Vulnerability analysis of the Porcupine Caribou Herd to potential development of the 1002 lands in the Arctic National Wildlife Refuge, Alaska

Photo by Peter Mather

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Don Russell and Anne Gunn
Shadow Lake Environmental Inc

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Cows and calves in a post-calving aggregation near the coast in the western portion of 1002, a region or high to medium hydrocarbon potential. The narrow coastal plain hosts groups of over 100,000 Porcupine caribou during insect season, an energetically stressful time for nursing cows. The coastal plain is narrow, restricted by the Brooks Range to the south (Photo by Peter Mather).

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Executive summary

We have undertaken a science-based risk assessment for how vulnerable the Porcupine Caribou herd (PCH) is to the proposed oil and gas development of 1002 lands (Coastal Region) in the Alaska National Wildlife Refuge. The Governments of Canada, Yukon Territory and the Northwest Territories through their role as signatories to the 1987 International Treaty for the Porcupine herd asked us to undertake the analyses to ensure that potential impacts to the herd, and therefore subsistence users, are fully understood.

We projected potential impacts using our computer model - the Caribou Cumulative Effects (CCE) Model to integrate quantitative analysis of caribou movements (exposure), sensitivity to climate and disturbance. We determined that:

- The potential impacts, under average climate, were 19% higher risk of a herd decline with 1002 development after 10 years when the starting herd size was the current size (218,000). The risk increased to 26% if the starting herd size was similar to population estimates in the early 1970s (100,000 caribou).
- The risk to the PCH from 1002 development affects the subsistence role of caribou in the lives of aboriginal people. The Porcupine Caribou Management Board (PCMB 2010) has identified thresholds of herd size that would trigger harvest management responses within Canada. With an initial herd size of 100,000 and average climate there was a 23% higher risk that herd size would fall below thresholds requiring severe harvest restrictions.

We also assessed PCH vulnerability based on how adaptive capacity (which includes mitigation) could potentially reduce the potential impacts of 1002 development. We applied BLM's (2018b) stipulations to rank BLM's development Alternative scenarios B to D2. We determined that:

- With a starting herd size of 100,000, there was a 10% - 19% (from Alt D2 to Alt B) higher chance that numbers would fall below the 80,000-threshold (when harvest is under allocation (orange zone) or severely restricted (red zone)) compared to baseline simulations.
- Throughout the risk analysis, Alternative B was only slightly better than full 1002 development with no special mitigation stipulations.

During our assessment of PCH vulnerability, we reviewed information in BLM's (2018b) leasing assessment but, mostly due to lack of analyses, we found gaps in how PCH was characterized especially with respect to post calving movements and distribution. Our analyses identified new information on exposure to development and sensitivity to climate. While we were compiling information on adaptive capacity – how the PCH will cope with a 1002 oilfield development - we did not find evidence in the draft 2018 leasing EIS to support statements about mitigation and we suggest that the parallels drawn between effects of oilfields on the Central Arctic herd calving, post-calving and summer ranges and the PCH are misleading. Consequently, we have included suggestions for mitigation to support adaptive capacity.

Compared to other North American migratory tundra caribou herds, the PCH has been relatively stable as the rate of increase and rate of decline are low. Productivity is low for the PCH which suggests the cow or calf's survival will have a disproportionate impact in limiting herd growth or exacerbating herd decline. As spring and summer conditions influence PCH productivity,

disruption of free movement and access to forage and insect relief areas during spring and summer would directly affect PCH productivity. A decline below the natural range of variability could have disproportionate effects on this herd given its low level of productivity and as a result could cause impacts to subsistence harvesting.

Our computer model - the Caribou Cumulative Effects (CCE) Model framework consists of three linked sub-models that, together, allow caribou managers to undertake "what-if" analyses of the cumulative effects of development, climate change and other stressors on various aspects of caribou biology. The sub-models in the CCE model include:

1) Movement: a model tracking movement patterns of a caribou herd with respect to past, present and future development;
2) Energy-Protein: a model of how an individual caribou allocates protein and energy obtained from foraging to maintenance body reserves and milk for calf over time; and
3) Population: a model of the caribou herd's population dynamics.

The model integrates movements, habitats and how the cow allocates her forage intake for her growth and chances of gaining sufficient reserves to become pregnant. The relationship between fall body weight of the cow and her probability of getting pregnant is predictable. For example, using an average body weight of 81kg, a body weight drop of 0.5 kg equates to a 1% drop in the probability of pregnancy. We developed these relationships to use in the model exercise to link our modeling of the cost of disturbance for an individual caribou to the herd scale. The model also projects if the cow's milk is sufficient for calf growth and its survival. The model then uses the individual caribou's chances of being pregnant and calf survival to project whether the herd will increase or decline.

Prior to running the CCE, we explored relationships between vital rates and weather to determine key relationships necessary for understanding PCH sensitivity. We found the PCH is sensitive to climate and annual weather as overwinter freezing rain and rain-on-snow are detrimental. Warmer fall and July temperatures are favourable and warmer springs as measured by May snow depth and plant growing degree days in June increase calf survival and subsequent fall body condition. Since 2000, June 10 growing degree days has increased significantly, which also might partially explain the increasing trend in the PCH since 2001. The chances that the herd will increase or decrease in response to the oil and gas development on the calving and post-calving habitats also depends on weather.

The draft 2018 EIS for leasing did not analyse movements and distribution so we analysed satellite collared caribou to quantify annual variations in distribution and exposure to climate and development. Annual variation in use of the 1002 lands is high as weather determines whether caribou will calve in the coastal areas in 1002 or Canada. If snow is shallow in May during migration, cows calve in 1002 and the survival of those calves to one month will depend on the available forage. In contrast, if the cows calve in Canada, although forage is important, the survival of the calf is related to how adverse the winter was (indexed by March 31 snow depth). The snow depth in years when cows calve in 1002 is the same as the years when they calve in outside of 1002, suggests that having access to 1002 enables the cows to "overcome" an adverse winter. Conversely, if denied access to 1002 due to a cows' sensitivity to development, on average, calf survival would be reduced by 9%.

The PCH's traditional calving area frequently includes the southeast portion of 1002 and after calving, those cows with their newborn calves balance their need for foraging against reducing their exposure to mosquito and warble fly harassment. The highest exposure of caribou to 1002 lands is in post-calving, which is when cow's energy and protein demand doubles and when calves can gain up to 400g a day if they can maintain their forage intake. The area used in 1002 lands during this critical post-calving time is much larger than the frequently used area for calving noted above. For cows that give birth in 1002, she and her calf will on average spend almost four weeks in 1002. If the calf is born outside 1002, the post-calving use of the 1002 area is reduced to 10 days.

A key gap in the draft EIS is the scale of post-calving aggregations. During warmer days with more mosquito harassment the caribou, especially cows and calves, aggregate into large groups as early as the 18th of June and as late as the 25th of June. Those groups move northwest further into 1002 which will expose them to moderate to high hydrocarbon potential areas. The rate at which the caribou move increases from <10 km per day prior to group formation to between 15 – 20 km/day after group formation and rates remain high even if groups start to disperse. On average (2014-2017), the aggregations persisted for just over 2 weeks and average 68,300 caribou (range 21,000 and 121,000). What we know about these large groups is that they have reduced feeding rates and are generally in a negative energy balance, continuously moving. What we do not know is how these "super groups" will react to oil fields and human activity and whether they have alternate insect relief habitats.

Adaptive capacity, as a component of the vulnerability assessment, is how caribou can cope with and persist under new conditions including a warmer climate. Building adaptive capacity will strengthen resilience of the Porcupine caribou-social-ecological system and is possible in part through integrating responses to industrial disturbance with herd management as shown by experience with the Central Arctic herd as harvest was kept low during oilfields construction and operation. Ensuring caribou's unimpeded passage through their calving and insect relief landscape through adaptive management will have an immediate and effective contribution to adaptive capacity.

The draft 2018 EIS describes mitigation implemented though stipulations and required operational procedures and the areas of land under the stipulations varied among the four alternatives, one of which will be selected by BLM. The effectiveness of mitigation remains largely unmeasured, except raising the height of pipelines and separating pipelines from roads is effective based on observational studies of caribou crossing and crossing attempts; evidence for specific actions such as convoying traffic and the thresholds for those actions as well as the stipulations such as halting construction but not drilling in the presence of caribou are of unknown effectiveness. Of particular concern is whether the larger post-calving aggregations will cross or be deflected by pipelines and roads either during their movement to the coast or returning when the motivational state of the caribou will be different.

Mitigation identified as stipulations and operating procedures are subject to suspension and the evidence base for and consequences of those variances are unrecorded. Related to the lack of evidence for the effectiveness of mitigation is the absence in the draft EIS of integrating monitoring and mitigation as adaptive management. Further compounding the uncertainties are lack of baseline analyses especially for movements.

Our projections for the Porcupine herd differ from what happened with oilfield development on the calving and post-calving ranges of the Central Arctic Herd as it initially increased in size during oilfield development. However, CAH management actions relative to harvesting contributed to the increasing herd trend. The management goals for the CAH since 1992 are to minimize the effects of the oilfield development by restricting the overall cow harvest to offset cumulative effects. The management goals also included working to reduce barriers to free movement; restricting harvest in Prudhoe Bay and along TAPS. Restricting harvesting from roads reduces the likelihood of caribou learning stronger avoidance distances and likely helps caribou tolerate oilfield activities. Despite mitigation such as increasing elevated pipeline height and separation from roads, CAH cows and young calves still avoid roads and calving remains displaced.

In addition, the geography of the CAH and PCH seasonal ranges, and the effects of climate differ. For the PCH, the coastal plain is much narrower and alternative calving habitats such as the foothills are available but have less forage, and higher predator densities resulting in reduced calf growth and survival. The PCH compared to the CAH has higher exposure to mosquito harassment. Spring and early summer forage conditions appear to be more critical to the PCH compared to the CAH, where fall conditions the previous year correlate best with early calf survival. Thus, the documented displacement of calving in the CAH, if experienced with development in the PCH, would have more significant impacts on calf survival (for the PCH) than occurred in the CAH.

Our model analyses and our appraisal of mitigation indicate a high degree of uncertainty about adaptive mitigation and thus the likelihood of residual effects remains potentially high. However, the shortcomings are also an opportunity for a collaborative approach and to share additional information. The draft 2018 EIS suggests construction of gravel pads and roads may not occur for 6-7 years which gives time. In Canada, experience is that a collaborative oversight or working group in designing monitoring and mitigation for major mines in the Northwest Territories (NWT) and Nunavut (NU) is proving effective in pooling knowledge and experience to design monitoring and mitigation. BLM already has experience with a working group for NPR-A planning. A retroactive review of the CAH and oilfield monitoring design would contribute to establishing effective monitoring and mitigation for PCH relative to proposed oilfield development. A review would also help integrate herd-scale and effects monitoring, enabling adaptive management to be related to herd management and support adaptive capacity. The key goal for adaptive mitigation to reduce vulnerability is as stated in the draft 2018 EIS (BLM 2018b:2-11) that "*All lands in the Arctic Refuge Coastal Plain are recognized as habitat of the PCH and CAH and would be managed to ensure unhindered movement of caribou through the area*." We agree, but the evidence and procedures presented in the draft EIS offers little evidence that this goal is yet achievable.

1. Introduction

The Porcupine Caribou herd (PCH) in northwest Canada and northeast Alaska has supported people for thousands of years as well as being a key driver in the mountain and coastal arctic food web (Bali and Kofinas 2008, Russell et al. 1993). A large part of the herd's Alaskan annual range lies within the Arctic National Wildlife Refuge which has a long history (Table 1). Starting in 1980, the US Congress' decision to expand and rename the 1957 Wildlife Refuge as the Arctic National Wildlife Refuge under the Alaska National Interest Lands Conservation Act (ANILCA) was controversial given opposing views on oil and gas development and wilderness values. Section 1002 of ANILCA identified a need to assess the oil and gas potential as well as the wildlife values. The 1.57 million acres Coastal Plain had not been included in the ANWR's wilderness designation. In this report we refer to the area covered by Section 1002 of ANILCA as "1002" lands.

The environmental assessment report for 1002 lands was completed in 1987 and reported on 5 years of baseline studies. The 1987 EIS described four alternatives: (i) authorize leasing the entire 1002 area; (ii) authorize leasing a part of the 1002 area; (iii) authorize further exploration including exploratory drilling, only; (iv) continue current refuge status. The limited leasing alternative (ii) excluded the southeastern 1002 as it was the PCH's concentrated calving area. After extensive consultation (11,300 letters received), the 1002 report recommended making the entire area available for leasing (Clough et al. 1987). The rationale referenced the apparent success of two decades of mitigation at Prudhoe Bay. However, uncertainty about evidence for the effectiveness of the mitigation is summarised in the Adaptive Capacity Section of this report. In 1989, submission of the proposed Act to open up the 1002 lands for leasing coincided with concerns following the grounding of an oil carrier loaded with oil from Prudhoe Bay and shipped to Valdez using the Trans-Alaska Pipeline. The proposed Act was dropped (Miller 1999).

Then, in December 2017, the status of 1002 changed when the U.S. Tax Act required the Bureau of Land Management (BLM) to oversee leasing for oil and gas development on the 1002 lands of the Arctic National Wildlife Refuge in Alaska (Comay et al. 2018). Specifically, BLM is required to oversee the leasing of 800,000 acres (two leases of at least 400,000 acres) of the Coastal Plain by December 2024. In December 2018, BLM submitted a Draft Environmental Impact Statement (BLM 2018b) in fulfilling its requirement under Section 20001 of Public Law (PL) 115-97 (Dec. 22, 2017). Specifically, the EIS Decisions to be made are to identify the lease tracts to be offered for sale, the lease stipulations and the Best Management Practices (BLM 2018b).

Table 1. Summary of key legislation and reports in northeastern Alaska.

Year	**Legislation or report**
1957	Alaska Lands withdrawn to protect wildlife and migratory birds
1968	Oil confirmed at Prudhoe Bay
1971	Alaska Native Claims Settlement Act (ANCSA) included selection surface rights lands
1972	Canadian Arctic Gas Pipeline Ltd. proposed a route to transport gas from the Prudhoe Bay fields in Alaska, across northern Yukon to the Mackenzie River delta
1976	Berger Commision report recommended the Arctic Gas Pipeline to the Mackenzie Valley, across the northern Yukon from Pruhoe Bay, be rejected.
1980	Alaska National Interest Lands Conservation Act (ANILCA) establishes Arctic National Wildlife Refuge (ANWR): ANCILA directed a report to assess development 1002 lands
1981	US Fish and Wildlife Service begin baseline studies
1987	US and Canada signed Agreement on the Conservation of the Porcupine caribou herd
1987	'1002 report' which is the Final Legislative Environmental Impact Statement (FLEIS) published
1989	Legislation to open 1002 for oil leasing halted by Exxon Valdez accident
2002	'2002' report; US Geological Survey assessed biological resources ANWAR , *Arctic Refuge Coastal Plain Terrestrial Wildlife Research Summaries*, Biological Science Report: USGS/BRD/BSR-2002-0001, 2002.
2003	National Research Council (NRC), Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope, March 2003, p. 452
2012	Revised Comprehensice Conservation Plan and Final Environmental Impact Statement published with preferred option with coastal plains recommended as wilderness designation
2017	US Public Law P.L. 115-97 signed which establishes an oil and gas program in the Refuge's Coastal Plain
2017	Updated version of "Arctic Refuge Coastal Plain Terrestrial Wildlife Research Summaries" by Douglas and others (2002), U.S. Geological Survey

Canada's interest in the conservation of the PCH and specifically its habitats is recognized through the 1980 Alaska National Interest Lands Conservation Act. Section 1005 of ANILCA states that in respect to oil and gas activity in 1002... "the Secretary shall consult with the appropriate agencies of the Government of Canada in evaluating such impacts particularly with respect to the PCH". In 1987, the Government of Canada and the Government of the United States of America signed an international treaty on the Conservation of the PCH with specific reference to consultation required prior to final decision if the activity is likely to cause a significant, long-term, adverse impact to the herd or its habitat.

In 2018, the U.S. Secretary of the Interior directed the Bureau of Land Management to initiate a Coastal Plain (1002 lands) Oil and Gas Leasing Program Environmental Impact Statement. In preparation for providing their position with respect to the EIS, Yukon and Canada have engaged Shadow Lake Environmental Inc. to assemble a science-based risk assessment of development of 1002 lands in the Alaska National Wildlife Refuge including uncertainties and information gaps. Our objectives are to:

1. Describe what constitutes a significant, long-term, adverse impact to the PCH or its habitat.
2. Provide detailed analyses on the cumulative effects anticipated by the program.
3. To fill in significant information gaps present in the EIS and to ensure complete information on reasonably foreseeable impacts of the program including potential alternatives
4. Describe if adaptive capacity through development mitigations could prevent long-term adverse impacts on the herd, its habitat, or to subsistence harvest using a risk-

based summary of the key impacts and any residual effects anticipated after mitigation; the cumulative uncertainty of the impacts and mitigation.

5. Describe how well residual effects can be assessed and can further information reduce risk to the degree that it increases the confidence in the assessment?
6. Describe required monitoring to ensure the assessment of risk is accurate if development were to proceed including overall risk given a full development scenario in the 1002 lands, implementation of all recommended adaptive measures, and the risk of not implementing specific provisions.

The assessment of risk is for both project-specific incremental and cumulative effects including a changing climate. The International Panel on Climate Change (IPCC 2013) has developed an approach to assessing risk from climate change based on vulnerability analysis. We had previously adapted the vulnerability analysis as a framework for assessing industrial impacts specifically oil and gas development on the winter range of the PCH in the Yukon (Russell and Gunn 2017).

1.1 Vulnerability analysis

IPCC (2013) described Potential Impact as a function of the sensitivity of a system to change (climate and industrial exploration and developments) and its exposure to those changes. The capacity to adapt to Potential Impacts (Figure 1) depends on herd and habitat management as well as mitigation of the industrial activity. Monitoring is the feedback between impacts and mitigations (adaptive mitigation). The outcome of adaptive capacity relative to potential impacts is the vulnerability of the system to the landscape changes.

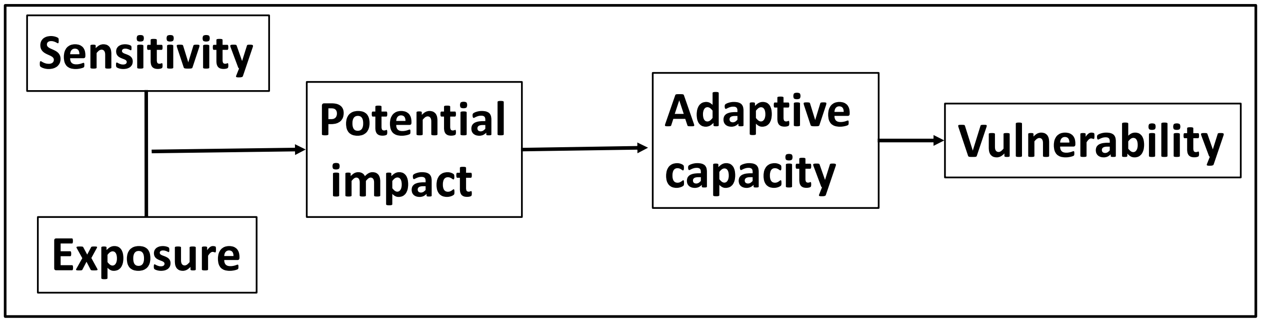

Figure 1. Components of a vulnerability analysis, adapted from IPCC (2013).

We have structured the components of the vulnerability analysis to answer specific questions for the PCH.

Sensitivity:

- A summary of reproductive biology and ecology of the PCH (including comparisons with the Central Arctic herd (CAH), and the importance of calving, post-calving, and early summer to the PCH.
- The current and possible future role of climate in PCH population dynamics.
- The neighboring CAH is relevant because it has been exposed to the Prudhoe Bay oil field for about 50 years. Compare and contrast these results to the CAH.

Exposure:

- How important are the 1002 lands to the PCH? What is the role of the 1002 lands in the life history of PCH, including figures showing use by biological period (e.g. calving, post-calving, early summer).
- Describe how the use of the 1002 lands by PCH varies annually and by decade, and the leading hypotheses for why those changes occur. Include all pertinent materials published on the herd, as well as relevant updates from the newest information available.

Potential Impact:

- Through the use of a caribou Cumulative Effects (CCE) model, quantify impacts of full development of 1002 throughout the phases of a population cycle and under changing climate conditions.

Adaptive capacity:

- Conduct a comparative analysis of the development alternatives provided in the EIS and use results from the full development scenario (from Potential Impact) as the measure of the effectiveness of landscape mitigation for each development alternative.

Vulnerability:

- Summarize key residual (quantified and unquantified) impacts

2. Sensitivity

We consider the PCH’s sensitivity to 1002 development through describing the current trend in herd size and the underlying vital rates. We summarize the reproductive biology and ecology of the PCH (including comparisons with the CAH) to describe the herd’s sensitivity to changes in calving, post-calving and early summer habitats. Our earlier studies (Russell et al.1993, Russell and Gunn In Prep.) identified climate as a strong influence on those vital rates so in this section on Sensitivity, we include climate. We had found that climate not only impacts vital rates but the impacts vary between neighbouring herds (Russell and Gunn In prep.), so we have also included the CAH relative to the PCH in this section.

2.1 Herd Productivity

2.1.1 Trend in herd size

The PCH is intensively monitored with locations of calving grounds identified every year since the early 1970's, early calf survival every year since 1983, and comparable population estimates since 1976 at an average frequency of 3.4 years (although variable). Herd size peaked in 1989 (178,000) then declined until the 2001 (123,000) based on censuses in 1992, 1994, 1998 and 2001. Early movement of the herd from the Alaskan coastal plain and cooler weather during late June and early July prevented a census until 2010 which revealed the herd had increased to 169,000 animals. A 2013 estimate indicated that the herd had an average annual growth rate of 5% from 2010 through 2013. The increasing trend continued based on a 2017 estimate of 218,000 animals with a more modest 2.5% annual increase from the 2013 estimate (Figure 2). The average annual percent change during the decline in the 1990s was 3.0 ± 0.3% SE. During the two periods of increase the average % change was 4.1 ± 0.27% SE. Of all migratory tundra herds in North America which increased in the latter quarter of the 20th century, the PCH had the lowest rate of increase; however, since 2001 the herd presently is the only major North American herd that is increasing (based on three consecutive estimates).

When the Central Arctic herd (CAH) was first documented in the mid-1970s, it was estimated to have 5000 caribou. The herd then increased at a high annual overall rate of 10% increase over 35 years partly because the harvest rate was kept so low. Herd size peaked at 70,000 by 2010 but then by 2016, Lenart (2017) estimated the herd had declined 69% to 22,630 caribou (range: 20,074–25,186; Figure 2) in 2010. The 2010 to 2016 rate of decline was an exponential rate of -0.193 - a halving rate of 4 years. Since 2016, the herd may have stabilized (Lenart 2018).

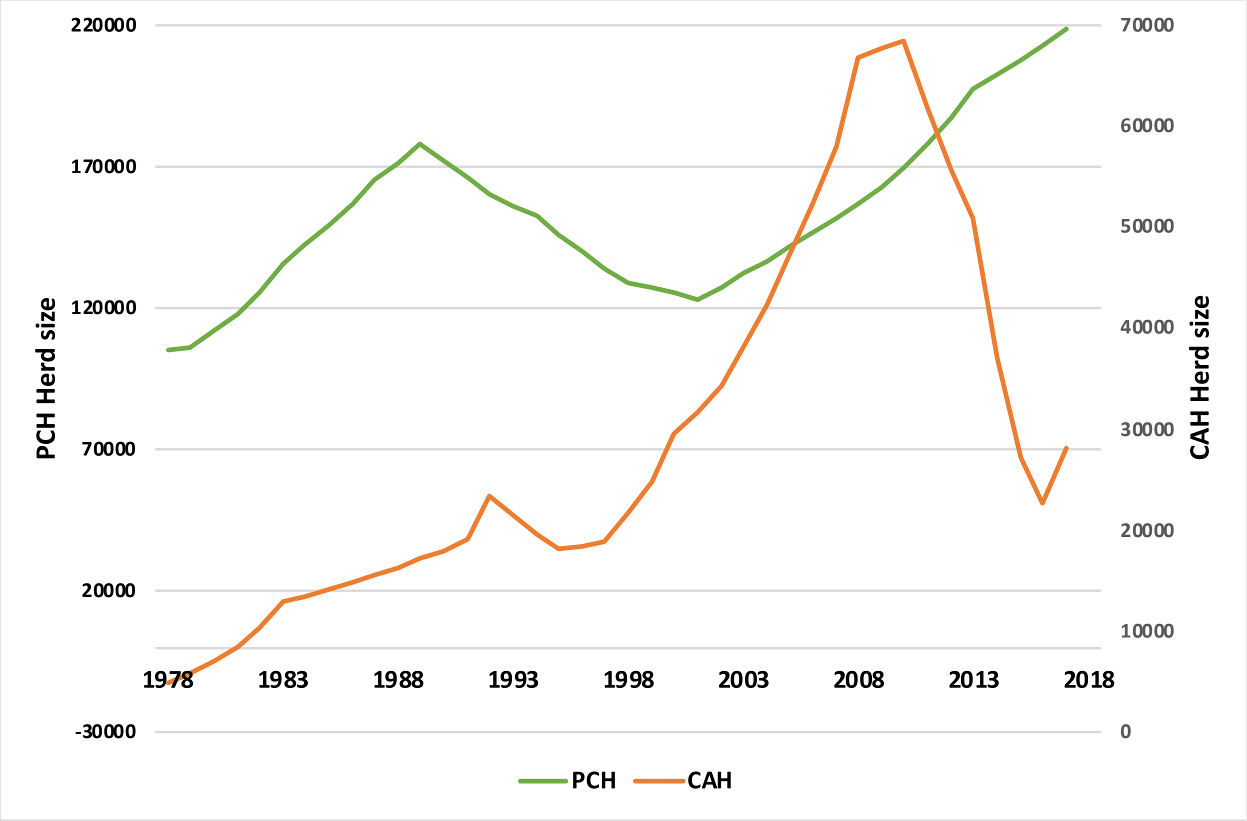

Figure 2. Trend in herd size 1978-2018 for the Porcupine (PCH) and Central Arctic (CAH) herds (data from Caikoski 2015, Lenart 2015; PCMB 2018;).

2.1.2 Vital rates

Porcupine Caribou Herd: Based on vital rates presented in Appendix A, Table 2 summarizes productivity since the early 1980s (Caikoski 2015). Although sample sizes in the 1980s are limited for most vital rates, during the three population trend phases, only adult cow survival appears to correlate with increase and decrease periods. Annual survival rates during increases averaged 86.6% and during the 1990s decline, 82%. In contrast, the ratio of spring calves:100 cows (recruitment rate) was higher in the 1990s compared to post-2000.

Table 2. Summary of vital rates for the Porcupine Caribou herd (Caikoski 2015). Adult cow mortality not in Caikoski (2015), references provided in Appendix A.

Year	Statistic	Adult Cow Survival %	Parturition	June calves: 100 cows	Early calf survival %	Spring calves: 100 cows
All years	mean	86	81	58	72	34
	stdev	5.3	6.4	10.0	11.2	9.3
	n	27	26	25	25	17
1978-1989 increase	mean	86	81	55	68	
	stdev	7.7	4.2	0	4.2	
	n	6	2	2	2	0
1900-2001 decrease	mean	82	80	61	75	36
	stdev	2.7	6.7	10.5	11.3	9.8
	n	5	12	12	12	11
2012-2017 increase	mean	87	82	56	68	31
	stdev	4.7	6.7	10.2	11.1	7.6
	n	16	12	11	11	6

CAH: Based on vital rates presented in Appendix A, Table 3 summarizes the productivity monitoring conducted by management agencies on the CAH since the mid-1990s (Lenart 2015). Although Lenart (2015) does not present early calf survival values (Appendix A), we calculated survival in the CAH by:

$$Early\ calf\ survival = 100 - \frac{(parurition - june\ calves\colon 100\ cows)}{parturition/100}$$

This metric is consistent with early calf survival reported for the PCH (Appendix A; ADGF 2015a). The CAH was increasing 1994-2010 and declined 2011-2015. Average annual adult cow survival rates during increase was 89% and during the post-2010 decline, 80%. Similar to the PCH herd, parturition rates in the CAH did not differ between the phases (86% increase, 85% decrease). June calves:100 cows declined from 76:100 during the increase to 67:100 during the decline and early calf survival declined from 87% during the increase to 79% during the decline in herd size.

Table 3. Summary of vital rates for the Central Arctic Herd (Lenart 2015).

Year	**Statistic**	**Adult cow survival**	**Parturition**	**June calves: 100 cows**	**Early calf survival**
All years	mean	86	86	74	85
	stdev	7.4	12.1	10.2	7.8
	n	18	20	21	19
1994–2010 increase	mean	89	86	76	87
	stdev	5.0	10.2	9.3	6.6
	n	13	14	14	13
Post-2010 decline	mean	80	85	67	79
	stdev	8.8	8.0	8.7	7.8
	n	5	4	4	4

2.1.3 Probability of pregnancy

The importance of the calving, post-calving and early summer habitats and seasons cannot be overstated. This is the period when calves are born; the cow's fat and protein reserves have to be replenished, energy and protein demands double due to lactation, high calf predation rates occur, and insect harassment and other factors cause the formation of large aggregations, compromising optimal foraging strategies. The International Porcupine Caribou Board identified calving and post-calving as the most sensitive habitats for the PCH (IPCB 1993). With respect to productivity, calving and summer are the time for the cow to ensure the survival of her calf while, at the same time, regain the condition she requires to increase her probability of getting pregnant in the fall. This trade-off manifests itself in the allocation of energy, the partitioning of protein and fat deposition and the timing of weaning. From sequential captures of over 200 individual caribou between 1992 and 1994, we developed a conceptual model of the weaning strategy of the PCH (Russell and White 2000; White et al 2013):

> Post-natal weaning occurs when biomass during the first week in June and rate of plant growth over the next three weeks are insufficient to maintain growth rates in the calf. Upon weaning the smaller-bodied calf dies and the cow increases her reserves and potential pregnancy rate in autumn.
>
> Summer weaning results when cow protein reserves fail to get replenished. The most likely cause is accidental injury or disease in the cow as we consider nitrogen availability not limiting when cows have uninterrupted access to forage in the summer range of the PCH.
>
> Early autumn weaning occurs when threshold fat reserves of the cow are not attained, primarily due to a combination of the factors listed above and a particularly bad insect year. As a result, the survival rate of the calf declines and the age of first reproduction of the calf is likely advanced. For the cow this strategy enhances her survival through winter and increases chance of getting pregnant.

Normal weaning, which is initiated during the rut, results in higher pregnancy rates for the cow. In this latter case both cow and calf have healthy levels of fat and protein reserves.

Extended lactation is common in the PCH and is associated with low fat reserves in the cow. As a consequence, the cow reduces her probability of getting pregnant due to "lactational infertility" but increases the overwinter survival of her calf.

The relatively low productivity and comparatively stable population size sets the PCH apart from herds east of the Mackenzie River. In the fall, the body condition of the cow dictates the probability that she becomes pregnant (Cameron et al 1993; Cameron and ver Hoef, 1994). The PCH and CAH differ from herds to the east in their functional response between body weight and the probability of getting pregnant (Russell unpublished data). Figure 3 is a clue as to why the PCH may be a less productive but a more stable herd compared to herds east of the Mackenzie River. Figure 3 was generated by the CircumArctic Rangifer Monitoring and Assessment (CARMA) Network body condition database and each curve was significant ($p<0.01$). In the figure below, "relative body weight" is the body weight relative to the 95th percentile of adult body weights for each herd. We used relative body weight given the variability in body weights between herds. For example, if the 95th percentile is 100kg and a cow weighed 85 kg then her relative body weight would be 0.85.

We interpret the curves of body mass and the probability of pregnancy in terms of resilience (steepness of the curve) and productivity (the lower the relative body weight to reach 0.5 probability of getting pregnant, the more productive is the herd). Thus, for the PCH we would conclude that they are very resilient (shallow curve) and not productive (second highest relative body weight required (0.74) to reach 0.5 probability of getting pregnant). The curve is similar for the CAH so in this incidence the herds are comparable with respect to resilience and productivity.

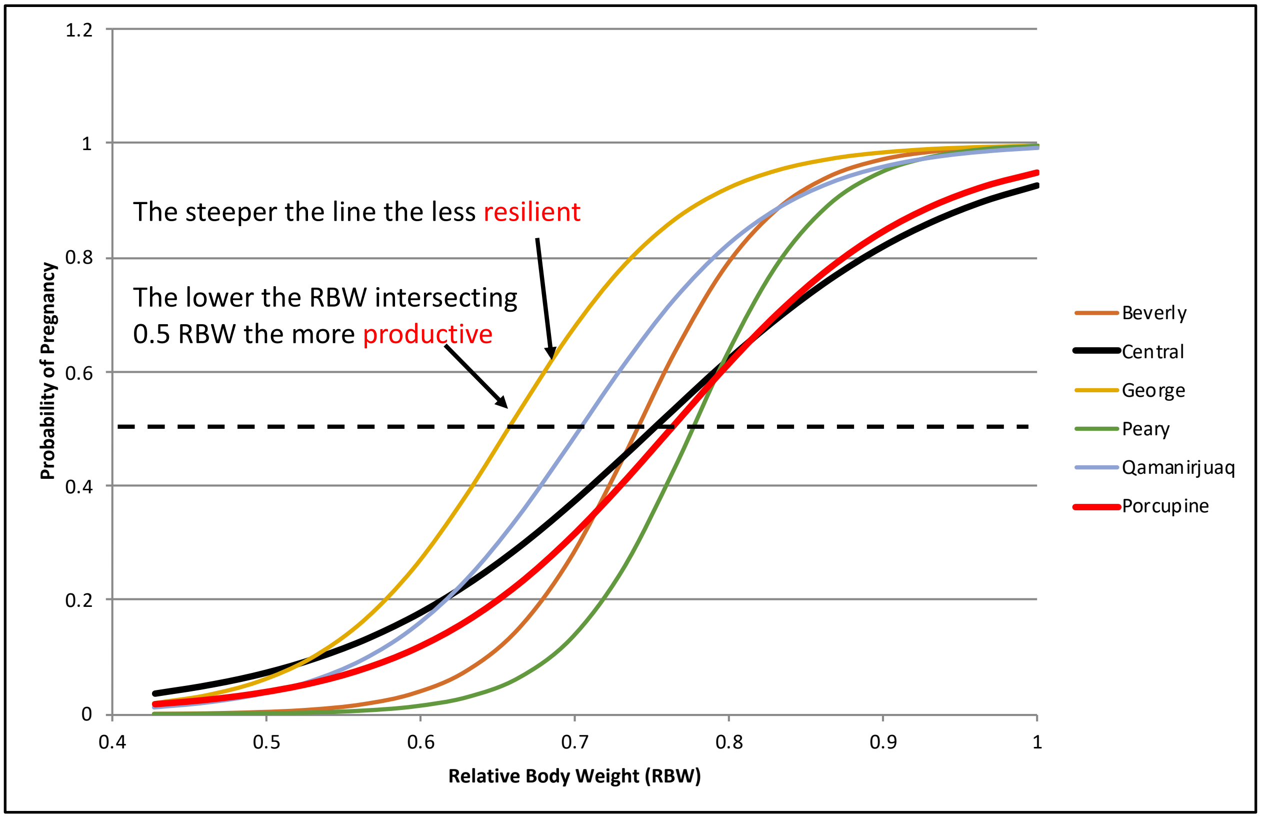

Figure 3. Relationship between relative body weight and probability of getting pregnant for six circumpolar herds.

2.1.4 Summary: herd productivity

In comparison to other North American herds, the PCH has been relatively stable as the amplitude of herd fluctuations in size is relatively small; both rate of increase and rate of decline are relatively low. The relationship between fall body weight of the cow and the probability that she will get pregnant is consistent with low productivity and high resilience. In one sense a herd that is resilient suggests that factors affecting body condition will not have a large effect on pregnancy rate. However, low productivity suggests factors that affect cow or her calf's survival will have a disproportionate impact in limiting herd growth or exacerbating a herd decline. In fact, we have seen that through two phases of increase and one phase of decline, pregnancy rates have stayed steady at 82%. Adult cow survival however appears to track population trend averaging 87% during increase phases and 82% during decline. It is worth highlighting that any small change in female survival will be highly significant for the herd.

These comments also apply to the CAH, as Cameron et al (2000) found that probability of pregnancy curves for the PCH and CAH generally overlap. In comparison to the CAH, the PCH had lower growth rate during increase phase and lower rate of decline during decrease phases. This is attributed to the PCH's overall lower adult cow survival rates during the increase and higher survival during the decline compared to the CAH (Lenart 2015). Average early calf survival also was higher in the CAH (85% versus 72%).

2.2 Climate trends

Recent reviews of climate and caribou describe effects of climate change as a bottom up phenomenon; climate through vegetation availability and quality impact body condition and body condition has direct links to vital rates, and vital rates collectively determine population trends. Those reviews include Mallory and Boyce (2016) while other studies link specific seasonal climate conditions to range quality (Heggberget et al 2002; Fauchald et al 2017), climate to body condition (Weladj et al 2003; Albon et al 2017; Mallory et al 2018); and to overall herd responses (Post and Forchhammer 2008; Joly et al 2011, Tyler 2010). However, extrapolating findings from one study to the species as a whole is simplistic, frequently precipitating rebuttals in the literature (for example, compare Post and Forchhammer 2008 with Tveraa et al. 2013, Veiberg et al. 2016, and Gustine et al. 2017).

To describe the sensitivity of the PCH to climate, we used CARMA's climate database (Russell et al 2013) to 1) quantify the climate "profile" of the PCH compared to the CAH, 2) quantify any climate indicators that had significant trends, and 3) quantify climate linkages among vital rates, climate and body condition.

In the EIS (BLM 2018b), climate change is only generally described and refers to regional effects of climate change in Section 3.2.4 of the GMT2 Final SEIS (BLM 2018a) which is a general account without analyses. Section 3 (p.108) of the 2018 draft EIS has a short general account of climate change and caribou with few specifics with respect to the PCH and CAH. In summarizing their discussion, the draft EIS states:

> "Because climate change could involve both adverse and beneficial effects on caribou, it is not possible to predict the impacts on the PCH and CAH; however, climate change could affect caribou demographics as well as habitat use and introduce additional uncertainty into projections of impacts due to development." BLM (2018b: 3-109).

In this section, we reduce uncertainty about climate change effects on caribou and their habitats, with an analysis to predict the impacts of climate on the PCH and CAH and to incorporate the climate analysis into our cumulative effects analysis. The availability of a comprehensive, spatial and standardized climate database (Russell et al. 2013) allows us to compare herds across the north. Seasonal climate indicators are based on spring, calving, summer, fall and winter herd-specific polygons (Figure 45). Table **4** summarizes key climate indicators for the PCH and CAH (1979-2016) indicating trends and if there was a significant difference between the herds. Both herds are undergoing increasing growing degree days (GDD), and therefore earlier green-up in June and July as well as warmer conditions in October on their fall range. The only difference between the herds is the trend toward decreasing drought index in the PCH presumably as the result of stronger positive trend in July precipitation.

Although climate trends are similar, there are significant differences in the average climate conditions between the two herds (Table 4). In general, the CAH has higher GDD in June, warmer July temperatures with corresponding higher oestrid index and more adverse drought conditions, while the PCH tends to have more adverse winter conditions with March and May snow depth, and a higher number of rain-on-snow and freezing rain days.

Table 4. Descriptive statistics for climate variables on the seasonal ranges of the PCH and CAH. Seasonal range maps can be found in Appendix A (Figure 45).

		PCH			CAH			t-test	
Climate indicator	**Range**	average	95% CI	trend	average	95% CI	trend	*p-value*	
Snow Depth 31 Mar. (m)	Winter	0.45	0.02		0.42	0.02		*	P>C
Snow Depth 15 May (m)	Winter	0.19	0.04		0.11	0.03		***	P>C
Snow Depth 10 June (m)	Calving	0.04	0.01		0.04	0.02			
Rain On Snow (mm)	Winter	24.0	3.47		22.0	3.48			
Rain On Snow # days	Winter	64.4	3.73		52.2	3.37		***	P>C
Freezing Rain (mm)	Winter	3.97	0.79		3.58	0.76			
Freezing Rain # days	Winter	35.7	2.69		26.7	2.66		***	P>C
Freeze Thaw events	Winter	36.4	3.10		35.0	2.63			
Cumulative growing degree days (above 0^{o}C) June 10	Calving	118.2	12.18	**	143.0	14.09	*	**	C>P
Cumulative growing degree days June 20	Calving	208.7	14.33	*	244.3	18.07	*	***	C>P
Cumulative growing degree days July 20	Summer	557.4	22.88	*	637.2	28.04	*	***	C>P
Oestrid Index	Summer	10.3	1.32		14.5	1.62		***	C>P
July monthly temperature (^{o}C)	Summer	11.5	0.49		12.6	0.50		***	C>P
July precipitation (mm)	Summer	48.7	5.22	***	40.6	5.86	**	**	P>C
Drought Index	Summer	8.72	2.60	***	16.0	5.15		**	C>P
October temp/ (^{o}C)	Fall	-10.5	0.95	**	-10.8	1.06	***		
Mushroom Index	Fall	13.2	2.67	*	8.93	2.89	**	**	P>C
Late season oestrid index		2.02	0.77		1.51	0.68			
Oct. 31 snow depth		0.19	0.02		0.17	0.02			

p-value * $0.05>p<0.1$; ** $0.01<p<0.05$; *** $p<0.01$

Although variability is often high, compared to the CAH, the PCH is characterized by some favorable conditions: higher (48% index) growing conditions for mushroom (a sought-after fall forage); 40% lower drought conditions partly because July rainfall is 20% higher and the oestrid fly index is 30% lower. Less favorable is that June growing degree days are 15% lower and March 31 snow depths are 13% higher.

