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Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

POPULATION REDUCTION SCENARIOS FOR NORTHWEST ATLANTIC HARP SEALS (*PAGOPHILUS GROENLANDICUS*)

Image: Pagophilus groenlandicus.

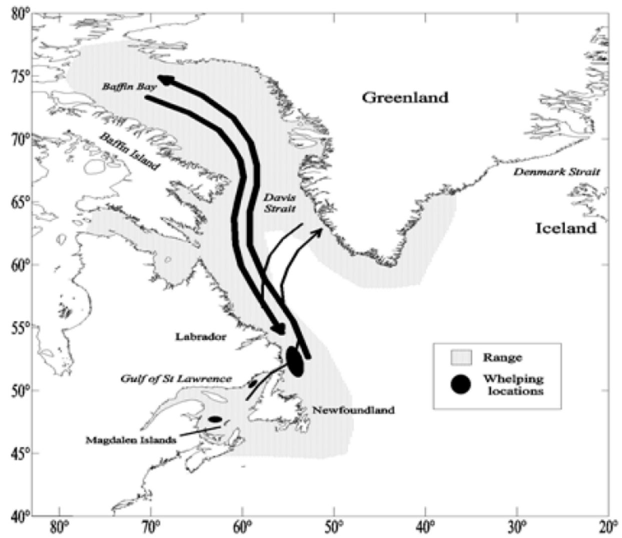

Figure 1. Range, migratory pathways and whelping locations of harp seals in the northwest Atlantic.

Context:

The harp seal is an abundant, medium-sized seal that 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. The Northwest Atlantic population summers in the eastern Canadian Arctic and Greenland. In the fall, these seals migrate southward to Atlantic Canadian waters where they give birth on pack ice in the Gulf of St. Lawrence ("Gulf") or off northern Newfoundland ("the Front") during late February or March. After moulting in April and May, they then return to the north.

Northwest Atlantic harp seals are hunted throughout their range. They are harvested for subsistence purposes by Inuit in Labrador, Arctic Canada and Greenland, and a commercial harvest occurs in the Gulf and at the Front. Approximately 80,000 animals are taken during subsistence harvests, mainly in Greenland. The commercial harvest removed over 300,000 seals per year between 2002 and 2006, but has declined to less than 100,000 seals per year since 2009 due to difficult ice conditions and weaker markets. Over 95% of the commercial harvest consists of young of the year (YOY). Approximately 12,000 seals are estimated to be removed incidentally during commercial fishing activities.

Subsistence harvests are currently not regulated while the commercial harvest is regulated by a five-year (2014-18) management plan.

To date, management objectives have been designed to maximize catches while remaining above a precautionary reference level. Industry stakeholders, however, have indicated that they are strongly in favour of reducing the population level to reduce potential predation on commercial fish stocks. As part of discussions concerning a new management plan, industry and Fisheries Management have asked for science to provide estimates of catches that would reduce the population below its current

Canada

population of 7.4 million and catches that would be sustainable at these reduced levels.

Science was requested to examine the following questions:

1) *Identify the catches necessary to reduce the population to 5.4 million animals assuming:*
   a) *Catches consisting of 90% YOY and 50% YOY*
   b) *Over time periods of 5, 10, and 15 years*
2) *Identify the catches necessary to reduce the population to 6.8 million assuming:*
   a) *Catches consisting of 90% YOY and 50% YOY*
   b) *Over time periods of 5, 10, and 15 years*
3) *Estimate the sustainable future catches possible with a reduced population, assuming there is a 95% probability of remaining above the Limit Reference Point (defined as the current N_{30}).*

