Wolf Technical Feasibility Assessment: Options for Managing Wolves on the Range of the Bathurst Barren-ground Caribou Herd

Wolf Feasibility Assessment Technical Working Group,
Yellowknife, Northwest Territories

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Executive Summary

The current decline in the Bathurst barren-ground caribou herd has led to strong public concerns about the future of the herd. Comprehensive planning for both range and herd management is currently underway. Harvest restrictions started in 2010 and reached a quota of zero by 2017 in the Northwest Territories. Without a Bathurst caribou harvest, there are strong concerns over food security and lost chances to transfer traditional knowledge and experience between generations. In 2015, adult and calf caribou survival in the Bathurst herd were still low and, despite a decline in wolf numbers, wolf predation likely accounts for a high proportion of caribou deaths. Importantly, if current environmental trends and caribou population dynamics continue, and if no additional management is implemented, e.g. wolf management or land use planning restrictions, the Bathurst herd is expected to continue to decline. Unfortunately, implementation of management initiatives does not always guarantee a reversal of population trends.

The Wolf Feasibility Assessment Technical Working Group (WG) was formed to compile information about wolf management options and their risks. These options are to be provided to management authorities, who in turn, and depending on their decisions, will submit specific management proposals for review in a public forum to allow for further discussion. The WG examined options for reducing wolf predation through lethal and non-lethal removal of wolves. Each option was reviewed under four criteria: humaneness, cost efficiency, likely effectiveness, and risks and uncertainties. The main text of this document was kept relatively brief with details provided in appendices. The WG applied detailed criteria to assess the humaneness and welfare of each option as well as examining the relative cost, while acknowledging that more details will be required for specific proposals. Risks include the limited information about wolf numbers and predation rates, and overlapping distribution of Bathurst caribou with neighbouring herds in recent winters. The overlap may locally increase caribou and wolves, but, in spring, the herds separate and return to their calving and summer ranges, and the wolves typically return to their dens on the herd's summer range.

Through evaluation of technical opinions and computer modelling, the WG found that removing about 124 wolves in the first year and maintaining low wolf numbers for 5 years, gives the highest likelihood of halting the Bathurst herd's decline and starting it toward recovery. Although the options are evaluated individually, combinations of options may have an increased probability of success.

Wolf Feasibility Assessment Technical Working Group Membership

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- Government of the Northwest Territories (GNWT), Environment & Natural Resources (ENR)
- Łutsel K'e Dene First Nation (LKDFN)
- North Slave Métis Alliance (NSMA)
- Tłı̨chǫ Government (TG), Department of Culture & Lands Protection
- Wek'èezhìı Renewable Resources Board (WRRB)
- Yellowknives Dene First Nation (YKDFN)

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Disclaimer: The Wolf Feasibility Assessment Technical Working Group conducted the Wolf Technical Feasibility Assessment because of commitments made by parties at the WRRB public hearings for Bathurst caribou in 2016, and this assessment is provided for review by decision-makers in ENR and TG. The Feasibility Assessment does not reflect specific support for wolf management by participants in the Wolf Feasibility Assessment Technical Working Group.

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Preamble

The Wolf Feasibility Assessment Technical Working Group (WG) is aware that this report addressed a subject that is controversial. The difficulties inherent in the assessing management options specific to wolf removal were apparent to the WG at the beginning of their task culminating in this report. The WG did not set out with the position that wolf management options assessed will be implemented; rather, the WG provides information to better understand what options exist, what they involve, and the level of effort that is required to assist the Bathurst herd stabilize and recover.

The WG took the approach that decision-makers will need information to make their decisions. The final decisions on any implementation will require the submission and review of management proposals in a public forum that allows for further discussion. The WG did not pre-suppose which options for wolf management would be viewed as appropriate by decision makers in the Northwest Territories (NWT), and as appropriate by the public. Decisions on how to address public perspectives remain outside the scope of this report.

Although lessons from other herds and jurisdictions offered insights, the WG recognized that the management options assessed have not been applied to an area the size of the Bathurst range. The WG used wolf abundance estimates based on wolf home range sizes, as wolves are difficult to aerially count so there is uncertainty as to the number of wolves associated with the Bathurst herd. While the WG recognized uncertainties, it also recognized that there are also risks – the risks to wolves, caribou and the people who depend on the caribou. Monitoring and adaptive management will reduce the risks and uncertainties.

Although WG members were not traditional knowledge holders, information on traditional practices regarding wolves was incorporated into this assessment based on existing literature. The WG strongly believes that future discussion of wolf management options must recognize traditional practices and laws, with traditional knowledge holders helping to decide what options are appropriate or not.

The WG recognized that the Bathurst herd's calving grounds and a substantial part of its summer range are in Nunavut (NU), where none of the NWT agencies or groups participating in the feasibility assessment have any jurisdiction. If any options in NU are considered for a wolf management proposal, this would require following relevant processes in NU, including a possible proposal to the Nunavut Wildlife Management Board, and discussion with the Government of NU, Nunavut Tunngavik Inc., Kitikmeot Inuit Association and affected communities.

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A) Purpose of this Assessment

The Bathurst herd of barren-ground caribou declined 96% between 1986 and 2015, based on photographic calving ground surveys, and has reached numbers lower than indigenous elders have known. This herd, like other migratory tundra herds, has fluctuated between periods of high and low numbers in the past, but recovery from low numbers is not certain. Harvest restrictions on the Bathurst herd have been implemented while comprehensive plans for range and herd management are being developed (Appendices A and B). Predator management is the third set of actions to be considered to stop the continued decline and support recovery.

The goal of wolf management is to reduce wolf numbers sufficiently to increase survival rates of both calf and adult Bathurst caribou, to promote stabilization and recovery in the herd. This feasibility assessment for wolf management is a result of public concerns for the Bathurst herd, and the Wek'èezhìı Renewable Resources Board's (WRRB) recommendations (Appendix B) that were in response to joint management proposals for the Bathurst herd, submitted in 2010 and 2015 by Environment & Natural Resources (ENR), Government of the Northwest Territories (GNWT) and Tłı̨chǫ Government (TG). The information in this assessment describes potential options which help to address the key question: "What can we do to help the caribou?". The main document summarizes key information with details listed in the appendices. The appendices provide the information generated by the Wolf Feasibility Assessment Technical Working Group (WG) that was used in the assessment of options, as well as background information in support of the assumptions and approaches. As a whole, the assessment addresses questions such as: "What types of wolf management are possible?", "What do wolf management techniques require to be successful?" and "How would we know that wolf management is helping the Bathurst herd?"

Prior to implementation of any wolf management actions, consultation with indigenous governments and organizations with wildlife management authority for the Bathurst herd is required. Further, the submission of a management proposal to the WRRB would also be required. The submission of a proposal would result in the commencement of public proceedings, which would involve review of the proposed management actions and any supporting evidence for the proposed actions, and decisions and recommendations. Any proposals for actions on the Nunavut portion of the range would have to follow appropriate processes in that territory.

B) Wolf Feasibility Assessment Technical Working Group

In 2015, ENR committed to conduct a collaborative feasibility assessment of wolf management options for the range of the Bathurst herd, including areas within and outside of Wek'èezhìı. ENR held a two-day workshop on wolf research and management in November 2015, which included participation of TG and WRRB technical staff. Further discussions led to the WRRB 's recommendation that the WRRB would take the lead and collaboratively establish a Wolf Feasibility Assessment Technical Working Group in May 2016 (Appendix C). The group was to collaboratively identify and assess the technical feasibility, costs, and potential effectiveness of wolf management techniques that may be implemented on the range of the Bathurst caribou herd to increase calf and adult caribou survival rates sufficiently to stabilize the herd and initiate recovery to higher numbers.

C) Feasibility Assessment

1. Overview of Wolf Management

In 2016, GNWT[1] updated a 1997[2] report that reviewed predator control programs in Alaska and Canada. The updated report described the status and results of recent wolf management programs in other jurisdictions, and provided information on lethal and non-lethal control options for wolf management in the NWT. Practical experience from jurisdictions outside of the NWT offers lessons about wolf removal techniques and monitoring, and four examples to illustrate the scale, methods and monitoring of wolf removal and caribou recovery are described in Appendix D.

Interpreting the impacts of predation is complex, and requires both understanding and the effective monitoring of harvest and predator management. It is also important to monitor key environmental indicators and pathways to help with interpretation of the effectiveness of management actions. Answers are not simple with regards to what extent and for what length of time wolf management techniques have met objectives to halt caribou declines or to lead to recovery. To complicate matters further, ecological manipulations may have unexpected effects, including implications for smaller-bodied predators and scavengers[3].

2. Current understanding of wolves in Bathurst caribou range

Wolf numbers

One of the first questions is "How many wolves are there on the Bathurst caribou range?" An aerial count for wolves associated with the Bathurst caribou on the winter range in 2006 estimated 211 ± 48 wolves was a likely under-estimate and was during the early stages of the herd's decline (Appendix E). On the summer range (Figure 1), the number of wolves was about 177 in 2013 as estimated from the size of their territories and caribou summer range size,[4] which is a decline from the mid-1990s (Appendix E). As the caribou summer range has contracted at low herd numbers, the denning wolves are further from the caribou and the wolves have difficulty feeding their pups. Consequently, recruitment of wolves is declining and the number of wolves at the den sites is less than in the 1990s (Appendix E). The WG has used the estimated number of wolves as 177 as a working number in assessing wolf removal options, while acknowledging uncertainty about the number of wolves (Appendix E).

The sighting rate of wolves during caribou late winter sex and age surveys while annually variable, has not, however, decreased since the 1990s, which suggests the wolves have no difficulty finding caribou despite the declines in both wolves and caribou (Appendix E). Variability in sighting wolves during caribou surveys possibly affects detection of trend in wolf abundance and this variability is acknowledged as a limitation (Appendix E).

[1] McLaren, A. 2016. Wolf Management Programs in Northwest Territories, Alaska, Yukon, British Columbia, and Alberta: A Review of Options for Management on the Bathurst Caribou Herd Range in the Northwest Territories. ENR File Report # 149

[2] National Research Council. 1997. Wolves, bears, and their prey in Alaska: biological and social challenges in wildlife management. National Academy Press, Washington, D.C. 224pp.

[3] Prugh, LR and SM Arthur. 2015. Optimal predator management for mountain sheep conservation depends on the strength of mesopredator release. Oikos 124: 1241-1250.

[4] Klaczek, M. R. 2015. Denning ecology of barren-ground wolves in the central Canadian Arctic. MSc Thesis. University of Northern British Columbia, Prince George, British Columbia. 116 pp.

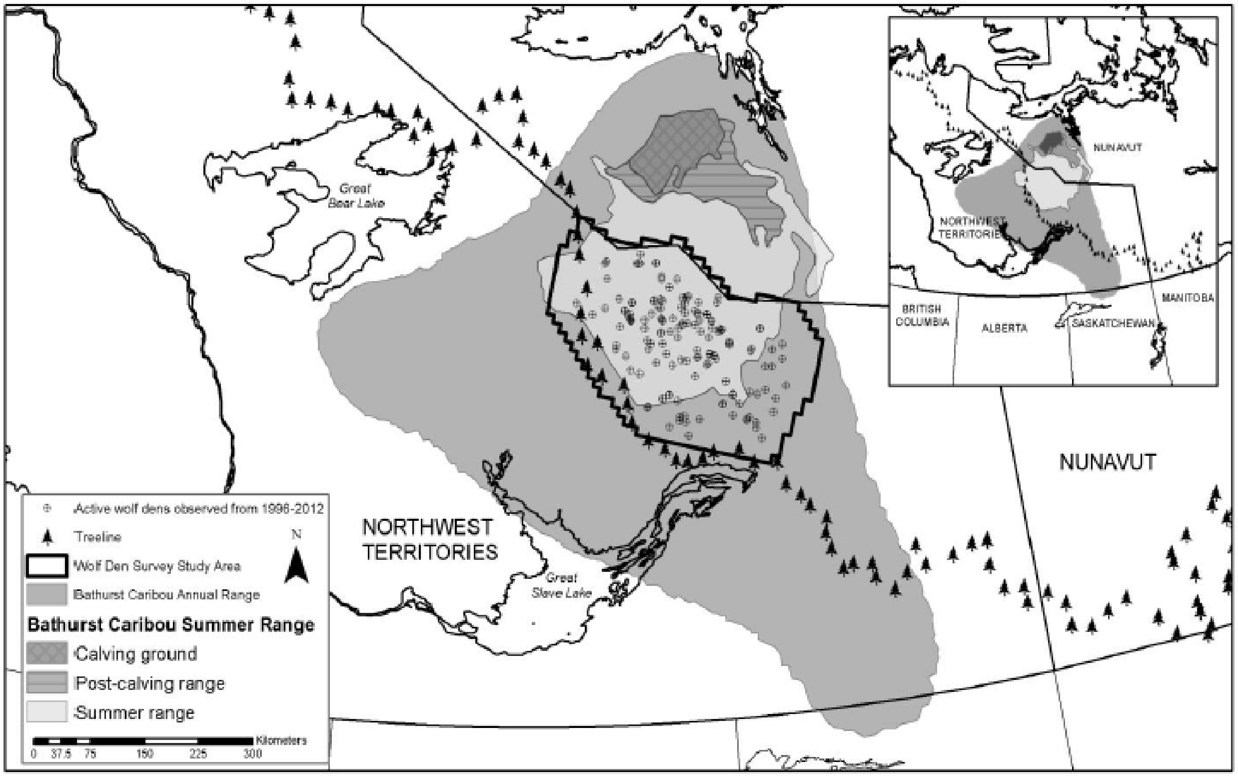


Figure 1 Bathurst herd's calving and annual range 1996-2012 and active wolf dens (n = 303) which were recorded during aerial surveys conducted in late May and early June, 1996-2012 (Klaczek 2015).

Although wolves associated with the Bathurst herd have likely declined, the remaining wolves may still have a limiting effect on the herd (Appendices E and H). If wolves are regulating caribou numbers, the rate of wolf predation would increase and decrease as caribou numbers increase or decrease, i.e. functional response. For the Bathurst herd, if wolves are regulating caribou numbers, their rate of caribou kill would decrease as the herd declined. When this question was tested for the Alaskan Western Arctic Herd in winter 1989 and 1990, the wolves were not regulating the caribou and that at low caribou densities, kill rates remained high.[5]

Recently, the overlap in neighboring caribou herds on the winter range has increased, which adds to the complication of estimating wolf numbers relative to caribou. Although the wolves travel in packs, during the winter, they are not territorial and move with the caribou herds. When neighboring herds overlap on the winter range, the wolves associated with herds will also likely overlap in distribution. The increase in wolves from the overlapping caribou herds during the winter is temporary as collar studies show the wolves return to breed on the summer ranges of the herds. The scale of the probable increase in local densities of caribou and wolves when they overlap on the winter ranges depends on the extent of the overlap. Between December 2013 and 2016, the average overlap of the Beverly-Ahiak and Bluenose East herds was 27 and 37% (ENR collar data).

[5] Dale, B., Adams L. G., & Boyer, R. T. 1994. Functional response of wolves preying on barren-ground caribou in a multiple prey ecosystem. - J. Anim. Ecol. 63: 644-652.

Predation risk
Wolves on the ranges of migratory tundra caribou catch and eat mostly caribou as other prey, such as moose, muskoxen, geese and beaver, are relatively uncommon and seasonal. This is a marked contrast with wolf ecology in the Yukon and Alaska where other prey, especially moose, are relatively common. Wolves on average can take 23-29 caribou a year, but it varies seasonally; when raising their pups, wolves can take more prey and surplus killing of newborn calves has been recorded on calving grounds (Appendix F).

3. Current approaches to wolf harvest

The 2010 Joint Proposal and resulting decision [6] recommended increased harvesting of wolves on the Bathurst range to reduce mortality of caribou due to wolf predation. Financial incentives for prime pelts ($400) and carcasses ($200) were used to increase harvest of wolves on the Bathurst winter range, with an objective of harvesting 80 to 100 wolves annually but success was relatively low. Current wolf harvesting is at a relatively low rate especially compared to the 1990s. Recent review of the fur harvest database also showed that not all harvested wolves are accounted for within the fur harvest database. The wolf harvest reported in the North Slave Region averaged 49 wolves/year from 2009-2013, and a substantial proportion of these were taken near community landfills or from ranges not recently used by the Bathurst herd (e.g. Reliance on the East Arm of Great Slave Lake). A complication is that wolves harvested near Wekweètì and Reliance are likely tundra wolves. Wolves harvested near Whatì and Gamètì are more likely to be boreal wolves as denning is known within the forest. Future monitoring will need to identify tundra versus boreal wolves using genetics.

TG Community-based Wolf Harvesting Project
Tłı̨chǫ community members have expressed concerns about wolf predation on caribou, as well as how abundant wolves are, and how wolves are increasing in and around communities. TG and ENR proposed a community-based wolf harvesting pilot project during the winter of 2015/16. People from Wekweètì were to be trained in effective field techniques to hunt, trap, skin and process wolves ensuring that Tłı̨chǫ cultural practices were followed; a minimum of 40 wolves would be harvested, but not more than 100. Unfortunately, successful implementation of this initiative did not occur in 2016. In 2017, the project restarted, with one participants from Wekweètì trained, and 11 wolves were harvested.

The Tłı̨chǫ have a great respect for the wolf and see him as an intelligent sacred animal (Appendix G). There are many rules that are established that the Tłı̨chǫ elders want the Tłı̨chǫ people to follow. Harvesters who work with wolves must find places away from their community and family home to ensure the well-being of women and children, and to ensure rules associated with respecting wolf power and its 'big spirit' are honoured. Further, it is disrespectful for people – including non-Tłı̨chǫ – to ask for specifics, such as names, about individuals who are sensitive to wolves or who have the ability to use wolf power for healing; therefore, one must support the privacy of Tłı̨chǫ harvesters when hunting/trapping and preparing wolves. Current documented Tłı̨chǫ knowledge and perspectives in which wolves live in an environment that includes Tłı̨chǫ and caribou can be found in Appendix G. Traditional knowledge about wolves was not available for this assessment from the NSMA, YKDFN or LKDFN.

[6] Report on a Public Hearing Held by the Wek'èezhìı Renewable Resources Board 22-26 March 2010 & 5-6 August 2010, Behchokǫ̀, NT and Reasons for Decisions Related to a Joint Proposal for the Management of the Bathurst Caribou Herd. 2010.

How wolves and caribou respond to wolf removal
How wolves and caribou respond to wolf removal is determined by the numbers of wolves and the season in which they are removed. The level of removal mostly likely to reduce wolf abundance depends on the extent to which the wolves, through reproduction and immigration, can annually replace themselves (Appendices D, E and I). For this reason, our conceptual model is that wolf removal on the summer range of Bathurst caribou results in additive wolf mortality, and removal on the winter range is partially compensated by immigration of tundra wolves from adjacent areas (Appendices H and I). The experience in Alaska and the Yukon is that through net immigration as well as large litters with high pup survival, wolves annually can withstand losing 30-40% of their numbers (Appendix D). This has led to a rule of thumb that 60-80% of the wolves should be removed to reduce their numbers and predation rates, which requires an estimate of wolf abundance. Once the wolf removal was halted, within 5-6 years, wolf numbers recovered through high pup survival and wolf immigration from neighboring areas (Appendix D).

The other consideration for determining the number of wolves depends on the relationship between the number of wolves removed and the subsequent increase in caribou survival to stabilize and recover the Bathurst herd (Appendix I). During wolf removal in Alaska and Yukon, both adult and calf caribou survival rates increased and then, as the wolves recovered, subsequent trends in herd size varied as situations for each herd differed (Appendix D). In Alaska and Yukon wolf-caribou systems, there are alternative prey to caribou and the wolves are year-round territorial, which in turn affects how they increase and decrease. Thus, the ecology of mountain caribou and wolves is quite different from migratory barren-ground caribou-tundra wolf systems.

The WG used computer modelling to project numbers of wolves removed for different changes in caribou survival and herd trend (Appendix I). Under the assumptions in the model, it would take the removal of just over 60 wolves to stabilize the Bathurst herd to 2016 levels and the removal of 80 or 100 wolves for the herd to increase. In practice removing, for example 60 or 80 wolves, requires reducing the present wolf population by 60 or 80 wolves respectively in 2017, and maintaining those lower wolf densities throughout 2018 to 2022. This does not mean killing 60, 80 or 100 wolves a year, just ensuring that the wolf population does not rebound during the five-year period that active wolf management is done (Appendix I).

How caribou respond to wolf removal is also influenced by their environment, including weather. For example, the Bathurst herd had a relatively low pregnancy rate in winter 2014-2015. This followed summer 2014 with the highest summer drought index on record for the Bathurst range (Appendix A), which likely reduced the cow's fall fatness to the point where they did not breed. Environmental factors will continue to affect the herd's productivity and trend, with or without actions to reduce wolf predation.

4. Development of Wolf Removal Options

The WG examined conceptual models for wolves and caribou (Appendices H and I) and then, through review of literature and discussions with wildlife management agencies both in and outside of the NWT, the WG identified options for wolf removal on the range of the Bathurst herd. The WG also engaged experts from outside of the NWT familiar with wolf ecology, management and humane treatment. Experts attended an in-person workshop held in Yellowknife in March 2017 (Appendix J), and presented on lessons learned from wolf management in Alaska and BC. The experts also commented on the options and described what implementation and monitoring of wolf management entails from a practical perspective.

Early in the assessment, the WG considered methods that would increase caribou survival directly, such as maternal penning and relocation (translocation) of caribou, but decided that those techniques involving handling caribou were not the primary focus of the WG. These intensive methods are being used for highly depleted boreal and mountain caribou herds in BC and Alberta. Also, a review of management techniques related to grizzly bears will be conducted as a feasibility assessment for grizzly bears separately[7].

The WG considered monitoring to evaluate the outcome of the options (Appendices K, L, and M) and developed criteria to rank the options (Appendices N, O, P and Q) by considering each option separately. Through discussions and input from experts, combining options could increase the likelihood of success and more effectively use staff and funds.

5. Wolf Removal Options Considered in this Feasibility Assessment

The WG considered 12 wolf management options. The first option does not include active wolf removal and is described as a 'business-as-usual" option; the remaining 11 options are categorized as non-lethal or lethal removal. As noted by GNWT, "*the purpose of this feasibility assessment is to consider other options, including more intensive wolf reduction that could be considered in future as part of an adaptive management process"* (B. Croft, Bathurst Caribou Herd Public Hearing, 23 Feb 2016; Transcript p. 79). As reflected by Tłı̨chǫ during the Bathurst Caribou Herd Public Hearings, this perspective is shared by TG, which considers the 'business-as-usual" option, an interim management approach.

> *"And so, as -- as to how -- if the wildlife -- if we're going to harvest the wolves, we -- we really need to kind of annually know exactly how many numbers that we need to harvest, how many wolves we need to harvest. And if we're harvesting wolves annually, is it -- will it show how well we know that we are helping the caribou?"* (J. Judas, Bathurst Caribou Herd Public Hearing, 23 Feb 2016; Transcript p. 117)

> *"So even though our leaders are not here, I spend a lot of time talking with them. I talk to our leaders when we're in Rae and I go to them and I tell them, What shall we do with the wolves? They say, Kill them. And I would -- we would do it and we would -- I would continue to support the staff here as much as I could, because what else am I going to do alone."* (J. Rabesca, Bathurst Caribou Herd Public Hearing, 23 Feb 2016; Transcript p. 133)

Thus, following completion of this Wolf Technical Feasibility Assessment, non-lethal and lethal wolf removal options will be considered by TG and ENR. If decisions are made to recommend wolf management based on active removal options, a joint management proposal would be submitted to the WRRB to determine whether and how implementation and management might proceed. Additionally, the Bathurst calving grounds and part of the summer ranges are in Nunavut; thus, any proposed options would need to follow Nunavut processes for wildlife management.

5.1. Business-as-usual

The 'business-as-usual' option is the status quo, and reflects recommendations in the 2016 joint management proposal by TG and ENR, and subsequent management determinations by the WRRB (2016) to support recovery of the Bathurst herd (Appendix B).

[7] Report on a Public Hearing Held by the Wek'èezhìı Renewable Resources Board, 23-24 February 2016, Yellowknife, NT and Reasons for Decisions Related to a Joint Proposal for the Management of the Bathurst ʔekwǫ̀ (Barren-ground caribou) Herd – Part B. 2016.

This option does not include specific wolf management actions, and instead emphasizes a revised GNWT financial incentive program for Aboriginal and non-Aboriginal hunters and trappers to increase the harvest of wolves.

5.2. Diversionary feeding

This option is providing carcasses (e.g. fish, seals, muskoxen; bison and potentially attractants such as beaver castor) to "distract" wolves (and potentially other predators) from feeding on caribou at a time where wolves are near the calving grounds. If there are fewer wolves on the calving grounds, more calves will survive the first few weeks. However, relatively few wolves use the calving grounds and collared cow mortality rates on the calving grounds have been low (Appendix A). An additional confounding factor is that the carcasses will likely attract other predators and scavengers to the calving grounds.

5.3. Relocation to remote areas

Wolves would be caught in winter and released in areas far enough away that they could no longer prey on Bathurst caribou and would not return to Bathurst ranges. The release areas would need to be able to support the released wolves, which may be a limitation given the uncertainties as to whether management authorities would be willing to accept wolves.

5.4. Relocation to zoos and/or captive facilities

Similar to Option 3, wolves would be caught in winter and sent to zoos and wildlife parks. This assumes that southern-based organizations would want the wolves, but the capacity or interest is unknown.

5.5. Surgical and/or chemical neutering

The breeding pair of wolves would be caught at their dens and would be surgically or chemically neutered. In following years, the breeding pair would not have pups but otherwise have normal breeding behavior such maintaining their territory. This has been successful in the Yukon and Alaska.

5.6. Aerial shooting on calving ground

Wolves would be found from the air and shot either from a fixed wing or helicopter. The expectation is that the location of calving grounds is relatively predictable, so the wolves may be easier to find.

5.7. Aerial shooting on winter range

The winter range of the caribou is monitored from the satellite-collared caribou increasing the likelihood of finding wolf packs, which generally follow the caribou. The wolves would be shot from either fixed wing or helicopter, with the intent being to remove entire packs.

5.8. Ground-based shooting on winter range

On the caribou winter range, bait would be used to attract the wolves, which would be shot by marksmen on the ground. Helicopters, fixed-wing, and snow machines support is necessary.

5.9. Snaring on winter range

Snares would be used to kill (not restrain) wolves, Reconnaissance flights and/or ground tracking would be used to locate wolves and to place baited snares to attract and trap wolves.

5.10. Poisoning on winter range

The use of poisoned bait to kill wolves on the caribou winter range would require reconnaissance flights and/or ground tracking to locate wolves, for bait placement, and for carcass and bait retrieval. Public, legal, and health and safety concerns will be high, and there is a high likelihood of other animals (predators and scavengers) being killed. In the 1950s and 1960s, poison was used in the NWT on winter ranges for the Bathurst and neighboring herds.

5.11. Ground shooting at wolf dens

A sharp-shooter placed at den sites would remove the breeding pairs and helper wolves before the pups are born. The dens are predictable locations to find the wolves and the locations of many dens are already known. Aerial support is necessary.

5.12. Summer harvest assistance

This option is to support hunters who are experts at harvesting wolves through reconnaissance flights and/or ground tracking to locate wolves, then placement of sharpshooter teams, and removal of wolves.

6. Criteria for assessment

The WG developed criteria to rate the options focused on humaneness and welfare, efficiency, effectiveness, and risks and uncertainties. As much as possible, the four criteria were objective and quantitative. The WG used a similar level of wolf removal for each option while accepting that the effort to achieve that target would vary among the options. Based on the rule of thumb of 60-80% annual removal and the 2013 summer range estimate of 177 wolves, the target is 106 to 142 wolves with the mid-point as 124 wolves.

While the WG ranked the options by the four criteria, it was also recognized that there are more formal ways to compare options. For example, disease risk assessment in wildlife uses a decision tree to compare options by showing the level of risk in the presence of uncertainty.

6.1 Humaneness and Welfare

Humaneness and welfare have social and ethical aspects (Appendix N). The WG drew on the experience of international agencies, especially Australia, and viewed "humaneness" for the individual wolf. Lethal options should cause immediate unconsciousness and subsequent death without excitement, pain or distress, and non-lethal options should cause minimal excitement, pain, injury, and/or discomfort. The WG also considered (Appendix N) the welfare of the individual wolf, members of its pack and other wildlife species, and rated welfare based on the five freedoms: freedom from hunger or thirst; discomfort; pain, injury or disease; to express (most) normal behaviour and freedom from fear and distress. However, the WG did not address issues related to reduction of predator abundance on other predators or scavengers. Ecological effects of wolf management or its absence and caribou were not included in the feasibility assessment.

The welfare impact scores were relatively high for the options (Figure 2) that involved handling and holding the wolves, either for surgical sterilization or future release as the timeframe for stress is hours or days. The welfare impact score for summer assisted wolf harvesting was increased because of the possible difficulty of finding wolf pups if the adults were harvested. Accurate shot placement increased the humaneness scores as aerial shooting is not considered ideal to achieve a quick death (Appendix N). Snaring and poisoning were scored high as instantaneous death is less likely. Poisoning would likely impact welfare of several other non-target species.

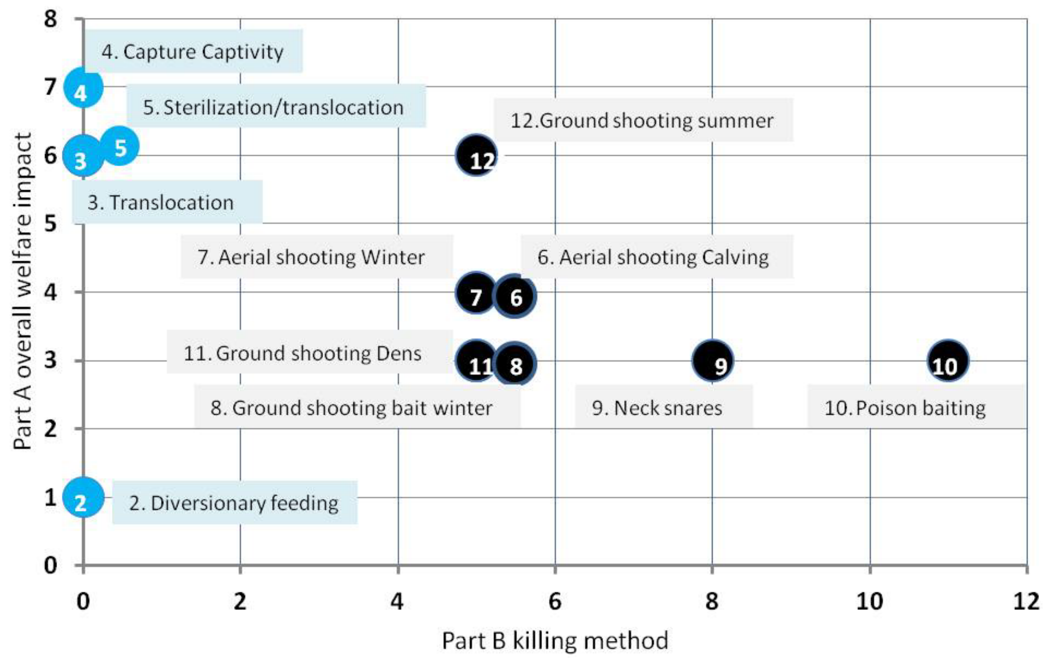


Figure 2. Matrix used to derive scores for ranking humaneness (degree of suffering) and welfare for options 2 to 12 (from Appendix N).