2.2.1 Climate linkages to vital rates and body condition

Porcupine caribou herd

Appendix B provides a regression analysis quantifying linkage among PCH and CAH vital rates, climate indictors and body condition indices (only for PCH). Figure 4 summarises linkages and their strength of the linkages (r^2-values) which identifies how PCH is sensitive to climate.

We did not find temporal trends in Porcupine Caribou vital rates although there was a negative relationship between late June calves:100 cows the previous year and current year's parturition rate. The higher the previous year's late June calves:100 cows, the lower the subsequent year's parturition rate. This suggests that the "cost" of successfully raising a calf has a carryover effect in the fall when body condition of the cow is linked to the probability of getting pregnant (see Figure 3).

Adult cow mortality was related to the number of rain-on-snow (ROS) days in the current winter and the 2-year running average of parturition rate the previous spring (Figure 4). This suggests that if there were 2 years of high parturition, more cows would be lactating in both years and therefore likely their body condition would be compromised. After 2 consecutive years of lactation, overall body condition may be reduced and, if followed by a winter with a high number of rain-on-snow events, then cow survival would be reduced. The link is consistent with our previous finding that late June calves:100 cows negatively affects parturition rate in the subsequent year.

Parturition rates were negatively correlated with Oestrid index after Aug. 5 the previous fall, but positively correlated with warmer temperatures in September to October. Thus, the higher the calf:cow ratio in the previous June and the longer the Oestrid season into late summer, the lower the parturition rate the next spring. These conditions were ameliorated if fall temperatures were warm, presumably after oestrids were no longer active. Early calf survival was related to the growing degree days (2-yr running average) in the birth year and the amount of freezing rain over the last two winters. Freezing rain was also found to be a significant indicator of spring body condition in the cow. Overall late June calves:100 cows was related to earlier spring green-up (indexed by growing degree days on June 10 and/or shallower May 15 snow depth) and warmer September temperatures the previous fall.

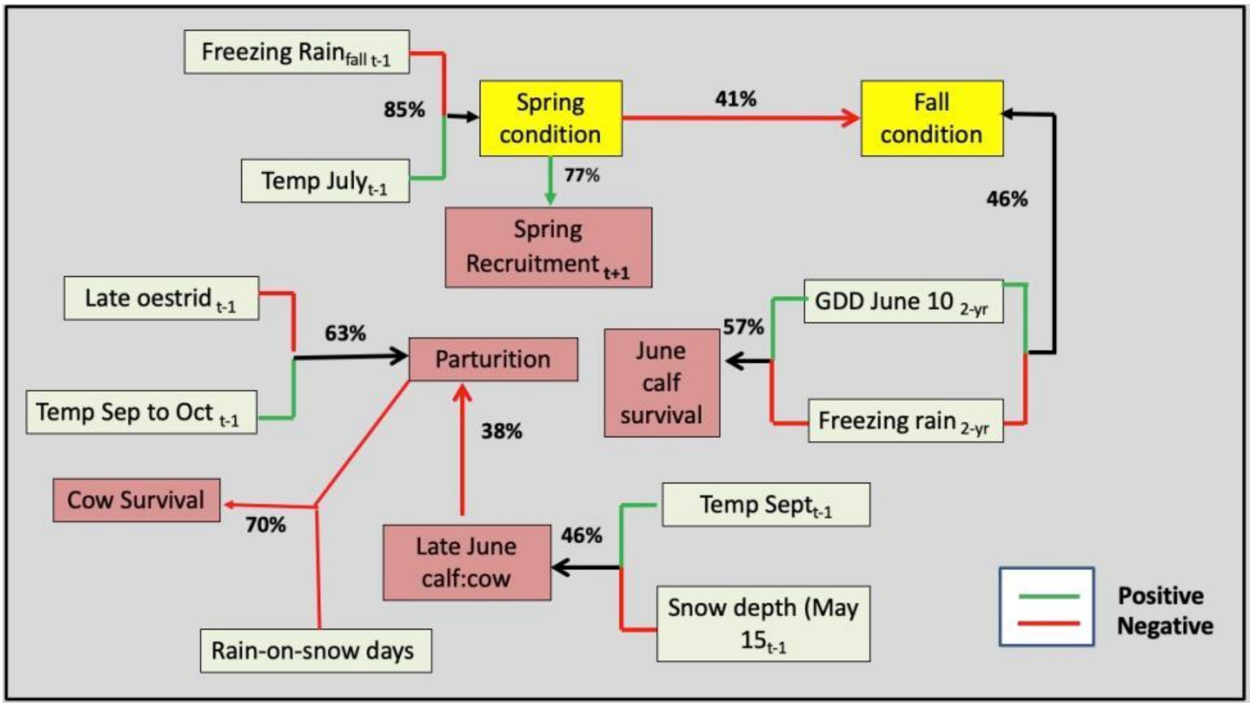

Figure 4. A summary of the sensitivity of Porcupine Caribou vital rates and body condition to climate indicators. Percentages between the linkages are the derived r^2 – value.

Central Arctic Herd

Figure 5 summarizes the linkages between vital rates and climate in the CAH (Appendix B). Between 1997 and 2012 there was a strong increasing trend in adult cow mortality in the CAH but no trend in parturition rate or late June calf:cow ratios. The 2-year running average of late June calves:100 cows accounted for 55% of adult cow mortality, suggesting a negative feedback between previous late June calves:100 cows and subsequent cow mortality in the CAH.

Fifty-nine percent of adult cow survival was negatively associated with higher fall rain-on-snow over the previous two autumns and warmer July temperatures over the previous three summers. The previous average September temperature had a positive relationship with parturition rate. However, the survival of those calves (early calf survival) and thus the late June calves:100 cows were negatively associated with October snow depth the previous fall. Early calf survival was further negatively associated with the average September temperature during the previous two years, while late June calves:100 cows was negatively impacted by warmer July temperatures.

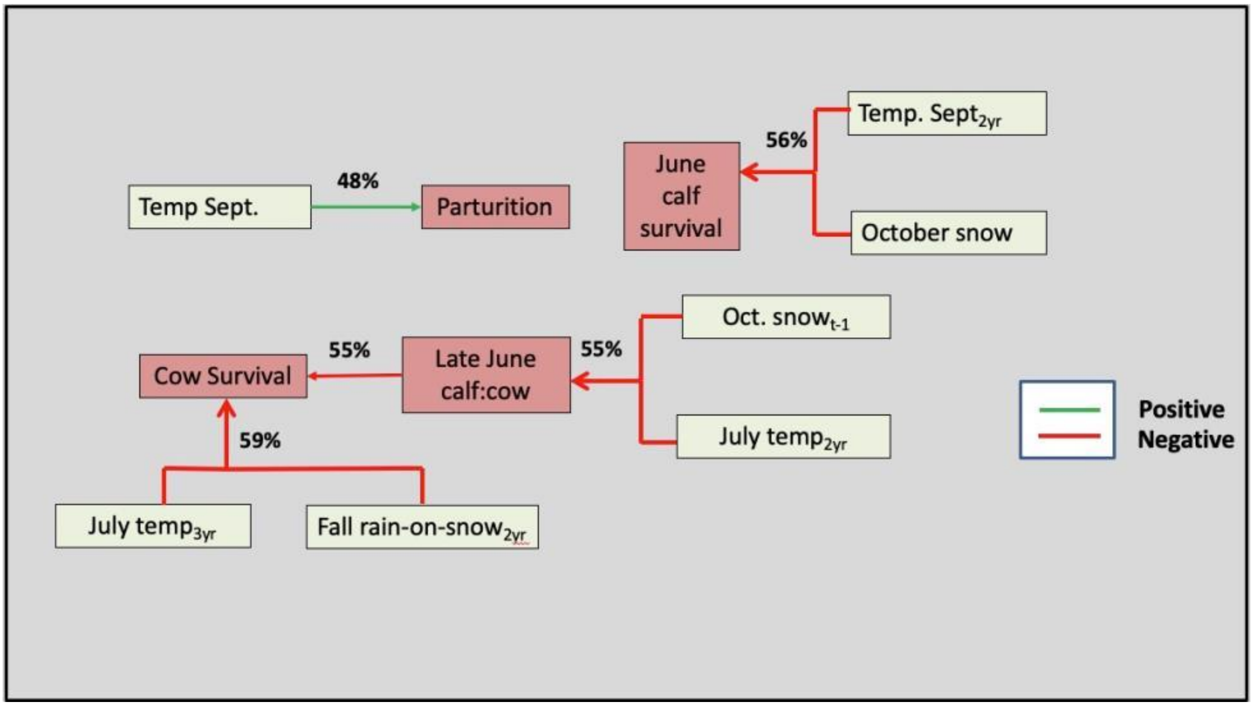

Figure 5. A summary of sensitivity for Central Arctic caribou vital rates to climate indicators.

2.3 Sensitivity discussion

The sensitivity of adult cow survival on both herds depends on how well the herds did in previous springs; PCH survival was negatively impacted if early calf survival was high the previous two springs. In the CAH survival was negatively impacted by the previous year's calf:cow ratios at the end of June. Cameron (1994) indicated that Central Arctic cows undergo breeding pauses every 4 years which he thought contributed to improved long term reproductive success.

We have noted differences between the PCH and CAH relative to how climate influenced vital rates. Most vital rates available for the CAH (no recruitment available) are related to fall climate. Generally, the warmer the temperature, the deeper the October snowfall and the higher the rain-on-snow from September to December, then the lower the productivity. The single exception was the positive linkage between September temperature and parturition rates the next spring. As well warmer July temperatures were negatively related to cow survival and late June calf:cow ratios.

In contrast, for the PCH, climate indicators were mainly related to overwinter freezing rain and rain-on-snow, both acting negatively, while warmer fall temperatures and July temperatures were positively related to vital rates. As well warmer spring conditions as measured by lower snow depth in May and higher growing degree days in June resulted in a positive response with calf survival and subsequent fall body condition.

Our finding with respect to warm fall temperatures and positive parturition rates and positive late June calves:100 cows overall might partially explain why in the 2000s the PCH has been increasing while the other Alaskan herds have been in decline. For the CAH, warmer fall temperatures, although having a positive effect on parturition rates, had a negative effect on adult cow mortality, early calf survival and/or late June calves:100 cows. Although there was no temporal trend on the calving grounds of the PCH in May snow depth since 2000, June 10 growing degree days has increased significantly since 2000 (p=0.008), which also might partially explain the increasing trend in the PCH since 2001.

As spring and summer conditions are important to PCH productivity, it suggests that disruption of free movement and access to forage resources and insect relief areas during spring and summer would directly impact on PCH productivity. In contrast most of the productivity linkages in the CAH are with fall climate conditions and July temperatures. The difference in climate effects between the CAH and PCH suggests that the documented displacement of the CAH from calving and immediate post-calving areas, may not be comparable to potential displacement for the PCH.

3. Exposure

Understanding how caribou are exposed to oilfield development is essential for predicting and mitigating effects. This importance was recognized in scoping comments for the leasing 1002 lands which emphasized concerns for the PCH. The EIS (2018b:1-3) reported the comments requiring that the EIS should "evaluate the use and importance of the program area to herd movement during different life stages and seasons". However, the draft EIS (2018b) does not provide analyses of movements and seasonal distribution. Maps 3-21 and 3-22 (Appendix A) for the PCH and CAH have five panels for seasonal distribution showing the percentage of years that caribou are present but that obscures both the annual scale and any trends in distribution which is essential information for describing potential effects and designing mitigation. The third map (Map 3-23; Appendix A) shows the percentage years that caribou are present in the alternative scenarios and by stipulation. The movements and distribution of both the PCH and CAH are briefly described in the draft EIS (2018b:3-16-3-107) but without analyses to describe the annual consistency and variation in use patterns.

Consequently, we have undertaken analyses to describe how many, when and for how long, cows of the PCH will be potentially exposed to oil and gas activities in 1002 lands to summarize how PCH exposure varies seasonally and annually. During calving, individual cows are relatively dispersed (compared to post-calving and early summer), which increases the probability of individual exposure. Early post-calving movements are a critical time for cows, energy and protein demands double to produce sufficient high quality, milk to raise her calf. Thus, allowing the cows unconstrained movement to seek out the highest quality landscapes is critical to ensure calves survive the first month of life. Later in the post-calving period cows and their calves begin to form larger groups primarily in response to insect harassment.

To quantify the exposure of the herd to 1002 development, we undertook four analyses based on the movement of satellite or GPS collars on cows between 1985 and 2017: 1) We describe the annual variability in seasonal distribution relative to 1002; 2) we describe the annual variability in calving distribution 3) we describe the annual variability in calving distribution relative to climate within and outside 1002 as the climate is the mechanism for how the location of calving influences early calf survival; and then 3) use of 1002 and surrounding areas during the formation, movement and dispersal of large post-calving aggregations.

In our PCH analysis, we refer to seasonal use of 1002 using dates based on Russell et al. (1993):

pre-calving: 20-30 May
calving: 1-10 June
post-calving: 11-30 June
summer: 1 July – 8 August

NOTE: The timing of "post-calving" as defined above combines Russell et al.'s (1993) designations of 11-20 June "post-calving" and 21-30 June "movement". Further we combine Russell et al 1993 "early summer" (1 -15 July) with "mid-summer" (16 July – 8 August) locations as "summer".

3.1 Annual variability in seasonal distribution relative to 1002

The pattern and intensity of use of 1002 depended on whether a cow gave birth within 1002 or outside of 1002 and therefore we treat these two cases separately. In years that concentrated calving was not in 1002, calving was on the Canadian and eastern ANWR portion of the range. In this report we refer to this area as the "non-1002" calving area (see Appendix A, Figure 46). We identified "1002 calving" cows as those that were in 1002 on June 4. Our rationale was that cows are relatively sedentary just before and after parturition (DeMars et al 2013), therefore the location of the cow on June 4 was likely close to the calving location, and thus the calf was likely born in 1002 even if calving occurred shortly after.

Figure 6 illustrates, through individual caribou tracks, the locations and density of use of the 1002 area for two sets of collars, those that calve in 1002 and those that calve outside of 1002 from the pre-calving to the summer period. For 1002 calving caribou, most calving occurs in the south east corner of 1002 with lower density use in the south west of 1002, similar to the pattern in the pre-calving period. Post-calving has the most intense use as these cows drift north west with concentration of use in a northeast to south west band starting south of Camden Bay. In summer, 1002 calving cows move generally south out of 1002 although still use 1002 to a lesser extent.

Non-1002 calving caribou make less use of the 1002 lands during the pre-calving and calving periods, however, those cows arriving later into 1002 have a similar distribution as 1002 calvers in the post-calving period. Although non-1002 calves arrive later into 1002, this group appears to stay longer with still many cows remaining in the summer period.

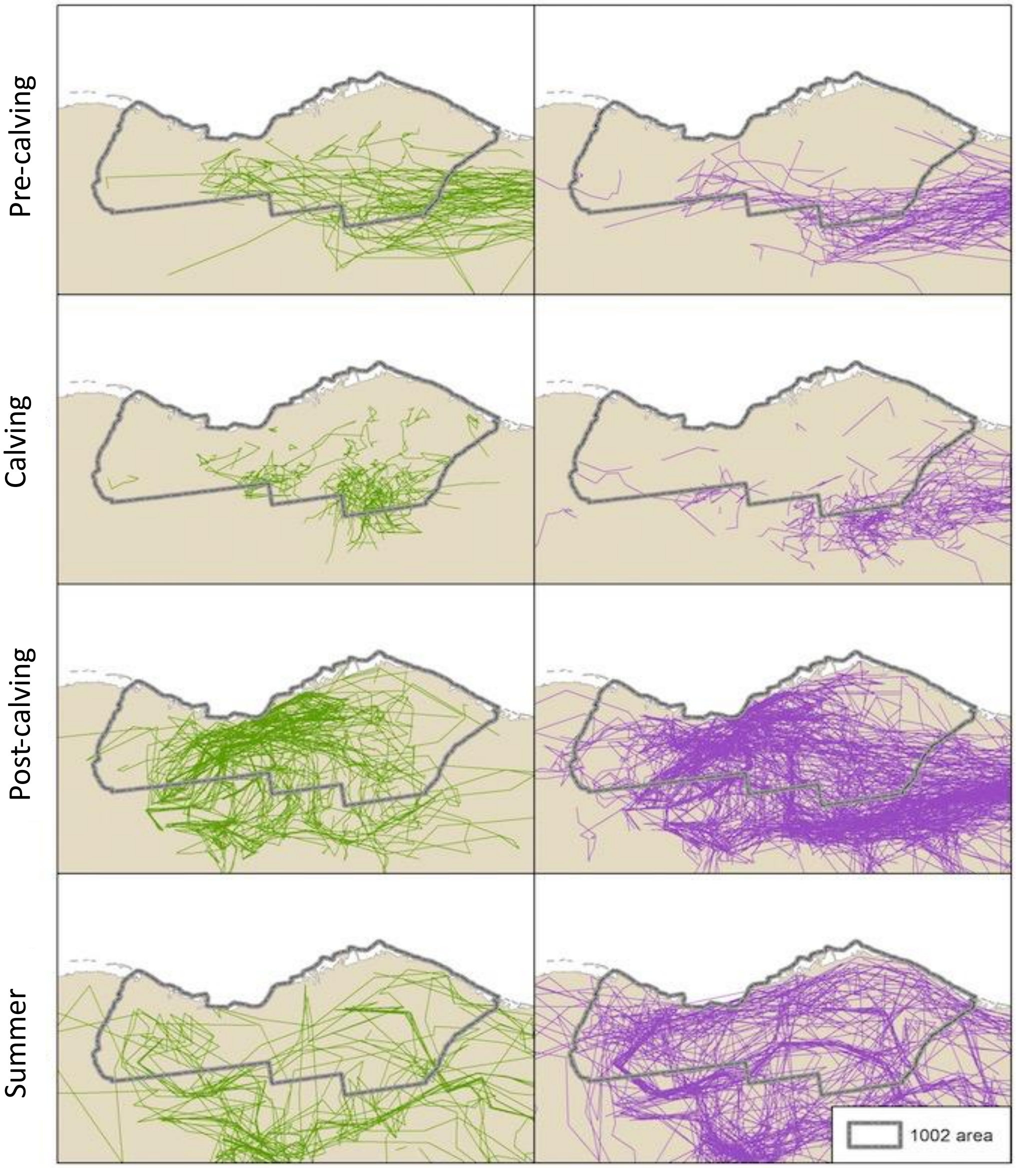

Figure 6. Seasonal movement paths for cows that calve in 1002 (left panels, green tracks) compared to cows that calve outside of 1002 (right panels, purple tracks).

Figure 7 separates the total collars by year into those that entered 1002 that year and those that did not enter. On average, 67% of the collared cows entered 1002, although the variability among years was high. In 2 years, there were no satellite collars (1996 and 1997). There were only 4 years when collars did not enter 1002 and, in those years, satellite collar numbers were low. Between 1985 and 1994, 96% of cows entered 1002. In the last 4 years (2013-2017), 92% of cows entered 1002 – potentially an average of 87,000 cows every year (based on assuming 45% of PCH comprised of adult cows and average herd size of 210,000).

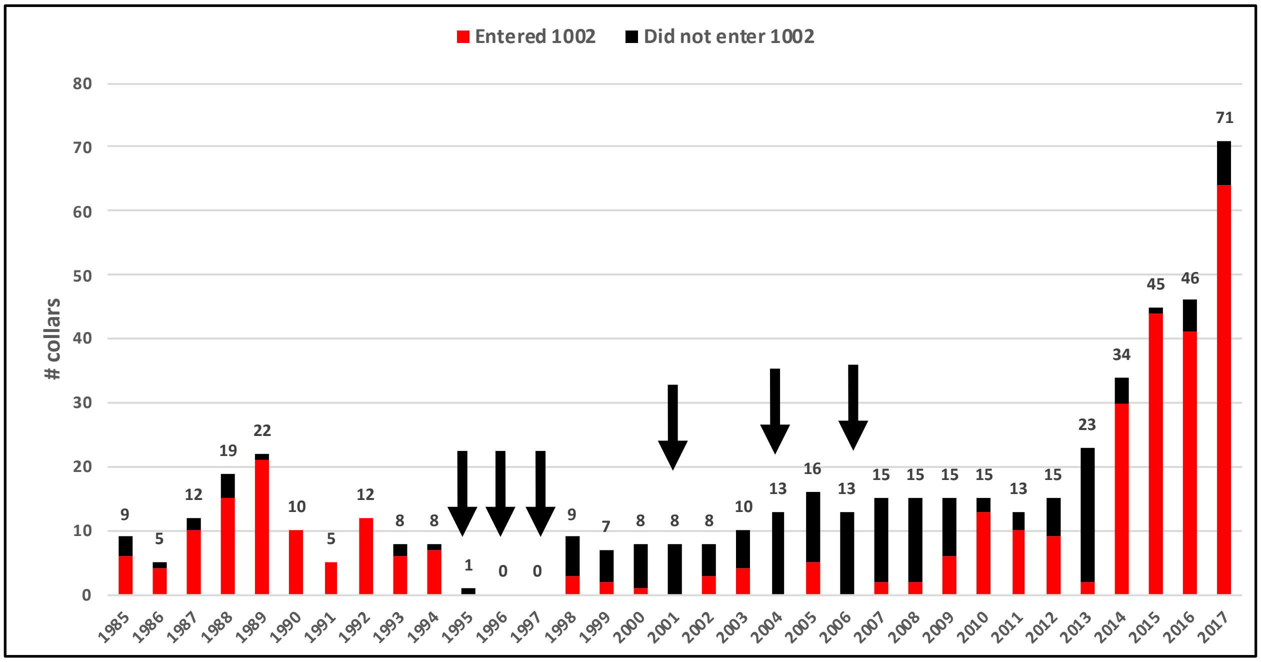

Figure 7. Total number of satellite collars on adult cows between 1985-2017 that either entered (red) or did not enter 1002 (black). Black arrows indicate years when there was no record of satellite collars entering 1002 or years with no satellite collars on the PCH (but see Figure 8).

In 14 of the 33 years, there were fewer than 10 collars being monitored and in 2 of those years (1996, 1997) there were no collars. Since 2012, collar deployment has increased, culminating with 71 collars available in 2017. In those years when no satellite collars entered 1002, it does not mean 1002 was not used by the PCH. Conventional VHF collars are not represented in this analysis as often there was only a single or a couple of locations obtained through aerial surveys during the calving to early summer period. Recently, the Yukon Government (Suitor et al unpublished report) updated Russell et al (1992) to include movements and distribution of the PCH using aerial surveys and VHF collars 1990-2016. According to Figure 7 there were no collars available or no satellite collars entering 1002 in 6 years (1995, 1996, 1997, 2001, 2004 and 2006). However extracting distribution maps based on sateliite and VHF collars, we note that cows used 1002 in all years and were in 1002 for calving in all years except 2001 (Figure 8). It is recognized the satellite colllar data may underestimate annual frequency of 1002 occupancy, but provides a quanitatitve way to evaluate use and potential impacts.

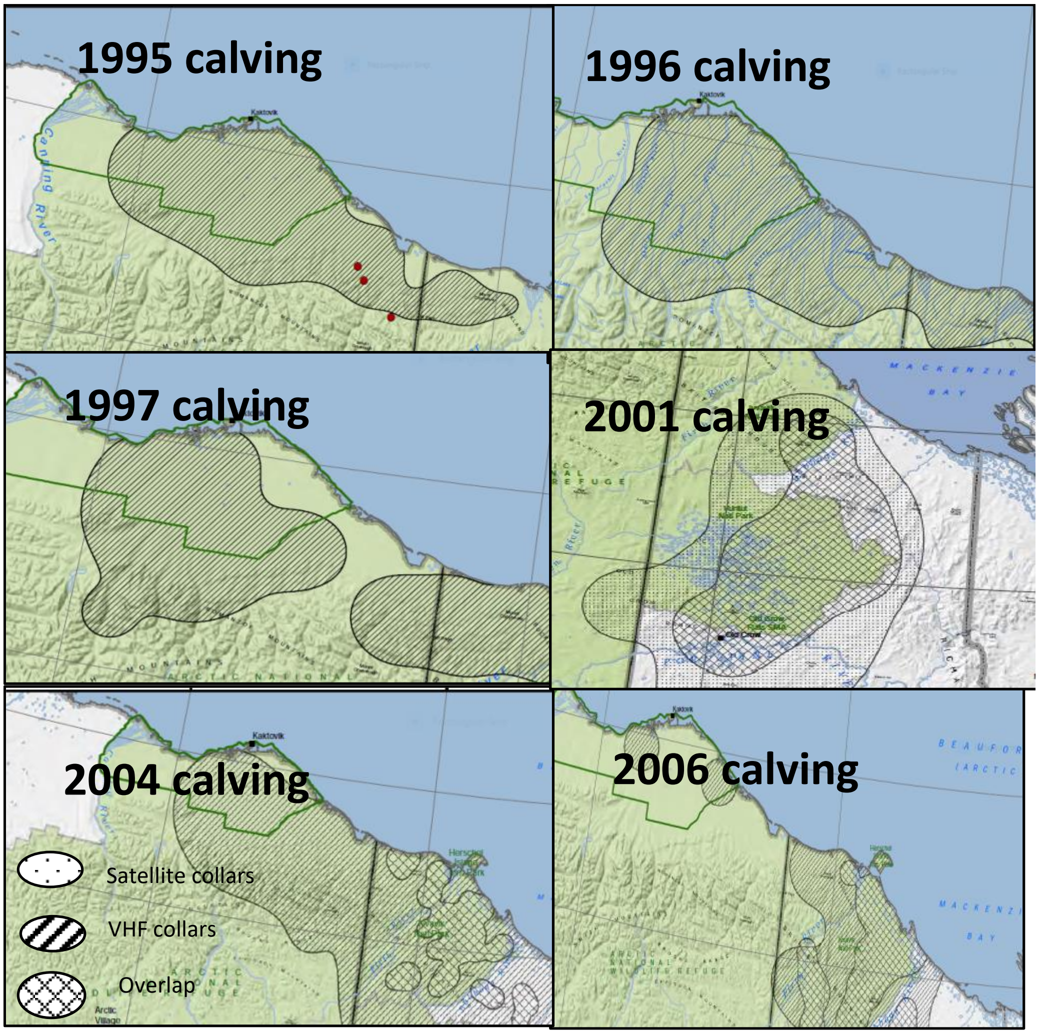

Figure 8. Calving distributions based on satellite and VHF collars in those years that satellite collar data indicated no collars entering 1002 (from Figure 7). NOTE: no calving in 1002 in 2001, although cows entered 1002 in the mid-summer period. Data from M. Suitor (Yukon Government, unpublished data). Red dots in 1995 are satellite locations.

The length of stay, once caribou enter the 1002 area, was variable. Reading from the left to the right (Figure 9) we present the cumulative percent of cows that occupy 1002. For example, five percent of cows spent greater than 7 weeks in 1002, 29% will spend greater than three weeks and 61% spend at least two weeks in 1002.

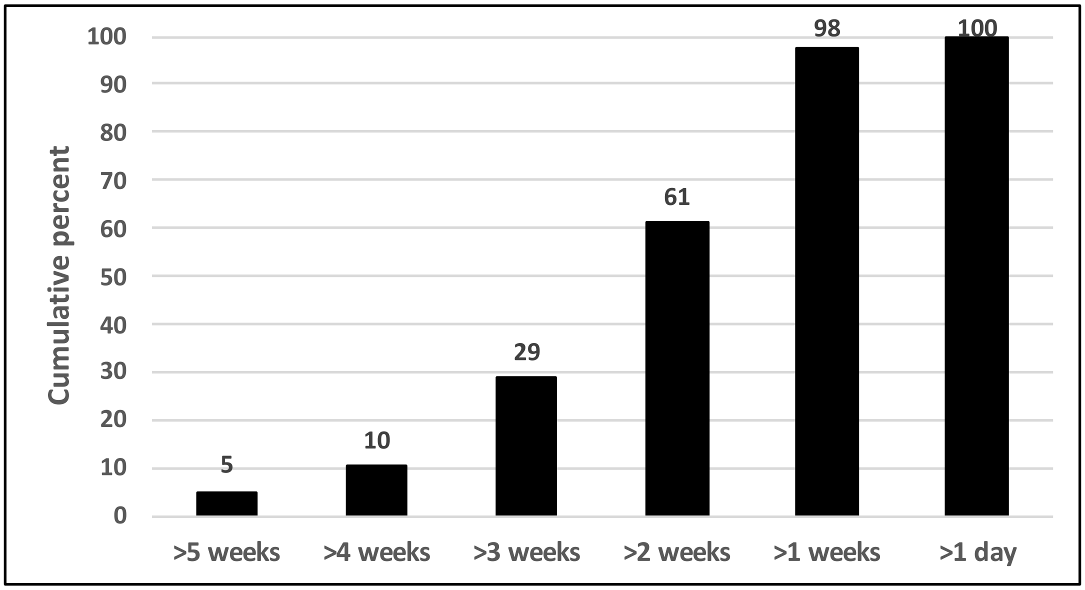

Figure 9. For the 67% of PCH cows entering 1002, the cumulative percent of days spent in 1002. For example, if they entered, 61% of cows spent at least two weeks in 1002.

We also examined seasonal distribution relative to hydrocarbon potential by overlaying collar locations from 20 May to 16 July on zones of hydrocarbon potential based on the draft EIS (BLM 2018b; Map B.1; Figure 10). Of collared cows that entered 1002, 17% of 1002 days were in High, 40% in Medium and 43% in Low hydrocarbon potential zones (Figure 10). Thus, with respect to potential development, cows would spend more time in High and Moderate hydrocarbon zones (57%) compared to the low hydrocarbon potential zone (43%). Collared cows spent 53% of 1002 time during the sensitive post-calving period, and the majority (67%; 36 of 53 days) of those days in the Medium and High hydrocarbon potential zones (Figure 11).

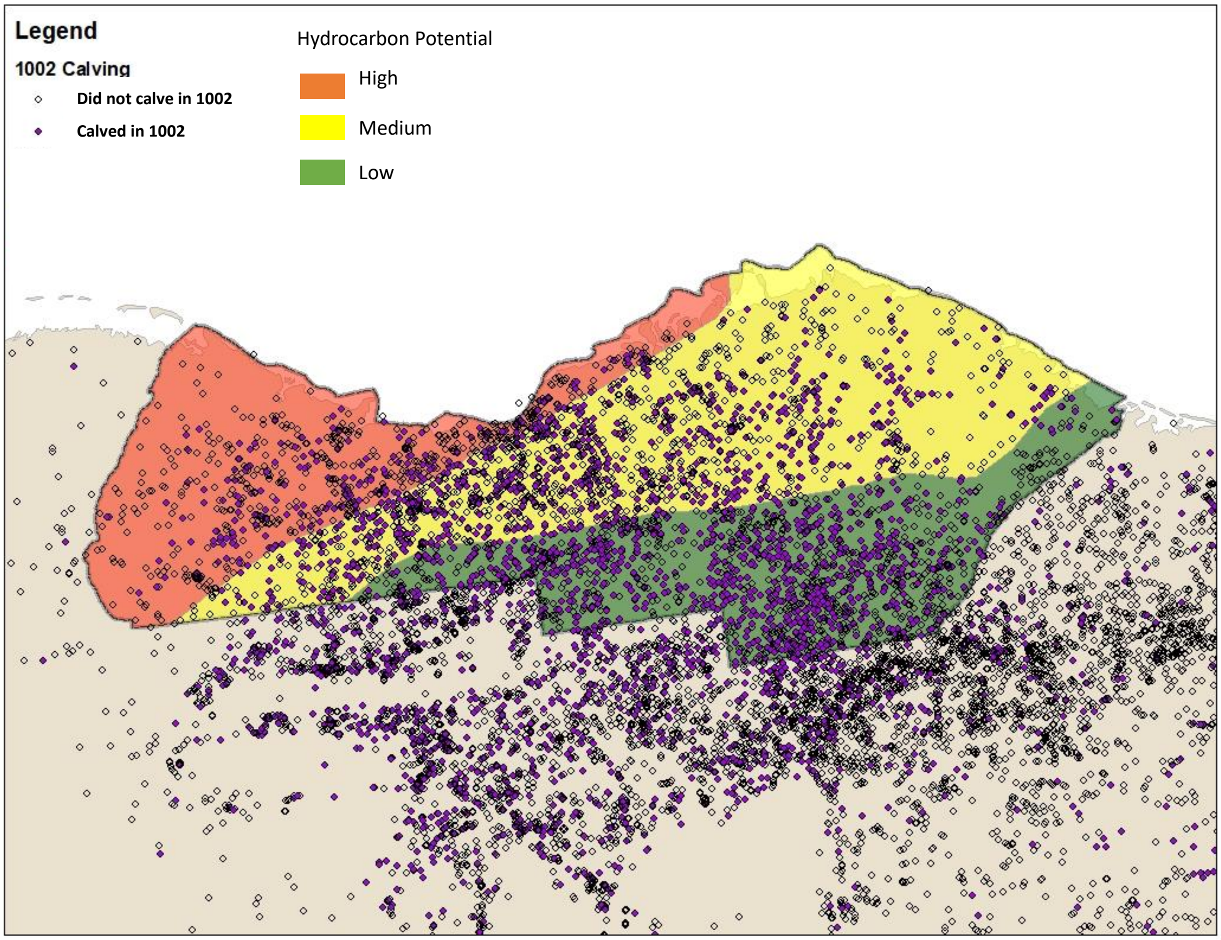

Figure 10. Collar locations of PCH 1985-2017 from pre-calving to early-summer in relation to 1002 hydrocarbon potential.

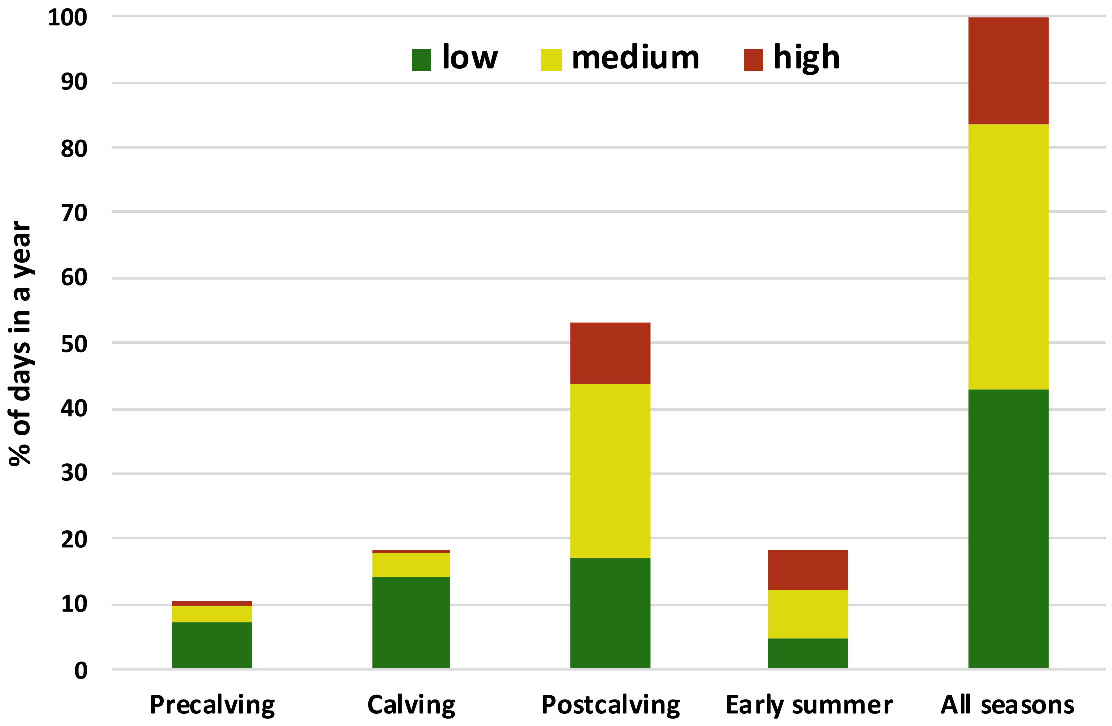

Figure 11. Seasonal use by collared caribou in 1002 with respect to potential hydrocarbon potential.

3.2 Annual variability in calving distribution

The seasonal breakdown of the average number of days that collared cows spent in 1002 depends on whether they calved in 1002 or calved outside of 1002 (Figure 12). On average, cows that calved in 1002 spent 26.5 days in 1002, while cows that did not calve in 1002 still spent 9.8 days in 1002. In both cases, most days were spent in 1002 in the post-calving period. With respect their time in 1002, 47% of the days for 1002-calvers were spent after the calving period, compared to 89% after the calving period for those that did not calve in 1002.

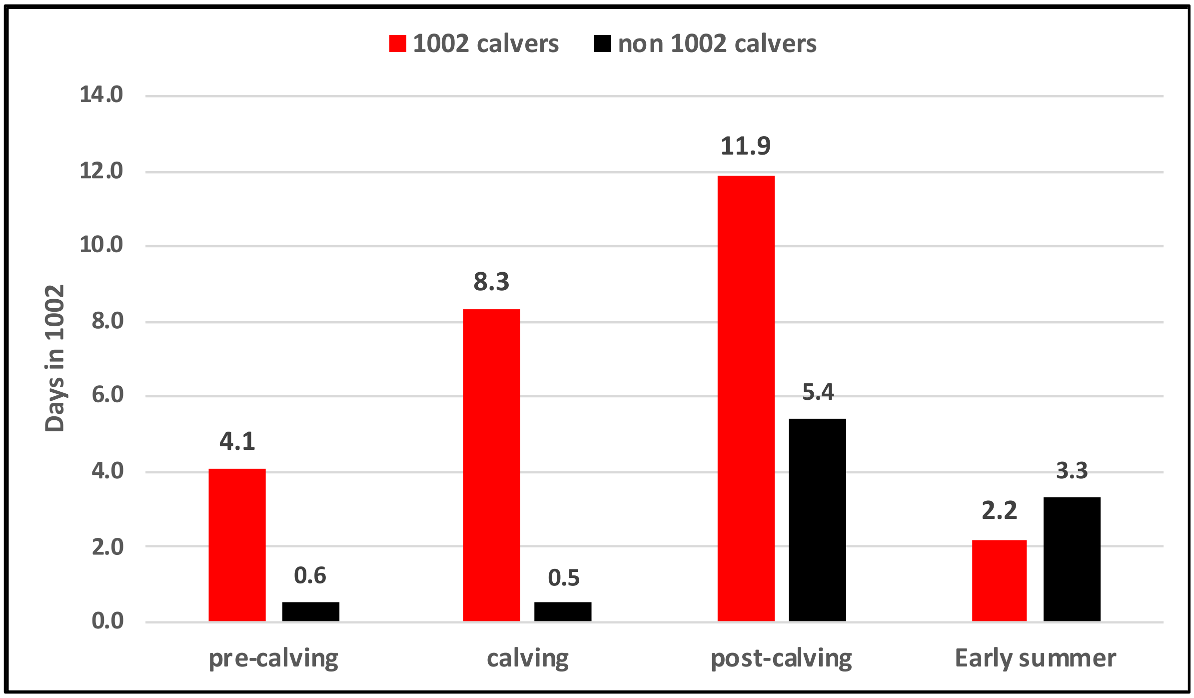

Figure 12. Average number of days 1002 calvers and non-1002 calvers spent in 1002.

3.3 Annual variability in calving distribution relative to climate within and outside 1002

To describe the annual variability in calving distribution relative to climate for the 1002 calving area compared to the "non-1002" calving range (Appendix B; Figure 46), we downloaded daily climate data (1979-2016) for the two areas following Russell et al (2013). Current climate trends (2000-2016) for the two calving areas (.

Table **5**) indicate an overall improvement in spring and summer foraging conditions – spring is getting warmer, snow melt earlier, and earlier green-up.

Table 5. Mean value and significant climate trends between 1979-2016 in the 1002 region compared to the "non-1002" portion of the calving range. All trends are positive unless denoted by (-) following p-value.

Indicator	non-1002		1002	
	mean	*p-value*	*mean*	*p-value*
March 31 snow depth	0.41		0.33	0.033 (-)
May 15 snow depth	0.18	0.003 (-)	0.11	0.007 (-)
June 1 GDD	52	>0.001	79	0.001
June 10 GDD	100	0.002	138	0.025
June 20 GDD	175	0.002	229	0.04

3.3.1 Climate associated with calving and relation to early calf survival

Calving in 1002 is generally associated with spring conditions on the Alaskan coastal plain (Griffith et al 2002). Average to early snow melt enables pregnant cows access to 1002. In this section, we analyse the role of climate in determining the location of concentrated calving and how location is related to early calf survival (survival to one month). Griffith et al (2002) reported that early calf survival could be determined from forage available on June 20 (indexed through Normalized Difference Vegetation Index, NDVI) and predator density. He used this information to calculate the change in survival if concentrated calving was displaced from the 1002 area. For this latter analysis, Griffith et al 2002 (and subsequent update to 2016; Griffith pers. comm.), listed the years when all or part of concentrated calving (polygon where calving density was greater than average) was within 1002 calving versus years of non-1002 calving. We use Griffith's (pers. comm.) list of 1002 calving years and non-1002 calving years in our analysis.

