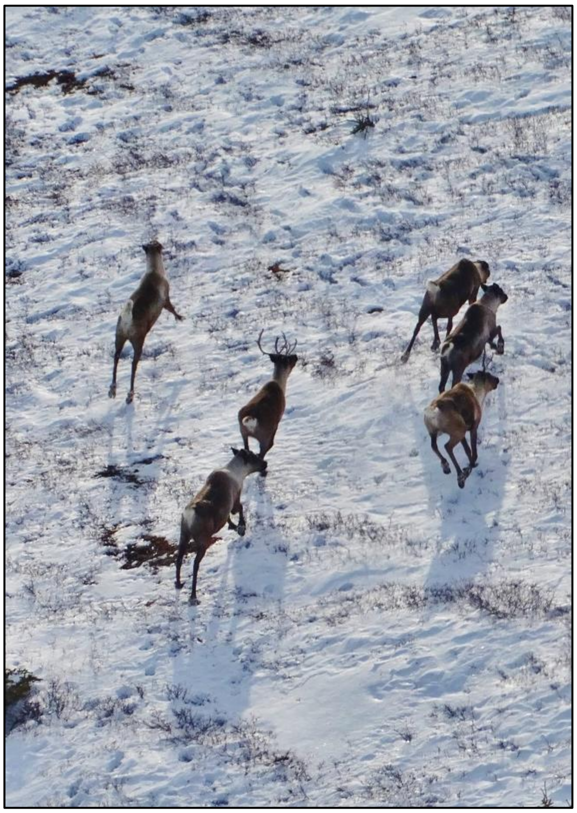
South Peace Caribou Recovery following Five Years of Experimental Wolf Reduction



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Foreword

Woodland caribou declines are caused by habitat alteration and loss that lead to more predators, and more efficient hunting by predators because of linear features created by humans. Unfortunately, if caribou are to be conserved, the best scientific evidence suggests that predator reductions will have to take place until habitat restoration and protection overcome the legacy of habitat loss. The report titled "South Peace Caribou Recovery following Five Years of Experimental Wolf Reduction" does an excellent job of documenting increased caribou survival and population growth rates as a result of predator reductions. The experimental design is sound and the data support the conclusion that the South Peace caribou herds responded positively to wolf reductions. Again though, the ultimate driver is habitat alteration, and over the long term, sustainable caribou populations will only be achieved if habitat gain exceeds habitat loss.

- Dr. Rob Serrouya, Director of Caribou Monitoring Unit – Alberta Biodiversity Monitoring Institute

Executive Summary

Experimental wolf reduction has occurred over a five-year period (2015-2019) within the South Peace region of northeastern British Columbia, Canada, in an attempt to address the rapid decline of Central Mountain caribou populations. These caribou herds have declined drastically in response to landscape changes that altered predator-prey dynamics and led to high rates of predation by wolves. The decrease in wolf abundance across the South Peace treatment area has shown conclusive evidence that intensive wolf reduction has halted and reversed the declining trends of the Klinse-Za, Kennedy Siding, and Quintette caribou populations. Although the first year of wolf reduction did not occur at a high enough intensity to elicit a caribou population effect, the following three years were sufficiently intensive (i.e. wolf densities were reduced to below 2 wolves/1000 km^2) to elicit a strong, positive population response in all three treatment herds. The reduction of wolves during the fifth year is also expected to elicit a positive population response, but will not be measured until March 2020. As a result of wolf reduction, the South Peace caribou populations have increased by 49% from 166 individuals in 2016 to 247 individuals in 2019. The three herds combined had an average annual population growth rate of 15% following three effective years of wolf reductions and calf recruitment and adult female survival has increased in almost all cases in response to intensive wolf reductions. In contrast, prior to the implementation of wolf reduction, these three herds were declining at a rate of approximately 15% annually (625 to 166 individuals; 2002–2015). The adjacent, non-treatment caribou herds continued to show strong evidence of rapid declines over the same timeframe in the absence of wolf reduction.

Aerial wolf reduction has been shown to be the most targeted and effective method of intensively reducing wolf populations over large geographic areas to elicit strong population responses in caribou herds. Both the efficacy and efficiency of the South Peace wolf reduction program has increased over time. The success of the program is contingent on utilizing experienced and proficient removal crews, operating during optimal weather conditions, and maintaining a high level of operational oversight by provincial Ministry staff. Wolf reduction is a management tool that must be used responsibly and ethically, and implemented with the highest standards for humaneness and scientific rigour. Wolf reduction programs should be considered as an effective interim management tool for halting and reversing caribou declines, while the ultimate causes (i.e. habitat alteration) of such declines are addressed. Based on the findings of the five-year wolf reduction program in the South Peace, it is highly recommended that wolf reduction continue to be implemented to support these particular caribou herds towards meeting the ultimate management objective of self-sustaining populations.

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1. Introduction

Throughout the 1990s and early 2000s, woodland caribou (*Rangifer tarandus caribou*) herds in the South Peace region of northeast British Columbia (BC) were presumed to be declining (Seip and Jones 2014). Increased monitoring efforts through the 2000s confirmed that these caribou herds were in fact decreasing at a rapid rate (Seip and Jones 2016). The status of the Central Mountain Designatable Unit (DU8; COSEWIC 2011) of woodland caribou found in the South Peace (Figure 1) has recently been updated to "Endangered" by the Committee on the Status of Endangered Wildlife in Canada. The South Peace herds include the Scott East and Moberly (which were combined in 2015 and are hereafter referred to as the Klinse-Za herd), Burnt Pine, Kennedy Siding, Quintette, Bearhole-Redwillow, and South Narraway (transboundary with Alberta). Within the South Peace region, these herds have further been grouped by local population units (LPUs), which includes the Pine LPU (composed of the Klinse-Za, Kennedy Siding, and former Burnt Pine herds), the Quintette LPU (composed of the Quintette herd), and the Narraway LPU (composed of the Bearhole-Redwillow and South Narraway herds). Prior to wolf reduction, all of these herds had been declining drastically, and the Burnt Pine herd was extirpated. These drastic declines followed extensive landscape change resulting from forest harvest, mining, oil and gas exploration, road construction and other industrial activities within or adjacent to caribou ranges. This has led to the direct loss of habitat and altered predator-prey dynamics. Many industrial activities promote early seral forests, which benefit species like moose (*Alces americanus*) and ultimately lead to increased wolf (*Canis lupus*) populations (moose are a primary prey species for wolves; Fuller et al. 2003). Such increases in wolf populations result in higher caribou mortality rates (Seip 1992), which can be further exacerbated by newly developed linear features that enhance wolf movement and provide access into caribou range. Wolf predation in the South Peace was occurring at rates that were unsustainable for caribou populations, leading to rapid population declines (Seip and Jones 2014).

Amongst the Central Mountain caribou herds found in the South Peace region, annual mortality rates of radio-collared adult females ranged from 12–24% (Seip and Jones 2014) prior to wolf reduction. Wolf predation accounted for 38% of all documented caribou mortalities, and 78% of all cases in which a conclusive cause of mortality was determined (Seip and Jones 2014). Calf recruitment ranged between 9–14% calves within the population (measured annually in late-March; Seip and Jones 2016), which was generally inadequate to compensate for adult mortality. The causes of calf mortality have not been investigated across the South Peace caribou herds; however, studies have shown wolves to be a significant predator of caribou calves in other jurisdictions (Gustine et al. 2006), and calf survival has been shown to increase in response to wolf reductions (Farnell and McDonald 1988, Seip 1992, Bergerud and Elliot 1998, Hayes et. al 2003). Previous research by Bergerud and Elliot (1986) concluded that wolf densities greater than 6.5 wolves/1000 km^2 resulted in caribou population declines. Furthermore, the Federal government's recovery strategy for woodland caribou recommends a target wolf density of less than 3 wolves/1000 km^2 across caribou range (Environment Canada 2014). Prior to the implementation of wolf reduction, wolf densities across the South Peace caribou herds were estimated at approximately 10–14 wolves/1000 km^2 (Seip and Jones 2014); well above the density thresholds associated with the persistence of caribou populations. The pre-reduction wolf density estimate has since been refined to 12.6 wolves/1000 km^2.

In response to dramatic caribou population declines, provincial wildlife managers from the BC Ministry of Environment and Ministry of Forests, Lands, Natural Resource Operations and Rural Development (hereafter referred to as the Province or Ministry) approved the implementation of predator management in the form of aerial wolf reduction. The initial approval was for a five-year aerial wolf reduction program, which commenced during the winter of 2014-2015, and has since completed its fifth year of reductions following the winter of

2018-2019. The wolf reduction program has occurred in combination with other recovery efforts, including maternal penning, supplemental feeding, and habitat restoration. In 2017-2018, the program was expanded to include the South Narraway caribou herd range. Wolf reduction was implemented as an interim management measure to assist the South Peace caribou herds in reaching self-sustaining status, with a population target of approximately 1,000 individuals (800 combined in the Pine and Quintette LPUs and 200 in the Narraway LPU). Serrouya et al. (2019) reported similar conclusions regarding population growth rates of the South Peace treatment herds; however, the following report has been developed to further investigate the mechanisms and drivers of caribou population change, such as variation in calf recruitment and adult survival, relative to wolf reduction treatments.

