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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

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ABSTRACT

Various jurisdictions in Canada and the United States have implemented programs to manage wolves, often in response to concerns for declining ungulate populations. Lethal and/or non-lethal methods have been used in Northwest Territories (NWT), Yukon, Alaska, British Columbia, and Alberta with varying results. Historically, trapping and ground shooting of wolves was encouraged through incentive programs, some of which included use of poisons. Current, on-going wolf management programs often integrate harvest-based techniques with more intensive approaches, such as aerial shooting. For programs that have included monitoring initiatives, results suggest that without continued, targeted wolf removals in the area of concern, any positive responses by the ungulate population(s) of concern are typically not sustained. In an effort to support recovery of the Bathurst caribou herd and contribute to an informed response, this report provides information on options for management of wolves using examples from jurisdictions surrounding NWT, including the effectiveness, cost, and humaneness of control methods, local and First Nations involvement in programs, and plans used to guide wolf management. A significant challenge to wolf management on the range of the Bathurst caribou herd is the migratory nature of this predator-prey system resulting in a potential need to consider management actions on wolves more broadly.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

In an effort to support recovery of the Bathurst caribou herd, the Government of the Northwest Territories (GNWT) contracted a comprehensive scientific review of available wolf management options, including the effectiveness, long-term success and limitations, and costs of wolf management options used in other jurisdictions. Russell (2010) provided a review for the Government of Yukon of wolf management programs in Alaska (AK), Yukon (YK), British Columbia (BC), Alberta (AB), and the Northwest Territories (NWT) and therefore, this report is intended to complement this previous review effort. Wolf management programs have been ongoing in AK, BC, and AB since the Russell (2010) review was published, so this report provides an update on the status and results of those programs. Additional information is also provided on lethal and non-lethal control options for wolf management in the NWT and humaneness of methods. Finally, this report discusses local and First Nations involvement in wolf-caribou management, plans used to guide wolf management, and the challenges associated with applying results of previous wolf programs to a migratory caribou herd. For purposes of this review, the terms ‘wolf management’ and ‘wolf control’ are used interchangeably.

SUMMARY OF THE RUSSELL (2010) REPORT

To support the review of the 1992 Yukon Wolf Conservation and Management Plan (Yukon Wolf Management Planning Team 1992), the Government of Yukon commissioned a review of wolf management programs in YK and surrounding jurisdictions. The resulting 47-page report titled, "A review of wolf management programs in AK, YK, BC, AB and NWT", summarized key components of wolf management, including available lethal and non-lethal options, effectiveness, cost, and public opinion of wolf control, predation influences on caribou and moose densities, and jurisdictional summaries of wolf management programs (Russell 2010). Information provided in the report was incorporated into the 2012 Yukon Wolf Conservation and Management Plan (Government of Yukon 2012).

The current review complements the Russell (2010) report with additional background information on wolf management and provides updates on active wolf management programs in jurisdictions surrounding the NWT.

RECOMMENDATIONS FOR PREDATOR MANAGEMENT: NATIONAL RESEARCH COUNCIL'S 1997 REPORT

Central to any review of wolf management options, is the awareness of the National Research Council (NRC)'s 1997 report. In 1994, the Alaskan Governor suspended the State's wolf management programs and indicated a thorough review of the programs was needed. Following this request, the NRC established a committee to do a scientific and economic review of the management of wolves and bears in AK, which included programs from Canadian jurisdictions (YK, BC, Saskatchewan, and Québec). In 1997, the NRC's report, "Wolves, Bears, and their Prey in Alaska: Biological and Social Challenges in Wildlife Management", was published and summarized 17 important conclusions, including:

- Wolves and bears in combination can limit prey populations.
- Wolf control has resulted in prey increases only when wolves were seriously reduced over a large area for at least four years.
- Data on habitat quality are inadequate.
- The design of most past experiments and the data collected do not allow firm conclusions about whether wolf and bear reductions caused an increase in prey populations that lasted long after predator control ceased.
- Many past predator control and management activities have been insufficiently monitored.
- Wildlife is, by definition, a public resource (allow the public to be involved in all stages of the process).

The review also examined 11 predator control programs (mainly involving wolves) and came to some general conclusions that complement the broader statements above:

- Data was collected on wolf and ungulate populations prior to making a decision to initiate a wolf control program.

- Wolf control programs that failed to increase ungulate populations may have been due to high predation rates by bears or habitat quality was poor.
- Some programs failed to reach necessary levels of wolf reduction to elicit a response by the ungulate population.
- Other management actions (e.g. reduced hunting) confounded the ability to interpret results of wolf control.
- Political pressures and budget constraints were problematic.
- Programs that appeared to increase ungulate abundance were conducted in areas where wolf reductions were intensive and other factors were favourable (low predation by bears, high habitat quality, and favourable weather).
- Aerial shooting was a common method of reduction in successful programs.

After reviewing predator control programs in AK and surrounding jurisdictions, the committee generated a set of guidelines to consider prior to finalizing a decision to implement predator management actions (Figure 1). The committee felt that following this set of guidelines would increase the likelihood of a management action having the desired effect on the ungulate population, albeit not guarantee it (NRC 1997).

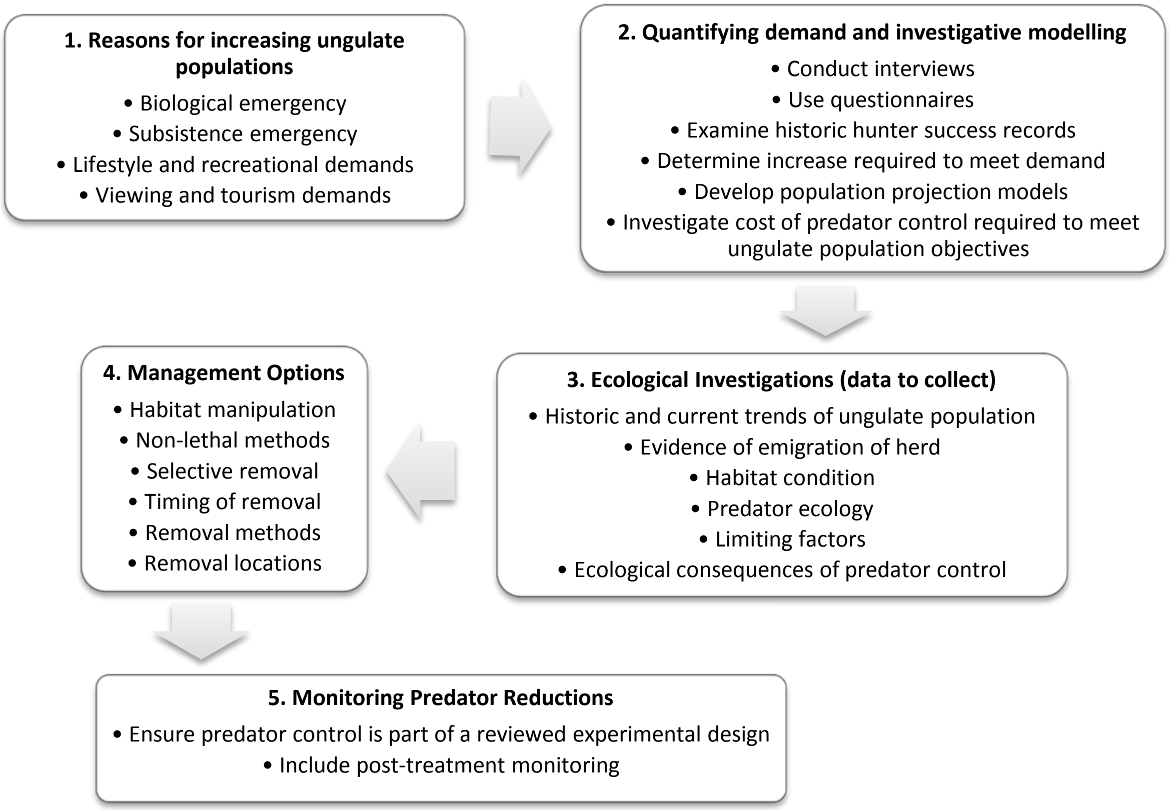

Figure 1. Guiding steps to decision-making for a predator management action (modified from NRC 1997).

OPTIONS FOR REDUCING WOLVES AND/OR THEIR PREDATION ON UNGULATES

A. Lethal Methods

i. Aerial Shooting

Aerial wolf control involves shooting wolves from a fixed-wing aircraft or helicopter. This method of wolf reduction is typically done in the winter and may include snow track surveys and radio collaring prior to control to determine target areas and size of packs (Cluff and Murray 1995, Hervieux et al. 2014). Aerial wolf control is the main method employed in current predator management programs in AK, BC, and AB. In addition, YK used aerial shooting as part of its wolf management programs on the Finlayson, Aishihik, and Southwest YK caribou herds (NRC 1997).