This Science Advisory Report is from the October 20-23, 2015 Annual Meeting of the National Marine Mammal Peer Review Committee (NMMPRC) held in Halifax, Nova Scotia. 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. Reported Canadian catches have declined from a peak of 355,000 in 2006 to 35,000 animals in 2015. Greenland catches have fluctuated, between 66,100 and 92,200 animals since 2003. Catches in the Canadian Arctic remain low (<1,000). Additional removals include bycatch, as well as estimates of animals killed, but not recovered (struck and loss). Total removals have been less than 250,000 animals each year since 2009.
- Females age 8 years and older (8+) account for approximately 70% of the pup production. Pregnancy rates for these ages were high throughout the 1960s, but have declined since the mid-1990s. Annual pregnancy rates have varied considerably, particularly since the early 2000s.
- The population assessment model used as input data, the time series of pup production estimates, including the 2012 estimate, as well as reproductive rates, estimates of ice-related mortality, and harvest information to 2013. The model provides an estimated 2012 pup production of 929,000 (Standard Error [SE]=148,000) and a total population of 7,445,000 (SE=698,000).
- The Atlantic Seal Management Strategy identifies three reference levels based upon the maximum observed population, which is referred to as N_{max}. The first reference level is a Precautionary Reference Level called N_{70} that is set at 70% of N_{max}. The Limit Reference Point, known as N_{30}, is set at 30% of N_{max}. Based upon the current model, the maximum population is estimated to be 7.8 million, the precautionary reference level is 5.5 million, and the Limit Reference Point is 2.3 million animals.
- The impacts of the different Canadian catch options on the projected population were tested under two scenarios. The first scenario (Model A) assumed that reproductive rates and Greenland catches were similar to that seen over the past 10 years. The second scenario, referred to as Model B, assumed that both reproductive rates increase and Greenland catches decrease when the population declines (i.e., density-dependent compensation).
- Under both scenarios the number of animals that need to be removed annually is strongly affected by the age composition of the harvest, and the speed in which the reduction was

achieved. Generally, higher numbers of seals must be removed annually if the reduction is to occur quicker, or if more YOY are included.

- The annual catches required to reduce the population to 6.8 million were similar under the two scenarios. However, the annual numbers required to reduce the population to 5.4 million were much higher when density dependence was assumed (Model B). A reduction to 5.4 million assuming annual catches of 90% YOY over 5 years is not possible under either scenario.
- Under most scenarios, after the population had been reduced, annual harvests had to be reduced considerably to permit the population to remain above the Limit Reference Point.
- These simulation results are very sensitive to model assumptions and should be considered for illustration only. The two scenarios represent two unlikely situations, one assuming reproductive rates and catches do not respond to changes in total population while the other assumes full compensation in reproductive rates and catches as the population declines. Based upon historical changes in reproductive rates, we expect that some density dependent compensation will occur, but recent environmental changes suggest that full compensation may not result. The estimated carrying capacity is based upon historical conditions and may no longer be the same. Therefore, the results presented here are only valid within the context of the modelling scenarios examined in this study.

INTRODUCTION

Northwest Atlantic harp seals were last assessed in 2013, based on aerial survey estimates of pup production from surveys up to and including the 2012 survey, and harvest and reproductive rate data up to 2013. In this exercise, the model inputs were not updated from the 2013 assessment; simulated impacts of the different harvest scenarios were projected forward based on the model parameters obtained from the 2013 assessment.

Northwest Atlantic harp seals have been managed under the Atlantic Seal Management Strategy. They are considered to be a data-rich population and has been managed for the last decade with the objective 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 waters off southern Labrador and northern Newfoundland ("the Front") where they give birth in late February or March on medium to thick first year pack ice. 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. 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 form large concentrations on the sea ice off northeastern Newfoundland and in the northern Gulf of St. Lawrence to moult in April and May. Following the moult, seals disperse and eventually migrate northward, primarily along the continental shelf. Small numbers of harp seals may remain in southern waters throughout the summer while a portion of the population remains in the Arctic throughout the year.

The Harvest

Harp seals are harvested commercially in Canada and for subsistence in northern Canada and Greenland (Fig. 2). A general description of the seal hunt, harvest levels, other sources of mortality, and struck and loss may be found in DFO (2011, 2014).