We separated the climate database for the two calving areas to compare the snow depths and green-up conditions to describe the herd's sensitivity to calving location, There was no significant difference between late March snow depth or Growing Degree Days (GDD) for June 1, June 10 and June 20 between years when calving was in 1002 compared to years when calving was in Canadian calving areas (based on the years identified by Griffith). The only climate indicator that was significantly different between 1002 calving years and non-1002 calving years was May 15 snow depth in the non-1002 calving range. Depths were significantly lower in 1002 calving years (p=0.02).

Even though we have already identified 2-year running average of June 10 cumulative Growing Degree Days as the best indicator of early calf survival (see Figure 52, Appendix B), we repeated the analysis for the two separate calving areas (1002 and non-1002, Figure 46) to determine the strength of this relationship depending on where they calved. In years when concentrated calving is in 1002, the climate indicator that best explained variability in early calf survival was the 2-year running average of June 10 growing degree days (r^2=0.47; p=0.01; Figure 13) but no relationship between early calf survival and late March snow depth (r^2<0.01; Figure 14). In contrast, for years when concentrated calving was outside of 1002, the climate indicator that best explained the variability in early calf survival was March 31 snow depth within the entire winter range of the PCH (r^2=0.78; p<0.01; Figure 14) while there was a weak relationship between calf survival and 2-year running average of June 10 GDD if caribou calved in outside of 1002 (r^2=0.16; Figure 13).

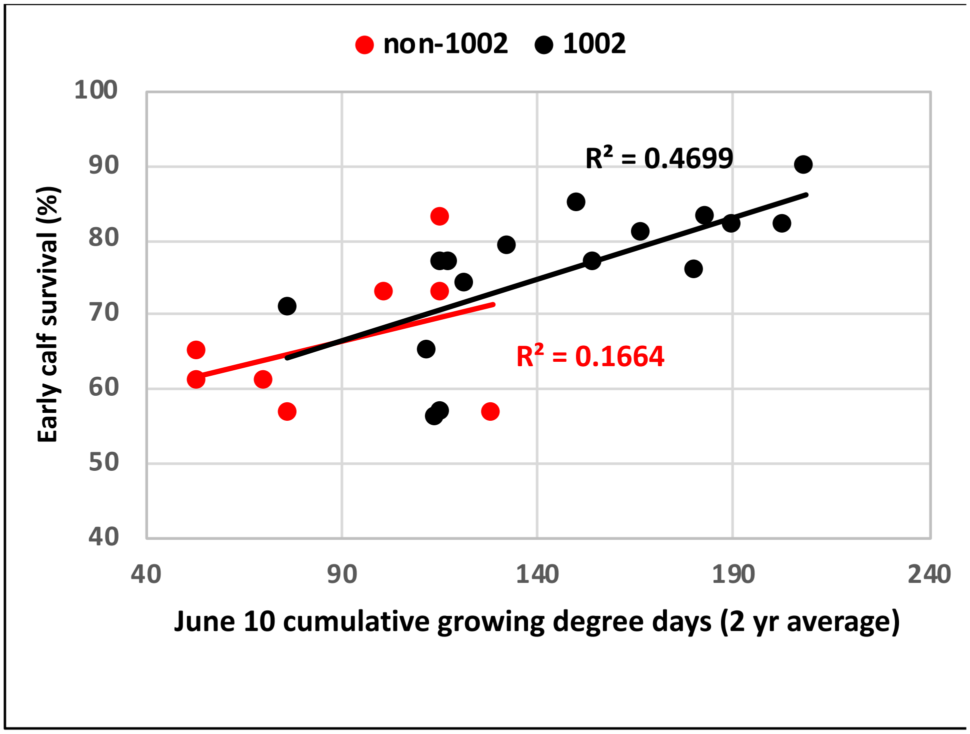

Figure 13. Early calf survival in the PCH and June 10, 2-year average, cumulative growing degree days (GDD) for years when concentrated calving was all or partly in 1002 or outside of 1002. GDD values relative to specific calving location.

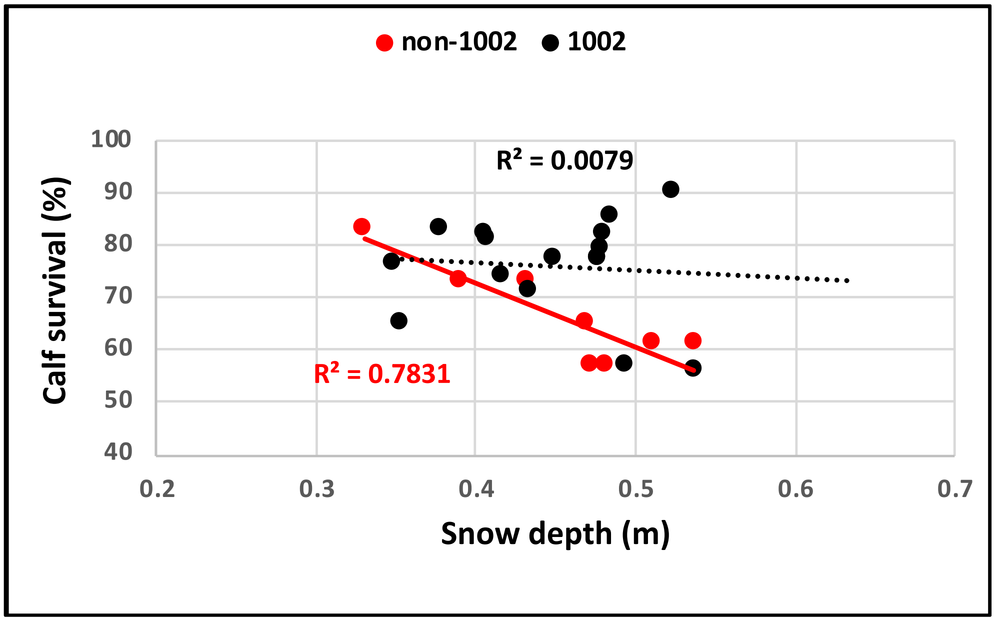

Figure 14. Variation in early calf survival in relation to March 31 snow depth on the PCH winter range.

Average March 31 snow depth on the overall long-term winter range does not differ for 1002 calving years compared to non-1002 calving years (mean: 45 cm and 44 cm, respectively). Thus, when concentrated calving was in 1002, the PCH, on average, experienced the same late winter snow depths as those years when they calved outside of 1002. Calf survival was not related to late winter snow depth in years when calving was in 1002, which suggests that foraging conditions were sufficient to overcome adverse winter conditions. In contrast, in years when calving was outside of 1002, forage conditions, although somewhat important (r^2=0.16, Figure 13) did not allow the cows to overcome adverse winter snow conditions and thus calf survival was largely predicted from late winter snow depth (r^2=0.78, Figure 14). The 1002 area provided better foraging conditions (higher GDD) throughout June, even in years when calving ended up outside of the 1002 area (

Table **6**).

Table 6. Growing Degree days (GDD) in the 1002 calving areas and non-1002 calving areas in years when concentrated calving was in 1002 and in years when calving was in the non-1002 calving area.

Indicator	**1002 calving years**		**non-1002 calving years**	
	1002 area	non-1002 area	1002 area	non-1002 area
June 1 GDD	90	62	71	45
June 10 GDD	144	108	140	97
June 20 GDD	231	181	240	180
Average	155	117	150	107

We can convert GDD on June 10 into a predicted early calf survival using a regression equation. The overall regression equation for all years and GDD June 10 (see Figure 15) is:

$$early\ calf\ survival = 0.2797 * GDDJune\ 10 + 39.4$$

We can interpret Table 6 in a number of ways:

1. Given the constraints of mid-May snow depths, in years when calving was outside of 1002, cows encountered on average 47 (144-97) lower GDD on June 10 compared to those years when cows were able to calve in 1002 (
2. Table **6**). Thus, there was a significant nutritional advantage to have access to 1002. Based on the equation above the difference resulted in a 13% higher early calf survival if they calved in 1002.
3. For years when non-1002 calving occurred, had mid-May snow depth not prevented access to 1002, cows would have been able to benefit from 43 (140-97) higher GDD by entering 1002 (Table 6). We know from conventional VHF collars that even if concentrated calving does not occur in 1002, calving distribution does penetrate the 1002 area thus allowing a portion of the herd access to higher forage conditions. This translates into an increase of 12% early calf survival for those cows that can access 1002 even though concentrated calving occurs outside of 1002.
4. If in years when concentrated calving did occur in 1002, cows were displaced by development from 1002, they would be foraging on sites with 38 (144–108) lower GDD because of being displaced (

5. Table **6**). Thus, if calving is displaced in years when 1002 should be available, early calf survival would be 10% lower.

3.3.2 Early calf survival in CAH versus PCH

The PCH and CAH differ with respect to how climate and development interacts with early calf survival. In the PCH, early calf survival is positively related to with GDD June 10, while in the CAH, June 10 GDD is unrelated to early calf survival (Figure 15). Based in our 38-year (1979-2016) CARMA climate database (Russell et al 2013), average June 10 GDD on the PCH calving range is 118±38 SD, compared to 143±44 SD within the CAH calving range.

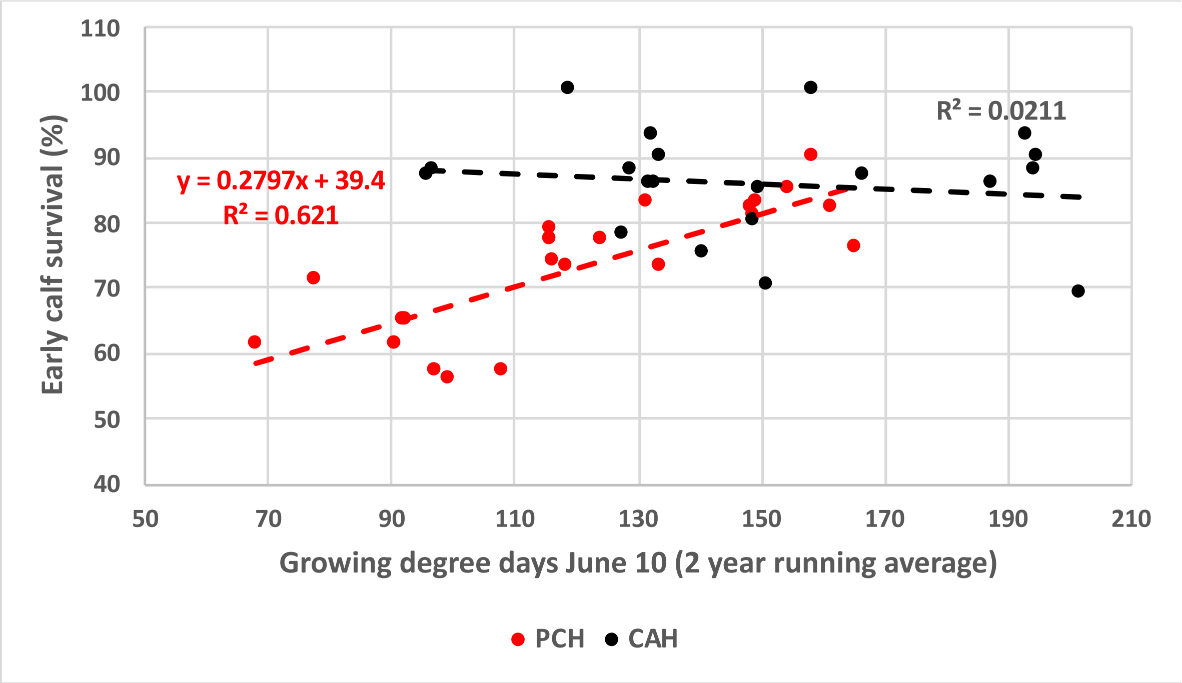

Figure 15. Correlation between June 10 GDD (2 year running average) and early calf survival in the PCH and CAH.

In contrast, early calf survival in the CAH is negatively correlated to late October snow fall but unrelated in the PCH (Figure 16).

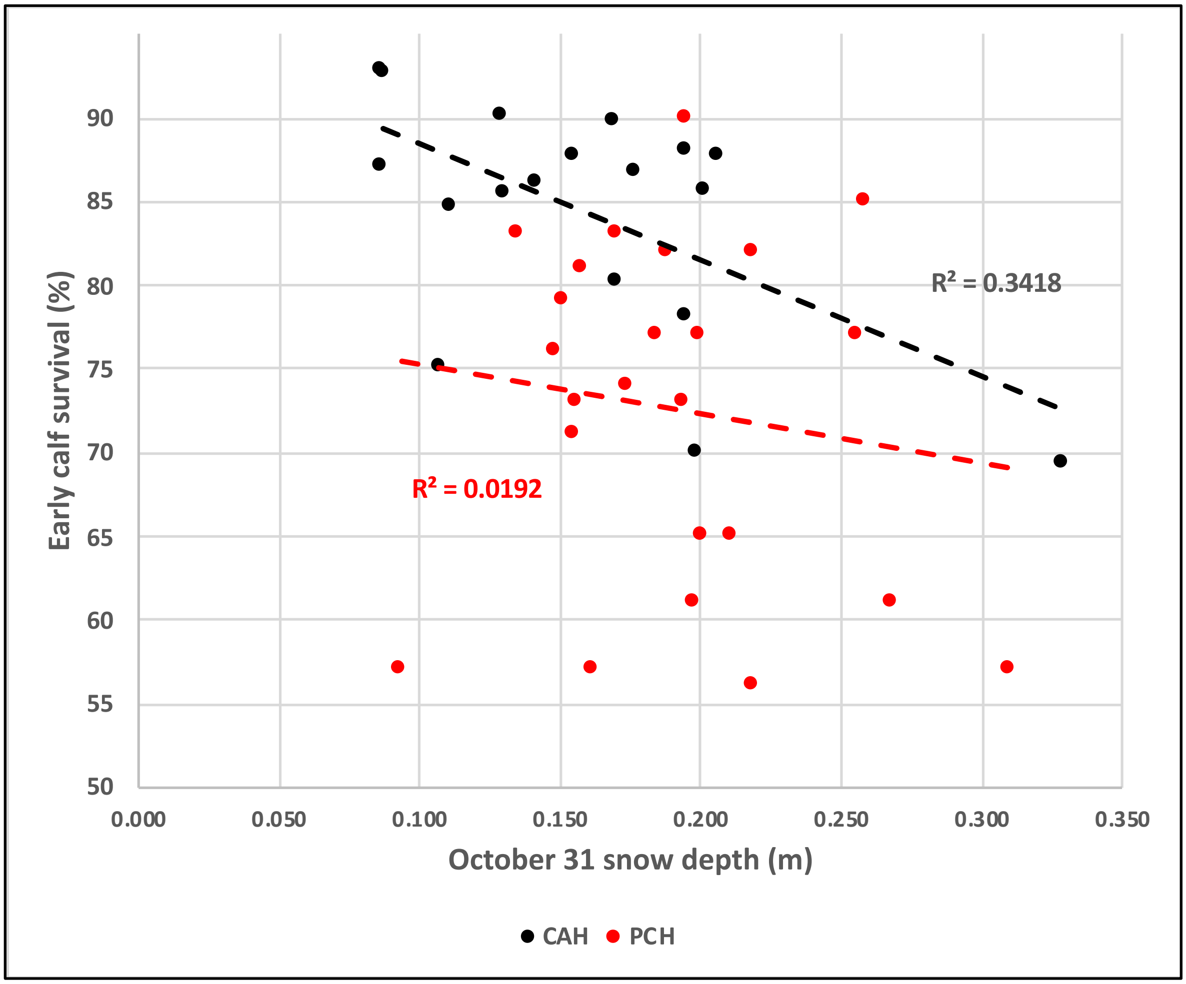

Figure 16. Correlation between early calf survival and late October snow depth in the year prior to calving in the PCH and CAH.

Spring and early summer forage conditions appear to be more critical to the PCH compared to the CAH, where fall conditions the previous year correlate best with early calf survival. Thus, the documented displacement of calving in the CAH, if experienced with development in the PCH, would have more significant impacts on calf survival (for the PCH) than occurred in the CAH.

3.3.3 Discussion: Early calf survival

Analysis of the CAH's response to development during calving shows that calving cows are displaced from or avoid development zones (Wolfe 2000). For PCH, we analyzed the linkages between early calf survival and climate for years when there was concentrated calving in 1002 and years when concentrated calving was outside of 1002, primarily in eastern ANWR and adjacent coast and foothills in Canada (Appendix B; Figure 46). Our assessment of PCH vital rate linkages with climate revealed a relationship between early calf survival and forage availability in early June (indexed by growing degree days). We determined that the climate component that characterized years when concentrated calving was not in 1002 was May 15 snow depth in the non-1002 calving range. These findings are consistent with Griffith et al (2002). If snow is shallow, pregnant cows will calve in 1002 and the survival of those calves to one month will depend on the forage available. In contrast if they calve in the non-1002 calving area, although forage is important, the survival of the calf is related to late winter snow depth (indexed by March 31 snow depth on PCH winter range). The fact that the March snow depth in years cows calve in 1002 is the same as the years when they calved outside of 1002, suggests that having access to 1002 enables the cows to "overcome" the potential impact of an adverse winters.

The importance of this conclusion is that in years when climate conditions allow access to calving in 1002, cows need free access and movement to locate the most optimal forage conditions to ensure adequate milk production for their calves in the first three weeks after birth. If development either disrupts foraging or displaces cows to lower quality habitats, there is a direct and predictable reduction in calf survival.

Griffith et al (2002) quantified the impact of displacing caribou from 1002 should full development of 1002 proceed. Using empirical data collected in the field, Griffith et al 2002, developed a relationship that explained early calf survival (to one month of age) and forage available (as indexed by Normalized Difference Vegetation Index; NDVI) June 20 and predator density. The higher the forage available and the lower the predator density, the higher the calf survival. For individual years (1985-2001) he mapped concentrated calving polygons (where calving density was higher than average) and predicted calf survival. If the concentration area was within the 1002 area, he "dragged" the polygon to the east until it was clear of the 1002 area by 4 km. He then re-inventoried forage and predator density and recalculated the "displaced" calf survival. From that analysis he concluded that calf survival between 1985 and 2001 would drop by 8.2% if calving concentrations were displaced from 1002. After 2001 there were several years of calving in Canada coincident with a negative phase of the Pacific Decadal Oscillation (Griffith unpublished data). In 2018 Griffith updated his analysis (2002-2017) and recalculated an average 6.2% decline in calf survival for the entire 1985-2017 period (Griffith unpublished data). For years during 1985-2001 when development would have caused displacement of the concentrated calving areas, calf survival would have been reduced by an average of 10% based on changes in June 20 NDVI and predation risk (Griffith et al. 2002). This estimate is the same as our estimate of reduction in calf survival (10%) between non-1002 calving and 1002-calving areas based on Growing Degree Days alone.

3.4 Post-calving and summer aggregations

During the post-calving period, larger and larger aggregations begin to form partially in response to mosquito harassment. These large groups are the basis of conducting a post-calving estimate of the herd size, taking advantage of maximum grouping to photograph and count individual caribou (Rivest et al 1998). While information on the range in sizes of the aggregations is potentially available from census reports, we also show that at the annual scale, we can analyze the collars to describe the dynamics of these large aggregations, using collar data from 2014-2017, when sample size (number of collars) is sufficient for the analysis (Figure 7).

3.4.1 Methods

Using the daily location of collars, we quantified the timing of when the large groups formed during the post-calving and early summer for 2014 to 2017. The median distance between collared caribou was used as the measure of clustering using the distance matrix tool in QGIS 3.4.1. The output of the tool provides a table of distances between all points in order of closest (k=1) to furthest (k=N-1, where N is the number of points in the layer). Distances between all caribou locations were calculated for each day during the post-calving and early summer periods.

For any given collar, distances from all other collars were skewed, so median values were used for all figures. The selection of an appropriate number of neighbouring caribou to represent the clustering of caribou was unclear. We chose to plot the median distance between the six nearest caribou as our nearest neighbour measure as adding additional collar distances did not change the median value to any degree. Median distances between caribou were plotted as a function of date. Based on the nearest neighbour approach there is no way of exactly determining the timing of formation and dispersion of large aggregations, other than assuming that the lower the median nearest neighbour measure, the tighter the group. For this analysis we make the assumption that:

- Formation was determined by choosing the first date when nearest neighbour distances showed a dramatic decrease and remained low for several days, or median distance dropped below and stayed below 5 km.
- Dispersion was determined by choosing the first date when nearest neighbour distances showed a significant increase approaching pre-aggregation distances or if median distance rose above and remained above 5 km.

By plotting daily locations of collared cows, we visually determined which cows were closely associated based on density of collars and similar movement patterns over a number of days. In determining aggregation size based on satellite collars of cows, we made the following assumptions:

- The proportion of collared cows in aggregation represents the proportion of cows in the herd.
- Adult cows are 45% of the overall herd (based on composition counts during population estimates at post-calving).
- For every 100 cows during post-calving, there are 58 calves (long term average, Table 2).
- Thus, cows in aggregation = cow collars in aggregation/total cow collars on herd * 0.45 * population size
- Total caribou including calves = cows in aggregation + cows in aggregation * 0.58

Areas used more intensively by the PCH during post-calving aggregations were estimated using a line density function in ArcGIS 10.5 (ESRI 2017). Paths were restricted to the estimated timing of aggregation for each year (Table 7). Based on dates presented in (Table 7), densities were calculated using 5 km search radii which approximately correspond to the upper range of the nearest neighbour distances. The outputs were surfaces with estimates of caribou path densities for each year 2014-2017.

Consistency of movement among years during the post-calving aggregations period was modelled using a membership function in ArcGIS 10.5. For each year, line densities lower than the mean were given the value 0 and line density greater than or equal to the mean were given a value of 1. Surfaces were combined for all years using a sum overlay function in ArcGIS 10.5 to provide an estimate of areas that were used more often during 2014 to 2017. Thus, maximum value of 4 indicated that the area was used in all four years.

3.4.2 Results

Aggregation formation

Figure 17 shows the results for all years (2014-2017) between June 15 (Julian 166) and July 15 (Julian 196) using the median distance of each collars closest six neighbours. On average, groups were most aggregated on July 1 (Julian day 182) where the median distance of a caribou to its six closest neighbours was 1.3 km. Figure 30 presents the average movement rates for those years throughout the aggregation period. Based on our criteria for interpreting nearest neighbour distances, groups form as early as 18 June (Julian 168) and as late as 25 June (Julian 175); dispersing around 8–9 July (Julian 188-189). We did not track groups after July 15th as by that time they generally leave the 1002 region (Table 7), however we know that smaller groups (but still comparatively large) can reform into August if warm days continue (Russell et al. 1993). The duration of these groups lasts from two to three weeks depending on the years.

Movement rates increase from below 10 km per day prior to group formation to between 15 – 20 km/day after group formation and rates remain high even if groups start to disperse (Figure 18).

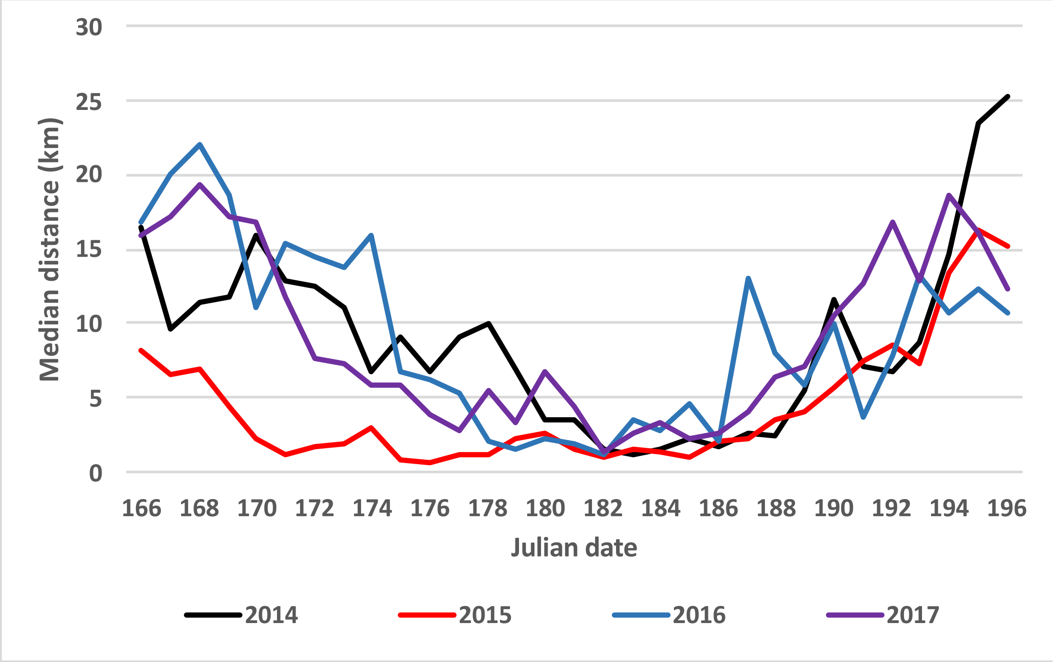

Figure 17. Median distance between nearest 6 collared caribou neighbours during post-calving and summer period, June 15 to July 15 (Julian 166-196), for the PCH 2014-2017.

Table 7. Estimated timing of group aggregation and dispersion (aggregation break-up) during the post-calving and early summer periods (June 15 to July 16).

Year	Aggregation	Dispersion	Estimated length of aggregation
2014	23 June	8 July	16 days
2015	18 June	9 July	21 days
2016	25 June	8 July	13 days
2017	22 June	8 July	16 days

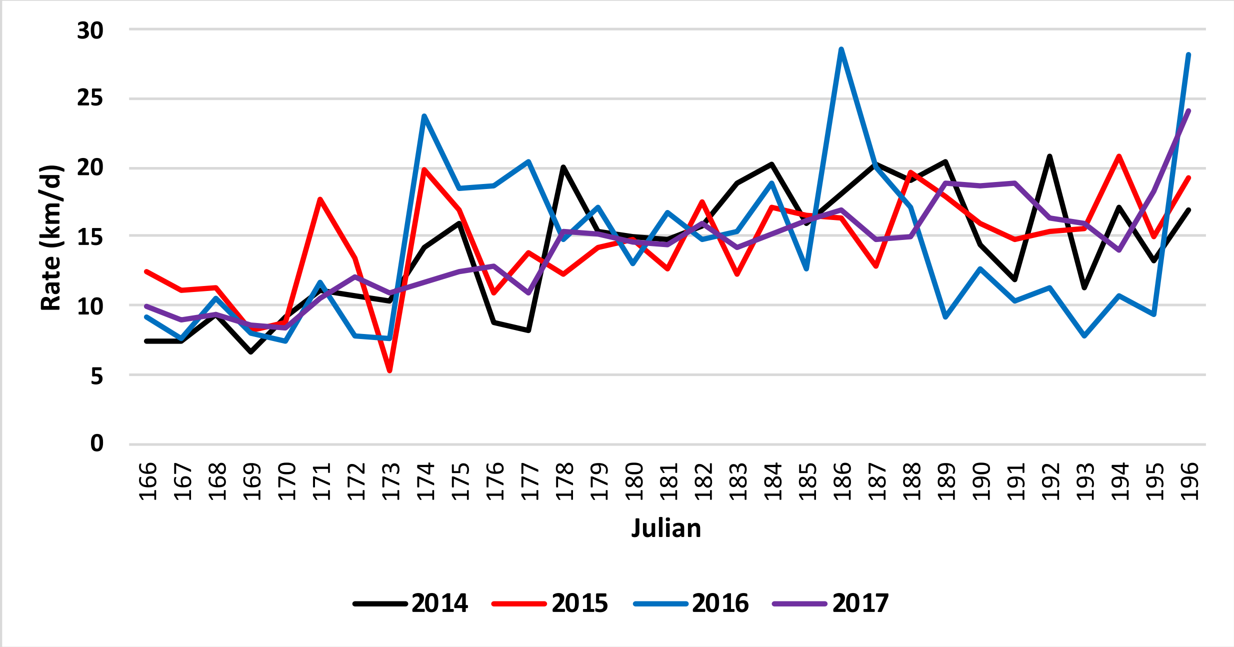

Figure 18. Average movement rates collared cows from June 15 to July 15 (Julian 166-196) between 2014 and 2017).

Movement patterns 2014-2017

In 2014 (Figure 19), an aggregation formed south of Camden Bay around the 29th June and moved southwest before veering east and out of 1002 around the Katakturuk River. After a couple of days, the aggregation again entered 1002 just west of the Sadlerochit River. Within 1002, the aggregation continued to move east before dispersing east of the Jago River on July 7. Within this aggregation there were 29 cow collars, which based on our algorithm detailed above, each collar approximates 3.1 % of the adult cows (total 32 collars). We would estimate that the 2014 aggregation was comprised of 121,000 caribou.

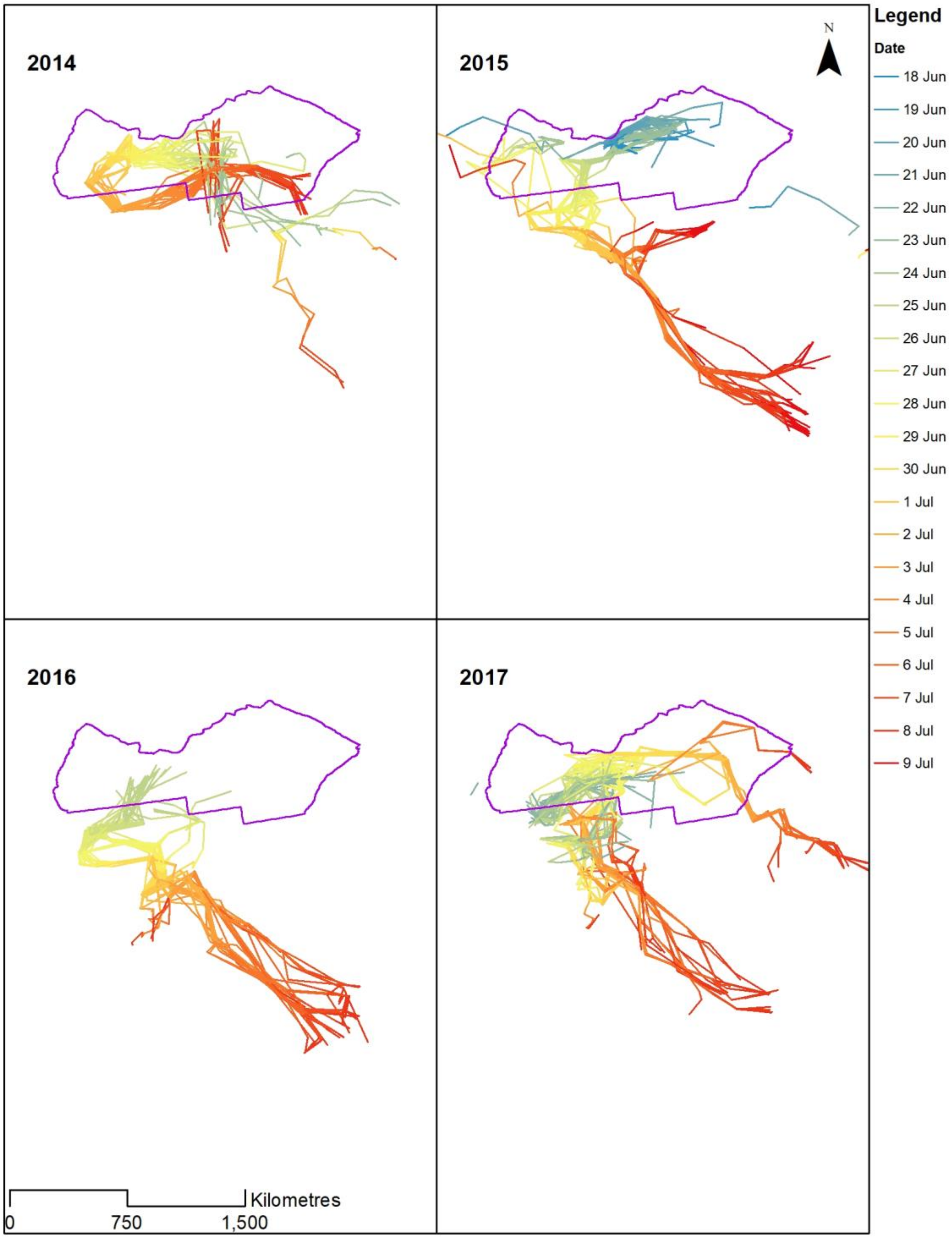

Figure 19. Collared caribou paths of 2014-2017 aggregations relative to 1002 area. Path colours indicate timing of movement from blue (Jun 18) to red (July 9) for progression of the movement.

In 2015 (Figure 19), an aggregation formed on June 19, 10 days earlier than in 2014. The aggregation formed just south of Kaktovik and moved west paralleling the coast until turning south inland near the Sadlerochit River. The aggregation continued south out of 1002 until dispersing on the 5-6 July. Within this aggregation there were 36 collars, which if we assume each collar approximates 2.4 % of the adult cows (total 42 collars), we would estimate that the 2015 aggregation was comprised of 117,000 caribou.

In 2016 (Figure 19), in contrast to the other years, most of the formation, movements and dispersal of the aggregation was south of the 1002 boundary. One large group aggregated around June 25th and dispersed July 8th. This large group contained 34 collars which assuming each collar represents 2.5% of the adult cows (total 40 collars), indicate the group size was 119,000 caribou. In moving further south this large group split into two groups, then reformed and continued south. The two groups that initially split contained 18 and 16 collars respectively, thus group sizes were 63,000 and 56,000 respectively.

The 2017 (Figure 19) movements were the most complex of the 4 years analyzed. A large aggregation formed 21 June near where the Sadlerochit River meets the southern boundary of 1002 and, unlike other years, moved north further into 1002. Just south of Camden Bay this large aggregation (containing 39 collars and about 100,000 caribou) split with one aggregation (46,000 caribou, 18 collars) turning south and retraced east of its original path, leaving 1002 west of the Jago River. The second group (54,000 caribou, 21 collars) headed due east of Camden Bay until west of the Jago River, then turning south-southeast, leaving 1002 in the vicinity of the Aichilik River. In addition, a smaller aggregation (21,000 caribou, 8 collars) formed just south of the 1002 boundary and eventually moved further south into the Brooks Range.

Role of climate

To explore the role daily temperature plays in the formation and duration of these groups, we regressed nearest neighbour distance to mean daily temperature from June 15 – July 15 for 2014, 2015, and 2016 (climate data not available for 2017). The best relationship for 2014 and 2015 was with a 3-day running average of temperature (Figure 20). In other words, aggregations are densest when there have been warmer temperatures in the last three days. In 2016 the relationship was poor. Although nearest neighbour distance was indicating the groups were dispersed, temperatures remained high. However, in 2016 compared to other years, most of the aggregations were south of 1002 and into the foothills and valleys of the Brooks Range (see Figure 19), terrain that may restrict the ability of large groups to stay together. We did note that between July 8 – 13, movement rates in 2016 were much lower than other years (see Figure 18). Although large aggregations formed, they were not sufficiently grouped for a photocensus to be attempted although Alaska Department of Fish and Game made significant efforts to do so (M. Suitor personal communication).

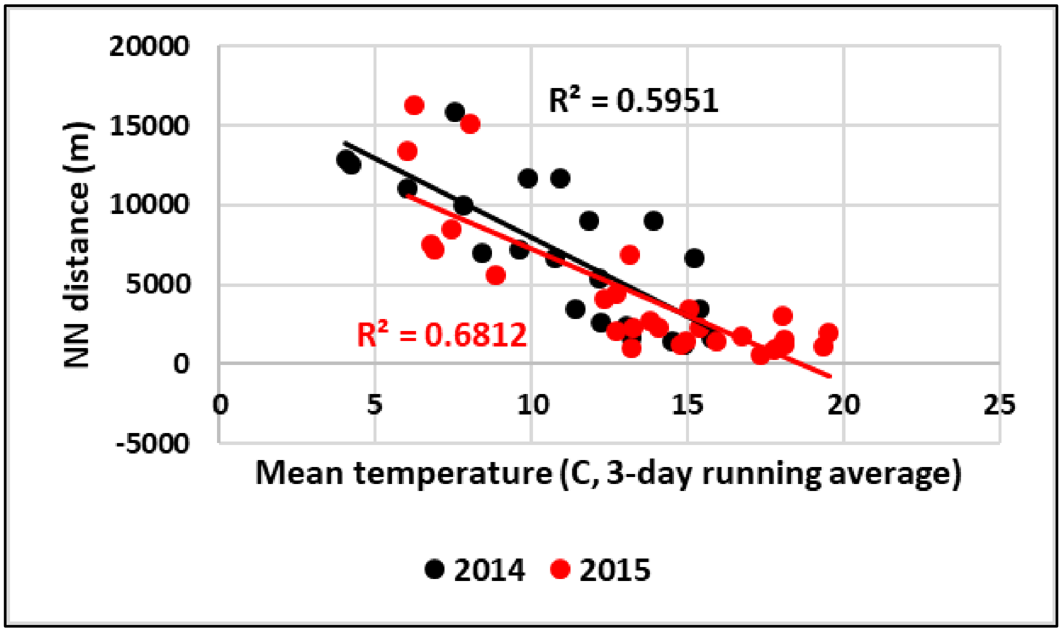

Figure 20. Relationship between nearest neighbour distance (NN) and mean daily temperature (3-day average) for 2014 and 2015.

Aggregation use patterns

We examined the relationship between the exposure of these aggregations to potential development of the 1002 lands.

Figure 21 summarizes the movement paths from Figure 19 to illustrate (for the years 2014-2017) the relative density of use within and surrounding the 1002 lands, while Figure 22 combines all years on a scale of 1-4. Although in any given year the movement patterns of large aggregations are unpredictable, aggregations, for the four years considered, were most concentrated in the western portion of 1002, south of Camden Bay.

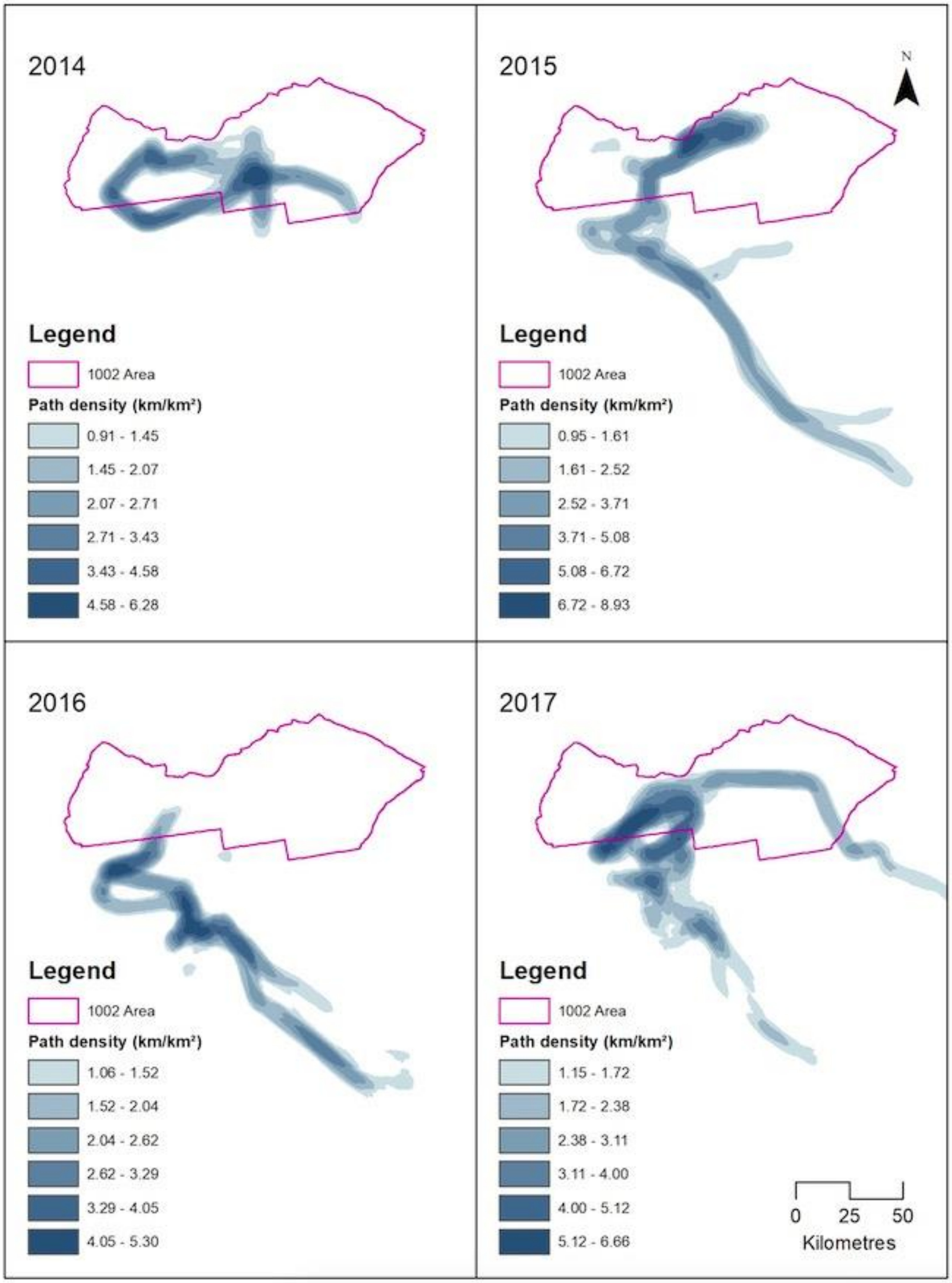

Figure 21. Path density (km/km^2) of 2014-2017 aggregations between Jun 18 and July 9 for the PCH.