6.2 Efficiency

Assessment of efficiency (Figure 3) was based on estimated costs related to implementing the options (Appendix O). The costs included: transport (type/hourly rate), fuels costs, equipment/supplies (e.g. collars, bait for diversionary feeding), and personnel (fees, per diems); but exclude GNWT staff time. Development of standardized rates (e.g. time/distance/fuel required to reach the Bathurst range) allowed for comparison across options. Costs were estimated both on a per capita basis (per individual wolf), as well as the total for the first year of implementation. The expectation is for a 5-year program followed by extensive re-appraisal. Subsequent annual costs change as for example, search effort and per capita costs (catch per unit effort) may increase as fewer wolves are needed to maintain the rate of removal, but those fewer wolves may be more difficult to find and remove.

In general, the four non-lethal options had the highest per capita costs, with the highest being more than $10,000 per wolf "removed" for diversionary feeding. The lowest per capita costs were for ground-based shooting, snaring and poison baiting, all in the winter. The cost estimates were based on the most realistic scenarios that WG members could define, including current costs of fuel, air charters and other field costs. However, the costs would likely change as real-world experience was gained.

Food security issues as a result of harvest closures for the Bathurst caribou herd have very real implications for Aboriginal communities. Although, the WG did not examine the relationship between the food security values of caribou relative to the costs of wolf removal, a basic comparison is illustrated here to give a context to relative costs. Simplistically, a wolf can remove 20-30 caribou annually, with an estimated meat replacement value of $900/caribou (average carcass weight of 45 kg and a beef replacement value of $20/kg[8]). This compares to the average estimated lethal removal cost per wolf at $4600 (Appendix O).

[8] InterGroup Consultants Ltd. 2013. Economic valuation and socio-cultural perspectives of the estimated harvest of the Beverly and Qamanirjuaq caribou herds. Prepared for the Beverly and Qamanirjuaq Caribou Management Board. October 2013 revised version (Original May 2008). Winnipeg, Manitoba.

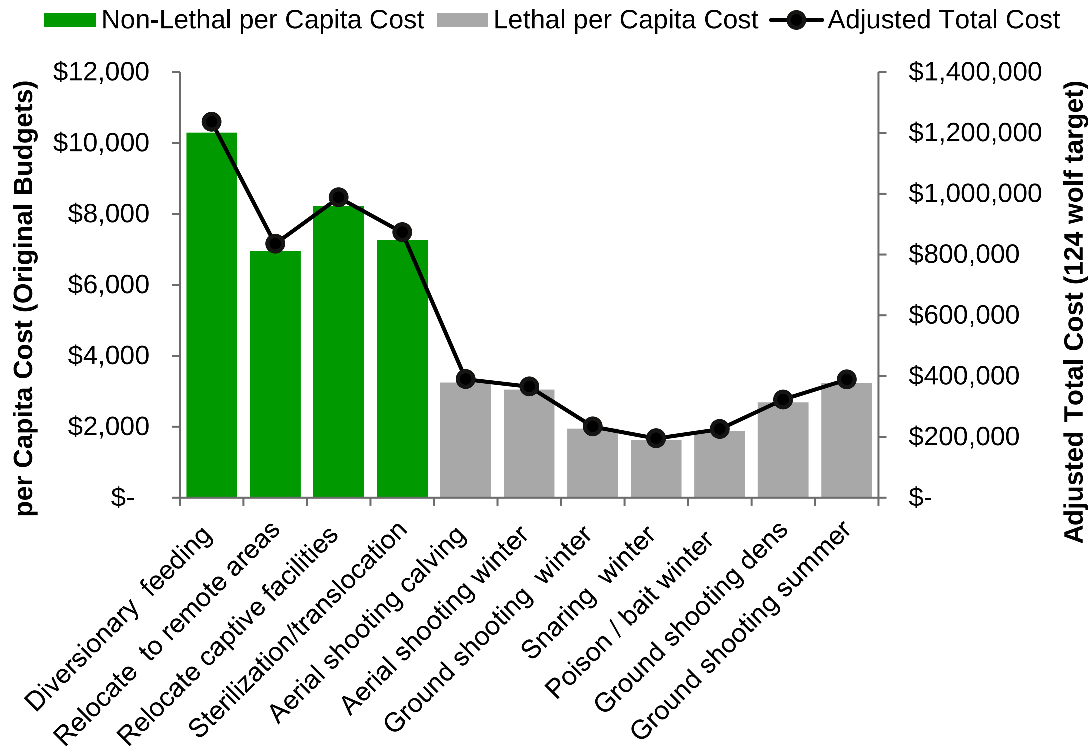


Figure 3. Summary of assessment of efficiency; per capita and total costs (for 1 year) of Options 2-12 with a wolf removal target of 124 wolves.

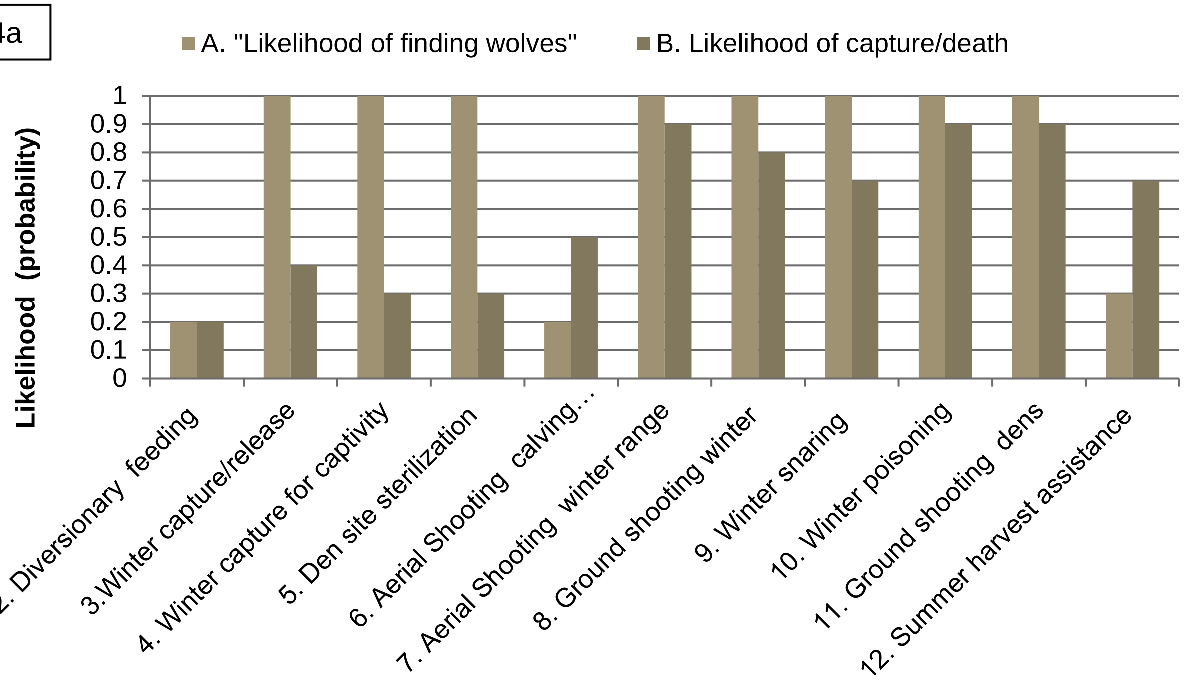
6.3 Effectiveness

Assessment of effectiveness was based on the combined likelihood of a) finding the target number of wolves and b) the option's required treatment (Figure 4). Estimates for both finding wolves and applying a treatment were given numerical rankings, with the rankings then multiplied to provide an overall estimate of effectiveness (Appendix P). Rating effectiveness is based on the likelihood of reaching the target number of wolves (124 which is the mid-point of 60-80% of the estimated 177 wolves in 2013).

The first step was assessing the likelihood of finding the wolves, which depends on the predictability of their locations. During the breeding season, the predictability is increased as the sites of many dens are already known and wolves re-use previous dens sites (Appendix E). The average finding rate for dens was 8 dens/1000 km of survey effort (1996-2006) on the Bathurst herd's range, which had the advantage of using collared wolves. Since 2006, the rate has declined to 4 dens/1000 km survey effort (Dean Cluff pers. comm. 2017). During other seasons, especially winter, wolves are associated with caribou whose locations are available from satellite and GPS collared caribou. Thus, using prior knowledge from monitoring will increase effectiveness. The sighting rate during caribou surveys is equivalent to catch per unit effort (assuming a factor for unsuccessful captures).

The second part of rating effectiveness is the likelihood that sighting a wolf will lead to its live capture or death. Live capture has a lower rate of success on the winter range, as during the handling time, the other wolves in the pack can seek refuge in the trees (assumed capture rate is 50% of sighting rate). For shooting, given that mean pack size = 3.5 and packs rarely exceed 6 wolves on the winter range, it is likely that entire packs could be removed (assumed capture rate is 80% of sighting rate). The catchment area of wolf availability for snaring, poison baiting, and diversionary feed is unknown, but

4a



4b

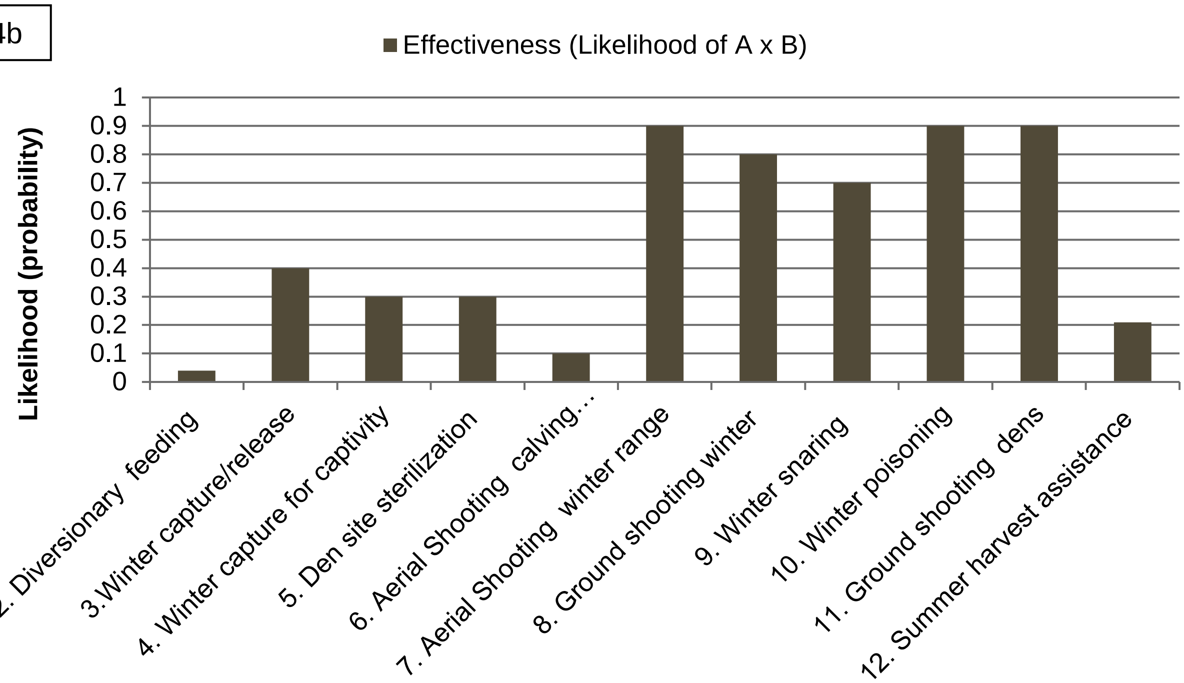


Figure 4. Ranking of options for wolf removal based on (4a) respective likelihoods of finding and removing wolves, and **(**4b) overall estimated effectiveness

given wolves have a good sense of smell but avoid novel smells, sights and sounds, the methods are likely to result in a moderate likelihood of 'capture', assumed to be 70%. For diversionary feeding, it is uncertain whether the bait stations will hold ('capture') the wolves for any length of time, and the potential exists for drawing in more wolves from a larger area.

6.4 Risks and Uncertainties

Risk can be measured as the likelihood of an outcome, whereas uncertainty is more a lack of knowledge and less amenable to estimating the likelihood. Initially, the WG approached assessment of risks and uncertainty from a quantitative perspective (e.g. attempting to determine likelihood); however, this proved to be difficult to apply to each option. Instead, the WG listed possible negative consequences associated with each option and assigned a relative overall rank of low, medium or high risk to the options (Appendix Q). Risks specific to humaneness or effectiveness are described in Appendices N and P. For example, the risk of not meeting the target number of wolves owing to the difficulty of locating them is considered in Appendix P as part of assessing effectiveness.

The WG noted there were underlying risks and uncertainty common to all options. There is uncertainty from the lack of precedent for wolf removal in logistically remote ranges of migratory tundra herds, such as the Bathurst herd. There are also uncertainties in estimates of the numbers of wolves (Appendix E), which leads to the risk that the number of wolves may be under or over-estimated. The balance between emigration of dispersing wolves from the Bathurst summer range to neighbouring caribou ranges and wolves immigrating to the Bathurst range (net immigration) from the neighboring ranges is uncertain. However, the neighboring herds are also declining which likely reduces wolf numbers on the neighboring caribou ranges.

The timing of the options also affects their risks and uncertainties. In some winters, the partial overlap in winter distribution of neighboring caribou herds with the Bathurst herd and associated wolves introduces a possible risk of diluting the effect of wolf removal for the Bathurst herd. However, risks and uncertainties can be reduced through monitoring and adaptive management.

7. Adaptive Management and Monitoring

The WG noted how different methods and limited information raised uncertainties about wolf abundance and the ratio of wolves to caribou during recent winters. Enhanced monitoring of wolf dens and analyses of caribou winter distribution will reduce the uncertainties and can be used to adapt the options. When the collars reveal overlapping winter distribution, the relative ratio between the wolves and caribou can be monitored during late winter caribou sex and age composition surveys. Changes in the relative number of wolf to caribou sightings can be used to adjust (adapt) the targets for wolf removal and projected effect sizes.

Monitoring is essential to determine whether wolf management has been effective in halting the decline and starting recovery of the Bathurst herd. Detailed monitoring would need to be described in any management proposal that might be developed. Reviews of predator management programs indicated that the numbers of predators removed, and responses of caribou or moose were not always monitored sufficiently to know whether the programs had been effective (Appendix D). Consequently, the WG has identified monitoring questions to assess results and make adaptive changes if necessary.

1. Were actions conducted in a verifiable manner that achieved the humaneness objectives?
This question would be addressed through ‘book-keeping’ during the field work (Appendix K) and additionally, the post-mortem examination of wolves. The findings could lead to revising field protocols if objectives were not met. In addition, it would be essential to inform co-management partners and the public about standards of humane treatment and wildlife welfare.

2. Were numerical targets for wolf removal met?
It is essential to accurately track the actual numbers of wolves removed (Appendix N) and the effort (e.g. number of flying hours per wolf). This is a key to adaptive management. If the required number of wolves was not removed, for example on the summer range, then additional effort could be undertaken during the winter.

3. Were proposed changes in the caribou herd's demography achieved?
The effect of wolf removals on the Bathurst caribou herd can be monitored through standardized herd-monitoring, such as estimating adult and calf survival rates, and trend in herd size. Estimates of effect size relative to the statistical power of the monitoring indicator will be necessary and the thresholds to trigger management actions. Monitoring should include environmental monitoring to describe other factors that may influence the caribou (Appendix M). The WG group recognizes that other factors (age structure, health, weather and environmental variables) will continue to affect the herd, thus possible changes in herd demography are not solely due to wolf management.

8. Communications plan

This assessment does not take a position on wolf management, nor does it make any recommendations or proposals on what should be done. This assessment will be used by management authorities to decide what, if any, management options to consider as part of the overall Bathurst caribou management approach. It is important to remember that any proposal for wolf management actions would require engagement with Aboriginal government organizations and wildlife management authorities in a public forum that allows for further discussion.

Communication is a shared responsibility. Respectful and cooperative dialogue between wildlife management authorities, researchers, harvesters and the public improves the decision-making process and implementation of management actions.

Effective communication around the wolf feasibility assessment helps to:

- Increase knowledge and awareness of the issues Bathurst caribou face, including wolf predation;
- Inform all parties of the options available to address wolf predation; and
- Build trust and confidence in the management process.

Communication also needs to be tailored to each community to be most effective. Community organizations are in the best position to suggest the most effective methods of communication in their respective areas.

If proposed management actions result from this assessment, members of the WG must work with their government organizations to communicate the report in support of an informed dialogue about wolf management and any actions under consideration.

D) Ranking options by the criteria

The WG ranked the options by their effectiveness, efficiency and humaneness as well as their risks and uncertainties. In particular, the seasonal timing of the options is a factor influencing several criteria as it affects the predictability of finding wolves, the likelihood of removal and the amount of inadvertent disturbance to caribou. The seasonal timing also affects whether calf or adult caribou survival is more likely to be influenced by wolf removal. This seasonal effect also increases the applicability of increasing efficiency and effectiveness by "bundling" options.

The WG ranked the three quantitative criteria for each option assuming that the best case is low humane/welfare scores, high effectiveness scores and low per capita costs. The WG then summed the three rankings (Table 1 and Figure 5).

Table 1. Scores and rankings for humaneness and welfare, efficiency and effectiveness criteria used to assess wolf removal options (low scores are the more humane and efficient but high for most effective)

Option	**Humane* Welfare score**	Rank	**Efficiency $/per wolf**	Rank	**Effectiveness score**	Rank	Summed ranks
1. Business as usual							N/A
11. Ground shooting dens	15	5	2,690	4	0.9	1	10
8. Ground shooting winter	15	5	1,950	3	0.8	4	12
7. Aerial Shooting winter	20	7	3,050	6	0.9	1	14
10. Winter poisoning	33	11	1,880	2	0.9	1	14
9. Winter snaring	24	9	1,620	1	0.7	5	15
3. Winter capture/release	6	2	6,960	8	0.4	6	16
5. Sterilization at den	6	2	7,270	9	0.3	7	18
4. Winter capture captivity	7	4	8,230	10	0.3	7	21
2. Diversionary feeding	1	1	10,300	11	0.04	11	23
12. Summer harvest assistance	30	10	3,240	5	0.21	9	24
6. Aerial Shooting calving	20	7	3,250	7	0.1	10	24

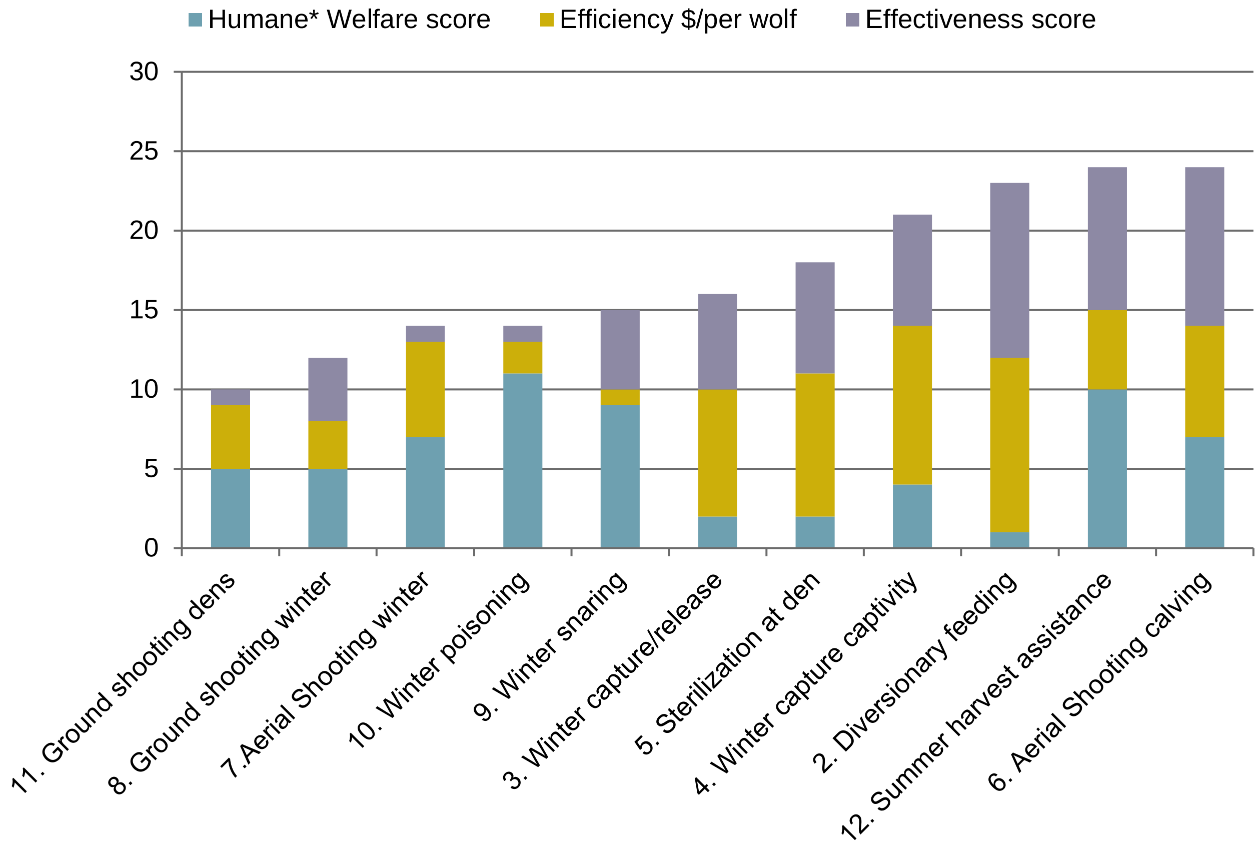


Figure 5. Cumulative rankings for humaneness and welfare, efficiency and effectiveness criteria used to assess wolf removal options.

E) Summary

The main findings of this technical feasibility assessment were:

- Although there is uncertainty in available information, the initial number of wolves that should be removed to reduce predation and help the Bathurst herd recover is in the range of 80 to 125; with the upper target likely having greater benefit to caribou recovery. This range is based on a combination of a) a rule-of-thumb that 60-80% of an estimated 177 wolves should be removed initially to reduce their numbers, and b) initial computer model simulations that suggest 80 to 100 wolves be removed during the first year of a wolf management effort. Following initial removals, wolf densities should be maintained at relatively low levels through active removals for at least 5 years to provide benefit to caribou.
-
- Implementation of wolf removal options will need to be undertaken collaboratively with Indigenous communities and co-management partners within an adaptive management framework. The adaptive management effort will need to be resourced appropriately for at least 5 years to incorporate robust monitoring that will be able to continually evaluate and improve management actions.

Appendices

Appendix A: Status, trends and co-management of the Bathurst herd

The Bathurst herd is the migratory barren-ground caribou that traditionally calves near Bathurst Inlet in Nunavut. The Bathurst caribou range (historically 350,000 km^2) extends from Bathurst Inlet (Figure A1) to southern and central Northwest Territories (NWT) overlapping Wek'èezhìı, and the North Slave region.

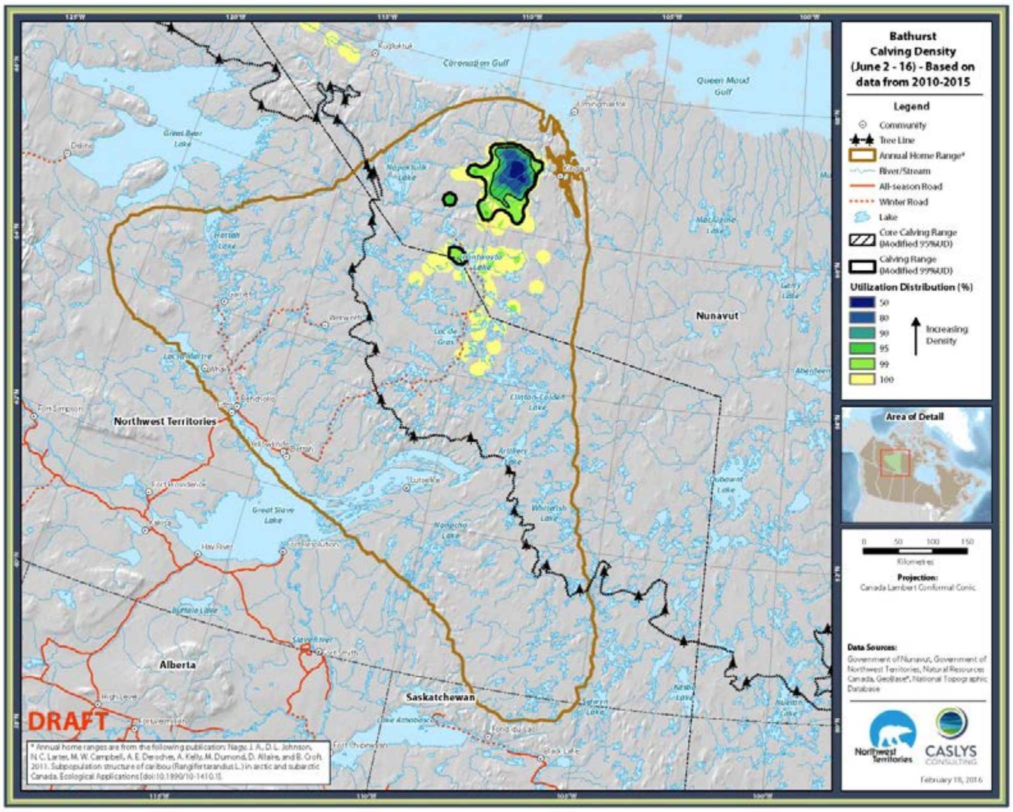


Figure A1.	Annual range of Bathurst herd

The Bathurst herd is a shared resource between many indigenous groups, who have depended on the herd for many years: Akaitcho Territory Government, Łutsel K'e Dene First Nation, NWT Métis Nation, North Slave Métis Alliance, Sahtú Got'ı̨nę (the Dene of Great Bear Lake, Délı̨ne), Tłı̨chǫ, Yellowknives Dene First Nation, as well as harvesters from Nunavut and Saskatchewan. The Bathurst herd has provided food, clothing, and materials for making shelter, tools, and important ceremonial items such as drums; many traditional place names in the Bathurst range refer to caribou (Hearings; Part A and B; Le). The relationship between indigenous peoples and caribou has been maintained through harvest and the respectful use of all that caribou can provide, with traditional laws speaking to how to maintain the relationship.[9]

[9] Legat, A., Chocolate, G., Gon, B., Zoe, S.A., and Chocolate, M. 2014. Caribou Migration and the State of their Habitat: Tłı̨chǫ Knowledge and Perspectives on ʔekwǫ̀ (Barrenland Caribou). Tłı̨chǫ Traditional Knowledge Reports: Series 2. Tłı̨chǫ Research and Training Institute.

Since the herd's peak in 1986, the Bathurst herd has declined 96% by 2015, resulting in major restrictions on subsistence harvesting by First Nations and indigenous communities, and the closure of outfitted and resident hunting of the herd in the Northwest Territories. As of 2015, hunter harvest of the Bathurst caribou herd has been reduced to zero in the Northwest Territories (WRRB Part A). In addition to food security issues, there are concerns that harvest restrictions sever connections between people and caribou, and prevent the passing on of traditional harvest practices. The concern remains that without the ability to harvest caribou – traditions will be lost (WRRB hearing transcripts).

<u>Status</u>

The Bathurst herd has declined from a historic peak population estimated at over 450,000 in 1986, to approximately 20,000 caribou as of 2015 - a decrease of 96% (Figure A2). Breeding cows have also decreased significantly with the estimated number of 16,000 in 2012 dropping to approximately 8,000 in 2015 – a decline of about 50% (Figure A3).

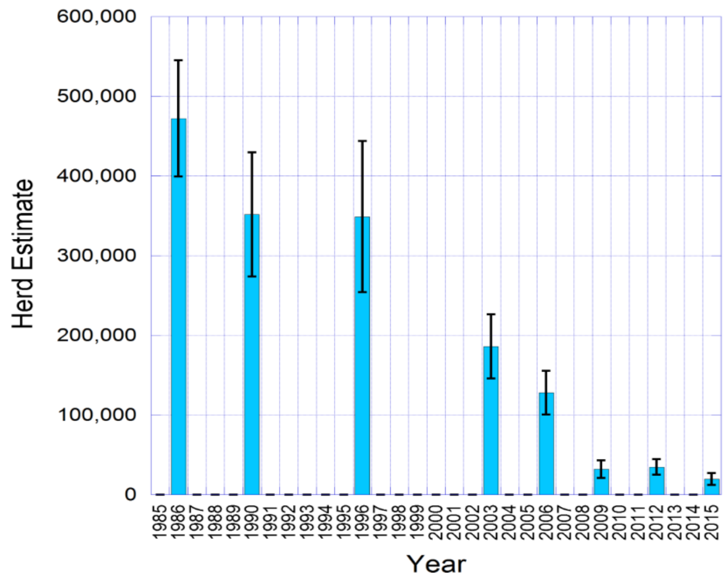


Figure A2. Estimates of the total number of adult caribou in the Bathurst herd (ENR 2015)

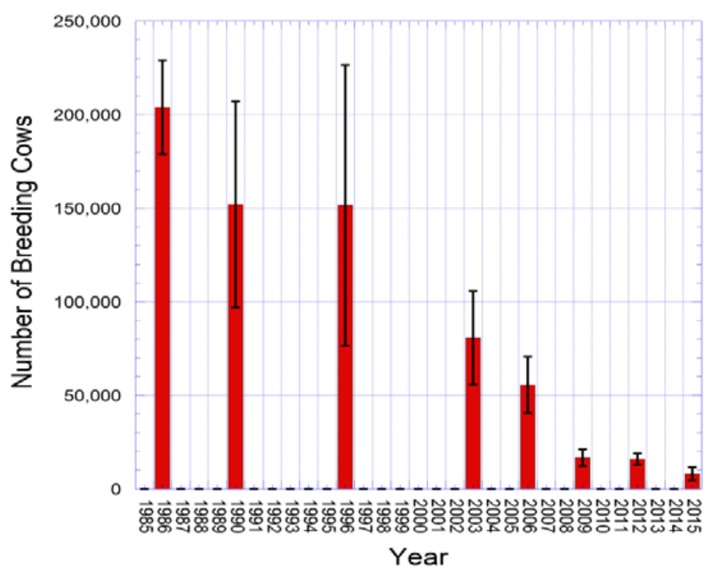


Figure A3. Estimates of the total number of breeding cows in the Bathurst herd (ENR 2015)

Trends

Calf survival is indexed from calf to cow ratios and a ratio of 30-40 calves per 100 cows is generally associated with stable herds. In recent years, calf recruitment surveys provided estimates of: 24 - 32 calves:100 cows for 2013-16[10] (Cluff *et al.* 2017). Cow survival between 2012 and 2015 was estimated at 78%, which is below the 80-85% associated with a stable herd. As well, the pregnancy rate in 2014/15 was approximately 60%, which is well below a rate of 80% typically seen in a healthy herd. During 2010-2016, cow deaths were concentrated on the summer range, (adult cow deaths on the calving grounds[11]) and those deaths may be associated with wolf or bear predation, although the exact cause was not usually known. Winter deaths have decreased between 2010 and 2016 compared to 1996-2010, which may reflect harvest restrictions.