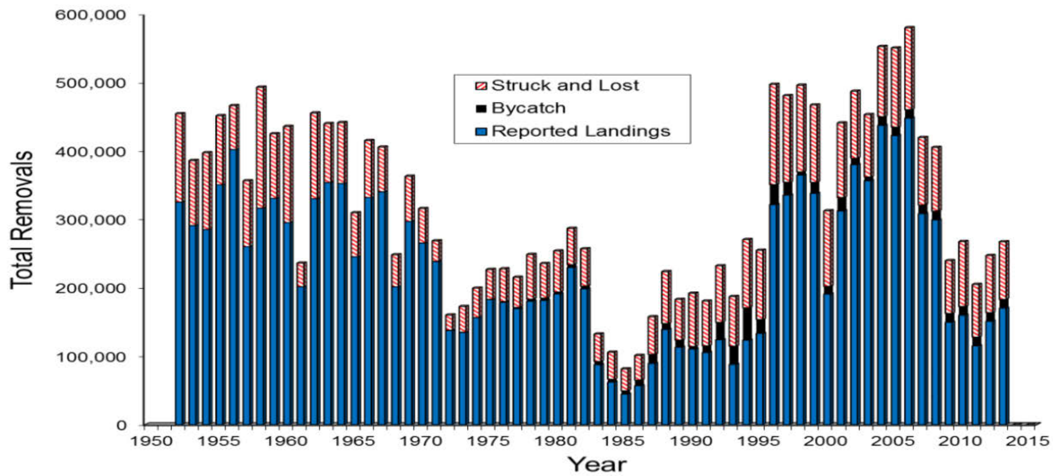

Figure 2. Total removals of Northwest Atlantic harp seals, with 1952 to 2013 including removals from commercial and subsistence harvests, and bycatch (DFO 2013).

ASSESSMENT

Resource Status

Estimates of total population are based on a population model that incorporates estimates of pup production with information on annual reproductive rates, catches in Canadian and Greenland, bycatch, struck and lost, and information on unusual pup mortality due to poor ice conditions.

The Northwest Atlantic harp seal population has increased significantly over the past four decades. Projecting the model to 2014, results in an estimated pup production of 853,000 (SE=202,000) and a total population of 7,411,000 (SE=656,000) animals. The population appears to be relatively stable, showing little change in abundance since 2004 (Fig. 3).

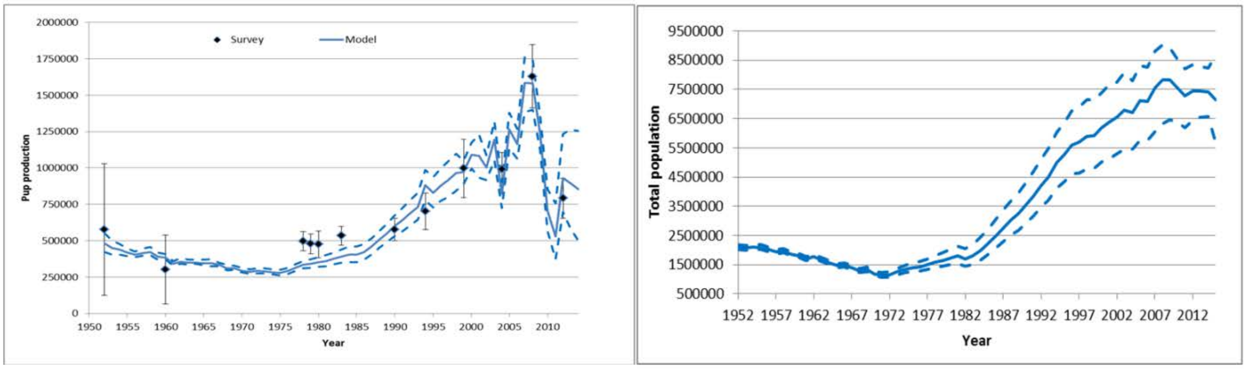

Figure 3. Survey estimates (±95% Confidence Interval [CI]) and model (±95% CI, line) estimates of pup production 1952 to 2014 (left panel). Estimates of total population for Northwest Atlantic harp seals (±95%CI) 1952-2014 (right panel).