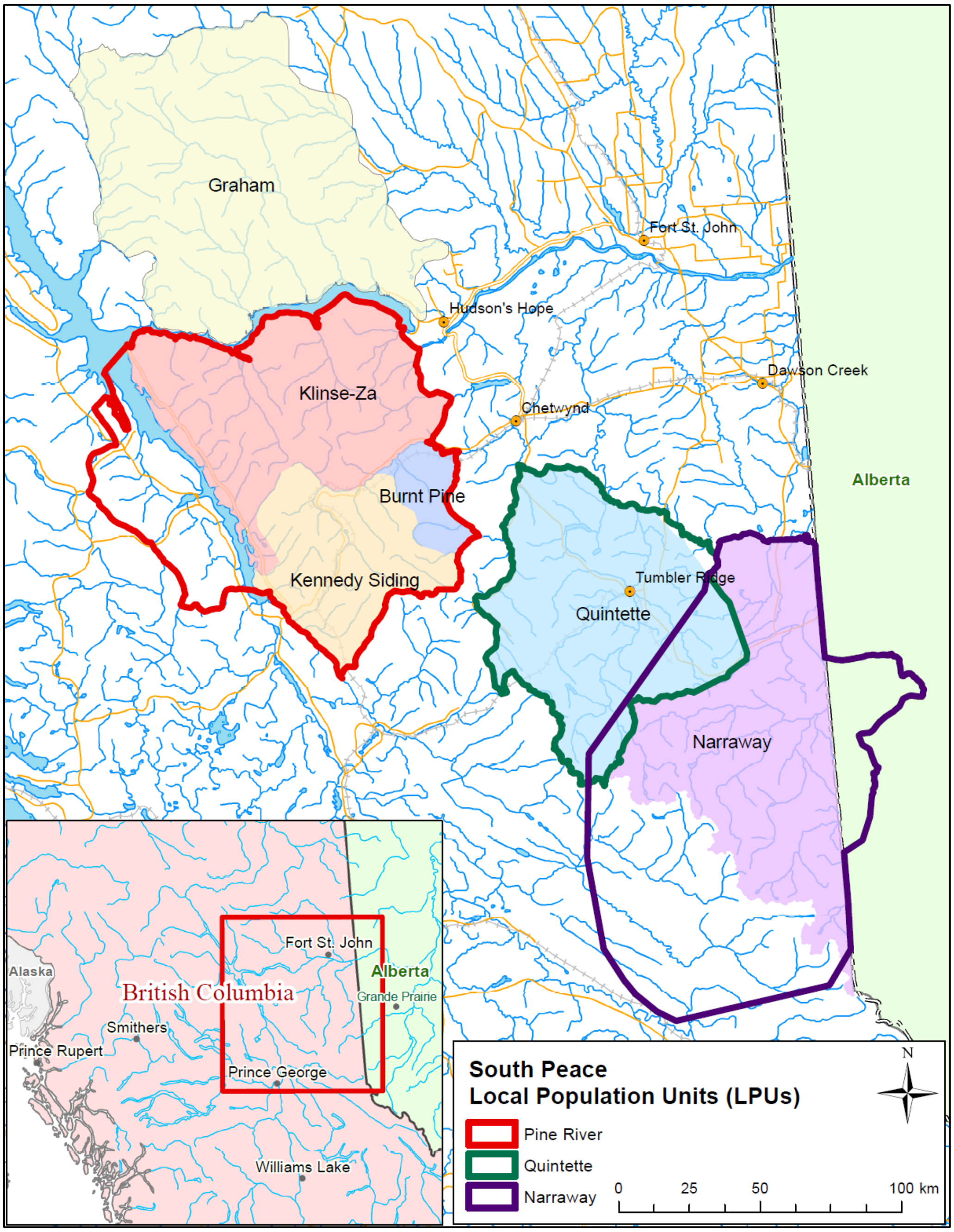

Figure 1. South Peace herd boundaries for Central Mountain caribou, including local population unit (LPU) boundaries in the Northeast Region of British Columbia, Canada.

2. Methods

Prior to the implementation of wolf reductions, baseline population data for both caribou and wolves were collected. These data were collected continually over the five-year study period to measure caribou population responses. Caribou population data, including population estimates and calf recruitment rates, were measured annually through aerial surveys. Adult female survival rates were calculated by monitoring a subsample of radio-collared individuals within the population, and cause of mortality was determined through mortality investigations of deceased radio-collared individuals. Wolf pack locations, habitat use, and density estimates were derived through radio-collaring of wolves. Additionally, the response by primary prey species (i.e. moose) to wolf reductions was also measured within and adjacent to the treatment areas through aerial surveys and radio-collaring studies.

The initial treatment area boundary was designed to encompass the majority of the Klinse-Za, Kennedy Siding, and Quintette caribou herd ranges; a wolf reduction zone of approximately 16,500 km^2 (Figure 2). Specifically, the boundary included the core high elevation and low elevation caribou habitat, and adjacent matrix habitat within the caribou ranges. The South Narraway treatment area was included in 2017-2018, with an additional area of approximately 1,600 km^2. These treatment areas formed the boundaries for intensive reduction of wolves using aerial gunning from helicopters, where the objective was to remove the majority of wolves within or immediately adjacent to the reduction zone and in doing so, reduce wolf densities to below 3 wolves/1000 km^2. Aerial gunning of wolves was deemed the most effective and humane method of removal, as properly applied shooting techniques results in wolves being quickly dispatched while eliminating the risk of bycatch. The reduction of wolves occurred during the winter months when snow levels facilitated optimal tracking conditions, and concentrated wolves' distribution at lower elevations. Reduction efficiency was increased by deploying radio-collars on individual wolves in all known wolf packs within or immediately adjacent to the treatment area boundary. This facilitated the relocation of the wolf packs and increased the likelihood of removing all wolves from each pack. The individual wolves were captured via helicopter net-gunning, which enabled crews to restrain the individuals and deploy GPS-satellite radio-collars, allowing for remote tracking of movements and locations, and relocation through the use of radio telemetry. The radio-collared individuals were often left alive following the conclusion of the winter reduction efforts in order to facilitate the location of wolves the following winter. Wolves that were found immediately adjacent to the reduction zone, or were tracked from within the boundary to adjacent areas were also removed (assuming these wolves had at least partial overlap with the treatment area).

Aerial wolf reduction was delivered primarily by external contractors, with operational oversight from Ministry staff. Overtime, the operational oversight was increased in order to ensure the efficacy and humaneness of the program and internal Ministry staff assisted with the delivery of the field operations as well. Initially, wolf removal crews attempted to retrieve the carcasses of deceased wolves; however, it was quickly determined to be an inefficient use of time, effort, and funds. Subsequently, the locations of accessible wolf carcasses were provided to First Nations and they retrieved those carcasses from the ground. The Province also collaborated with local First Nations to support wolf reduction through ground trapping programs. Although deemed ineffective on its own (Webb et al. 2011), ground trapping was thought to offer an additional source of wolf removal, while providing opportunities to collaborate with local First Nations communities. The ground trapping efforts were generally focused within the Klinse-Za caribou range, in close proximity to local First Nations communities and the caribou maternal penning site[1].

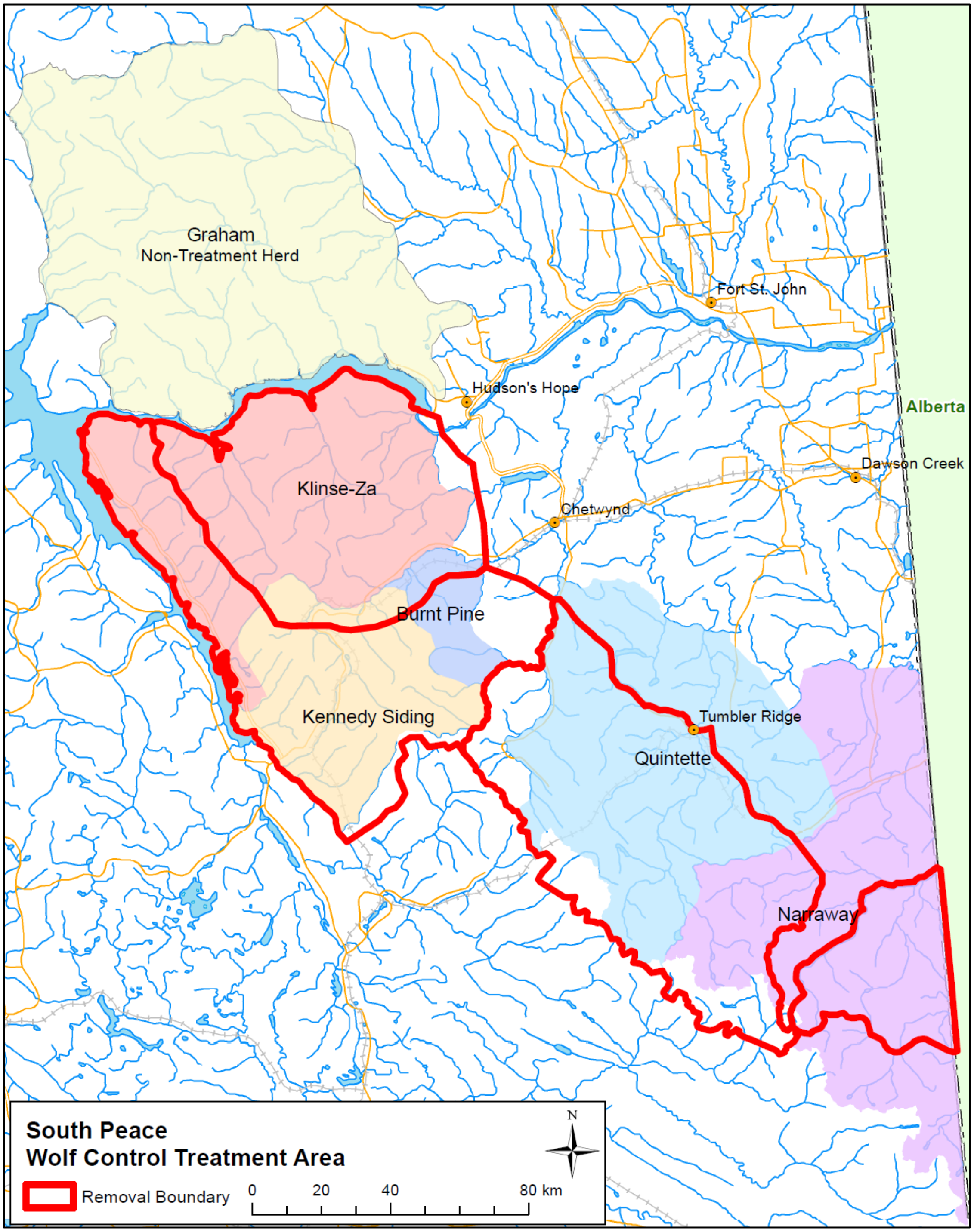

Figure 2. Treatment herds and wolf reduction boundaries across the South Peace caribou range in the Northeast Region of British Columbia, Canada.

[1] Maternal penning was an ongoing management initiative in the Klinse-Za caribou range that was occurring concurrently with wolf reduction (McNay et al. 2019)

The reduction of wolves occurred during five winters (2015-2019) and the response within caribou populations was measured during each of the following winters. Aerial surveys of most herds were conducted annually to estimate population size, calf survival/recruitment, and calculate population growth rates (also referred to as lambda λ; based on annual changes in population estimates). The Kennedy Siding herd was monitored via motion-sensitive cameras at supplemental feeding sites[2], allowing researchers to obtain total counts of the population, including population demographics (Heard and Zimmerman 2018). Additionally, a subsample of radio-collared female caribou was maintained in each herd during the five-year program to calculate adult female survival rates. Two adjacent, non-treatment herds (Graham and South Narraway herds) were identified as the experimental control populations for this program, allowing for population and demographic parameters to be compared between treatment and non-treatment herds over time. The South Narraway herd was subsequently removed as a non-treatment herd in 2017-2018 due to its continued rapid decline and urgent need for recovery measures (i.e. wolf reduction).

An initial wolf density estimate within the focal caribou herd ranges was derived through the radio-collaring of the majority of wolf packs in the area and through comparisons of previously recorded wolf densities observed in similar mountainous caribou ranges in neighbouring jurisdictions (Kuzyk 2002, Hayes et al. 2003). The estimates were further refined over the course of each winter's reduction efforts by documenting all wolves and wolf packs encountered during wolf removal flights. This allowed for relatively accurate documentation of the proportion of wolves removed each winter, and the subsequent density of wolves remaining following each winter's reduction efforts. The wolf density estimates were also calculated at the LPU level based on the number of wolves removed and number remaining following each winter season of wolf reduction. Similarly, wolf densities were also estimated across the non-treatment caribou herd ranges using a combination of radio collaring and extrapolation (i.e. Graham and South Narraway herds).