Aerial wolf control was recommended in the 1992 Yukon Wolf Conservation and Management Plan as the most effective method of reducing wolves to target levels (Yukon Wolf Management Planning Team 1992). To achieve success, the Mountain Caribou Recovery Implementation Plan Progress Board (2012) recommends that aerial wolf control follow three basic principles: achieve a minimum of 80% reduction, be conducted for at least five years, and over a large enough area to eliminate packs within and peripheral to the ungulate herd's range. Intensive aerial removal of wolves on caribou ranges with high wolf densities (e.g. 25/1,000km^2) has been successful at slowing population declines of those herds (e.g. Little Smoky caribou herd (LSM); Hervieux et al. 2014), but long-term benefits of wolf reductions, in the absence of continued reductions, are unknown due to the lack of long-term monitoring (NRC 1997).

Although seen as an effective reduction method, aerial wolf control disregards local participation in management and local use of resources (e.g. may reduce trapping success of local trappers). The method of wolf reduction is also highly controversial and attracts public scrutiny, as seen recently in the wolf control programs in BC and AB. In their review of wolf control on the range of the LSM in AB, Brook et al. (2015) contended that aerial shooting does not consistently kill wolves humanely, which contravenes the Canadian Council on Animal Care's guidelines.

ii. Trapping and Ground Shooting with Incentive (Bounty) Programs

Trapping and hunting of wolves can be encouraged by lengthening the harvest season, increasing bag limits, and/or providing financial incentives (bounties). Currently, the GNWT offers three incentive options to hunters and trappers to increase wolf harvesting (Sahtú Renewable Resources Board 2016):

1. $200 for intact (unskinned) wolf.
2. $400 for wolf pelt skinned to traditional standards; additional $50 for the skull.
3. Up to $800 for wolf pelt skinned to Genuine Mackenzie Valley Fur auction standards (if pelt sells for more than $200 at auction; skull must be turned in).

Attempts to encourage increased wolf harvest, however, are often ineffective at managing wolf populations. Traditional methods of wolf harvest are able to remove fewer wolves than a large-scale wolf removal program (Wilson 2010, Hervieux et al. 2014) and often fail to achieve desired levels of wolf reduction (Mountain Caribou Recovery Implementation Plan Progress Board 2012), which may be especially true in remote, inaccessible areas. A territory-wide wolf incentive program in YK in the 1980s failed to effectively reduce wolf abundance and was discontinued after three years (Cluff and Murray 1995). Similarly, incentives offered to trappers in the Slave River Lowlands of the NWT in the late 1970s were ineffective at achieving desired improvements to the declining bison population (Heard 1983, Van Camp 1987). Further, if incentive programs are implemented, there is no guarantee that animals submitted for payment are from the target area of management interest (see Proulx and Rodtka 2015).

A more targeted approach to wolf harvest may have some potential. For example, trapping efforts to reduce wolf abundance may be successful if conducted near active dens or rendezvous sites in the desired area, a method conducted as part of the wolf reduction program in the South Selkirk area of BC (Government of BC 2014*b*). It is also possible to use statistical predation risk models with collared caribou data and kill site investigation data to predict areas of greatest predation risk to caribou (McNay 2009). McNay et al. (2009) suggested that using such information to focus efforts by licensed trappers could reduce wolf abundance in caribou ranges and avoid a large-scale predator control program. Preliminary results from their study in north-central BC showed that targeted removal of wolves has reduced caribou mortality, increased calf recruitment, and increased herd size.

If increased harvest of wolves by trapping is encouraged for management purposes, it should be ensured that methods used are efficient and humane. A common and effective tool used by trappers for wolves is killing neck snares, but there have been recent challenges to the selectivity and humaneness of the popular trapping device. In their review, Proulx et al. (2015) stated that trapper experience and expertise are important factors in proper use of kill snares, a statement reinforced in earlier published work in AK by Gardner (2010). Despite trapper experience, however, killing neck snares may not render an animal unconscious quickly, do not guarantee the capture area is restricted to the neck, and are non-selective (Proulx et al. 2015). In fact, neck snares have killed non-targets including lynx, white-tailed deer, wolverines, fishers, eagles, hawks, and owls. Black bears and grizzlies have also been captured in neck snares set for canids (Proulx et al. 2015). In AK, neck snares have captured moose and caribou, with some dying as a result of their injuries (Gardner 2010). Issues of non-target captures are being addressed in AK and research has been conducted to modernize the design of snares so that they are effective at catching wolves while reducing risk to non-target species, like moose and caribou (Gardner 2010).

Alternatives to killing neck snares are non-lethal cable restraints, which rely on the trapper to dispatch the captured target species, while releasing any non-target captures. A pilot study in Ontario using non-lethal cable restraints demonstrated the value of this trapping device to effectively capture canids, while minimizing non-target species capture and injury or death

(Garvey and Patterson 2014). Certainly, any program involving use of neck snares would likely benefit when considerations are placed on humaneness and selectivity of the trapping device.

In addition to neck snares, foot-hold traps that are modified with padded or off-set jaws and the ability to adjust tension on spring pans can be successful at catching wolves, while minimizing injuries and capture of non-targets (Cluff and Murray 1995).

In general, however, the practicality of trapping wolves on the tundra and near the treeline, such as on the range of the Bathurst caribou herd, has been questioned (see Cluff et al. 2010), because these methods are usually intended for forested landscapes. Thus, the use of trapping, compared to ground shooting, as a means of wolf management on barren-ground caribou herd ranges needs further evaluation.

iii. Poisoning

Historically, there was extensive use of poison against wolves in North America including the use of strychnine, sodium monofluoroacetate, cyanide, and thallium (Cluff and Murray 1995). Specifically in the NWT in the 1950s and 1960s, wolf control programs included the use of poisons (Kelsall 1968, Van Camp 1987, Cluff et al. 2010). In 1951, government control of wolves in the NWT began through use of strychnine after aerial surveys indicated barren-ground caribou herds were declining (Kelsall 1968). Poisoned baits were deployed on almost all barren-ground caribou winter ranges, despite uncertainties in the real cause of the decline. At the peak of the program, approximately 1,000 wolves were killed annually, including many non-targets, and overall, the program was considered a success (Kelsall 1968). The rate of decline of caribou slowed by 1955 and by 1960, fewer wolf den sites were occupied and sightings of wolves had declined. It was assumed that the removal of wolves through poisoning was the reason for the positive response of the caribou herds, but the program lacked any monitoring studies to confirm this assumption (Kelsall 1968). The program ended in 1964 and the wolf population recovered quickly thereafter (Heard 1983). Recently, the Government of AB used strychnine as part of their wolf control program in the province from 2005-2012 (Hervieux et al. 2014). They are the only Canadian jurisdiction having recently used poison to kill wolves (154 in total) to aid caribou recovery (Mountain Caribou Recovery Implementation Plan Progress Board 2012).

Although effective at killing wolves, poisons are considered inhumane, contravene wildlife care guidelines, including those of the Canadian Council on Animal Care (i.e. strychnine), and are non-selective (Kelsall 1968, Brook et al. 2015, Proulx et al. 2016). Research into target-specific poisons with improved considerations for animal welfare, such as reduction of suffering and anxiety, is on-going (Littin and Mellor 2005).

ALTERNATIVE METHODS TO LETHAL WOLF CONTROL

Evaluating the means of achieving desired reduction targets should take a broad approach and consider additional methods to those discussed above, including non-lethal actions, to use in conjunction with a lethal control program. A combination of methods has been successful at increasing caribou abundance in some jurisdictions (e.g. Aishihik caribou recovery program; Hayes et al. 2003).

Russell (2010) described several non-lethal and alternative methods to enhance ungulate populations including diversionary feeding, relocation or sterilization of predators, caribou maternity pens, alternate prey reductions, and prescribed burning. Here, an attempt is made to provide additional details on these options and evaluate their feasibility in the NWT on the Bathurst caribou herd range.

B. Non-Lethal Methods

i. Diversionary Feeding

Studies from AK have demonstrated that providing carcasses to predators during calving season can lead to increased moose calf survival to early winter by diverting predation, especially by bears, away from cows and their calves (Alaska Department of Fish and Game 2007). However, supplementary feeding is likely unfeasible in the remote barren-ground caribou ranges of the NWT, including their calving grounds in Nunavut. First, a source of carcasses is not readily available. Roads are limited in the NWT and most road kills of large mammals are wood bison (T. Armstrong, personal communication), which would not be appropriate to use in barren-ground caribou range, as it is beyond the current range of bison in the territory. Second, transportation of a desirable number of carcasses to the remote calving grounds to effectively divert predators away from newborn calves is likely cost prohibitive and logistically challenging. Even if possible, results from AK suggest that any benefits gained from diversionary feeding are often short-term and cease once feeding is terminated (Alaska Department of Fish and Game 2007).

ii. Relocation

Capturing and relocating grizzlies and/or black bears in AK have been shown to significantly decrease moose calf mortality, but the programs were often expensive and impractical. Wolf relocations are often deemed ineffective when conducted in absence of other management techniques (see Farnell 2009), because wolves, particularly dominant individuals, quickly return to their home ranges (Alaska Department of Fish and Game 2007). Further, relocation of predators may not be acceptable by the public and wildlife managers, because it could divert predation pressure to nearby ungulate populations, which in turn may lead to mismanagement of that population or herd. Barren-ground caribou herds are declining in the NWT and the role of predation in these declines is not well understood. Therefore, as a precaution, it may be inadvisable to relocate predators from one range to another.

iii. Sterilization

The 1992 management plan for wolves in YK recommended that non-lethal wolf control options be considered (Yukon Wolf Management Planning Team 1992). As a result, a sterilization experiment was conducted as part of the Aishihik caribou herd recovery program (Yukon Department of Environment 2011). From 1996-1998, researchers captured and surgically sterilized wolves (vasectomy on males; tubal ligation on females) from six packs that held territories near the calving grounds of the Aishihik caribou herd (Spence et al. 1999). Where possible, both the breeding male and female were captured and sterilized. The study found that all sterilized pairs maintained their pair bonds and territories, consistent with results from other wolf sterilization programs (Mech et al. 1996). It was concluded that sterilization, in combination with lethal methods, was effective at reducing the rate of increase of wolves in the Aishihik range (Hayes et al. 2003).