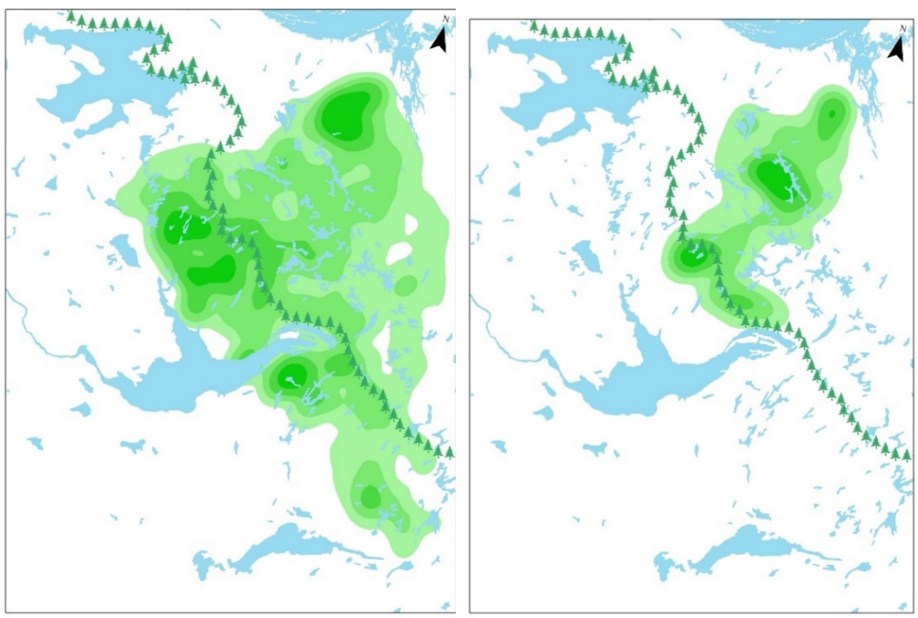
Figure A4. Wildfire history in the NWT, with focus on the Bathurst barren-ground caribou herd range.

[10] Cluff, H.D., Croft, B., and Boulanger, J. 2017. Calf Production and Adult Sex Ratio in the Bathurst and Bluenose East Herds of Barren-Ground Caribou 2006-2016. Unpublished draft Manuscript Report. Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT.

[11] Boulanger, J. and J. Adamczewski. 2017 Analysis of environmental, temporal, and spatial factors affecting demography of the Bathurst and Bluenose-East caribou herds Draft report to ENR

Drought conditions on the summer range of the Bathurst herd increased between 2009 and 2014, with a peak in 2014. These conditions likely resulted in poor plant growth and, subsequently, poor feeding conditions. Biting flies (e.g. mosquitoes, black flies and warble flies) can interfere with summer feeding, with the activity of biting flies related to temperature and wind speed. A review of the warble fly index for the Bathurst herd from 1979 to 2014 shows a trend towards increased insect harassment. Southern portions of the historic Bathurst range have been impacted by wildfires, with the severe 2014 fire season impacting areas close to Tłı̨chǫ communities

Since 2000, the Bathurst annual range has contracted (Figure A5), with reduction in range size and shift in location most noticeable in the fall and winter. Location data from collared caribou have shown reduced use in the south and east, for example southeast of Great Slave Lake and the boreal forests of northern Saskatchewan (BCRP 2017). In winter, there may be overlap between the Bathurst herd and neighbouring barren-ground caribou herds. Location data from collared caribou have shown both the Bluenose-East herd (located to the west), and the Beverly-Ahiak herd (located to the east) overlap with the Bathurst, though ranges may overlap to varying degrees from year to year, with no consistent pattern being displayed The Quaminirijuaq herd, located further south east of the Beverly-Ahiak herd, may also occasionally overlap with the Bathurst herd (BCRP 2016).



1998-2001 2014-2017

Figure A5. Reduction in the Bathurst caribou herd annual range, based on kernel analysis of radio-collar locations of satellite-collared cows. A. Smith, ENR.

Co-management

Under the NWT Wildlife Act, the GNWT is responsible for barren-ground caribou management in accordance with the law and following consultation with all traditional harvesters of the herd, including TG, YKDFN, LKDFN, NWT Métis Nation, NSMA and Athabasca Denesuline. The Nunavut Wildlife Management Board and WRRB are the two co-management boards with primary management authority over the Bathurst herd (WRRB Part A).

Discussions are ongoing between wildlife management authorities and traditional users of the Bathurst herd, and, in 2010 and 2017 respectively, the Barren-ground Caribou Technical Working Group and the Bathurst Caribou Advisory Committee were formed. The Committee and Working Group are using the 2004 Draft Bathurst Caribou Herd Management Plan as a guide to build a future management plan within a one-year timeframe. In 2014, GNWT initiated a range planning process to provide guidance on ways to manage and reduce disturbance to caribou and caribou habitat resulting from human land use.

(Information from WRRB Public Registry: (PR (BATH) - 004: Joint Proposal on Caribou Management Actions for the Bathurst Herd: 2016-2019. 2016, PR (BATH) - 162: ENR to WRRB - Final Written Argument - Bathurst Caribou Herd Public Hearing. 2016, PR (BATH) - 061: Overview: Monitoring of Bathurst and Bluenose-East Caribou Herds, Sept. 2014 Unpublished Report., PR (BATH) - 006: TG & ENR Information Request No.1 Responses - Bathurst Caribou Herd. 2016, PR (BATH) - 129: TG & ENR Information Request No.2 Responses - Additional Information for Question #1 – Bathurst Caribou Herd. 2016).

Appendix B: Previous Joint Management Proposals related to Bathurst Caribou Herd, and Summary of WRRB Recommendations

2007 Proceeding

The WRRB became fully operational in August 2006 and received its first management proposal, entitled "Bathurst Caribou Herd Harvest Reductions" from ENR on December 14, 2006 to reduce Bathurst ʔekwǫ̀ herd harvest levels. The proposed management actions, based on the 2006 decline were intended to limit the harvest to 4% of the 2006 estimated herd size for a total of 5120 Bathurst ʔekwǫ̀. This included eliminating all commercial meat tags held by Tłı̨chǫ communities, reducing the number of tags for non-resident and non-resident alien hunters from 2 to 1, and reducing tags for all outfitters from 1559 to a total of 350.

Due to the significance of the management actions proposed, and the fact that the WRRB, as a new organization, had not yet heard from other Parties affected by the ENR proposal, the Board decided to conduct a public hearing in March 2007 before making any decisions on the proposal.

During the course of the hearing, ENR officials admitted that the Minister and Department had not consulted the Tłı̨chǫ Government about their proposal, as required in the Tłı̨chǫ Agreement, before it was submitted to the Board. Once the evidentiary phase of the proceeding was completed, the Board decided to adjourn the proceeding in order to give ENR and the Tłı̨chǫ Government time to initiate a consultation process. Specifically, ENR and the Tłı̨chǫ Government were directed to report to the WRRB on the outcome of their consultations by April 23, 2007.

On April 20, 2007 and April 23, 2007 respectively, the Tłı̨chǫ Government and ENR filed letters with the WRRB indicating that the consultation process had not been concluded, thereby requiring an additional 90 days to finish the consultations. The WRRB advised ENR and the Tłı̨chǫ Government, in early May 2007, that it had decided to extend the period of adjournment in the proceeding by 30 days to permit the Parties to conclude the consultations by June 1, 2007. The Board indicated that if the consultation efforts were not producing substantial progress, it would bring the proceeding to a close and prepare its Recommendations Report for submission to the Minister of ENR and the Tłı̨chǫ Government.

Emergency Measures

On April 17, 2007, the Minister of ENR advised the Tłı̨chǫ Government and the WRRB that the Big Game Hunting Regulations had been amended to reduce the number of tags available for outfitted hunts for barren-ground caribou in Unit "R" to 750 for the 2007 season. The letter noted that this decision was made under the authority of Section 12.5.14 of the Tłı̨chǫ Agreement as ENR considered its action necessary due to an emergency situation regarding declining populations of the barren-ground caribou.

Board Decision

On May 30, 2007 and June 4, 2007 respectively, the Tłı̨chǫ Government and ENR submitted letters to the Board indicating that they were making substantial progress but required an extension to September 28, 2007 in order to develop a new joint caribou management proposal. The WRRB was concerned that any further adjournments could adversely affect the interests of other Parties affected by the proposal. ENR had already taken steps to implement portions of its proposal on the grounds that an emergency situation existed. Further extension of the proceeding to accommodate consultation which, in the Board's view should have taken place before the proposal was advanced, seemed inconsistent with the urgency asserted by ENR. For these reasons, the WRRB decided not to grant a further adjournment of its proceeding.

Based on the WRRB's review of the evidence presented during the proceedings, the Board recommended that ENR's proposal to undertake management actions to reduce the harvest of the Bathurst caribou herd not be implemented as submitted. The WRRB strongly encouraged ENR and the Tłįchǫ Government to continue their consultations towards the development of a joint proposal for the management of the Bathurst caribou herd. Additionally, the WRRB indicated that any future management actions that propose to limit any component of the harvest to a particular number, including zero, would be treated as a proposal for the establishment of a total allowable harvest.

Barren-ground Outfitter's Association Tag Request

In October 2007, the Barren-ground Caribou Outfitter's Association requested that the tag quota for caribou outfitters be restored to 1260 for the non-HTA outfitters and 396 for the HTA outfitters due to financial hardships experienced by the outfitters and supporting businesses. The Board did not recommend the tag increase to the GWNT as the WRRB is not mandated to address issues of economic viability. Further, the WRRB considered any requests for changes to tag quotas to be premature prior to the submission of a joint proposal regarding the management of caribou in Wek'èezhìı by ENR and Tłįchǫ Government.

2010 Proceeding

In June 2009, a calving ground photographic survey conducted by ENR confirmed that the total number of breeding females was 16,649 (95% confidence interval (CI) =12,153-21,056). The total population estimate was 31,900 (95% CI=21,000-42,800), a decline of 70% in 3 years.

On November 5, 2009, TG and ENR submitted the Joint Proposal on Caribou Management Actions in Wek'èezhìı, which proposed nine management actions and eleven monitoring actions, including harvest limitations, for the Bathurst, Bluenose-East and Ahiak ʔekwǫ̀ herds. While there was agreement on the majority of actions proposed, there was no agreement reached on the proposed levels of Aboriginal harvesting.

Upon review of the proposal, the WRRB held that any restriction of harvest or component of harvest to a specific number of animals would constitute a TAH. Thus, the Board ruled that it was required to hold a public hearing. Registered Parties were notified on November 30, 2009 of the Board's decision to limit the scope of the public hearing to Actions 1 through 5 of the joint proposal, which prescribed limitations on harvest. All other proposed actions were addressed through written submissions to the Board.

On January 1, 2010, ENR implemented interim emergency measures, which included the closure of ʔekwǫ̀ commercial, outfitted and resident harvesting in the North Slave regions. In addition, all harvest was closed in a newly established no-hunting conservation zone. This decision was made by the Minister of ENR under the authority of Section 12.5.14 of the Tłįchǫ Agreement. The Minister considered these emergency actions necessary due to the rapidly declining population of the Bathurst ʔekwǫ̀ herd. The Board was informed of the Minister's decisions on December 17, 2009.

Originally scheduled for January 11-13, 2010, the public hearing eventually took place March 22-26, 2010 in Behchokǫ̀, NT. Once the evidentiary phase of the proceeding was completed, TG requested the WRRB adjourn the hearing in order to give TG and ENR time to work collaboratively to complete the joint management proposal. The Board agreed to grant the application for adjournment with the condition that any revised proposal be filed by May 31, 2010 and that such a proposal address both harvest numbers and allocation of harvest for both the Bathurst and Bluenose-East ʔekwǫ̀ herds.

On May 31, 2010, TG and ENR submitted the Revised Joint Proposal on Caribou Management Actions in Wek'èezhìı. This revised proposal changed the original management and monitoring actions and incorporated an adaptive co-management framework and rules-based approach to harvesting. TG and ENR were able to reach an agreement on Aboriginal harvesting. Following review of the information and comments from registered Parties, the WRRB accepted the revised proposal. Therefore, the WRRB reconvened its public hearing on August 5-6, 2010 in Behchokǫ̀, NT, where final presentations, questions and closing arguments were made.

2010 Board Decision

On October 8, 2010, the WRRB submitted its final recommendations and reasons for decision report to TG and ENR[12]. Based on all available information, the Board concluded that a conservation concern existed for the Bathurst ʔekwǫ̀ herd and management actions were vital for herd recovery. However, rather than imposing a TAH, the WRRB was persuaded by TG and ENR's argument to recommend a harvest target of 300 Bathurst ʔekwǫ̀ per year for harvest seasons 2010/11, 2011/12 and 2012/13. Further, the Board recommended that the ratio of bulls harvested to cows should be 85:15.

The Board concluded that a limited harvest of 270-330 ʔekwǫ̀ with 60 or fewer cows was an appropriate management option to help stabilize the herd. While the strongest measures to maximize the potential for the recovery of the herd would have been to end all harvesting, including the Aboriginal harvest, the Board recognized the linkage between Aboriginal peoples, ʔekwǫ̀ and culture and the hardship that a total ban would entail. Therefore, the WRRB sought a balance between maintenance of those important linkages and minimizing impact of the harvest on the Bathurst ʔekwǫ̀ herd.

The Board recommended that all commercial, outfitted and resident harvesting of the Bathurst ʔekwǫ̀ herd in Wek'èezhìı be set to zero. The Board also made harvest recommendations for the Bluenose-East and Ahiak ʔekwǫ̀ herds.

The WRRB made additional ʔekwǫ̀ management and monitoring recommendations to TG and ENR, specifically implementation of detailed scientific and Tłı̨chǫ Knowledge (TK) monitoring actions, implementation of an adaptive co-management framework and development and implementation of a Bathurst ʔekwǫ̀ management plan.

The WRRB also recommended to the Minister of INAC (formerly Indian and Northern Affairs Canada) and ENR to collaboratively develop best practices for mitigating effects on ʔekwǫ̀ during calving and post-calving, including the consideration of implementing mobile ʔekwǫ̀ protection measures, and for monitoring landscape changes, including fires and industrial exploration and development, to assess potential impacts to ʔekwǫ̀ habitat.

The WRRB was requested to make recommendations to TG and ENR regarding dìga. The Board recommended that the harvest of dìga should be increased through incentives but that focused dìga control not be implemented. If TG and ENR were to contemplate focused dìga control in the future, a management proposal would be required for submission to the WRRB for its consideration.

The Minister's emergency interim measures remained in effect until the WRRB's recommendations on ʔekwǫ̀ management in Wek'èezhìı were implemented on December 8, 2010. On January 13, 2011, TG and ENR responded to the Board's recommendations, accepting 35, varying 22 and rejecting three of the 60 recommendations. TG and ENR submitted an implementation plan to the WRRB on June 17, 2011, which the Board formally supported on June 30, 2011.

[12] Report on a Public Hearing Held by the Wek'èezhìı Renewable Resources Board 22-26 March 2010 & 5-6 August 2010, Behchokǫ̀, NT and Reasons for Decisions Related to a Joint Proposal for the Management of the Bathurst Caribou Herd. 2010.

2016 Proceedings

On June 27, 2012, following the completion of the 2012 Bathurst ʔekwǫ̀ herd calving ground survey, the WRRB requested a joint management proposal from TG and ENR to address any changes in the 2010 management actions. On March 6, 2013, TG and ENR notified the Board that discussions had commenced in an effort to have a joint proposal filed by May 1, 2013, with implementation of recommendations for the 2013 fall harvest. However, on May 6, 2013, TG and ENR advised the Board that, due to incomplete community consultations and the Tłı̨chǫ Government's 2013 election period, the joint management proposal would not be submitted until after September 16, 2013.

In the interim, on May 31, 2013, the WRRB reviewed and recommended continued implementation of recommendations made in its October 2010 Recommendations Report for the 2013/2014 harvesting season. On December 6, 2013 and January 16, 2014, TG and ENR, respectively, accepted the Board's recommendation for continued implementation of the 2010 recommended management actions for the Bathurst ʔekwǫ̀ herd.

On June 30, 2014, TG and ENR submitted the "Joint Proposal on the Caribou Management Actions in Wek'èezhìı (2014-2019)" under separate cover. On July 11, 2014, the WRRB deemed the joint management proposal to be incomplete until receipt of consultation reports that TG and ENR promised would be available by July 15, 2014 and September 2014, respectively. These consultation reports were never provided. Given the circumstances, the Board recommended that, in order to ensure a consistent management approach, the recommendations made for the 2013/14 harvest season should remain in place for 2014/15.

Following the June 2014 reconnaissance survey of the Bathurst ʔekwǫ̀ herd, on August 27, 2014, the Minister of ENR held a meeting of Aboriginal leaders and wildlife management authorities to discuss the results, which suggested a continuing declining trend. Subsequently, on August 29, 2014, the WRRB requested clarification from TG and ENR regarding their intentions to either confirm or revise the management actions proposed in the joint management proposal submitted in June 2014. On September 15, 2014, TG and ENR requested that the Board defer consideration of the joint management proposal until the two governments could determine whether the proposed management actions were still appropriate.

On January 20, 2015, ENR submitted a management proposal to the Board to establish a Mobile Core Bathurst Caribou Conservation Area (MCBCCA) (Figure 3), based on the locations of satellite-collared ʔekwǫ̀. Harvest of ʔekwǫ̀ was not permitted within the MCBCCA; however, harvest of a limited number of Bathurst ʔekwǫ̀ bulls, up to a maximum of 15, would be considered by ENR within the MCBCCA for ceremonial purposes upon submission of a written proposal by an Aboriginal government with traditional harvesting rights for the Bathurst ʔekwǫ̀ herd. On January 23, 2015, the WRRB supported the establishment of the proposed MCBCCA through wildlife regulations and the amendments to the Big Game Hunting Regulations to require authorization cards for harvest within R/BC/01, R/BC/02, and R/BC/03.

On August 25, 2015 and September 22, 2015, respectively, TG and ENR provided short-term ʔekwǫ̀ management recommendations for the 2015/16 harvest season. The Board responded to TG and ENR, on September 25, 2016, with reasons for decisions and a list of recommendations for the 2015/16 harvest season, including agreeing on and implementing a further reduction in the number of ʔekwǫ̀ harvested by subsistence users of the Bathurst ʔekwǫ̀ herd, and whether the MCBCCA or Wildlife Management Units Subzones is the most effective way to differentiate between barren-ground caribou herds. In addition, in order to implement determinations and/or recommendations by July 1, 2016, the WRRB requested the submission of a joint management proposal for the Bathurst ʔekwǫ̀ herd, for the 2016/17 harvest season and beyond, by no later than October 15, 2015.

Due to consultation requirements, TG and ENR approached the Board on October 15, 2015 requesting an extension of the time for the submission of a joint management proposal for the Bathurst ʔekwǫ̀ herd until December 15, 2015. On October 21, 2015, the Board accepted the extension request despite concerns about future timing issues, including the implementation of management actions in the 2016/2017 harvest season. On November 27, 2015, TG and ENR accepted the WRRB's recommendations and came to an agreement to implement, for the 2015/16 harvest season, a harvest target of zero for the NWT Aboriginal harvest of the Bathurst ʔekwǫ̀ herd, and the continued use of a renewed version of the MCBCCA, called the Mobile Core Bathurst Caribou Management Zone (MCBCMZ).

TG and ENR submitted the *"Community Based Wolf Harvesting Project"* management proposal to the Board on January 13, 2016. The 2015/16 pilot project proposed to train participants from Wekweètì in effective field techniques to hunt, trap, skin and process dìga and to utilize Tłı̨chǫ cultural practices. Field camps would be established near large lakes within the MCBCMZ. If successful in Wekweètì, the project would then be offered in the communities of Gamètì and Whatì in 2016/17. On January 18, 2016, the WRRB supported the establishment of the proposed Community-based Wolf Harvest Project as a pilot training program only and not as a management action to reduce any potential impacts to the Bathurst ʔekwǫ̀ herd given that no accurate population estimate is available for dìga in Wek'èezhìı or the broader NWT.

On December 15, 2015, the TG and ENR submitted the *"Joint Proposal on Caribou Management Actions for the Bathurst Herd: 2016-2019"* to the WRRB outlining proposed management actions for the Bathurst ʔekwǫ̀ herd in Wek'èezhìı, including new restrictions on hunter harvest, predator management to reduce dìga populations on the winter range of the Bathurst ʔekwǫ̀ herd and ongoing monitoring (Appendix A). More specifically, TG and ENR proposed the closure of all harvesting of the Bathurst ʔekwǫ̀ herd and the development of mobile dìga-hunter camps. The WRRB considered the proposed restriction of harvest as the establishment of a TAH and, therefore, was required to hold a public hearing. The Board initiated its 2016 Bathurst Caribou Herd Proceeding on January 18, 2016, and held its public hearing in Yellowknife, NT on February 23-24, 2016.

<u>2016 Board Decision – Part A</u>
On May 26, 2016, the WRRB submitted its first of two final reports to TG and ENR. The WRRB concluded, based on all available Aboriginal and scientific evidence, that a serious conservation concern exists for the Bathurst ʔekwǫ̀ herd and that additional management actions are vital for herd recovery. However, to allow careful consideration of all the evidence and to meet legislated timelines, the WRRB decided to prepare two separate reports to respond to the proposed management actions in the joint management proposal.

This first report, Part A, dealt with the proposed harvest management actions that required regulation changes in order for new regulations to be in place for the start of the 2016/17 harvest season, as well as the proposed mobile dìga-hunter camp and the dìga feasibility assessment.

The WRRB determined that a total allowable harvest of zero shall be implemented for all users of the Bathurst ʔekwǫ̀ herd within Wek'èezhìı for the 2016/17, 2017/18, 2018/19 harvest seasons. As monitoring of the ʔekwǫ̀ wildlife management units and Bathurst ʔekwǫ̀ harvest are intricately linked to the implementation of a TAH, the Board recommended that TG and ENR agree on an approach to designating zones for aerial and ground-based surveillance throughout the fall and winter harvests seasons from 2016 to 2019. These harvest management actions are to be implemented by July 1, 2016, the start of the 2016/17 harvest season. Additionally, the WRRB recommended timely implementation of hunter education programs in all Tłı̨chǫ communities.

The Community-based Dìga Harvesting Project, proposed by TG and ENR as a pilot training program, is to train Tłı̨chǫ harvesters, in a culturally appropriate manner, to hunt and trap dìga on the Bathurst herd range. The Board continues to support the Project as a training program, with recommendations related to implementation and assessment. Prior to Project start up, the Board requests an update from TG and ENR in December 2016.

The WRRB also recommended that the dìga feasibility assessment set out in the proposal be led by the Board with input and support from TG and ENR. The feasibility assessment would primarily be an examination of all options for dìga management, including costs, practicality and effectiveness. The Board requested that this assessment be initiated in June 2016.

<u>2016 Board Decision – Part B</u>
As the Bathurst ʔekwǫ̀ herd situation is so dire, the Board felt that it would be irresponsible to address harvest management only as there is a real risk that the herd will be extirpated within a few short years. Therefore, the second report, Part B[13], dealt with self-regulation, additional predator management actions, biological and environmental monitoring, and cumulative effects.

The WRRB understands that in order for Tłı̨chǫ Citizens to fully take ownership of the Board's determinations and recommendations it is imperative that Tłı̨chǫ laws are implemented to continue the Tłı̨chǫ way of life and maintain their cultural and spiritual connection with ʔekwǫ̀. Therefore, the WRRB recommended consultations with Tłı̨chǫ communities to determine a path forward for implementation of Tłı̨chǫ laws.

In addition, the WRRB recommended several Tłı̨chǫ Knowledge (TK) research and monitoring programs focusing on dìga, *sahcho* (grizzly bear), stress and other impacts on ʔekwǫ̀ from collars and aircraft over-flights, and an assessment of quality and quantity of both summer and winter forage. The Board recommended a biological assessment of sahcho as well as requesting that the Barren-ground Caribou Technical Working Group (BGCTWG) prioritize biological monitoring indicators and develop thresholds under which management actions can be taken and evaluated. All scientific and TG monitoring data is to be provided to BGCTWG annually to ensure ongoing adaptive management.

The WRRB recommended the implementation of Tłı̨chǫ Land Use Plan Directives as well as completing a Land Use Plan for the remainder of Wek'èezhìı. In addition, the completion of the Bathurst Caribou Range Plan[14] and the long-term Bathurst Caribou Management Plan are requested with measures to be implemented in the interim to provide guidance to users and managers of the Bathurst ʔekwǫ̀ herd range.

The Board recommended the development of criteria to protect key ʔekwǫ̀ habitat, including water crossings and *tataa* (corridors between bodies of water), using the Conservation Area approach in the NWT's *Wildlife Act*, offsets and value-at risks in a fire management plan. Additionally, the WRRB recommended the continued refinement of the Inventory of Landscape Change (ILC), the integration of Wildlife and Wildlife Habitat Protection Plans (WWHPP) and Wildlife Effects Monitoring Programs (WEMP) objectives for monitoring the effects of development on ʔekwǫ̀ in Wek'èezhìı, and the development of monitoring thresholds for climate indicators.

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[13] *Report on a Public Hearing Held by the Wek'èezhìı Renewable Resources Board, 23-24 February 2016, Yellowknife, NT & Reasons for Decisions Related to a Joint Proposal for the Management of the Bathurst Ɂekwǫ̀ (Barren-ground caribou) Herd – Part B.*

[14] Bathurst Caribou Range Plan (BCRP) 2017. Interim Range Assessment and Technical Methods Report. March 2017.

Appendix C: Wolf Feasibility Assessment Technical Working Group - Terms of Reference

In 2015, ENR committed to conduct a collaborative feasibility assessment of wolf management options for the range of the Bathurst herd, including areas both within and outside of Wek'èezhìı. ENR initiated work on the feasibility assessment with a 2-day workshop on wolf research and management in November 2015, which included participation of TG and WRRB technical staff. A review of wolf management programs in other jurisdictions was also conducted, including a review of literature and discussions with agencies and individuals involved in these programs (see McLaren 2016).

Previously, in 2010, WRRB indicated that focused wolf control should not be implemented (WRRB 2010 recommendations report). However, if TG and ENR contemplated focused wolf control in the future, a management proposal should be provided to the WRRB. In response to the Board's recommendations, ENR, in consultation with TG, agreed to provide a proposal with potential options and costings, relevant to wolf monitoring, research, and management This proposal could help determine whether current management actions were working, or more intensive management was required to facilitate caribou recovery (093: ENR & TG to WRRB – Recommendation Report – Revised Joint Proposal, 13 Jan 2011). However, a proposal was not submitted.

In the 2016 joint management proposal, ENR stated they would carry out the outstanding technical feasibility assessment of wolf management options, with the assessment completed collaboratively with TG and the input of other interested parties. During the 2016 Bathurst proceedings, it was clarified that that the WRRB would be part of the assessment. Further discussions led to the WRRRB 's recommendation indicating the WRRB would take the lead. Subsequent discussions led to the establishment of the Wolf Feasibility Assessment Technical Working Group (WG) which relies on a collaborative process. The WG has been meeting since May 2016.

Objectives

The WG shall:

a) collaboratively identify and assess the technical feasibility, costs, and potential effectiveness of different wolf management techniques that may be implemented on the range of the Bathurst caribou herd to increase calf and adult caribou survival rates sufficiently to stabilize the herd and initiate recovery to higher numbers;
b) bring forward any currently available traditional and/or scientific knowledge relevant to the assessment;
c) support the development and timely implementation of a communication strategy regarding wolf management by communications experts;
d) treat all reports and supporting material as confidential, unless otherwise specified; and,
e) set up meeting procedures necessary to its operations.

Terms of Reference

This WG has been established to identify and assess the technical feasibility and potential effectiveness of a series of different wolf management techniques in the annual range of the Bathurst caribou herd. The primary scope of the assessment is the herd's range in the Northwest Territories. The WG will communicate with appropriate agencies in the Northwest Territories and Nunavut, request their input at appropriate points and respect jurisdictional boundaries.

The WG is accountable for overseeing, reviewing and providing advice on a feasibility assessment for wolf management on the annual range of the Bathurst caribou herd by:

a) Fostering collaboration and ensuring that both existing traditional and scientific knowledge are used to assess all possible options for wolf management on the annual range of the Bathurst caribou herd (objectives; technical approach and methodology, including time to effectively implement, effectiveness of whether they meet the objectives and how measured, likelihood of success and failure, costs, and monitoring; public acceptability and considerations of humaneness of possible actions; political and legal framework);

b) Summarizing experience with wolf management and monitoring in other North American jurisdictions and its relevance to wolves associated with migratory tundra caribou; and,

c) Ensuring that an effective communication strategy is developed to inform and educate the public and other parties with interest in the Bathurst caribou herd on wolf management, including reviewing existing communication strategies to build on recent experiences of others.

- The members of the WG shall include representatives from each of the following organizations:
    - Tłı̨chǫ Government (TG), Department of Culture & Lands Protection
    - Government of the Northwest Territories, Environment & Natural Resources (ENR)
    - Wek'èezhìı Renewable Resources Board
    - North Slave Métis Alliance
    - Yellowknives Dene First Nation
    - Łutsel K'e Dene First Nation.

- The WG shall engage with appropriate Nunavut agencies, organizations and experts to ensure cross-border collaboration and respect for jurisdictional boundaries.

- The WG may also seek input from additional WG members' staff as well as other agencies, organizations and experts, including Nunavut, as required by the WG members. Following WG consensus, non-members shall be invited to attend meetings either in person or via teleconference.

- The individual group members are responsible for reporting back on activities of the WG and seeking advice from their respective organizations.

- The membership of the WG will commit to attending all scheduled meetings, where possible; sharing all communications and information with WG members; and making timely decisions.

- The Chair of the WG will be chosen at the beginning of each meeting. Quorum will be representatives from at least three organizations of the WG (in person or via teleconference).

- The WG will seek consensus (everyone supports the decision and agrees to move forward) on all decisions. When differences arise, the following steps will be taken:
    - Every effort will be made to resolve issues, recognizing that compromise is required to accommodate differences.
    - Should the WG fail to find ways to compromise with each other to accommodate all members, both the majority view and the dissenting view(s) will be recorded and included in the final recommendations report.