3. Results

Wolf Reductions

The wolf reduction program to support caribou recovery in the Klinse-Za, Kennedy Siding, and Quintette herds was initially approved during the winter of 2014-2015. The late approval for the program resulted in a delayed start to the field operations and an underspending of the budget (approximate cost of $200,000). This late start, combined with poor winter conditions (i.e. lack of snow) and relatively new removal crews, led to an ineffective wolf reduction effort. The initial wolf population estimate within or immediately adjacent to the treatment area was 208 wolves and a density of 12.6 wolves/1000 km^2. Overall, 57 wolves were removed from the reduction zone (41 removed by aerial gunning, 16 removed by ground trapping), equating to a reduction of only 27% of the wolf population. There was an estimated 151 wolves remaining in the treatment area, and a density of 9.4 wolves/1000 km^2 following the wolf reduction efforts. The remaining density estimates at the LPU scale were 10.8 wolves/1000 km^2 in the Pine LPU, and 6.5 wolves/1000 km^2 in the Quintette LPU.

Three external contractors were hired to deliver the majority of the field operations for the second year (2015-2016) of the wolf reduction program, with minimal operational oversight or field involvement from Ministry staff. Overall, 201 wolves were removed across the treatment area (155 removed by aerial gunning, 46 removed by ground trapping). The reduction rate was estimated at 97%, with only seven wolves remaining in the treatment area and a density estimate of 0.4 wolves/1000 km^2 following reduction efforts. At the LPU level, there was a remaining density estimate of 0.5 wolves/1000 km^2 in the Pine LPU, and 0.3 wolves/1000 km^2 in the

[2] Supplemental feeding is an ongoing management initiative in the Kennedy Siding caribou range (Heard and Zimmermann 2018)

Quintette LPU. Although the level of wolf reduction during the second year was very high, a lack of Ministry oversight resulted in inflated program costs of approximately $800,000.

The program was primarily delivered by two external contractors in the third year (2016-2017) of the program. There was a slight increase in operational oversight by Ministry staff, but minimal field involvement. Upon the conclusion of the third year of reduction efforts, an adequate number of wolves had been removed at a cost of approximately $475,000. Overall, 103 wolves were removed (62 by aerial gunning, 31 by ground trapping, and an additional 10 by ground shooting at den sites in the spring). The wolf reduction rate was estimated at 79%, with 27 wolves remaining in or adjacent to the treatment area and a density of 1.7 wolves/1000 km^2 following the reduction efforts. Within the Pine LPU, there was an estimated density of 2.0 wolves/1000 km^2 remaining, and 1.1 wolves/1000 km^2 remaining in the Quintette LPU.

The fourth year (2017-2018) of wolf reductions was delivered by one primary contractor and a secondary crew led by Ministry staff. The level of operational oversight by Ministry staff was increased significantly. The wolf reduction efforts upon conclusion of the winter season were highly successful, both in terms of reduction efficacy and cost efficiency (total cost of $376,000). Overall, 116 wolves were removed across the three treatment herds (all by aerial gunning; there were no conclusive reports of ground trapping removal). The wolf reduction rate was estimated at 92%, with only 10 wolves remaining within or immediately adjacent to the treatment area following the reduction efforts. This equated to a remaining density of 0.6 wolves/1000 km^2. At the LPU level, there was a density estimate of 0.3 wolves/1000 km^2 in the Pine LPU, and 1.1 wolves/1000 km^2 in the Quintette LPU. The winter of 2017-2018 also marked the first year of wolf reduction in the South Narraway caribou range. Fourteen wolves were removed on the BC side of the border (an additional 10 wolves were removed on the Alberta side). The reduction efforts in BC equated to an estimated reduction rate of 74%, with approximately five wolves remaining and a density of 3.1 wolves/1000 km^2. The total cost of conducting wolf reductions in the South Narraway was $81,000.

During the fifth year (2018-2019) of wolf reductions, field operations were delivered primarily by one contractor, with a high level of operational oversight from Ministry staff. The wolf reduction efforts were once again effective and relatively efficient, with a total cost of approximately $340,000. Overall, 61 wolves were removed (51 by aerial gunning, 10 by ground trapping). This equated to a reduction rate of 77%, with an estimated 18 wolves remaining within or immediately adjacent to the treatment area and a density of 1.1 wolves/1000 km^2. There was a remaining wolf density estimate of 1.0 wolves/1000 km^2 in the Pine LPU, and 1.3 wolves/1000 km^2 in the Quintette LPU. Within the South Narraway caribou range, it appeared that the wolf recovery rate was extremely low following the previous winter's reduction efforts. Only one wolf was removed from the BC side of the South Narraway range in 2018-2019, resulting in a remaining wolf density estimate of 1.9 wolves/1000 km^2.

Annual Caribou Population Results

The level of wolf reduction during the first year of wolf removals did not lead to a positive caribou population response, as evidenced by the population parameters reported the following year. Across the three caribou herds, the population had declined by an additional 13.5% ($\lambda = 0.865$) over the course of the year, the adult female survival rate was 78.7% ($n = 41$), and the proportion of calves in the population was 15.6% (measured late-March 2016). Within the Pine LPU, the population had increased by 14% ($\lambda = 1.14$), with an adult female survival rate of 85.7% ($n = 24$), but only 13.0% calves in the population. The Quintette LPU had declined by 38.0% ($\lambda = 0.62$), adult female survival was 64.7% ($n = 17$), however there were 20.0% calves in the population.

Following the second year of wolf reductions, the caribou population had increased across all three herds by 15.6% (λ = 1.156), the adult female survival was 92.7% (n = 41), and the proportion of calves in the population was 22.9%. Within the Pine LPU, the population had increased by 19.5% (λ = 1.195), with an adult female survival rate of 93.1% (n = 29) and 24.5% calves in the population. The Quintette LPU had increased by 10% (λ = 1.10), the adult female survival was 91.6% (n = 12) and 18.4% calves in the population.

Following the third year of wolf reduction, the caribou population increased by 6.7% (λ = 1.067), the adult female survival rate was 91.8% (n = 46), and the proportion of calves in the population was 18.6% (measured late-March 2018). Within the Pine LPU, the population had increased by 5.5% (λ = 1.055), with an adult female survival rate of 87.1% (n = 31) and 16.8% calves in the population. Within the Quintette LPU, the population increased by 9.0% (λ = 1.09), the adult female survival was 100% (n = 15), and 19.4% calves in the population.

The fourth year of wolf reductions led to a caribou population increase of 22.0% (λ = 1.22), the adult female survival rate was 89.2% (n = 46), and the proportion of calves in the population was 21.0% (measured late-March 2019). Within the Pine LPU, the population increased by 23.5% (λ = 1.235), with an adult female survival rate of 92.6% (n = 27), and 19.5% calves in the population. Within the Quintette LPU, the population increased by 18.9% (λ = 1.189), with an adult female survival rate of 77.8% (n = 9), and 25.0% calves in the population. Aerial survey efforts in the South Narraway documented a minimum observation of 38 caribou (up from 26 in March 2018), the adult female survival was 100% (n = 12), but only 13.2% calves in the population. The increase in caribou observations was likely explained by differences in survey efficacy between years.

Based on the results from previous years, the level of wolf reduction achieved during the fifth year of the program should be sufficient to elicit a strong, positive response in the caribou populations. The results of these reduction efforts, however, will not be measured until March 2020. According to the documented population trends, it is predicted that the fifth year of wolf reduction efforts will elicit approximately 15% caribou population growth (λ = 1.15), 90% adult female survival, and 21% calves in the population, across all three South Peace treatment herds. The effects of wolf reductions towards the South Narraway herd, and subsequent predictions, will require further investigation and monitoring.

Overall Caribou Population Results

The overall results measured during the five-year wolf reduction program suggest that the reduction of wolves to low densities can have significant, positive effects towards caribou populations. The level of wolf reduction during the first year did not lead to a caribou population response, however, the following three years of wolf reduction resulted in positive caribou responses in almost all population parameters measured (i.e. lambda, adult female survival, and calf recruitment) across all treatment herds (Table 1). The level of wolf reduction achieved in Year 5 is expected to elicit similar responses, but will not be measured until March 2020.

The total population size across the three treatment herds had increased from 166 individuals in 2016 to 247 individuals in 2019 (a 49% population increase). The average annual population growth rate following the three years of effective wolf reduction was 15% (λ = 1.15). The Pine LPU increased from 104 individuals to 159, with a total population increase of 53%. The Quintette LPU increased from 62 individuals to 88, with a total population increase of 42%. When forecasting the future population trend, assuming an average annual growth rate of 15% and considering density-dependent growth, the caribou population across the three treatment herds could double in size by year 2027 and approach the population objective (n = 800) by 2037 (Figure 3).

Table 1. Wolf reduction and caribou population results across all three South Peace caribou treatment herds in the Northeast Region of British Columbia, Canada.

	2015	2016	2017	2018	2019	2020
Caribou population estimate	192*	166	192	205	247	275**
Calf recruitment	15.5%*	15.6%	22.9%	18.6%	21.0%	21.0%**
Adult female survival	82.5%*	78.7%	92.7%	91.8%	89.2%	90.0%**
Annual population growth rate	-10.0%*	-14.0%	15.6%	6.7%	22.0%	15.0%**
Proportion of wolves reduced during previous winter	0%*	27%	97%	79%	92%	77%
Individual wolves remaining after previous winter's reduction	208*	151	7	27	10	18
Wolf density remaining after previous winter's reduction (wolves/1000 km^2)	12.6*	9.4	0.4	1.7	0.6	1.1

*Parameters measured prior to the implementation of wolf reduction
**Predicted caribou population response based on 2018-2019 wolf reduction

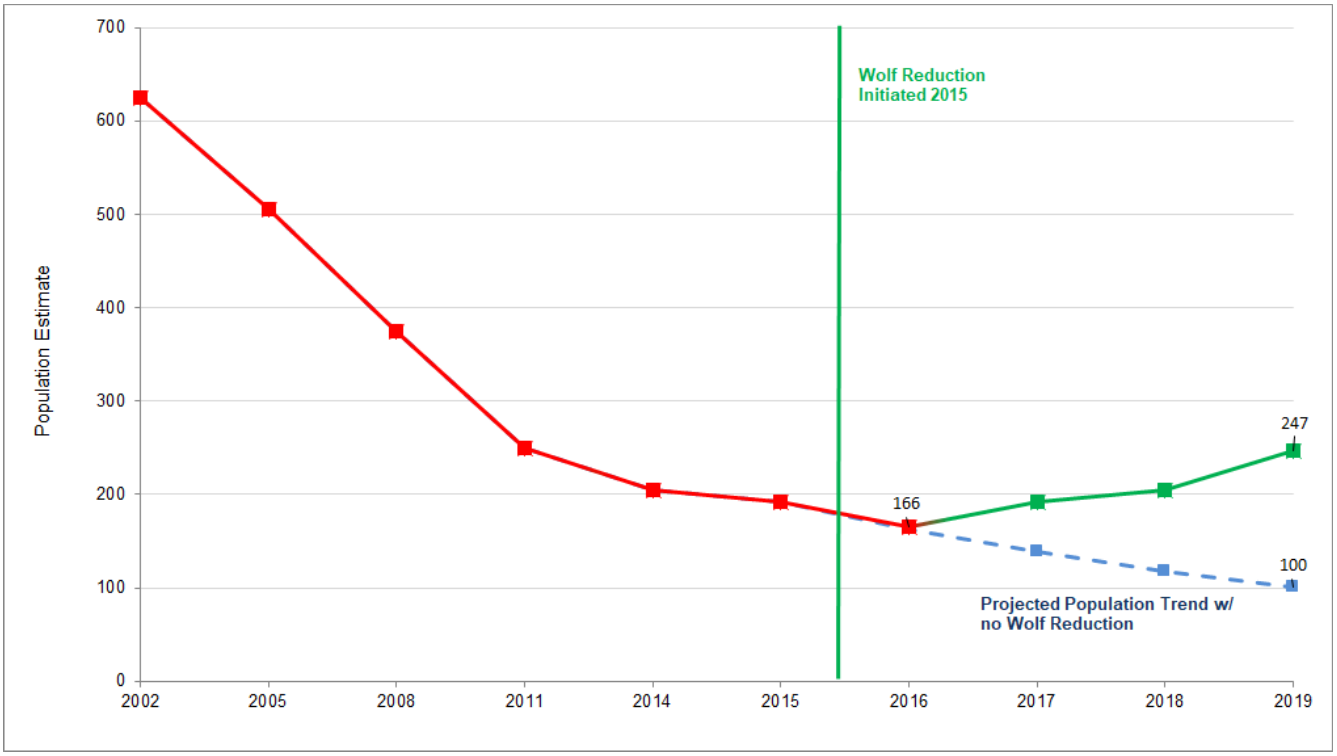

Figure 3. Population trends for three South Peace caribou herds (Klinse-Za, Kennedy Siding, and Quintette) prior to, and in response to, intensive wolf reductions.