A similar sterilization program was conducted for five years (1997-2002) on dominant wolves from 15 packs holding territories on the calving range of the Fortymile caribou herd (FCH).

Combined with relocation of subordinate wolves and a reduction in human harvest, this led to a rapid increase in the size of the herd (Farnell 2009).

Results from a more recent wolf sterilization program in the Quesnel Highland area of BC support findings from the fertility control programs for wolves on the Aishihik and FCH ranges. In the Quesnel study, sterilizing the dominant male and female from the majority of packs in the treatment area and lethal removal of subordinate individuals led to a stabilization of the wolf population at a low density (Hayes 2013). Effects of wolf treatment on caribou response were not clear due to poor study design, but it was suggested that treatment led to slight increases in caribou abundance (Hayes 2013).

It is difficult to assess the effectiveness of sterilization only, because all of these programs involved additional management strategies. It is believed, however, that the positive response of caribou herds in areas where sterilization of wolves was conducted was the result of the reduction of pack size and subsequent modification of summer pack hunting behaviour. Spence et al. (1999) described that during denning, the breeding male and female are confined to the den area, leaving subordinate wolves to seek out and hunt small animals and ungulate calves, resulting in several hunting units from this one pack. If, however, the breeding pair is sterilized, the pack size will be reduced over time, pairs will not be confined to a den, and they will hunt together as one hunting unit, with an overall reduction in predation events on ungulate calves (Spence et al. 1999).

As a part of the considerations of effectiveness of wolf sterilization, there are challenges to evaluate, including animal welfare risks (Hampton et al. 2015). First, sterilization is invasive, there are risks of infection, and logistics may make it difficult to do at a large scale (Spence et al. 1999). Chemical sterilization has been suggested as an alternative to surgical sterilizing to address these concerns, including oral administration of mibolerone to females, use of immunogens (porcine zona pellucida), or injection of chemical sclerosing agent into the ductus deferens of males (Spence et al. 1999), but information on the effectiveness and feasibility of this form of sterilization for management of wild wolves is lacking.

Further, priorities need to be placed on sterilizing both the breeding male and female, despite the simplicity of male-only sterilization in the field (Mech et al. 1996). If only the breeding male is sterilized and he dies before breeding season, efforts will be wasted if the female finds a new mate (Spence et al. 1999).

In addition, a wolf population will quickly rebound to pre-treatment densities when sterilization is not continued (e.g. within three years; Hayes 2013). With periodic treatment of wolves in the area, sterilization may have the same effect on wolf population growth as lethal removals, except that lethal methods can require removal of twice as many wolves (Haight and Mech 1997). Sterilization may also be better suited on small remnant wolf populations after lethal wolf control is conducted (Spence et al. 1999) or used in combination with lethal removal of subordinate individuals from the pack (Hayes 2013).

Finally, fertility control may be more publicly acceptable than lethal methods in general, but there may be local cultural sensitivity to reproductive manipulation of wildlife (NRC 1997). This is likely pertinent in First Nations cultures where a high degree of value and respect is placed on wildlife.

C. Other Methods to Reduce Impacts of Predation

i. Caribou Maternity Pens

Capturing of pregnant cows and transporting them into fenced areas for calving has been done for boreal caribou populations in YK (Chisana herd) and AB (LSM) and mountain caribou populations in BC (Columbia North herd). Typically, the number of pregnant cows captured and placed in pens is low (e.g. ten cows from LSM, Smith and Pittaway 2008; 20-50 cows from Chisana herd; Chisana Caribou Recovery Team 2010). Captive-rearing programs involve continual inspection of the fence and caribou, supplemental feeding, and post-release monitoring of calves born inside and outside the pen for comparison (Smith and Pittaway 2008). The feasibility of this on barren-ground caribou herds who migrate vast distances to remote calving grounds is not known. Furthermore, most calving grounds of barren-ground caribou herds in the NWT, such as the Bathurst herd, are outside of the territory's jurisdiction and would require support and implementation from those jurisdictions (i.e. Nunavut).

ii. Alternate Prey Reductions

In forested ecosystems, it is believed that human-caused habitat disturbance has led to an increase in the primary prey of wolves—mainly moose and deer—subsequently increasing wolf populations and their incidental predation on caribou, which are considered a secondary prey species (apparent competition hypothesis; Skogland 1991, Thomas 1995, Wittmer et al. 2007, DeCesare et al. 2010). This is considered to be the main reason for declines in boreal (Hervieux et al. 2014) and mountain caribou (Wilson 2009, Government of British Columbia 2014*a*) populations. As a result, moose reductions are conducted in Revelstoke and Parsnip, BC as part of the mountain caribou recovery program, in addition to predator management (Wilson 2009, Mountain Caribou Recovery Implementation Plan Progress Board 2012).

Availability of alternate ungulate prey for wolves on the range of the Bathurst caribou herd (i.e. muskoxen and moose) is limited (Ecosystem Classification Group 2012) and therefore, this likely will not be an applicable management tool. However, what remains applicable from the apparent competition hypothesis is the idea that there are ultimate (e.g. habitat modification) and proximate (e.g. increased wolf abundance and predation) causes of caribou decline that need to be addressed with management actions.

iii. Prescribed Burning

Prescribed burning to enhance habitat would not be applicable to barren-ground caribou populations in the NWT, but the method emphasizes the importance of habitat conservation in the management of ungulate populations. Managing habitat so that it is of suitable quality and quantity should be considered in combination with predator management (see Alaska Department of Fish and Game 2014, Hervieux et al. 2014).

ANIMAL WELFARE AND HUMANENESS OF WILDLIFE CONTROL METHODS

When assessing the various wolf control methods, the viability, effectiveness, cost, and political and public support are factors that can be used to standardize evaluation of the methods. However, equally as important of a selection criterion is consideration for animal welfare, which has been briefly addressed in previous sections in this report. The recent attention paid to ethical and animal welfare considerations for management of free-ranging pest species (Braid et al. 2015, Hampton et al. 2015, Baker et al. 2016), can equally be applied to wolf management. Littin and Mellor (2005) argue that it is important to ensure that the intended control measure is necessary, it is done in a way that minimizes the duration and intensity of pain and distress, and the benefits of the control are maximized. They also suggest that part of the decision-making process should include the following questions: (a) is the action necessary and do the animals need to be killed to be controlled, and (b) is the action justified (decided with a cost-benefit analysis)? In general, if the proposed benefits of a management action are not achievable, then the action is not justified (Littin and Mellor 2005).

An additional useful tool to consider in the decision-making process is an animal welfare assessment model, which has proven beneficial in objectively ranking different management techniques (Sharp and Saunders 2011). Such a model considers the negative impacts of a control method on an animal's welfare, and for lethal methods, it examines how the animal is killed using scoring matrices (Sharp and Saunders 2011). Thus, when decisions are made on a particular management technique, the humaneness of that technique relative to other methods is known, because of outputs of the welfare model (Braid et al. 2015, Baker et al. 2016). Such methods of assessing humaneness of wildlife control techniques could also be used to evaluate any proposed wolf management strategies in the NWT.

UPDATE ON JURISDICTIONS

Alaska

The sustained yield principle guides wildlife conservation in AK, which aims to manage game populations at levels that support a high level of human harvest. Predator control programs in the State are initiated under the Intensive Management Law, a law in place to ensure ungulate populations identified by the AK Board of Game are large enough to allow for sustained harvest (Alaska Department of Fish and Game 2014). It has been argued that such a law has led to unattainable objectives and continued predator control programs in AK (Van Ballenberghe 2004, 2006).

(a) Inactive Programs

All predator reduction programs in AK have target objectives for predator and prey populations. When prey objectives are achieved (e.g. meet or exceed calf:cow ratios, harvest thresholds, etc.) and/or when the predator population is reduced to the target objective (measured as an absolute number, prey:predator ratio, density, etc.), the predator management program in the game management unit (GMU) is suspended.

Current inactive or temporarily suspended programs in AK include (ungulate(s) under intensive management indicated) GMU 1A (Sitka black-tailed deer), GMU 3 (Sitka black-tailed deer), GMU 9D (caribou), GMU 13 (moose), GMU 15C (moose), GMU 20A (caribou and moose), GMU 20D (caribou and moose), and GMU 21E (moose) (Alaska Department of Fish and Game 2016*a*).

(b) Active Programs

AK has several active predator management programs for both moose and caribou populations, but for purposes of this review, only those programs involving caribou will be discussed. Predator management aimed at increasing moose populations only include GMU 15A, GMU 16, GMU 19A, GMU 19D (East), and GMU 24B. Bears are reduced in addition to wolves in some of these programs.