- The WG shall:
    1. Collaboratively identify and assess the technical feasibility, costs, and potential effectiveness of different wolf management techniques that may be implemented on the range of the Bathurst caribou herd to increase calf and adult caribou survival rates sufficiently to stabilize the herd and initiate recovery to higher numbers;
    2. Bring forward any currently available traditional and/or scientific knowledge relevant to the assessment;
    3. Support the development and timely implementation of a communication strategy regarding wolf management by communications experts;

4. Treat all reports and supporting material as confidential, unless otherwise specified; and,
5. Set up meeting procedures necessary to its operations.

- ENR shall ensure administrative support to the WG including:
    - organizing meetings, including providing physical location and/or teleconference information;
    - preparation of meeting correspondence;
    - co-ordination of the preparation of background information; and
    - minute/note taking.

- ENR shall take the lead in providing definitions of any key technical terms while TG will provide definitions based on traditional knowledge.

- All parties will be responsible for expenses of their representatives on the WG.

- This Terms of Reference is effective from 31 May 2016 and continues until the completion of the assessment.

Appendix D: Examples of wolf management outside of NWT

This section summarizes four examples of planned reductions in wolf numbers for mountain caribou herds in Alaska and the Yukon which led to increases in caribou calf survival and herd size. We have not included all possible examples and their varied success or lack of it except to note that relatively high numbers of alternate prey (moose) and or insufficient wolf removal are impediments to increasing caribou numbers - McLaren (2016) provides a detailed review.

The four herds differ as to the extent of the decline before wolf control was applied and the duration of the effects of wolf control partly depends on the method (Figure 1). Sterilization and reduction in pack size by removing non-breeders affected caribou for 2-3 years longer than direct removal of wolves. The sterilized wolves maintained their territories which reduced wolf immigration (Hayes 2013, Boertje *et al.* 2017). The effect of wolf control is typically monitored through calf survival (indexed by fall calf to cow ratios), adult survival and the trend in herd size. Figure 1 shows how wolf management was applied to three smaller herds (<5000) which were declining with reduced fall calf:cows and the wolf removal did increase herd size and calf survival (based on fall calf-cow ratios) but the effects were restricted to a few years after wolf removal. Farnell (2009) acknowledged the short-term effect of wolf removal and observed that over the longer-term a comprehensive long-term management plan to limited human harvest and land-use activities was needed. The situation was different for the Fortymile herd where calf survival was relatively high prior to wolf control which was intended to accelerate recovery.

The mountain caribou herds in Alaska, Yukon and BC differ in factors affecting their vital rates including hunting, industrial activities, fire, and environmental variability (winter snow and ice; summer forage growth, drought and insect harassment). There are added complexities such as interactions with other predator (i.e., bear) and prey (i.e., moose), as well as the interactive effects of multiple factors on age structure of a caribou herd. An additional complication is that in Alaska has a constitutional and statutory provision to manage wildlife on a sustained yield basis. This, since 1994, has various triggers (such as caribou herd size and harvest) for ‘Intensive Management’ which includes using predator management to increase or recover harvesting opportunities. Alaska also differs as the regulated public wolf harvesting is relatively high and public wolf control can also be implemented and supplemented by state control.

Lessons can be learnt especially about the wolf removal techniques and required monitoring (such as Hayes 2013, Russell 2010). In the Finlayson herd’s range in the Yukon, wolves were reduced by aerial wolf control to 15% of the original numbers in the first year of wolf reduction. For the following 5 years, removal kept the numbers at 14–17% of the original numbers. Wolf density was reduced from 10.3 to between 1.4 and 1.8 wolves/ 1000 km^2 (Farnell 2009). By comparison, wolf densities on the Bathurst summer range were estimated 0.62 ± 0.05 SE wolves/ 1000 km^2 2008-2002.

However, answers are not simple on the extent and for how long wolf management met objectives to halt caribou declines or to lead to recovery (Figure D1, Tables D1 and D2). The ecological framework for interpreting predation is complex and needs (i) understanding/monitoring harvest and predator management and ii) the importance of monitoring other key environmental impact pathways and indicators to help interpret effectiveness of management actions. Ecological manipulations may have unexpected effects across the different trophic levels including implications for smaller-bodied predators and scavengers (Prugh et al 2009).

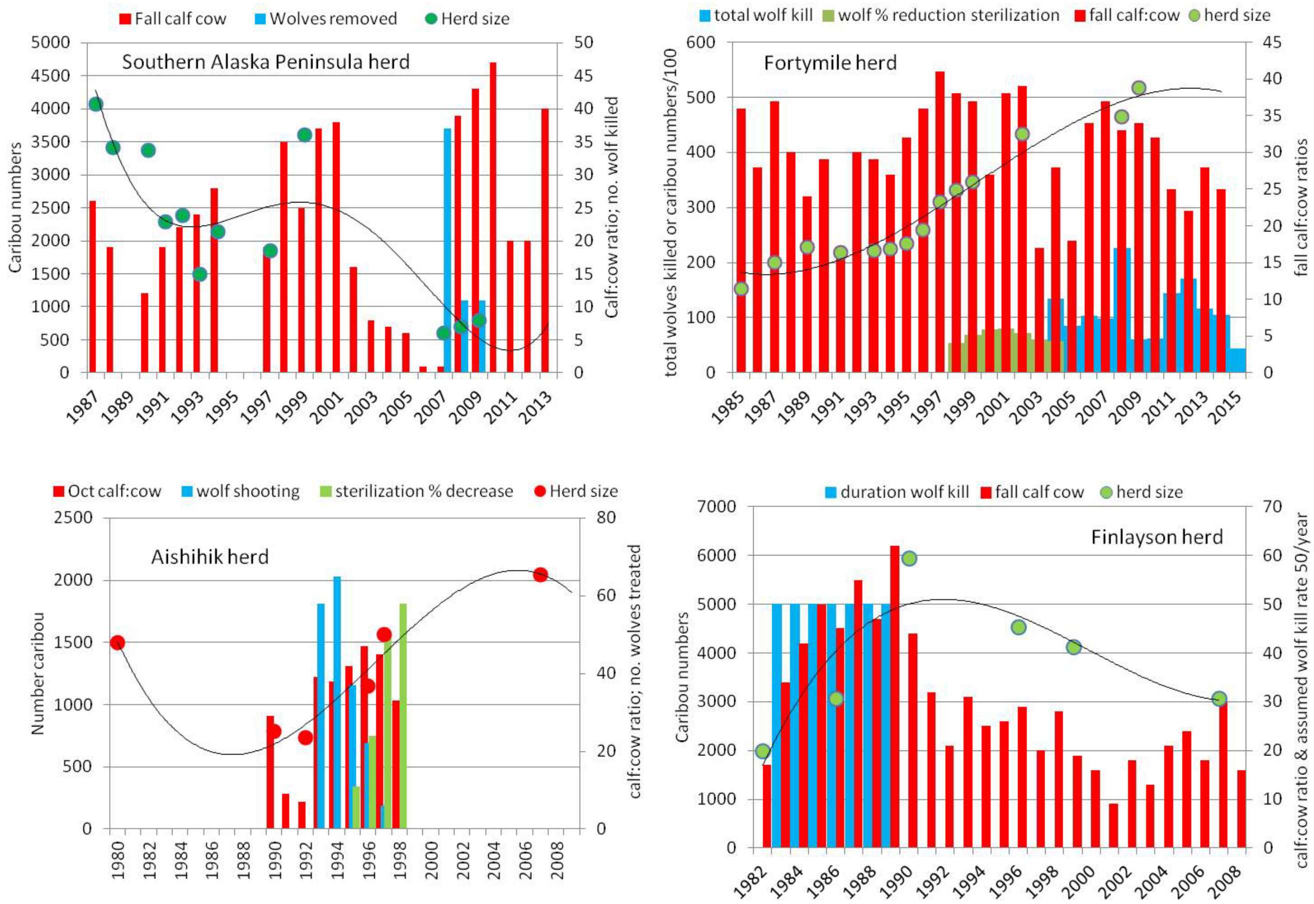


Figure D1. Summary of trends in herd size, wolf management and fall calf:cow ratios (sources in Appendix H). The graphs show fall calf:cow ratios (an index to calf survival); estimates of herd size and the timing of wolf sterilization and wolf removal.

Table D1. Summary of Wolf Removal/Reduction Programs: Effects on Caribou Survival Rates

Herd; range herd size		Treatment phases	Period	No. years	Trend	Average +/- SE Fall calf:cow	Adult survival
Fortymile 15.300-51,700		Prior to treatment	1985-1997	12	increase 40% λ1.18	29.5 +/- 1.67	unmeasured
	sterilization + translocation	During	1997-2000	4	increase 11% λ1.07	35/7 +/- 3.04	unmeasured
	shooting/ trapping	During/ Current	2004-2015	11	increase 33%	29.3 +/- 1.91	
South Alaska Peninsula		Prior to treatment	1999-2007	8	decline 84%	17.3+/- 5.11	unmeasured
600-4000	shooting on calving	During treatment	2007-2009	3	increase 25%	27.7 +/- 3.38	unmeasured
		After treatment	2010-2013	4	no estimates	31.75 +/- 9.3	unmeasured
Aishihik 200-2000		Prior to treatment	1981-1992	3	decline 52%	15 +/- 7.02	87%
	Shooting - range-wide	During treatment	1993-1997	5	increase 50%	40.7 +/ - 2.08	91%
		After treatment	1997 - 2007	11	increase 34%	28 +/- 2.4	unmeasured
Finlayson		Prior to treatment	1982	1	declining	17	unmeasured
	Shooting - range-wide	During treatment	1983-1989	7	Increase 5%	47.9 +/- 3.41	unmeasured
		After treatment	1990-2006	17	decline 49%	23.2 +/- 2.0	unmeasured

Table D2. Wolf Removal and Effects on Wolves: Some Case Studies from WG

	Wolf Removal			Study area		Wolf Ecology		
Herd	Extent	Method	Number wolves (packs)	Duration	Area	Dispersal Rates	Reproductive Rates	Source
Finlayson		Shooting trapping	451 (17)	1983-1989	Winter			Farnell 2009
Aishihik		Sterilization	13 (6)	1996-1997	Winter			Hayes et al. 2003
		Shooting trapping	188	1993-1998	Winter			
Fortymile		Sterilization	39 (15)	1997-2001	Calving			Boertje & Gardner 2003
		Shooting trapping	1350	2005-2015	Winter			Gross 2015
Southern Alaska Peninsula		Aerial shooting	59	2007-2009	Calving			ADF&G 2011
Mountain Central Alaska, Brooks Range	12% Annual Harvest natural mortality 11.4%			1986-1992	24,700km^2	Emigration >19% annually; yearling wolves' emigration 47%,	Litter size average 5.2 pups	Adams *et al.* 2008 Valkenburg *et al.* 2016

Sources for examples of wolf control in Yukon and Alaskan caribou herds

The graphs (Figure 1) are based on information extracted from government reports as well as published journal papers. The Alaskan Department of Fish and Game provides inventory reports for the caribou herds at 2-3 year intervals. The reports include considerable detail for annual levels of sex and age composition, mortality, pregnancy and survival as well as estimates of herd size and harvest. ADF&G also reports on intensive management actions including reports on predator management to Alaskan Board of Game.

Fortymile herd

Alaska Department of Fish and Game. 2014. Annual report to the Alaska Board of Game on intensive management for moose and caribou with wolf predation control in the upper Yukon/Tanana Rivers. Division of Wildlife Conservation, Juneau.

Gross, J. A. 2015. Units 20B, 20C, 20D, 20E, and 25C caribou. Chapter 12, 12–1 through 12–34 [In] P. Harper and L. A. McCarthy, editors. Caribou management report of survey and inventory activities 1 July 2012–30 June 2014. Alaska Department of Fish and Game, Species Management Report ADF&G/DWC/SMR-2015-4, Juneau.

Boertje, R. D., and C. L. Gardner. 1999. Reducing mortality on the Fortymile caribou herd. Alaska Department of Fish and Game, Division of Wildlife Conservation, Federal Aid Research Performance Report 1 July 1998–30 June 1999, Federal Aid in Wildlife Restoration Study 3.43, Juneau.

Boertje, R. D., and C. L. Gardner. 2003. Reducing mortality on the Fortymile caribou herd. Alaska Department of Fish and Game, Division of Wildlife Conservation, Federal Aid Research Performance Report 1 July 1997–30 June 2003, Federal Aid in Wildlife Restoration Study 3.43, Juneau.

Southern Alaska Peninsula herd

ADF&G Department of Conservation. 2011. Annual Report to the Alaska Board of Game on Intensive Management for Caribou with Wolf predation control on Southern Alaska Peninsula.

Peterson, C. 2015. Unit 9D Southern Alaska Peninsula caribou. Chapter 5, Pages 5-1 through 5-11 [In] P. Harper and L. A. McCarthy, editors. Caribou management report of survey-inventory activities 1 July 2012–30 June 2014. Alaska Department of Fish and Game, Species Management Report ADF&G/DWC/SMR-2015-4, Juneau.

For the Yukon herds, the Government of Yukon publications were searched for reports on the Finlayson and Aishihik herds

Environment Yukon. 2016. Science-based guidelines for management of Northern Mountain caribou in Yukon. Yukon Fish and Wildlife Branch Report MR-16-01. Whitehorse, Yukon, Canada.

Hegel, T., and K. Russell. 2010. Aishihik and Kluane northern mountain caribou herds census, 2009. Yukon Fish and Wildlife Branch Report SR-10-02. Whitehorse, Yukon, Canada.

Adamczewski, J., R. Florkiewicz, R. Farnell, C. Foster, and K. Egli. 2010. Finlayson caribou herd late-winter population survey, 2007. Yukon Fish and Wildlife Branch Report SR-10-01. Whitehorse, Yukon, Canada.

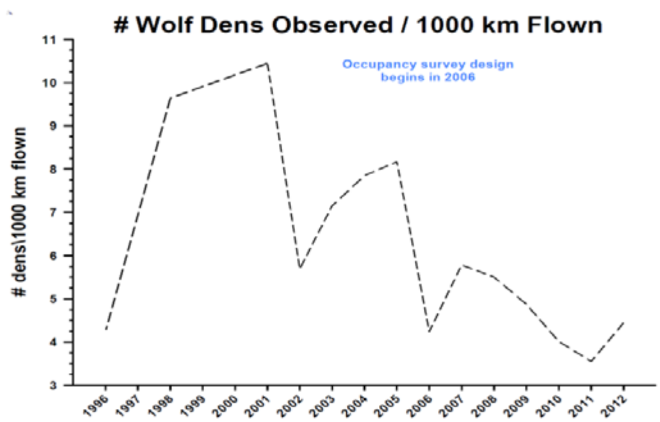
Farnell, R. 2009. Three Decades of Caribou Recovery Programs in Yukon: A Paradigm Shift in Wildlife Management. Yukon Fish and Wildlife Branch Report MRC-09-01, Whitehorse, Yukon, Canada.

Appendix E: Wolf abundance and seasonal distribution on the range of the Bathurst caribou herd

<u>Wolf abundance</u>

Wolf abundance on the Bathurst caribou range has declined since the mid-1990s based on indices to abundance (pers. comm. 2017 Dean Cluff, Klaczek 2015[15]). Recruitment of pups has declined from 3.5 pups/pack (1996-2000) to 1.8 pups/pack (2007-2012); the number of occupied dens has declined; and pack size at den sites has declined (Figure E1). The number of pups initially recorded at a den site did not show a trend but the number of active dens in August sharply declined suggesting either litter loss or the wolves were relocating their pups to distant rendezvous sites (Figure E2). From 1996-2006, 53% (± 5 SE) of the dens initially occupied in spring were still active in late summer and from 2007-2012 (Klaczek 2015), the rate of den abandonment increased and only 9 ± 2% of the dens initially occupied in spring (21 ± 0.1SE) were active in late August (2 ± 0.4). The recruitment levels were used in a stochastic population model which suggested an increasing rate of decline in wolf numbers after 2006 to 2012 leading to a 95% decline in relative abundance (Klaczek 2015).

a



b

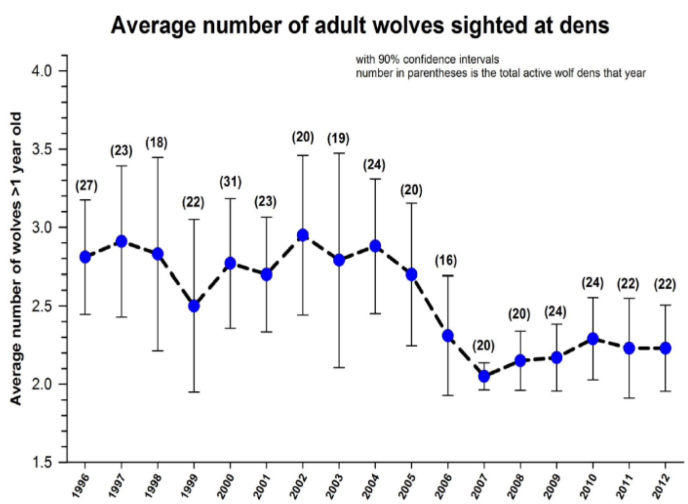


Figure E1. The sighting rate of wolf dens (number dens/1000 km flown) (a), and the number of adult wolves during aerial surveys Bathurst herd summer range (b);(pers. comm. Dean Cluff, ENR).

[15] Klaczek, M. R. 2015. Denning ecology of barren-ground wolves in the central Canadian Arctic. MSc Thesis. University of Northern British Columbia, Prince George, British Columbia. 116 pp.

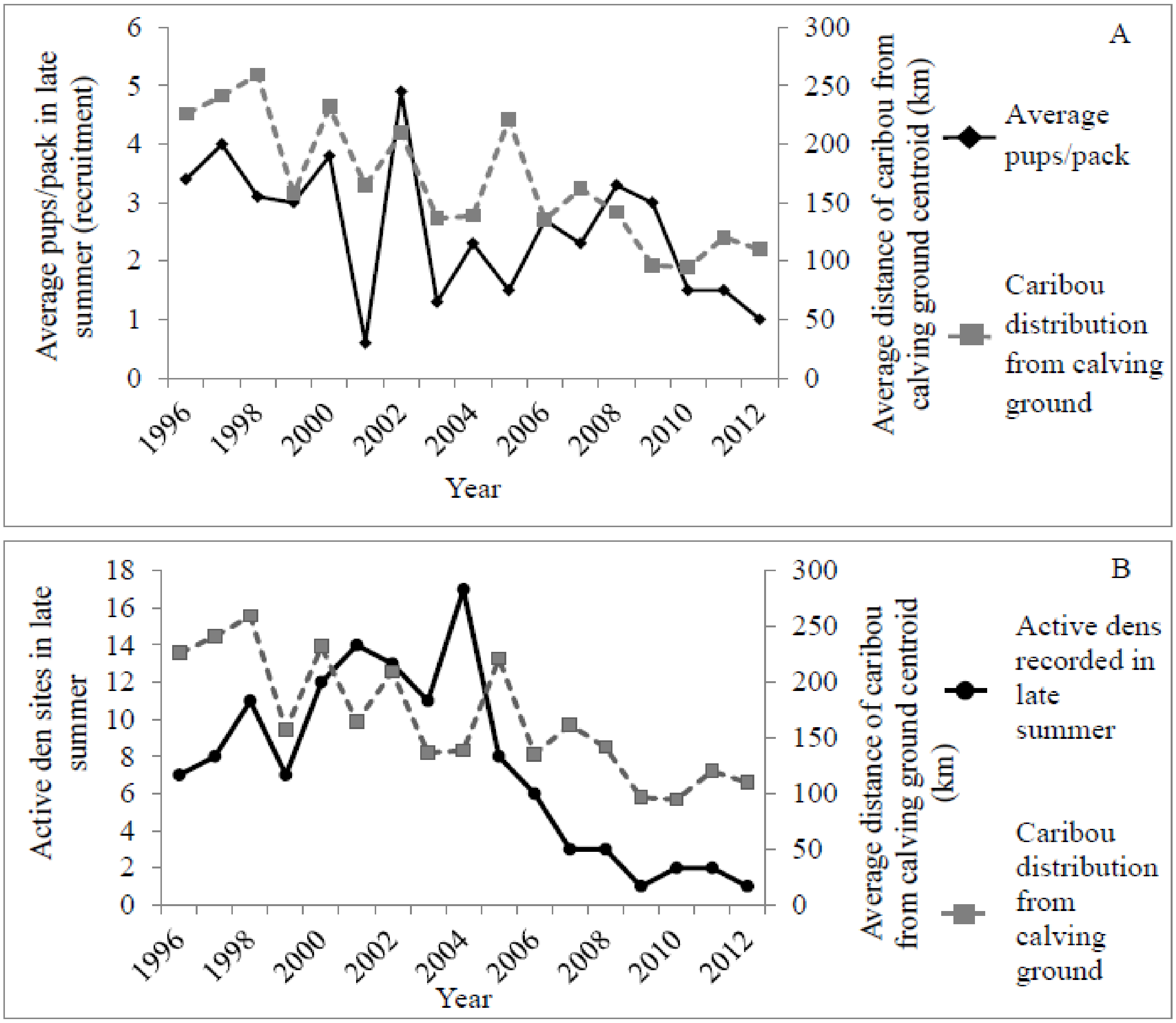


Figure E2. Temporal patterns for A) wolf pup recruitment and B) late-summer den occupancy recorded during aerial surveys in relation to the relative late-summer distribution of caribou from the calving ground (1996-2012) (From Klaczek 2015).

While estimating wolf abundance is generally recognized as difficult [16]; for the Bathurst herd, retroactive estimates based on mean home range size, an assumed pack size and extrapolated to the caribou summer range for 1996-2000, 2002-2006 and 2006-2012 gives the estimated number of wolves for the three periods of high, moderate and low caribou abundance as 497, 295 and 177 wolves (Klaczek 2015). The 177 wolves in 2013 is based on an estimated summer range of 71,000 km^2 and a wolf density of 2.5 wolves/1000 km^2. Since then, the herd's annual and summer ranges have both contracted to smaller areas.

Klaczek's (2015) extrapolation of wolf numbers in summer 2002-2006 estimate is relatively similar to a single direct estimate of 211 ± 66 (standard error) wolves based on 51 wolves recorded during aerial counts on the late winter caribou range in late winter 2006[17] (Mattson *et al.* 2009). The late winter estimate was extrapolated from aerial surveying 10 x 10 km cells within the mapped distribution of the satellite-collared cows on the winter range. Both approaches are repeatable although imprecise (the winter survey had a Coefficient of Variation 31%) and the extrapolation from home range size requires an adequate sample of radio-collared wolves to estimate size of the wolf home ranges.

An alternate and preliminary approach to estimating wolf abundance is based on prey biomass (Kusyk and Hatter 2014, D. Cluff pers. comm., 2017). Using estimated moose and caribou biomass on the winter range, the number of wolves was 548 to 707 and 650 to 819 wolves on the summer range using estimates of muskoxen and caribou. If the Cluff biomass estimate is used (5.1 wolves/1000 km^2 and 71,000 km^2), then the estimate would be 362 wolves. The Bathurst annual and summer range has contracted since 2013, however. If the two density estimates are applied to an annual range of 96,469 km^2 (2014-2017), estimated wolf numbers are 241 and 492 wolves. If the density estimates are applied to a smaller summer range of 40,351 km^2 (2014-2017), the estimates are 101 and 206 wolves. The biomass approach is based on work in BC which concluded "We suggest the ungulate biomass regression model is useful to estimate the abundance of wolves for management purposes when precise estimates are not required, and wolf populations are not heavily exploited or recovering" (Kusyk and Hatter 2014).

Wolf numerical and functional responses

The wolves have numerically responded and declined relative to the decline in caribou as suggested by a wolf population model that used field estimates of pup recruitment. Additionally, the evidence for a numerical response (a decline) on, at least, the summer range is estimated wolf numbers based on mean home range size, an assumed pack size and extrapolated to the caribou summer range (Klaczek 2015). While the reduction in pup recruitment is part of the numerical response to the decline in caribou on their summer range, the relationship is not straightforward (Klaczek 2015). As the caribou abundance declined, their summer range contracted northeast which increased the distance for wolves hunting from their den sites (Figure E3) and the wolves did not shift their den sites in response. This suggests that the functional response of the wolves to the declining caribou increased search time which reduced predation rates.

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[16] Kunkel, K., C. M. Mack, and W. E. Melquist. 2005. An assessment of current methods for surveying and monitoring wolves. Nez Perce Tribe, Lapwai, Idaho, USA. p.79.; and Frame, P.F., and H.D. Cluff. 2009. Using wolf observations from caribou surveys as an index of abundance. Manuscript submitted July 2009. Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT.

[17] Mattson, I.J.K., C.J. Johnson, and H.D. Cluff. 2009. Winter survey of Bathurst caribou and associated wolf distribution and abundance. Department of Environment and Natural Resources, Government of the Northwest Territories. Manuscript Report No. 185. 53 pp.

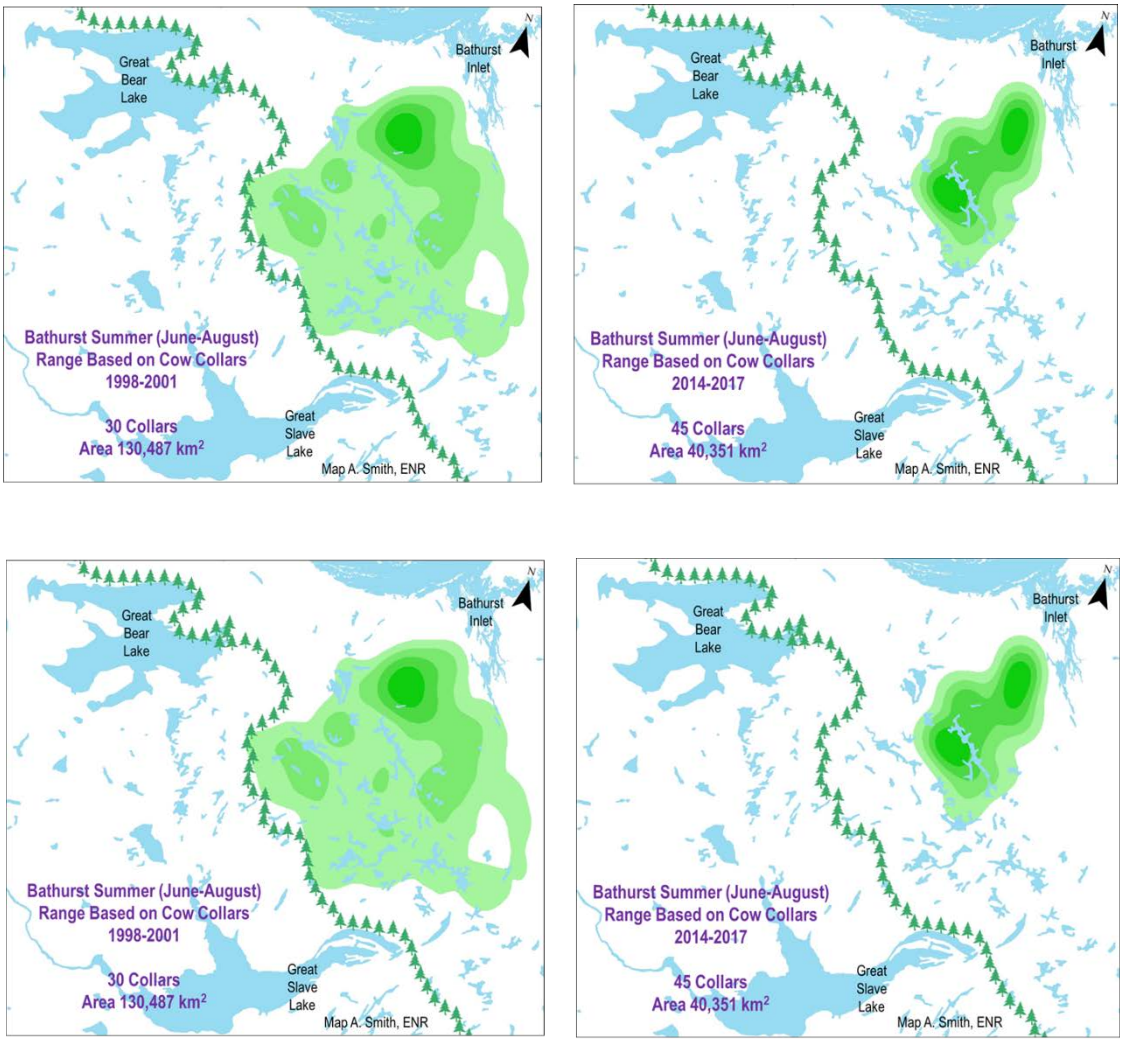

Figure E3. Annual and summer ranges of the Bathurst herd in 1998-2001 and 2014-2017 based on kernel analyses of female satellite collar locations. Maps A. Smith, GNWT ENR.

On the caribou calving grounds, where prey are aggregated, the wolves' numerical and functional response differ from the summer range as the wolves likely kill at a higher rate when caribou are accessible[18] (Clarkson and Liepins 1992). However, wolves are relatively few and are likely non-breeding wolves (Heard and Williams 1992). The sighting rate of wolves on the Bathurst calving ground (2006-2015) was 1.3 ± 0.031 (SE)/10 hours compared to 4.9 ± 1.56 grizzly bears/10 hours (D. Cluff unpubl. data, Poole *et al.* 2014). Predation may be compensatory mortality if wolf-killed calves had a pre-existing health condition which on the Beverly calving ground 1981-83, was 13% of wolf-killed calves (Miller *et al.* 1985). The functional response curve for wolves on the calving grounds is modified by the likelihood of surplus killing (incomplete utilization of the calf carcasses) which has been described for the Beverly herd's calving ground (Heard and Williams 1992, Miller *et al.* 1988).

On the winter range where the wolves travel with the caribou, they are not restricted to hunting within the vicinity of their den. Despite the decline of wolves on the summer range, during late winter caribou sex and age composition surveys, the mean sighting rate wolves/10 hours (1985-2015; D. Cluff unpubl. data) is annually variable (CV=15%) and neither pack size nor the sighting rates show trends (Figure E4). The sighting rates of wolves during caribou sex and age composition surveys on the late winter range and on the calving ground may not be directly related to wolf abundance (Frame and Cluff in press).

Net immigration of wolves from the summer range of neighbouring herds may contribute to the winter sighting rate on the Bathurst winter range but this highly uncertain. In part, it is based on Alaska where about 20-25% of the wolves in fall dispersed each year (mainly wolves < 3 years old). Some remain in the area and while some emigrate to other areas (and other dispersing wolves immigrate into the area). The level of net immigration and non-territorial wolves on the Bathurst range is uncertain. The reduced number of helper wolves at the den sites and the low and declining density might argue that on the summer range numbers of non-territorial wolves is low. In the fall as wolves typically disperse, the reduced litter size might also suggest a potentially low number of dispersing wolves. On the winter range when neighboring caribou herds overlap, the net immigration of wolves to the Bathurst range is unknown, but wolves associated with the Bluenose-East and Beverly/Ahiak herds likely travel with them and are likely mixed if the herds overlap (as in 2016-2017).