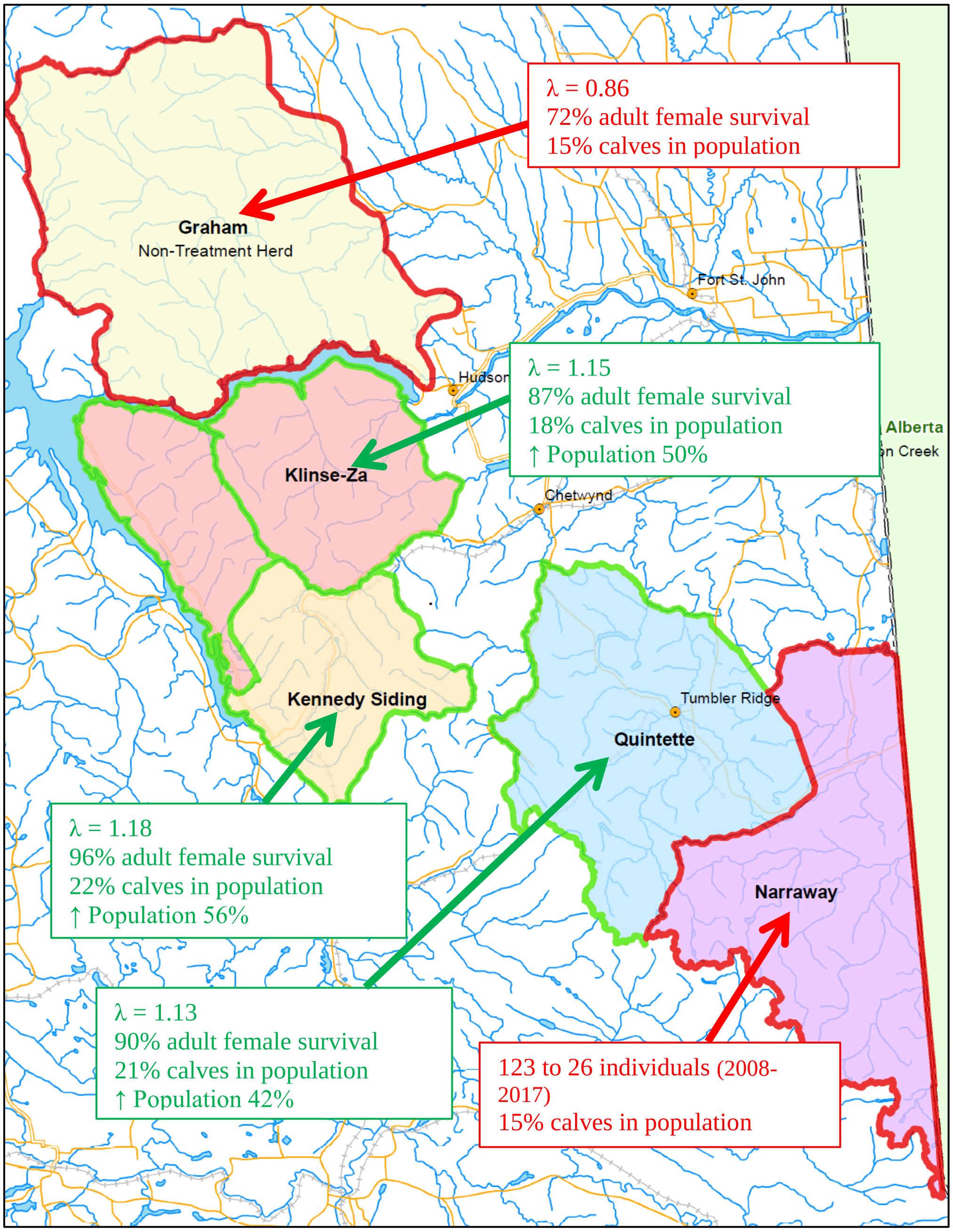

Figure 4. Average and overall population results for each treatment herd (green) in response to three years (2016-2018) of effective wolf reductions, and average population parameters for non-treatment caribou herds (red) over the same timeframe in the Northeast Region of British Columbia, Canada.

Prior to implementing wolf reductions (wolf density of 12.6 wolves/1000 km^2) and following an ineffective wolf reduction effort (Year 1 – wolf density of 9.4 wolves/1000 km^2), all measured caribou population parameters were indicative of declining populations. In each year following effective wolf reduction (i.e., reduction to two wolves/1000 km^2 or less), the population growth rate (Figure 5), calf recruitment (Figure 6), and adult female survival (Figure 7) were indicative of increasing caribou populations in all cases. The linear trend relating caribou population growth to wolf density appeared to suggest stable caribou populations could exist at a wolf density of approximately seven wolves/1000 km^2 (similar to the wolf density equilibrium reported by Bergerud and Elliot [1986]).

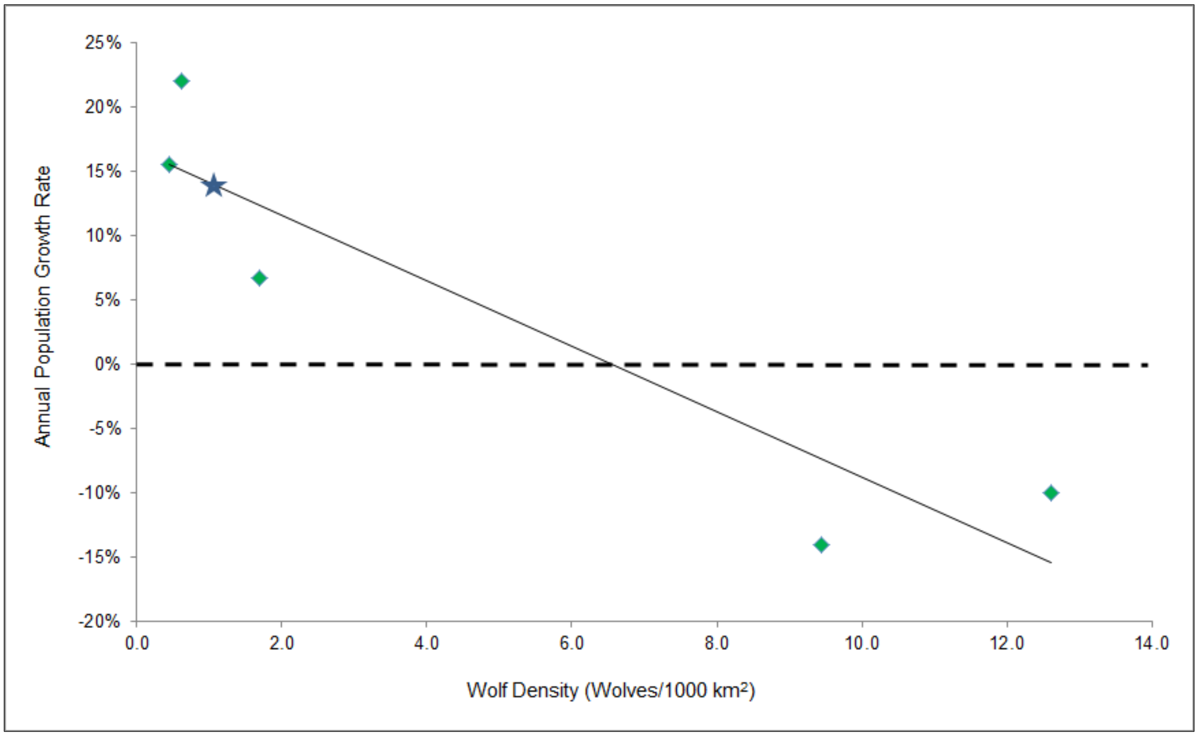

Figure 5. Annual caribou population growth rates relative to wolf density following reduction efforts across the three treatment herds. The "star" symbol represents the predicted response based on wolf reduction following the winter of 2018-2019. The linear trend line intersects with a stable population growth rate at a density of approximately 7 wolves/1000 km^2.

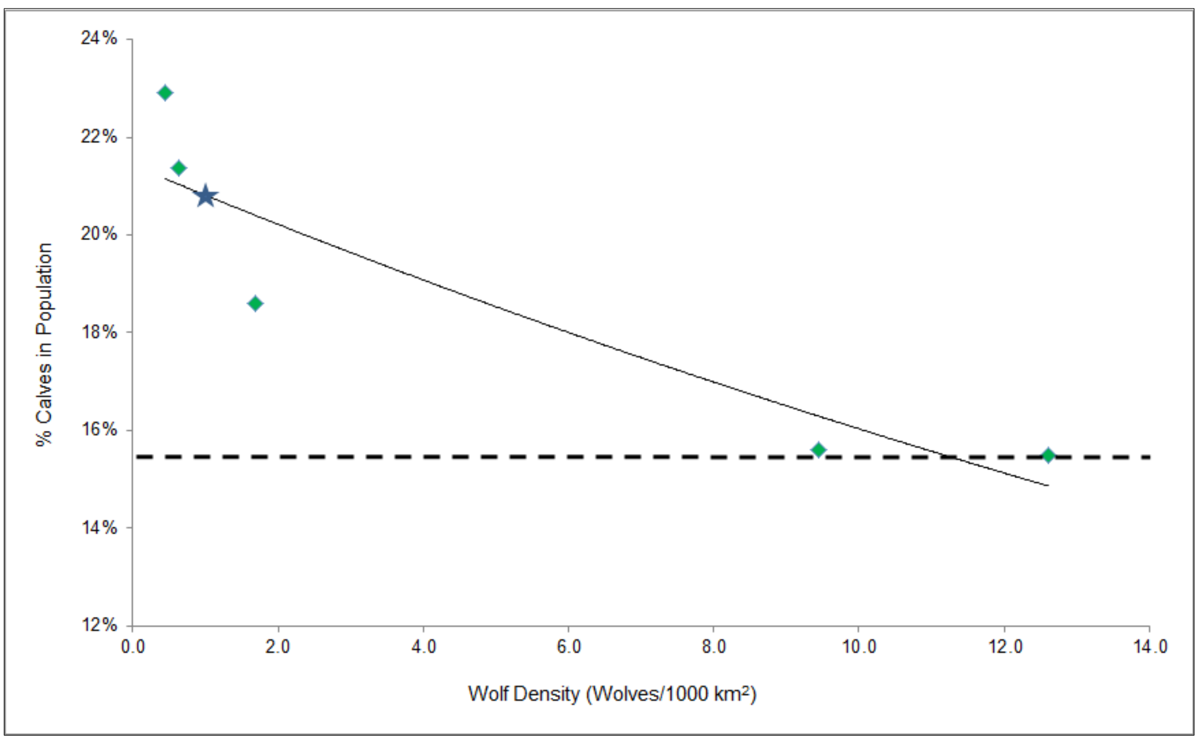

Figure 6. Proportion of caribou calves in the population relative to wolf density following reduction efforts across the three treatment herds. The "star" symbol represents the predicted response based on wolf reduction following the winter of 2018-2019. The proportion of calves in the population that represents population stability is approximately 15.5% (Bergerud 1992).