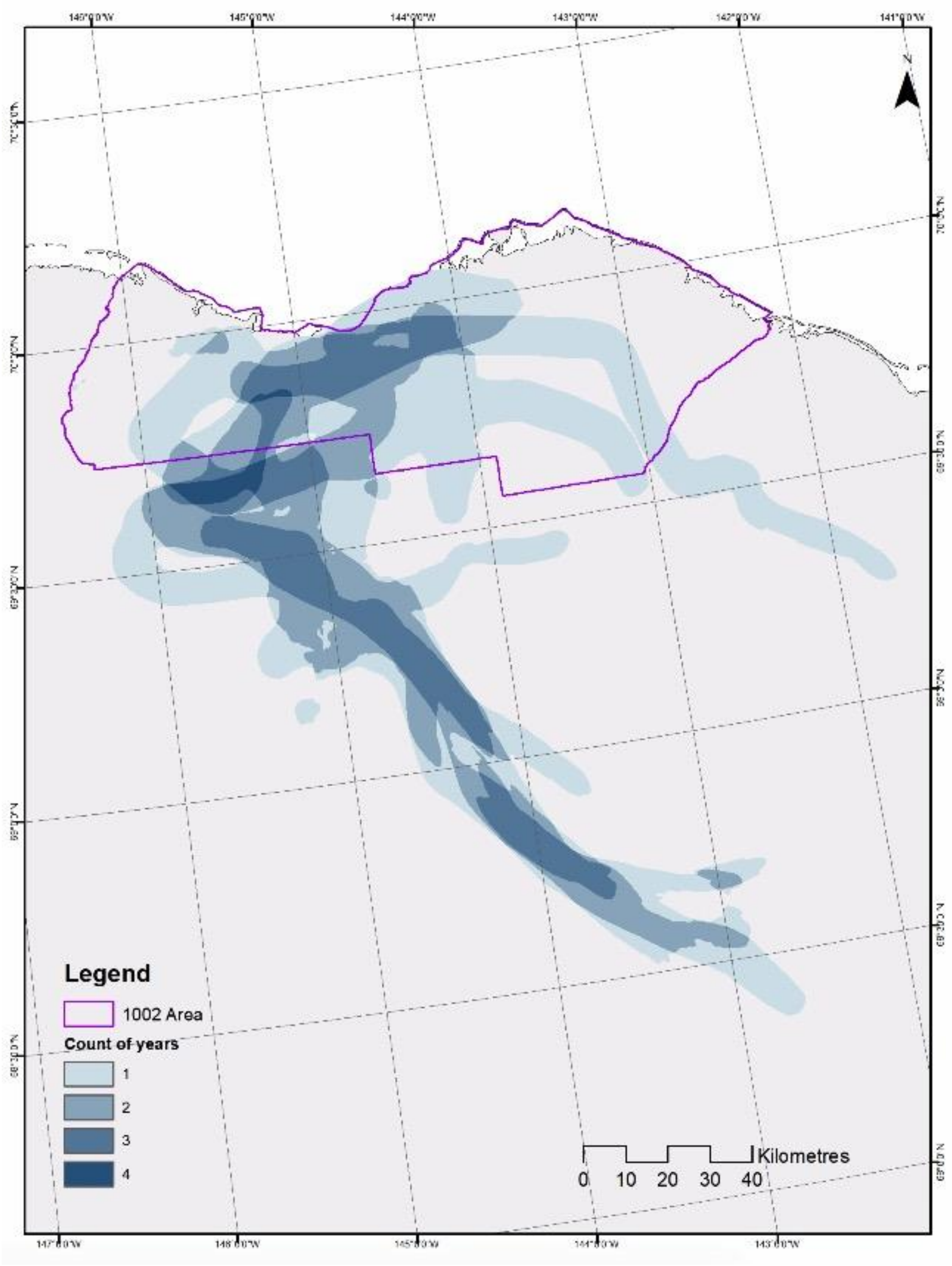

Figure 22. Combined path densities 2014-2017, on scale 1-4 with 4 indicating aggregations were present in all four years.

The four years with enough satellite collars reveal that the timing of formation varies, the location and movement of these groups, and the integrity of the groups changes on a daily basis related to daily temperature. Groups will split, reform and split again, often going in totally different directions. Based on the four years of aggregation data we analyzed, location of aggregation movements largely falls on the boundary between high and moderate hydrocarbon potential as defined on the EIS (BLM 2018b; Map B.1), an area where leasing is most likely to be offered.

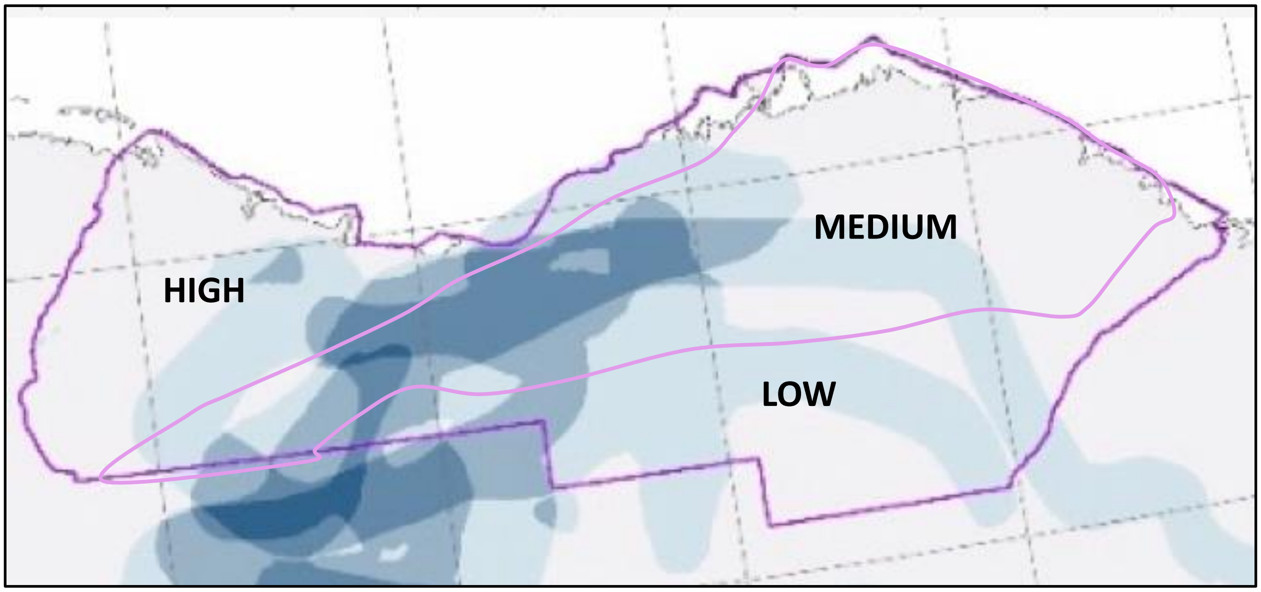

Figure 23. Overlay of aggregation movement path density (2014-2017; Figure 22) on 1002 hydrocarbon potential (adapted from Map B.1 BLM (2018b)).

3.4.3 Post-calving aggregation discussion

By late June as temperatures rise, members of the PCH start to form larger and larger aggregations. In the last 4 years, when sufficient collars allowed us to map their movements, the most satellite collars, which if representative of the herd, are located in one massive aggregation, estimated as sometimes numbering over 120,000 caribou. These groups, mostly cows and calves, move continuously and the integrity of the groups, at least those that were in the 1002 area, are driven by warmer daily temperatures. Movement rates often exceed 20 km per day and average between 15 and 20 km for the aggregation period. Visualizing the movement of these groups indicates they will form, split, reform, shift directions and eventually disperse. When in 1002, aggregations can be found anywhere although in general, groups are more in the western portion of 1002, from the coast to the foothills, a region of high to moderate hydrocarbon potential.

Manseau (1996) studied the dynamics of large aggregations in the range of the George River herd and reported that animals in low aggregation densities could meet their energetic requirements for maintenance and lactation. However, the animal's intake rate decreased rapidly and individuals at densities higher than 100 caribou/km^2 only obtained 60% of their requirements. The cost of aggregation density on intake rate was primarily explained by a decrease in time spent feeding per day. The proportion of animals feeding decreased significantly from 54% in densities lower than 50 caribou/km^2, to about 27% in densities higher than 300 caribou/km^2. The forage requirements of these large aggregations are high and thus the groups have to be constantly on the move as forage is quickly depleted by higher densities of caribou. The conclusion is that these large aggregations are already at an energetic disadvantage when their calves are only 3-4 weeks old. In our analysis we have not calculated a density as referred to by Manseau (1996), but rather for the 4 years, we mapped the regions with the highest path densities.

We have surveyed colleagues across North America and Russia and can find no knowledge on how these large aggregations would react to major development. The most direct comparison would be with the CAH, but as we have documented in three of the four years, the largest aggregations in the PCH were nearly twice as large as the total size of the CAH at its peak. In fact, the EIS (BLM 2018b:3-115), mentions the potential for impacts when large aggregations interact with infrastructure:

> "Large aggregations of PCH and CAH moving in midsummer through the program area during periods of mosquito harassment would have to navigate any infrastructure they encounter. Caribou may expend more energy, take more time, or exhibit reduced crossing success where traffic rates exceed 15 vehicles per hour and pipelines are within 300 feet of roads (Curatolo and Murphy 1986; Cronin et al. 1994; Murphy and Curatolo 1987; Johnson and Lawhead 1989; Lawhead et al. 1993), however, the 7-foot minimum height at VSMs and placement of elevated pipelines at least 500 feet from adjacent roads have been found to be adequate to maintain caribou passage in the oilfields west of Prudhoe Bay."

The references that the EIS cites in the quotation above, rather than provide insights to how large aggregations may react to pipelines in 1002, are either inappropriate or contradict the effectiveness of mitigations given above. Murphy and Curatolo (1987) indicate that larger groups encountering high disturbance increased running from 3 – 33% compared to low disturbance. Furthermore, the "large" groups that Murphy and Curatolo (1987) studied were groups larger than 10 caribou, and thus not applicable to the PCH. Cronin et al (1994), concedes that large (>100 caribou) have lower crossing success than small groups, and states that:

> Such large differences in herd and range size (of Western Arctic Herd and PCH) make extrapolating results from the CAH questionable. Other aspects of the annual cycle and ecology of these populations differ in ways that could affect application of effective mitigation measures….. During the post calving and insect periods, groups of up to 50,000 PCH caribou could encounter oil fields. One cannot predict the effect of oil field structures on such large groups.

More recently, Lawhead et al (2006) indicate that the data on large groups (defined as >100 caribou) are equivocal with respect to crossing success for roads and pipelines. One of the major problems was the lack of data as "large groups occurred less frequently, so sample sizes tended to be small and not always conducive to statistical analysis".

3.5 Exposure discussion

Based solely on satellite and GPS collars over the last 33 years, 67% of cows spent time in 1002. Of those collars that used 1002, at least 5% spent over five weeks in the area and 61% spent at least three weeks in 1002. The highest use was in the post-calving period, a period when cows energy and protein demand double, when calves can gain up to 400g a day if forage resources are adequate (Griffith et al 2002). If conditions are bad or if the cow/calf pair are unable to freely access the landscape, cows can wean the calf early if the calf isn't gaining enough weight or if the cow is unable to replenish her protein reserves. In both cases the calf dies. For cows that give birth in 1002, she and her calf will on average spend almost four weeks in 1002. If the calf is born outside 1002, use of the 1002 area is reduced to 10 days.

The location of calving tends to be in the south east corner of 1002, an area of low hydrocarbon potential. After calving, those cows and their newborns move north and west further into 1002 and most of the time during post-calving and early summer will occupy regions with primarily moderate to high hydrocarbon potential. In total if in 1002, 57% of the time cows and their calves will be in regions of moderate to high hydrocarbon potential.

Post calving aggregations form as early as the 18th of June and as late as the 25th of June and their formation is related to warmer temperatures suggesting that mosquito harassment is an under-lying mechanism. Based on 2014-2017, movement rates increase from <10 km per day prior to group formation to between 15 – 20 km/day after group formation and rates remain high even if groups start to disperse. The mean duration of the aggregations is 16.5± 1.7 days. The major issue with these aggregations relative to exposure is the number of caribou involved. For 2014-2017, the number of caribou in the aggregations identified from the satellite collars was estimated in the 21,000 to 121,000 range for seven aggregations (mean 68,300 caribou). High movement rates and their apparent tendency to form and travel in regions of higher hydrocarbon potential would result in higher likelihood for disruption. Further to add to the uncertainty, the behavioral responses of large aggregations to oilfield structures including roads and elevated pipelines and activities is unknown.

4. Potential Impact

Concerns for the potential impacts on the PCH through leasing 1002 lands for oil and gas development were frequent during the scoping sessions (BLM 2018b:1-3). The 2018 draft EIS is repeatedly clear that while issuing the leases themselves has no impact, the leases grant certain rights to explore and develop oil and gas reserves. "Therefore, the analysis is of potential direct and indirect impacts . . . from on-the-ground post-lease activities". But to stay within 2,000-acre footprint limit (PL 115-97), the likely maximum at any one time is three Central Processing Facilities each with 6 satellite pads and, 125 km gravel roads and linked to an elevated oil pipeline. The Central Processing Facilities are also linked to the coast for a 48 km saltwater pipeline and a road (draft EIS, Appendix B). However, the spatial configuration of the three complexes in 1002 is uncertain at this stage which is a limitation as, for example, the 1987 EIS stated for caribou, the "The key determinant of impacts on caribou will be where development occurs, not necessarily how much". Volume II of the draft 2018 EIS (Appendix C) suggests that development is likely to start in the west with Camden Bay or Point Thompson as the first barge site.

In the absence of the specific information, both the draft 2018 EIS and the 1987 EIS estimated the development footprint for all prospective areas and relied on the scientific literature to suggest that caribou would be displaced as a consequence of behavioral responses. The 1987 EIS used the 3 km sphere [zone] of influence based on caribou distribution before and after construction at Milne Point. However the 3 km zone was measured at Milne Point, when the traffic on the roads was low (<10 trucks/day) and only 1 active drill rig during 2 of 4 years post-construction (Dau and Cameron 1986, Clough et al. 1987). Since 1987 however, studies have expanded our understanding of avoidance distances relative to roads. although the draft 2018 EIS does refer to the literature, it selects a 4km zone of influence also from CAH reports although the draft EIS did note the variability in the avoidance distance. Although BLM (2018b) commented that the PCH might be more responsive as they had less exposure to industrial development, they also used Johnson and Russell's (2014) analysis of PCH movements for "*some indication of habituation to infrastructure by PCH caribou during winter*". However, Johnson and Russell (2014) could not identify that the PCH caribou habituated to settlements and also the response distance to roads declined from 30 to 18.5 km from main roads during a period of reduced hunting activity. BLM (2018b) does not address the effect of why caribou's response distances would vary and the fact that the CAH is not exposed to hunting in the Prudhoe Bay oilfield (see Adaptive Capacity section).

The 2018 draft EIS likely under-estimates the complexity of caribou behavior and mischaracterizes 'habituation' which could lead to lost opportunities for mitigation. Caribou behavior is complex, for example, caribou make trade-off type decisions to modify their responses to predation and forage availability (Basille et al. 2015). Caribou have a similar behavioral plasticity to human activities (hunting and industrial disturbance) as they do to predation (Lima and Dill 1990), and their learnt experience can both increase and diminish a behavioral response. For example, Russell and Gunn (2017) and Plante et al. (2018) summarize how caribou response distance (Zone of Influence) is greater when caribou are hunted. Hunting associated with roads increases the road ZOI from 0-3 km to 15 km (Plante et al. 2018). The draft EIS indicates subsistence harvesting would be allowed along gravel roads in ANWR (p. 3-28), and that workers, once off shift, would also be allowed to hunt (p.3-173).

Caribou make individual decisions about trade-offs between risks such as seeking shade under elevated pipelines to reduce exposure to oestrid flies relative to disturbance (Shideler 1986). Haskell and Ballard (2008) identified the likely role of hunting and the possible habituation of caribou in the CAH to roads and traffic. They predicted that calving caribou from the Teshekpuk herd will not habituate and even further, they stated that "*caribou will not coexist with hunted oilfields as they have with oilfields as a refuge*" (Haskell and Ballard 2008:634).

The draft 2018 EIS (p.3-118) states that caribou (except cows and young calves) may habituate to oilfield activities and roads based on experience in North Slope oilfields. However, there are uncertainties as to whether, without carefully designed studies, that habituation has been observed. Habituation is a special case of animal conditioning, a learned response by an individual to a repeated stimulus, for which identification requires long-term sequential measures of an individual's responses (Thorpe 1963 in Bejeder et al. 2009, Blumstein 2016). Tolerance is defined as the intensity of a disturbance that an individual is able to tolerate before responding in a measurable (i.e., behavioral) way (Nisbet 2000 in Bejeder et al. 2009). It can be measured at a single point in time (such as several caribou groups varying in response levels). However, as highlighted in Johnson and St-Laurent (2011), physiological responses (i.e., increased stress levels) may occur before behavioral responses are detected. Bejder et al. (2009) wrote that "*It is vital that impact studies clearly distinguish between habituation/sensitization as ongoing behavioural 'processes' and tolerance as a behavioural 'state' that can be measured at a single point in time*". It is equally as essential that modifying flight initiation distances as a learned behavior (Blumstein 2016) becomes part of describing potential impacts and their mitigation.

The draft 2018 EIS's approach to direct and indirect effects is an incomplete description based largely on the CAH for responses during calving and post-calving insect harassment but also cite the published projections of PCH displaced calving from 1002 (Griffith et al. 2002). Attention is drawn to possible responses to roads including delays and deflections on other ranges and that similar findings have not been documented for CAH. However, the telemetry data for CAH has not yet been analysed using similar methodology to determine whether or not there are delays or deflections. The draft 2018 EIS describes the PCH seasonal distribution within the alternatives relative to the stipulations based on extrapolations of areas by the 4km zone of influence.

4.1 Cumulative effects

The BLM's Final Scoping report identified cumulative effects as a primary issue raised during the public comment period (BLM 2018b; p.3.5). In the Fish and Wildlife section commentators asked,:

> "…*will the EIS require the BLM to monitor, mitigate, and address the cumulative impacts on caribou and other wildlife populations from the proposed program and climate change?"* (BLM2018b; p.3-9).

Specifically, commentators:

- "*…suggested that the BLM consider a zone of influence and modeling of potential impacts at the individual and population level for caribou*, (BLM2018b; p.3-9)
- "*…noted that the cumulative effects of climate change and the proposed program may result in negative impacts on caribou and other wildlife populations*, (BLM 2018b; 3-10)

> "*requested that the EIS fully analyze existing and reasonably foreseeable impacts of climate change on caribou and other wildlife populations, including in the environmental baseline and affected environment, across alternatives, and within cumulative effects*" (BLM 2018b; 3-11)

While Appendix F in the EIS sets out the general approach to Cumulative Effects, for the PCH the draft 2018 does not quantify the cumulative effects of 1002 development nor link climate, oilfield development and the PCH demography; no analysis of the impact of the current infrastructure within the range of the PCH was attempted. This latter analysis is required to quantify the added (or cumulative) impact of 1002 development from existing conditions (we also note that no comparable analysis is available for the CAH which would have been a useful point of comparison).

Consequently, we undertook a quantitative assessment of current and potential future development within the range of the PCH, and how those impacts would vary under different climate conditions and at different phases of the population cycle of the PCH. We apply a Caribou Cumulative Effects (CCE) model. Components of the model have been verified through applications that emphasize energy expenditure such as energy consequences of low flying fighter jet aircraft (Delta caribou herd: Luick et al., 1996), road and pipeline effects at Prudhoe Bay [CAH: Murphy et al., 2000], integration of nutritional components to determine responses to climate change (PCH: Griffith et al., 2002; Kruse et al., 2004), effects of climate change (PCH: Russell et al., 1996; CAH: Murphy et al., 2000), summer range assessment (George River Herd: Manseau, 1996), and full integration of components for application to development (e.g., North Baffin Herd (Russell 2012, 2014a), Qamanirjuaq Herd (Russell 2014b), Bathurst Herd (Nishi 2017), Dolphin Union Herd and Akiak herds (Russell 2018). The models have recently been applied to assess the current impacts of development on the PCH (Russell 2017).

The Caribou Cumulative Effects (CCE) model framework consists of three linked sub-models that, together, allow caribou managers to undertake "what-if" analyses of the cumulative effects of development, climate change and other stressors on various aspects of caribou biology. The sub-models in the CCE model include:

> <u>Movement</u>: a model tracking movement patterns of a caribou herd with respect to past, present and future development;
> <u>Energy-Protein</u>: a model of how an individual caribou allocates protein and energy obtained from foraging to maintenance body reserves and milk for calf over time (White et al 2013); and
> <u>Population</u>: a model of the caribou herd's population dynamics (Figure 24)

The initial inputs for the CCE are satellite or GPS collar movement data, spatial layers for vegetation, climate and the starting development footprint, and scenario details about future development rates and the extent of their impacts or ZOI. The Movement model, tracking individual movement paths from collared caribou across the herd's range, produces output on the caribou's daily environment. The Energy-Protein model takes output from the movement model and uses estimates of activity budgets, forage biomass, forage quality and climate indicators to simulate daily energy and nitrogen intake and allocation to project changes in body condition of an individual caribou over time (White et al 2013). The outputs of the body condition sub-model include the fall body weight of a cow and her calf which can be interpreted in terms of probability of a cow becoming pregnant (see Figure 3) and calf survival rates which are fed into the Population model. Inputs to the Population model are initial population size, age/sex composition, mortality, fecundity and harvest. The population model then projects the future size and composition of the caribou herd.

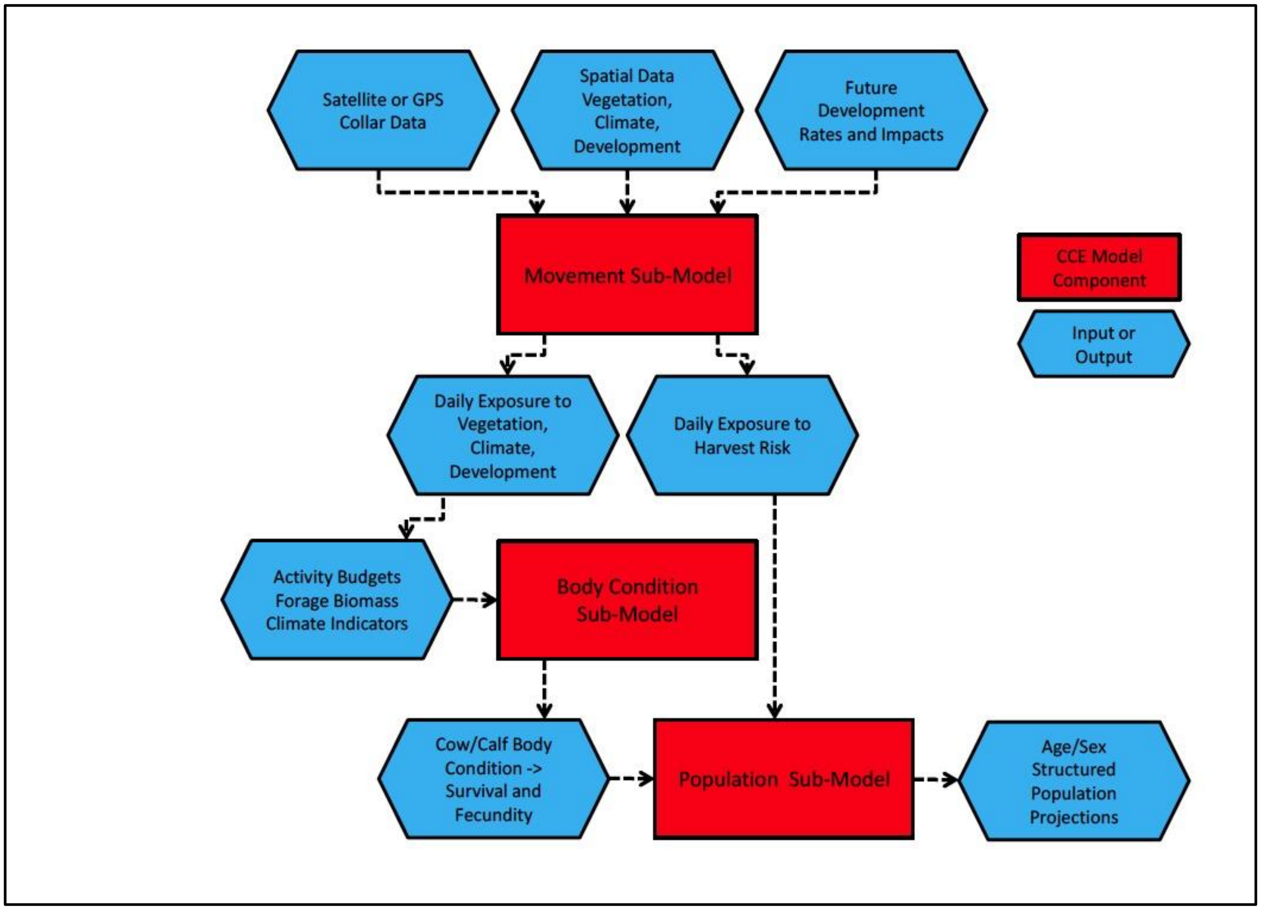

Figure 24. Schematic of the Caribou Cumulative Effects (CCE) Model showing sub-model components in red and various sub-model inputs/outputs in blue.

4.1.1 Caribou Cumulative Effects modeling

Movement model input

Caribou Movements: Satellite collar locations 1985-2017 were provided by the Porcupine Caribou Technical Committee (see Figure 7). The original dataset had a number of collars years that only contained limited data and were eliminated from the analysis if there were not at least 20 locations from 20 May to 31 July. In total 414 collar-years were modelled from the existing dataset. Because the CCE model requires the daily location of caribou, if there was more than one collar location per day, the location closest to 12 noon was chosen. Conversely if a day was not represented in the dataset, locations were interpolated from the immediately preceding and the immediately following location. We choose to model all 414 collar-years to more accurately reflect the PCH use of the 1002 area.

Footprint: Figure 25 was prepared by the Porcupine caribou Technical Committee to represent human footprints within the range of the PCH. In the model the "Baseline" development conditions incorporate this map. We note that the full footprint in Alaska was not available at the time this database was created. The majority of human disturbance in Canada are seismic lines established the 1960s and 1970s. Although there is research currently being conducted to document the re-vegetation seismic lines (M. Suiter pers. comm.), caribou use and/or avoidance is poorly understood. Johnson and Russell (2014) did measure an avoidance ZOI that declined through time either as an habituation or because lines had recovered to a more natural state.

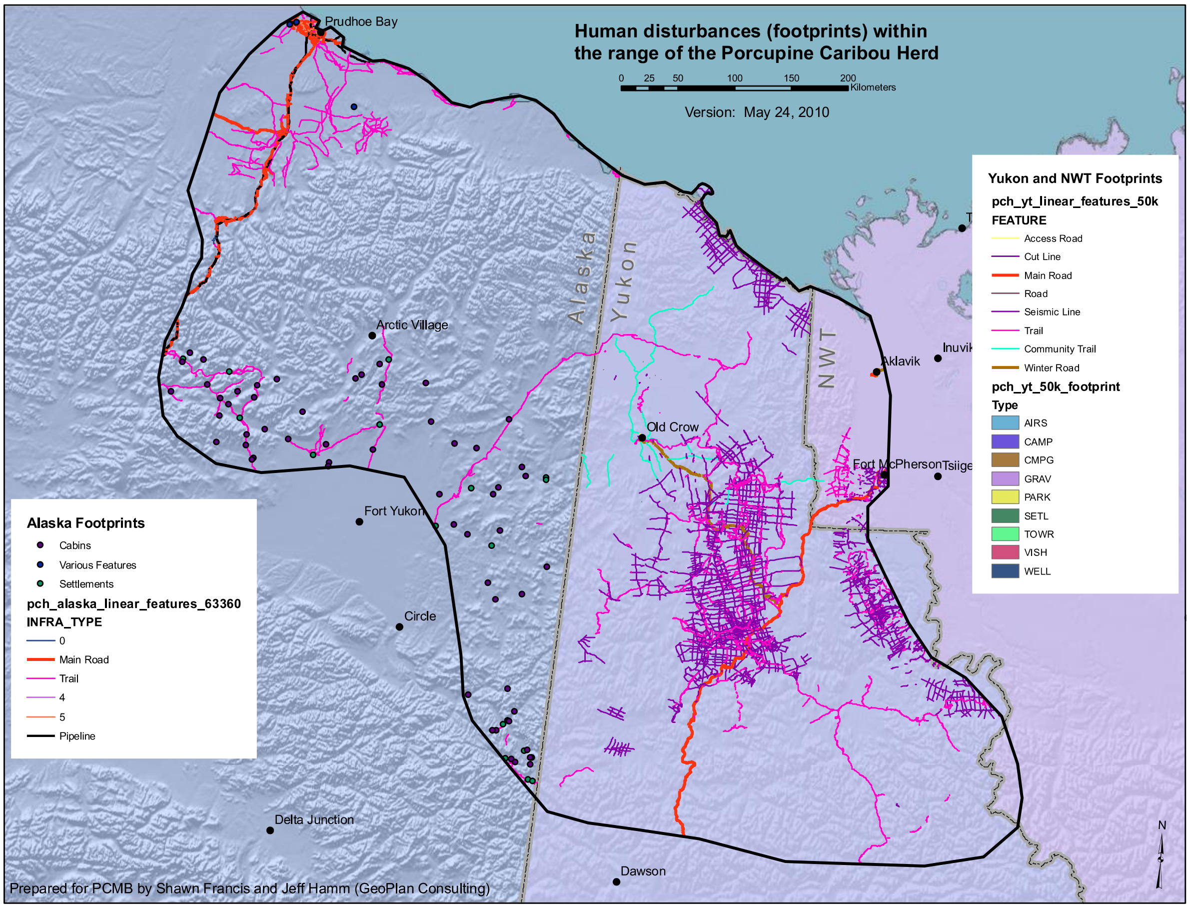

Figure 25. Historical human footprint within the range of the Porcupine Caribou Herd, not accounting for recovery of seismic lines mostly made during the 1960s and 70s (this map and line scaling over-emphasizes current footprint) (Source: PCMB, Shawn Francis). NOTE: the full footprint was not available for Alaska.

With 1002: To compare the impacts of baseline development within the range of the PCH to the added impact of 1002 development, in this section on Potential Impacts, we modelled the worst-case scenario with respect to 1002 development, making the assumption that any area in 1002 would be potentially developed in the future. Further, in this worst-case scenario there are no effective mitigation that would reduce potential impacts. This is a consequence of the draft EIS being at the leasing stage (EIS p. ES4). Further any day a caribou spends in 1002 would potentially cause it to be disturbed. Without specific footprints, our modeling could not be applied on a finer scale. Note that in the next section on Adaptive Capacity we assess the impacts under four proposed development options and apply mitigation though lease stipulations that partially mitigate potential effects.

Vegetation: A habitat map for the PCH range was prepared by S. Francis for the Porcupine Caribou Management Board based on a circa 2000 classified 30m LANDSAT TM mosaic provided by I. Olthof et al. (2008) of the Canada Centre for Remote Sensing, Ottawa. The original range mosaic combines classification approaches from the Landcover of Northern Canada (REF) and Earth Observation for Sustainable Development of Forests (EOSD) (Canadian Forest Service 2005). For the CCE modeling exercise we reduced the vegetation classes to four types: Taiga, Shrub, Herb, and Barren (Table 8).

Table 8. Vegetation Classes used in the CCE Movement model.

NAME	Original CCRS map classes	CCE mapped
Needleleaf Forest	40, 38, 58, 37, 39, 47, 136	Taiga
Mixed Forest	41, 61, 49, 51, 103, 59	Taiga
Upland Shrub	69, 108, 87, 89, 77, 200	Shrub
Tall Shrub	13, 113	Shrub
Low Shrub Tundra	14	Shrub
Moist Sedge-Dryas Tundra	9, 15	Herb
Moist Sedge-Willow Tundra	7, 8	Herb
Tussock Tundra	4, 5, 6, 11	Herb
Alpine Tundra	10	Barren
Barren	3, 30	Barren

CCE scenario runs: Figure 26 illustrates how the CCE model was applied within the three sub-models to assess the impacts of 1002 development over and above baseline development impacts.

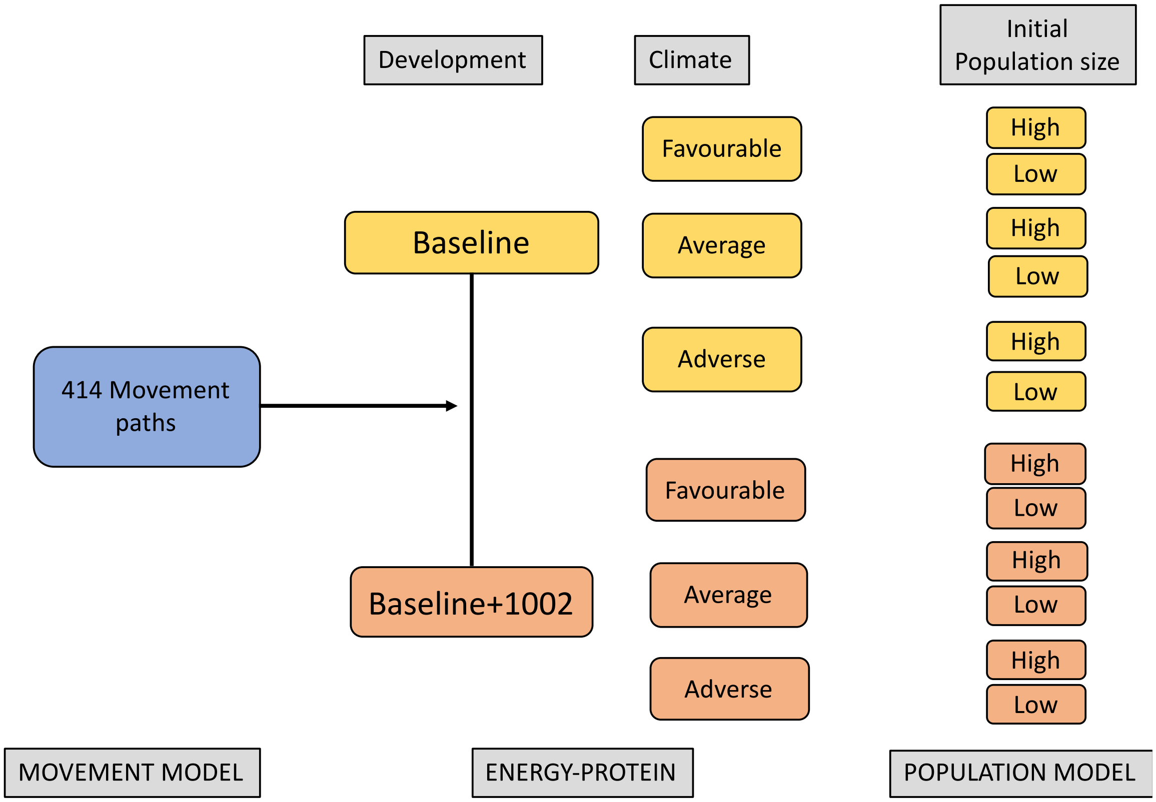

Figure 26. Scenarios modelled in the CCE model: one (1) run of Movement Model, six (6) runs of Energy-protein model and 12 runs of the Population model.

Movement model runs: We only required one run of the movement model which output the daily location of 414 collar-years over a one-year period. The Movement model output contained, for each collar, the daily location, vegetation type and whether it was in a ZOI or outside of a ZOI. If in a ZOI the model distinguished if the collar was in a "Baseline" ZOI (for example near a community or the Dempster Highway) or in 1002 The Movement model output was then passed to the Energy-Protein model.

Energy-protein model runs: We created six scenarios within the energy-protein model. First under the "Baseline" scenario if a caribou was in a baseline ZOI then a "penalty" was assigned. The penalty amounted to change in daily activity budget when in a ZOI. A collared animal in a development zone spent less time foraging and more time walking and running. As well the proportion of time that a caribou spent ingesting food while in the foraging period was also reduced. For a description of the penalties assigned see following section on "Penalties". For all "Baseline" development scenarios, if the caribou was in the 1002 area, no penalty was assigned.

In the "Baseline+1002" scenario the same penalties were applied if the collar was in the ZOI of baseline development. However, penalties were also assigned if the collar was in 1002. Thus, comparing the results of runs under "Baseline" development with results under "Baseline+1002" was interpreted as the added impact of 1002 development.

In the Energy-Protein model we created three climate scenarios that were applied to each development scenario. Climate is from CARMA's climate database (Russell et al 2013). In the Energy-Protein model:

1. Snow depth impacts energy expenditure during winter, both in travelling through the snow and in digging feeding craters to access forage, primarily lichens (Russell et al 1993).
2. Energy balance is also impacted due to less time spent foraging and ingesting food, if snow is deep (Russell et al 1993).
3. Early spring snowmelt provides early green forage in late spring, coinciding with calving and post-calving (Finstad 2008).
4. Warmer summer conditions effect the phenological changes in forage, higher biomass but lower quality (digestibility and nitrogen; Finstad 2008).
5. Warmer summers also mean higher insect harassment (Russell et al 1993). Higher insect activity reduces foraging time, reduced feeding intensity and increases standing, walking and running.
6. We created a Cotton-grass index as warmer mid-June to mid-July temperatures quantitatively dictate the biomass of cotton-grass (Eriophorum vaginatum) the following spring (Shaver et al 1986). Cotton-grass is an important forage item as snow melts in the spring, offering early highly digestible food during the early calving period (Russell et al 1993)
7. May precipitation in previous year and June precipitation in f the current year are mushroom biomass in year. Mushroom are a highly nutritious food later in summer and early fall when vascular plants become less and less nutritious.

The climate indicators listed above are required to set up any energy-protein model run. In our application, we model good, average and poor climate scenarios. To set those conditions up we created a spreadsheet with climate indicators for 1979 – 2016, sorted each from most adverse to most favourable and calculated the 1st and 3rd quartiles as well as the mean. Thus, "poor" climate conditions equated to the values of each indicator in the 1st quartile, "average" was the mean value or each variable and "good" was the values in the 4th quartile. We are aware that other climate indicators undoubtedly play a role in the energy-protein balance of caribou, however, until we can determine a functional response between that climate indicator and vegetation, activity budgets or diet, we cannot model the animals' response to changes in those climate indicators.

The output of the six energy-protein runs were fall cow and calf weight for the 414 individuals modeled. We used a baseline value as the average fall cow weight determined from our results of "Baseline" development and "average" climate. In the other five scenarios, departures from this baseline weight were calculated. To equate drop in cow body weight with probability of pregnancy, we used the established logistical regression derived for the PCH (Russell unpublished data); $b_1 = -9.4456$, $b_2 = 12.4123$; see Figure 3). For example, using an average body weight of 81kg, a body weight drop of 0.6 kg equates to a decline in the probability of pregnancy of 1.15%.

A similar process was applied to calf body weight. Baseline fall body weight was the mean fall body weight of "Baseline" and "average" climate. Baseline calf body weight was equated to average overwinter calf survival. Departures from calf body weight was converted to departures from baseline overwinter survival using a relationship we developed from data presented in Arthur and Del Vecchio (2009; Figure 27). Arthur and Del Vechhio (2009) captured and weighed calves in the CAH in September and tracked survival with collared cows through March. They concluded that calves that were heavier in September were more likely to survive the following winter (P <0.0001). We combined their Table 1 (mean calf weights by year and capture location) with Figure 5 (overwinter survival by year and capture location) to produce Figure 27.

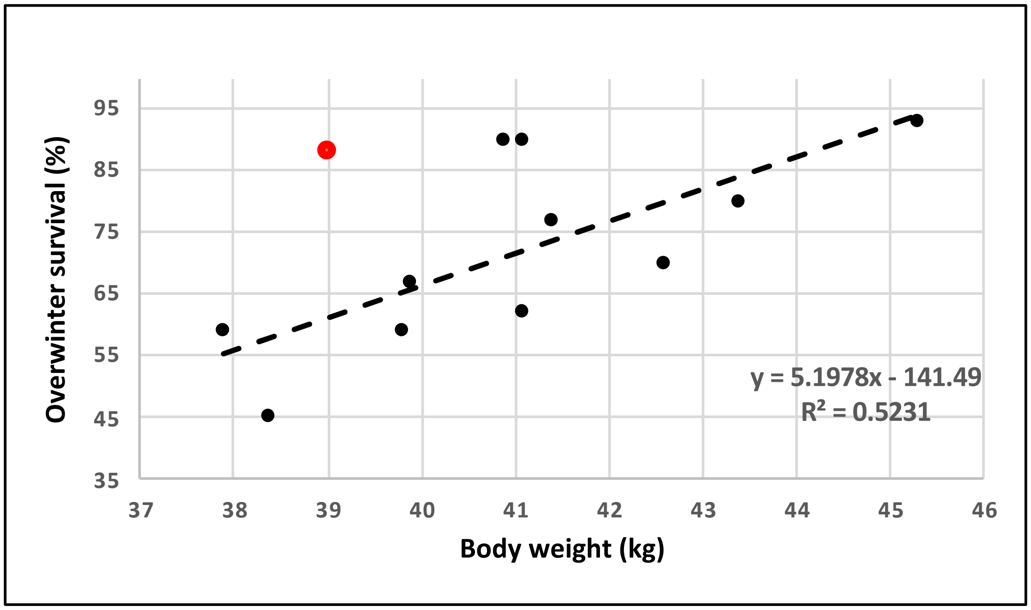

Figure 27. Correlation between fall body weight and overwinter survival calculated by combining data from Arthur and Del Vecchio (2012) Table 1 and Figure 5. The red dot we considered an outlier in the formulation of this correlation.