[18] Clarkson, P. and I. Liepins. 1992. Inuvialuit Wildlife Studies. Western Arctic Wolf Research Project Progress Report April 1989-January 1991. Department of Renewable Resources, Government of the Northwest Territories, Manuscript Report No. 54, 42pp.

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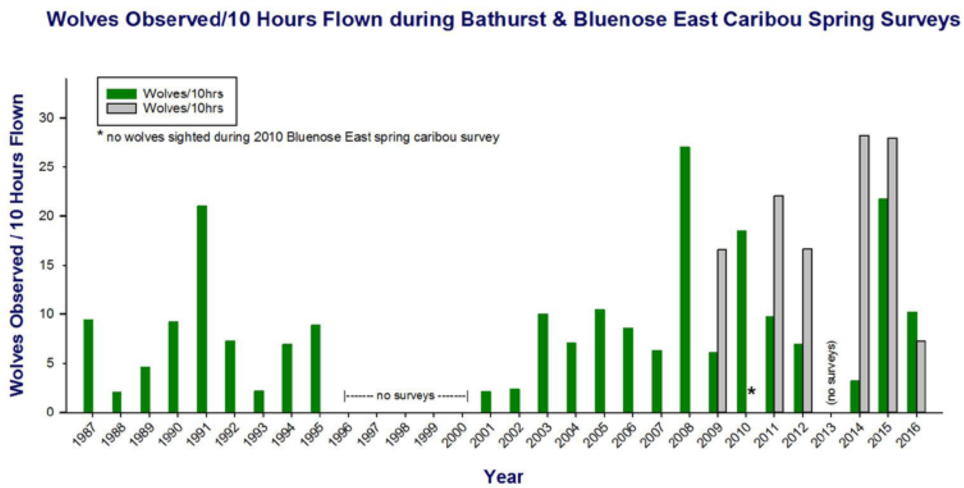

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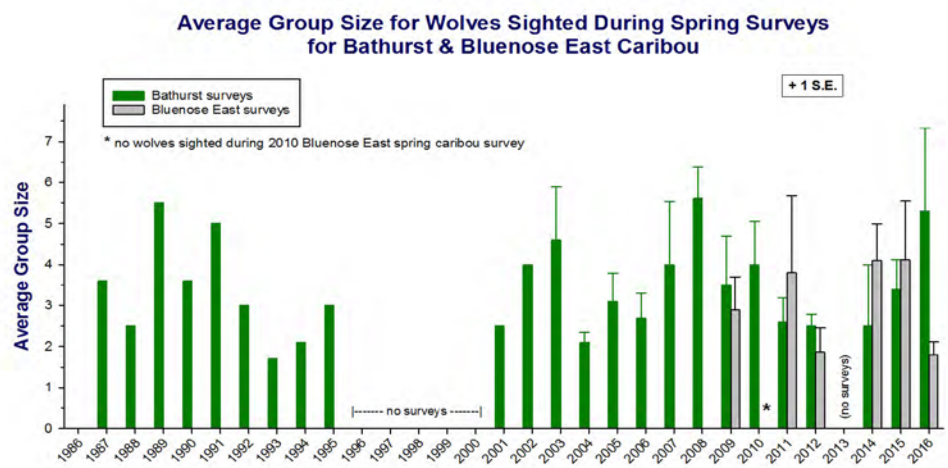


Figure E4. The sighting rate of wolves (number wolves/10 flying hours) during caribou sex and age composition surveys, late winter, Bathurst and Bluenose East herd winter range (a), and pack size (b); (pers. comm. Dean Cluff, ENR).

Appendix F: Estimating Wolf Kill Rates

Understanding how many caribou a wolf may kill in a year is needed to predict effects of wolf removal to reverse the decline of caribou. Wolves are recorded as killing at the average daily rate of 0.08 caribou per day in winter, which can be extrapolated to 30 caribou/year if wolves killed at the same rate year-round. In this explanation, we have information from four herds including the Bathurst Herd. For the Western Arctic, Porcupine and Bluenose West herds kill rates were determined by following radio collared caribou throughout the winter. For the Bathurst Herd, kill rates were based on how wolves concentrate cesium they obtain from eating caribou. Caribou concentrate cesium found in lichens and the more caribou wolves eat, the higher their cesium levels (Case *et al.* 1994).

Table F1. Summary of wolf daily and annual kill rates

Caribou/ year Mean ± SE	Caribou /day Mean ± SE	Season	Methods	Herd	Reference
15-30		Possibly winter 1980s	Radio-cesium lichen-caribou-wolf	Bathurst	Case *et al.* 1994
29.2 ± 10.95	0.08 ± 0.03	March April 1989	VHF & daily relocation; 7 packs avg 4 wolves	Porcupine	Hayes & Russell 2000
31.5 ± 2.71	0.086 ± 0.007	March 1989; March November 1990	VHF & daily relocation; 11 packs avg 8 wolves	Western Arctic	Dale et al., 1994
20.4 ± 7.39	0.056 ± 0.02	April 1989	VHF & daily relocation; 4 packs avg 5 wolves	Bluenose West	Clarkson & Liepins 1992

Table F1 shows the rates are consistent between herds although variable (which likely reflect the number of packs and their size). The daily kill rate was typically measured from radio-tracking wolves at least once a day and observing whether they have killed a caribou (Clarkson and Liepens 1994, Dale *et al.* 1994, Hayes and Russell 2000). Wolves and caribou have been mostly studied in the boreal forests and mountains, but there are studies for three migratory tundra caribou (Table F1). Although the kill rate has not been measured during the decline of the Bathurst herd, between 1989 and 2015, the sighting rate of wolves during caribou sex and age composition aerial surveys in late winter is annually variable and appears to have increased (Appendix E). Appendix E suggests that the wolves, although reduced in number (Klaczek 2015), are still able to find the caribou which may suggest that the kill rate has not decreased despite the decline in both wolf and caribou numbers.

The kill rate may be greater in summer than winter as the wolves will be feeding their pups, but evidence is mostly lacking. An exception is Clarkson and Liepins (1992) who radio-tracked one pack (four adult wolves and seven pups) 17 July – 2 August 1989. Aerial searches once a day located 7 kills in 17 days (4 confirmed as caribou and 3 unknown ungulate), which is a daily rate of 0.10 caribou/wolf/day and 37.6 caribou/wolf/year. However, it is a small sample size being a single pack in one year. Wolves in summer on the tundra and tree line also hunt other wildlife including voles, moose, ground squirrels, arctic hare and muskoxen. On the Bathurst herd's summer range, 71% of wolf scats collected in 2013 had caribou with low percentages of the other mammals (Klaczek 2015).

One factor that may increase the kill rate is when there is a high proportion of vulnerable age classes such as calves especially if wolves kill a caribou but make little or no use of it. This is termed 'surplus' killing and is known for calving grounds where newborn calves are easy to kill (Miller *et al.* 1985). However, relatively few wolves are seen on the Bathurst calving grounds as in June most wolves are at their den sites closer to the tree line. Since 2006, between 1 and 2 wolves/10 flying hours are recorded for the Bathurst calving grounds (Dean Cluff pers. comm.)

Pack size affects kill rates as wolves in smaller packs may kill at a higher rate especially if ravens scavenge the kills (Hayes and Russell 2000). On the Bathurst winter range, pack size as recorded during caribou sex and age aerial surveys has annually varied with no trend (Figure 2) as wolf numbers have declined (Klaczek 2015). Average pack size is 3.4 (SE ± 0.22), similar to pack size recorded for the Porcupine and Bluenose West herds when kill rates were measured (Table F1).

Estimating kill rates from radio-tracking collared wolves once a day even with back-tracking trails in the snow may under-estimate the kill rates. Research using GPS collars with hourly locations allow researchers to find cluster of locations which may be kill sites. Findings from a study of wolf-killed moose in Scandinavia using GPS collars suggested that estimated rates based on radio-tracking wolves and searching for kills may lead to under-estimating kill rates at least for moose.

Literature Cited

Clarkson, P. and I. Liepins. 1992. Inuvialuit Wildlife Studies. Western Arctic Wolf Research Project Progress Report April 1989-January 1991. Department of Renewable Resources, Government of the Northwest Territories, Manuscript Report No. 54, 42pp.

Dale, B., Adams L. G., & Boyer, R. T. 1994. Functional response of wolves preying on barren-ground caribou in a multiple prey ecosystem. - J. Anim. Ecol. 63: 644-652.

Hayes, R. D. and D. E. Russell. 2000. Predation rate by wolves on the Porcupine caribou herd. Rangifer Special Issue No. 12, 51-58.

Miller F. L., A. Gunn and E. Broughton. 1985. Surplus killing as exemplified by wolf predation on newborn caribou calves. Can. J. Zool. 63: 295-300.

Sand, H., Zimmermann, B., Wabakken, P., Andren, H. & Pedersen, H.C. (2005) Using GPS technology and GIS cluster analyses to estimate kill rates in wolf-ungulate ecosystems. Wildlife Society Bulletin, 33, 914–925.

Appendix G: Wolf – Tlicho Knowledge and Perspective, Legat & Chocolate 2016

Appendix H: Conceptual model for wolf management

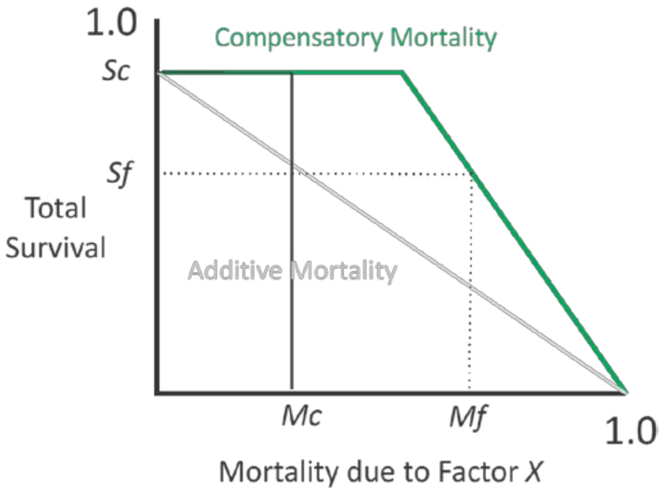
The feasibility assessment's numerical objectives provide an initial estimate for the number of wolves to be annually removed. The underlying logic for the annual wolf target is based on a predicted (expected) and measurable increase in annual survival of adult female caribou. The predicted increase in caribou survival that would occur from wolf control is based on our understanding of kill rates by wolves on caribou, which reflects our current ecological understanding of the barren-ground caribou-wolf ecological system.

A first step to predict an effect on caribou survival is to assess the number of individual wolves to be removed through control actions. A key source of uncertainty and variability that influences predicted effect size of wolf control is whether removal of individual wolves will be additive to natural mortality rates in the population, and/or whether removals are compensated through increased immigration or higher reproductive rates. Thus, the degree to which control actions result in additive or compensatory mortality affects the wolf population's numerical response, which is a key driver of wolf predation rates on caribou and in turn affects survival rates of caribou. The numerical response of the wolf population to wolf removal is the link to a caribou numerical response, which is mediated primarily through an increase in caribou survival rates, plus secondarily an increase in calf productivity because a) there are more breeding females to birth calves, and b) the calves would likely have higher survival (recruitment) rates.

Simply put, since the objective of wolf control is to reduce wolf population size to reduce the number of caribou killed, then the magnitude of reduction in the wolf population is a key factor in determining the true effect on caribou survival. Whether mortality is compensatory or additive influences effect size (of the treatment) and the power of monitoring to detect effect size. An approximation for wolf removal target is ~ 124 wolves, which is based on 60-80 % of Klaczek's (2015) estimate of 140-162 wolves on the Bathurst summer range. Additional information on compensatory and additive mortality in wolves and caribou is provided below.

(a) Wolves
Experience in Alaska (Adams *et al.* 2008) is that typically 60-80% of the wolves have to be removed annually to reduce or control them as wolves can sustain annual removals of 30-40%. This rate of removal assumes compensatory mortality.

<u>Compensatory and additive mortality</u>
Alaskan wolves may numerically recover from reductions in their numbers as they have high potential reproductive rates and because they are often territorial with a proportion of non-territorial 'floater' wolves that can replace territorial wolves that are killed. This means that up to a certain level, wolves can compensate for human-caused mortality of wolves from harvesting or management.



The figure to the left illustrates the concept of compensatory mortality and wolf control actions, where *Sc* is the current level of survival in adult wolves that corresponds to natural mortality and current levels of hunting of wolves by people (*Mc)*.

In order to reduce current survival rate (Sc) of wolves to a lower survival level in the future (Sf), wolf control measures must increase the current mortality rate (Mc) to a higher level in the future (Mf).

The Wolf Control Rate, expressed as the Number of Wolves Killed Through Control Measures annually / Wolf Population Size requires that wolf control measures increase wolf mortality above a threshold value (i.e., the inflection point in the green line) to reduce the survival rate. If the wolf removal is not compensated for by immigration or reproduction, it is a source of additive mortality.

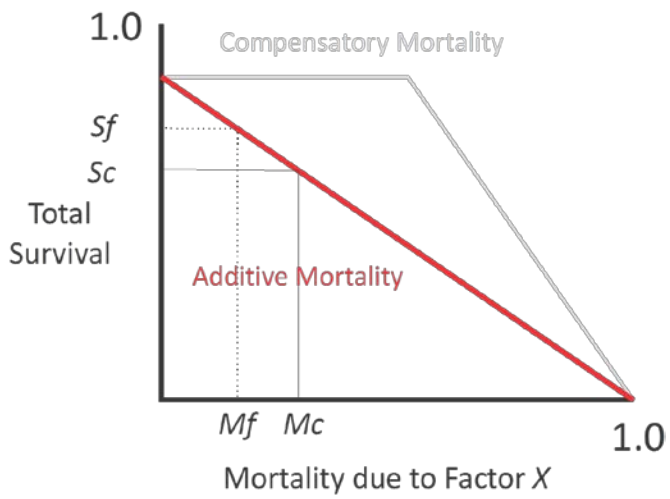
<u>Conceptual model for wolves on Bathurst caribou summer and winter ranges</u>

The conceptual model for the wolves separates the summer and winter caribou ranges based on wolf territoriality. On the summer range, wolves are territorial with family packs raising pups (Heard and Williams 1992, Klaczek 2015). The caribou summer range has contracted northeast increasing the distance for wolves hunting from their den sites (Klaczek 2015, Bergerud *et al.* 2008). At current low caribou densities, wolf pup recruitment has declined and is related to caribou distribution being further from den sites. Thus, summer wolf removal may not lead to any compensatory increase in wolf pup survival or recruitment, and control actions of wolves in summer will likely result in additive mortality.

The Bathurst caribou winter range has also shifted and contracted during the decline in herd size. Overlap between the Bathurst winter range and winter ranges used by neighbouring herds has varied widely (for example; low in 2015-2016 and high in 2016-2017). In the absence of detailed analyses of range overlap between the Bathurst and neighbouring herds which are also declining, it is uncertain about whether and the extent of compensatory increase in wolf immigration on the Bathurst winter. The degree of overlap of collared cows December 2013 to 2016) was 37%. The wolf sighting rate for Bluenose East and Bathurst winter range is annually variable suggesting that the wolf numerical response to caribou has not declined. At the scale of wolves returning to breed on the Bathurst summer range, wolf removal on the winter range may be partially compensatory depending on the net result of ingress and egress of wolves from neighbouring herds. At the scale of the three herds (Bluenose East, Bathurst and Beverly-Ahiak), wolf removal on the overlapping winter range is likely additive.

(b) Caribou
A caribou-centric conceptual model proposes that caribou mortality due to wolf predation is additive, and predicts that a decrease in wolf predation should directly reduce caribou mortality.

Compensatory and additive mortality
A key assumption is that mortality of caribou due to wolf predation is largely additive. The assumptions and implications of the caribou-centric perspective are summarized below.



Assumption
The figure to the left illustrates the concept of additive mortality, where Sc = Current level of survival in adult female caribou (~73-78%) that corresponds primarily to predation rate by wolves on caribou.

Management Objective
In order to increase current survival rate (Sc) of adult cows to a higher survival level in the future (Sf) (e.g., 83-88%), then mortality rate in the future (Mf) due to predation (Predation Rate) needs to be reduced relative to its current level (Mc)

The difference between Mc and Mf is the net reduction in Predation Rate that is required to achieve the management objective of an increase in adult female survival (e.g. 10%).

Management Implication
Based on the assumption of additive mortality in caribou, a management objective for wolf control may be expressed as a Predation Rate on caribou, where:
Predation Rate = Number of Caribou Killed by Wolves Annually / Caribou Population Size
And where: Number of Caribou Killed by Wolves Annually = Average Annual Kill Rate of Caribou per Wolf x Number of Wolves.

Predation Rate is a way of expressing ‘pressure’ of predation on the caribou population (*sensu* Vucetich et al. 2011), which is expressed in a comparable manner to Harvest Rate (i.e., Number of Caribou Killed by People Annually / Caribou Population Size). For example, a rule-of-thumb approach to harvest rate for caribou generally recommends 3-5% of caribou population size as being sustainable depending on herd size and trend (e.g., GNWT 2013).

Thus, an approach to define a rationale for wolf control would be to define an objective that reflects an improvement in vital rates for caribou. This would be based on an estimate of adult female caribou that need to survive annually to meaningfully and measurably increase current rates of survival.

As an example, a first order approximation would be to use current information on the estimate of adult Bathurst females (breeding cows) and adult female survival rates as follows:

- If there are 8075 breeding females and survival is 0.78, then the number of females dying annually on average = 8075 x (1.0-0.78) = 1777 caribou.

- If there are 8075 breeding females and the objective is to increase survival by 10% to be 0.88, then the number of females dying annually on average = 8075 x (1.0 – 0.88) = 969
- Then in order to improve survival and if mortality is additive, then 808 more adult female caribou (1777-969) need to survive annually.
- If the average kill rate for wolves = 29.2 caribou / wolf / year (Appendix D; Hayes and Russell 2010 and see Dale et al. 1994[19]), and we assume wolves only eat adult cows, then the number of wolves needed to be removed to allow 808 cows to be added to the population = 808 caribou / 29.2 caribou per wolf per year = then ~28 wolves need to be removed annually.
- However, we know that wolves do not just eat breeding cows, so the estimate needs to be adjusted by the age/sex composition of caribou that are killed (average composition should be estimated and simulated as a range of values). In particular, consideration for increasing calf survival adds complexity to estimating effects. Increasing calf survival will have a lag effect as the females do not contribute to productivity until they are typically 3 years old. However, increased calf survival will build strong cohorts that increase resilience to environmental variation.
- The average kill rate should be simulated as a range of values (i.e., min and max, or ± 1 standard deviation based on a normal distribution).
- Another key source of uncertainty is the degree to which mortality of caribou due to predation by wolves is additive or compensatory. In this simple example, mortality due to wolf predation is assumed to be completely additive, but that is certainly not to be the case. Other sources of mortality could be attributed to predation by grizzly bears, accidents, starvation, disease, etc. and these causes of mortality may be more important for calves. The true sources and rates of mortality would influence the relationship between caribou survival and total mortality, although we assume that wolf predation is the primary cause of death in caribou. This simple example highlights the importance of describing our assumptions regarding the influence of wolf predation on caribou survival.

<u>Summary</u>

- This conceptual model for caribou is focused on developing a numerical target for wolf control that would consequently reduce predation rate of caribou by wolves, which is predicted to result in an increase in survival of caribou and therefore a positive population growth rate.
- This perspective considers mortality of caribou due to wolf predation to be largely an additive mortality factor.
- The number of wolves removed from the caribou-wolf system is a key indicator.
- This approach does not necessarily require an estimate of wolf density or abundance, as a performance indicator, and instead is focused on vital rates of the caribou population (i.e., survival) as a response variable that would be related to the number of wolves removed annually from the system.
- This approach could be further developed with assumptions that define how environmental variability may affect either productivity (pregnancy and early calf survival), and or adult caribou survival.
- Need to review approach and assumptions, and check/confirm whether this is a biologically plausible means of defining and estimating a numerical target for wolf removal (would withstand peer review).

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[19] Extrapolated average annual kill rate of caribou by wolves was estimated to be 33.6 with a range of 21.9 – 40.2 (from Dale et al. 1994, Table 1)

- A more detailed methodology should be developed to estimate numerical targets, which incorporates uncertainty and variability in parameters.

References

Adams, L. G., R. O. Stephenson, B. W. Dale, R. T. Ahgook, and D. J. Demma. 2008. Population dynamics and harvest characteristics of wolves in the Central Brooks Range, Alaska. Wildlife Monographs **170**:1-25.

Bergerud, A.T., S.N. Luttich, and L. Camps. 2008. The return of caribou to Ungava. McGill Queen’s University Press, Canada.

GNWT. 2013. Harvest recommendations for barren-ground caribou based on herd risk status: A rule of thumb approach. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 6 pp. Online [URL]: http://www.wrrb.ca/sites/default/files/ENR_thumb_2013.pdf

Hayes, R. D., and D. E. Russell. 2000. Predation rate by wolves on the Porcupine caribou herd. Rangifer Special Issue No. 12:51-58.

Heard, D. C., and T. M. Williams. 1992. Distribution of wolf dens on migratory caribou ranges in the Northwest Territories, Canada. Canadian Journal of Zoology **70**:1504-1510.

Klaczek, M. R. 2015. Denning ecology of barren-ground wolves in the central Canadian Arctic. MSc Thesis. University of Northern British Columbia, Prince George, British Columbia. 116 pp.

Vucetich, J. A., M. Hebblewhite, D. W. Smith, and R. O. Peterson. 2011. Predicting prey population dynamics from kill rate, predation rate and predator–prey ratios in three wolf-ungulate systems. Journal of Animal Ecology 80:1236-1245.

Appendix I: Modeling the response of caribou to wolf removal by Don Russell (11 August 2017)

Basic model structure

The Caribou Cumulative Effects (CCE) model was used to explore wolf removal options with respect to the recovery of the Bathurst Caribou herd. DG-Sim is a software framework suitable for developing demographic simulation models of caribou populations. The software allows users to simulate population numbers, age structure and sex ratios forward in time under alternative "what-if" scenarios; the framework is general enough that it can easily be configured for any caribou population. Model inputs are initial population size, age structure, sex ratio, recruitment rates, mortality rates, harvest rates and, for retrospective analyses, past population census data. DG-Sim uses a Monte Carlo simulation approach whereby input parameters are optionally sampled stochastically from user-defined probability distributions. Model results include confidence estimates for population projections based on the uncertainty in input parameters and the degree of agreement of future projections with past census data.

Utilization to explore wolf removal options

Using average adult cow survival estimates (for the Bathurst herd over the last 5 years (~65%), I constructed an estimated mortality profile for all age/sex cohorts (Figure I1). I also created a likely age/sex initial structure for the Bathurst herd for a 2012 starting population of 32000 (age 1+) individuals (Figure I2).

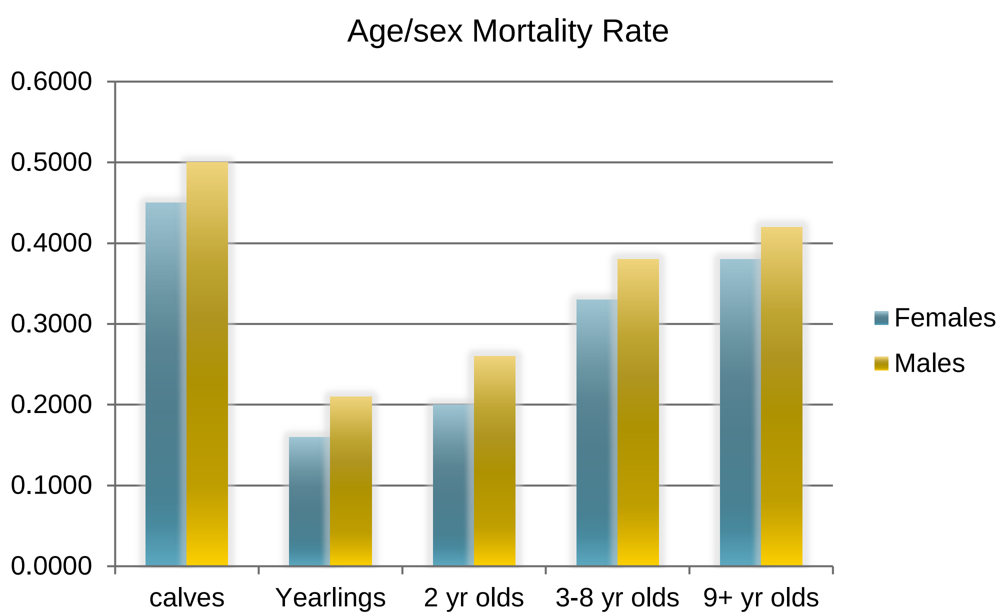

Figure I1. Mortality rate assumptions for age and sex classes in the Bathurst caribou herd.

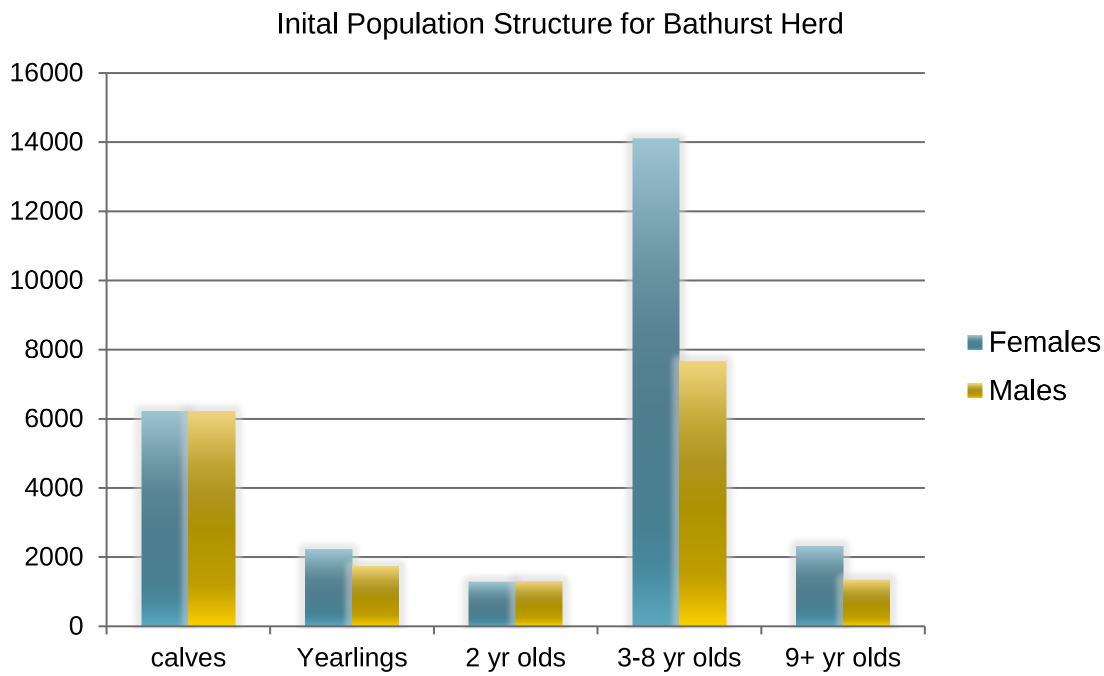

Figure I2. Initial age/sex structure used in model. Note calves represent newborn calves just after parturition.

To model wolf removal, I first estimated the ratio of total caribou mortality attributable to wolves to total non-wolf mortality. Starting in 2016, I split the mortality into non-wolf and wolf based on an estimate of 140 wolves taking 29 caribou per wolf. Non-wolf mortality would include disease, age/condition, accidents, non-wolf predation (eagles, bears, etc.) and human harvest. In the model, I treated the non-wolf mortality as a rate and the wolf mortality as an absolute number. For the run, I present here I assumed a 60% wolf to 40% non-wolf split. This was based on the total mortality between 2015 to 2016 with an average of 140 wolves taking 29 caribou per wolf per year.

For simulated trend from 2012 to 2022 and assuming that wolf removal started in 2017, there were five scenarios: No action, and removing 40, 60, 80, and 100 wolves. In practice removing, for example 80 wolves requires reducing the present wolf population by 80 wolves in 2017 and maintaining those wolf numbers throughout 2018 to 2022. This does not mean killing 40, 60, 80 or 100 wolves a year, just ensuring that wolf population don't rebound for the five-year period. Figure I3 shows the results of the scenario runs.

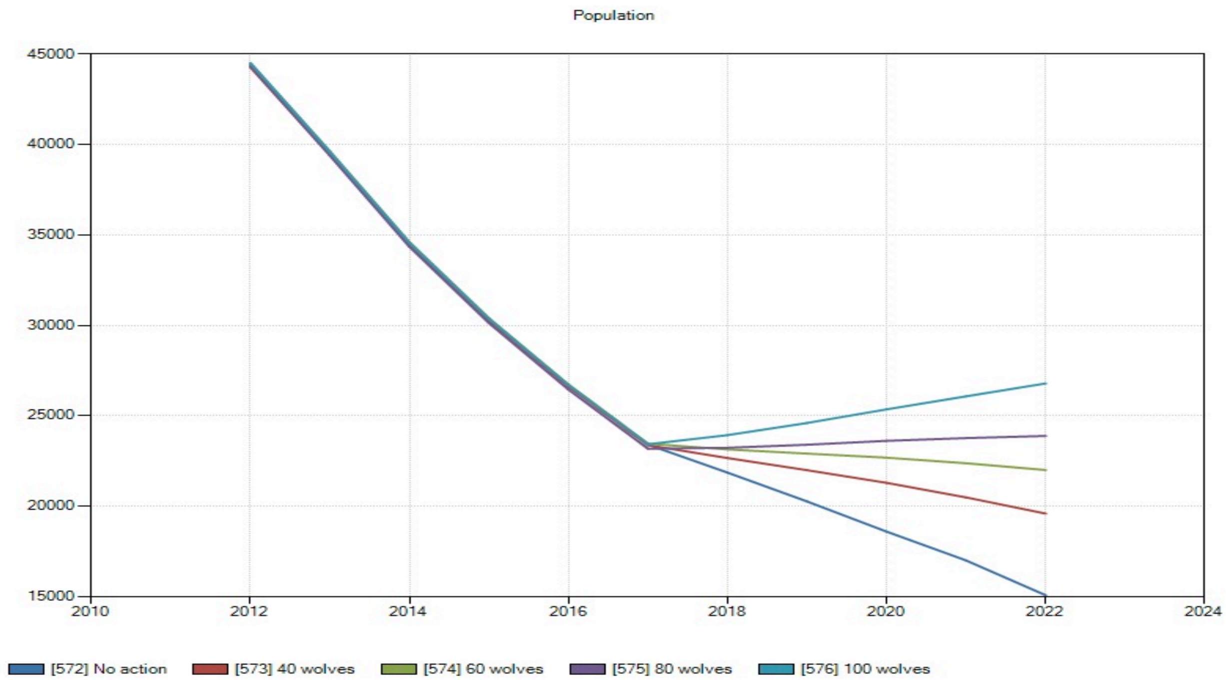

Figure I3. Simulated projections of implementing 5 wolf removal polices from 2017 – 2022 for the Bathurst caribou Herd.