Catch options

Science was requested to examine the following questions:

1. Identify the catches necessary to reduce the population to 5.4 million animals assuming:
   a. Catches consisting of 90% YOY and 50% YOY
   b. Over time periods of 5, 10, and 15 years
2. Identify the catches necessary to reduce the population to 6.8 million assuming:
   a. Catches consisting of 90% YOY and 50% YOY
   b. Over time periods of 5, 10, and 15 years
3. Estimate the sustainable future annual catches possible with a reduced population and assuming there is a 95% probability of remaining above the Limit Reference Point.

Analyses

To examine the impacts of the different population reduction scenarios, the population model was projected into the future, using as a starting point, the estimates of 2014 population size, pup production, natural mortality (M), and carrying capacity (K).

Assumptions associated with future reproductive rates and levels of the Greenland catch are necessary. Therefore, the impacts of the different Canadian catch options on the projected population were estimated under two major scenarios (Table 1). In the first scenario (Model A), it was assumed that future reproductive rates, and Greenland catches were based upon the observed rates from the past 10 years (see below). In the second scenario (Model B), both future reproductive rates and Greenland catches behaved in a density-dependent manner, i.e., as the population declines, Greenland catches decline and pregnancy rates increase to an asymptotic value, whereas when the population increases, Greenland catches increase to an asymptotic value and reproductive rates decline.

In both scenarios, it is assumed that the age structure and mortality from bycatch and the Canadian Arctic harvest remain constant at 2013 levels, and that the proportion of seals struck and loss for the different harvests remain unchanged. Both models assume that survival of juveniles is density dependent (i.e., decreases as population approaches carrying capacity).

Table 1. Comparison of model assumptions.

-	Model A	Model B
Greenland catches	Fixed at average over past 10 years	Catches vary with population size when less than 7.1 million harp seals
Ice related mortality	Selected randomly from a vector of recently observed rates	Same
Pregnancy rates	Selected from a vector of recently observed rates	Density-dependent decreases as population approaches carry capacity Proportion pregnant varied to account for changes in food supply (based upon recent observations)
Mortality rates of YOY	Density-dependent increases as population approaches carry capacity	Same

Once the target population level was achieved, the model was further projected forward to determine the annual level of catches that will respect the management plan (i.e., 95% likelihood of population remaining above the Limit Reference Point) for an additional 15 years which ensures that catches are sustainable while they propagate through the population age structure. Therefore, the total length of the projection varied with each reduction scenario (i.e., total of 20, 25 and 30 years). Since the management objective changed following the reduction, the mean estimated population did not necessarily remain at the target level.

The predicted changes in the population trajectory were affected very strongly by the age composition of the harvest used to reduce the population, the speed in which the reduction was achieved, and whether the scenario used a population whose dynamics were assumed to be similar to what has been seen in the past 10 years (Model A) or assumed to vary in a density-dependent manner (Model B).

Model A Scenario

A large number of animals would need to be removed annually if the population reduction was to be achieved rapidly, or with an annual harvest comprised primarily of YOY (Table 2). For a population whose future dynamics are described by current conditions (Model A), up to 610,000 animals would need to be removed annually if the population was to be reduced to 6.8 million within 5 years. Fewer animals need to be removed annually if the removals were spread over a longer time period, or if animals aged one year of age and older (1+) years comprised a larger proportion of the harvest (Table 2). It was not possible to achieve a target population of 5.4 million seals within 5 years (Table 2) if YOY comprised 90% or more of the annual harvest.

Once the target level was achieved, the annual catch levels that would ensure a 95% probability of remaining above the Limit Reference Point were much lower than the harvest levels allowable during the reduction phase (Table 2).

The higher annual removals needed to reduce the population within 5 years, particularly those with a higher proportion of YOY in the harvest, had a long-term impact on the population than removals that were spread over a longer time period, or had a higher proportion of older seals. In the 5 year scenario to reduce the population to 6.8 million animals, the population continued to decline during the monitoring period, although there was still a 95% probability of the population remaining above the Limit Reference Point.

