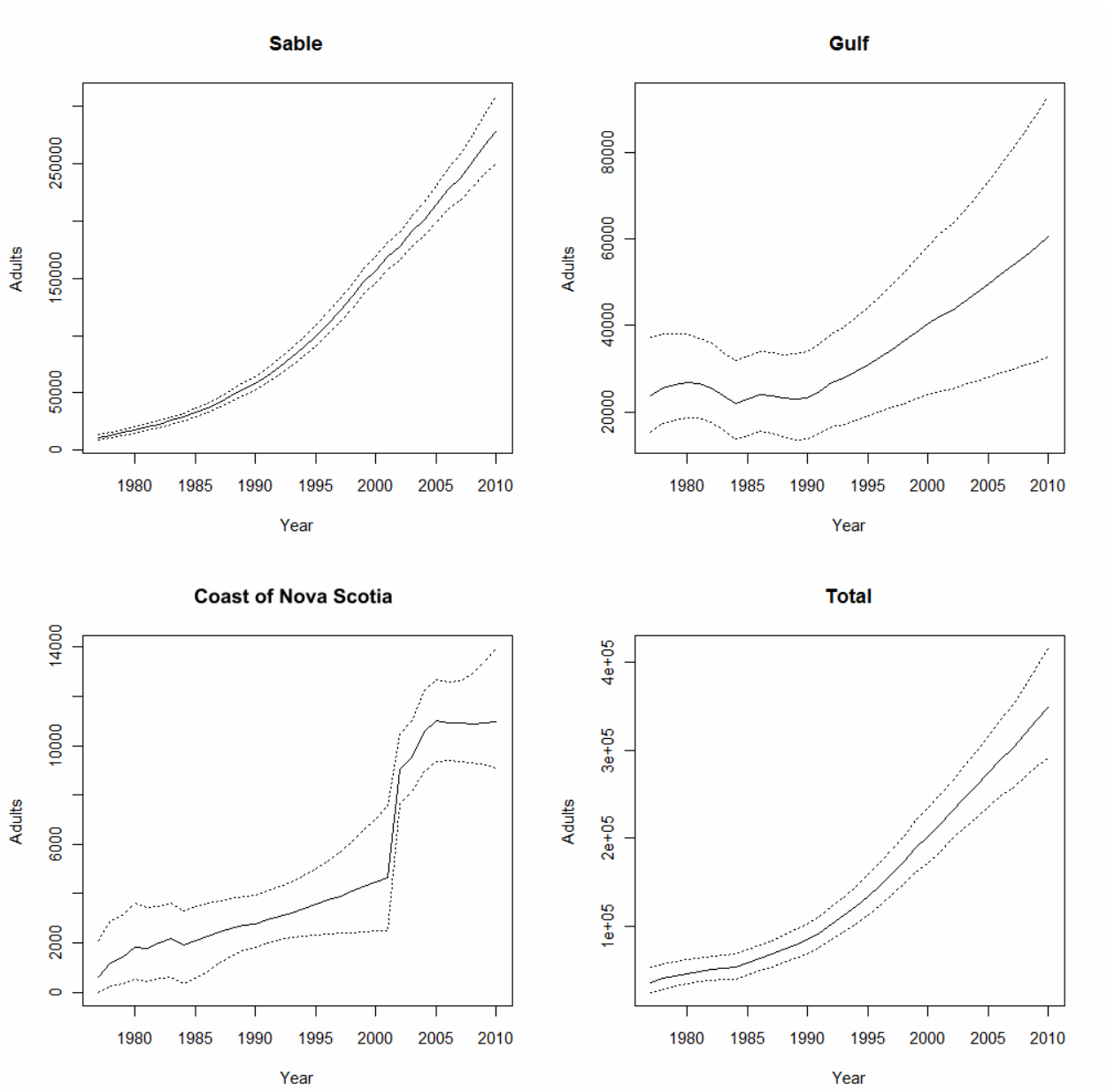

Figure 2. Estimated trajectories of the different herds and the total Northwest Atlantic grey seal population.

Removals of 95% young-of-the-year and 5% older animals could achieve higher total harvest levels, up to 70,000 animals per year, and still meet the management objective over 20 years. This is possible because adult females have such long reproductive lives. However at the end of the 20-year period such high harvest levels would result in a population collapse. Higher quotas could be sustained over shorter time periods, but for a long-lived species such as grey seal, more work is needed to determine if 20 years is a long enough time window to judge long-term sustainability.

Table 4. Results from population projection under harvest scenario 50% young-of-the-year, 50% age 1+ animals. p(pop>244,230) is proportion of simulations where total population size was greater than 244,230. Mean(pop) is mean population size over simulations. 80%LCL(pop) is the lower 80th percentile of population sizes over simulations.