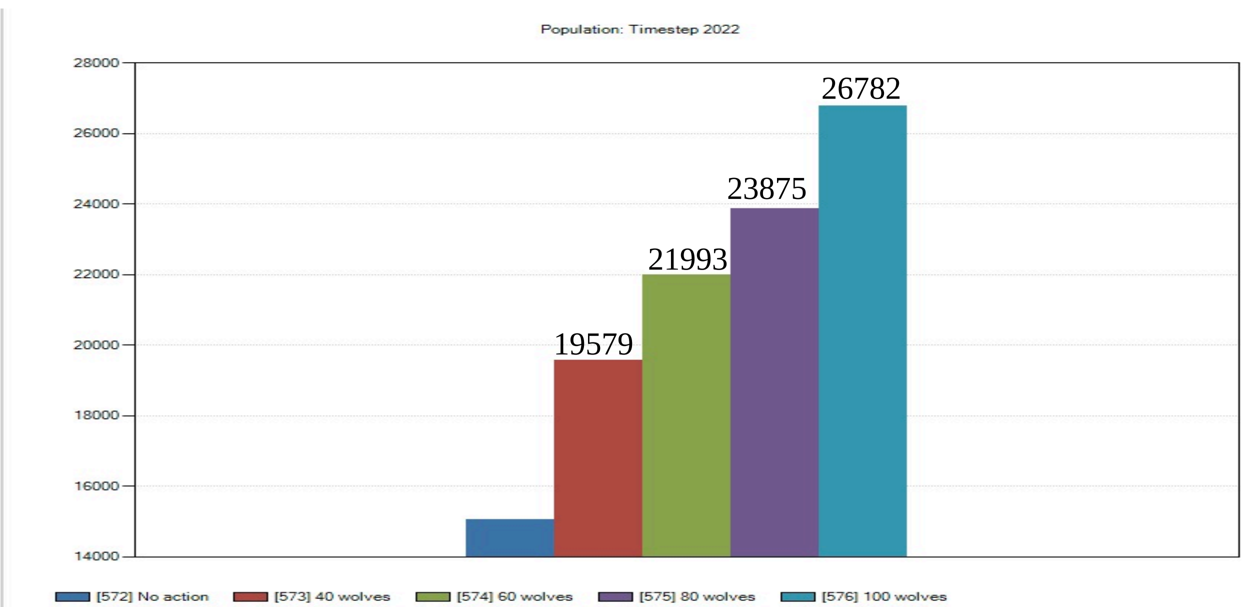

Figure I4. The simulated population size of Bathurst caribou in 2022 for 5 wolf management scenarios, which were simulated from 2017-2022 and an initial population size of 23,000 caribou.

The model projects that the removal of a wolf translates into an average of 118 more caribou after a 5-year removal program. Under the assumptions in the model, it would take the removal of just over 60 wolves to stabilize the herd to 2016 levels and 80 or 100 wolves for the herd to increase.

I assumed a population of 140 wolves with a kill rate of 29 wolves per wolf which is consistent with current knowledge. The scenarios used the total mortality between 2015 and 2016 and assumed a wolf number and kill rate to derive a 60% wolf to 40% non-wolf ratio. The model also assumes wolves take prey in proportion to the age/sex in the caribou population.
Caveat: Because the model was designed to explicitly implement harvest policies, I discovered that in the current version of the model I can't "harvest" calves. Thus, given I treated wolf kill as a harvest, I could not reduce calves, so I assumed the same high rate of annual mortality for calves throughout the model run (i.e. I did not split calf mortality into wolf versus non-wolf but maintained the normal mortality throughout the run.

<u>Effect of compensatory mortality</u>
In the second series of model runs, questions were raised about how results were affected by varying the recovery rate of wolves through net immigration from adjacent regions (removal is compensatory). To simulate wolf removal, I used Bathurst-specific age/sex mortality data (Figure 1) and divided values into non-wolf versus wolf mortality, depending on the percent of total mortality due to wolf predation. I ran the model with no wolf control from 2012-2016. Based on the size of each a cohort I then ran a number of wolf management scenarios from 2017-2022. I treated wolf mortality as "harvest" and the effect of wolf removal was essentially a reduction in harvest.

The model was used to explore the success of wolf removal with respect to five factors:

1. Current trend of caribou population – the Bathurst Herd is currently declining at an exponential rate of -13.9% per year. Governments may however start a removal program when the population stabilizes at a low number and thus the current trend of the population should affect the ability to aid in the recovery of the herd.
2. Recovery rate of wolves – Wolf removal would be less effective if wolves were quickly able to repopulate areas that were the subject of wolf control. The total annual kill rate of caribou by wolves was multiplied by the recovery rate of wolves that was expressed as a proportion. Thus, for a wolf recovery rate of 1 month, the total annual kill rate became 0.083 (1/12) of its assumed value; for a wolf recovery rate of 6 months, the total annual kill rate became 0.5 (6/12) of its assumed value; and for a wolf recovery rate of 12 months, the total annual kill rate was its assumed value (12/12).
3. Percent of total caribou mortality due to wolves – The higher the current role of wolves, the more effective would be a wolf removal program
4. Percent of wolves removed – Increasing the percent of wolves removed, increases the effectiveness of a control program.
5. Kill rate of wolves – the model assumes a kill rate of 29 caribou per wolf but once data becomes available overall kill rate may be lower, especially in the winter when wolf territories overall the distribution of the Bathurst and Bluenose East caribou populations.

<u>Model Runs</u>
<u>I</u> ran the model with three levels of each of the first four factors listed above. All combination resulted in 81 separate runs of the model plus three runs to represent "no action" with respect to wolf control.

1. Current trend of the population: Exponential rate of change of -13.9%, -0,53% and +0.25%. Trends were determined by simply lowering the total mortality from baseline levels; thus 13.9% = 100% current mortality levels; -0.053 is 80% of current levels and +0.025 is 60% of current levels.

2. Recovery rate of wolves: I modeled the implications of wolf recovery of 1 month, 6 months and 12 months. I assumed that if wolves returned in 1 month that the total kill rate was reduced by 1/12; 6 months by 6/12 and 12 months = 12/12
3. Percent of mortality due to wolves: I modeled contribution of wolves at 40%, 60% and 80%.
4. Percent of wolves removal: I modeled a 40%, 60% and 80% removal rate

<u>Model Results</u>

Figure I5 presents the results of running the three levels of population trends but with "no action" with respect to wolves from 2017-2022.

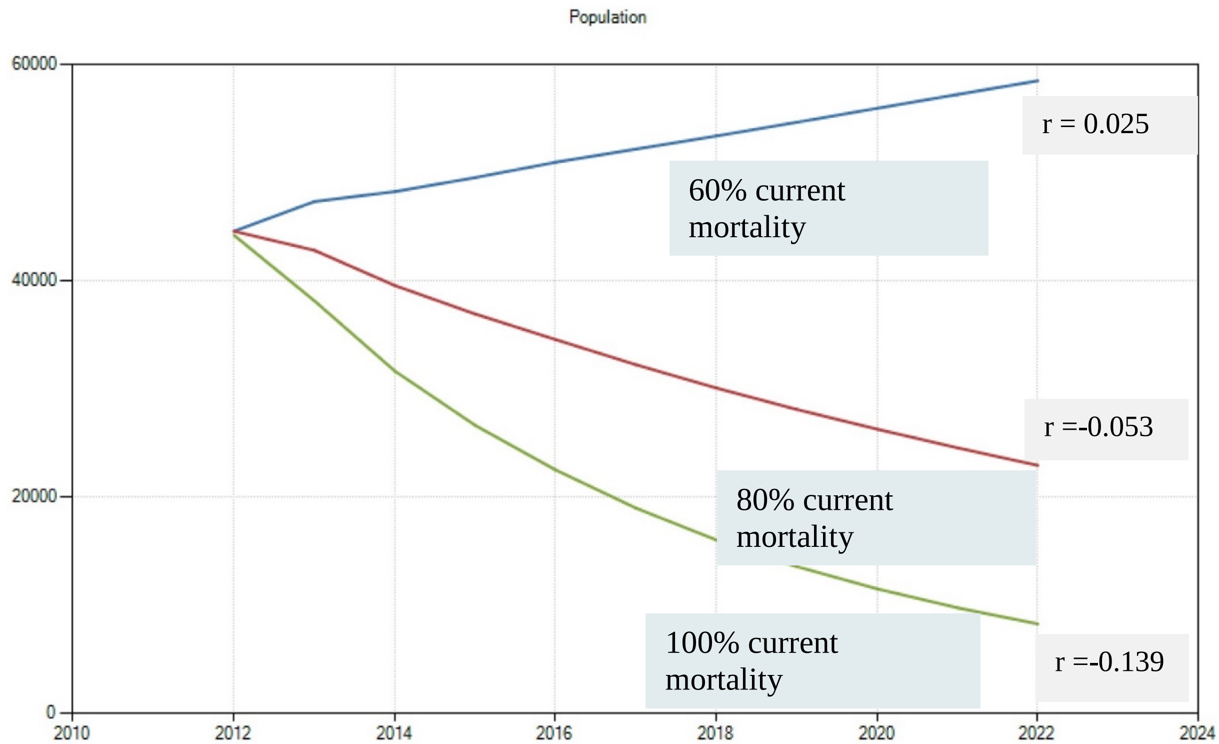

Figure I5. Results of "no action" runs for three level of herd population trends

All combinations for the four factors varied resulted in 81 model runs (Figure I6).

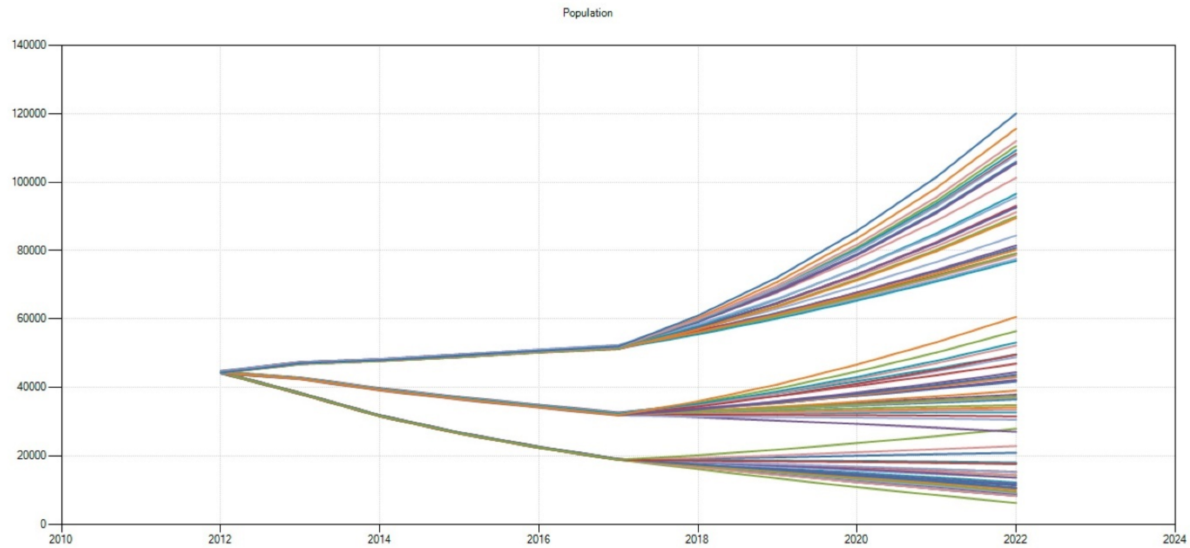

Figure I6. All combinations of four factors effecting the success of a wolf removal program

Model projections are valuable to explore ‘what if scenarios’. To view the results better I collapsed the results into a multiple regression (Figure 7) and created an animated tool in Excel. (Figure I8, available as a separate file).

Multiple Regression Model: r = (-0.09281) + (1.248) * trend + (0.001915) * % wolf mort + (0.000642) * removed + (0.005705) * Recovery

Figure I7. Multiple regression equation

Figure I8. Interactive tool predicting exponential rate of change by 5 variables relevant to the success of a wolf control program.

<u>Recovery Rate of Wolves</u>

One of the factors I was asked to model was the recovery rate of wolves after removal. The concern is that if wolves can quickly repopulate a control area, the success of the control program may be diminished. From the model runs, recovery rate (1-12 months) can be an important factor. But how likely are wolves going to quickly repopulate the control area? The best monitoring program of wolves after removal was done for the Finlayson herd in central Yukon. The protocol for removal was that wolves should be annually cropped to 80% of pre-control levels. For the Finlayson herd range wolves had a pre-control density of 10.3 wolves per $1000/km^2$.

- start 237 wolves ($10.3/km^2$)
- annually reduced to ~ 1.5 wolves $/km^2$
- annually recovered to 3.7 wolves $/km^2$
- thus, removal year 1 was 195 wolves
- average removal year 2-6 ~ 50 wolves
- Took 3 years for the number of packs to reach pre-control levels; took 5 years number of wolves to reach pre-control levels. (Figure I9)

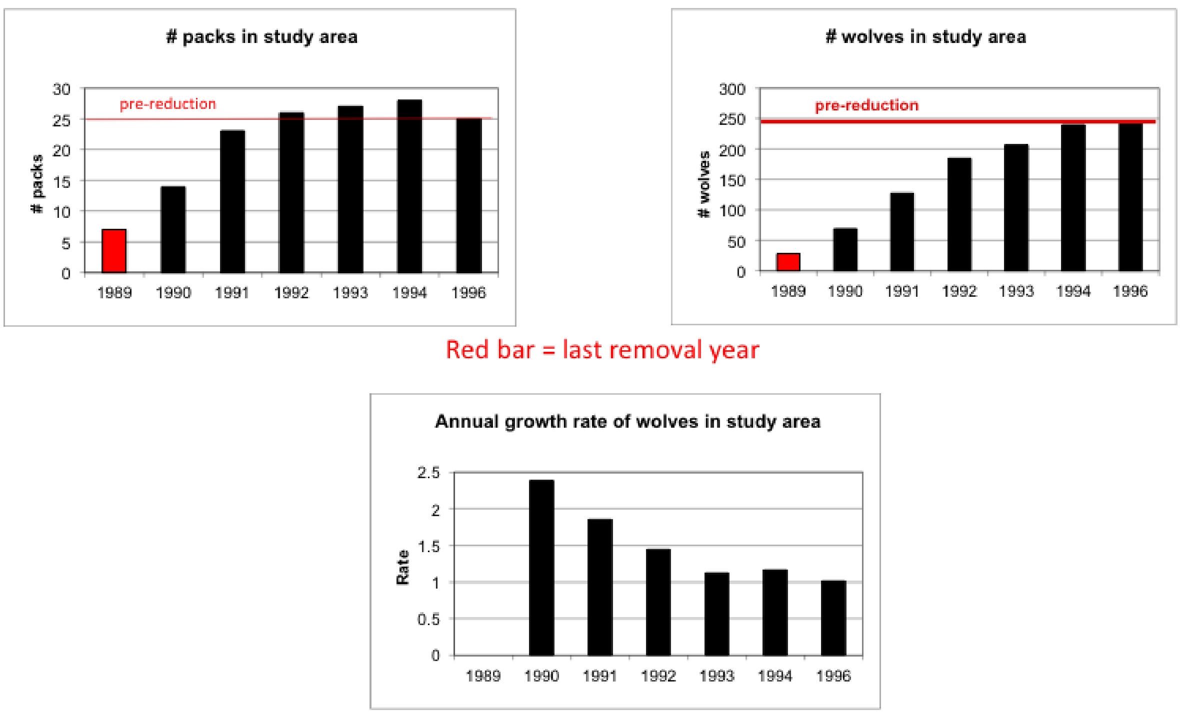

Figure I9. Recovery of packs, wolves and wolf growth rate after completion of 6-year wolf control program on the. Finlayson caribou herd, Yukon.

I could hypothesize that the wolf recovery rate in the Finlayson example is optimistic given the high density of wolves, plenty of alternative prey, and equally high densities in adjacent ranges.

Limitations

Calves: currently the population model does not have the option of harvesting calves which is a limitation to applying for assessing wolf control. For the runs, I assumed that calf remained at the level used to model population response from 2012-2017. Wolf kills were then applied to non-calf cohorts from 2017-2022 in proportion their abundance in the population. This limitation over-estimates the impact of wolf control.

Did not vary kill rate: I assumed that a wolf kills 29 caribou per year. However, it is possible that wolves would not kill only Bathurst caribou, especially on winter range when the Bathurst herd can overlap with Bluenose East and Ahiak/Beverly herds. This limitation over-estimates the impact of wolf control.

Could run more scenarios beyond the current boundaries: For the interactive tool, I constrained the ability to view results within the levels that I modeled. For example, for the percent of wolves removed I modeled 40, 60 and 80% removal. To ensure the interactive tool did not stray from known results the user can only view effects of wolf control between 40-80% wolf removal.

Assumes no harvest in all scenarios: All runs assume there is no harvest on the herd. It is possible that Bathurst caribou are harvested either against policy or inadvertently while hunting in areas here more than one herd overlap. This limitation over-estimates the impact of wolf control.

Application of the Tool

While creating the interactive tool, it soon became obvious that predicting the outcome of a wolf control program may not be straightforward. I varied 5 variables that impact the success of a control program. Clearly my approach cannot incorporate behavioral response of wolf population to different applications of a control program. For example, there is some evidence that taking whole packs is more effective than partial packs which may result in more, smaller fragmented packs. Kaczensky et al (2004) found that raven-wolf competition is highest for small packs, where ravens manage to remove up to 75% of the edible biomass and very low for large packs where ravens hardly manage to remove any edible biomass. The model projections could be improved by further defining the expected range of all 5 variables and replacing the recovery rate variable with wolf kill rate (currently fixed at 29) – this would allow to explore implication of overlap with other herds on winter range and better model the effects of seasonal removal.

Appendix J: March 2017 NWT Wolf Feasibility Assessment Workshop – Key Messages

On 1-3 March 2017, WG members met with several invited technical experts to review progress to date on the assessment approaches taken, review options under consideration, and to gain a better appreciation for potential challenges that may be encountered when considering and/or implementing wolf reduction efforts. Highlights of the discussions are listed here.

WOLF FEASIBILITY ASSESSMENT MANDATE AND APPROACH

Mandate: To identify and assess the technical feasibility, costs and potential effectiveness of a range of different wolf management techniques that may be implemented on the range of the Bathurst caribou herd to increase calf and adult caribou survival rates sufficiently to stabilize the herd and initiate recovery to higher numbers. Approach – identify options, develop criteria and assess options.

STATUS AND MANAGEMENT OF THE BATHURST CARIBOU HERD

Review of herd decline since 1986, harvest reductions, key management events with joint TG-ENR proposals. Increased incentive for wolf pelts has not led to substantial increase in harvest. WRRB recommended a Feasibility Assessment be conducted; current WG began in summer 2016.

WOLVES IN THE BATHURST CARIBOU RANGE

Survey approaches: Wolf den sites, occupancy modeling, collaring, and geospatial surveys. Estimating wolf numbers is difficult since they occur at low densities and easily missed on surveys.

Abundance ratios (caribou: wolf) are more complex in the winter than summer due to overlap in herds/wolves. Level of abundance of wolves (or density) has a high level of uncertainty. Difficult to identify the wolves for one herd; there is high degree of uncertainty when herds overlap, confounding management actions. Effectiveness of wolf reduction on caribou survival is higher when overlap is lower.

HUMANENESS CONSIDERATIONS FOR WOLF REDUCTION

Animal Welfare: concerned with the effects on the target individual; versus Wildlife Welfare: concerned with the effects on the target and non-target animals, including larger effects over larger time scales

EXPERIENCE FROM BRITISH COLUMBIA AND ELSEWHERE

Specifically, timed removal of wolves on barren ground caribou ranges could be almost completely additive. This is uncertainty over the effect of transient or immigrant wolves, and whether removed wolves are replaced. There is uncertainty as to the effectiveness of management options (additive versus compensatory) which needs to be clearly laid out to decision makers.

EXPERIENCE FROM ALASKA

Only high (>40 % of the wolf population) level of wolf removal will reduce the wolf population. Wolf populations have high proportion of transients and floaters that may join packs; human caused removals are often compensatory; this is a source of uncertainty for several options. Wolves are highly productive, there is high dispersal of young wolves, and harvest influences dispersal.

MODELING

Reviewed effect of potential wolf removal levels on the Bathurst herd. Population model used to explore different scenarios: high wolf removals could allow herd to attain positive growth. Discussed limitations of the model and how it could be updated. Model could be updated to consider further iterations and used to evaluate assessment options.

DEVELOPING AN ASSESSMENT FRAMEWORK/ MODEL OF POPULATION DYNAMICS AND RESPONSE BEHAVIOUR

Reviewed experience and characteristics of other wolf removal programs. Successful programs involved removal of at least 45-50% of wolf population, maintained for 4-5 years, target a large area, need good weather /conditions for ungulate survival. Ecosystem involves primary wolf/caribou relationship. Bathurst density estimates range from 2.4 wolves (Klaczek) to 5.1 wolves/1000 km^2 (biomass equations used by Cluff) - suggesting a range of 100-500 wolves.

Need to develop an assessment framework/model to explain and predict population dynamics, response behaviour, effects on both wolves and caribou, and clear objectives for caribou.

DEVELOPMENT OF A DESCRIPTIVE ASSESSMENT MODEL FOR THE FEASIBILITY ASSESSMENT

<u>Objectives:</u> Core goal - i.e. 5-10% annual increase in Bathurst herd; or assess options for intensive wolf management to increase survival of calf and adult caribou by 10-20% over 5 years to promote stabilization with defined growth rates.

<u>Stopping Rule:</u> There are 2 competing theories: a) a stopping rule is an essential part of the process, or; b) maximum effectiveness requires a large of take of wolves with no stopping rule.

<u>Model:</u> require a model to describe input (wolf reduction) and output (stabilize, then increase caribou herd). Follow up modelling could explore relationships, and how replacement by transient or immigrant wolves might affect the results. Set caribou recovery objective: i.e. 5-10% annual growth.

<u>Define Core system dynamics</u>: Levels of pregnancy/productivity/survival; assume stable mortality; translate herd growth into cow and calf survival. Compare to wolf relationship, assumed kill rate. Consider functional response: wolves at dens vs. on winter range. Timing of removal influences additive/compensatory nature of wolf response. Winter overlap of herd ranges (Bathurst, BNE and Bev/Ahiak) in some years - can pose a difficult challenge. Modelling would be imprecise without specific information on current/historical wolf abundance. Two views: uncertainty could be accounted for, vs. lacking data required to model wolf numbers or the wolf-caribou relationship.

<u>Uncertainty</u>: Higher wolf removal rates - less uncertainty over altering caribou survival rates. Impact of removing entire pack versus majority of pack. Uncertainty over weather, insect harassment, and forage availability - impacts on caribou; done in conjunction with modeling wolf-caribou relationship.

<u>Level of wolf removal</u> – One view is to take as many wolves as possible, since current estimates of wolf abundance are imprecise. Examples 0f high wolf removal produced a

pronounced effect on the caribou population; low levels of removal had limited or no effects. Strong monitoring is required to demonstrate effects.

REVIEW OF CORE ASSESSMENT CRITERIA

Humaneness: target individual immediate versus delayed effects; non-target individual of same species; non-target individuals of other species (immediate and delays). Necropsies could be used to assess humaneness? Humaneness of shooting depends on the method used (aerial vs. ground vs. snowmobile vs. bait vs. trap) and experience of the shooter.

Effectiveness (likelihood of success): Based on combined likelihood of a) finding wolves and b) enacting the treatment option on the wolves found. Cost variability is related heavily to search effort and method used variability. Likelihood of finding wolves is heavily based on the method used.

Efficiency (cost and resource effort): Review of annual per-capita costs for each of 11 options. There is uncertainty around cost estimates. Discussion on the cost estimates of a) finding wolves and b) enacting treatment. The cost of finding wolves (e.g. hours of flight time per wolf found) could change dramatically over time as new wolves become more difficult to find. A compromise value could be the "likelihood of finding enough wolves to attain the treatment goal". Standardized rates of different costs were used. Monitoring to demonstrate an effect was not included in the costs.

Risks and Uncertainties: Review of risk and uncertainty of the 11 assessment options. There are high degrees of uncertainty around all the options as there is no precedent for these kinds of large-scale operations in remote areas for a migratory tundra herd like the Bathurst (with perhaps the exception of the poisoning efforts in the 1960's).

Non-lethal options (1-4):

- Risk is medium for all options except diversionary feeding, which has high chance of being ineffective in reducing predation, and could potentially attract additional predators.
- Disease risk of movement/captures options is low if quarantine procedures used; but added cost.
- Capture and sterilization: Complication of what to do with non-treated wolves.
- Transport distance of wolves should be sufficient to sure that wolves don't return. Capturing wolves at den sites: 1) not all of the den associated wolves may be present and 2) logistical challenges of dealing with pups.
- Uncertain whether captive facilities or remote ranges available to receive large numbers of wolves.

Lethal options (5-11):

- Wolf reduction efforts within Nunavut obviously require participation with NU agencies and the GN.
- Winter range removal options have worked elsewhere (i.e. BC, AB and AK), but never on a broad scale or with this degree of overlap between herds.
- Rennie Lake example cited as evidence that ground-based winter shooting could be quite effective.
- Snaring has not been done on a large scale, so it comes with a medium-high degree of uncertainty. Option seen as a good way to collaborate with community harvesters; works on a smaller scale.

- Poisoning - concerns were raised about bycatch, humaneness of animal deaths, and risk to the public. This method has worked before and was carried out in the NWT in the 1960s and 1970s.
- Killing at den sites was discussed. Uncertainty in this option was rated at low-medium, as finding den sites is still of unknown difficulty.
- Summer harvest was rated with a medium risk. Noted that this may actually increase predation if reduction efforts don't achieve a high level of wolf reduction. Pack splitting may result instead.

CONDITIONS FOR SUCCESS
To maximize the likelihood that wolf reduction will increase caribou population growth:

1. Manage wolf reduction over a big area – reduces immigration rate
2. Develop a multi-year program – maximizes effect; overrides annual variation in other factors
3. Program objectives need to be clear; I understand the 2 options being considered are:
   a. Kill as many wolves as time and money allow. This objective eliminates concept of, and modelling to estimate, a stopping point, and assumes it will be impossible to kill all the wolves in the population.
   b. Decide on an acceptable caribou population growth rate and kill only as many wolves as required to achieve that rate.
4. Use combination of methods.
5. Do in combination with other recovery actions (e.g., do not start hunting caribou again)
6. The degree of compensatory responses to wolf removal will depend on the extent to which wolf population growth is density-dependent.
7. Compensation for mortality can come from reduced mortality from other factors, increased reproduction or increased net immigration. Compensation should be considered on an annual or year-over-year versus seasonal basis to allow for reproduction and other seasonal processes to occur.
8. Compensation is least likely in summer because wolves are faithful to den sites, and when herds are relatively separate.
9. Unlikely that any increase in caribou survival from reduced wolf predation would be compensated for by increases in other forms of mortality.
10. Additive and compensatory responses should be considered along a continuum, i.e., point 8, "most" summer losses will not be compensated for, so the losses will be "largely" additive.
11. Model the ecological story as best you can – in increasing order of value; written conceptual -> written qualitative -> quantitative mathematical mechanistic response/outcomes to actions
12. Plan of action over short term should include an exit strategy
13. Medium term plan should include a review every 5 year
14. Long term -> naturally self-sustaining
15. Monitoring plan should be part of any wolf reduction program
16. Research is different than monitoring and would be beneficial but is not essential.

Catch per Unit Effort (CPUE) modeling was proposed as a way of determining if wolves have been reduced to a desired level. This would be used during a management action.

- There is no good example case to compare to the Bathurst situation. The effectiveness of wolf removal on wolf populations is clearly established, but the effect of decreased wolf populations on caribou (in the Bathurst case) is largely unknown.
- The more wolves removed, the greater the potential impact on caribou survival rates.

- Multiple methods used in combination would have more success. Removal timing should occur early in the biological year. Consider: collar breeding pairs at the den site in spring. Go back in the fall, kill the other den associated wolves and sterilize the collared pair. This method could minimize the compensatory response, issues with killing pups from the den (palatability/practicality issues). Use of professional hunters/trackers with experience from other wolf removal programs to maximize efficiency of helicopter time.
- Program needs to clearly communicate goals and predictions of the expected response of caribou, to monitor and to evaluate.
- To monitor any response in the caribou population more collars (approx. 60-100 total, only cows) would be useful, & conduct population counts more often (given that 3 points are needed for trend).

There are different ways to assess stress imparted to wolves as part of any management action, with a view to assessing changes in fitness. Publications are available on the topic of wildlife welfare. Discussion on the humaneness of ground snaring.

ASSESSMENT REPORT STRUCTURE

Report should include a plain language executive summary, a detailed option by option review, and detailed technical appendices providing the rationale. Potential sections of the report were discussed:

- Introduction: details what the report is and what it isn't (not a management proposal)
- Experience from elsewhere: Summary of information gained from other programs including commentary on the ecological validity of programs as well as the social license issues.
- Review of the 11 options: detailed description and implementation suggestions. Discussion of how to monitor potential results. It was noted that these are not management proposals, and the report should be careful to provide information without ranking the options explicitly. Discuss what the options need to accomplish to get a useful result.
- Communications plan approach (discussion deferred).
- Appendices (including but not limited to): details on the predictive model (the scientific rationale for the options discussions), and a detailed review of the mandate/history of the WG.
  A predictive model could be used as a criterion for each of the options: give a likelihood value of each options/combination of options of achieving a population growth objective. The population growth objective is a little arbitrary, and a recommendation in itself. Seasonality needs to be explicitly laid out in the model.

A basic modeling approach could be used to determine the level of overlap between herds, and how this might impact the effectiveness of any management option applied on the winter range. Concerns were raised over the level of accuracy of the information that any collar based model could give, given the experience from Alaska; that overlap is poorly demonstrated with collared animals.

COMMUNICATIONS CONSIDERATIONS

Part of the assessment report mandate is to outline the communications needs of the 11 options. The main considerations raised were:

- Any public posting of the assessment report or a management report would require a formal set of communications documents from the GNWT. The high-level messaging could be shared with partners in the WG.
- There will be communications needs surrounding the assessment report release, and communications strategies/principles for each of the individual options.
- The main approach for the GNWT will be to focus on high-level messaging and supporting its co-management practice with its partners.
- There was some discussion about having some material in the front end of the assessment about these standard messaging/context issues.
- Tying in the communications of this report with those surrounding the potential listing of BGC under COSEWIC was suggested.
- There is interest in other regions of the NWT in this feasibility assessment, as other herds have also reached very low numbers and in some cases, have stayed at low numbers.