GMUs 12, 20B, 20D, 20E, 25C (Fortymile Caribou Herd)

(From Alaska Department of Fish and Game 2016*b*, unless otherwise noted)

1. Rationale: Residents have expressed concern about the declining FCH since the 1980s and believe the main cause of the herd's low density is high wolf predation. In 2005, predation control was implemented in the area, initially for intensive management of moose, but expanded in subsequent years to include the range of the FCH (Alaska Department of Fish and Game 2010).
2. Target Ungulate(s): caribou
3. Target Predator(s): wolves
4. Ungulate Objective(s): population 50,000-100,000; harvest 1,000-15,000
5. Predator Objectives(s): 60-80% of pre-control fall abundance in year 1 of program; number remaining each year must be at least 88
6. Method(s) of Reduction: public aerial shooting permits, public land and shoot permits, hunting, trapping, departmental removals by helicopter (Alaska Department of Fish and Game 2010)
7. Duration: on-going (started January 2005)
8. Size of Treatment Area: ~48,560 km^2
9. Experimental Control Area Used: no
10. Ungulate Response:

Table 1. Summary of composition data from 2004-2015 for FCH.

Year	Composition (Number per 100 Cows)			Abundance
	Calves	Bulls	Total (n)	
2004	n/a	n/a	n/a	n/a
2005	n/a	n/a	n/a	n/a
2006	34	43	4,995	43,837
2007	37	36	5,228	44,673
2008	33	37	4,119	46,510
2009	34	59	4,503	51,675
2010	32	43	7,169	n/a
2011	25	42	3,949	n/a
2012	22	40	4,832	n/a
2013	28	38	3,921	n/a
2014	25	34	4,794	n/a
2015	28	46	5,663	n/a

(Modified from Table 1, pg. 5, in Alaska Department of Fish and Game 2016*b.*)

11. Predator Response:

Table 2. Summary of wolves removed and fall and spring abundance estimates for intensive management of FCH.

Year	Fall Abundance	Harvest Removal		Department Control Removal	Public Control Removal	Total Removal	Spring Abundance
		Trap	Hunt				
2004	350-410	52	23	n/a	60	135	215-275
2005	300-370	58	10	n/a	17	85	215-285
2006	300-425	73	7	n/a	23	103	197-322
2007	366-398	57	14	n/a	27	98	268-300
2008	372	82	11	84	49	226	146
2009	235	31	4	15	10	60	175
2010	262-285	26	11	0	25	62	200-223
2011	315-342	62	17	56	8	145	170-197
2012	368-403	41	12	40	78	171	197-232
2013	338-373	44	10	31	31	116	222-257
2014	357-393	38	10	33	24	105	252-288
2015	390-426	6	12	0	26	44	n/a

(Modified from Table 3, pg. 7, in Alaska Department of Fish and Game 2016*b.*)

12. Department's Evaluation of Program: objectives are being achieved; herd increased 2% annually between 2003-2010, modelled population estimate (51,675) is within target, harvest objective has been met many years.

GMUs 9B, 17B&C, and 19A&B (Mulchatna caribou herd)

(From Alaska Department of Fish and Game 2016*c*, unless otherwise noted.)

1. Rationale: The Mulchatna caribou herd (MCH) declined from 200,000 individuals in 1996 to 30,000-40,000 in 2008. Nutritional limitations are not believed to be affecting the herd's status. Wolves are a major predator of caribou on the range and anecdotal evidence suggests wolves are abundant in the area (Alaska Department of Fish and Game 2016*d*).
2. Target Ungulate(s): caribou
3. Target Predator(s): wolves (Note: brown bears are responsible for up to 40% of caribou calf mortalities within the first two weeks of life. Brown bear control is not part of the control plan.)
4. Ungulate Objective(s): population 30,000-80,000; harvest 2,400-8,000
5. Predator Objectives(s): 100% removal
6. Method(s) of Reduction: public aerial shooting permits, public land and shoot permits, hunting, trapping, departmental removals
7. Duration: on-going (started March 2011)
8. Size of Treatment Area: ~7,430 km^2
9. Experimental Control Area Used: No. The wolf removal area comprises a small portion of the annual range of the herd, but given movement of caribou within and outside the treatment area, it is difficult to examine trends in treatment and non-treatment areas.
10. Ungulate Response:

Table 3. Summary of composition data for the MCH from 2010-2015 in non-treatment and treatment areas.

Area	Year	Composition (Number per 100 Cows)			Abundance (Areas Combined)	
		Calves	Bulls	Total (n)	Year	
Non-treatment area (no wolf removals)	2010	17	13	2,581	2010	n/a
	2011	14	18	2,649		
	2012	22	17	2,217	2011	n/a
	2013	14	27	1,479		
	2014	33	31	2,226		
	2015	31	32	2,827	2012	19,000-27,000
Treatment area (wolf removals)	2010	23	23	2,011	2013	15,000-22,000
	2011	28	34	1,995		
	2012	38	29	2,636	2014	21,000-32,000
	2013	23	27	1,743		
	2014	27	38	2,567	2015	30,736-38,190
	2015	27	38	2,587		

(Modified from Table 1, pg. 5-6, in Alaska Department of Fish and Game 2016*c*.)

11. Predator Response:

Table 4. Summary of wolves removed and spring abundance estimates for the intensive management of the MCH. The wolf assessment area (A) includes the entire study area (GMUs 9, 17, 19A and B). The treatment area (T) comprises a small portion of the assessment area.

Year	Harvest Removal from Area A		Department Removal from Area T	Public Removal from Area T	Total Removal	Spring Abundance in Area A
	Trap	Hunt				
2011	14	63	0	11	88	14
2012	1	8	0	4	13	n/a
2013	0	10	0	0	10	n/a
2014	0	0	0	0	0	n/a

(Modified from Table 3, p. 8, in Alaska Department of Fish and Game 2016*c*.)

12. Department's Evaluation of Program: bull:cow ratios are increasing, calf:cow ratios are variable, abundance estimates show increasing trend, harvest objective has not been reached.

GMUs 9C and 9E (Northern Alaska Peninsula caribou herd)

(From Alaska Department of Fish and Game 2016*e*, unless otherwise noted.)

1. Rationale: The Northern Alaska Peninsula (NAP) caribou herd peaked in the 1940s and 1980s at 20,000 individuals, but has since declined to an estimated 2,000-2,500 caribou. The initial decline in the herd was attributed to parasites, disease, and nutritional stress due to range depletion. Increased pregnancy rates, increased neonate weights, and increased calf weights suggest nutritional conditions have improved, but with no positive effect on the herd. Calf survival during the first two months of life is low (40% during the first two weeks, 34% from two weeks to two months) and is mainly attributed to bears (31%) and wolves (43%) (Alaska Department of Fish and Game 2016*d*).
2. Target Ungulate(s): caribou
3. Target Predator(s): wolves
4. Ungulate Objective(s): population 6,000-15,000; harvest 600-1,500
5. Predator Objectives(s): 100% removal
6. Method(s) of Reduction: public aerial shooting permits
7. Duration: on-going since March 2010, but Department recommended suspension of the program in their 2016 annual report (Alaska Department of Fish and Game 2016*e*)
8. Size of Treatment Area: ~26,800 km^2
9. Experimental Control Area Used: no
10. Ungulate Response:

Table 5. Summary of composition data from 2010-2015 for the NAP caribou herd.

Year	Composition (Number per 100 Cows)			Abundance
	Calves	Bulls	Total (n)	
2010	18	25	1,795	n/a
2011	20	26	2,395	2,500-3,000
2012	22	28	1,352	n/a
2013	21	31	2,076	2,400
2014	34	40	2,295	2,700
2015	29	38	2,122	2,950

(Modified from Table 1, p. 5, in Alaska Department of Fish and Game 2016*e.*)

11. Predator Response:

Table 6. Summary of wolves removed in the wolf assessment area (A) and treatment area (T) for the intensive management of the NAP caribou herd.

Year	Harvest Removal from Area A		Department Removal from Area T	Public Removal from Area T	Total Removal	Spring Abundance in Area A
	Trap	Hunt				
2010	29	3	0	0	32	n/a
2011	16	80	0	10	106	n/a
2012	9	9	0	5	23	n/a
2013	11	27	0	0	38	n/a
2014	13	10	0	1	24	n/a

(Modified from Table 3, pg. 7, in Alaska Department of Fish and Game 2016*e.*)

12. Department's Evaluation of Program: increases in bull:cow and calf:cow ratios and abundance estimates since the mid-2000s are not attributed to wolf control (since the increasing trend started before wolf control was initiated); bull:cow ratios have exceeded objective and harvest of surplus bulls will be opened in 2016.

British Columbia

Contrary to wolf management policies in AK, BC supports use of predator control to protect species at risk and not to enhance ungulate populations for hunting (BC Ministry of Forests, Lands and Natural Resource Operations 2014). For example, the province's 2007 Mountain Caribou Recovery Implementation Plan included recommendations for predator management to facilitate caribou recovery, including targeted removal of wolf packs (Wilson 2009).