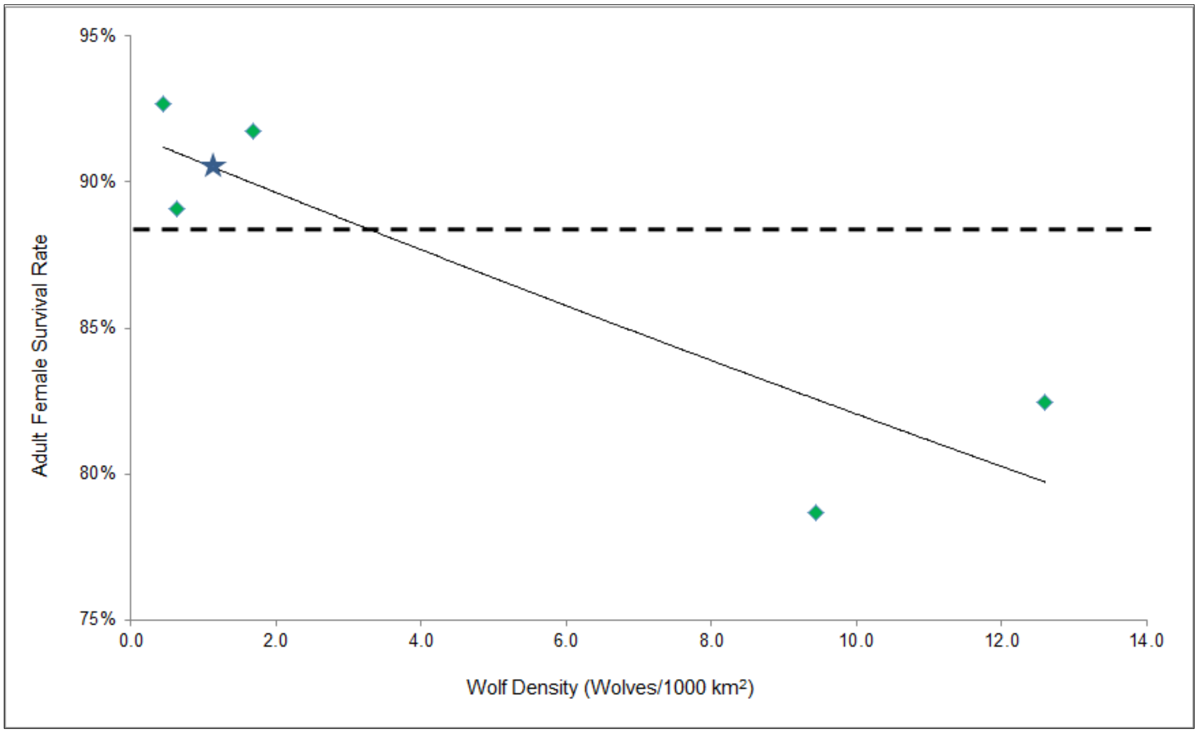

Figure 7. Adult female caribou survival rates relative to wolf density following reduction efforts across the three treatment herds. The "star" symbol represents the predicted response based on wolf reduction following the winter of 2018-2019. The adult female survival rate threshold for population stability is approximately 88% (Bergerud and Elliot 1986).

Adjacent, Non-Treatment Herds

During the years of wolf reduction across the South Peace caribou ranges, the adjacent non-treatment herds (i.e. Graham and South Narraway herds) showed demographic parameters suggestive of continued population declines. The wolf densities across the non-treatment herd ranges were assumed to have remained constant during that time, with an estimate of 12–14 wolves/1000 km^2 in the Graham caribou range and 11–12 wolves/1000 km^2 in the South Narraway core caribou range (FLNRORD *unpubl*.). During the years of effective wolf reduction in the treatment herds (2016-2019), the proportion of calves in the Graham herd ranged between 11.6–16.2% (compared to 16.8–25.0% in treatment herds; Figure 8). The adult female survival rate during that timeframe ranged between 60.0–80.8% (compared to 77.8–100% in treatment herds; Figure 9). The calf recruitment rate in the Graham herd was insufficient to compensate for the adult mortality rate, indicating a declining population trend. Calf recruitment in the South Narraway herd had ranged between 13.2–17.4%; however, there was an insufficient sample size of radio-collared caribou to monitor adult survival rates. The annual population growth rate for the Graham herd[3] had continued to suggest negative growth, declining between 10.3–31.9% annually (Figure 10), while the treatment herds exhibited positive population growth in all years following effective wolf reductions (5.5–23.5% population growth).

[3] Population estimates via aerial census had not been derived consistently for the Graham caribou herd. Lambda (λ) was calculated using Hatter and Bergeruds' (1991) recruitment-mortality equation, where: *λ = adult female survival rate/(1-recuitment)*

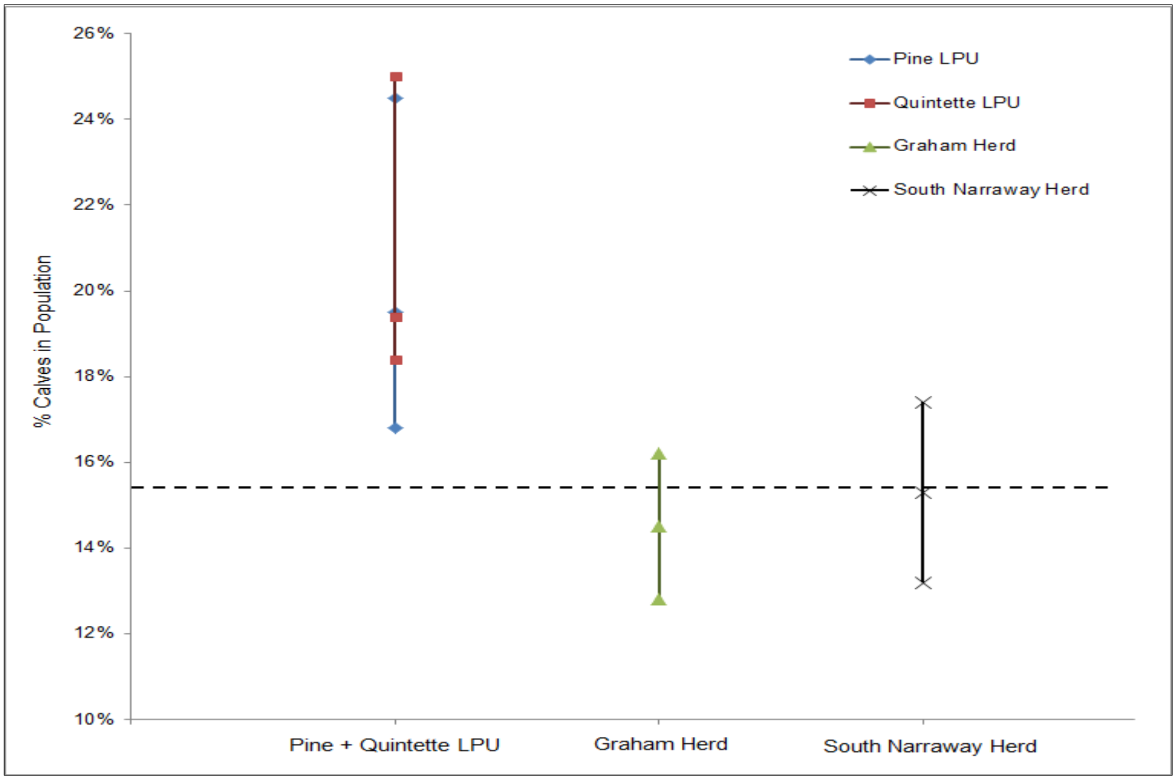

Figure 8. Proportion of calves in the treatment populations (Pine LPU and Quintette LPU) following three effective years of wolf reductions compared to the non-treatment populations (Graham herd and South Narraway herd).

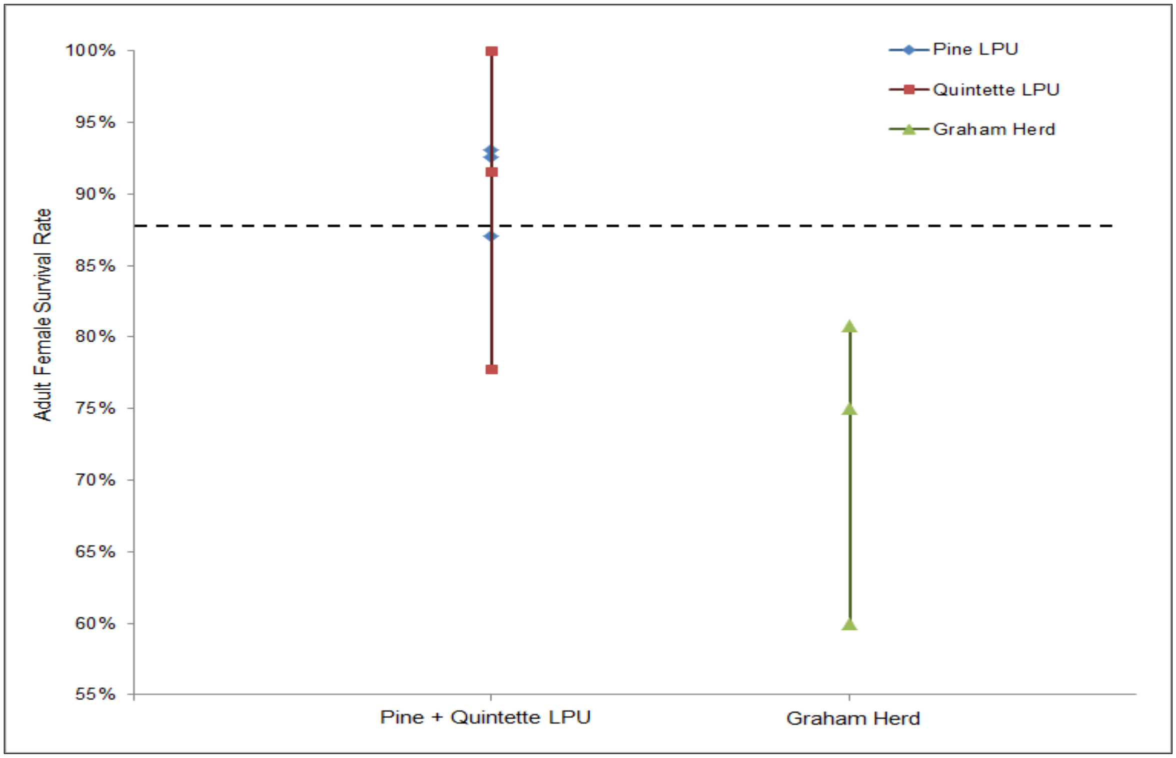

Figure 9. Adult female survival rate observed in the treatment populations (Pine LPU and Quintette LPU) following three effective years of wolf reductions compared to the non-treatment population (Graham herd).