Annual harvest quota	After 3 years			After 5 years			After 20 years		
	p (pop> 244,230)	***Mean (pop) 000s***	***80% LCL (pop) 000s***	***p (pop> 244,230)***	***Mean (pop) 000s***	***80% LCL (pop) 000s***	***P (pop> 244,230)***	***Mean (pop) 000s***	***80% LCL (pop) 000s***
10000	1	368	340	1	395	364	1	607	546
15000	1	360	333	1	381	350	1	541	480
20000	1	353	326	1	366	335	1	470	412
25000	1	346	318	1	351	320	1	394	337
30000	1	339	311	1	336	305	**0.81**	**311**	**250**
35000	1	331	304	1	321	290	0.30	213	147
40000	1	324	296	0.99	305	275	0.05	98	9
45000	1	316	289	**0.94**	**290**	**259**	0	18	0
50000	1	309	281	0.78	274	243	0	2	0
55000	0.99	301	274	0.66	258	227	0	0	0
60000	0.98	293	266	0.49	241	211	0	0	0
65000	0.95	286	258	0.27	225	194	0	0	0
70000	**0.90**	**278**	**251**	0.09	207	177	0	0	0
75000	0.76	270	243	0.06	189	159	0	0	0
80000	0.70	262	235	0.04	171	140	0	0	0

Sources of Uncertainty

The Gulf herd breeds on small islands and on the pack ice in the Gulf of St. Lawrence. Considerable variability in pup production has been observed, particularly over the last decade and overall, estimates of pup production are likely conservative (Table 2). This may be related to changes in ice conditions, resulting in high pup mortality or the displacement of animals to other sites prior to completion of counts. In poor ice years, the extended pupping season means that patches forming early in the season might be lost before being surveyed, as seen in 2010. Flights made following the 26 January storm indicated that the ice in the Strait was largely destroyed and that mortality among animals from the 24 January survey was likely to be high. Although mortality may not have been 100% since some animals may have drifted ashore, the absence of any significant number of older pups in any of the stage or transect surveys indicates that mortality was extensive. This would have resulted in the loss of up to 700 animals or about 16% of the animals born on the ice in 2010. Additional sources of mortality for young of the year grey seals also include coyotes near islands such as Pictou and Saddle Island and predation from Bald Eagles in the area. Further analyses should consider ice cover as a covariate to help account for this variability.

New small colonies have appeared throughout the Gulf and along the coast of Nova Scotia including Hay Island (1993), Henry Island (1997), Oak Island (2007), Pictou Island (2007 assessment, but reports of some pupping since 1997), Kouchibouguac National Park (2007) and Anticosti Island (2007), Brion Island (2010) and Saddle Island (2010). The presence of pups at Anticosti Island is particularly surprising, since the Northern Gulf was thought to be too

cold for pup survival. However, if mild winters continue, then expansion may be expected in areas where there is little human disturbance. Although surveyed and there are a number of suitable beaches are found along the south coast and on Miquelon, no pupping colonies have been observed in Newfoundland to date.

On Sable Island, a change in the duration of the age-specific stages was observed between data collected in 1997, 2007 and 2010. It is more difficult to collect these stage data for the non-Sable Island herd, so stage duration values were used from both the 1997 and 2007 experiments on Sable Island. The use of Sable Island estimates is not expected to result in significant bias.

Currently, harvesting is directed towards the coastal Nova Scotia and Gulf herds. The available reproductive data used in the model were collected from the Gulf herd only. Although large numbers of nuisance seal licences have been issued, there is incomplete reporting on removals under the nuisance seal permit program. Almost all of these licences have been issued in Nova Scotia.

The population model should be treated with some caution because: (1) the biological model showed clear lack of fit, particularly to the Gulf data where extending the model to account for ice and weather conditions would be useful; (2) sensitivity of the results to the priors used has not been assessed; and (3) the fitting algorithm may have caused some (small) biases.

The population projections are preliminary, and more discussion of potential harvest strategies and management goals are needed. Note also that the results are dependent on the adequacy of the population dynamics model used. The nature and extent of density dependence in vital rates is poorly understood and may change over time. How density dependence acts on vital rates will have an impact on sustainable harvest scenarios

The uncertainty in population projections currently does not include sources of variability such as trends in the environment that may affect productivity.

ADDITIONAL STAKEHOLDER PERSPECTIVES

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 must be removed from filets of some commercial fish species during processing. Although not toxic the worms are a cosmetic nuisance and increase costs associated with processing of fish. High worm burdens will reduce the quality rating of the filet, reducing the added on value. 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.

CONCLUSIONS AND ADVICE

In 2007, a new assessment was completed, which enabled moving grey seals from the Data Poor to a Data Rich category. Under OBFM, harvest levels for Data Rich populations are to be set to maintain the population above 70% of the observed maximum population size. The development of a Bayesian model to examine the dynamics of this population offers a more rigorous framework to incorporate uncertainty into the assessment of changes in the size of the

grey seal population. Overall, the Northwest Atlantic grey seal population continues to grow, driven by increases in the component of the population breeding on Sable Island.

Harvests as high as 70,000 and 45,000 animals per year over a 3-year and 5-year period, respectively, given a harvest that was 50% young-of-the-year and 50% older animals, and assuming that mortality was distributed among ages, sexes and regions in proportion to relative abundance in the population, have an 80% probability of maintaining the population at or above 70% of the largest estimate to date. However, harvesting is directed towards the coast of Nova Scotia and Gulf components of the herd, where there is much less certainty associated with the dynamics of these components of the population.

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