South Peace Region (Moberly, Scott/Kennedy Siding, Quintette caribou herds)

1. Rationale: Woodland caribou in the South Peace region are part of the Southern Mountain population, which was upgraded from Threatened to Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) after reassessment

in 2014. Declines in mountain caribou herds in the South Peace region are believed to be the result of increased predation caused by human-induced changes to the landscape and increases in alternate prey. At least 37% of adult mortalities are attributed to wolf predation. The causes of calf mortality are not known, but believed to be the result of wolf predation. The Burnt Pine caribou herd is considered to be extirpated and some of the remaining herds are at low abundance (Moberly: n=22; Kennedy Siding n=25-35; Quintette n=98-113; Scott: n=20) (Government of British Columbia 2014*a*).

2. Target Ungulate(s): caribou
3. Target Predator(s): wolves
4. Ungulate Objective(s): 10% annual growth rate of caribou herds
5. Predator Objectives(s): 100% removal
6. Method(s) of Reduction: winter aerial shooting
7. Duration: ≥10 years recommended
8. Size of Treatment Area: three areas (Quintette: 6,354 km^2; Moberly: 4,855 km^2; Scott/Kennedy Siding: 5,285 km^2)
9. Experimental Control Area Used: Graham caribou herd range
10. Ungulate Response: Adult mortality rate and calf recruitment are being monitored in treatment and non-treatment ranges. Trends are not available yet.
11. Predator Response: Trends not available yet

South Selkirk Caribou Herd

1. Rationale: The South Selkirk caribou herd moves between BC, Idaho, and Washington and is collaboratively managed by Canada and the United States. There is a correlation between the establishment of wolf packs in the area in 2009 and the decline of the caribou population and extirpation is likely without wolf management. The estimated population size of the herd is 18 caribou (Government of British Columbia 2014*b*).
2. Target Ungulate(s): caribou
3. Target Predator(s): wolves
4. Ungulate Objective(s): no further declines of herd, eventual recovery
5. Predator Objectives(s): >80% removal

6. Method(s) of Reduction: winter aerial shooting, ground-based trapping at active dens and rendezvous sites
7. Duration: ≥5 years recommended
8. Size of Treatment Area: n/a
9. Control Area Used: unknown
10. Ungulate Response: Herd will be surveyed annually. Mortalities of collared cows will be investigated. Trends are not available yet.
11. Predator Response: Abundance and distribution within caribou herd range will be monitored at least every three years. Trends are not available yet.

Alberta

1. Rationale: All woodland caribou populations in AB (boreal ecotype) have been classified as 'very unlikely' or 'unlikely' of achieving self-sustainability (Environment Canada 2012). In an attempt to evaluate the effectiveness of wolf management in caribou herds facing apparent competition-induced declines, the Government of AB implemented a wolf reduction program on the range of the LSM (Hervieux et al. 2014)
2. Target Ungulate(s): caribou
3. Target Predator(s): wolves
4. Ungulate Objective(s): increase caribou population growth rate; not quantified
5. Predator Objectives(s): remove approximately 45% of wolf population annually (mean of 11.6 wolves/1,000 km^2)
6. Method(s) of Reduction: aerial shooting, toxicant bait stations (aerial shooting of elk and moose and application of toxicant to carcasses), licensed fur trapping
7. Duration: winter 2005/06 to winter 2011/12
8. Size of Treatment Area: 10,000 km^2
9. Experimental Control Area Used: Redrock-Prairie Creek caribou herd range
10. Ungulate Response: government compared demographics of the treatment and control caribou herds during five years before wolf reductions to demographics after wolf reductions.

Little Smoky Herd (treatment area):

- cow survival increased from 0.89 before wolf removal to 0.91 after wolf removal
- calf recruitment increased from 0.12-0.19
- population growth rate increased from 0.94-0.99 (population stabilized but did not increase)

Redrock Prairie-Creek herd (control area):

- cow survival decreased from 0.83 (in five years before wolf control in treatment area) to 0.79 (after treatment)
- recruitment decreased from 0.19-0.17
- population growth rate decreased from 0.90-0.86 (population continued to decline)

11. Predator Response: removed 579 wolves by aerial shooting, 154 wolves by toxicant bait stations, and 108 wolves were removed by fur trappers. Data on wolf population after treatment was not specified.

Hervieux et al. (2014) concluded that predator control was an effective short-term strategy for slowing population decline in the LSM, but that control programs in combination with long-term habitat conservation and management could increase the population.

Yukon

There are no active predator control programs under implementation in caribou ranges by the Government of YK as of publication of this report. Previous wolf control programs in YK were reviewed by Russell (2010).

Northwest Territories

There are no active predator control programs under implementation in the NWT, although, wolf harvest incentive programs are on-going (see previous sections). Past wolf control programs were conducted in the territory to address concerns about declining barren-ground caribou and bison populations and included sporadic wolf removals around Wood Buffalo National Park, bounties, poisoning programs, aerial shooting, and subsidized hunting of pups in dens (Kelsall 1968, Van Camp 1987). In addition to the government's poisoning program from 1951-1964 (see *Poisoning* section), wolf control was conducted by the government from 1977-1979 in a 5,600 km^2 area of the Slave River Lowlands through aerial shooting by helicopter and increased incentives to trappers. These control efforts aimed to address concerns about the declining bison population, and although wolf removals reduced predation on bison and improved calf recruitment, herd sizes did not increase, likely owing to additional factors (disease, winter severity, other predators; Heard 1983, Van Camp 1987). Ultimately, wolf control ended due to a lack of cooperation by hunters, who continued to harvest bison (Heard 1983).

An on-going program that removes wolves from barren-ground caribou winter ranges in the NWT, albeit not intended to be specific to wolves or their management, is the annual Border A-licensed hunt at Rennie Lake. First Nations hunters from northern Saskatchewan communities regularly come to the Rennie Lake area to hunt caribou, wolves, and wolverines in the winter. Approximately 260 wolves are harvested annually and the total harvest is generally related to pelt prices and abundance of wolves on the caribou winter range (Cluff et al. 2010). A significant portion of the annual NWT wolf harvest is attributed to the Rennie Lake hunt (Cluff et al. 2010).

COST OF PREDATOR CONTROL PROGRAMS

Publicly available costs of predator control programs can be difficult to obtain. Budgets allocated to programs involving non-lethal control of predators (e.g. diversionary feeding, relocation, sterilization), in particular, have not been found. Russell (2010, p. 21) gave some examples of costs associated with past predator control programs in AK, YK, and AB. Cluff and Murray (1995, p. 499) provided references for costs associated with aerial shooting of wolves which ranged from $140/wolf to $2,500/wolf.

In BC, aerial removal of 154 wolves in the South Peace Region in winter 2015/16 cost approximately $400,000 and included three helicopter crews (for capturing, radio collaring, shooting of wolves and bait placement), a fixed-wing aircraft for snow tracking, and aerial transport of wolf carcasses for use by First Nations trappers (D. Seip, personal communication). Further, the South Selkirk wolf control program cost the government $106,000 during the 2015/16 fiscal year and included ground trapping to deploy collars and aerial tracking surveys and shooting of wolves by helicopter. A total of nine wolves were removed from two packs (L. DeGroot, personal communication). In AB, the recent aerial wolf control program on the range of the LSM has been estimated at $35/km^2 annually (Schneider et al. 2010).

Alaska's annual reports to the Board of Game for its various predator control programs outline the money spent annually on research associated with predator control programs (if applicable), in addition to the operational costs of implementation (examples in Table 7). Costs for predator management in GMU 19A for moose are included in Table 7 to show expenditures for a program involving both wolf and bear reductions. The true cost of the AK programs, however, may be underestimated in these reports if the programs include permitted private citizens, because they are not paid for their removal services.

Table 7. Cost of predator control and associated research activities (USD) in AK.

Area	Year	Predators Removed (Department and Private Contractors)[a]		Salary and Operations Costs (USD)	Research Costs (USD)	Method of Predator Reduction
		Wolves	Bears			
[1]GMU 12, 20B, 20D, 20E, 25C (FCH)	2011	64	n/a	$3,500	$67,000	Public aerial shooting permits, public land and shoot permits, departmental removals by helicopter
	2012	118	n/a	$242,500	$80,300	
	2013	62	n/a	$136,100	$12,000	
	2014	57	n/a	$96,000	$98,000	
[2]GMU 19A (Moose)	2011	8	n/a	$3,500	0	Public aerial shooting permits (wolves), public land and shoot permits (wolves), departmental aerial, land and shoot and ground-based removal (wolves and bears)
	2012	0	89	$3,900	0	
	2013	6	64	$408,700	0	
	2014	2	0	$260,300	0	

[1] modified from Table 8, pg.8, in Alaska Department of Fish and Game 2016*b*
[2] modified from Table 7, pg.9, in Alaska Department of Fish and Game 2016*f*
[a] does not include unpaid private permit holders

The cost of a predator control program should be viewed more broadly than the direct money allocated to implementing and monitoring the program. Additional activities can be affected, either positively or negatively, by predator management and be seen as additional costs including changes in opportunities for hunting/recreation (for both ungulate and predator populations), tourism/wildlife viewing, and First Nations and local subsistence and traditional uses. Additionally, indirect costs to the government implementing the program can also occur. For example, unless additional government resources (funding and staff) are made available upon proceeding with a predator control program, the costs and time associated with implementation and research and monitoring of the program could reduce or eliminate the ability to deliver on other wildlife initiatives (NRC 1997).