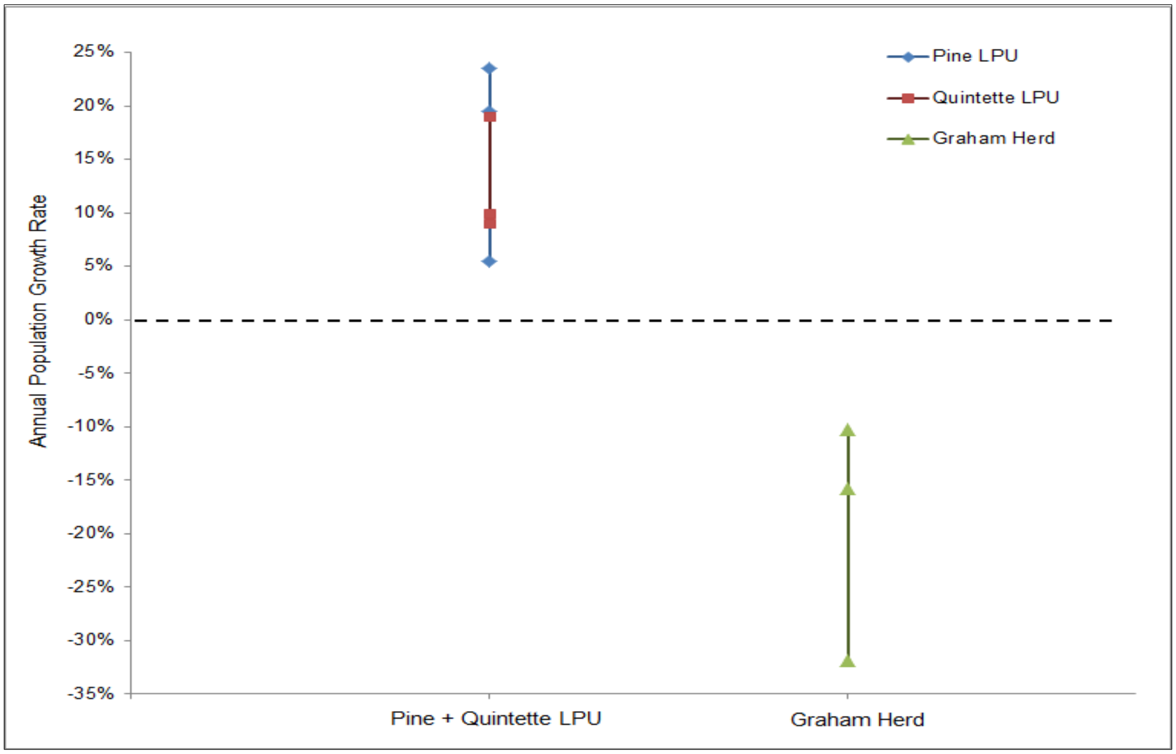

Figure 10. Annual caribou population growth rates observed in the treatment populations (Pine LPU and Quintette LPU) following three effective years of wolf reductions compared to the non-treatment population (Graham herd). Lambda was calculated in the Graham population using Hatter and Bergerud's (1991) recruitment-mortality equation.

Wolf Recovery Rates

The rate at which wolves recovered[4] in the treatment area relative to the initial population varied depending on the proportion of wolves that were removed during previous winters (Figure 11). Following wolf reduction in Year 1, when only 27% of wolves were removed, there appeared to be 100% recovery of wolves relative to the initial population. After removing approximately 97% of the wolves in Year 2, wolves recovered at a rate of 63% of the initial population the following winter, and a similar rate was observed following Year 3 (61% recovery relative to the initial population). After achieving a 92% wolf reduction in Year 4, wolves appeared to have recovered to only 38% of the initial population the following winter. The recovery rate after Year 5 of wolf reductions will be measured during the winter of 2019-2020. Over time, the results suggest that wolf recovery rates can be reduced with successive years of intensive reduction efforts.

Furthermore, the level of wolf reduction necessary to reduce wolf recovery rates on an annual basis appeared quite high (Figure 12). For example, the removal of 79% of wolves in Year 3 still resulted in a high annual recovery rate of approximately 97%. Only following winters when wolves were reduced by greater than 90% (Years 2 and 4) were annual wolf recovery rates reduced to approximately 63%. The preliminary results suggest that a reduction of over 85% of wolves each winter is required to reduce annual recovery rates.

[4] Either through population growth (i.e. producing litters) or recolonization (which occurs between the timeframe following the conclusion of wolf reduction at the end of the winter and commencement of wolf reduction at the beginning of the following winter)

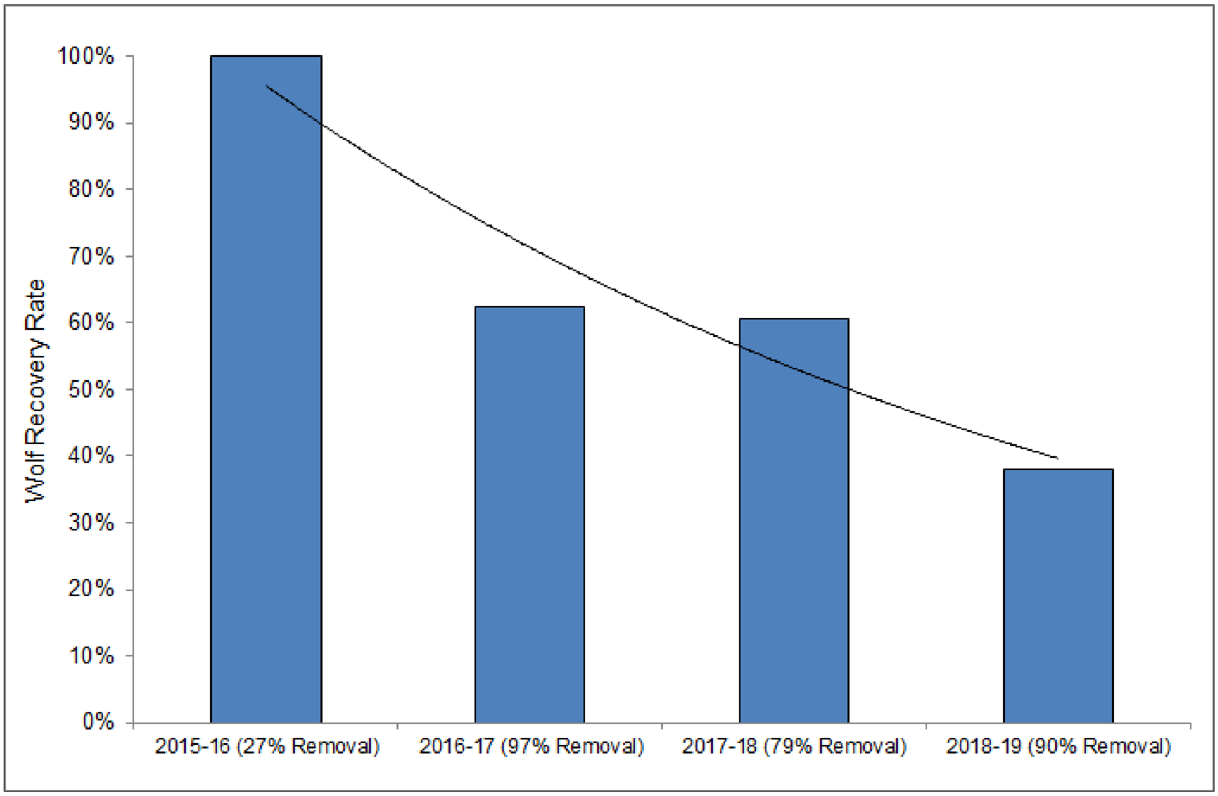

Figure 11. Wolf recovery rates relative to the initial population of wolves (n = 208) in the treatment area.

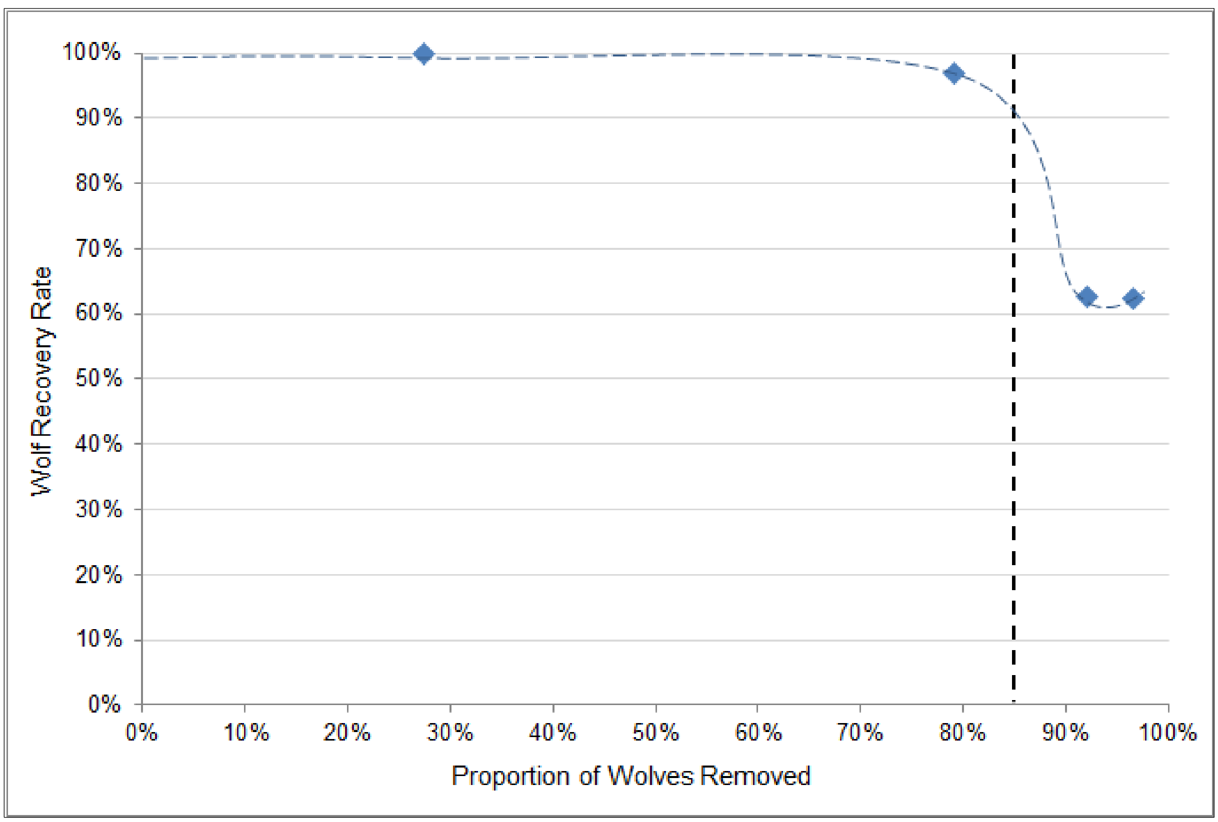

Figure 12. Annual wolf recovery rates following wolf reductions across the treatment area, with a threshold of greater than 85% indicating reduced annual recovery rates.