Using Arthur and Del Vecchio's (2009) data (Figure 27) with respect to fall body weight and overwinter survival, we applied a 1 kg change in baseline calf body weight to a 5% change in overwinter mortality.

Population model runs: Departures from overwinter calf survival and cow probability of pregnancy for the six energy-protein scenarios were linked to the Population model. As we wanted to determine the potential impact of 1002 development on the PCH throughout the cycle of abundance, we ran two scenarios for each of the six energy-protein runs: at the current population size (218,000) and at population lows (100,000). The latter population size was similar to estimates in the 1970s before the PCH started to increase. We simulated over ten years (2017 to 2027) using 1000 Monte Carlo iterations varying adult cow survival and pregnancy rates within long term means and standard deviations for the PCH. For pregnancy rate, the long-term average was (81.2% ± 6.4) and for adult cow survival, we used the weighted average (84.5% ± 5.3) between the increase and decrease population phases (see below).

From our analysis of PCH vital rates during population increases and declines, we determined that adult cow survival was the only vital rate that tracked population trend. Although the survival rate averaged 86% for all 27 years; mean survival for increasing years was 87% and for declining years was 82% with a weighted average of 84.5%. We calculated the exponential rate of change from 2017 to 2027 of each of the 1000 iterations in each scenario. Rates of change were classified into one of three population trends (Table 9) as we had been asked to assess impacts of 1002 development for the different phases of the population cycle. To present those results, we assumed that the current population size (218,000), represented a PCH population high and a starting population low was 100,000.

Table 9. Projected population trend classes as defined by exponential rate of change in Population model outputs.

Trend	Exponential rate of change
Decline	< -4%
Stable	-4% to 4%
Increase	> 4%

Penalties

In the CCE model we assigned "penalties" to daily activity budgets when caribou are in the ZOI of development infrastructure and associated human activity. Many factors can affect the magnitude of those penalties including:

Type of infrastructure
Level of human activity
Presence or absence of hunting activity
Season of year
Other associated disturbance (predation, insect harassment, hunting).

Caribou are integrating several factors on a daily and seasonal basis. Therefore, there is significant natural variability in how caribou allocate their time feeding, standing, walking, running and resting. Factors such as snow depth and snow melt, the timing of plant growth and the harassment of insects can alter activity budgets (Russell et al 1993). On a daily basis, seasonal changes in the length of the active/rest cycles, often queued by sunrise and sunset, produce distinct patterns of activity and rest (Russell et al 1993). Thus, the challenge is to account for these natural influences while documenting the added effects of disturbance from human activity.

There are few attempts to quantify disturbance impacts within and around a ZOI. For calving, post-calving and summer ranges (i.e., the period PCH are predominantly in 1002), little data exists. Many studies about the effects of oilfield development on caribou are contradictory, and many older papers lack the scope of more recent works. Vistnes and Nellemann (2008) reviewed 85 disturbance studies and found that 83% of the regional studies concluded that the impacts of human activity were significant, while only 13% of the local studies did the same.

Murphy and Curatolo (1987) partially paired development study areas with control areas and determined that caribou close to development (roads, traffic, and pipelines) did not reduce feeding in the presence or absence of insects, but development resulted in an increase of up to 15% in running activity at the expense of lying and, less so, standing. What is missing in their study was the activity of those groups after they passed through the development zone, as caribou require a fixed, but, seasonally-specific alteration in active and rest cycle for proper rumination. Disturbed animals may have just delayed their rest cycle until out of sight. Fancy (1983), also in the Prudhoe Bay area, documented activity budgets near development infrastructure and traffic compared to control sites 4 km away. Although they did measure a 10% and 8% (in the absence and presence of insects, respectively) lower feeding times near development, sample sizes were low, coefficient of variation varied between 36-38%, and he thus concluded there was no significant development effect. Further, these studies were conducted during times when no hunting was associated with the infrastructure. Hunting activity can exacerbate the impact of other human activity (Russell and Martell 1985, Johnson and Russell 2014, Plante et al 2018).

As part of monitoring requirements, diamond mines in NWT are required to document disturbance effects of development on caribou. BHPB (2004) reported a 10-13% decline in feeding time for caribou closer than 5 km of a large open pit mine complex compared to caribou beyond 5 km. As with most scan surveys, sample sizes were too small to detect a significant difference.

However, data does exist with respect to movement rates through ZOI. Figure 28 is derived from a number of path analyses of movement rates of different barren-ground herds that move into and out of a ZOI (Russell unpublished data). On average, movement rate increases by 65% when entering or leaving a ZOI between two subsequent days. For Boreal caribou, Leblond et al (2013) recorded an increase in movement rate 683 m/hr before crossing a wide highway (traffic frequency (18-786 vehicles/hour) and 1011m/hr while crossing. The movement rate further increased when traffic activity was higher.

Assuming for the PCH, an average percent of day walking and running is 23% (Russell et al 1993, Table 4.5), then a 65% increase would be a 14% increase in walking and running. It is possible not all that time is directly taken from feeding, as animals could reduce searching time or increase vigilance while feeding.

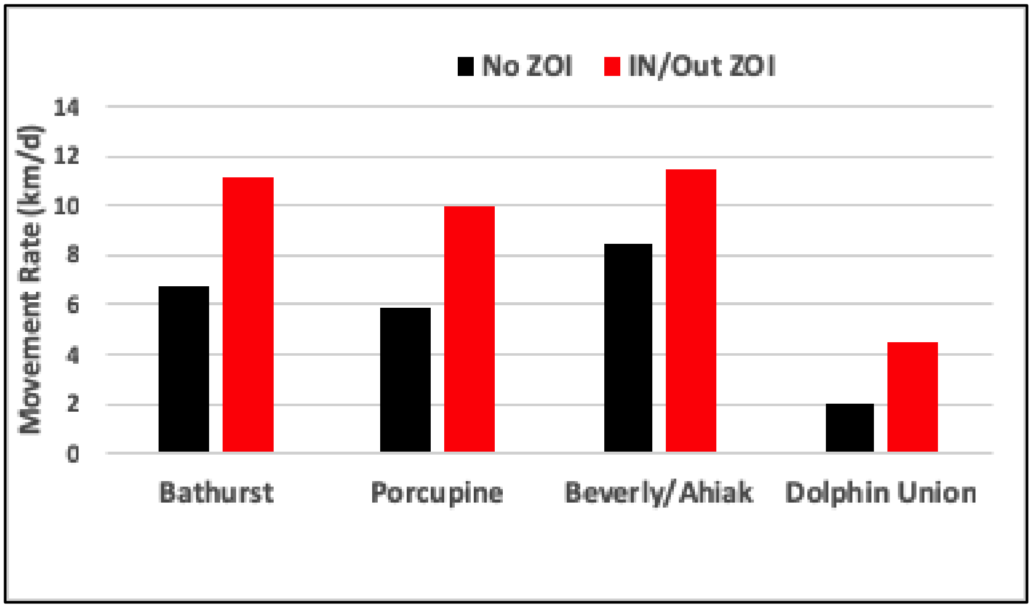

Figure 28. Daily movement rates for days when caribou either entered or left a ZOI (In/Out ZOI) compared to days when caribou not associated with ZOI (No ZOI) for four North American herds.

In our modelling, for periods not including calving, post-calving and summer, we have assumed a penalty for being in the ZOI is:

6% decrease in foraging,
3% increase in walking,
3% increase in running and
3% decline in feeding intensity (the % of the foraging time actually spent ingesting food).

These values could be conservative in the presence of hunting, when both the degree of reaction and the distance from the human activity that caribou react both increases. Given the equivocal results described above and uncertainty inherent (Harwood and Stokes 2003) in quantifying disturbance, we feel these penalties are a logical compromise to allow us to objectively assess the cumulative effects of development.

We however did not apply these "base" penalties to the calving, post-calving and summer period. There is a common thread through the literature to suggest that 1) cows and newborn calves are most sensitive to human disturbance during the calving (Cameron et al 1992; Wolfe et al 2000, Vistnes and Nellemann 2001; Reimers and Coleman 2006) and post-calving period when cows give birth, calves become mobile and lactating cows' daily requirement for energy and protein doubles (Russell et al 1993) and 2) the larger the group the less likely they will be able to successfully cross through development zones (Smith and Cameron 1985). It is during the post-calving period that larger and larger aggregations begin to form, partially or wholly in response to insect harassment.

Due to the sensitivity of caribou during calving and the relationship between larger groups lack of success dealing with infrastructure, for these three periods we doubled the penalties in the ZOI of development.; a decrease of 12% feeding, 6% increase in walking, a 6% increase in running and a 6% decline in feeding intensity.

4.1.2 Results:

Fall body weights

Figure 29 summarizes the modeled body weights at rut (day 283) for lactating cows and calves for the six scenarios. The average "cost" of 1002 development increased as climate conditions improved ranging from 1.5 kg for calves and 0.3 kg for cows under poor climate conditions to 1.9 kg for calves and 0.7 kg for cows in good climate conditions.

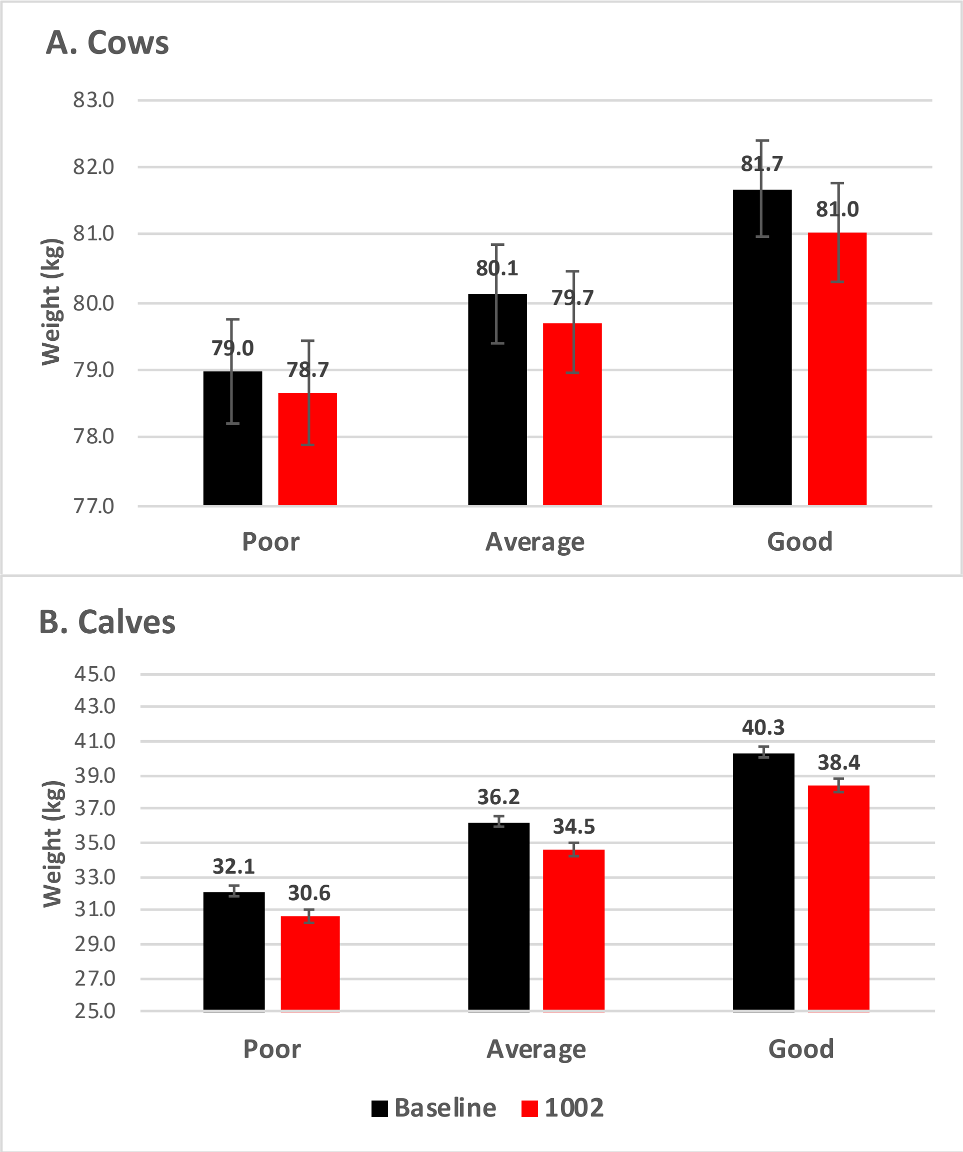

Figure 29. Fall mean body weight and 95% CI for panel A. Cows and B. Calves under six scenarios: poor, average and good climate conditions, for both baseline development and baseline plus 1002 development.

Population model output

Figure 30 shows the final average population size for the six scenarios at high (A) and low (B) starting population sizes. Figure 30, shows variability (average coefficient of variation among the 12 simulations was 36%). Comparing final population size to "Baseline" runs indicates that for a low starting population size the PCH would be 28% (poor climate), 22% (average) and 25% (good) lower after 10 years. For a high population size those values are 25%, 20% and 25% for poor, average and good climate conditions respectively.

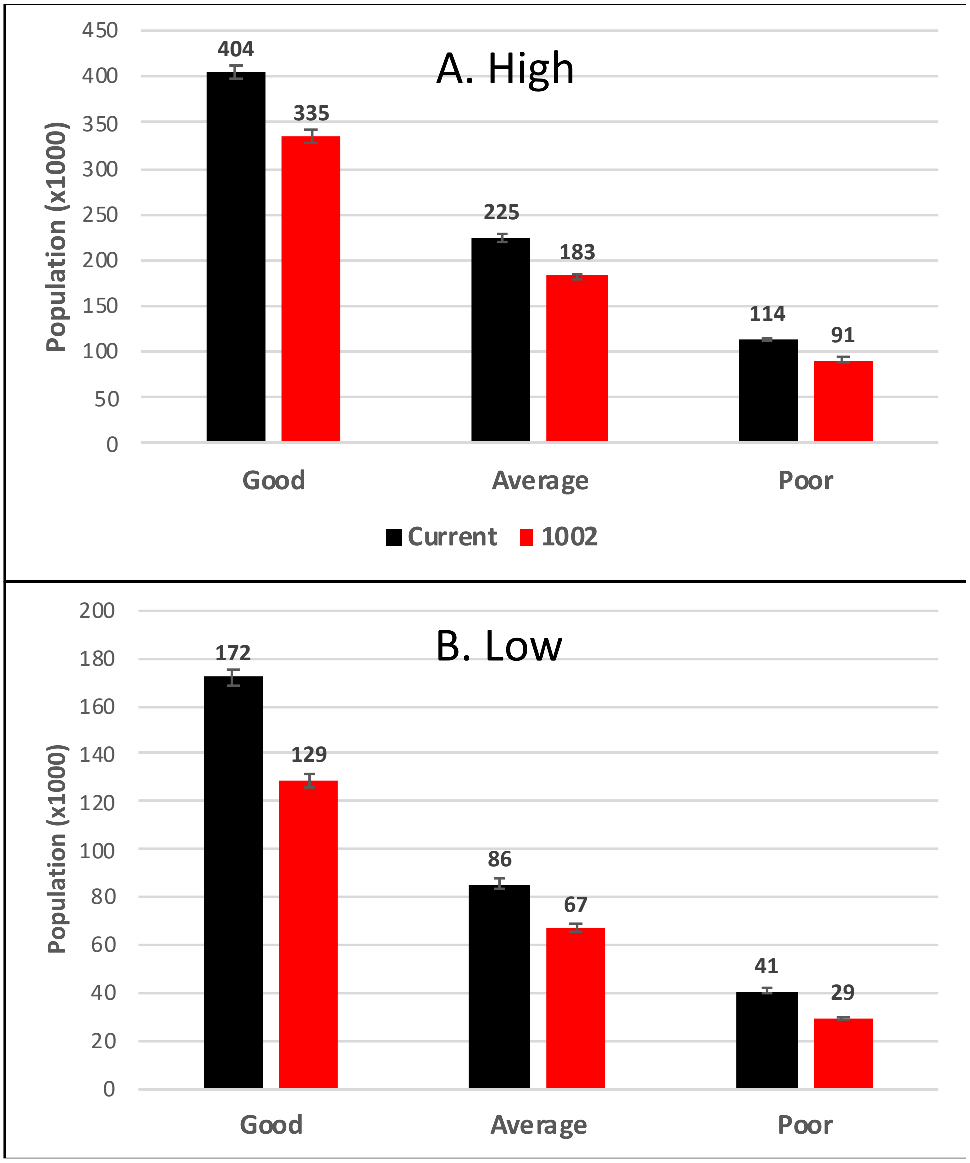

Figure 30. Mean and 95%CI of final population size for A. High (218,000) and B. Low (100,000) initial population size with three climate scenarios

Risk analysis

We used all 1000 iterations to compare resultant population trends (between baseline development and baseline with the addition of 1002 development). After projecting populations for 10 years we subtracted the final population size from initial population size, calculated the exponential rate of change, and classified each iteration as one of three trends (Decline, Stable, Increase). We then used Excel's histogram function to create a frequency of population trends according to the criteria presented in Table 9. For this analysis we define the three population trends as follows:

- Stable – within the normal range of variation in the PCH (+ 4% exponential rate of change)
- Increasing – rates of increase above the normal exponential rate of variation (i.e. > 4%)

- Declining – rate of decline below the normal exponential rate of variation (i.e. < -4%)

Based on these classes we determined the percent frequency of the 1000 iterations for low and high population size and the three climate conditions (Figure 31 and Figure 32)

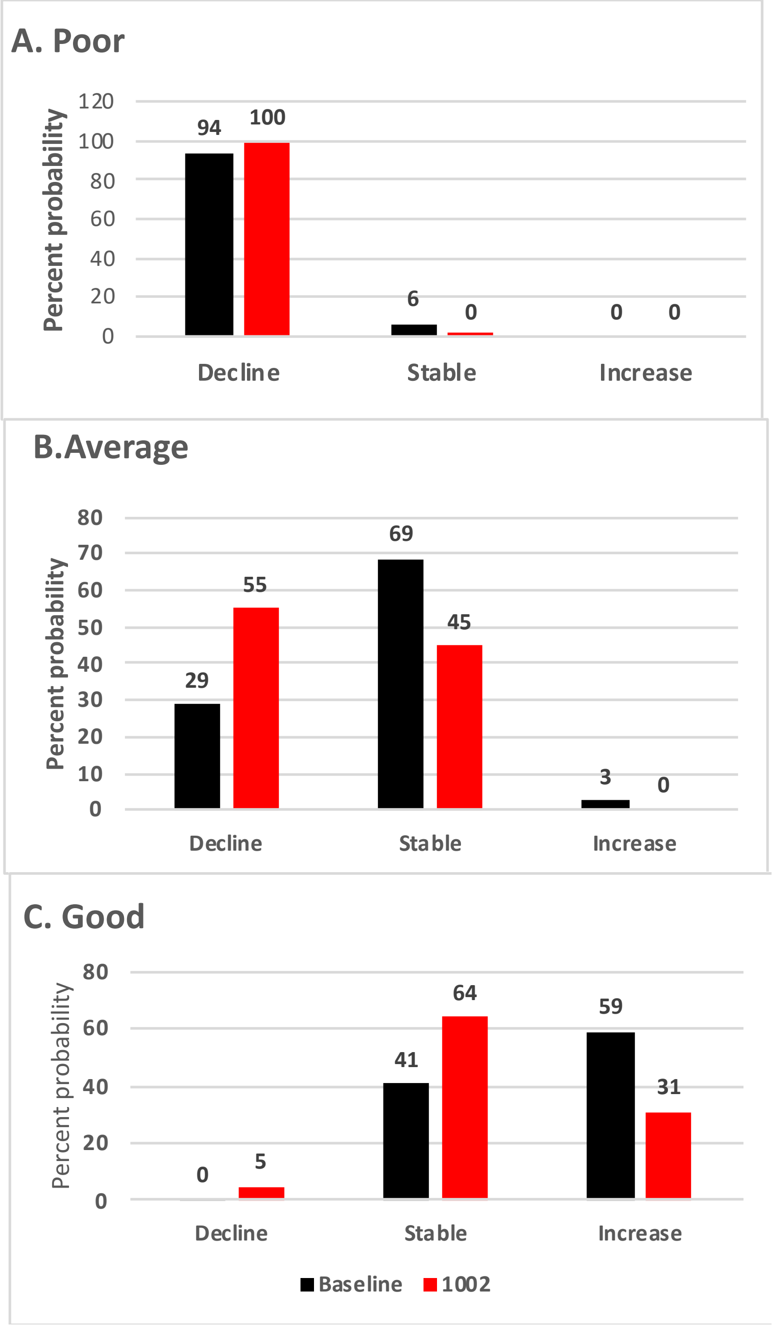

Figure 31. Risk of being in one of three population trends under poor, average and good climate conditions assuming a starting population of 100,000 caribou in the PCH.

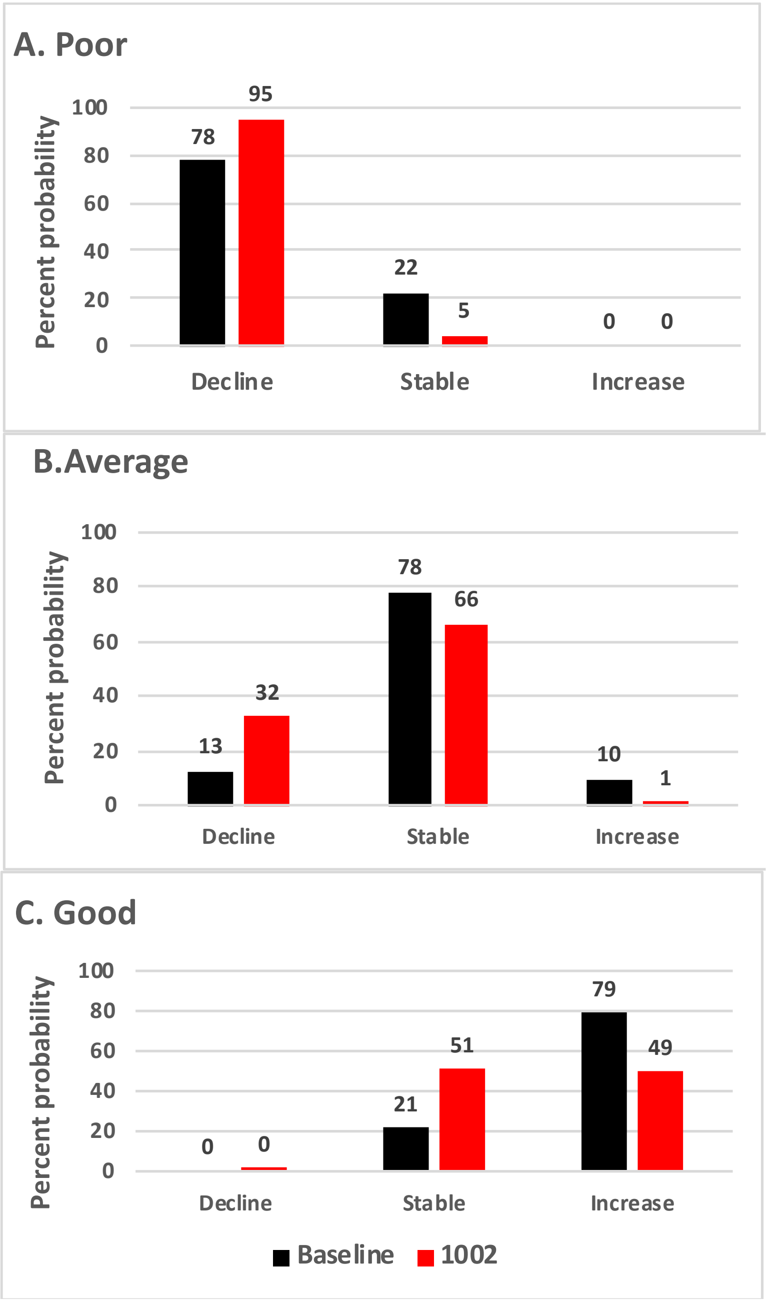

Figure 32. Risk of being in one of three population trends under poor, average and good climate conditions assuming a starting population of 218,000 caribou in the PCH.

The analysis presented in Figure 31 and Figure 32 allows us to acknowledge the variability in the population model outcome while providing a clearer idea of the risks of developing the 1002 lands.

At LOW population levels:

Under poor climate conditions, there was a 6% greater probability of a <u>decline</u> with 1002 development

Under average climate conditions, there was a 26% greater probability of a <u>decline</u> with 1002 development

Under good climate conditions, there was a 28% lower probability of a population increase with 1002 development

At HIGH population levels:

Under poor climate conditions, there was a 17% greater probability of a decline with 1002 development

Under average climate conditions, there was a 19% greater probability of a decline with 1002 development

Under good climate conditions, there was a 30% lower probability of a population increase with 1002 development.

1002 and Subsistence

In 2010, the signatories to the Porcupine Caribou Management Agreement in Canada, formulated a Harvest Management Plan designed to guide harvest management decisions as the PCH fluctuates in abundance. The Plan presents four zones based on population size, that when invoked by herd numbers recommends management specific actions (Figure 33).

Herd Size	Licensed Hunters	Aboriginal Hunters
Green Zone More than 115,000 animals	Up to two animals harvested Mandatory bulls only	No harvest limit Cows and bulls may be taken
Yellow Zone 80,000 to 115,000 animals	Only one animal harvest Mandatory bulls only	No harvest limit Voluntary bulls only
Orange Zone 45,000 to 80,000 animals	Harvest limit through permits	Harvest limit through subsistence allocation
Red Zone Less than 45,000 animals	No harvesting	No harvest except for ceremonial purposes

Figure 33. PCH population zones and recommended management actions from the PCH Harvest Management Strategy from PCMB.ca website.

Based on our population model runs, Figure 34 summarizes the percent probability of being in one of the four harvest management zones as described within the HMS for three climate conditions and 2 starting population sizes.

With a starting population size of 218,000 only 10 years of poor climate will result a substantial probability of the PCH dropping out of the green zone. The probability of falling into the orange or red zone increases 27% (from 18% to 45%) with 1002 development.

When population size starts at 100,000 (i.e. in the yellow zone), under average climate conditions the probability of dropping into the orange or red zone is 49% under baseline conditions and increases to 72% if 1002 is fully developed.

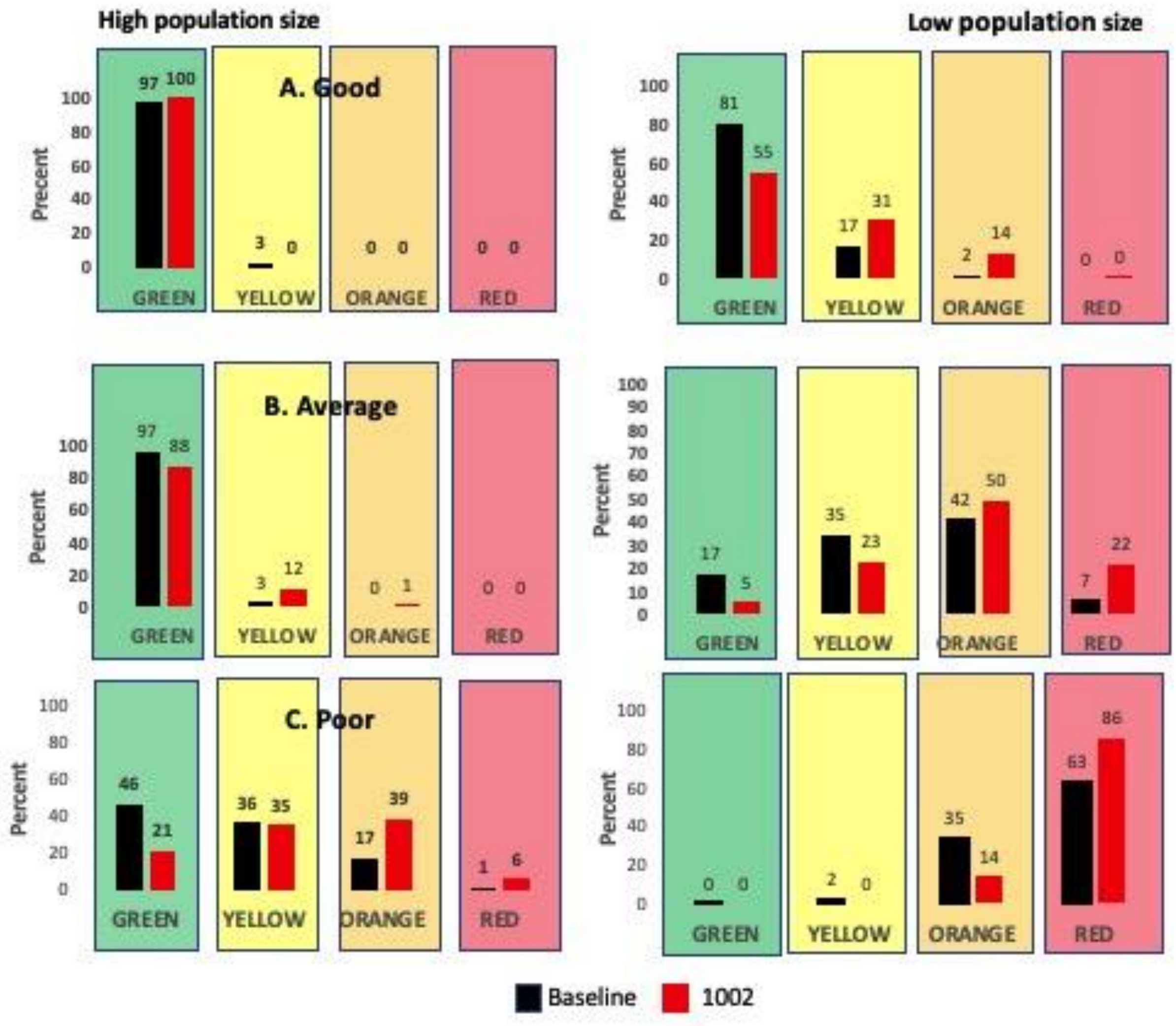

Figure 34. Percent probability of being in one of four harvest management zones under A. Good, B. Average and C. Poor climate conditions and with a starting population of 218,000 (left) or 100,000 (right) caribou.

4.2 Potential Impact discussion

We have applied our CCE model with the objective of determining the relative difference in population size of the PCH projected 10 years into the future between baseline and 1002 development. We used as a baseline the current landscape of climate, vegetation, harvest and development. To assess the cumulative impact of 1002 development, we ran a "1002" scenarios assuming full development of 1002.

The difference in outcomes between baseline versus added 1002 development is related to the variable use of 1002 by our (414) modelled caribou, where penalties in activity budget (forage time, e.g.) are applied when caribou are in 1002, affecting the cow's energy/protein balance and ultimately the body condition of the cow and her calf at the rut (outcome of Energy-Protein model). We then applied functional relationships between body condition of the cow to probability of pregnancy and for the body condition of the calf to overwinter mortality and ran these changes through a population model. We do not have enough data on possible linkages between changes in body condition and the mortality of the cow, although we are aware that 1002 may increase cow mortality by facilitating more access to harvesting. However, we did not add additional harvest in the model from 1002 development. Thus, the cumulative effect of 1002 development is solely based on outcomes of the population model reflecting changes in calf survival and pregnancy rate.

There is considerable individual variability in the energy-protein model outputs with respect to fall body weight of cows and calves. This variability is the result of initial cow age, cow weight and fat at the beginning of the simulation and the "choices" the cow makes with respect to daily habitat use throughout the year – both in terms of vegetation type and exposure to development. The relatively narrow 95% confidence intervals for cow and calf weight in Figure 3, (± 0.75 kg for cows and ± 0.36 kg for calves) reflects averages and SD for 343 pregnant cows (pregnancy rate 80% for the 414 modelled cows) and their calves from our model. If there was a requirement to monitor cow calf pairs in the field, it would be impractical to collect that many animals to detect quantitative impacts of 1002 development. Between 1987 and 1998, sample size of PCH cows collected in the fall during a number of studies averaged 37 per year (CARMA body condition database). Using a sample size of 37 caribou, we randomly sampled 300 random "collections" of cows and their calves from our model output. With those smaller sample sizes, the average 95% CI was ± 2.7 kg for cows and ±1.1 kg for calves. Given the difference in body weight between baseline and 1002 development under average climate was 0.4 kg for cows and 1.7 kg for calves, it would be hard to conceive of a long-term monitoring program that could detect changes in body weight due to exposure to 1002 development. The impact of chronically lower cow and calf body weights, however are projected to have demonstrable changes in population trends.

We choose to present the differences between baseline conditions and added 1002 development, 1) with respect to the probability that population trend will decline, stay stable or increase and 2) that the final population size will have implications to harvest management in Canada. From that analysis we determined that the PCH is most vulnerable to 1002 development when climate is poor and when population size is low. Under average climate, for example there was an 19% higher risk of a population decline with 1002 development when the starting population size was the current size (218,000). The risk increased to 26% if the starting population size was similar to estimates in the early 1970s (100,000 caribou).

From our analysis of vital rates and linkages between vital rates and climate we determined that during the years of increase and decline of the PCH, the only vital rate that tracked population trend was adult cow mortality and the only climate indicator related to adult cow mortality was rain-on-snow. In contrast the difference in population rate of change in the model output between baseline and 1002 development scenarios was, by design, related to calf mortality and pregnancy rate, hinging on the modelled body weights of cows and calves during the rut. This suggests that changes in climate and factors that may increase adult cow mortality would exacerbate the impacts of 1002 development.

5. Adaptive capacity

5.1 Adaptive capacity and adaptive management frameworks

Adaptive capacity, as a component of the vulnerability assessment is how a species can cope with and persist under new conditions including a warmer climate and, for this report, oil and gas development. Adaptive capacity for caribou partially depends on their evolutionary and behavioral plasticity (Beever et al. 2015, 2017; Glick et al. 2011). Adaptive capacity also depends on how the landscape is managed to allow caribou unhindered movement so they can adjust their behavior to variations in weather, insect harassment and forage conditions. Adaptive capacity also depends on how a warming climate and an oilfield are integrated into herd management, which can be a complex process dependent upon adequate knowledge of potential impacts. Building 'Adaptive Capacity' is in the tradition of Aldo Leopold (Leopold 1991) who recognized that "*conservation…is a positive exercise of skill and insight, not merely a negative exercise of abstinence or caution* and further "*the less violent the manmade changes, the greater the probability of successful readjustm*ent" of the land.

However, implementing adaptive capacity in complex and incompletely understood systems is uncertain. Holling (1973, 1978) brought together the complexities of ecological systems and the uncertainties in managing them to advance the idea of "resilience", the ability of social-ecological system to absorb changes while maintaining viability. Resilience (and vulnerability) while variable in how researchers have used them to characterise ecological and social systems (Miller et al. 2010), are concepts that emphasize the ability of systems to cope with changes.

Building adaptive capacity will strengthen resilience of the Porcupine caribou-social-ecological system and is possible in part through integrating responses to industrial disturbance with herd management as shown by experience with the CAH (summarised in Section 'Compensatory and Offsetting Mitigation'). However, the caribou's unimpeded passage through their calving and insect relief landscape through adaptive management will be a more immediate and effective contribution to adaptive capacity. Table 2.2 (2018 draft EIS) refers to "*All lands in the Arctic Refuge Coastal Plain are recognized as habitat of the PCH and CAH and would be managed to ensure unhindered movement of caribou through the area*."

Adaptive capacity and adaptive management are complementary and operate at different scales as adaptive management is the nuts and bolts of how monitoring tests and verifies how well mitigation is working relative to a previously identified threshold. It is a formal relationship between monitoring and a management action (mitigation): the monitoring measures whether the mitigation achieved a desired outcome or needs to be adjusted. The actual performance and desired outcome are equivalent to hypothesis testing. Although adaptive management has gained ground in natural resource management, it is stronger in theory than practice, at least as seen through the eyes of the US courts (Fischman and Ruhl 2010). Adaptive management has become a standard approach in environmental assessment to determine the effectiveness of mitigation. The US Department of Interior outlines the conditions necessary for the successful application of adaptive management and acknowledges that it is difficult to do in practice (Williams et al. 2009).

5.2 Mitigation

First, we summarize the proposed mitigation for 1002 based on the 2018 draft EIS and which are based on avoiding or minimizing effects. Secondly, we use the CCE model to explore applying the proposed 1002 mitigation to the PCH. Thirdly, we summarize uncertainties in the proposed mitigation.

5.2.1 Proposed avoidance and minimization mitigation for 1002

BLM (2018b) describes a complex system of nine area and date-based stipulations and five Required Operating Procedures to mitigate through avoiding or minimizing effects on the PCH. Stipulations and ROPs have sets of individual mitigation actions in varying degree of detail. The 2018 draft EIS bundles the stipulations into three leasing alternative development scenarios (B, C, D although D has two versions, D1 and D2) which differ in the areas of the four development activity stipulations and the area available to be leased (Figure 35). Stipulations are attached to the leases and govern the timing and type of the proposed oil and gas activities which can be specific (e.g.: dates) and have thresholds (such as 100 caribou) for their implementation (BLM 2018b: Table 2.2). Stipulations such as the Time Limited stipulations may also require the later submission of a work plan to deal with the caribou cow's early arrival. The difficulty for reviewing the draft EIS is that there is not even an outline of minimum requirements for the work plan.

Required Operating Procedures (ROPs) are sets of measures applied to activities such as roads, pipelines or aircraft. ROP 34 applies to all Alternatives and restricts aircraft over flight altitudes. The ROPs may have specific requirements. For example, ROP 23 determines the height of a pipeline and/or requires future plans whose implementation is subject to a BLM Authorized Officer. ROP 23 has conditions 1-4 relating to the pipelines (height, exterior finish, separation from roads, and ramps and buried sections) and three additional conditions: (5) a requirement to design facilities so as to not corral or impede caribou movements; (6) a study on caribou movements and (7) a vehicle use management plan. Five of the seven conditions depend on the approval of the BLM Authorizing Officer which raises questions as to public and technical input and review.

In ROP 23, requirement for the study of caribou movement (unless a PCH and CAH study has been completed within the last 10 years) has a precedent based on the movements study that BLM required for the Teshekpuk herd (Person et al. 2007). Analytical techniques have advanced to measure movement rates and trajectories relative to potential road/pipeline corridors and habitat factors (Flydal et al. 2018, Wilson et al. 2014, Panzacchi et al. 2015, Wilson et al. 2016, Kite et al. 2017, Bali 2016). However, there is a question of scale if the lessee's movements study is to support the design of the facilities to avoid corralling or impeding movements. Wilson et al. (2013) describe a spatial modelling approach which is applicable at the scale for designing the proposed 'Caribou Area Stand-alone Oil Development Facility' (BLM 2018b: Figure B-2). BLM (2018b) has three area-based stipulations #s 6, 7 and 8 which identify PCH seasonal habitat (summer, calving, and post-calving, respectively). Two stipulations (#1 and #9) restrict developments in proximity to river courses and the coast, respectively. Four stipulations apply to specific areas and describe which development activities can be undertaken and when (Time-limited, No Surface Occupancy, Controlled Surface Use, and Standard).

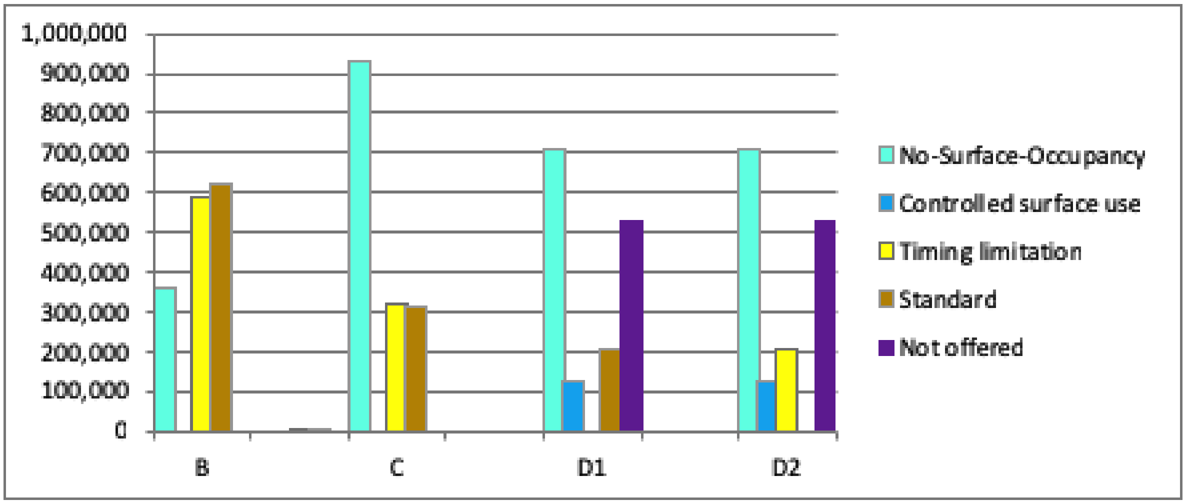

Figure 35. Areas (acres) of four lease stipulations and area (acres) not available for leasing compared among four alternatives for 1002 lands (based on BLM 2018b).