PREDATOR PIT HYPOTHESIS

Justification for predator control occasionally references the predator pit hypothesis or two-state equilibrium hypothesis. Messier (1994) used the hypothesis to explain regulation in predator-prey systems (i.e. predation-food two-state model). At the low-density equilibrium state, prey are limited by predation. Recruitment into the population is not enough to compensate for losses due to predation, so prey populations remain in the lower equilibrium (referred to as the “predator pit”; Messier 1994, NRC 1997). If prey populations can overcome the predator pit, they stabilize at a high-density equilibrium and are resource-limited (e.g. by food availability). Predator densities are also high at this equilibrium, but predation rates do not regulate the prey population. If this theory of two stable states exists in predator-prey systems, short-term predator control could be effective at releasing prey from the predator pit, leading to high prey densities, but support for this hypothesis is rare (Messier 1994, NRC 1997).

The best potential evidence for this hypothesis comes from predator control in GMU 20A in AK. Past predator control efforts in the area have resulted in continued high moose densities that now support both high human harvest and high predation rates by wolves (Alaska Department of Fish and Game 2007, Titus 2007). Moose in the area are now limited by food (Alaska Department of Fish and Game 2016*a*), suggesting that predator control (1976-1982), combined with hunting restrictions, and favourable weather (Boertje et al. 1996), released moose from the predator pit. GMU 20A experiences low predation on moose by bears (Boertje et al. 2010), indicating predator control in this one-predator system (i.e. wolves) may have also led to greater success of the program.

Short-term wolf control for intensive management of the Delta caribou herd (DCH) in GMU 20A (1993-1994), however, was largely unsuccessful and increases in calf survival and caribou abundance could not unequivocally be attributed to a reduction of wolves (Valkenburg et al. 2004). Boertje et al. (1996) suggested that, unlike with moose populations, it is difficult to maintain caribou at high densities for extended periods of time without periodic wolf control, weakening the argument of the ability of short-term predator control to release caribou from the predator pit.

FIRST NATIONS AND COMMUNITY INVOLVEMENT IN MANAGEMENT

From their review of predator programs in AK (and Canada), the NRC (1997) came to 17 conclusions from its findings, four of which included reference to involvement of the public in decision-making and management processes. Examples from past caribou recovery programs in YK emphasize the importance of cooperative management. Considerable involvement of local communities and First Nations people in all aspects of the Aishihik and Chisana caribou herd recovery programs was believed to lead to their success (Hayes and Couture 2004). In the Aishihik program, local citizens, First Nations, and wildlife management officials worked together to develop a wolf management plan prior to implementing any wolf control measures. First Nations people were also consulted on the Aishihik herd recovery plan and methods of wolf control, in addition to participating in local trapping of wolves, population surveys, and patrols of the herd to ensure compliance with harvest restrictions (Hayes and Couture 2004). Captive-rearing used in the Chisana caribou recovery program was decided as the best method of recovering the herd after various workshops were held and attended by scientists, First Nations, and local residents. Local participation continued through all stages of the program (Hayes and Couture 2004).

These program successes emphasize that involving local people in all stages of a project leads to overall acceptance of the management action and ensures a sense of pride and community ownership of the program. Furthermore, with greater local support for programs, it is easier for governments to justify investing in those programs and continuing their management and recovery efforts (Hayes and Couture 2004).

GUIDING DOCUMENTS

In BC and YK, management and conservation of wolves is guided by objectives and recommendations contained in provincial/territorial wolf management plans. The general framework of a management plan incorporates knowledge on the species' biology, habitat, population and distribution, and threats, and includes management goals and objectives, as well as information on current management practices. Such plans incorporate feedback from public consultations and First Nations people, in addition to input from government wildlife biologists and stakeholders (Government of YK 2012, BC Ministry of Forests, Lands and Natural Resource Operations 2014). Thereby, the plans provide recommendations on management actions that balance various interests and concerns, enhancing public involvement and transparency of wildlife management.

A central component of the wolf management plans in BC and YK is that they are adaptive and evolved as management and conservation knowledge of wolves changed. For example, the 1992 Yukon Wolf Conservation and Management Plan were largely focused on large-scale wolf control programs and recovery of ungulate populations. The Plan included guidelines on (a) which conditions must exist for wolf control to be considered, (b) whether to proceed with a wolf control program, and (c) implementation of a wolf control program (Yukon Wolf Management Planning Team 1992). This plan was developed during a period when wolf reduction programs were underway or being considered.

In contrast, the 2012 Yukon Wolf Conservation and Management Plan represented a shift in management objectives. The Plan no longer supported use of aerial wolf control as a management tool, demonstrating an adaptive management response to results of previous management actions. BC's current wolf management plan also reflects a change in government policies, which no longer support management of wolves for enhancing populations of game species for hunting purposes (BC Ministry of Forests, Lands and Natural Resource Operations 2014).

The province of AB's wolf management plan was last updated in 1991, and therefore, it is unclear if it is still used as a guiding document for current wolf management practices. The 1991 Management Plan for Wolves in AB clearly outlined the conditions that needed to be met before wolf population reductions could be considered (i.e. wolf predation was identified as an important limiting factor for endangered, threatened, or rare ungulate populations) and the information required before any control was initiated (Government of Alberta 1991). It can be argued that such guidelines were used to support the recent wolf control program on the range of the LSM.

The NWT currently does not have a wolf management plan and therefore, any considerations of wolf management on the range of the Bathurst caribou herd cannot be informed by management goals and objectives for wolves from a broad territory plan.

PREDATOR MANAGEMENT ON MIGRATORY CARIBOU HERD RANGES

It is challenging to extrapolate predator management strategies and their results from other jurisdictions to the barren-ground caribou herds of the NWT, because these programs were not conducted on migratory caribou ranges with migratory wolves. Despite AK's extensive experience with predator control programs, none have been on the ranges of their four migratory caribou herds (Porcupine, Central Arctic, Western Arctic, Teshekpuk); results from predator control on the range of the FCH may be the best comparison.

Generally, an understanding of the complexity associated with wolf management in a migratory predator-prey system is warranted. Barren-ground caribou herds, such as the Bathurst, can migrate large distances between northern calving grounds and southern wintering ranges along or below the treeline. As they migrate, migratory tundra wolves will follow, but it is unknown if these wolves associate with and prey upon one herd continuously. This is particularly apparent in the winter, when multiple barren-ground caribou herds may overlap in the same area, which can result in a concentration of wolves associated with various herds, some travelling as far as 600 km to follow caribou to their winter range (Cluff et al. 2010). This is believed to have happened in the Rennie Lake area of the NWT in 1997/98 when caribou from the Beverly, Bathurst, and Ahiak herds all congregated on the same winter range, causing an unusually large abundance of wolves that normally associate with the herds elsewhere in the winter (Cluff et al. 2010). This mixing of wolves between caribou herds can make it challenging to implement a program with the objective of managing wolves and/or their predation specific to one herd. Further, because barren-ground caribou winter at or below the treeline, sedentary boreal wolves have access to them on their winter ranges (Cluff et al. 2010), contributing to additional predation on these herds seasonally. Therefore, implementing a wolf management program on a migratory caribou herd would need to consider all wolves in the system. Overall, wolf management for the Bathurst caribou herd may require management action on wolves from multiple migratory caribou herds and on sedentary wolves associated with the herd only seasonally, potentially complicating the decision-making and justification processes.

When considering some of the predator control programs showing promising results in AK, BC, and AB, four common characteristics are (a) caribou herd under management is small with a small range (FCH and MCH are exceptions), (b) wolves associated with caribou herd of concern are sedentary/resident, (c) high wolf abundance prior to control is sustained by alternate prey (e.g. moose, deer, elk), and (d) there is the ability to quantify demographics of the caribou herd in the treatment area with a herd in a control area. The effectiveness of predator control programs is often dependent on these characteristics, which may not be applicable to tundra ecosystems with migratory caribou.

The closest comparisons for the large, migratory caribou herds in the NWT are the migratory woodland caribou herds in the provinces of Newfoundland and Labrador (George River) and Québec (Leaf River, George River); neither herd having active predator control programs despite concerns over declining caribou abundance.

Similar to the Bathurst herd, the George River caribou herd (GRCH) has experienced a severe decline. The herd is presently at <1% of its former abundance (J. Pisapio, personal communication). Under the province of Newfoundland and Labrador’s 2011-2017 Labrador Caribou Initiative (LCI) and in collaboration with the province of Québec and Caribou Ungava (Laval University), research and monitoring programs have been established to better understand the reasons for the decline of the GRCH and to generate science-based information to inform management decisions (Labrador and Aboriginal Affairs 2011). In 2013, the province of Newfoundland and Labrador implemented a five-year ban on all hunting of George River caribou in Labrador in response to findings generated from the LCI, which showed continuing and extensive decline of the herd.