Primary Prey Response

Primary prey species, particularly moose, were expected to respond to wolf reductions at a level equal to, or greater than the response observed in the caribou populations. However, baseline data for moose populations across the entire treatment area were incomplete, making for difficult interpretation of population trends. Moose populations have been monitored more frequently in recent years since the implementation of wolf reductions. During the winter of 2016-2017, an aerial population composition survey for moose in the Quintette caribou range reported a ratio of 38 calf moose per 100 cow moose (FLNRORD *unpubl*.). This result does not suggest a rapidly increasing moose population (more likely stable to increasing); however, this result occurred following only one year of effective wolf reductions, thus additional data were required to inform population response. During the winter of 2018-2019, a comprehensive moose survey occurred within the Quintette caribou range and yielded a moose density estimate of 0.19 moose/km^2 and a ratio of 33 calves per 100 cows (FLNRORD *unpubl*.). Despite three years of intensive wolf reduction prior to the survey, the moose population density was relatively low with a calf ratio suggesting a stable population. Within the Kennedy Siding herd range, a moose inventory was conducted in 2015, just prior to the implementation of wolf reduction, but has not been surveyed since. At the time of the survey, there was a density estimate of 0.49 moose moose/km^2 and 36 calves per 100 cows (Klaczek et al. 2016).

Within the Klinse-Za caribou range, a moose survey in 2017-2018 (following two years of effective wolf reduction) reported a moose density estimate of 0.44 moose/km^2 (no significant change from the previous estimate in 2012-2013) and a calf ratio of only 21 calves per 100 cows (Sittler and McNay 2018). Additionally, a comprehensive moose survival study in the Klinse-Za caribou range had occurred concurrently with wolf reduction efforts, and compared moose population parameters in response to wolf reductions with those of an adjacent, non-treatment population of moose (Sittler 2019). Overall, adult female moose had a 7% greater survival rate in the Klinse-Za range than in the non-treatment moose population, including one year of 100% survival (n = 40) following Year 4 of wolf reduction (when 96% of wolves in the Klinse-Za range were removed). Adult female survival ranged from 92–100% following three years of effective wolf reduction, whereas survival in the non-treatment population ranged from 83–93%. Calf recruitment was lower than expected in two of the years following effective wolf reductions, with a higher calf recruitment rate observed in the non-treatment population. Calf recruitment in the treatment population has since increased to 35 calves per 100 cows in March 2019. Lambda calculations suggested positive population growth rates in all years following wolf reduction (as was observed in the non-treatment population). Over the course of the study, wolf predation was the cause of one of five (20%) moose mortalities in the Klinse-Za range, while wolf predation was the cause of four of 11 mortalities (36%) in the non-treatment population.

4. Discussion

Caribou Population Results

The positive response measured across the South Peace caribou population following intensive wolf reduction provides strong support for the use of wolf reduction as a tool to increase caribou herds. The results show a conclusive, positive response by the treatment herds following three years of effective wolf reductions, whereas non-treatment caribou herds continued to show evidence of rapid declines. It was evident that a high level of wolf reduction was required to elicit the positive response in treated caribou populations; reduction of wolf densities to < 7 wolves/1000 km^2 may contribute to population stability or growth, but reduction to < 2 wolves/1000 km^2 is required to elicit the strongest possible population response (Serrouya et al. 2019). The results achieved in the South Peace treatment herds have equalled, or surpassed, those achieved by other jurisdictions that have implemented wolf reduction to enhance caribou populations (Farnell and McDonald 1988, Boertje et al. 1996, Bergerud and Elliot 1998, Hayes et al. 2003, Hervieux et al. 2014). Wolf reduction as a caribou recovery tool may be particularly valuable for herds that require immediate recovery actions while the ultimate causes of caribou population declines (e.g. habitat alteration) are addressed.

Caribou calf recruitment remained lower than expected in the Klinse-Za herd despite intensive wolf reduction. This was further evidenced when comparing the survival rates of calves released from the maternal pen to those of the unpenned calves in the population (McNay et al. 2019). For example, in 2018, the annual survival rate of penned calves following their release was 77% versus only 17% survival amongst unpenned calves. Calf survival had increased substantially in the other South Peace treatment herds following effective wolf reduction, which suggests there were factors specific to the Klinse-Za range that were inhibiting calf survival. Bears (*Ursus spp*.) are believed to be abundant throughout the Klinse-Za range and have been shown to be significant predators of calf caribou (Adams et al. 1995). Similarly, calf recruitment observed in the South Narraway herd following one year of wolf reduction was lower than expected; however, further years of treatment may be required in order obtain stronger inferences. It would be beneficial to implement research studies to investigate the cause of low survival of unpenned wild calves in the Klinse-Za caribou herd.

Prior to population declines, it is believed that approximately 1,000 caribou inhabited the South Peace caribou range (approximately 800 amongst the Klinse-Za, Kennedy Siding, and Quintette herds, and 200 within the South Narraway herd; Ministry of Environment 2013, Seip and Jones 2014). Assuming continued annual population growth of approximately 15% (achieved solely through wolf reduction or in conjunction with other management initiatives), the treatment herds could double in size by 2026-2027 and the objective of 800 caribou in the Pine and Quintette LPUs could be met by 2036-2037. In order for those caribou herds to achieve a self-sustaining status, however, the ultimate causes of declines (i.e. industrial landscape change and apparent competition) must be addressed through habitat protection, recovery, and restoration. It is too early to determine whether the population target of 200 caribou in the South Narraway range can be achieved through wolf reduction.

Annual Wolf Recovery

Previous wolf reduction programs have experienced challenges with rapid population growth or recolonization by wolves on an annual basis (Bergerud and Elliot 1998, Hayes et al. 2003, Hervieux et al. 2014). During years of intensive wolf reduction in the South Peace, there were few or no breeding pairs remaining in the treatment area following the winter removal efforts (as determined by closely documenting wolf presence throughout the aerial reduction efforts), which reduced the likelihood of litter production during the spring. Thus, the subsequent recovery of wolves was occurring primarily through colonization of new wolves into the treatment area. Wolf recolonization is presumed to occur rapidly when primary prey within the treatment area remains abundant, and where there are few geographic barriers inhibiting wolf movement into the treatment area. In the South Peace, the low presence of linear disturbance (relative to many Boreal caribou ranges) combined with the mountainous landscape bordered by large waterbodies (on the western and northern extent) may slow the rate of wolf recolonization relative to those rates observed in highly disturbed and less mountainous landscapes (Hervieux et al. 2014). Additionally, wolf reduction occurring to the east of the treatment area in Alberta may also reduce the rate of wolf dispersal from neighbouring jurisdictions.

Wolf reductions in the South Peace have shown that annual population growth and recolonization rates by wolves were significant when less than 80% of wolves were removed during the winter. Following winters of intensive reduction (greater than 90% removal), the subsequent wolf populations had only amounted to approximately 65% of the previous year's population. Prior to reduction efforts in the winter of 2018-2019, the wolf population within the treatment area was only 38% of the initial wolf population present prior to the program's commencement in 2014-2015. These results suggest that continued, intensive wolf reduction can decrease the overall presence of wolves in a treatment area on an annual basis. As reported in similar studies (i.e. Bergerud and Elliot 1998), over the course of multiple years of reduction efforts wolves were recolonizing in smaller pack sizes; an expected result based on the breeding and dispersing behaviour of wolves (Fuller et al. 2003). Small and numerous wolf packs increase the difficulty of removing a high proportion of wolves, as they are more challenging to locate than larger packs and have less-established territories.

Primary Prey

Relative to caribou recovery, an increase in primary prey populations would be considered an undesirable side effect of wolf reductions, due to the apparent competition hypothesis (Seip 1992). In other jurisdictions, wolf reduction has been used as a management tool to deliberately increase primary prey populations for species such as moose, elk (*Cervus canadensis*), and thinhorn sheep (*Ovis dalli*) and has been successful in doing so in many cases (Boertje et al. 1996, Bergerud and Elliot 1998, Hayes et al. 2003, Keech et al. 2011). Based on the results of those programs, it is expected that primary prey species in the South Peace, particularly moose and to a lesser extent deer (*Odocoileus spp.*) and elk, would respond at an equal or greater level to that of the caribou populations. A lack of baseline data for moose populations across the treatment area makes for difficult interpretations of the response to wolf reduction; however, the available data do not suggest as strong of a response as expected. Although survival rates of adult moose have likely increased and positive population growth has occurred (i.e. within the Klinse-Za range; Sittler 2019), there has been a lesser response in calf moose survival and recruitment. This may indicate that there are other factors slowing the rate of population growth amongst moose, such as bear predation on neonate calves, or health factors (Kuzyk et al. 2018). Other jurisdictions within BC have recently reported high moose population growth and calf recruitment in response to wolf reduction (Serrouya and Legebokow 2018).

The response of primary prey to wolf reduction requires further monitoring, and wildlife managers must consider options for managing primary prey in order to reduce the recovery rates by wolves. This may be achieved through liberalized licensed hunting opportunities or managing habitat such that it is less suitable for primary prey species. Messier's (1994) numeric response model predicts that moose densities below 0.13 moose/km^2 are necessary for wolves to meet the threshold associated with caribou population stability (6.5 wolves/1000 km^2; Bergerud and Elliot 1986). Similar prey biomass equations estimate that moose densities below 0.3 moose/km^2 are required for wolf densities below 6.5 wolves/1000 km^2 (Fuller 1989, Wilson 2009), which is comparable to Bergerud's (1996) research which suggested caribou cannot persist when moose densities exceed 0.2–0.3 moose/km^2. Furthermore, moose densities of less than 0.2 moose/km^2 have been associated with reduced wolf recruitment (Messier 1985, Serrouya et al. 2017). Moose densities of greater than 0.2–0.3 moose/km^2 in the South Peace may not impede caribou recovery efforts so long as intensive wolf reduction continues to be used as a management option. However, it would be detrimental to allow moose abundance to occur beyond such densities, as it would continue to facilitate annual wolf recovery, and ultimately hinder caribou populations from achieving self-sustaining status. Furthermore, wolf reduction is not viewed as a long-term management tool, thus moose abundance should be addressed through active moose population management and caribou habitat recovery. It must be recognized that there are significant social and logistical challenges in maintaining or reducing moose densities through licensed hunting, particularly due to First Nations' desire for abundant moose populations to meet their food, social, and ceremonial rights.