Model B Scenario

The estimated number of removals needed to reduce the population to 6.8 million was similar under the A and B scenarios (Table 3). However, higher annual harvests were possible over the following 15 years, while still ensuring that the population had a 95% probability of remaining above the Limit Reference Point, when it was assumed that reproductive rates increased and catches in Greenland decline as the population declined (i.e., density-dependent responses). This is because of the compensation assumed in reproductive rates and catches.

The annual catch levels needed to reduce the population to 5.4 million were much higher when density-dependent compensation was assumed when compared to the assumptions used in Model A (Table 3). However, as in Model A, annual harvests had to be reduced considerably once the target was reached to allow the population to remain above the Limit Reference Point (Table 3).

Once the target population level was reached, the continuing annual catches that would maintain a 95% likelihood that the population remained above the Limit Reference Point were estimated (Table 3). This management objective did not require the population to remain at the target level and in some scenarios the population continued to decline. As a result, annual catches may have to be further reduced following the 15 year simulation period as the population was predicted to decline during the post reduction period.

Table 2. Annual removals (in 1000s) needed to reduce the population from current levels to 6.8 or 5.4 million within a period of 5, 10, or 15 years. Catches were assumed to comprise 90%, or 50% young of the year (YOY). Continuing annual removals represent the total removals allowed that would maintain a 95% likelihood that the population would remain above the Limit Reference Point (N_{30}) for 15 years. Simulations examined removal impacts assuming future reproductive rates and Greenland harvests were similar to that seen over the past decade.

Scenario	**90%YOY Reduction**	**90%YOY Continuing**	**50%YOY Reduction**	**50%YOY Continuing**
6.8 million	-	-	-	-
5 Y	610	350	270	190
10 Y	450	250	220	150
15 Y	400	230	190	100
5.4 million	-	-	-	-
5 Y	*	-	480	90
10 Y	670	100	320	40
15 Y	540	40	260	20

* indicates target impossible to achieve in time frame and age composition

Table 3. Annual removals (in 1000s) needed to reduce the population from current levels to 6.8 or 5.4 million within a period of 5, 10 or 15 years, assuming future reproductive rates and Greenland harvest follow a density-dependent manner. Catches were assumed to comprise 90%, or 50% young of the year (YOY). Continuing annual removals represent the total removals allowed that would maintain a 95% likelihood that the population would remain above the Limit Reference Point (N_{30}) for 15 years.

Fixed	90%YOY Reduction	90%YOY Continuing	50%YOY Reduction	50%YOY Continuing
6.8 million	-	-	-	-
5 Y	560	560	250	280
10 Y	420	500	200	260
15 Y	370	500	180	270
5.4 million	-	-	-	-
5 Y	*	-	560	250
10 Y	860	400	400	200
15 Y	770	300	350	170

* indicates target impossible to achieve within time frame and age composition.

Sources of Uncertainty

The scenarios did not include potential impacts of an unusual mortality event resulting from disease or unusually poor ice conditions, or a continued warming trend due to climate change resulting in poorer ice conditions over time. Changes in ice conditions impact harp seals directly by increasing pup mortality, as well as indirectly though changes in prey availability which influence reproductive rates. Many climate change models predict that ice conditions will continue to deteriorate but there is considerable uncertainty as to the extent. The impact of a trend in declining conditions was not examined but would likely reduce the sustainability of the population.

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. Very few samples of this or other age classes are obtained in many years and as a result, there is considerable uncertainty in reproductive rates in some years.

The current assessment model estimates natural mortality rates to fit observed data on reproductive rates and pup production. The model assumes that mortality is constant for seals one year of age and older, and does not change over the projection period. However, natural mortality is likely to vary over time and with age. This is particularly true for young seals. It was assumed that survival of YOY varied in a density-dependent manner based upon changes observed in the reproductive rates. However, true mortality rates are uncertain and changes will have a significant impact on the population trajectories. Therefore, independent estimates of mortality are needed to verify model predictions and to improve information concerning the dynamics of this population.

CONCLUSION

These simulation results are very sensitive to model assumptions and should be considered for illustration only. The population dynamics of Northwest Atlantic harp seals will depend upon future reproductive rates, commercial harvest levels in Canada, and harvests in the unregulated Greenland subsistence seal hunt, as well the response of these seals to changes in food availability and ice conditions. Any error in the assumptions can result in significant changes in the predicted population trajectories.