According to the Senior Wildlife Biologist, the general approach being taken with respect to predation considerations is to conduct intensive wolf and black bear collaring studies to support decision making. Preliminary data from the wolf collaring program suggest that wolf numbers have likely declined substantially along with the decline of the George River herd. Collaring studies on both caribou and wolves (and also black bears on the caribou calving grounds) are intended to support a science-based assessment of the relative impact and significance of wolf (and bear) predation on the GRCH under the current conditions of low caribou abundance. In addition to predation considerations, other areas of investigation relating to the GRCH include caribou blood-borne pathogens and viruses, stress hormone studies, caribou movements, distribution and habitat use, land-use activities and disturbances, and range condition (J. Pisapio, personal communication).

In Québec, the Leaf River Caribou Herd (LRCH) has declined from approximately 600,000 to 300,000 since the early 2000s (V. Brodeur, personal communication). The provincial government and in collaboration with Caribou Ungava is monitoring the herd to assess trends and determine reasons for its decline. A reduction in the number of tags issued by the provincial government to outfitters for sport hunting is the main management action that was taken to address this significant decline. Reports from First Nations communities, outfitters, and observations during government field operations of an increasing number of caribou kills suggest that wolf abundance on the range of the herd is increasing. However, there is currently not a significant interest by the communities to increase their harvest of predators, which is close to null on the herd's wintering range where wolves are believed to have the best access to caribou. Recently, there has been a proposal by the government to allow outfitters to offer sport hunting of wolves on the winter range of the LRCH, but the purpose of the proposal is not to manage wolves, but rather to diversify hunting and economic opportunities on a species that appears to be abundant. At present time, the objectives of the government are to gather and evaluate scientific data from collaring studies on the herd and its predators to determine appropriate management actions (V. Brodeur, personal communication).

In the absence of any current predator management initiatives being implemented on migratory caribou ranges from which to extrapolate results, it may be advisable to ensure any decision to implement a wolf management program on the range of the Bathurst herd is supported by evidence of the requirement for such actions, and also sufficient indication that this would result in the desired outcome (i.e., long-term growth of the herd) given the challenges presented by the migratory predator-prey system. Following the decision-making approach suggested by the NRC during their review of predator control programs (i.e. Figure 1) may prove to be beneficial.

KEY CONCLUSIONS ON WOLF MANAGEMENT

In summary, some key points can be concluded from past and current wolf control programs:

- Rationale for wolf management should include evidence suggesting wolf predation is a limiting factor on the ungulate population.
- Critical to justify, implement, monitor, and evaluate the program with data.
- Justification of program should include evaluation of humaneness of methods proposed.
- Set attainable objectives keeping in mind a high percentage of the wolf population needs to be removed annually (≥55%, NRC 1997; 80%, Hayes et al. 2003, Mountain Caribou Recovery Implementation Plan Progress Board 2012).
- Assess geographic scale required for conducting control efforts.
- Aerial wolf reduction programs are more likely to reach target objectives than traditional harvest methods (hunting and trapping).
- Wolf populations quickly rebound when treatment is removed due to immigration from surrounding areas, high reproductive rates, and improved ungulate abundance (wolf control is a short-term solution).
- Combination of lethal and non-lethal methods should be considered.
- Wolf reduction should be a last resort management tool.
- Requires substantial resources for implementation and long-term monitoring.
- Long-term recovery of ungulate populations may require additional management actions (e.g. harvest restrictions, habitat restoration and conservation).

Despite a lack of knowledge of the effectiveness of wolf management on ranges of migratory caribou, these broad conclusions from previous and on-going programs can still be informative in the decision-making process for wolf management on the range of the Bathurst caribou herd.

PERSONAL COMMUNICATIONS

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LITERATURE CITED

Alaska Department of Fish and Game. 2007. Predator management in Alaska. Division of Wildlife Conservation, Juneau, AK. 32pp.

Alaska Department of Fish and Game. 2010. Upper Yukon/Tanana predation control implementation plan and activities: Division of Wildlife Conservation report to the Alaska Board of Game. Division of Wildlife Conservation, Juneau, AK. 6pp.

Alaska Department of Fish and Game 2014. Stories of success. Division of Wildlife Conservation. Juneau, AK. 16pp.

Alaska Department of Fish and Game. 2016*a*. Intensive management in Alaska. www.adfg.alaska.gov/index.cfm?adfg=intensivemanagement.main. Accessed 15 March 2016.

Alaska Department of Fish and Game. 2016*b*. Annual report to the Alaska Board of Game on intensive management for Fortymile caribou with wolf predation control in the Upper Yukon-Tanana predation control area of Game Management Units 12, 20B, 20D, 20E and 25C. Division of Wildlife Conservation, Juneau, AK. 9pp.

Alaska Department of Fish and Game. 2016*c*. Annual report to the Alaska Board of Game on intensive management for caribou with wolf predation control in Game Management Units 9B, 17B&C, and 19A&B, the Mulchatna Caribou Herd. Division of Wildlife Conservation, Juneau, AK. 10pp.

Alaska Department of Fish and Game. 2016*d*. 5 AAC 92.111. Intensive management plans I. www.legis.state.ak.us/basis/folioproxy.asp?url=http://wwwjnu01.legis.state.ak.us/cgi-bin/folioisa.dll/aac/query=[JUMP:%275+aac+92!2E111%27]/doc/{@1}?firsthit. Accessed on 24 March 2016.

Alaska Department of Fish and Game. 2016*e*. Annual report to the Alaska Board of Game on intensive management for caribou with wolf predation control in the Northern Alaska Peninsula, Game Management Unites 9C and 9E, Northern Alaska Peninsula Caribou Herd. Division of Wildlife Conservation, Juneau, AK. 9pp.

Alaska Department of Fish and Game. 2016*f*. Annual report to the Alaska Board of Game on intensive management for moose with wolf, black bear, and grizzly bear predation control in Game Management Unit 19A. Division of Wildlife Conservation, Juneau, AK. 9pp.

Baker, S.E., T.M. Sharp, and D.W. Macdonald. 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.

BC Ministry of Forests, Lands and Natural Resource Operations. 2014. Management plan for the grey wolf (*Canis lupus*) in British Columbia. BC Ministry of Forests, Lands and Natural Resource Operations, Victoria, BC. 48pp.

Boertje, R.D., P. Valkenburg, and M.E. McNay. 1996. Increases in moose, caribou, and wolves following wolf control in Alaska. Journal of Wildlife Management 60: 474–489.

Boertje, R.D., M.A. Keech, and T.F. Paragi. 2010. Science and values influencing predator control for Alaska moose management. Journal of Wildlife Management 74: 917–928.

Braid, A.C.R., E. Cameron, A. Fisher, R. Gibbs, J. Hampton, B. Jones, P. McGreevy, R. Rose, and T. Sharp. 2015. Assessing the humaneness of wild horse management methods: Kosciuszko National Park Wild Horse Management Plan. A report on the outcomes of a humaneness assessment panel assembled on behalf of the Independent Technical Reference Group (ITRG), Office of Environment and Heritage, New South Wales, Sydney, Australia. 70pp.

Brook, R.K., M. Cattet, C.T. Darimont, P.C. Paquet, and G. Proulx. 2015. Maintaining ethical standards during conservation crises. Canadian Wildlife Biology and Management 4: 72–79.

Chisana Caribou Recovery Team. 2010. Recovery of the Chisana caribou herd in the Alaska/Yukon borderlands: captive-rearing trials. Yukon Fish and Wildlife Branch Report TR-10-02, Whitehorse, YK. 35pp.

Cluff, H.D. and D.L. Murray. 1995. Review of wolf control methods in North America. Pages 491-504 *in* L.N. Carbyn, S.H. Fritts, and D.R. Seip, eds. Ecology and Conservation of Wolves in a Changing World. Canadian Circumpolar Institute, University of Alberta, Edmonton, AB.

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 235-259 *in* M. Musiani and L. Boitani, eds. The World of Wolves: New Perspectives on Ecology, Behaviour, and Management. University of Calgary Press, Calgary, AB.

DeCesare, N.J., Hebblewhite, M., Robinson, H.S., and M. Musiani. 2010. Endangered, apparently: the role of apparent competition in endangered species conservation. Animal Conservation 13: 353–362.

Ecosystem Classification Group. 2012. Ecological regions of the Northwest Territories - Southern Arctic. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NWT. 170pp.

Environment Canada. 2012. Recovery strategy for the woodland caribou (*Rangifer tarandus caribou*), boreal population, in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa, ON. 138pp.

Farnell, R. 2009. Three decades of caribou recovery programs in Yukon: a paradigm shift in wildlife management. Government of Yukon, Department of Environment Branch Report MRC-09-01, Whitehorse, YK. 22pp.

Gardner, C.L. 2010. Reducing non-target moose capture in wolf snares. Alces 46: 167–182.

Garvey, M.E. and B.R. Patterson. 2014. Evaluation of cable restraints to live-capture coyotes (*Canis latrans*) in southern Ontario, Canada. Canadian Wildlife Biology and Management 3: 22–29.

Government of Alberta. 1991. Management plan for wolves in Alberta. Wildlife Management Planning Series Number 4. Forestry, Lands and Wildlife, Fish and Wildlife Division, Edmonton, AB. 100pp.

Government of British Columbia. 2014*a*. Experimental wolf reduction to enhance the recovery of threatened caribou herds in the South Peace. 13pp.