Links to Other Caribou Recovery Initiatives

Wolf reduction as a caribou recovery tool is likely to achieve the greatest results when it occurs in conjunction with other recovery initiatives that address underlying causes of caribou population declines (Serrouya et al. 2019). The long-term recovery of caribou populations requires the recovery of caribou habitat to a state that resembles pre-disturbance conditions. Habitat change that has benefited primary prey species or enhanced wolf movement across the landscape must be addressed in order for the long-term caribou recovery objectives to be met. Across the South Peace caribou range, habitat protection and restoration initiatives are underway and continue to be pursued (MFLNRO 2017, Woods and McNay 2019). Such initiatives are necessary to support caribou recovery, particularly if and when wolf reduction is halted as a management tool for South Peace caribou. Furthermore, social acceptance for wolf reduction is contingent on the Ministry's ability to demonstrate commitment to addressing the ultimate causes of caribou population declines. Wolf reduction should be viewed as a short-term recovery tool that supports South Peace caribou herds while habitat conditions improve.

There are other short-term caribou recovery measures occurring in conjunction with wolf reduction across the South Peace caribou ranges. In the Kennedy Siding herd, supplemental feeding of caribou during the autumn and early winter has occurred for several years (Heard and Zimmermann 2018). While the positive effects of feeding caribou are somewhat inferred (i.e. improved nutritional status), the Kennedy Siding herd did not show a measurable population response to supplemental feeding in the absence of wolf reduction. Within the Klinse-Za caribou range, an ongoing maternal penning program has been underway since 2014 (McNay et al. 2019). Initial results from the maternal penning efforts, prior to the initiation of wolf reduction, suggested that penning was ineffective if wolf populations were not reduced. During the program's first year, five of nine calves were killed soon after their release from the pen (a higher mortality rate than unpenned calves) and adult mortality remained high (Seip and Jones 2016). However, when combined with intensive wolf reduction in subsequent years, calf survival has increased (Seip and Jones 2018, McNay et al. 2019). Calf survival of penned calves has been higher than that of unpenned calves in all years with concurrent wolf reduction, suggesting that the maternal penning efforts are contributing additional calves to the population that may otherwise have perished. The maternal penning project does retain some risk, however. The repeated capture, retention, and rearing of caribou can be stressful, result in injury and death, and may have short- and long-term health and behavioural implications. Additionally, the costs associated with maternal penning relative to population growth are significantly higher when compared to wolf reduction alone (i.e. the cost per caribou added to the population through maternal penning is approximately one order of magnitude greater than that of wolf reduction). In the South Peace, maternal penning is not supported, nor would it be expanded to include new caribou herds, in the absence of intensive, concurrent wolf reduction. Furthermore, the Kennedy Siding and Quintette caribou herds have shown comparable or greater annual population growth and calf recruitment than the Klinse-Za herd through wolf reduction alone.

Operational Considerations

Overall, the delivery of the wolf reduction program in the South Peace has increased in efficacy and efficiency over time as crews have gained more experience and familiarity with the treatment area and as the operational oversight by Ministry staff has increased. Cost efficiency is dependent on the experience and proficiency levels of the removal crews, weather conditions, and the abundance and pack sizes of wolves within the treatment area. The effort required to reduce wolf densities to a low level is substantial. Generally, greater than 225 hours of helicopter flight time are flown to achieve successful wolf reduction across the South Peace treatment area. This necessitates a substantial financial commitment, as well as commitment of time and capacity from the aerial removal crews and Ministry staff. A sufficient budget must be forecasted each year, as well as a multi-year funding commitment. Ministry staff capacity must also be forecasted, and wolf reduction crews with demonstrated proficiency must be identified and procured. The results reported during this program suggest that wolf reduction must be very intensive, and to implement a program that is anything less than intensive would be considered unethical. Scientific rigour is required to deliver the removal aspects of this program and accurately measure the response of both wolves and caribou to wolf reduction. Wolf reduction has proved to be most efficient and effective when conducted under optimal weather conditions that facilitate the tracking, locating, capturing and radio collaring, and ultimately the removal of the majority of wolves within the treatment area. The intensity of wolf reductions achieved during this program has generally exceeded those reported in other jurisdictions where wolf reduction has occurred (Bergerud and Elliot 1998, Hayes et al. 2003, Hervieux et al. 2014).

A critical factor to a successful program is the radio collaring of most, if not all, wolf packs within the treatment area. The deployment of radio-collars greatly reduces search times when locating wolf packs, and aids in the facilitation of complete pack removal. Wolves captured and fitted with new, active radio-collars were generally left alive following the reduction efforts in order to facilitate relocation of packs the following winter. Under most circumstances, the lone radio-collared wolves had not bred successfully, thus were not part of new family units the following winter. Furthermore, it was rare that these lone wolves were accepted into new packs that may have colonized the treatment area. The most common scenario was that radio-collared wolves partnered with other individuals or pairs of wolves to form new pairs or small groups. Most years, approximately half of the radio-collared wolves survived or remained within the treatment area by the following winter. Although the removal of the radio-collared wolves annually would have resulted in a lower wolf density at the end of each winter's reduction efforts, the value of leaving those wolves is believed to outweigh the benefits of removing them.

The concurrent ground removal programs implemented by First Nations (in the Klinse-Za range) provided an additional source of wolf reduction, as well as an opportunity to collaborate with local First Nations communities on caribou recovery initiatives. In treatment areas where there were no ground removal programs (i.e. Kennedy Siding and Quintette), the aerial removal on its own was shown to be sufficiently effective. There were also risks of actively trapping in conjunction with aerial removal, the primary risk being that a radio-collared individual could have been accidentally trapped and killed. Due to the elusive nature of wolves, their large home ranges and propensity for remote, inaccessible locations, trapping and hunting is unlikely to achieve wolf reduction targets as a standalone measure. Furthermore, the reduction of wolves through hunting or trapping has been shown to have little effect on wolf populations (Webb et al. 2011). Given these factors, it is unlikely that wolf reduction through hunting and/or trapping is sufficient to elicit positive responses in caribou populations.

The cost effectiveness of the South Peace wolf reduction can be measured using several variables. Most notably, the cost per caribou added[5] to the population following three years of effective wolf reduction equates to approximately $11,000 per caribou. During that time, there has been one caribou added to the population for every 2.9 wolves that have been removed. The cost per wolf removed (through aerial shooting) has averaged approximately $5,100 over the past five years; this cost has fluctuated annually and is dependent on the proficiency of the removal crews, weather conditions, abundance of wolves, and pack sizes (where more effort is required over time to remove numerous, but small packs). The overall cost to deliver wolf reduction in the South Peace treatment area may be lessened over time, provided the wolf recovery rate remains low, as was observed in 2018-2019. The program costs and number of wolves removed are largely independent of the

[5] Calculated by identifying the number of caribou added to the population as well as the number of caribou that would have been lost from the population in the absence of wolf reduction

caribou population size; thus, the cost and number of wolves removed annually may remain constant over time, but the number of caribou added annually will increase as the caribou population size increases (assuming similar lambda results are achieved). If primary prey populations (and their preferred habitats) are managed and caribou populations continue to increase at their current rate, it is possible that a lesser effort to reduce wolves could be applied on an annual basis, or wolf reductions could occur on two- or three-year cycles. As the caribou population increases, the cost per caribou added and the number of caribou added per wolf removed (presuming similar population growth rates are achieved)

During Years 1 and 2 of the reduction program, there were attempts made to retrieve the majority of wolf carcasses by helicopter in order to provide pelts to local First Nations. It soon became evident that the retrieval of carcasses was highly inefficient (required much additional helicopter flight time and time on the ground by removal crews), increased the safety risks for removal crews, and had low uptake from First Nations relative to utilization of the pelts. In the subsequent years of the program, Ministry staff and removal crews have coordinated the ground retrieval of wolf carcasses that were relatively accessible, which were then distributed to local First Nations. This has been a much more efficient method of retrieving and distributing carcasses, and has generally provided a sufficient number of pelts to First Nations to support their social and ceremonial interests.

Aerial shooting is the most effective method of reducing wolf densities over large geographic areas while eliminating the risk of bycatch and ensuring the highest likelihood of quickly dispatching wolves. The humaneness of wolf removal in the South Peace has been examined more thoroughly as Ministry staff has become more involved in the operational delivery. In 2018-2019, humaneness was examined by Ministry staff by documenting shooting proficiency, shot locations, and subsequent dispatch times of a large subsample of wolves removed during program delivery (including the South Peace and two other treatment areas in the region). Of the documented subsample of 98 wolf removals, the vast majority of wolves were dispatched instantaneously or within seconds following one well-placed shot or a quick succession of multiple shots. Only six wolves took longer than 30-seconds to expire after an initial shot, and only one wolf was never visually confirmed to have expired after being shot (although it appeared to have expired out of sight in a tree well). It is important that Ministry staff, working closely with the removal crews, continue to document the shooting proficiency and effectiveness during wolf reduction programs and adjust methods as necessary to ensure wolf reduction occurs at the highest possible level of humaneness.

5. Conclusion and Recommendations

The South Peace aerial wolf reduction program has demonstrated conclusively that the reduction of wolves across the treatment area has had a strong, positive effect on the caribou populations. Wolf reduction is a management tool that must be used responsibly and ethically, and implemented with the highest standards for humaneness and scientific rigour. Reducing wolf populations may be the most effective interim management measure for halting and reversing caribou population declines over the short-term while the ultimate causes of such declines are addressed through habitat protection and restoration and primary prey management. Wildlife managers and Ministry decision-makers should consider the following recommendations that have been identified during the five-year review of wolf reduction in the South Peace region:

1. Continue the intensive reduction of wolves across the South Peace treatment areas until caribou populations approach a self-sustaining status (approximately 1,000 individuals)
    - Consider approval of an additional five years of wolf reduction, followed by a comprehensive review of the program

    - Implement multiple management tools, including habitat protection and restoration, concurrently to help address the ultimate causes of population declines
2. Consider lessening the wolf reduction intensity if wolf recovery remains low and caribou continue to trend towards self-sustaining levels
    - Contingent on habitat restoration, protection, and maintenance of primary prey populations
3. Consider a "maintenance" approach to wolf reductions for the South Narraway caribou herd, provided wolf recovery remains low
    - This may be achieved through reducing the annual reduction effort, or conducting reductions on a two- to three-year cycle
4. Continue to use experienced and proficient removal crews that can be trusted to deliver wolf reduction in a professional and humane manner
5. Maintain Ministry staffs' responsibility and role in project coordination, operational oversight, and field involvement
6. Continue the intensive monitoring of caribou populations in response to wolf reductions, including the documentation of annual population estimates, population trend, calf recruitment, and adult female survival rates
7. Monitor the response by primary prey to wolf reductions, establish target densities for primary prey species (i.e. moose) within the treatment areas, and implement measures that can be used to achieve and maintain those objectives
    - Consider using licensed hunting to manage for moose population densities between 0.2–0.3 moose/km^2
8. Consider habitat protection and restoration measures such that habitat gain exceeds habitat loss within and adjacent to caribou core ranges
9. Continue to rigorously document the humaneness of the wolf reduction efforts
10. Continue to support the ground retrieval of carcasses to be distributed to local First Nations
11. Continue to implement a collaborative approach to wolf reduction by supporting ground trapping programs by local First Nations
12. Consider research opportunities to investigate causes of caribou calf mortality (i.e. predation by bears or other predators, health-related causes, etc.)
13. Continue to implement the Ministry's safe work practices for aerial shooting of wolves and net-gunning capture of wolves

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