TRADITIONAL KNOWLEDGE

The mandate for the WG requires assessing information from both a scientific and a traditional knowledge (TK) context:

- Aboriginal WG members were invited to contribute existing Traditional Knowledge about wolves to the feasibility; the TG has contributed a summary but otherwise material has been limited.
- Timing and availability of additional TK to assist the assessment will limit how TK will be used in the report

COMBINED OPTIONS

Two combined options were presented:

1. Winter: Aerial shooting with ground snaring and ground shooting
2. Summer: Den removal and sterilization

The options should be explicit on the seasonality of actions, how communities would be involved, and how the combination of actions affects effectiveness (as a key criterion).

There was also discussion of potentially combining summer methods (killing at dens, sterilization) with removals on the winter range.

Appendix K: Monitoring to evaluate humaneness and welfare for wolf removal

Option	Fate	Description of Wolf Management Option	Welfare Outcomes of Wolf Removal Actions
1	non-lethal	Business as Usual	Not applicable
2	non-lethal	Diversionary wolf feeding during pre-calving and calving period	• Field observations (including remote cameras): relative abundance / occurrence of wildlife species; rate of aggressive intra and inter species encounters
3	non-lethal	Relocation of wolves to remote areas	• <u>Capture</u>: chase and handling times, number of nets fired, injuries and deaths; type of restraint and any chemicals used; monitor stress through body temperature, blood; hair and fecal for cortisol and its precursors • <u>Post-capture holding period</u>: time and conditions and subsequent flight times prior to release
4	non-lethal	Relocate wolves to Zoos and/or Captive Facilities	• <u>Capture</u>: chase and handling times, number of nets fired, injuries and deaths; • <u>Post-capture processing</u>: type of restraint and any chemicals used; monitor stress through body temperature, blood; hair and fecal for cortisol and its precursors holding time; flight duration and conditions, and conditions and subsequent flight times prior to release • <u>Captivity</u>: behavioral observations of translocated wolves at receiving facilities to test for traumatic stress disorder
5	non-lethal	Sterilization breeding pairs and translocation non-breeders	• <u>Capture</u>: chase and handling times, number of nets fired, injuries and deaths • <u>Post-capture processing</u>: type of restraint and any chemicals used; monitor stress through body temperature, blood; hair and fecal for cortisol and its precursors; holding time; flight duration and conditions, and conditions and subsequent flight times prior to release
6	lethal	Aerial shooting non-breeder wolves (assumed) on Bathurst calving grounds	• <u>Capture</u>: initial pack size; chase time; firearm and bullet details; number shots and placement; time to death; wounding rate; number wolves killed / pack size • <u>Post-mortem necropsy</u>: location of bullet-wound tracts; wolf condition, reproductive and health status, sample for stress from hair, blood and fecal, stomach contents.

7	lethal	Aerial shooting of wolves on Bathurst winter range	• Capture: initial pack size; chase time; firearm and bullet details; number shots and placement; time to death; wounding rate; number wolves killed / pack size • Post-mortem necropsy: location of bullet-wound tracts (carcass necropsy); wolf condition, reproductive and health status, sample for stress from hair, blood and fecal, stomach contents.
8	lethal	Ground shooting wolves on Bathurst winter range	• Capture: initial pack size; chase time; firearm and bullet details; number shots and placement; time to death; wounding rate; number wolves killed / pack size • Post-mortem necropsy: location of bullet-wound tracts; wolf condition, reproductive and health status, sample for stress from hair, blood and fecal, stomach contents
9	lethal	Snaring wolves on Bathurst winter range	• Field observations: Document snare site for signs struggle • Post-mortem necropsy: snare cable location and skin lacerations; neck and trachea trauma; signs relative to onset loss of unconsciousness; reproductive and health status; sample for stress from hair, blood and fecal
10	lethal	Poison / bait wolves on winter range	• Field observation (including remote cameras): ratio of poisoned wolves found to index of wolf abundance at poisoned bait sites; amount of bait removed; number and type of snow tracks within 5m bait site; distance of poisoned animals from bait site (closer distance assumes quicker time to death). • Post-mortem necropsy: Age-class, sex, number and location of non-target animals seen or found killed at each bait-site; reproductive and health status, sample for stress from hair, blood and fecal; stomach contents (?)
11	lethal	Lethal wolf removal - spring wolf den sites	• Capture: initial pack size, chase time; firearm and bullet details; number shots and placement; time to death; wounding rate; number wolves killed / pack size • Post-mortem necropsy: location of bullet-wound tract (carcass necropsy); wolf condition, reproductive and health status; sample for stress from hair, blood and fecal, stomach contents
12	lethal	Harvest assistance in summer	• Capture: initial pack size, chase time; firearm and bullet details; number shots and placement; time to death; wounding rate; number wolves killed/pack size • Post-mortem necropsy: location of bullet-wound tract (carcass necropsy); wolf condition, reproductive and health status, sample for stress from hair, blood and fecal, stomach contents

Appendix L: Monitoring to evaluate numerical targets for wolf removal

Option	Fate	Description of Wolf Management Option	Numerical Target for Wolf Removal
1	Non-lethal	Business as Usual	Not applicable
2	non-lethal	Diversionary wolf feeding during pre-calving and calving period	• Estimate rate of use of meat by wolves and other animals: remote cameras at each of 10 sites to monitor meat consumption, use by wolves & other animals • Estimate wolf abundance on calving grounds: fixed-wing survey on calving grounds to monitor wolf relative abundance • Monitor field time and effort by crews
3	non-lethal	Relocation of wolves to remote areas	• No. wolves captured • No. of wolves relocated • No. wolves euthanized (non-suitable candidates, or severely injured) • Collared wolves would assist in monitoring fate and subsequent movements • Monitor field time and effort by crews
4	non-lethal	Relocate wolves to Zoos and/or Captive Facilities	• No. wolves captured • No. wolves relocated • No. wolves euthanized (non-suitable candidates, or severely injured) • Monitor field time and effort by crews
5	non-lethal	Sterilization breeding pairs and translocation non-breeders	• No. wolves treated and their health (disease), reproductive status and condition. • Monitoring litter size and survival at neighboring untreated dens • Fate of translocated wolves (harvest, collar movements or mortality signal)
6	lethal	Aerial shooting non-breeder wolves (assumed) on Bathurst calving grounds	• No. wolves killed and their health (disease), reproductive status and condition. • Locate and necropsy calf carcasses on the calving ground • Record grizzly bear sightings on the calving grounds • Monitor wolf use of den sites and litter size • Monitor field time and effort by crews
7	lethal	Aerial shooting of wolves on Bathurst winter range	• No. wolves killed and their health (disease), reproductive status and condition. • Locate and sample caribou carcasses during the searches for wolves • Monitor use of wolf dens and litter size • Monitor field time and effort by crews
8	lethal	Ground shooting wolves on Bathurst winter range	• Monitor number of wolves harvested by all crews; • Monitor field time and effort by crews (increased effort to find fewer wolves might suggest wolf numbers depleted)
9	lethal	Snaring wolves on Bathurst winter range	• No. of wolves killed • Age and sex of harvested wolves • Necropsy of wolves • Monitor field time and effort by crews

10	lethal	Poison / bait wolves on winter range	• Relative abundance at bait sites from remote cameras • Number and location of dead wolves at each bait-site • Age and sex of dead wolves • Post-mortem assessment of condition, heath and diet of wolves
11	lethal	Lethal wolf removal - spring wolf den sites	• No. wolves killed and their health (disease), reproductive status and condition. • Monitoring litter size and survival at neighboring untreated dens
12	lethal	Harvest assistance in summer	• No. wolves killed • Age and sex of harvested wolves • Monitor field time and effort by crews

Appendix M: Monitoring to evaluate Bathurst caribou and conditions on Bathurst range

Indicator(s)	Rationale	Desired Response	Adaptive Management Options	How Often	Notes
1. Numbers (density) of 1+ year old caribou on calving ground from reconnaissance surveys	Provides index of number of breeding cows on calving grounds; number of 1+ year old caribou correlated with number of breeding females.	Increasing trend in numbers of 1+ year old caribou on annual calving ground.	If trend in 1+ year old caribou is increasing, continue as before; if trend stable-negative, re-consider management.	Annual (between photo-surveys)	Precision improved 2013 using 5-km spacing between flight lines.
2. Estimate of breeding cows from calving ground photo survey	Most reliable estimate for abundance of breeding cows & can be extrapolated to herd size based on pregnancy rate and sex ratio.	Increasing trend in numbers of breeding cows by 2018.	If trend in breeding cows increasing, continue as before; if trend stable-negative, re-consider management.	Every 3 years	Last surveys 2009, 2012, 2015, next in 2018. Trend in breeding females is most important for herd trend.
3. Cow productivity; composition survey on calving ground in spring (June)	Relatively low calf:cow ratio in June 2009 – many sub-adult cows not yet breeding; establishes basis for potential calf recruitment through fall & winter.	High calf:cow ratio (80-90 calves:100 cows).	Low ratio indicates poor fecundity and poor nutrition in previous summer; survey data integrates fecundity & neonatal survival.	Every 3 years	Essential component of calving ground photographic survey.
4. Fall sex ratio; composition survey (October)	Tracks bull:cow ratio; Bathurst ratio increased from 31-38 bulls/100 cows 2004-2009 to 57-58/100 in 2011-2012; prime bulls key for genetics, migration.	Maintain bull:cow ratio above 30:100.	If bull:cow ratio below target, consider reducing bull harvest. Fall calf:cow ratios indicate spring & summer calf mortality relative to June ratios.	Every 2-3 years	Needed for June calving ground photographic survey – extrapolation to herd size. Provides fall estimate for calf:cow ratio.
5. Calf:cow ratio in late winter (March-April); composition survey	Herd can only grow if enough calves are born and survive to one year, i.e., calf recruitment is greater than mortality.	>40 calves:100 cows on average.	If average calf:cow ratio ≥ 40:100, continue as before; if average ratio ≤ 20:100, herd likely declining; re-evaluate management.	Annual	Calf productivity & survival vary widely year-to-year, affected by several variables, including weather.
6. Cow survival rate (estimated from OLS model, including collar data)	Cow survival estimated 67% in 2009, 78% in 2012 (from model). Need survival of 83-86% for stable herd.	Increase to 83-86% by 2018	If cow survival increases to 83-86%, continue as before; if survival stays below 80%, re-assess harvest & wolf management.	Regular (every 3 years)	Population trend highly sensitive to cow survival rate; recovery will depend on increased cow survival.
7. Maintain 50 collars on Bathurst herd (30 cows & 20 bulls, with annual increments)	Reduce uncertainty in defining winter herd distribution; improve confidence in assigning herd identity to hunter-kills and improve overall harvest management; provide a direct & more precise estimate of adult female survival	More reliable harvest management & improve datasets for OLS model analysis of demography.	Develop options for implementing new management zones with Tłįchǫ communities; has potential for improved zoning strategies that permit more flexible and effective harvest management.	Annual deployment of collars to maintain 50 on the herd	Tracking movements and locations of collared bulls (n=20) would assist in directing hunters to areas with bulls.
8. Monitor annual indices of environmental conditions	Indices of range condition, drought index, warble fly index may help explain trends in calf:cow ratios, pregnancy rates	Indices positive for herd, but focus is explanatory.	Adaptive management does not apply but indicators may help explain and predict possible herd responses	Annual	Trends in environmental indices may help explain underlying drivers of change in herd trend.

Appendix N: Welfare and humane criteria for wolf management

Our emphasis on humaneness and welfare as criteria to assess the wolf management options is based on professional and public views which represent the complexity of animal ethics (Fraser and Macrae 2011, Sharp and Saunders 2011, Fraser 2012). A comparison of public attitudes to wolf management considered the methods were less humane in 2014 compared to 1994 and revealed that the public preferred non-lethal methods (Slagle *et al.* 2017). However, while recognizing this public preference, we were also aware of the need to evaluate both lethal and non-lethal methods especially as people may differ in their values about the different methods and the trade-offs inherent in intervening in ecology (Paquet *et al.* 2010).

We have assessed the level of humaneness and welfare for the individual wolves, and as they are highly social, we have also included effects on pack members in our assessment. The basis for scoring the effect of pack-splitting is because there is evidence to suggest that heavily hunted wolves (including wolves in areas of wolf control) have higher cortisol levels which Bryan et al. (2014) suggested were "consistent with social instability caused by an increased frequency of inter-individual interactions that have unpredictable outcomes" (references in Bryan et al. 2014 and Haber 1996, Borg et al. 2015). Our approach also acknowledges the importance of sub-lethal effects (for example Wilson et al. 2014). The assessment considered each option although cumulative effects of humanness will be needed when different methods are combined (sterilization with helicopter capture plus helicopter-based shooting).

We use 'humane' to mean that for a lethal option to act in a manner that causes immediate unconsciousness and subsequent death without causing additional excitement, pain or distress. For a non-lethal action, humane means to act in a manner that causes the least harm, i.e., minimal excitement, pain, injury, and/or discomfort (Sharp and Saunders 2011). Welfare is a complex topic which reflects how animals experience their world (Botreau *et al.* 2007) and raises social and ethical issues (Fraser 1993). Our adaption of Sharp and Saunders (2011) assessment of welfare explicitly acknowledges that effects may extend beyond the individual animal including disruption of social groups and starvation of dependent pups (Dubois et al., 2017). Where individuals of other wildlife species may be affected, we have included this in the assessment, but we have not, in this humane and welfare assessment addressed the wider issues of reducing a predator's abundance on other predators or scavengers.

Although there has been lethal and non-lethal wolf control in Canada and Alaska, there is almost no reporting of how the humaneness of the approach was assessed, how the protocols were implemented and monitored. This why, for example, Brook *et al.* (2015) criticized Hervieux *et al.*'s (2014) shooting of wolves from a helicopter. In contrast, for example, Hampton *et al.* (2013, 2014, 2016) provide a detailed assessment of how lethal techniques were monitored (chase times, incidence of wounding and shot placement and time to insensibility for feral camels shot from helicopters). As well as experience and training of the shooter, the firearm and bullet type are also key to time to death, instantaneous death rate and wounding rate (Hampton *et al.* 2014, 2016b). To ensure that protocols (for example Sharp 2010 for wild dogs) are met in the field and can be adaptively modified, monitoring is necessary both before and after death (such as necropsies to determine bullet tracks and wounding; Hampton 2014). Hampton *et al.* (2016a) emphasized the need for validation studies rather than assuming that protocols are both appropriate and followed.

We based our quantitative rating on the detailed approach developed by Sharp and Saunders (2011) and Saunders's (2011) procedure developed in Australia and New Zealand because those countries have considerable experience in lethal and non-lethal efforts to control wildlife.

The experience was compiled through collaborative efforts of agricultural, animal welfare, wildlife management and veterinary science collaborators to develop an evidence-based and transparent ranking for non-lethal and lethal methods for wildlife management (for example, Baker, Sharp, and Macdonald (2016). We also used where applicable NWT experience. From the NWT's experience of wolf capture and handling (about 150 wolves for research since 1996), Dean Cluff (pers. comm. 2017) recommends net-gunning in the summer, and hand injecting a sedating drug.

Sharp and Saunders (2011) based their ranking for non-lethal methods and the activities prior to lethal methods on both health and welfare (Part A). This is expressed through rating the overall effect (no impact to extreme) for the five freedoms (freedom from hunger or thirst; discomfort; pain, injury or disease; to express (most) normal behavior and freedom from fear and distress (Beausoleil *et al.* al. 2014). The duration of those five freedoms was estimated and used to derive a numerical score (Figure O1). For lethal options, the humaneness of the killing method is assessed in Part B to rank the time to insensibility and suffering potential which are ranked as an alphabetic score (Figure O1). We then converted the alphabetic score to a numerical rating (A=1; B=2; C=3; D=5 etc. through to H=38). The two scores for Part A and B are then combined to systematically rank the options.

Part A

Overall impact on welfare	Duration of impact				
	Immediate to Seconds	Minutes	Hours	Days	Weeks
EXTREME	5	6	7	8	8
SEVERE	4	5	6	7	8
MODERATE	3	4	5	6	7
MILD	2	3	4	5	6
NO IMPACT	1	1	1	1	1

Part B

Level of suffering (after application of the method that causes death but before insensibility)	Time to insensibility (minus any lag time)				
	Immediate to Seconds	Minutes	Hours	Days	Weeks
EXTREME	E	F	G	H	H
SEVERE	D	E	F	G	H
MODERATE	C	D	E	F	G
MILD	B	C	D	E	F
NO IMPACT	A	A	A	A	A

Figure O1. Matrix used to derive scores for ranking welfare for non-lethal methods and the activities prior to lethal methods on both health and welfare (Part A) and for ranking humaneness (degree of suffering) for lethal methods (Part B) from Sharp and Saunders (2011).

Table O1. Summary scores for ranking welfare for non-lethal methods and the activities prior to lethal methods on both health and welfare (Part A) and for ranking humaneness (degree of suffering) for lethal methods (Part B).

Option	Type	Method	Season	Part A: overall welfare	Part B killing method	Part B - numerical score	Overall humaneness score A*B
1	non-lethal	Business as Usual	Not applicable				
2	non-lethal	diversionary feeding	pre-calving	1	n/a	0	2
3	non-lethal	capture/ release	late winter	6	n/a	0	6
4	non-lethal	capture/ captivity	late winter	7	n/a	0	7
5	non-lethal	sterilization/ release	late winter	6	n/a	0	6
6	lethal	aerial shooting	calving	4	D	5	20
7	lethal	aerial shooting	late winter	4	D	5	20
8	lethal	ground shooting /bait	late winter	3	D	5	15
9	lethal	lethal neck snares	late winter	3	E	8	24
10	lethal	poison bait	late winter	3	F	11	33
11	lethal	ground shooting	denning	3	D	5	15
12	lethal	ground shooting	summer	6	D	5	30

<u>References</u>

Baker, S. E., Sharp, T. M., and Macdonald, D. W. (2016). Assessing animal welfare impacts in the management of European rabbits (*Oryctolagus cuniculus*), European moles (*Talpa europaea*) and carrion crows (*Corvus corone*). PloS One 11, e0146298.

Beausoleil, N. J., and Mellor, D. J. (2014). Advantages and limitations of the Five Domains Model for assessing welfare impacts associated with vertebrate pest control. New Zealand Veterinary Journal 63, 37–43. doi:10.1080/00480169.2014.956832

Borg, B. L., S. M. Brainerd, T. J. Meier, and L. R. Prugh. 2015. Impacts of breeder loss on social structure, reproduction and population growth in a social canid. Journal of Animal Ecology 84:177-187.

Bradshaw EL, Bateson P (2000) Animal welfare and wildlife conservation. *In*: Behaviour and Conservation, pp.330-348. L.M. Gosling & W.J. Sutherland (eds.), 2000 Cambridge University Press, Cambridge.

Bryan, H.M., Smits, J.E.G., Koren, L., Paquet, P.C., Wynne-Edwards, K.E., and Musiani, M. 2014. Heavily hunted wolves have higher stress and reproductive steroids than wolves with lower hunting pressure. Funct. Ecol. doi:10.1111/ 1365-2435.12354.

Dubois S, Fenwick N, Ryan EA, Baker L, Baker SE, Beausoleil NJ, Carter S, Cartwright B, Costa F, et al. (2017) International consensus principles for ethical wildlife control. Conservation Biology DOI: 10.1111/cobi.12896
Fraser, D. (1993). Assessing animal well-being: common sense, uncommon science. In 'Food Animal Well-Being Conference Proceedings and Deliberations, 13-15 April 1993, Indianapolis'. pp. 37-54. (Purdue University Office of Agricultural Research Programs: West Lafayette).
Fraser, D, and A M Macrae. 2011. "Four Types of Activities That Affect Animals : Implications for Animal Welfare," 581–90.
Fraser, David. 2012. "A '" Practical "' Ethic for Animals," 721–46. doi:10.1007/s10806-011-9353-z.
Slagle,K., J. T. Bruskotter, A. S. Singh, and R. H. Schmidt. 2017. "Attitudes toward Predator Control in the United States : 1995 and 2014" 98 (1): 7–16. doi:10.1093/jmammal/gyw144.
Haber, G. C. 1996. Biological, conservation, and ethical implications of exploiting and controlling wolves. Conservation Biology 10:1068-1081.
Hampton, J. O., Cowled, B. D., Perry, A. L., Miller, C. J., Jones, B., and Hart, Q. (2014). A quantitative analysis of animal welfare outcomes in helicopter shooting: a case study with feral dromedary camels (*Camelus dromedarius*). *Wildlife Research* 41, 127−145.
Hampton, J. O., Hyndman, T. H., Laurence, M., Perry, A. L., Adams, P., and Collins, T. (2016a). Animal welfare and the use of procedures documents: limitations and refinement. *Wildlife Research* 43, 599–603.
Hampton, J. O., Adams, P., Forsyth, D. M., Cowled, B. D., Stuart, I. G., Hyndman, T. H., and Collins, T. (2016b). Improving animal welfare in wildlife shooting: the importance of projectile energy. *Wildlife Society Bulletin* 40, 678–686.
Hampton, J. O., Hyndman, T. H., Barnes, A., and Collins, T. (2015). Is wildlife fertility control always humane? *Animals* 5, 1047−1071.
Hervieux, Dave, Mark Hebblewhite, Dave Stepnisky, Michelle Bacon, and Stan Boutin. 2014. Managing wolves (*Canis lupus*) to recover threatened woodland caribou (*Rangifer tarandus caribou*) in Alberta. Can. J. Zool. 92: 1029–1037.
Paquet PC, Darimont CT (2010) Wildlife conservation and animal welfare: two sides of the same coin? Animal Welfare 19: 177-190.
Sharp, T. (2010). 'Standard Operating Procedure CAM002: Aerial Shooting of Wild Dogs' (Invasive Animals CRC: Canberra.) http://www.pestsmart.org.au/wp-content/uploads/2010/07/DOG003_ground-shooting.pdf
Sharp, Trudy, and Glen Saunders. 2011. A Model for Assessing the Relative Humaneness of Pest Animal Control Methods Second Edition June 2011.
Wilson, S.M., Raby G.D., Burnett N.J., Hinch S.G., Cooke S.J. 2014. Looking beyond the mortality of bycatch: sub-lethal effects of incidental capture on marine animals. Biological Conservation 171: 61-72.

Option 1. Business as usual.
This option does not include specific wolf management actions, and was not scored for humane and welfare

Option 2. Diversionary feeding of wolves between denning areas and calving grounds		
Part A: Assessment of overall welfare impact		
DOMAIN IMPACTS	Rating	Summary of evidence:
1. Water or food restriction, malnutrition	None	No impact in this domain
2. Environmental challenge	None	Possible very slight impact arising from exercise during flight response (wolves flee from aircraft placing bait).
3. Disease, injury, functional impairment	None	Unlikely to be injured due to flight response.
4. Behavioural or interactive restriction	Mild	The impact was considered as to whether feeding could cause social strife between neighboring packs
Anxiety, fear, pain, distress, thirst, hunger	None	Sufficiently unlikely to be rated as no impact
DURATION	Second s	Any responses to the placement of the bait would be seconds; altercations between neighboring packs is rated as uncertain and not included
	SCORE	Overall Impact + Duration = MILD + Seconds = 2
Option 2		Comments: Part B Assessment of killing method not applicable
Overall humaneness score	2/0	

<u>Assumptions:</u>

1. Wolves migrate to dens and non-breeders to calving grounds where they may function as effective single predators on calves. If they are well-fed away from the calving grounds, they may remain away from the calving grounds during the perinatal and neonatal period.
2. Wolves on calving grounds may have high predation rates on young calves; wolves sometimes show “surplus killing” of young calves.
3. 5 weekly re-supply periods, 10 field sites; bison meat
4. No risk to wolves from grizzly bears attracted to bait

Option 3. Relocation of Wolves to Remote Areas		
Part A: Assessment of overall welfare impact		
DOMAIN IMPACTS	Rating	Summary of evidence:
1. Water or food restriction, malnutrition	Mild	The wolves will be captured, crated, and transported, which would take place over multiple days. A mild stress-relate effect on food and water intake is likely despite food and water being made available during that period. Animals would need to be monitored for dehydration during the capture and transport phases (especially if a sedative is used)
2. Environmental challenge	Mild	Mild impact arising from exercise during flight response (after at least one wolf in group has been captured).
3. Disease, injury, functional impairment	Mild	There is a risk of injury during the net-gunning. There is a mild risk of not being able to follow-up injured animals, but they can be tracked in the snow.
4. Behavioural or interactive restriction	Mild	The impact was graded in relation to the effect on wolves after the first animal is shot (the first animal is naïve to behavioural impact). The disruption of the social group is likely to be stressful as the wolves are socially bonded.
5. Anxiety, fear, pain, distress, thirst, hunger	Moderate	1. Moderate level of human contact even with a minimum of physical handling. 2. Holding the wolves and then transporting them to a release site will cause anxiety and fear. 3. There will be impact due to wolves being frightened by the capture and if other wolves in the pack flee after the first shot and are not captured, will cause stress and also removal of individuals in a pack will likely cause distress.
DURATION	Days	The chase and the handling will be limited to minutes, but the holding and release may be days. The duration of adapting to new ranges is unknown.
	SCORE	Overall Impact + Duration = Moderate + Days =6
Option 3		Comments: Part B Assessment of killing method not applicable
Overall humaneness score	6/0	

<u>Assumptions:</u>

1. Use of professional team should reduce injuries and stress during capture (Contract helicopter pilot, capture crew use of net-gun, and veterinarian).
2. Wolves may be held for hours or several days – depending on final destination, likely transported by air and released under favourable conditions. Even if sedated, this holding will add to capture stress. A mild stress-relate effect on food and water intake is likely despite food and water being made available during that period. Animals would need to be monitored for dehydration during the capture and transport phases (especially if a sedative is used), Wolves determined not to be eligible for translocation will be euthanized on site
3. Assumes a hard release rather than further handling for a soft release
4. Establishing a pack and hunting in a novel range may be behavioral stress together with food shortage and interactions with existing wolves may cause stress.
5. Published experience is Hayes et al. 2003 (Aishihik) and Boertje et al. 2017 (Fortymile) but scant details except low survival for the sub-sample radio-collared (35 of 129 wolves translocated; 66% dead within 1 year).

Option 4. Relocation of Wolves to Captive facilities		
Part A: Assessment of overall welfare impact		
DOMAIN IMPACTS	Rating	Summary of evidence:
1. Water or food restriction, malnutrition	None	No impact in this domain
2. Environmental challenge	Mild	Mild impact arising from exercise during flight response (after at least one wolf in group has been captured).
3. Disease, injury, functional impairment	None	There is a risk of injury during the net-gunning. There is a mild risk of not being able to follow-up injured animals, but they can be tracked in the snow.
4. Behavioural or interactive restriction	Mild	The impact was graded in relation to the effect on wolves after the first animal is shot (the first animal is naïve to behavioural impact). The disruption of the social group is likely to be stressful as the wolves are socially bonded.
5. Anxiety, fear, pain, distress, thirst, hunger	Moderate	1. Moderate level of human contact even with a minimum of physical handling. The holding and then transport to captive facilities will cause anxiety and fear. 3. There will be impact due to wolves being frightened by the capture and if other wolves in the pack flee after the first shot and are not captured, will cause stress and also removal of individuals in a pack will likely cause distress.
DURATION	Days	The chase and the handling will be limited to minutes but the holding and adaption to captivity may take weeks
	SCORE	Overall Impact + Duration = Moderate + weeks = 7
Option 4		Comments: Part B Assessment of killing method not applicable
Overall humaneness score	7/0	

<u>Assumptions:</u>

1. Use of professional team should reduce injuries and stress during capture (Contract helicopter pilot, capture crew use of net-gun, and veterinarian).
2. Candidate wolves receive preventative chemotherapy for parasites and pathogens, long-acting sedative, and housed individually in approved shipping crates and held on site for up to 3 days, or until enough candidate wolves are captured to send out in a Twin Otter to Yellowknife. Upon arrival in Yellowknife, wolves are transferred to another cargo aircraft and according to air transport routings to designated recipient facilities. Wolves determined not to be eligible for translocation will be euthanized on site
3. Assumes permanent captive facility with no further relocations.
4. Adapting to captivity may be cause behavioral stress which may last weeks

Option 5. Capture and sterilization (breeding pairs) and Relocation of Wolves to other ranges		
Part A: Assessment of overall welfare impact		
DOMAIN IMPACTS	Rating	Summary of evidence:
1. Water or food restriction, malnutrition	Mild	The captured wolves will be hours without food during surgery or transport.
2. Environmental challenge	Mild	Mild impact arising from exercise during flight response (after at least one wolf in group has been captured).
3. Disease, injury, functional impairment	Moderate	There is a risk of injury during the net-gunning but references below for capture suggest this is minimal . The surgery has a high degree of human contact and restraint and post-surgical risks are also possible. 60 wolves sterilized in Alaska with no reported deaths (Boertje et al 2017)
4. Behavioural or interactive restriction	Mild	The impact was graded in relation to the effect on wolves after the first animal is captured (the first animal is naïve to behavioural impact). The disruption of the social group is likely to be stressful as the wolves are socially bonded.
5. Anxiety, fear, pain, distress, thirst, hunger	Moderate	1. Moderate level of human contact with minimum of physical handling. 2. Impact due to wolves being frightened by the capture and if other wolves in the pack flee after the first shot and are not captured, that will cause stress. Transport and release of non-breeding wolves into unfamiliar territory will be stressful. The wolves will be caught before pupping (risk to 3rd trimester breeding female) or when pups are 2 weeks old and can survive breeding pair absent for a few hours.
DURATION	Days	The chase, capture and surgery will take hours but the holding and transport for release could take days
	SCORE	Overall Impact + Duration = Moderate + days = 6
Option 5		Comments: Part B Assessment of killing method not applicable
Overall humaneness score	6/0	

<u>Assumptions:</u>

1. Use of professional team should reduce injuries and stress during capture (Contract helicopter pilot, capture crew use of net-gun, and veterinarian).
2. Breeding pairs will be flown to a temporary camp and surgically sterilized while non-breeder wolves will be translocated. The sterilization will be vasectomy on males; tubal ligation on females
3. Assumes permanent captive facility with no further re-homing of the wolves
4. Adapting to captivity may be cause behavioral stress which may last weeks - social adjustment will likely depend on the age of the wolf.
5. The welfare implications of the sterilization are not well described -Spence 1999 found previous trials of field sterilization for wolves has only noted whether the wolves survived.
6. For Aishihik, 3 of 5 years lethal control was also sterilization (Hayes et al. 2003) raising question of cumulative stress). For the Fortymile, sterilization plus translocation and lethal removal were sequential (Boertje et al. 2017).