Government of British Columbia. 2014*b*. South Selkirk mountain caribou wolf management plan. 6pp.

Government of Yukon. 2012. Yukon wolf conservation and management plan. Environment Yukon, Whitehorse, YK. 24pp.

Haight, R.G. and L.D. Mech. 1997. Computer simulation of vasectomy for wolf control. Journal of Wildlife Management 61: 1,023–1,031.

Hampton, J.O., T.H. Hyndman, A. Barnes, and T. Collins. 2015. Is wildlife fertility control always humane? Animals 5: 1,047-1,071.

Hayes, B. 2013. Quesnel Highland wolf sterilization pilot assessment 2012: An independent evaluation. Prepared by B. Hayes, Wildlife Management Planning and Analysis, Smithers, British Columbia. 30pp.

Hayes, R.D., R. Farnell, R.M.P. Ward, J. Carey, M. Dehn, G.W. Kuzyk, A.M. Baer, C.L. Gardner, and M. O'Donoghue. 2003. Experimental reduction of wolves in the Yukon: ungulate responses and management implications. Wildlife Monographs 67: 1-35.

Hayes, K. and G. Couture. 2004. Community involvement in recovering woodland caribou populations: Yukon success stories. Pages 1-7 *in* T.D. Hooper, ed. Proceedings of the Species at Risk 2004 Pathways to Recovery Conference. Victoria, BC.

Heard, D.C. 1983. Historical and present status of wolves in the Northwest Territories. Pages 44-47 *in* L.N. Carbyn, ed. Wolves in Canada and Alaska: their status, biology, and management. Canadian Wildlife Service. Report Series 45. Ottawa, ON.

Hervieux, D., M. Hebblewhite, D. Stepnisky, M. Bacon, and S. Boutin. 2014. Managing wolves (*Canis lupus*) to recover threatened woodland caribou (*Rangifer tarandus caribou*) in Alberta. Canadian Journal of Zoology 92: 1,029–1,037.

Kelsall, J.P. 1968. The migratory barren-ground caribou of Canada. Canadian Wildlife Service, Department of Indian Affairs and Northern Development. Ottawa, ON. 340pp.

Labrador and Aboriginal Affairs. 2011. Standing Strong for Labrador through the Northern Strategic Plan, Government of Newfoundland and Labrador. www.releases.gov.nl.ca/releases/2011/laa/0419n13.html). Accessed 22 March 2016.

Littin, K.E. and D.J. Mellor. 2005. Strategic animal welfare issues: ethical and animal welfare issues arising from the killing of wildlife for disease control and environmental reasons. Revue Scientifique et Technique-Office International des Epizooties 24: 767-782.

McNay, R.S. 2009. Spatial and temporal patterns of predation risk on woodland caribou in the Wolverine and Chase herds, north-central British Columbia, 1991-1996. Peace/Williston Fish and Wildlife Compensation Program Report No. 323. 22pp.

McNay, R.S., F. MacDonald, and L. Giguere. 2009. Mitigating risk of predation for woodland caribou in north-central British Columbia. Wildlife Infometrics Inc. Report No. 314. Wildlife Infometrics Inc., Mackenzie, BC. 56pp.

Mech, L.D., S.H. Fritts, and M.E. Nelson. 1996. Wolf management in the 21st century: from public input to sterilization. Journal of Wildlife Research 1: 195-198.

Messier, F. 1994. Ungulate population models with predation: a case study with the North American moose. Ecology 75: 478–488.

Mountain Caribou Recovery Implementation Plan Progress Board. 2012. Annual report on activities and accomplishments of the Mountain Caribou Recovery 2011-12. 27pp.

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.

Proulx, G. and D. Rodtka. 2015. Predator bounties in western Canada cause animal suffering and compromise wildlife conservation efforts. Animals 5: 1,034–1,046.

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

Proulx, G., R.K. Brook, M. Cattet, C. Darimont, and P.C. Paquet. 2016. Poisoning wolves with strychnine is unacceptable in experimental studies and conservation programmes. Environmental Conservation 43: 1–2.

Russell, D. 2010. A review of wolf management programs in Alaska, Yukon, British Columbia, Alberta and Northwest Territories. Prepared by D. Russell, Shadow Lake Environmental Consulting, for Yukon Wolf Conservation and Management Plan Review Committee. 47pp.

Sahtú Renewable Resources Board. 2016. Addendum to Environment and Natural Resources Responses to Bluenose-East Caribou Herd Management Proposal Sahtú Renewable Resources Board Information Requests Round 1. 12pp.

Schneider, R.R., G. Hauer, W.L. (Vic) Adamowicz, and S. Boutin. 2010. Triage for conserving populations of threatened species: the case of woodland caribou in Alberta. Biological Conservation 143: 1,603–1,611.

Sharp, T. and G. Saunders. 2011. A model for assessing the relative humaneness of pest animal control methods. Vertebrate Pest Research Unit – Industry & Investment, New South Wales, Canberra, Australia. 126pp.

Skogland, T. 1991. What are the effects of predators on large ungulate populations? Oikos 61: 401–411.

Smith, K.G. and L. Pittaway. 2008. Little Smoky woodland caribou calf survival enhancement project. Rangifer 19: 97–102.

Spence, C.E., J.E. Kenyon, D.R. Smith, R.D. Hayes, and A.M. Baer. 1999. Surgical sterilization of free-ranging wolves. The Canadian Veterinary Journal 40: 118–121.

Thomas, D.C. 1995. A review of wolf-caribou relationship and conservation implications in Canada. Pages 261-273 *in* L.N. Carbyn, S.H. Fritts, and D.R. Seip, eds. Ecology and Conservation of Wolves in a Changing World. Canadian Circumpolar Institute, University of Alberta, Edmonton, AB.

Titus, K. 2007. Intensive management of wolves and ungulates in Alaska. Transactions of the North American Wildlife and Natural Resources Conference 72: 366–377.

Valkenburg, P., M.E. McNay, and B.W. Dale. 2004. Calf mortality and population growth in the Delta caribou herd after wolf control. Wildlife Society Bulletin 32: 746–756.

Van Ballenberghe, V. 2004. Biological standards and guidelines for predator control in Alaska: application of the National Research Council's recommendations. Paper presented at 2004 Carnivore Conference, November 16, 2004 in Santa Fe, New Mexico, USA. Defenders of Wildlife, Washington, DC. 13pp.

Van Ballenberghe, V. 2006. Predator control, politics, and wildlife conservation in Alaska. Alces 42: 1–11.

Van Camp, J. 1987. Predation on bison. Pages 25-33 *in* H.W. Reynolds and A.W.L. Hawley, eds. Bison Ecology in Relation to Agriculture Development in the Slave River Lowlands, NWT. Canadian Wildlife Service Paper No. 63. Canadian Wildlife Service, Minister of Supply and Services Canada 1987. Cat No. CW 69-1/63E.

Wilson, S.F. 2009. Recommendations for predator-prey management to benefit the recovery of mountain caribou in British Columbia. Prepared by S. Wilson for BC Ministry of Environment, Victoria, BC. 25pp.

Wilson, S.F. 2010. Estimating the short-term benefit of wolf management to mountain caribou herds. Prepared by S. Wilson for Ecosystems Branch, BC Ministry of Environment, Victoria, BC. 10pp.

Wittmer, H.U., B.N. McLellan, R. Serrouya, and C.D. Apps. 2007. Changes in landscape composition influence the decline of a threatened woodland caribou population. Journal of Animal Ecology 76: 568–579.

Yukon Department of Environment. 2011. Can non-lethal methods effectively reduce wolf numbers? Results of the Aishihik wolf fertility control experiment. Yukon Fish and Wildlife Branch Report TR-11-02, Whitehorse, YK. 6pp.

Yukon Wolf Management Planning Team. 1992. The Yukon wolf conservation and management plan. Yukon Renewable Resources. 17pp.

APPENDIX

Glossary

Chemical sterilization: non-surgical procedure that involves injection of steroids, vaccines, or chemical compounds into an individual to interfere with normal reproductive processes and cause infertility.

Herd range: geographic area over which a herd is distributed; can vary by season and change in location and size annually.

Migratory wolf: does not defend a specific area on the landscape and may move vast distances with prey as they migrate seasonally (e.g. barren-ground caribou).

Proximate cause: immediate trigger for an observed situation; describes how a situation occurred and is related to the ultimate cause.

Recruitment: addition of new individuals into a population, usually through birth and survival of juveniles.

Relocation: movement of a target individual from one location to another; usually requires capture and sedation.

Rendezvous site: area used by wolf pups when they are old enough to leave the den, but not old enough to accompany adults on hunts; adult wolves may move pups between multiple rendezvous sites.

Resident wolf: occupies and defends a specific geographic area (territory) and carries out all basic life requirements (e.g. breeding, pup rearing, hunting, etc.) in this same area year-round, generally with a mate and other members of a pack; the occupied area is defended through scent-marking, howling, and harassment of any wolves that attempt to intrude.

Tubal ligation: surgical procedure on females whereby the fallopian tubes are severed and tied to prevent contraception.

Ultimate cause: underlying or real reason for observed situation; describes why a situation occurred.

Vasectomy: surgical procedure on males whereby the vas deferens (tubes carrying sperm from the testes) are severed to prevent contraception.