We have summarised BLM's (2018b) description of the stipulations as follows (the draft 2018 EIS gives a more detailed listing):

Standard: standard lease terms and conditions (however, we did not find a definition of what this means in the draft EIS).

Controlled surface use: BLM (2018b) categorises this as a moderate constraint stipulation that allows some use and occupancy of public land, while protecting identified resources or values. It allows truck-mounted drilling and geophysical exploration equipment off designated routes and construction of wells and pads but does allow BLM to require special operational constraints, or the activity can be shifted more than 656 feet to protect the specified resource or value.

Timing limitation (TL): BLM (2018b) categorizes this stipulation as a moderate constraint and closes areas for specified time periods to construction, drilling, completions, and other intensive operations. But the stipulation does not close operation and basic maintenance, including associated vehicle travel, unless otherwise specified. TLs can overlap spatially with no surface occupancy and controlled surface use, as well as with areas that have no other restrictions.

No-Surface-Occupancy: is open for mineral leasing but does not allow the construction of surface oil and gas facilities to protect other resource values.

Not offered: Not available for lease

We looked at PCH exposure to these four time/activity stipulations and the area not available for leasing based on our analysis of satellite and GPS collar movements in 1002. The annual allocation of days among the lease stipulation zones (Figure 36) is highly variable. However, these are average values and in some years there were few collars (1991 has only one collar). The high annual variability of exposure reduces predictability for lease operators as caribou may be present in low numbers in one year, while present in high numbers the following year.

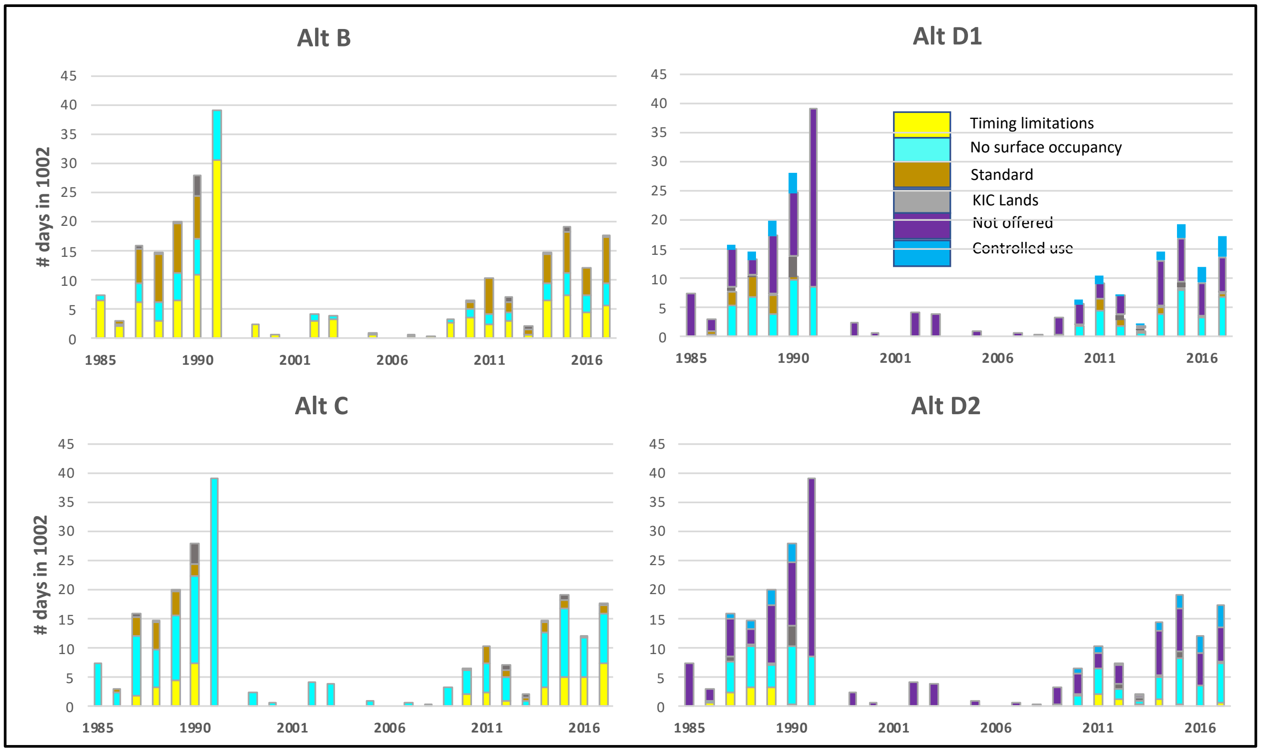

Figure 36. Annual average number of days collared caribou spend in specific proposed lease stipulation areas in 1002 under four alternative development options.

The four timing/activity stipulations are applied within the seasonal habitat stipulations which are defined as areas (Table 10). The interactions between different stipulations for activities and PCH seasonal habitats are shown in the draft 2018 EIS Appendix maps 2.1 – 2.8.

Lease Stipulation 6—PCH Summer Habitat which is "*all lands in the Arctic Refuge Coastal Plain are recognized as habitat of the PCH and CAH and would be managed to <u>ensure</u> <u>unhindered</u> movement of caribou through the area*" (BLM 2018b: Table 2.2). The objective for Stipulation 6 is to <u>minimize</u> disturbance and hindrance of caribou or alteration of caribou movements [our underlining]. Lease Stipulation 7 is for PCH Primary Calving Habitat is to minimize disturbance and hindrance of caribou or alteration of their movements in the area with a higher-than-average density of cows about to give birth during more than 40 % of the years surveyed. Lease Stipulation 8 is for PCH Post-Calving Habitat and is the area with a higher-than-average density of cows during the post-calving period for more than 40 % of the years.

For the three area-based stipulations (calving, post-calving and summer), BLM (2018b) then applies timing/activity stipulations (Table 10; draft 2018 EIS Appendix Maps 2-2 to 2-8). For PCH calving, the three alternatives differ in proposed mitigation. Within the calving area used in 40% of the years (Stipulation 7), in Alternatives B and C, the Time Limited Stipulation applies 20 May to 20 June and allows drilling operations and basic maintenance including road travel. Equipment is to be stockpiled prior to calving so as to reduce traffic but the expected level of traffic is not provided. If caribou are within 0.8km of the road, speed is to be reduced. The lessee will have to describe other strategies such as limiting trips, using convoys and different vehicle types "*to the extent practicable*" in a future vehicle use plan. The area of Time Limited in Alternative C is smaller (465 km^2) than in Alternative B (2918 km^2) as in Leasing Alternative C, 2453 km^2 have No Surface Occupancy (no surface construction). The lack of detail and criteria for such plans leaves their effectiveness uncertain and it is essentially unknown as to whether the permitted activities during calving in lease Alternative B could lead to calving displacement. For Alternatives D1 and D2, most of the calving area (Stipulation 7), is not available for leasing (1929 km^2) and the small area that is available is No Surface Occupancy (990 km^2).

For the post-calving area (Stipulation 8) in lease Alternative B, there are no other stipulations applied and the only mitigation of effects is through ROP 23 and 34. Operation of drills from existing pads and maintenance but not construction can also proceed throughout lease Alternative C for post-calving as the Time Limited Stipulation will be applied June 15–July 20 throughout the area. In addition, there is a specific requirement that sections of road would be evacuated when 100 or more caribou attempt to cross the road. However, this is vague and it is uncertain how it would happen in practice. Similar to lease Alternate B, ROP 23 would be applied to lease Alternative C.

Mitigation for post-calving in leasing alternative D1 and 2 depends on the Controlled Surface Use[1] stipulation which restricts the construction of CPFs but well pads, roads, airstrips, and pipelines would be permitted subject to ROP 23. In addition, the Time Limited Stipulation applies June 15–July 20 throughout the area with the specific requirement that sections of road would be evacuated when 100 or more caribou attempt to cross the road.

The only mitigation for PCH summer habitat proposed for Alternatives B, C and D1 1002 is the application of ROPs 23 and 34. Alternative D2 has the same application of ROPs 23 and 34 plus a Time Limited Stipulation (draft 2018 EIS Table 2.2). The Time Limited stipulation is worded to allow for oil development related activities if caribou are not likely to be disturbed in significant numbers (greater than approximately 10 percent of the estimated calving cow population or 1,000 during insect-relief periods). If caribou arrive before 20 May or are still present after July 20, major construction would be suspended according to a stop work plan. The logic for the thresholds is not provided and it is uncertain whether the thresholds can be adjusted to the herd's resilience such as if the herd is increasing or declining.

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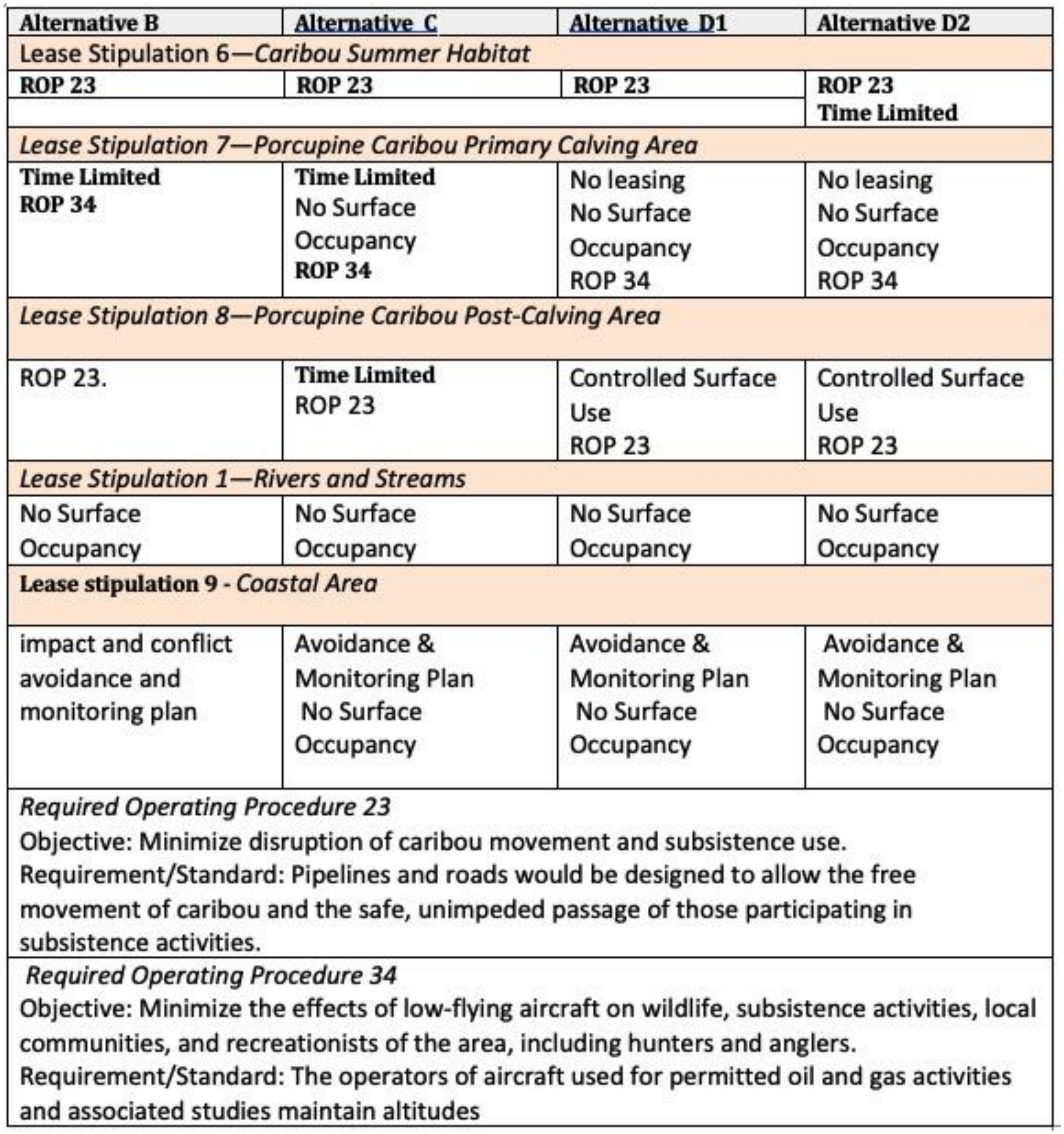
[1] In the description of permitted activities in CSU Table 2.2 (draft EIS) refers to Infrastructure would be limited across the area to 100 acres per township, not to exceed 510 acres total.

Table 10. Summary of the stipulations and Required Operating Procedures for the four alternative scenarios (based on Table 2.2, 2018b draft EIS).



Alternative B	**Alternative C**	**Alternative D1**	**Alternative D2**
Lease Stipulation 6—*Caribou Summer Habitat*			
ROP 23	**ROP 23**	**ROP 23**	**ROP 23** **Time Limited**
Lease Stipulation 7—Porcupine Caribou Primary Calving Area			
Time Limited **ROP 34**	**Time Limited** No Surface Occupancy **ROP 34**	No leasing No Surface Occupancy ROP 34	No leasing No Surface Occupancy ROP 34
Lease Stipulation 8—Porcupine Caribou Post-Calving Area			
ROP 23.	**Time Limited** ROP 23	Controlled Surface Use ROP 23	Controlled Surface Use ROP 23
Lease Stipulation 1—Rivers and Streams			
No Surface Occupancy	No Surface Occupancy	No Surface Occupancy	No Surface Occupancy
Lease stipulation 9 - *Coastal Area*			
impact and conflict avoidance and monitoring plan	Avoidance & Monitoring Plan No Surface Occupancy	Avoidance & Monitoring Plan No Surface Occupancy	Avoidance & Monitoring Plan No Surface Occupancy
Required Operating Procedure 23 Objective: Minimize disruption of caribou movement and subsistence use. Requirement/Standard: Pipelines and roads would be designed to allow the free movement of caribou and the safe, unimpeded passage of those participating in subsistence activities.			
Required Operating Procedure 34 Objective: Minimize the effects of low-flying aircraft on wildlife, subsistence activities, local communities, and recreationists of the area, including hunters and anglers. Requirement/Standard: The operators of aircraft used for permitted oil and gas activities and associated studies maintain altitudes			

ROP 28 and ROP 33 are a basis for refining future mitigation. ROP 28 is a requirement to use ecological mapping for wildlife habitat before determining locations for permanent facilities. ROP 33 is to provide information for monitoring and assessing wildlife movements during and after construction by compiling a GIS catalogue of roads, pads and other structures.

The proposed stipulations and required operating procedures are a contrast in their complexity compared to the 1987 environmental assessment report for 1002 lands. However, both in 1987 and 2018, there is consistency on the concern is for calving and the large groups seeking insect relief habitat (Table 11). However, we suggest that while ROP 23's (BLM 2018b) condition for an elevated pipeline separated from a road is evidence-based (Lawhead et al. 2006), there is less experience to know how to apply other ROP 23 conditions such as how to orient infrastructure to avoid impeding caribou migration and to avoid corralling effects. From our analysis of movements of the large aggregations in the 1002 lands, it seems hard to imagine how to plan facilities to avoid hindering movements, given the magnitude of the groups and the unpredictable nature of their movement. The Time Limited Stipulation (15 June to 15 July) requires that road sections would be evacuated when a large number of caribou (approximately 100 or more) are about to attempt to cross the road but without suggesting the type of monitoring would be required.

Table 11. Summary of proposed mitigation for caribou based on 1987 EIS (Clough et al. (1987).

Mitigation for calving:	**Coastal insect relief/large groups**
Nonessential development facilities should be outside core calving areas	Time and area closures, restrictions on activities and access imposed, or traffic controlled when caribou seek insect-relief, June 20-August 15.
Minimize footprints	Curatolo and Murphy (1983): separating pipelines from heavily traveled roads and constructing ramps at strategic locations over elevated pipelines.
Time and space restrictions 20 May to 20 June	Preliminary information indicates that a separation of 400-800 feet improves crossing success (Curatolo and Reges, 1986).
Off-road vehicle use should be prohibited within 5 miles of all pipelines, pads, roads except for local subsistence	Drill pads and production facilities allowed within the zone 1.5 to 3 miles from the coast, on a site-specific, case by-case basis only.
2,000 feet AGL from May to August.(Davis & Valkenburg 1979)	

5.2.2 Compensatory and Offsetting mitigation

In addition to avoidance and minimization, the third part of the mitigation hierarchy (BLM 2016) includes remediation and rehabilitation and then compensation for or offsetting relative to any residual effects. BLM has considerable experience in compensatory and offsetting mitigation which are applied using different techniques (for example, Clement et al. 2014) which include habitat conservation banking and in-lieu fee mitigation. BLM (2016) recognized that despite mitigation for oilfield development in NPR-A, there would be unavoidable residual impacts which would likely impact people's harvesting. To compensate for these residual impacts BLM required the oil company to fund a $8 million compensation fund which contributed to a collaborative Regional Mitigation Strategy (BLM 2016). The Regional Mitigation Strategy and its accompanying technical report (Argonne National Laboratory 2016) operated at the landscape scale and spells out when and how compensatory mitigation is required for residual effects. It also included how to monitor the effectiveness of mitigation to adapt it if needed. However, in

2018, BLM subsequently switched to accepting only voluntary proposals for compensatory mitigation[2] and the topic is not included in the draft 2018 EIS.

Alaska Department of Fish and Game's (ADF&G) management goals for the CAH include managing for the effects of Prudhoe Bay oilfield on the herd. It is in the language of goals and objectives (Table 12) which link keeping the cow harvest low relative to the cumulative effects of the oilfield that has led us in this report to identify the low harvest rate as 'offsetting' mitigation.

Valkenberg (1992) stated that the management goals and objectives were "*based on the hypothesis that displacement, if of sufficient magnitude, would be harmful to the CAH (Cameron 1983)".* The first goal to minimize effects of the oilfield had three objectives (Table 12) to prevent barriers to movements, minimize disturbance and maintain hunting restrictions. The second goal was to manage hunting levels at a level to not affect CAH population dynamics and included the objective to minimize the harvest of cows (Valkenberg 1992).

ADF&G's approach to managing the CAH relative to the oilfield developments continued through the 1990s into the 2000s. Lenart (2003) wrote "*Based on the hypothesis that displacement of sufficient magnitude would be harmful to the CAH (Cameron 1983), we worked with the oil industry to minimize disturbance to caribou movement due to physical barriers created by oil development".* Lenart (2003, 2005, 2009) reported working with the oil industry to mitigate the oilfield effects but without describing details. Lenart (2013, 2015) commented that ADF&G have not determined the success of the mitigation measures.

In addition, given that stress is cumulative, ADF&G reduced hunting activity in areas adjacent to the oilfield and the Dalton Highway and also restricted the cow harvest." The goals and objectives had changed slightly by 2000 (Table 12) and lists Objective 4 (Limit the annual harvest of cows to a maximum of 3% of the cows) in support Goal 1 which was to minimize the adverse effects of development on CAH caribou. Lenart (2003, 2005) reported that the cow harvest has been <1% since 1992 partly through having a bulls-only season during the time of year when hunting pressure is highest. As the CAH increased 13% annually 2002-2008 and had reached 66,772, Lenart (2009) recommended removing the 3% limit to the cow harvest.

Table 12. Summary of management goals for the CAH in response to oilfield development.

Management Goals and Objectives CAH 1992, 1999

1. Minimize the adverse effects of development on caribou.
2. Work with industry to prevent the construction of barriers to the free passage of caribou.
3. Work with industry and other agencies to minimize disturbance to caribou in proximity to developments, except where caribou constitute a hazard.
4. Maintain necessary restrictions on caribou hunting.
5. Provide for continued caribou hunting at a level which does not significantly affect population dynamics of the CAH, especially in areas away from developments.
6. Determine the influence of current harvest levels on the CACH.
7. Minimize harvest of cows from the CAH.
8. Maintain a bull: cow ratio of at least 40: 100.

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[2] https://www.blm.gov/policy/im-2019-018

9. Maintain opportunities for people to see caribou along the Dalton Highway and in the oilfields.
10. Work with industry and other agencies to minimize disturbances to caribou in proximity to developments, except where caribou constitute a hazard.
11. Regulate hunting along the Dalton Highway so that cont1icts between -hunters and non-consumptive users are minimized, and so that caribou are not displaced from the vicinity of the road by hunting.

MANAGEMENT GOALS 2003

Goal 1 Minimize the adverse effects of development on CAH caribou.

Goal 2 Maintain a CAH population level that will support a harvest of at least 600 caribou without precluding population growth.

Goal 3 Provide the opportunity for a subsistence harvest of CAH caribou.

Goal 4 Maintain opportunities to view and photograph CAH caribou.

MANAGEMENT OBJECTIVES

Objective 1 Maintain a population of at least 18,000–20,000 caribou. (Goals 1, 2, 3)

Objective 2 Maintain accessibility of seasonal ranges for CAH caribou. (Goal 1)

Objective 3 Maintain a harvest of at least 600 caribou if the population is ≥18,000 caribou. (Goal 2)

Objective 4 Limit the annual harvest of cows to a maximum of 3% of the cows in the population. (Goals 1, 2, 3)

Objective 5 Maintain a ratio of at least 40 bulls:100 cows. (Goals 1, 2, 3)

Objective 6 Reduce conflicts between consumptive and non-consumptive uses of caribou along the Dalton Highway. (Goal 3)

5.2.3 Mitigation – Modelling relative impacts of Alternative options

The modelling analyses in the Potential Effects section are based on the hypothetical baseline scenario (BLM 2018b; Appendix B in the EIS) which assumes all potentially productive areas will be leased, subject to standard terms and conditions; meaning that caribou will be disturbed whenever they enter 1002. In contrast, in this section on Adaptive Capacity, we quantify the relative impacts of implementing the four development alternatives with their stipulations as described in the draft EIS (BLM 2018b). The stipulations describe the different levels of mitigation.

The objective of the draft EIS, as stated many times, is not to authorize development but to provide the necessary background to proceed with lease sales in fulfillment of the Tax Act. In assessing the relative impact of each alternative, we applied the CCE Model in the same manner that we assessed full 1002 development, however instead of assuming that collars in the 1002 were equally exposed to development throughout, we partitioned the landscape into the lease stipulation areas corresponding to the four development Alternatives in the EIS. To make the number of runs manageable, we assumed average climate conditions in all analysis (Figure 37) while acknowledging that an average climate for the full 10 years is unlikely but it allows us to examine the relative effects of the mitigation.

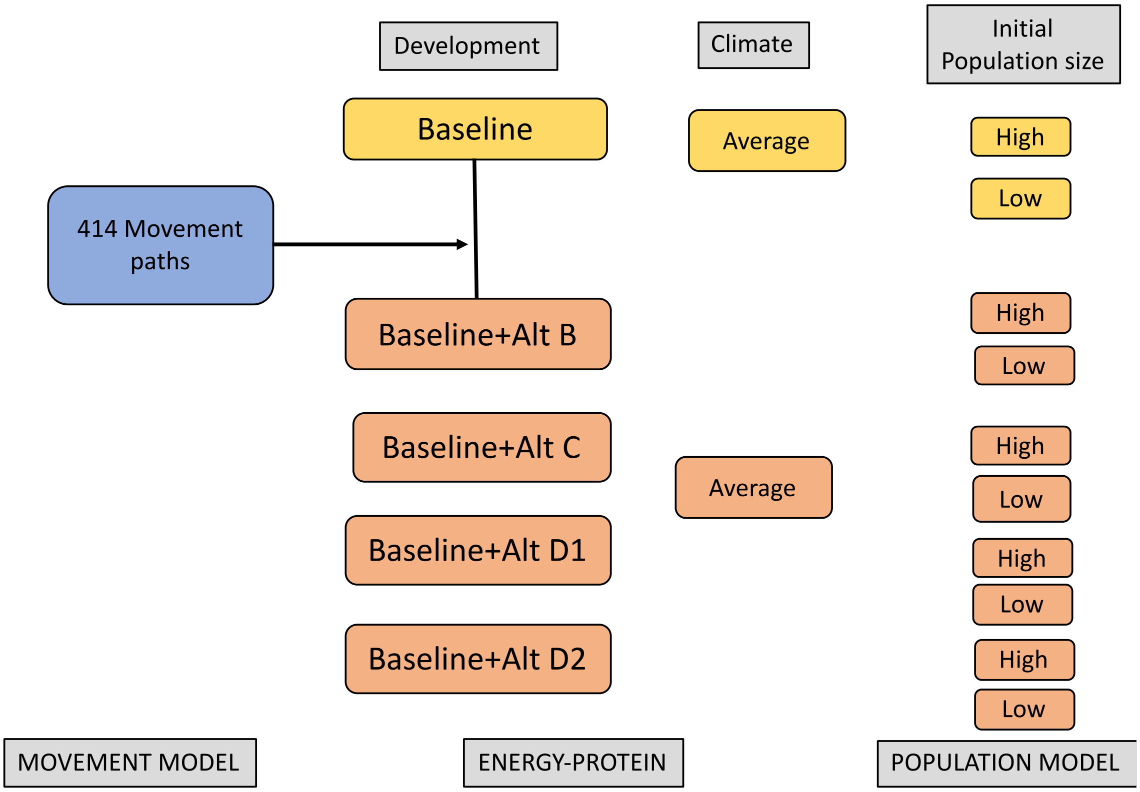


Figure 37. Scenarios run in the CCE to compare relative impacts of four development alternatives under average climate conditions and two starting population levels.

To differentiate impacts when caribou were in the different lease stipulation areas ("Areas"), we varied the disturbance values by assuming the mitigation implicit in the lease stipulations would reduce the penalties (Table 13). But in all cases, we reduced penalties if we were uncertain from the draft 2018 EIS how disturbance would be mitigated and whether the mitigation would be effective. The base values for the penalties are described in Section C. We used our professional judgement to scale the penalties relative to each other because we lack specific knowledge about how caribou could respond to the activities permitted under the different stipulations. On one hand, the model may under-estimate disturbance costs as the penalties are based on changes in foraging, bedding and movement and do not include any other costs of disturbance such as costs of displacement, stress or increased responsiveness from hunting (Russell and Martell 1985). On the other hand, the model assumes that are exposed to disturbance anywhere in the stipulation area as the pattern of development is uncertain.

Table 13. Penalties (percent changes) in baseline activity budgets used in the CCE Model based on lease stipulations associated with the four development Alternatives.

Map designation	Lease stipulation	Season	Foraging	Walk	Run	Eating Intensity	Rationale
1	Timing	Pre-calving	-4	2	2	-2	Assumes 20 May to 16 July; what activity allowed undefined
		Calving - post-calving	-8	4	4	-4	
		Early - mid summer	-12	6	6	-6	
2	No surface Occupancy	Pre-calving	-3	1.5	1.5	-1.5	adjacent activity zones; pipelines, roads and gravel pits are allowed (No "oil and gas" facilities); designation can be changed in field; less strong protection than no lease
		Calving - post-calving	-6	3	3	-3	
		Early - mid summer	-6	3	3	-3	
3	Standard Operating	Pre-calving	-6	3	3	-3	assumes standard ZOI penalties
		Calving - post-calving	-12	6	6	-6	
		Early - mid summer	-12	6	6	-6	
4	KIC Lands	Pre-calving	-6	3	3	-3	development and lease conditions undefined
		post-calving	-12	6	6	-6	
		Early - mid summer	-12	6	6	-6	
5	No Lease	Pre-calving	0	0	0	0	Not in a ZOI although if development is directly adjacent to the No lease zone, displacement and disturbance will occur near the boundary zone
		Calving - post-calving	0	0	0	0	
		Early - mid summer	0	0	0	0	
6	Controlled use	Pre-calving	-4	2	2	-2	Unclear how controlled use will mitigate
		Calving - post-calving	-12	6	6	-6	
		Early - mid summer	-12	6	6	-6	

Model Run Results:

We used the same methodology as applied in the Potential Impacts section, with the exception that in modeling the four alternatives we tracked in which lease stipulation zone the caribou was in and applied the appropriate penalties (Table 13. While collared cows were in 1002, Figure 38 illustrates the average percent of days that collared cows within a lease stipulation category for the four development alternatives outlined in the EIS.

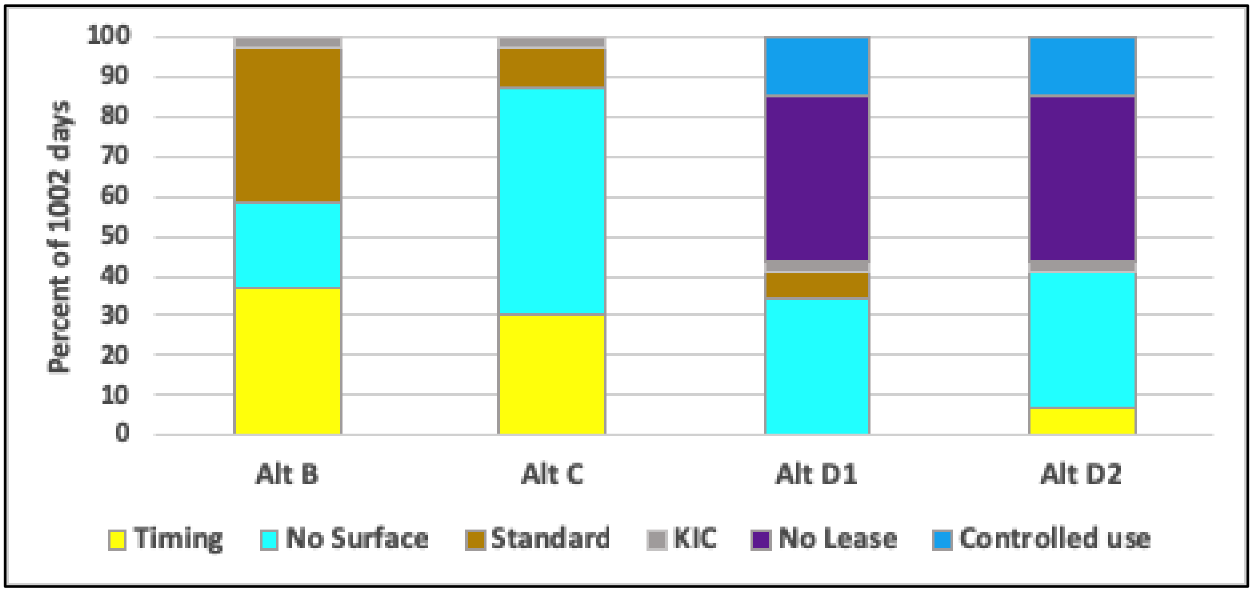
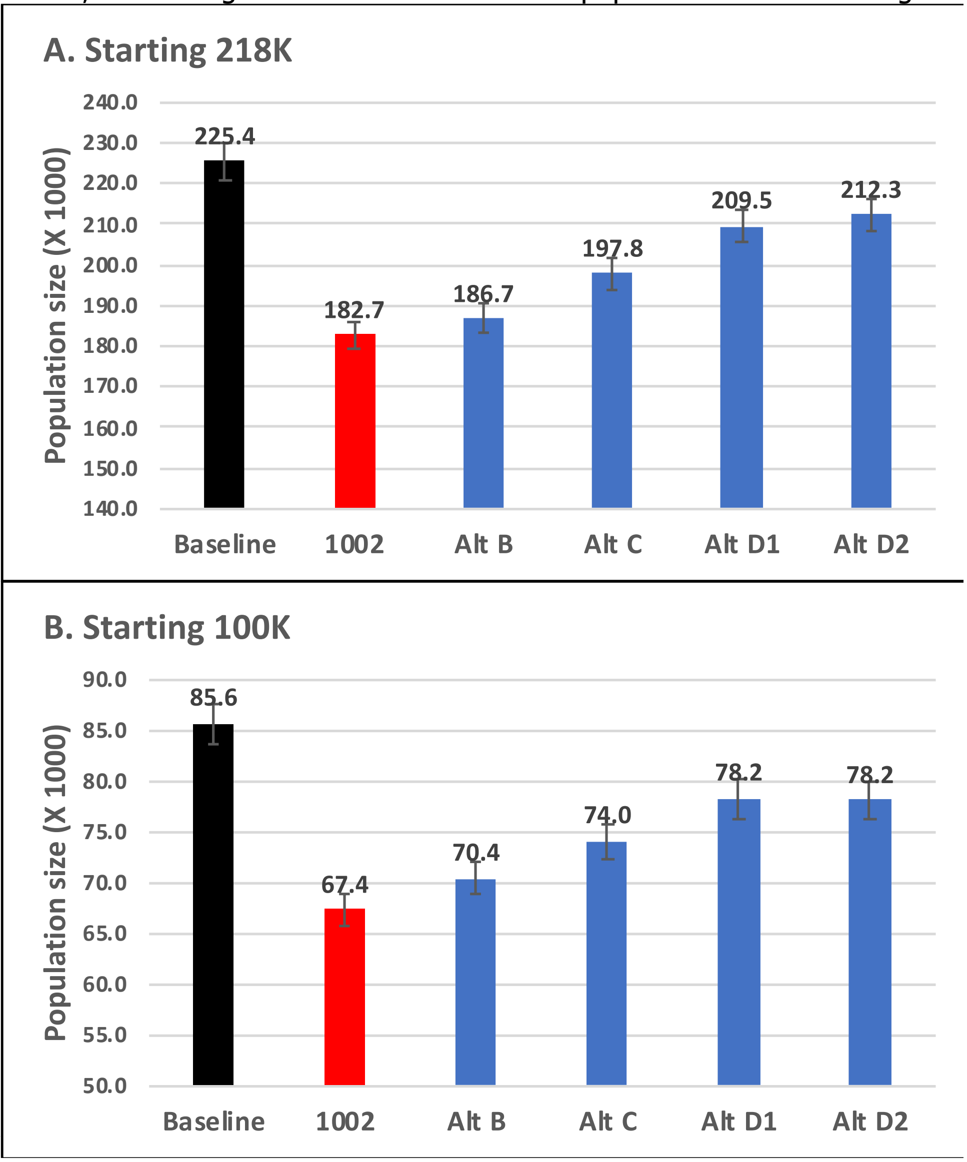


Figure 38. Percent of "1002" days spent in specific lease stipulation zones for the four development alternatives.

With a starting population size of 218,000, the average final population size (after 10 years) varied from 187,000 to 212,000 among the four alternatives with population size increasing from Alt B to Alt D2 (**Figure 39**A). By comparison, under baseline development, the final population size was 225,000, a slight increase over the 10-year simulation. Final population size for the worst-case scenario, full 1002 development with no effective mitigation, was 183,000. Thus, for the four alternatives, the cumulative effect by development of 1002 starting at a high population size (218,000) was:



17% decline for Alternative B
12% decline for Alternative C
7% decline for Alternative D
6% decline for Alternative D2

With a starting population size of 100,000, the average final population size (after 10 years) varied from 70,000 to 78,000 among the four alternatives with population size increasing from Alt B to Alt D2 (Figure 39B). By comparison, under baseline development infrastructure, the final population size was 86,000, a decline over the 10-year simulation. Final population size for the worst-case scenario, full 1002 development with no effective mitigation, was 67,000. Thus, for the four alternatives the cumulative effect of development of 1002 starting at a low population size (100,000) was:

18% decline for Alternative B
14% decline for Alternative C
9% decline for Alternative D1
9% decline for Alternative D2

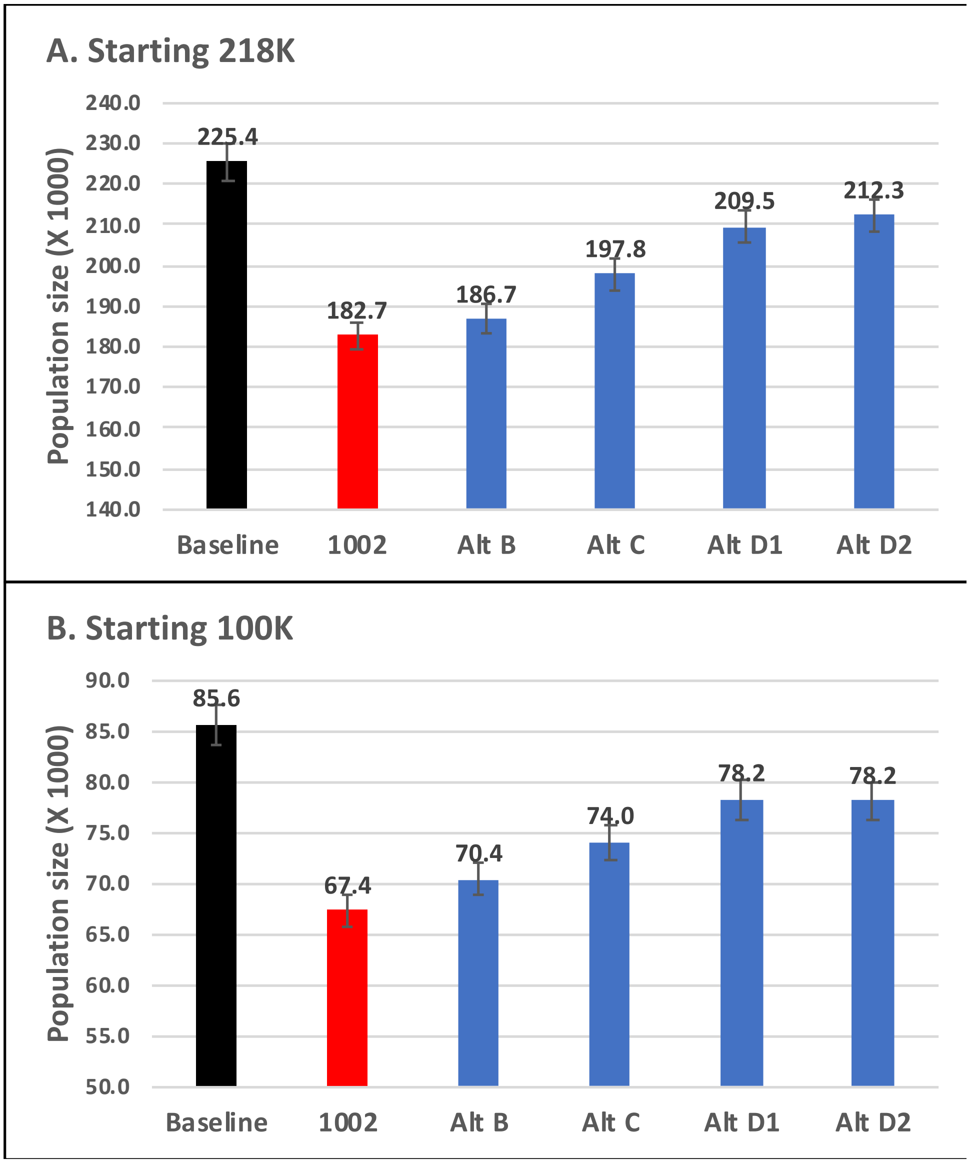


Figure 39. Final population size (± SE) after 10 years for four development alternatives compared to population size projections for Baseline development and full 1002 development (from Figure 30).

We determined the percentage probability that the PCH would stay stable, increase or decline calculating the exponential rate of change for each of the 1000 iterations in the population model (see Table 9). Based on that analysis, we projected that, for a starting population size of

100,000, the percent probability that the herd would decline dropped from a 50% probability under Alternative B to a 40% probability under Alternative D2. By comparison under baseline conditions there was a 29% probability that the herd would decline.

For a starting population size of 218,000, the percent probability that the herd would decline dropped from a 27% probability under Alternative B to a 16% probability under Alternative D2, compared to a 2 and 7 % probability, respectively, that the PCH would increase. By comparison under baseline conditions, the probability was 13% that the herd would decline and a 10% probability that the herd would increase.

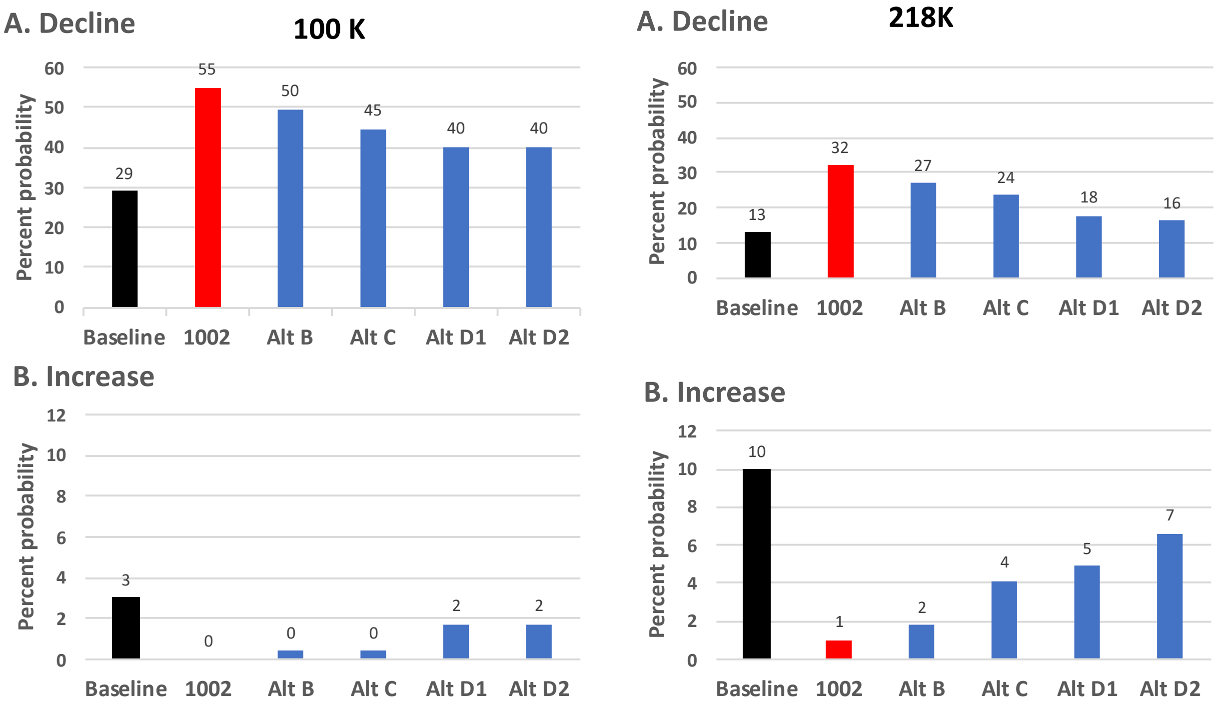


Figure 40. Percent probability that the population trend will A. decline and B. increase for starting population sizes of 100,000 (left panel) and 218,000 (right panel) for the four development alternatives. For comparison the corresponding probability for Baseline and full 1002 development (from Figure 31 and Figure 32) development are listed as well.