The possible response of the population to a programme of intensive removals over different time frames and age composition of the harvest were examined in order to provide an illustration of the potential levels of removals needed to reduce the population and estimate the sustainable harvest levels at these different population levels. Other simulations will produce different results based on different assumptions, and simulation periods. Attempting to simulate how a population responds 30+ years into the future is extremely uncertain. Nonetheless there are some general features of the simulations that provide insights into how a population might respond to a significant intervention.

The reduction scenarios were run under two different sets of assumptions. One model (A) assumed that Greenland harvests, and reproductive rates were similar to what we have observed over the past 10 years, while in the other (Model B), the Greenland harvest and reproductive rates were assumed to compensate for the reduction in population size in a density dependent manner. In both scenarios young of year survival varied in a density-dependent manner, ice-related mortality of pups was similar to that seen over the past decade, and annual pregnancy rates were varied to account for fluctuations in environmental conditions.

Under both scenarios the number of animals that need to be removed annually was strongly affected by the age composition of the harvest, and the speed in which the reduction was achieved.

The two scenarios examined represent two unlikely situations, one assuming conditions remain constant while the other assumes that reproductive rates and catches will compensate in some way (density-dependent response) as the population declines. Based upon historical changes in reproductive rates, we expect that some density-dependent compensation will occur, but recent environmental changes suggest that full compensation may not result. The estimated carrying capacity is based upon historical conditions and may no longer be the same. Therefore, the results presented here are only valid within the context of the modelling scenarios examined in this study.

The modelling showed that under all scenarios, for any significant reduction in the population to occur with catches similar to those seen in recent years, it must involve a significant proportion of animals that are age 1+ years. In both scenarios similar numbers of animals would need to be removed annually to reduce the population to the target sizes. Following a reduction, only relatively low annual harvests would allow the population to remain above the Limit Reference Point in the case of Model A, while much higher harvests could be permitted in the case of a population whose dynamics were governed by density-dependent factors (Model B).

It should also be noted that the catch levels estimated to meet the management objective (95% likelihood of being above the Limit Reference Point) were only maintained for a period of 15 years while the impact of the removals on the population would continue well beyond this period. For example, continuing annual catches at even the reduced 'post-reduction' level in the density-dependent scenarios could cause the population to continue to decline and eventually fail to meet the management objective. If this occurred, annual catches would have to be further reduced to respect the management objectives.

OTHER CONSIDERATIONS

Subsistence harvests in Greenland and Arctic Canada are currently not regulated. Harvest levels in these areas, particularly in Greenland, can have a significant impact on the population dynamics of this population.

In the past decade, ice conditions have declined in the whelping areas and climate change models predict that these declines will continue. Increases in YOY mortality due to poor ice conditions, especially at the Front will have a significant impact on the ability of the population to withstand any given level of harvest.

This modelling exercise is based upon a large number of assumptions. If any management action is contemplated, the changing dynamics of the population must be monitored through regular surveys and obtaining annual reproductive rates.

The simulated reductions assumed very specific age compositions of the harvests and assumed that the sex ratios of the removals were 1:1. Other age structures composition of the harvest will have very different impacts on the population and future trajectories.

Since 1990, harp seals have been assessed every 4-5 years when new pup production survey results became available. Since the harvest targets YOY, which are not fully recruited until they are 8-10 years old, changes in pup production, resulting from very high exploitation rates or unusual mortality will not be detected for a minimum of 15-20 years. The long-term impacts of removing large numbers of YOY were not examined beyond 30 years (15 year reduction plus 15 year continuing catches), although such impacts, particularly from scenarios involving significant removals over a period of 15 years, will have significant impacts on the population beyond the time period examined here.

SOURCES OF INFORMATION

This Science Advisory Report is from the October 20-23, 2015 Annual Meeting of the National Marine Mammal Peer Review Committee (NMMPRC) held in Halifax, Nova Scotia. 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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