Option 6. Aerial shooting wolves on caribou calving grounds		
Part A: Assessment of overall welfare impact		
DOMAIN IMPACTS	Rating	Summary of evidence:
1. Water or food restriction, malnutrition	None	No impact in this domain
2. Environmental challenge	Mild	Mild impact arising from exercise during flight response (after at least one wolf in group has been shot).
3. Disease, injury, functional impairment	Moderate	Possibly as bare ground and boulder fields increase likelihood of injuries while trying to escape the helicopter. There is a risk of not being able to follow-up injured animals.
4. Behavioural or interactive restriction	Mild	The impact was graded in relation to the effect on wolves after the first animal is shot (the first animal is naïve to behavioural impact). The disruption of the social group is likely to be stressful as the wolves are socially bonded.
5. Anxiety, fear, pain, distress, thirst, hunger	Moderate	Impact due to wolves being frightened by gunshots and if other wolves in the pack flee after the first shot was fired. If some wolves in a pack are not killed, the impact on the remaining animals in unknown but we assumed that removal of individuals in a pack will likely cause distress.
DURATION	Minutes	Fear during the chase will be limited to minutes and the duration of any anxiety from pack splitting is unknown (likely days).
	SCORE	Overall Impact + Duration = Moderate + Minutes = 4
Part B Assessment of killing method (chest shot)		
Time to insensibility (minus any lag time)	Minutes	With chest shots, time to insensibility can range from seconds to a few minutes. The time to loss of consciousness and the time to death will depend on which tissues are damaged and, in particular, on the rate of blood loss and hence the rate of induction of cerebral hypoxaemia. Loss of consciousness and death is likely to be quick when animals have been shot in the heart.
Level of suffering (after application of method that causes death but before insensibility)	Moderate	Animals that are chest shot and still conscious may have a short period of suffering, though the extent of suffering will vary depending on which tissues are damaged and the rate of blood loss. During hemorrhage, there is likely to be tachypnoea and hyperventilation, which, when severe, would indicate that there is a sense of breathlessness before the loss of consciousness.

Option 6. Aerial shooting wolves on caribou calving grounds, continued

	SCORE	Time to insensibility + Extent of suffering = Minutes + Moderate = D
Option 6		**Comments:** When animals are shot at, some will be killed outright, others will be missed, and some will be wounded but not killed. Of the ones that are wounded, some will be killed by subsequent shots, but some will escape to either die later or recover. Therefore, to determine welfare impact, we are interested in the extent of injury or wounding associated with aerial shooting and its likelihood. The small pack size (1-3 wolves) may reduce this.
Overall humaneness score	Chest shot 4/D	

Assumptions:

1. Best practice NT/NU Animal Care Committee) will be followed where available
2. The shooter is competent marksman and will make accurate decisions about whether the shot can be successfully placed.
3. There is high risk and unavoidable risk from the low-level overflights to the newborn caribou calves even although wolf chase time will be kept brief. Caribou cow and calf deaths and injuries are likely.
4. The impacts were considered on the wolf pack being targeted – the first animal would be naïve, but the impact would increase with each subsequent animal, but the pack size will 1 or 2 non-breeding wolves.
5. An accurate head shot is unlikely as the wolf will be on bare ground and able to twist and turn quickly when pursued. In Australia, aerial shooting of feral dogs is not supported in the federal protocols

Option 7. Aerial shooting wolves on caribou late winter ranges		
Part A: Assessment of overall welfare impact		
DOMAIN IMPACTS	Rating	Summary of evidence:
1. Water or food restriction, malnutrition	None	**1** No impact in this domain
2. Environmental challenge	Mild	Mild impact arising from exercise during flight response (after at least one wolf in group has been shot).
3. Disease, injury, functional impairment	Moderate	Possibly although snow-covered ground may reduce injuries while trying to escape the helicopter. Snow cover would help with tracking any injured animals.
4. Behavioural or interactive restriction	Mild	The impact was graded in relation to the effect on wolves after the first animal is shot (the first animal is naïve to behavioural impact). The disruption of the social group is likely to be stressful as the wolves are socially bonded.
5. Anxiety, fear, pain, distress, thirst, hunger	Moderate	There will be some impact due to wolves being frightened by the noise of the gunshot and if other wolves in the pack flee after the first shot was fired. If some wolves in a pack are not killed, the impact on the remaining animals in unknown but we assumed that removal of individuals in a pack will likely cause distress.
Duration	Days	Fear during the chase will be limited to minutes and the duration of any anxiety from pack splitting is unknown (likely days).
	SCORE	Overall Impact + Duration = Moderate + Minutes = 4
Part B Assessment of killing method (chest shot)		
Time to insensibility (minus any lag time)	Minutes	With chest shots, time to insensibility is from seconds to minutes. The time to loss of consciousness and the time to death will depend on which tissues are damaged and, in particular, on the rate of blood loss and rate of induction of cerebral hypoxaemia. Loss of consciousness and death is likely to be quick when animals have been shot in the heart.
Level of suffering (after application of method that causes death but before insensibility)	Moderate	Animals that are chest shot and still conscious are likely to have a short period of suffering, though the extent of suffering will vary depending on which tissues are damaged and the rate of blood loss. During hemorrhage, there is likely to be tachypnoea and hyperventilation, which, when severe, would indicate that there is a sense of breathlessness before the loss of consciousness

Option 7. Aerial shooting wolves on caribou late winter ranges, continued

	SCORE	Time to insensibility + Extent of suffering = Minutes + Moderate = D
Option 7		**Comments:** When animals are shot at, some will be killed outright, others will be missed, and some will be wounded but not killed. Of the ones that are wounded, some will be killed by subsequent shots, but some will escape to either die later or recover. Therefore, to determine welfare impact we are interested in the extent of injury or wounding associated with aerial shooting and the likelihood of it happening. The small pack size (2-6 wolves) may reduce this.
Overall humaneness score	Chest shot 4/D	

Assumptions:

1. Best practice (Canadian and NT Animal Care Committee) will be followed
2. The shooter is competent marksman and will make accurate decisions about whether the shot can be successfully placed.
3. There is risk from the low-level overflights to caribou in the vicinity of the wolves even although chase time will be kept brief.
4. The impacts were considered on the wolf pack being targeted – the first animal would be naïve, but the impact would increase with each subsequent animal and will depend on the pack size (mean 3.4 range 2-6 for Bathurst late winter ENR unpublished 1985-2015).
5. An accurate head shot is less likely as the wolf will be on snow covered ground and still able to twist and turn quickly on snow-covered lakes or reach the cover of trees.

Option 8. Ground shooting wolves over bait on caribou late winter ranges		
Part A: Assessment of overall welfare impact		
DOMAIN IMPACTS	Rating	Summary of evidence:
1. Water or food restriction, malnutrition	None	No impact in this domain
2. Environmental challenge	Mild	Mild impact arising from exercise during flight response (after at least one wolf in group has been shot).
3. Disease, injury, functional impairment	Mild	Possible escape of any injured wolves
4. Behavioural or interactive restriction	Mild	The impact was graded in relation to the effect on wolves after the first animal is shot (the first animal is naïve to behavioural impact). The disruption of the social group is likely to be stressful as the wolves are socially bonded.
5. Anxiety, fear, pain, distress, thirst, hunger	Mild	There will be some impact due to wolves being frightened by the noise of the gunshot and if other wolves in the pack flee after the first shot was fired. If some wolves in a pack are not killed, the impact on the remaining animals in unknown and we assume that any fear reactivity of the remaining pack members will be offset by strict chase limits.
Duration	Minutes	Fear during the chase will be limited to minutes and the duration of any anxiety from pack splitting is unknown.
	SCORE	Overall Impact + Duration = Mild + Minutes = 3
Part B Assessment of killing method (head shot)		
Time to insensibility (minus any lag time)	Minutes	With head shots, a properly placed shot will result in immediate insensibility but shooting from a snow machine is unlikely to cause instantaneous insensibility
Level of suffering (after application of method that causes death but before insensibility)	Moderate	When animals are rendered insensible immediately with a well-placed head shot that causes adequate destruction of brain tissue there should be no suffering. If snow machine chases are accepted with death by shooting, head shots are unlikely, and the best case may be chest shots

Option 8. Ground shooting wolves over bait on caribou late winter ranges, continued

	SCORE	Time to insensibility + Extent of suffering = Minutes + Moderate = D
Option 8		**Comments:** When animals are shot at, some will be killed outright, others will be missed, and some will be wounded but not killed. Of the ones that are wounded, some will be killed by subsequent shots, but some will escape to either die later or recover. Therefore, to determine welfare impact we are interested in the extent of injury or wounding associated with aerial shooting and the likelihood of it happening. The small pack size (2-6wolves) may reduce this. There do not appear to be any reported wounding rates from ground shooting of wolves.
Overall humaneness score	3/D	

Assumptions:

1. Best practice (Canadian and NT Animal Care Committee) will be followed
2. The shooter is competent marksman and will make accurate decisions about whether the shot can be successfully placed.
3. There is risk from the wolves scattering after the first wolf is shot and limited ability to follow injured wolves or rest of packs as snow machine chases are stressful to wolves and any caribou in the vicinity.
4. Snow machine chases are likely for example see Cluff et al. 2010 as snowmobile use was part of the Rennie Lake controversy (Cluff, H.D., P.C. Paquet, L.R. Walton, and M. Musiani, 2010. Wolf ecology and management in northern Canada: Perspectives from a snowmobile wolf hunt. Pages 135-163 *in* M. Musiani, P. Paquet, and L. Boitani (editors). The world of wolves: new perspectives on ecology, behaviour and management. University of Calgary Press, Calgary, Alberta)
5. The impacts were considered on the wolf pack being targeted – the first animal would be naïve but the impact would increase with each subsequent animal.
6. An accurate head shot is possible as the wolf will be stationary while at the bait site but not during a snowmobile chase.

Option 9. Winter Range – Snaring (Lethal wolf removal)		
Part A: Assessment of overall welfare impact		
DOMAIN IMPACTS	Rating	Summary of evidence:
1. Water or food restriction, malnutrition	None	No impact in this domain
2. Environmental challenge	Mild	Mild impact arising from exercise during flight response (after at least one wolf in group has been shot).
3. Disease, injury, functional impairment	Mild	Possible escape of any injured wolves
4. Behavioural or interactive restriction	Mild	Only one wolf at a time will likely be removed from a pack and the disruption of the social group is likely to be stressful as the wolves are socially bonded.
5. Anxiety, fear, pain, distress, thirst, hunger	Mild	The impact on the remaining animals in a pack is unknown but we assumed that removal of individuals in a pack will likely cause distress.
Duration	Minutes	Any anxiety to pack members from the snared wolf is likely minutes and the duration of any anxiety from pack splitting is unknown (likely days).
	SCORE	Overall Impact + Duration = Mild + Minutes = 3
Part B Assessment of killing method (head shot)		
Time to insensibility (minus any lag time)	Minutes	With a correctly placed snare, the AHTS standard is insensibility within 5 minutes (300 sec) s but the frequency of this for snares is unknown.
Level of suffering (after application of method that causes death but before insensibility)	Severe	Severe anxiety, fear, and pain are likely
	SCORE	E
Option 9		**Comments:** Considerable uncertainties remain about the how long a wolf will take to die in a snare (Proulx et al. 2015).
Overall humaneness score	3/E	

Option 9. Winter Range – Snaring (Lethal wolf removal), continued

Assumptions:

1. Best practice (Canadian and NT Animal Care Committee) will be followed
2. Experienced trappers use neck snares along wolf trails and/or with aid of bait stations. Although season is open from August 15th - May 31st, focus would be directed to the winter range
3. Ram powered snare system, with cam locks – is approved snare for wolves. Canada ratified the 1997 Agreement on International Humane Trapping Standards (AIHTS) but it did not include snares. It needs to be clarified how this snare system will reduce the incidence of leg body captures.
4. Human activity (i.e. snaring) in concentrated areas may disturb caribou.
5. Snaring could include the entanglement, injury, or killing of non-target species, although incidence is expected to be quite low.
6. Accidental capture moose and possibly caribou can be reduced by modifying the snare (http://www.alaskatrappers.org/pdf/30740_breakaway_snare_altered2.pdf)

Proulx, G., Rodtka, D., Barrett, M. W., Cattet, M., Dekker, D., Moffatt, E., & Powell, R. A. 2015. Humaneness and selectivity of killing neck snares used to capture canids in Canada: a review. Canadian Wildlife Biology & Management 4: 55–65.

Option 10. Poison / bait wolves on winter range		
Part A: Assessment of overall welfare impact		
DOMAIN IMPACTS	Rating	Summary of evidence:
1. Water or food restriction, malnutrition	None	No impact is likely in this domain
2. Environmental challenge	None	No impact is likely in this domain
3. Disease, injury, functional impairment	None	No impact is likely in this domain
4. Behavioural or interactive restriction	Mild	Although an objective would be to remove entire packs that encounter a poisoned bait site, the number of wolves removed from a pack is likely to be variable, which could lead to disruption of the social group is likely to be stressful as the wolves are socially bonded.
5. Anxiety, fear, pain, distress, thirst, hunger	Mild	The impact on the remaining animals in a pack is unknown but we assumed that removal of individuals in a pack will likely cause distress.
Duration	Days	Fear during the struggles of the poisoned wolf and duration of any anxiety from pack splitting is unknown (likely days).
	SCORE	Overall Impact + Duration = Mild + Days = 3
Part B Assessment of killing method (poisoning)		
Time to insensibility (minus any lag time)	Hours	A study involving oral dosing of dingoes with 1080, recorded latent periods of 4.8-14.6 hours and time until death in the range of 5.3-10.8 hours. In an experimental study of foxes dosed with 1080 in meat baits, there was a mean time of 4.05 hours between dosage and onset of clinical signs and a mean of 1.57 hours from onset of clinical signs until death (references in Sharp and Saunders 2011). See text box for PAPP rating as a poison although not yet available in Canada
Level of suffering (after application of method that causes death but before insensibility)	Severe	The latent period is likely to be associated with minimal pain or distress: during the onset of clinical signs individuals likely experience distress, confusion, anxiety and pain when they are retching, displaying manic running and little or no CNS disturbance. After severe CNS dysfunction has developed, it is unknown if animals are perceiving pain as CNS dysfunction appears to alter the normal behavioural indicators of pain. Also, perception of pain by the animal requires that it is conscious which is difficult to assess if animals are conscious during convulsive episodes. During prolonged convulsions, the animals may be lucid between fits and would may experience pain and/or anxiety.
	SCORE	F
Option 10		**Comments:** - Use of poison is considered to be in violation of the International Union for Conservation of Nature (IUCN) Wolf Manifesto and is against the guidelines set out by the Canadian Council on Animal Care (CCAC).
	3/F	

Option 10. Poison / bait wolves on winter range, continued

Assumptions:

1. Distribution of bait sites would be centered on distribution of collared caribou
2. Poisons need to be evaluated prior to application: strychnine, compound 1080 (sodium monofluoroacetate), sodium cyanide, PAPP (para-aminopropiophenone). Para-aminopropiophenone is being licenced for wild dogs in Australia (and for weasels in New Zealand). http://www.pestsmart.org.au/papp-for-wild-dog-and-fox-control/
3. This assessment is based on the use of 1080 and would differ for the other poisons; cyanide might cause less suffering than 1080 and strychnine more suffering (references available)
4. Initially, up to 10-12 bait-sites would be established and managed during a 3-month period (Feb-Apr), with weekly monitoring via fixed wing aircraft and snow machine where feasible.
5. Bait-sites would be designed to test and adapt different methodologies for baiting and using toxicants; they will be designed according to recommended practices and expert opinion, and will comprise of a combination of poisoned and non-poisoned drop baits (&/or M-44 ejectors) arranged around a larger poisoned or non-poisoned draw bait.
6. Methods to optimize lethal exposure events to wolves will be developed and adapted based on trials and monitoring performance indicators.
7. A key issue is the acceptable threshold for the number (and species) of non-target animals that are killed (i.e., wolverine, fox, raven, gray jays, weasels, others)
8. "PAPP poisoning results in relatively rapid unconsciousness followed by death without any prolonged clinical signs. Poisoned animals show few signs of pain or distress, although minor whimpering and other vocalisations sometimes occur with wild dogs. The doses of PAPP in baits have been optimised so unconsciousness generally occurs within 60 minutes of bait ingestion, and death occurs up to an hour later."
9. Its use would be hours to insensibility and moderate pain = E
10. Foxes, wolverine and weasels would still be killed but secondary poisoning is less likely.

Option 11. Ground shooting wolves at den site		
Part A: Assessment of overall welfare impact		
Domain	Rating	Summary of evidence:
1. Water or food restriction, malnutrition	None	No impact in this domain
2. Environmental challenge	Mild	Mild impact arising from exercise during flight response (after at least one wolf in group has been shot).
3. Disease, injury, functional impairment	Mild	Unlikely to be injured due to flight response. There is a mild risk of not being able to follow-up injured animals but can be tracked in the snow.
4. Behavioural or interactive restriction	Mild	The impact was graded in relation to the effect on wolves after the first animal is shot (the first animal is naïve to behavioural impact). The disruption of the social group is likely to be stressful as the wolves are socially bonded.
5. Anxiety, fear, pain, distress, thirst, hunger	Mild	There will be some impact due to wolves being frightened by the noise of the gunshot and if other wolves in the pack flee after the first shot was fired. If some wolves in a pack are not killed, the impact on the remaining animals in unknown but we assumed that removal of individuals in a pack will likely cause distress.
DURATION	Minutes	Any distress for the other wolves after the first wolf is shot would be minutes.
	SCORE	Overall Impact + Duration = MILD + Minutes = 3
Part B Assessment of killing method (head shot)		
Time to insensibility (minus any lag time)	Immediate	With head shots, a properly placed shot will result in immediate insensibility
Level of suffering (after application of method that causes death but before insensibility)	No suffering	When animals are rendered insensible immediately with a well-placed head shot that causes adequate destruction of brain tissue there should be no suffering
	SCORE	Time to insensibility + Extent of suffering = Immediate + No suffering = A
Part B Assessment of killing method (chest shot)		
Time to insensibility (minus any lag time)	Minutes	With chest shots, time to insensibility can range from seconds to a few minutes. The time to loss of consciousness and the time to death will depend on which tissues are damaged and, in particular, on the rate of blood loss and hence the rate of induction of cerebral hypoxaemia. Loss of consciousness and death is likely to be quick when animals have been shot in the heart.

Option 11. Ground shooting wolves at den site, continued

Level of suffering (after application of method that causes death but before insensibility)	Moderate	Animals that are chest shot and still conscious are likely to have a short period of suffering, though the extent of suffering will vary depending on which tissues are damaged and the rate of blood loss. During haemorrhage, there is likely to be tachypnoea and hyperventilation, which, when severe, would indicate that there is a sense of breathlessness before the loss of consciousness.
	SCORE	Time to insensibility + Extent of suffering = Minutes + Moderate = D
Option 11		**Comments:** When animals are shot at, some will be killed outright, others will be missed, and some will be wounded but not killed. Of the ones that are wounded, some will be killed by subsequent shots, but some will escape to either die later or recover. Therefore, to determine welfare impact we are interested in the extent of injury or wounding associated with ground shooting and the likelihood of it happening. The small pack size (2-3 wolves) at den sites will considerable reduce this and the use of scent attractants or bait would help further. There do not appear to be any reported wounding rates from ground shooting of wolves but Inuit likely can contribute information or studies of denning behavior of disturbed wolves.
Overall humaneness score	Head shot 3/A	
	Chest shot 3/D	

<u>Assumptions:</u>

1. Best practices (Canadian and NT Animal Care Committee) will be followed
2. The shooter is competent marksman and will make accurate decisions about whether the shot can be successfully placed.
3. The presence of the den site in late April will act as a lure and reduce chases but the timing of the wolves' arrival at the den sites is incompletely documented
4. When the female is shot, she will be examined to ensure she was pregnant and had not given birth.
5. The marksman will be at a vantage point, camouflaged and have radio-contact with nearby aircraft
6. The impacts were considered on the wolf pack being targeted – the first animal would be naïve but the impact would increase with each subsequent animal but the pack size will only be the breeding pair and 1 or 2 helper wolves.

Option 12. Ground shooting wolves on summer range		
Part A: Assessment of overall welfare impact		
Domain	Rating	Summary of evidence:
1. Water or food restriction, malnutrition	None	No impact in this domain
2. Environmental challenge	Mild	Mild impact arising from exercise during flight response (after at least one wolf in group has been shot).
3. Disease, injury, functional impairment	Mild	Unlikely to be injured due to flight response. There is a mild risk of not being able to follow-up injured animals.
4. Behavioural or interactive restriction	Mild	The impact was graded in relation to the effect on wolves after the first animal is shot (the first animal is naïve to behavioural impact). The disruption of the social group is likely to be stressful as the wolves are socially bonded.
5. Anxiety, fear, pain, distress, thirst, hunger	Moderate	There will be some impact due to wolves being frightened by the noise of the gunshot and if other wolves in the pack flee after the first shot was fired. If some wolves in a pack are not killed, the impact on the remaining animals in unknown but we assumed that removal of individuals in a pack will likely cause distress for days if the shot wolves are breeding wolves and the pups are dependent on them.
Duration	Minutes	Any distress for the other wolves after the first wolf is shot would be minutes. The duration of suffering for the pups if one or both parent wolves are removed is likely days even if the den location is known and the pups are removed.
	SCORE	Overall Impact + Duration = MODERATE + Days = 6
Part B Assessment of killing method (head shot)		
Time to insensibility (minus any lag time)	Immediate	With head shots, a properly placed shot will result in immediate insensibility
Level of suffering (after application of method that causes death but before insensibility)	No suffering	When animals are rendered insensible immediately with a well-placed head shot that causes adequate destruction of brain tissue there should be no suffering
	SCORE	Time to insensibility + Extent of suffering = Immediate + No suffering = A
Part B Assessment of killing method (chest shot)		

Option 12. Ground shooting wolves on summer range, continued

<table>
<tr><td>Time to insensibility (minus any lag time)</td><td>Minutes</td><td>With chest shots, time to insensibility can range from seconds to a few minutes. The time to loss of consciousness and the time to death will depend on which tissues are damaged and, in particular, on the rate of blood loss and hence the rate of induction of cerebral hypoxaemia. Loss of consciousness and death is likely to be quick when animals have been shot in the heart.</td></tr>
<tr><td>Level of suffering (after application of method that causes death but before insensibility)</td><td>Moderate</td><td>Animals that are chest shot and still conscious are likely to have a short period of suffering, though the extent of suffering will vary depending on which tissues are damaged and the rate of blood loss. During haemorrhage there is likely to be tachypnoea and hyperventilation, which, when severe, would indicate that there is a sense of breathlessness before the loss of consciousness.</td></tr>
<tr><td></td><td>SCORE</td><td>Time to insensibility + Extent of suffering = Minutes + Moderate = D</td></tr>
<tr><td>Option 12</td><td></td><td rowspan="3">Comments: When animals are shot at, some will be killed outright, others will be missed, and some will be wounded but not killed. Of the ones that are wounded, some will be killed by subsequent shots, but some will escape to either die later or recover. Therefore, to determine welfare impact we are interested in the extent of injury or wounding associated with ground shooting and the likelihood of it happening. There do not appear to be any reported wounding rates from ground shooting of wolves. An issue is the fate of pups if breeding wolves are killed.</td></tr>
<tr><td rowspan="2">Overall humaneness score</td><td>Head shot 6/A</td></tr>
<tr><td>Chest shot 6/D</td></tr>
</table>

Assumptions:

1. Best practice (Canadian and NT Animal Care Committee) will be followed
2. The shooter is competent marksman and will make accurate decisions about whether the shot can be successfully placed.
3. The marksman will be at a vantage point, camouflaged and have radio-contact with other team members
4. The impacts were considered on the wolf pack being targeted – the first animal would be naïve but the impact would increase with each subsequent animal.
5. When the first wolf is shot, the shooter will wait to see if the other wolves come back to investigate or to return to the bait.
6. An accurate head shot is achievable.
7. An assumption is that breeding wolves may be shot which leaves the fate and suffering of their pups in question.

Appendix O: Efficiency criteria for wolf management

1. The initial per capita costs provided to the WG used individual author's assessment of a wolf control target (50 - 170 wolves). After discussions, the per capita costs were revised in August 2017 based on a removal target of 124 wolves. This annual adjusted cost estimate was generated to compare control options on a consistent basis and was simply derived by multiplying 124 wolves by the respective per capita costs for each control option.
2. These cost estimates are based on simple assumptions and do not address the likelihood that annual removal rates will decline over time as the wolf population dynamics adjust to the level of removal. Also, the assumptions do not reflect the high likelihood that per capita costs will increase over time as wolf numbers decline due to control efforts. Economic assessments of wildlife control programs consistently show that per capita costs increase as densities of target animals are reduced.

	Wolf Management Option	Non-Lethal Per capita Cost	Lethal per Capita Cost	per Capita Cost (Original Budgets)	Adjusted Total Cost 124 wolves
1	Business as Usual				N/A
2	Diversionary feeding	10,298		10,298	1,235,753
3	Relocate to remote areas	6,958		6,958	834,900
4	Relocate captive facilities	8,230		8,230	987,545
5	Sterilization/translocation	7,274		7,274	872,863
6	Aerial shooting calving		3,246	3,246	389,488
7	Aerial shooting winter		3,046	3,046	365,464
8	Ground shooting winter		1,948	1,948	233,733
9	Snaring winter		1,622	1,622	194,594
10	Poison / bait winter		1,877	1,877	225,192
11	Ground shooting dens		2,689	2,689	322,674
12	Ground shooting summer		3,236	3,236	388,366
	average	*8,190*	*2,523*	*4,584*	*550,052*
	SD	*1,506*	*694*	*3,024*	*362,846*
	Min	*6,958*	*1,622*	*1,622*	*194,594*
	Max	*10,298*	*3,246*	*10,298*	*1,235,753*

Appendix P: Effectiveness criteria for wolf management

Option	Rationale and assumptions	A) Likelihood of finding wolves (based on prior knowledge)	B) Likelihood of capture/death of targetted wolves	Effectiveness (Likelihood of A x B)
1. Monitoring only (status quo)	No active wolf removal actions. Reflects recent joint management proposal by TG and GNWT, and subsequent management determinations by WRRB (2016) to support recovery of the Bathurst herd.	n/a	n/a	n/a
2. Diversionary feeding	On calving ground, prior sighting rate suggests low probability of finding 124 wolves. During 6 years, highest number seen during 37 h flying was 5 wolves so assume x5 more wolves if 37h is 20% catchment area . Likelihood of wolves diverted by bait low	0.2	0.2	0.04
3.Winter capture/release	Prior sighting rate suggests rate of finding wolves 99 wolves/100 flying hours +/- 20 SE (range 21-270). finding 60 wolves, Highest number seen during 27 surveys was 62 during 23 hours flown. Capture, handling and release time lengthy so reducing likelihood	1	0.4	0.4
4. Winter capture for captivity	Likelihood of capturing targeted number of wolves is high, but the likelihood of finding suitable recipient locations for wolves is likely low after one year of capturing 50 wolves. Capture, handling and release time lengthy and likely recipients availability so reducing likelihood	1	0.3	0.3
5. Den site sterilization	i) AT the rate of a breeding pair/den need 25 occupied dens. in the absence of search efficiency for occupancy wolf dens, assumed 100% of wolf locations known with 10km scale (=60%) , Capture, handling and release time lengthy so reducing likelihood	1	0.3	0.3
6. Aerial Shooting calving ground	On calving ground, prior sighting rate suggests low probability of finding 124 wolves. During 6 years, highest number seen during 37 h flying was 5 wolves so assume x5 more wolves if 37h is 20% catchment area . Singles and pairs and open ground so difficult to shoot	0.2	0.5	0.1
7. Aerial Shooting winter range	Prior sighting rate suggests rate of finding wolves 99 wolves/100 flying hours +/- 20 SE (range 21-270). finding 60 wolves, Highest number seen during 27 surveys was 62 during 23 hours flown. Lakes and muskegs help shooting wolves	1	0.9	0.9
8. Ground shooting winter	Prior sighting rate suggests rate of finding wolves 99 wolves/100 flying hours +/- 20 SE (range 21-270). finding 60 wolves, Highest number seen during 27 surveys was 62 during 23 hours flown. Delays in placing shooter on ground may reduce success	1	0.8	0.8
9. Winter snaring	Prior sighting rate suggests rate of finding wolves 99 wolves/100 flying hours +/- 20 SE (range 21-270). finding 60 wolves, Highest number seen during 27 surveys was 62 during 23 hours flown. Delays in placing snares on ground may reduce success	1	0.7	0.7
10. Winter poisoning	Prior sighting rate suggests rate of finding wolves 99 wolves/100 flying hours +/- 20 SE (range 21-270). finding 60 wolves, Highest number seen during 27 surveys was 62 during 23 hours flown. Likely effectiveif enough bait and duration of attraction	1	0.9	0.9
11. Ground shooting dens	Assumed a rate of a breeding pair/den need 62 occupied dens. In the absense of search efficiency estimate for wolf den occupancy rates, assumed 30 dens known do double search effort. High likelihood of marksmen shooting pairs	1	0.9	0.9
12. Summer harvest assistance	No estimate for search efficiency for occupancy wolf dens; assumed 60% of wolf locations known with 10km scale (=60%) , but high rates of den abandonment and location of rendevous sites is less predictable	0.3	0.7	0.21

Appendix Q: Risks and Uncertainty criteria for of wolf management

The WG noted some risks relate to humaneness and welfare. These are not included here to reduce repetition, please refer to Appendix N for details on humaneness and welfare.

<u>Non-lethal options (1-5):</u>

- Risk is medium for all options except diversionary feeding, which has the highest chance of not being effective in reducing predation and potential to support and draw in additional predators such as grizzly bears (opposite of intended effect).
- Disease risk of movement or captures options is low if standard quarantine procedures are followed. However, there is extra cost and effort associated with quarantine.
- Capture and sterilization: Complications associated with the sterilization option include what to do with non-treated wolves.
- Transport of wolves needs to be far enough to make sure that wolves don't return (unknown distance in this system). Capturing wolves at den sites has two risks: 1) not all of the den associated wolves may be present at any given time and 2) either pups or pregnant wolves require specific techniques to ensure their humane treatment.
- It is unclear that there would be captive facilities or remote ranges where removed live wolves would be accepted.

<u>Lethal options (6-12):</u>

- Some wolf reduction such as on the calving grounds would be in Nunavut and would need consultation with approval from NU agencies, including the Government of Nunavut (GN). Risk and uncertainty are high for any calving ground removal options due to this.
- Winter range removal options have lower uncertainty because the methods have been shown to work elsewhere (e.g. aerial shooting in BC, AB and AK), but never with this scale or with this degree of overlap between herds.
- Snaring may not been done on this scale, so it comes with a medium-high degree of uncertainty.
- Poisoning - concerns were raised about bycatch, and risk to the public. This method was carried out in the NWT in the 1960s and 1970s.
- Killing at den sites was discussed. Uncertainty in this option was rated at low-medium, as finding enough den sites is still of unknown difficulty.
- Summer harvest was rated with a medium risk. It was noted that this may actually increase predation if reduction efforts don't achieve a high level of wolf reduction. Pack splitting may result instead.