We determined the percent probability that the final population size of each or the 1000 iterations in the population model would fall into one of four harvest management zones (see Figure 33). Although there was a small probability that over the next 10 years the PCH would remain in any other zone than green, there was from a 4% -12% (from Alt D2 to Alt B) chance that numbers would fall below the 115,000 threshold and enter the yellow zone, compared to a 3% probability under baseline development conditions (Figure 41).

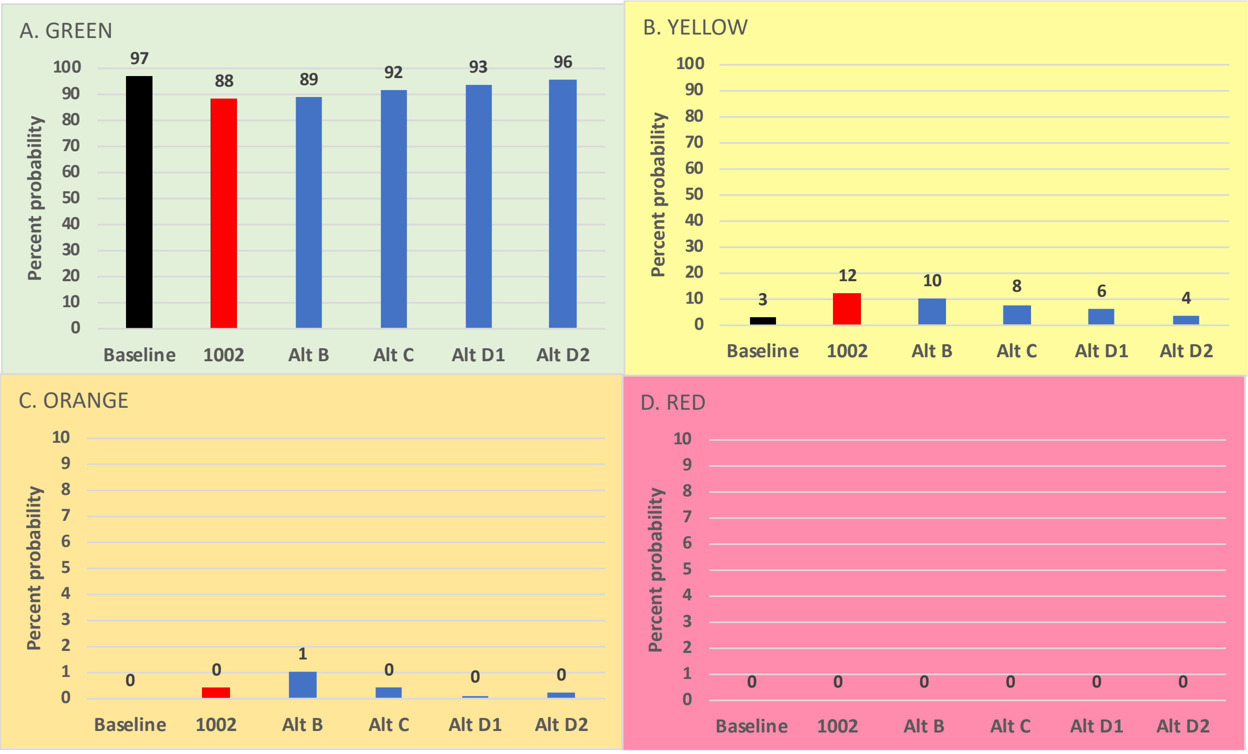


Figure 41. For a starting population size of 218,000 caribou, percent probability that final population size (after 10 years) will fall into one of four harvest management zones (Green, Yellow, Orange, Red) for the four Alternative development options. For comparison the corresponding probability for Baseline and full 1002 development (from Figure 34) development are listed as well.

There was a considerable shift in probability of staying in the yellow zone using a starting population size of 100,000 caribou (below the yellow to green threshold of 115,000). Under baseline development conditions there was then a 42% chance that the PCH number would be in the orange zone. That percent increased to between 47% to 51% under the 1002 development options.

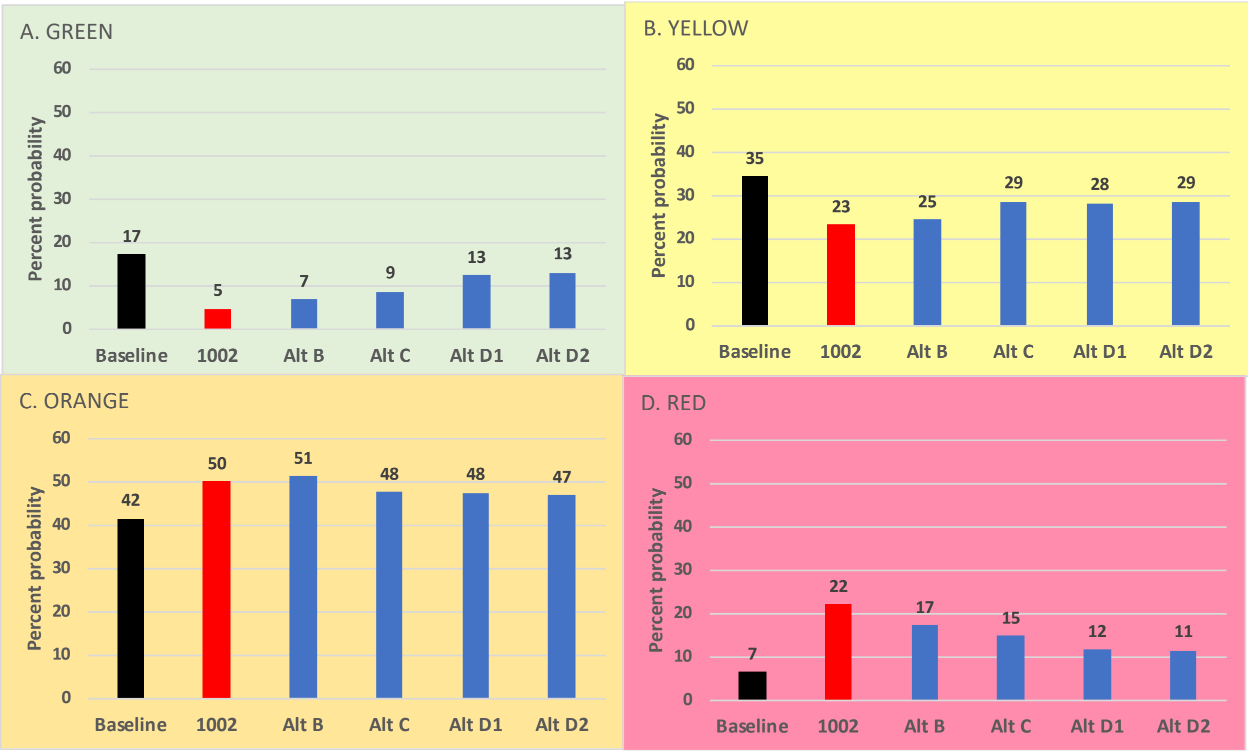


Figure 42. For a starting population size of 100,000 caribou, percent probability that final population size (after 10 years) will fall into one of four harvest management zones (Green, Yellow, Orange, Red) for the four Alternative development options. For comparison the corresponding probability for Baseline and full 1002 development (from Figure 34) development are listed as well.

5.2.4 Gaps and Uncertainties in mitigation

We have identified gaps and uncertainties in the stipulations and operating procedures which leads to uncertainties in the degree of protection for the PCH.

Contingency mitigation for annual variation in calving and post-calving distribution

This is a major gap. Stipulations 7 and 8 describe calving and post-calving habitat as those areas with a higher-than-average density of cows during more than 40 percent of the years surveyed. Contingencies for variation in annual use are unknown which introduces uncertainty into the effectiveness of the mitigation. The maps in the draft 2018 EIS Appendix suggest that annual variation in calving and post-calving can reduce the protection as calving or post-calving outside the areas specified in Stipulations 7 and 8 could expose the cows and calves to less restrictive stipulations as the more protective stipulations do not ‘move’ with the annual variations in distribution as the caribou respond to the annual changes in weather and forage availability.

Experience from other EISs on the Alaska North Slope

The 2018 draft EIS does not clearly relate how the draft 2018 EIS stipulations and operational procedures are derived from and consistent with elsewhere on the North Slope such as the

Alpine oilfields. As oilfield development spread west from Prudhoe Bay, requirements for monitoring and mitigation have increased through Reasons for Decision reports following public and agency input to environmental assessments. The state and federal requirements for mitigation apply at different stages of leasing and permitting and have become more specific over time with agency and public concerns and input.

Where we could compare the draft 2018 EIS with other BLM stipulations and conditions, we found similarities but also differences, for example. For the NPR-A: The permittee or a contractor shall observe caribou movement from May 20 through August 20, or earlier if caribou are present prior to May 20. Based on these observations, traffic will be stopped to temporarily allow a crossing by 10 or more caribou. Sections of road will be evacuated whenever an attempted crossing by a large number of caribou appears to be imminent[3]. In the 2018 draft EIS, the criterion is 100 caribou with no rationale or evidence to why this mitigation is less restrictive than that set out in the NPR-A. The experience in Prudhoe Bay is that high rates of traffic (>15 vehicles/hour) reduced crossing success for caribou but BLM (2018b) did not then propose traffic frequency based on caribou responses as a threshold for traffic management.

BLM has considerable experience in reviewing oil developments west of Prudhoe Bay as they spread into the NPR-A (BLM 2004, 2014, 2015). The expansion of oil development into the National Petroleum Reserve-Alaska led BLM to collaboratively develop in 1998 and then 2004, an Integrated Action Plan to determine how BLM will manage oil development in the NPR-A. BLM finalized the current IAP in 2013 and the Record of Decision for the NPR-A IAP/EIS incorporated 217 best management practices. However, in 2018, BLM has announced a review of the Integrated Action Plan[4].

Waivers

BLM can authorize exceptions, changes or waivers for stipulations and operating conditions. The conditions for waivers can be spelt out in BLM's EISs and Reasons for Decision reports. For example the BLM (2018a) Record of Decision (ROD) for Moose's Tooth included the rationale for deviations to one stipulation included in the 2008 Northeast NPR-A IAP/EIS ROD and one best management practice (BMP) from the 2013 NPR-A IAP/EIS ROD (Lease Stipulation 41 (now Lease Stipulation E-2): to allow oil infrastructure within 500 feet of water bodies; and Best Management Practice E-7(c): to allow less than a 500 foot separation distance between pipelines and roads).

The 2018 draft EIS has several instances where the BLM Authorizing Officer as specified in the stipulations and operating conditions, can vary existing stipulations by removing or adding conditions. The criteria for how the Authorizing Officer's decisions or reference to examples of waivers are not provided. In this context, the US General Accounting Office has questioned the consistency and rationale of how BLM waives lease stipulations and operating conditions and concluded that "*without sufficiently detailed documentation of inspections and effective use of data from inspections, BLM is unable to fully assess the effectiveness of its best management practices policy to mitigate environmental impacts*". USGAO (2017).

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[3] https://eplanning.blm.gov/epl-front-office/projects/nepa/65817/127982/155729/Appendix_J-_2013_NPR-A_Integrated_Activity_Plan_Record_of_Decision_Best_Management_Practices_and_State_of_Alaska_Regulations_Protecting_Environmental_Quality.pdf

[4] https://eplanning.blm.gov/epl-front-office/eplanning/planAndProjectSite.do?methodName=dispatchToPatternPage&currentPageId=174096

Administrative changes

Mitigation has a long history in the US as it dates back to the 1930s (Clement et al. 2014). During that time, mitigation has developed through successive administrations and as our collective understanding of ecology and wildlife management has improved. The US Department of the Interior, through policy changes, consecutive impact assessments and integrated action plans, can rescind or strengthen mitigation through changes to stipulations and operating conditions.

An example of changing mitigation is Teshekpuk Lake calving and insect relief habitat (Clement et al. 2013). The area was classified as a wildlife reserve and unavailable for leasing in 1998 (Appendix D) but in a revised environmental impact statement in 2004, most of the reserve was offered for leasing when the 2004 ROD for the Northwest NP-A, identified as the Preferred Alternative was for all BLM-administered lands to be made available for oil and gas leasing. In 2006, public concerns and a court challenge from conservation organizations led to the leasing of the reserve being deferred. By 2008, BLM revised the Integrated Activity Plan/Environmental Impact Statement which spelt out the importance of the Teshekpuk Lake area for caribou and BLM would not open most of Teshekpuk Lake and its islands to oil and gas leasing. Then, BLM in December 2018, is now undertaking a new Integrated Activity Plan and Environmental Impact Statement (IAP/EIS) for the NPR-A.

Another example, of changes in mitigation is that in July 2018, the Deputy Secretary of The Interior's Order No. 3360[5] rescinded sections of the 2016 Mitigation Handbook that deal with compensatory mitigation and required a review of the 2016 draft Regional Mitigation Strategy for the NPR-A and Technical Report. The Regional Mitigation Strategy has set out landscape scale mitigation for iterative oilfield developments in NPR-A including compensatory mitigation for residual effects.

Mitigation effectiveness

The draft 2018 EIS has little to offer on whether and to what extent mitigation actions are effective. BLM is aware of the importance of effectiveness as for example, BLM (2016) in the Regional Mitigation Strategy for NPR-A recognized the need to determine the effectiveness of mitigation especially determining residual effects. Specific studies to determine mitigation effectiveness are few. The question of what was the minimal height for the pipeline for Prudhoe Bay was a question in the 1970s and when oil development expanded west to the Alpine field and the stipulated height was increased to 2.1 m (BLM 2005) as concerns were that snow drifts could reduce the effective height under the pipeline. BLM requested that pipeline height and caribou crossings be reviewed and Lawhead et al. (2006) summarized the design and results for nine pipeline and caribou crossing studies. The recommendations were a 1.5 m height and to be as effective as possible, elevated pipelines should be at least 122-152 m from roads which also eliminates snow drifts under pipelines next to roads (Lawhead et al. 2006).

Pipeline height and separation from parallel roads has become a standardized stipulation in, for example, ROP 23. But the draft 2018 EIS does not acknowledge how the mitigation effectiveness is incompletely assessed as it is based on observational studies on the CAH and not, for example, for very large caribou groups. Pritchard et al. (2017a and b) monitoring reports for Alpine and Kuparuk fields map individual GPS collared caribou crossing pipelines but

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[5] https://www.eenews.net/assets/2018/01/05/document_gw_04.pdf

the rate and direction of approaches, crossings and return crossings are not analysed especially for large groups during mosquito harassment.

The draft 2018 EIS does not have evidence for the effectiveness of reduced vehicle speed relative to other vehicle management techniques such as vehicle convoys. Convoys could increase the duration and predictability of gaps especially for large groups to cross roads. When oil companies investigated mitigation effectiveness for the Meltwater project in 2001, they used an interagency panel to review monitoring design to determine whether traffic convoying and pipeline height were effective mitigation (Lawhead et al. 2004). However, for unexpected reasons, low levels of traffic were too low and the study does not appear to have been repeated.

A complication and a gap for describing the effectiveness of mitigation for roads is if the use of the roads changes. BLM (2018b:3-22) has acknowledged that use of roads for hunting "*could further displace caribou and other mammals away from gravel roads, potentially delaying habituation*". Hunting in the vicinity of the roads may sensitize the caribou and increase responsiveness (Russell and Martell 1985, Johnson and Russell 2014, Plante et al. 2018). Further monitoring and mitigation such as "*letting the leaders pass*" policies (Padilla 2010) may be necessary. In Prudhoe Bay, the CAH was not hunted but west of Prudhoe Bay, harvesters reported existing mitigation especially for aircraft flight ceilings was not effective as caribou were displaced which affected harvesting (SRB&A 2017). However, the consequence of the ineffectiveness of aircraft mitigation was that the Nuiqsut residents adapted by hunting caribou along gravel roads within the oilfields (BLM 2014).

5.3 Monitoring

The 2018 draft EIS has few references to or requirements for monitoring relative to caribou. This lack of this information on monitoring hinders our assessment for the 1002 oil and gas leasing. Monitoring is needed (1) to identify the thresholds used to trigger mitigation; (2) to describe the effectiveness of mitigation (3) to describe any need to adjust mitigation (adaptive management) and (4) to measure residual effects. The lack of an overall approach to monitoring is concerning as elsewhere BLM has designed monitoring protocols for a rapidly developing oilfield (Boone et al. 2011).

A specific example which could improve the Oil and Gas leasing program for the 1002 lands is that the Time Limited stipulation (draft 2018 EIS Table 2.2) leaves monitoring details to future lessee plans. The monitoring will be necessary to measure if and when caribou numbers and local distribution relative to roads will trigger specific mitigations. Although it is individual lessees who will produce the individual project proposals, BLM (2018b) to increase predictability and standardization of methods could develop a framework to guide the individual lessee plans. Monitoring methods to describe how caribou numbers to trigger traffic restrictions is not included in the draft 2018 EIS which hinders reviewing the thresholds. For CAH, (for example Smith et al. 1994), the reliance has been on truck-based surveys but cameras, drones and Height-of-land surveys have potential as does real-time use of satellite and GPS collars. Monitoring to implement mitigation has to be scaled to the speed with which caribou can move such as the relatively high speeds of 15 – 20 km/day during mosquito harassment.

Before and after disturbance is useful in measuring effect size and CAH monitoring did include some pre-construction years relative to observations during construction and operation (Dau and Cameron 1986, Cameron et al. 1992). More recently, Lawhead et al. (2002) compared 4-year pre and post Tarn Road construction. Duration (number of years should be scaled to annual variability: Smith et al. (1992) report relatively standardized observations during truck surveys over a 13-year period while annual aerial surveys of calving and post-calving distribution have run from 1993 and 1995-2013 (Lawhead et al. 2014). Since 2000, industry has reported on annual plant biomass, snow cover, and snow melt for the areas where caribou distribution is seasonally mapped (Lawhead et al. 2015, Pritchard et al. 2017a and b). Accommodating the scale of the annual variability is essential to measuring any effects of oil development for the PCH. Matching effect size and sampling design to ensure sufficient statistical power to detect or reject the effect size (of the response): Cameron et al. (1992) reported that July and October body weights, over-summer weight gain, the incidence of two successive pregnancies, and perinatal calf survival tended to be lower for females to the west (exposed to oilfields) than for those to the east of Prudhoe Bay (relatively unexposed) but individual differences were not significant at the 95% confidence level.

The question of residual effects is a limitation for reviewing the draft 2018 EIS and monitoring is essential to measure them. To an extent, for CAH and the residual effects of Prudhoe and the oilfields to the west residual effects including displacement of calving cows and newborn calves and overall seasonal distribution relative to the oilfields is measured through long-term aerial surveys (summarised in Pritchard et al. 2017a and b, Lawhead et al. 2013, Noel et al. 2002). However, the monitoring methods and survey areas differ between the companies involved. Other monitoring gaps include inadequate analyses of monitoring movements (collars) and not using long-term local knowledge from oilfield workers (cf Backensto 2010).

Monitoring activities on the oilfield are not included in the draft 2018 EIS (such as traffic frequency). Although earlier studies refer to the importance of traffic frequency in determining caribou responses to roads (for example Shideler et al. 1986), annual trends in the daily and seasonal frequency of traffic appear unavailable for Prudhoe Bay oilfield although the most recent proposals west of Prudhoe Bay include traffic frequencies. For proposed new multi-well drill pad and facilities such as for Greater Mooses Tooth GMT2 (BLM 2014: Appendix B), during the first year of construction the projected rate is 256 vehicles/day (annual total 93,600 vehicle passages of which 84% is gravel hauls) dropping to 25 vehicles/day (6000/years) after the initial construction period.

Monitoring is an essential part of adaptive management which is about making mitigation more effective and reduced or intensified as necessary. The draft 2018 EIS does not refer to adaptive management except in the context of reclamation. Collaboration is useful for to implement adaptive mitigation and is helped through the collective experience. Affolder et al. (2011) review the performance and structure of oversight bodies established for the monitoring and mitigation of mines in the NWT. BLM (2013) already has experience with advisory bodies although not explicitly for adaptive mitigation. For NPR-A, BLM (2013) reaffirmed the NPR-A Subsistence Advisory Panel to advise BLM on mitigating impacts from development and also established the NPR-A Working Group (local governments, Alaska Native Tribes, and Alaska Native Corporation) to advise on land management decisions, local concerns, and recommendations of local residents.

5.3.1 Monitoring and adaptive capacity

At the scale of cumulative effects, monitoring has to integrate herd and landscape monitoring to maintain and build adaptive capacity. The PCH is exceptional among North American caribou herds as it has a formal Porcupine Caribou Technical Committee which for 40 years has depended on government agency staff in Alaska and Canada to annually monitor adult and calf survival and parturition rates (Section A Sensitivity; Appendix A). The Technical Committee is ideally placed to support integrating industrial project- specific monitoring into an effective, long term program for the herd. Community-based ecological knowledge is annually reported through the work of the Arctic Borderlands Ecological Knowledge Society (https://www.arcticborderlands.org/). The annual monitoring updates are coordinated by the Porcupine Caribou Management Board (http://www.pcmb.ca/).

The frequency and duration of the PCH herd monitoring is similar to the CAH although indicators differ for the timing of calf survival and recruitment (Appendix A). During the early decades of oilfield construction on the CAH seasonal ranges, ADF&G monitored caribou distribution and behavioral responses. By 2002, ADF&G had shifted to monitoring vital rates but still with attention to the effects of Prudhoe Bay. Parturition rates are reported for study areas east and west of Prudhoe Bay (Figure 43): the average for the west is 82.5 +/- 2.61% and the east is 87.35 +/- 2.64% (from Lenart 2015, 2018).

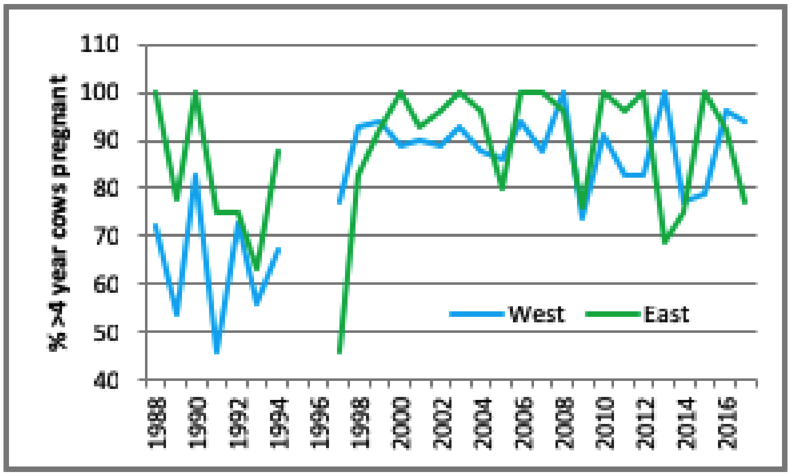

Figure 43. Comparison of parturition rates for radio-collared cows on the Central Arctic herd’s calving ground west of Prudhoe Bay (with oilfield activities) and east (very little oilfield activity), 1988-2017 (from Lenart 2018).

5.4 Summary: lessons from the oil fields and the Central Arctic Herd

Monitoring for the CAH and oilfield development has not always increased the clarity or strength of conclusions stated about the effects of the oil developments and contradictions remain (for example Cronin 2017). However, a retroactive review of the CAH and oilfield monitoring and mitigation and then with further testing of mitigation and monitoring would contribute to improved monitoring and mitigation for the PCH and proposed oilfield development. In contrast, differences between CAH and PCH limit how any lessons on the effects from the development of Prudhoe Bay and associated oil fields on the CAH apply to the PCH. The draft 2018 EIS recognized this when they wrote (BLM 2018b p, 3-116) states:

> “*The patterns of CAH demography following development should be applied to the PCH with caution for several reasons: movements and demography of the PCH are different from the CAH, concentrated calving density of the PCH is much higher than the CAH, and areas next to the PCH calving grounds contain less high-quality forage and higher predator densities and exhibit more topographic relief than do the current PCH calving grounds (Clough et al. 1987; Griffith et al. 2002).*”

To these points, we add further points. Firstly, the CAH, especially cows and calves, altered their behavior and distribution as risk aversive responses to the oilfields and those responses have persisted for over 40 years. Current monitoring describes cows and newborn calves continuing to avoid roads and shifted calving distribution based on aerial surveys and location of collared caribou which does raise questions about the effectiveness of mitigation. Although as the draft EIS (BLM 208b) notes the raised pipeline height contributed to insect-relief movements crossing the pipeline and roads (when traffic frequency is <15 vehicles/hour), lack of analyses of the existing movement data and traffic frequency hinders understanding the likelihood of delays and deflections (BLM 2018:3-115). Secondly, is that the response distances (avoidance of roads) is less than half that reported elsewhere. There is no hunting and predation risk in the oilfields is low which modifies the caribou's perception of landscape risk.

Thirdly, the CAH was initially resilient to the effects of oilfield development on its calving and post-calving ranges from the 1970s to about 2010 (when CAH peaked in size). The resilience was partly because the caribou cows 'had the space' to progressively shift their calving distribution to reduce exposure to the oilfields. However, caribou also were trading-off their need to reach coastal insect relief habitat relative to the costs of disturbance by some of them moving through Prudhoe Bay oilfield. Fourthly, ADF&G's herd management contributed to the CAH resilience: The management goals for the CAH since 1992 are to minimize the effects of the oilfield development by working to reduce barriers to free movement, restricting harvest in Prudhoe Bay and along TAPS, and restricting the harvest to offset cumulative effects. Fifthly, the geography of the two herd's post-calving ranges differs and this shows for example in mosquito activity as the CAH has 70% area of lower mosquito activity compared to 20% for the PCH (Bali 2016). The different landscapes suggest that PCH is more vulnerability to mosquito harassment which is a concern to avoid interrupting the PCH insect relief movements.

We have already commented on the absence of a recent cumulative effects analysis for the oilfield effects on the CAH (subsequent to NRC 2003). We note the absence of detailed demographic analyses for the CAH and the neighboring Teshekpuk Lake herd, also was at low numbers similar to the CAH in the 1970s (Figure 45) despite the high standard and availability of herd monitoring data. The increase in CAH abundance during Prudhoe Bay development (Figure 45) is not evidence for the extent of oilfield effects and in fact raises more questions than it answers for several reasons.

Only a proportion of the CAH cows are seasonally exposed to oilfield construction and operation as use of the calving and post-calving east of Prudhoe Bay oilfield has persisted (Cameron et al. 1995, Wolfe 2000, Arthur and Del Vecchio 2009). A second reason is that the proportion that the area of oilfield relative to CAH habitat requirements is unanalysed and whether the proportion of oilfield area is approaching any limits for caribou is unknown relative to changing caribou requirements with abundance. In other words, we lack information to hypothesize what a herd response curve to oilfield development for the PCH could look like and how it would compare to the CAH. A third reason is that the harvest management goals should have resulted in half the harvest in the CAH compared to the Teshekpuk Lake herd. Questions remain about why CAH did not increase at a higher rate given the lower harvest.

Figure 44 reveals limitations in the information available to track the overall exposure of the CAH to the development of the Prudhoe Bay oilfield. The information available for this report is limited to oil production and the footprint of structures as indexed by area of gravel (Figure 45). Construction of drill pads and roads had started by 1968 at Prudhoe Bay with commercial oil production beginning in 1977 and peaking in 1989. By peak oil production, the rate of gravel-based structures and road length had reached a plateau (NRC 2003, Raynolds et al. 2014). However, relating oil production to the number and spacing of drills is limited as oilfield technology changed. For example, 1970 to 2018, there was a 5-fold reduction in drill pad area for new pads, a 7 fold increase in drilling radius, and a 40-fold increase in the drilling area accessible from the pad through changes in extended reach drilling (NRC 2003:Appendix E; Conoco Phillips 2018).

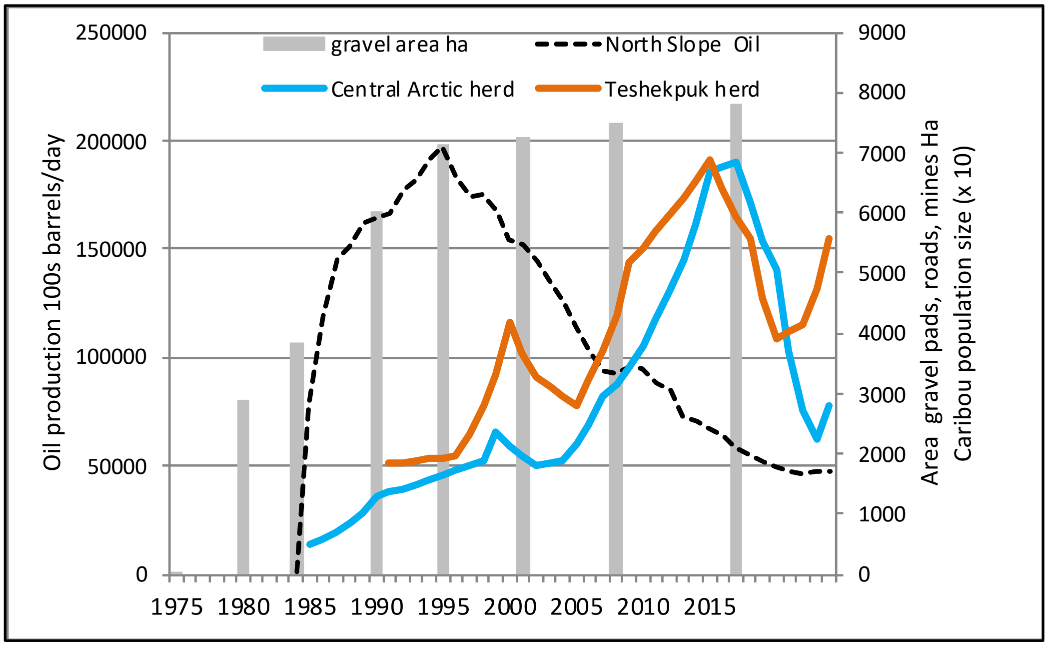

Figure 44. Central Arctic and Teshekpuk herd size 1981-2017 numbers and North Slope oil production, and total hectares of gravel pads, roads and mines

Our analyses of calving distribution and climate suggest that spring and early summer forage conditions appear to be much more critical to the PCH compared to the CAH, where fall conditions the previous year correlate best with early calf survival. Thus, the documented displacement of calving in the CAH, if experienced with development in the PCH, would have a greater impact on calf survival, than occurred in the CAH.

5.5 Adaptive Capacity Discussion

The draft 2018 EIS is the first step in leasing for an oilfield on the calving, post-calving and summer ranges of the Porcupine herd. The conservation goals for ANWR require confidence that a high standard of effective mitigation and monitoring will persist over the 50 -85 years of an oilfield's lifespan. However, BLM's (2018b) proposed mitigation, monitoring and adaptive management does not have enough information to be confident that there is no short or long term risk to the Porcupine caribou herd, harvest availability or its habitat.

The stipulations and required operating conditions are inconsistent in their level of detail and lack contingencies which causes uncertainties in how risk will be mitigated. It is a constraint reviewing mitigation that many details are in the future as the current mitigation will require individual lessee plans such as traffic management. BLM (2018b) could have provided standards and criteria to be provided in those plans and to which the approval mechanism could be expected to adhere. Other uncertainties are the lack of evidence about mitigation effectiveness and almost no information on monitoring and adaptive management. It is not only gaps in the draft 2018 EIS but despite the opportunities in existing oilfields, much remains uncertain about mitigation effectiveness. For example, whether, traffic speed or reduced frequency create more predictable chances for caribou to cross roads.

In the absence of adaptive management, the stipulations and required operating procedures are not flexible to either changes in industrial practices or to caribou behavior and distribution. Based on what we know about caribou behavior, we argue that their initial exposure to oilfield construction should be predictable disturbances such as daily road closures or very low thresholds (numbers of caribou) for road closures. This would afford a greater likelihood of caribou learning to tolerate disturbance and monitoring their response distances would be feedback on whether the mitigation was effective or required adjustment. We would also argue that permitting hunting along oilfield corridors would exacerbate disturbance to caribou and greatly complicate the adaptive management process.

While the draft 2018 EIS has contingency planning for oil and contaminant spills, it does not include contingencies for shifts in caribou distribution or unusual movements. For example, Stipulations 7 and 8 for calving and post-calving, respectively, are area-based (areas with a higher-than-average density of cows during more than 40 percent of the years surveyed). It is uncertain what the contingency mitigation is if caribou move for calving or post-calving into areas with less protection.

The lessons to be learnt from the effects and mitigation on the Central Arctic Herd's ranges are limited which also adds to uncertainties to mitigation for the Porcupine herd. Geography and herd management played a role in why the CAH did not decline during oilfield construction and operation. Only part of the herd's calving and post-calving was exposed to Prudhoe Bay (cows that calved east of Prudhoe Bay were not exposed) and the width of the coastal plain was extensive enough to accommodate displaced calving from west of Prudhoe Bay. Herd management included a low rate of harvesting. A concern is that despite mitigations, local and calving displacement is still measurable which raises questions about mitigation effectiveness and caribou behavior.

Across 1002 landscape, caribou exposure, mitigation intensity (based on stipulations) and oilfield development potential show east-west trends in likelihood of intensity. BLM (2018b) has proposed four alternatives each with a different combination of stipulations which have a west-east spatial trend in the degree of protection. In the absence of any analyses in the draft 2018 EIS to compare the effect of the stipulations as proposed in the alternatives, we estimated the risk to the Porcupine Caribou Herd. We applied a similar modelling approach that we used to estimate potential effects of full development. With a high starting herd size of 218,000 we found there was a small probability from a 4% -12% (for Alternative D2 to Alternative B) that the PCH numbers after 10 years would fall below the 115,000 threshold and enter the yellow warning harvest zone, compared to a 3% probability under current no-development conditions.

Adaptive Capacity as a component of a vulnerability analysis for the Porcupine caribou herd is about the consequences of how successful landscape management is to enable unhindered movement of caribou. Unhindered movement is the key to how caribou adapt to annual variations in forage availability and insect harassment. Limitations in adaptive management (mitigation and monitoring) may reduce the caribou's selection of habitats within 1002 lands and reduce calf survival.

6. Vulnerability

PCH ecology contributes to the herd's vulnerability since productivity is relatively low compared to other herds, suggesting that the herd is vulnerable to even a small decrease in adult survival. Productivity (especially early calf survival) is linked to spring conditions and thus the need to avoid displacing calving and post-calving from 1002. Climate trends include warmer springs which may increase the PCH's use of 1002 going forward.

Any assessment of residual impacts and vulnerability is subject to a high level of uncertainty. Uncertainties start with the exposure of PCH to potential oilfield development. The purpose of the draft 2018 EIS is to decide on a leasing program, so the spatial layout and configuration of roads, pipelines and drill pads, etc. is unknown and will eventually depends on it is one large or many small oil fields.

The PCH's use of 1002 for calving is annually variable and is relatively unpredictable as it is influenced by May 15 snow depth. Warmer temperatures and low wind speeds determine the level of mosquito harassment which in turns governs the formation of large post-calving aggregations that can exceed 100,000 caribou. These huge aggregations contribute to uncertainties of exposure and potential effects as we have no experience how such aggregations will respond to oilfield development.

Additionally, uncertainties arise from the lack of evidence for the effectiveness of mitigation. We simply do not know whether, for example, continuing drilling while shutting down construction (Time Limited stipulation) is effective mitigation. While there is some evidence for the effectiveness of pipeline height and separating roads from pipelines, effectiveness of other mitigations is not supported by evidence. West of 1002, we have seen a waiving of initial lease stipulations in the absence of a rigorous adaptive management framework to assess the impact of changes on BLM controlled land and thus have concerns whether proposed lease stipulations in 1002 will exist in the long-term. A key uncertainty for potential effects is how hunting with access provided by 1002 development will exacerbate the caribou's behavioral response to human activity and increase avoidance distances. The EIS makes several references to the residents of Kaktovik being able to reach hunting areas in the future by driving on roads (EIS p. 3-172). Studies elsewhere documented a much wider Zone of Influence around human activity when roads are associated with hunting (Plante 2018).

The PCH is vulnerable to the cumulative impacts of oilfield development along the coastal plain which could mean reduced sustainability of the harvest. The draft 2018 EIS for leasing the 1002 lands did not quantify cumulative impacts for the PCH and so we undertook an analysis of movements and a risk analysis approach to cumulative effects. Our measure of vulnerability is the likelihood of cumulative effects increasing the percent probability of future declines and shifting the PCH population size downward into more restrictive harvest management zones based on an existing Harvest Management Plan (PCMP 2010).

From our modelling, the PCH is more vulnerable to the cumulative effects of 1002 development when population size is low (100,000 in our example) and when climate conditions are poor. For the four proposed development alternatives, under average climate conditions, the PCH is 11–21% (Alt D2 – Alt B) more vulnerable to a population decline when at a low population size and 3–14% (Alt D2 – Alt B) when at a population high.

We also assessed vulnerability in respect to the probability that the PCH could sustain an unrestricted subsistence harvest. Using the thresholds established in the Harvest Management

Plan (PCMB 2010), we determined the percent probability of the PCH dropping into Orange and Red Zones (where legislated harvest restrictions are imposed) is increased by 10% -18% (Alt D2-Alt B) compared to baseline conditions.

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We thank Beth Lenart, Lincoln Parrett and Dick Shideler (ADF&G) for their prompt and thoughtful responses to our questions.

Such is the nature of science that we build on the efforts of those who have preceded us. For this report, we acknowledge with warmth, the ecological insights and integrity of Drs. Robert White, Brad Griffith and the late Ray Cameron.

We dedicate this report to Dr. Archana Bali, who left an indelible mark on all of us in the short time she had to contribute to our knowledge of caribou ecology.

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Glossary

Activity budget	The partitioning of daily activity into foraging, bedding, and moving needed to fulfil daily requirements for maintenance, growth and reproduction
ADF&G	Alaska Department of Fish and Game
Adaptive capacity	How caribou can cope with and persist under new conditions including a warmer climate and, for this report, oil and gas development
Adaptive management	Management practices based on clearly identified outcomes and monitoring to determine whether management actions are meeting desired outcomes; and, if not, facilitating management changes that will best ensure that outcomes are met or re-evaluated[1].
Alternative	The different means by which objectives or goals can be attained. One of several policies, plans, or projects proposed for decision-making[1].
ANILCA	Alaska National Interest Lands Conservation Act
ANWR	Arctic National Wildlife Refuge
Authorized Officer (BLM)	Designated BLM personnel responsible for a certain area of a project; for the Leasing EIS, generally this would be the BLM State Director[1]
BLM	Bureau of Land Management (US Department of the Interior)
Baseline	For this report, we use baseline to be current development footprint
CAH	Central Arctic Herd
CARMA Network	Circum-Arctic Rangifer Monitoring and Assessment Network
CCE	Caribou Cumulative Effects (model)
CPF	Central Processing Facility
Cumulative effects/impacts	The impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions[1].
Compensatory mitigation	Actions taken to compensate for (or offset) some of the residual impacts of an authorized land-use; it may include monetary payments made towards accomplishing the offsetting actions or projects
Contingency	A provision for an unforeseen event or circumstance.
CSU	Controlled surface use
Disturbance	Human activities that result in a caribou behavioral or physiological response
Effect/impact	Effect and impact are synonymous; environmental change resulting from a proposed action[1]

EIS	Environmental Impact Assessment
Exposure	The nature and degree to which caribou are faced with climate and industrial activities
Exponential	exponential growth rate r or e^r is the factor by which a population increases
GDD	(plant) growing degree days (cumulative above 0 °C)
Habituation	A learned response by an individual to a repeated stimulus, for which identification requires long-term sequential measures of an individual's responses
IPCB	International Porcupine Caribou Board
Mitigation	Avoiding the impact altogether by not taking a certain action or parts of an action; minimizing impacts by limiting the degree or magnitude of the action and its implementation; rectifying the impact by repairing, rehabilitating, or restoring the affected environment; reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and compensating for the impact by replacing or providing substitute resources or environments[1]
Monte Carlo	Statistical procedure using repeated random sampling to obtain numerical results
NDVI	Normalized Difference Vegetation Index
Nearest neighbor	Statistical technique to analyze distances between each point and the closest point to it, and then compares these to expected values for a random sample of points.
NPR-A	National Petroleum Reserve Alaska
NSO	No-Surface-Occupancy
NU	Nunavut, Canada
NWT	Northwest Territories, Canada
Oestrid	Parasitic nose-bot or warble fly (insect family Oestridae)
Offsetting	Intentional management steps to compensate for ecological losses in response to human development which are residual after avoidance, minimization and remedial mitigation
Parturition	Giving birth and measured by the number of females about to give birth or with newborn calves.
PCH	Porcupine Caribou herd
PCMB	Porcupine Caribou Management Board
Penalty	Change in daily activity budget when in a Zone of Influence

Post-calving aggregation	Grouping of caribou coming together usually in response to mosquito harassment indexed by low wind speed and warmer temperatures. The groups maybe 10s of 1000s of caribou.
Polygon	Straight-line enclosing area used by caribou based on point locations from satellite or GPS collars
Productivity	The outcome of pregnancy and calf survival
ROS	Rain-on-Snow, when temperatures allow precipitation to be rain or a mix of rain and snow which can lead to icing conditions as temperatures drop
Recruitment	Number of 1-year-old caribou (usually measured in late winter composition counts so they may be 9- to 10-month-old calves) and index the potential rate of increase.
Resilience	the ability of the caribou social-ecological system to absorb changes while maintaining viability
Residual impacts	Any adverse reasonably foreseeable effects that remain after the application of the first four steps in the mitigation hierarchy; also referred to as residual impacts[1]
Sensitivity	The degree to which a caribou is affected, either adversely or beneficially, by climate or human-related stimuli
Stipulation	A requirement or condition placed by the Bureau of Land Management on the leaseholder for operations the leaseholder might carry out within that lease[2].
ROP	Required Operating Procedure
Telemetry	Data remotely transmitted from a device on a collar fitted to an individual caribou and received by satellite.
TL	Time limited stipulation; potential lease area that will have time limited conditions on development
Tolerance	the intensity of a disturbance that an individual is able to tolerate before responding in a measurable (i.e., behavioral) way (Nisbet 2000 in Bejeder et al. 2009
1002 (lands)	Section 1002 of ANILCA identified a need to assess the oil and gas potential and environmental values in a spatially defined regions of the Coastal Plain in ANWR (known as the 1002 land)
Uncertainty	Incomplete information which includes natural variation, observation error; model error and implementation error (Harwood and Stokes 2003)
Vital rates	Vital rates (also called demographic rates) are the mechanisms for why populations change in size: birth rate; death rate (mortality) and how many disperse from their birth population

Vulnerability	The likelihood to be adversely affected.
ZOI	The zone of influence around infrastructure that caribou are either disturbed or displaced

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[1] Argonne National Laboratory. 2016. Draft Technical Companion to the Regional Mitigation Strategy for the Northeastern National Petroleum Reserve in Alaska. Prepared for U.S. Department of the Interior Bureau of Land Management, Technical Report Number ANL/EVS-16/5 BLM/AK/PL-16/009+1600+9301

[1] BLM (2018b)

Appendix A. Vital Rates

Data for parturition, June calf survival, June calves/100cows and spring calves/100 cows from Lenart (2015). Adults cow survival from: 1983-1992 (Fancy et al 1994); 2000-2012 (Hegel unpublished data); 2014-2017 Caikowski (unpublished data).

Table 14. Vital rates of the Porcupine Caribou Herd (1983-2017).

Year	Parturition	June calf survival	June calves: 100 cows	Spring calves: 100 cows	Annual Adult Cow Survival Rate
1983					90
1984					92
1985					78
1986					89
1987	78	71	55		75
1988	84	65	55		93
1989	78	74	58	43	78
1990	82	90	74		83
1991	74	82	61	22	84
1992	86	57	49	30	82
1993	81	56	45	32	
1994	91	77	70	40	
1995	69	85	59	46	
1996	89	81	72	38	
1997	75	77	58	39	
1998	83	82	68	28	
1999	84	83	70	56	
2000	73	61	44	27	85
2001	84	61	51	31	90
2002	87	65	56	38	88
2003	87	79	69	33	88
2004	82	57		24	75
2005	64	77	49		81
2006	79	73	58	39	86
2007	88	83	73		90
008	79	73	59		84
2009	77	57	44		89
2010	85	76	65	20	91
2011	86	48	41		88
2012					88
2013	86				
2014			49		86
2015					80
2016					89
2017					94
average	81	72	58	34	86

All CAH data from Lenart 2015, except June calf survival determined as:

$$Early\ calf\ survival = 100 - \frac{(parurition - june\ calves\!: 100\ cows)}{parturition/100}$$

Table 15. Vital rates of the Central Arctic Herd (1994-2015).

Year	Parturition	June calf survival	June calves: 100 cows	Annual Adult Cow Survival Rate
1994	73	88	64	
1995	56	100*	63	
1996			69	
1997	61	100*	75	
1998	88	90	79	96
1999	93	86	80	96
2000	96	78	75	87
2001	91	87	79	82
2002	92	88	81	94
2003	96	80	77	86
2004	91	90	82	91
2005	83	86	71	80
2006	96	93	89	90
2007	93	87	81	93
2008	98	93	91	89
2009	75	69	52	88
2010	97	88	85	86
2011	91	85	77	91
2012	92	75	69	83
2013	80	70	56	67
2014	76	86	65	77
2015		0		80
Average	86	78	74	86

Appendix B. Linking climate to vital rates

To adequately assess impacts of development and climate change, a better understanding how climate indicators are related to annual variability in vital rates is needed. Similar analysis has been conducted on several North American herds (Russell and Gunn, in prep.)

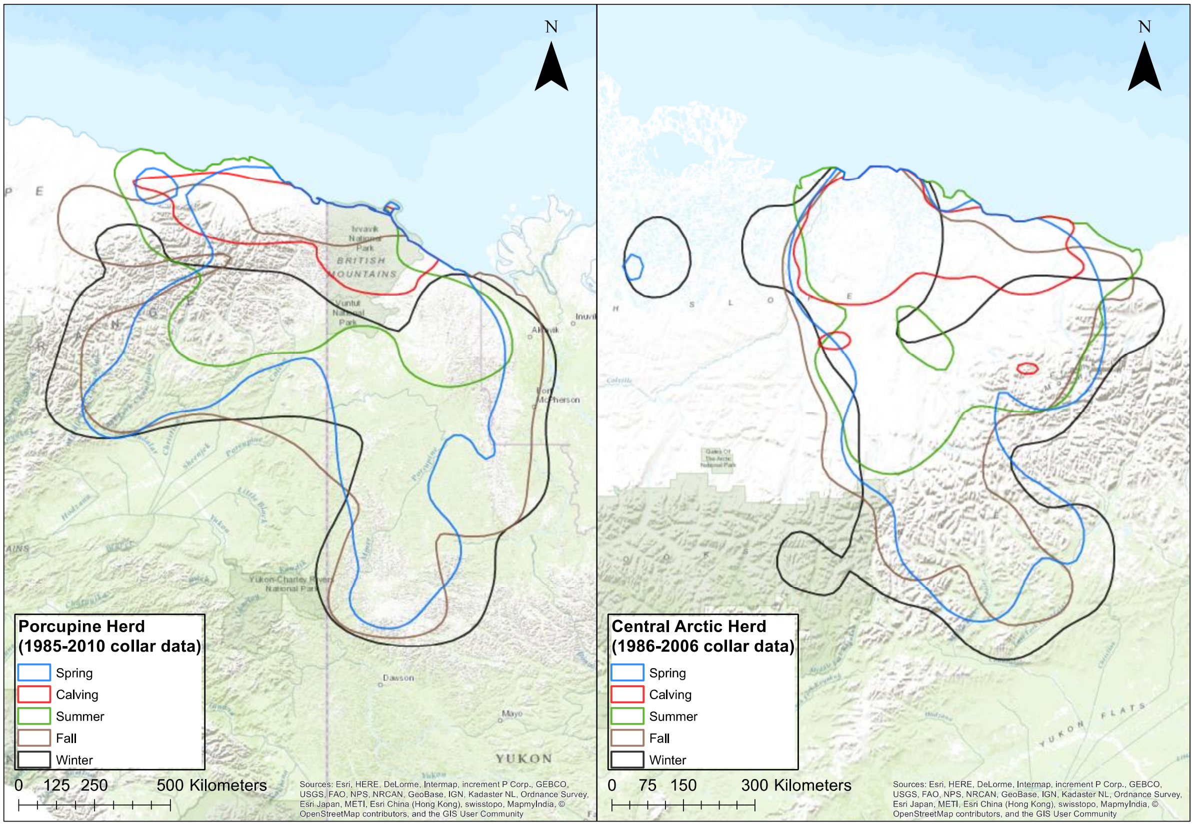
Methods

MERRA variables

We used NASA's Modern Era Retrospective Analysis for Research and Applications (MERRA) dataset (http:// gmao.gsfc.nasa.gov/research/merra/). NASA's Global Modeling and Assimilation Office's MERRA project was undertaken with the objectives of placing the observations from NASA's Earth Observing System satellites in a climate context and improving upon earlier analyses. The resolution of the MERRA grid is 1/2 degrees latitude by 2/3 degrees longitude and data are provided daily for most variables. MERRA was chosen over other datasets because it covers the modern remotely sensed data (from 1979 through the present), attempts to address problems with previous reanalysis products, and is focused on the hydrological cycle. Russell et al. (2013) describe MERRA's climate variables and how caribou-specific derived climate variables were developed from the downloaded MERRA variables.

For this analysis, we chose a number of MERRA and derived climate indicators (

Table **16**) that represented all seasonal ranges (summer, fall, winter spring and calving) and which are based on the satellite collars (Figure 45).



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 45. Seasonal ranges of the PCH and CAH used to download MERRA climate data. Methodology in developing the polygons explained in Russell et al (2013)

To compare climate conditions by calving area for the PCH, we downloaded climate in 1002 boundary and calving in typical distribution outside of 1002 (Figure 46). The resulting differences in calving climate are reported in the Exposure Section.

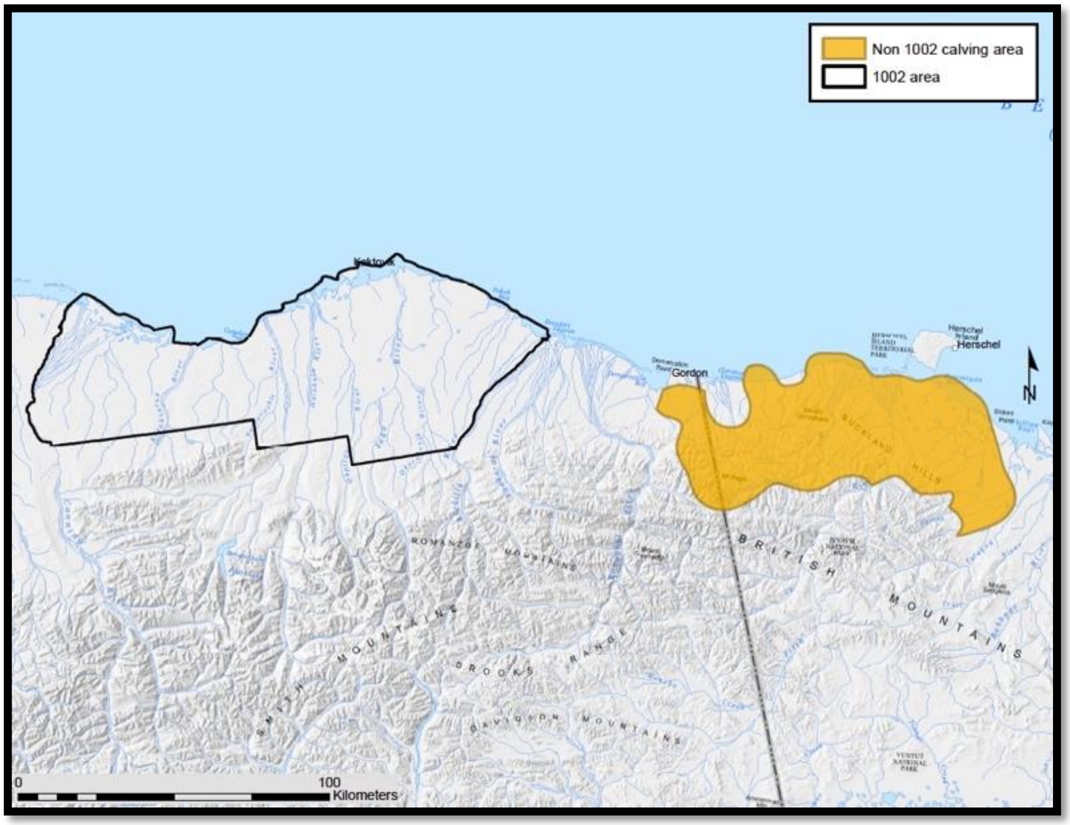


Figure 46. The 1002 area and the “non-1002 calving area” (based on the 2007 calving distribution; Mike Suitor, unpublished data). Polygons used to create area-specific climate data for the two distributions.

Table 16. Climate variables from CARMA's climate database used in the analysis.

Indicator	MERRA data	Acronym	Seasonal Range
March Snow Depth	Snow depth March 31	SNOWmr	Winter
Annual Rain On Snow	Cumulative rain-on-snow September to May 31	ROS	Winter
Annual Rain On Snow days	Cumulative rain-on-snow days September to May 31	ROSdays	Winter
Annual Freezing Rain	Cumulative freezing rain Septmber to May 31	FZRN	Winter
Annual Freezing Rain days	Cumulative freezing rain days	FZRNdays	Winter
Annual Freeze Thaw days	Cumulative days with freeze/thaw events January 1 to May 31	FZTWdays	Winter
May Snow Depth	Snow Depth 15 May	SNOWmy	Spring
June Snow Depth	Snow Depth 10 June	SNOWjn	Spring
May rainfall	Sum of daily May values	PPTmy	Calving
Early June Cumulative growing degree days	Cumulative growing degree-days June 10	GDD10jn	Calving
Late June Cumulative growing degree days	Cumulative growing degree-days June 20	GDD20jn	Summer
July Cumulative growing degree days	Cumulative growing degree-days July 20	GDDjy	Summer
Summer Oestrid Index	Cumulative oestrid index to Aug 5	OESag	Summer
July monthly temperature	Average daily mean values	TMPjy	Summer
July rainfall	Sum of daily July values	PPTjy	Summer
July Drought Index	Average daily drought index	DRTjy	Summer
Mushroom Index	Annual index calculated from Kreb's et al (2008)	MUSH	Fall
Late Oestid index	Cumulative Oestrid Index from 15 September to 31 October	SNOWoc	Fall
Fall Rain-On-Snow	Cumulative rain-on-snow September to December	ROSspdc	Fall
Fall Rain On Snow days	Cumulative rain-on-snow days September to December	RODdcspdays	Fall
Fall Freezing Rain	Cumulative freezing rain September to December	FZRNspdc	Fall
Fall Freezing Rain days	Cumulative freezing rain days September to December	FZRNspdcdays	Fall
September temperature	Average daily mean values	TMPsp	Fall
October temperature	Average daily mean values	TMPoc	Fall
October Snow Depth	Snow depth October 31	SNOWoc	Fall

Analysis

The analysis of the climate and vital rate data was largely restricted because of the often small sample size for vital rates. We used a general rule of thumb that you should have at least 10 data points per explanatory variable. Given our average vital rate sample size is 21.7 years we decide to restrict our analysis to a 2-independent variable regression model. We had three sets of vital rate data with sample sizes of <10 (lowest was 8), seven data sets between 11 and 19. As these sample sizes violate our general rule we present both a single and a double independent variable model in those instances.

Using Excel regression analysis tools, we correlated vital rate data to our core climate variables in

Table **16**. If a climate indicator correlated with a vital rate with a p-value <0.10, we tested whether 2 and 3-year running averages of the climate variables improved the correlation. We present only variables with a p-value of <0.05. This allowed us to explore carryover effects up to 3 years. After conducting the simple regression analysis with the climate variable with the highest Pearson R value, we redid the analysis using the residuals of the simple regression and determined the climate correlate that had the highest Pearson R value with the residuals, and thus reported the best two independent variable model.

Another issue that we needed to deal with was if vital rates trended over the period of the data set. Thus, if a significant ($p<0.05$) climate correlation was determined with a climate variable it may simply mean both variables trended over the observation period and no cause and effect relationship exists. Therefore, for all climate variables that were related to a trending vital rate we "detrended" the data by plotting the difference between consecutive points for the two variables. If these differences are correlated, we assumed there is a real correlation between the two variables. Thus, for trending vital rates we present the 2-independent variable model using the climate variable with the highest r^2 with variables that were still significant after the data was detrended.

ABEKC database on body condition

The ABEKC conducts annual interviews within the user communities of the PCH. Of the animals seen or taken, the interviewees were asked to indicate the relative body condition. The categories of answers varied among interview session, community and year but were collapsed into "good', "mixed", and "poor". To directly compare from one interview session to the next an index of caribou condition was developed, i.e. collapsing all responses into one metric. The caribou condition index was calculated as:

$$Condition\ Index = 3 * good + 2 * mixed + poor$$

where "good", "mixed" and "poor' were the frequency of those responses for an interview session.

Results

Porcupine Caribou Herd

Vital rates:

Data for the PCH (Caikoski 2015) included parturition rate (1987-2013, n=26), June calf survival (1987-2011, n=25), June calves:100 cows (1987-2014, n=25) and spring calves:100 cows

(1989-2010, n=17). Adult cow mortality is reported for the period July 1 through the following June and thus mortality 2010, for example, represents mortality of adult cows from July 2009 to June 2010. In the following sections we first determine if there are temporal trends in vital rates, if those vital rates are correlated and then which climate indictors best account for vital rate variability. If vital rates indicate a temporal trend, we detrended the data to ensure we were not dealing with simple correlation but were more confident that a real cause and effect relationship existed. We found no temporal trends in PCH parturition rates, June calf survival or late June calves:100 cows (p=0.78, 0.98 and 0.93 respectively).

Correlation among vital rates:

Thirty-one percent in the variability in parturition rate of the PCH was explained by the previous year's late June calves:100 cow ratio (r^2= 0.31, p=0.005; Figure 47). This relationship suggests that the higher the calving success in year one (as indexed by late June calves:100 cows) the lower the parturition rate the following year.

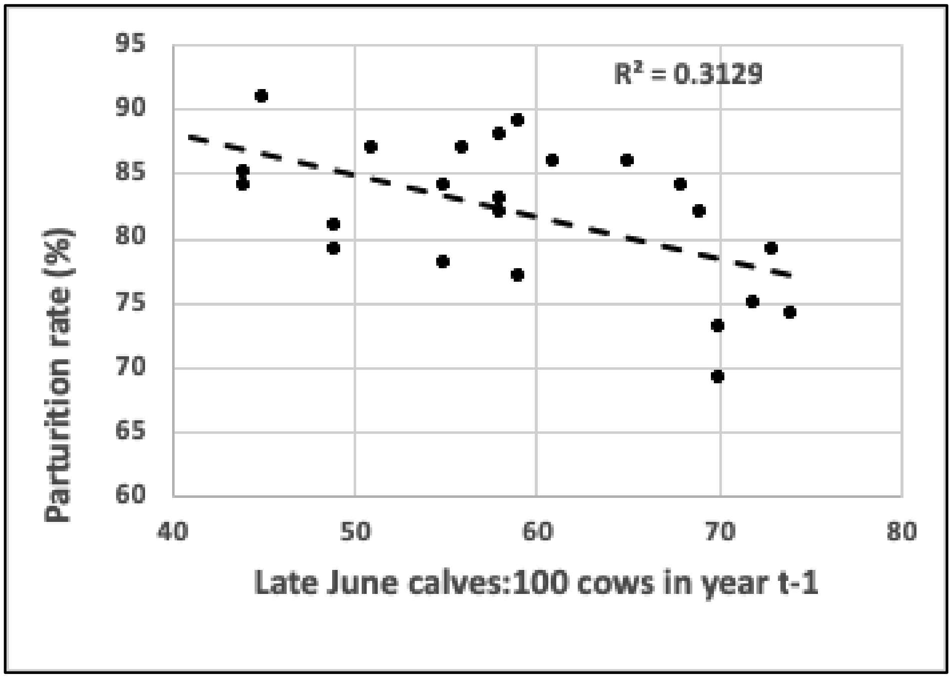


Figure 47. Parturition rate versus late June calf: cow ratio in previous summer in the PCH.

Climate

Adult cow mortality

There was a positive correlation between adult cow mortality and the number of rain-on-snow days that winter (r^2=0.40; p=0.001; n=21; Figure 48). The variable that accounted for most of the variation in the residuals was the 2-year running average in parturition in the previous spring (r^2= 0.48; p=0.001; Figure 49)

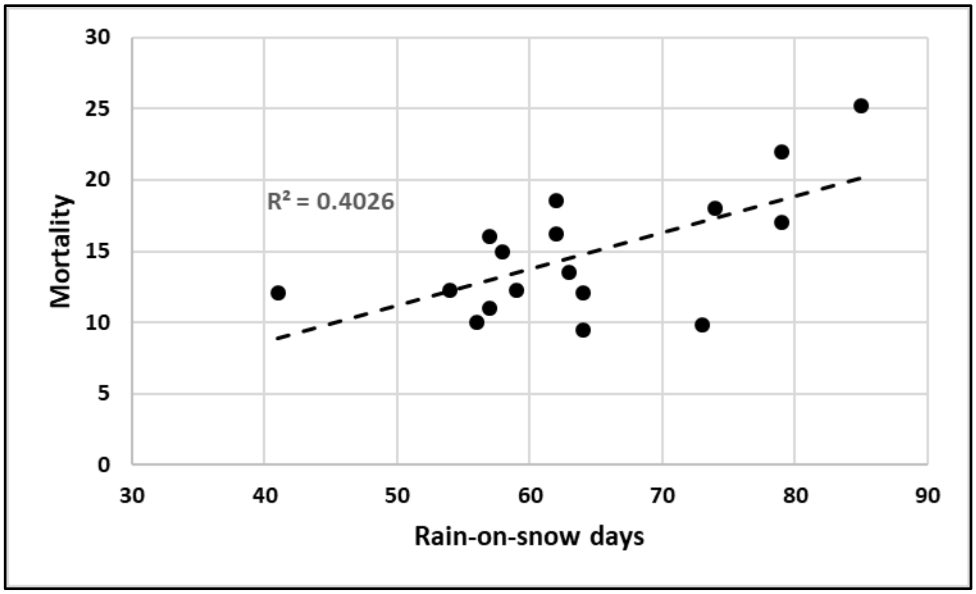


Figure 48. Relationship between rain-on-snow days and adult cow mortality in the PCH.

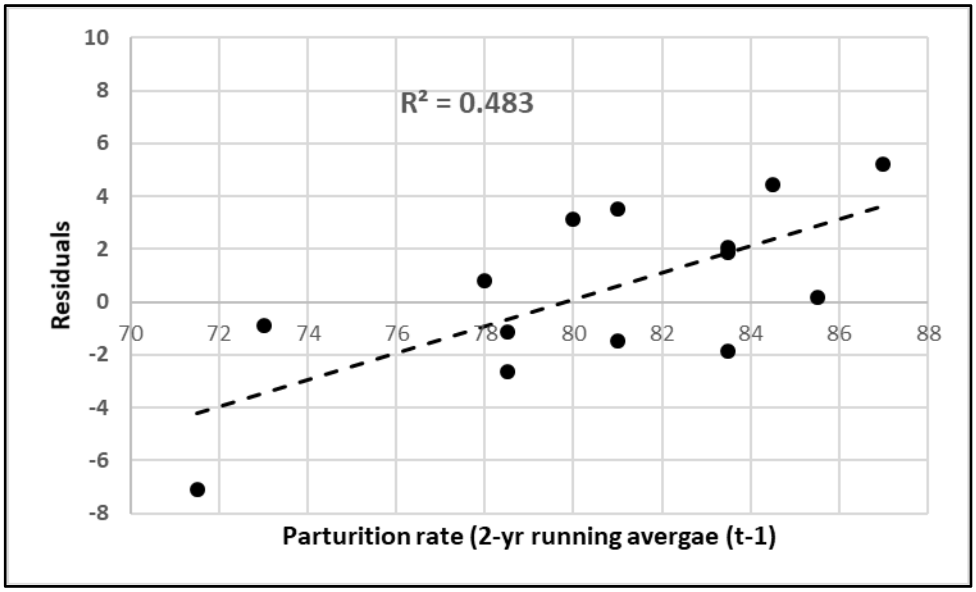


Figure 49. Relationship between parturition rate (2-yr running average) in year t-1 and the residuals from Figure 48.

Together rain-on-snow and previous parturition accounted for 70% of the variability in adult cow mortality (F=16.2; p<0.001`) in the PCH.

Parturition:

There was a negative correlation between parturition rate and the late Oestrid index (cumulative index after August 5th in year$_{t-1}$ (r^2=0.38; p=0.001; Figure 50). The climate variable that accounted for most of the residuals was average September to October temperature in year$_{t-1}$ (r^2=0.40, p=0.001; Figure 51).

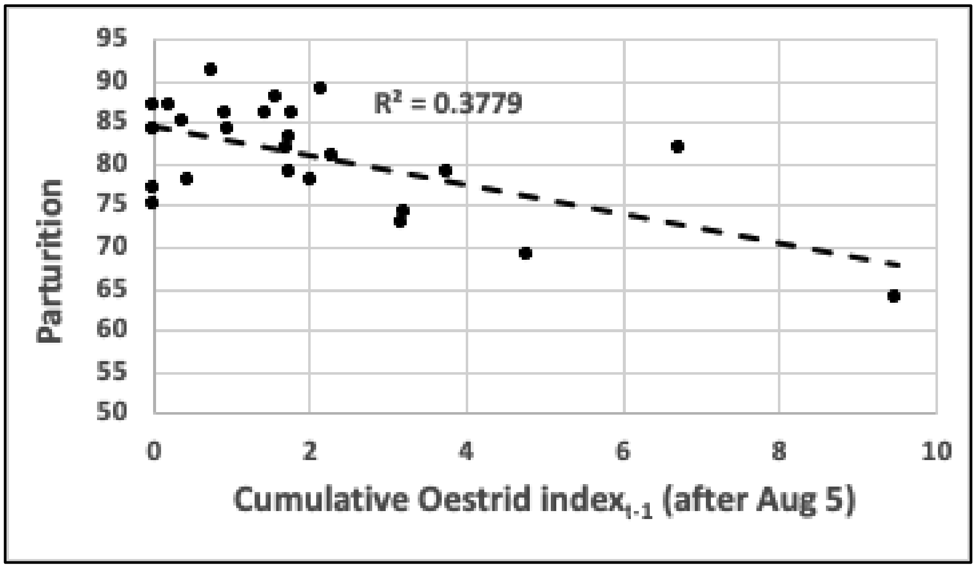


Figure 50. The relationship between parturition rate and late Oestrid index the previous fall in the PCH.

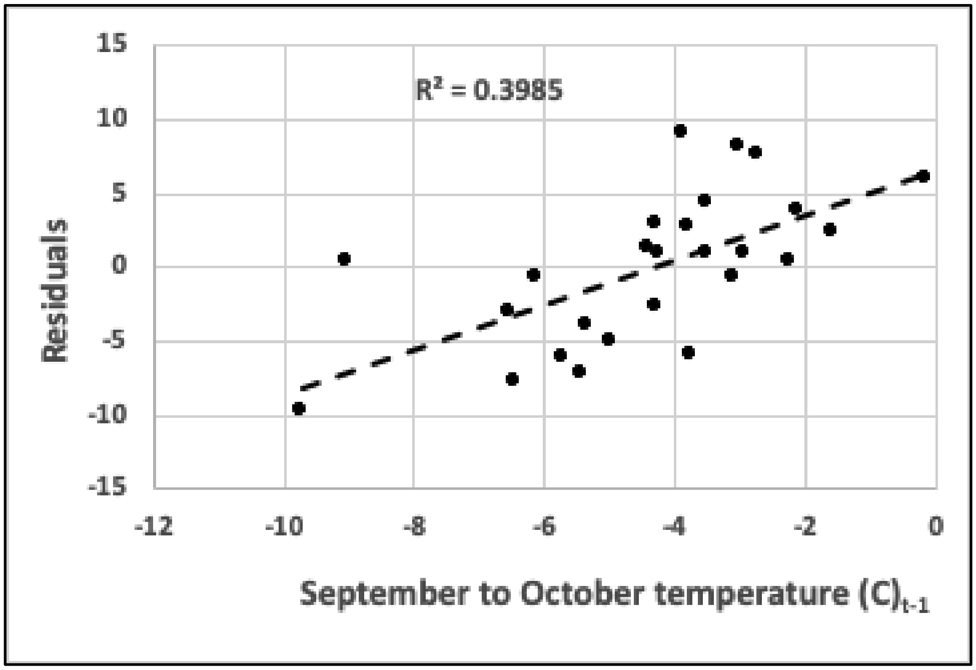


Figure 51. Mean September to October temperature in the range of the PCH versus the residuals from Figure 50.

Together the multiple regression accounted for 63% of the variability in parturition in the PCH (F=14.1, p<0.001).

Early calf survival:

There was a positive correlation between June calf survival and the 2-year running average in June 10 growing degree days in year$_t$ (r^2=0.47; p<0.001; Figure 52). The climate variable that accounted for most of the residuals was the 2-year running average of freezing rain in year$_{t-1}$ (r^2=0.17, p=0.037; Figure 53).

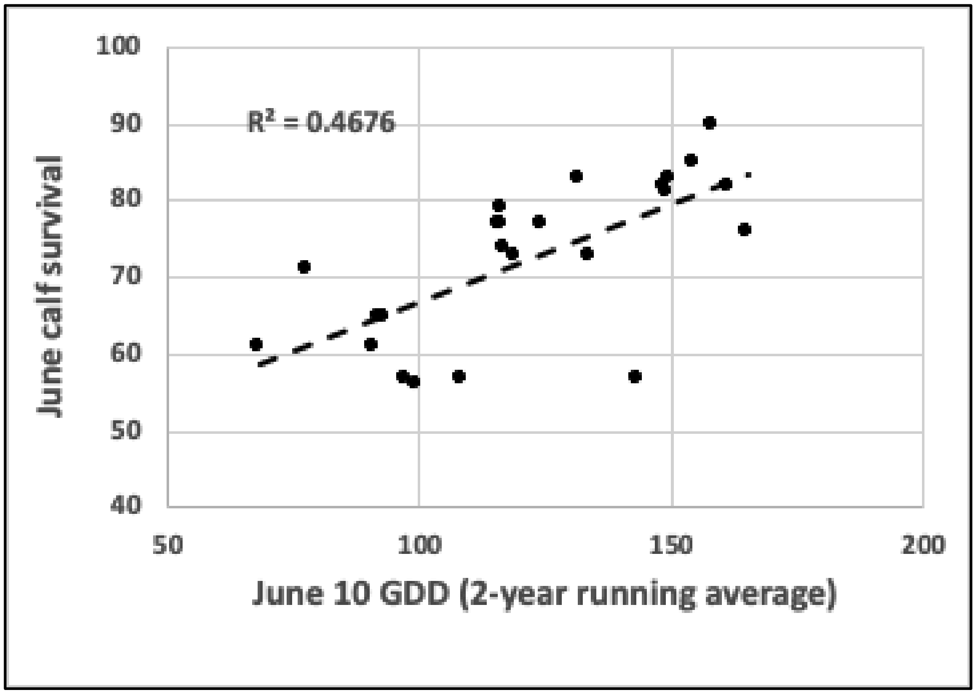


Figure 52. relationship between June calf survival and June 10 growing degree days (2-year running average) in the PCH.

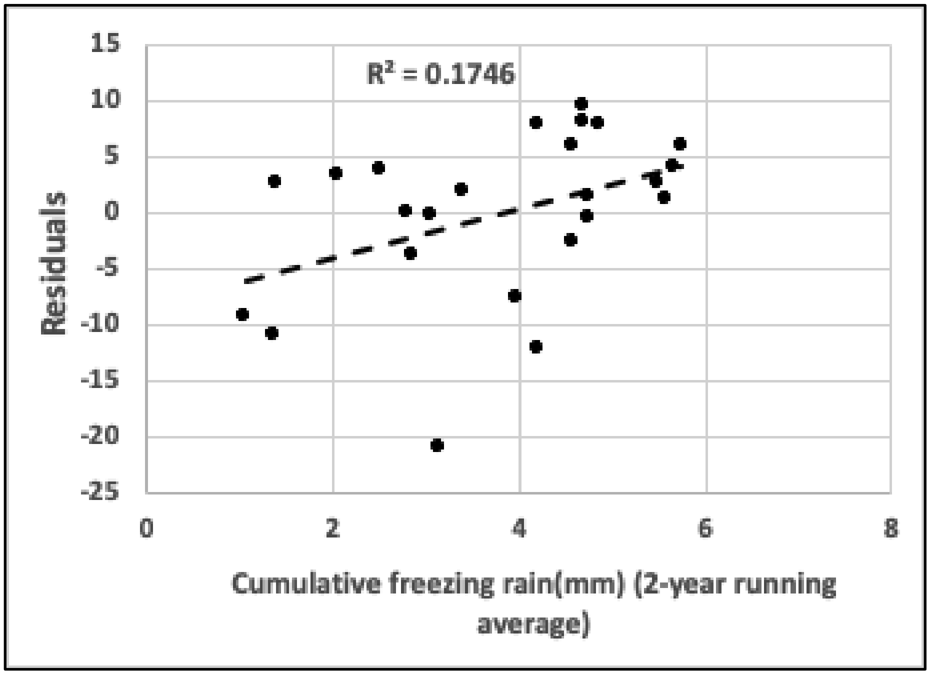


Figure 53. Relationship between cumulative freezing rain previous winter and residuals from Figure 52 in the range of PCH.

Together the multiple regression accounted for 57% of the variability in calf survival in the PCH (F=13.7, p<0.001).

June calves:100 cows:

The strongest correlation between June calves per 100 cows in the PCH was September temperature in year$_{t-1}$ (r^2=0.36; p=0.002; Figure 54). The climate indicator that most accounted for residuals from this correlation is the 2-year running average of June 10 growing degree days in year$_t$ (r^2=0.33; p=0.003; Figure 55).

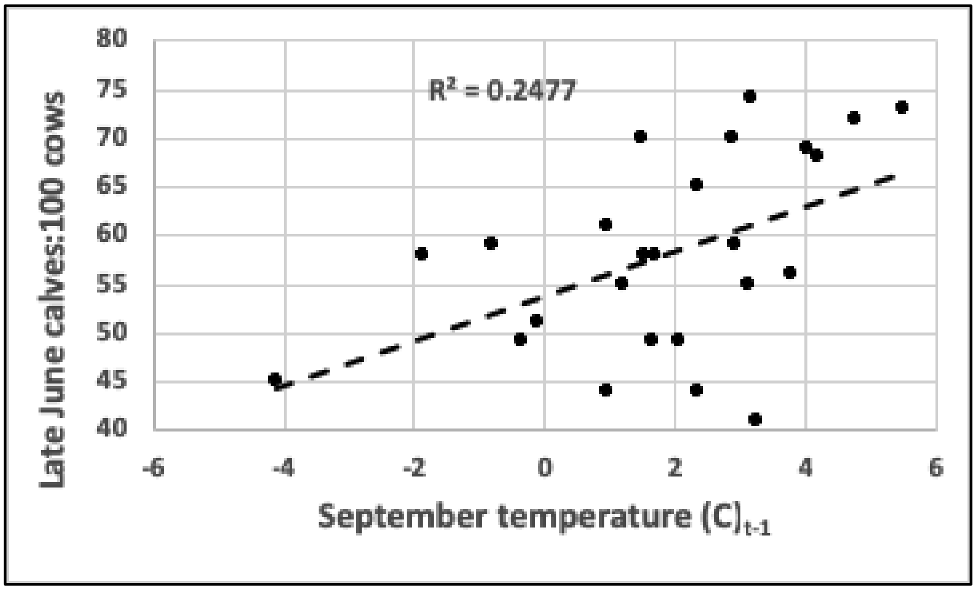


Figure 54. Relationship between late June calves:100 cows and previous fall September temperature in the PCH.

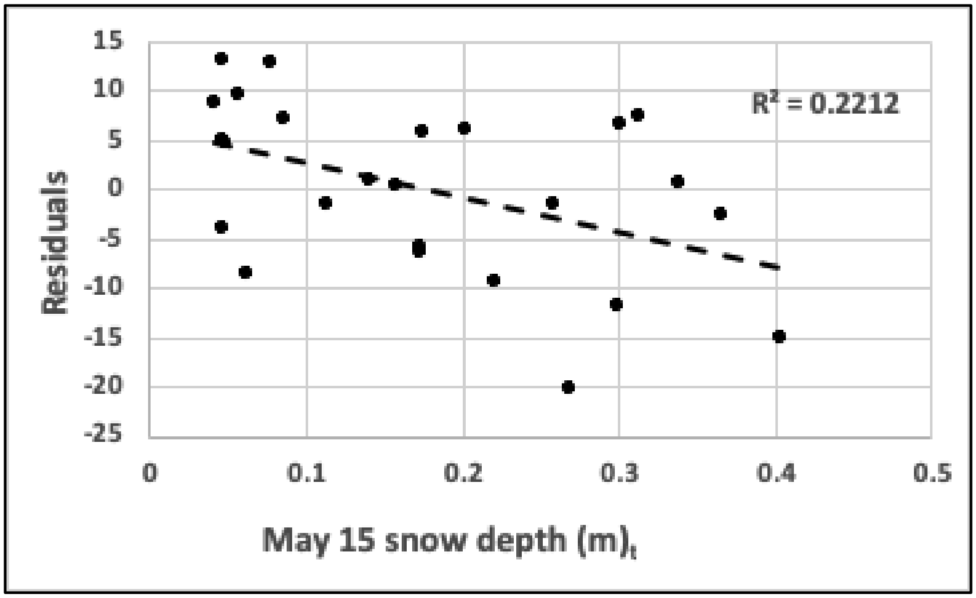


Figure 55. Relationship between May 15 snow depth and the residuals from Figure 54 in the PCH.

Together the multiple regression accounted for 46% of the variability in June calves:100 cows in the PCH (F=9.3, p=0.001).

Body condition links to climate and vital rates

The previous section provides direct links between climate and vital rates. Substantial literature exists on the link between climate and body weights of cows and calves. To gain a more thorough understanding, in this section we explore the linkages between the Arctic Borderlands Ecological Knowledge Cooperative's (ABEKC) body condition indicator to climate and vital rates for the PCH.

Fall condition:

After detrending, the strongest correlate to Fall body condition index in the PCH was June 10 growing degree days in year_t (r^2=0.24; p=0.0589, n=15; Figure 56). After detrending, the climate variable that accounted for most of the residuals was cumulative freezing rain from $\text{September}_{(t-1)}$ to $\text{May}_{(t)}$ (r^2=0.28, p=0.041, n=13; Figure 57).

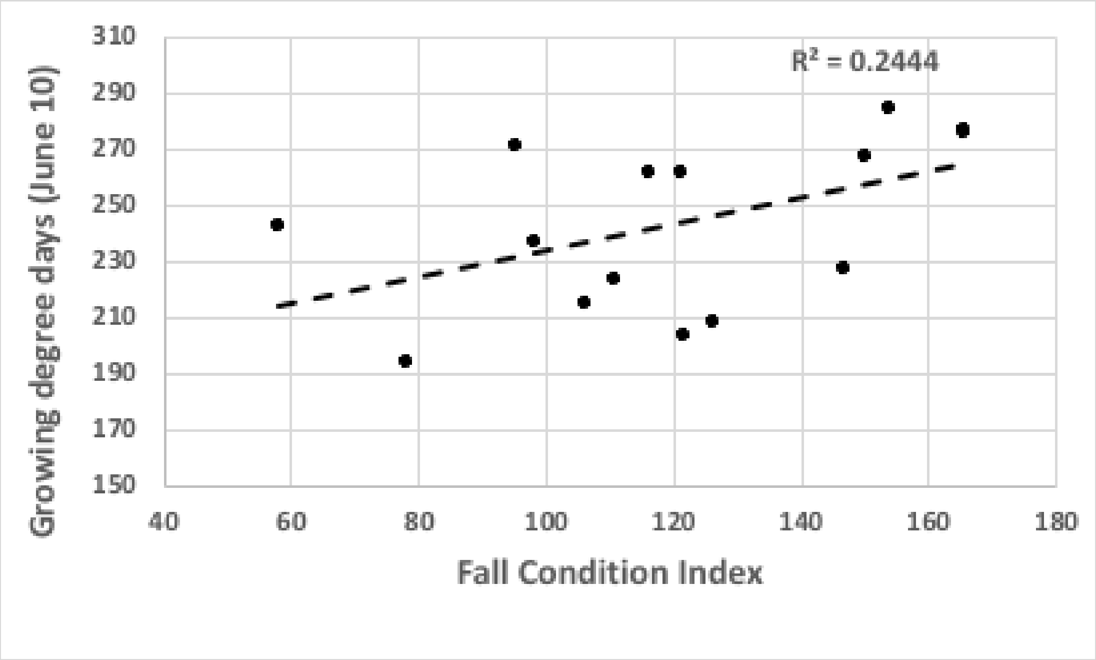


Figure 56. Correlation between June 10 growing degree days and fall body condition index in the PCH.

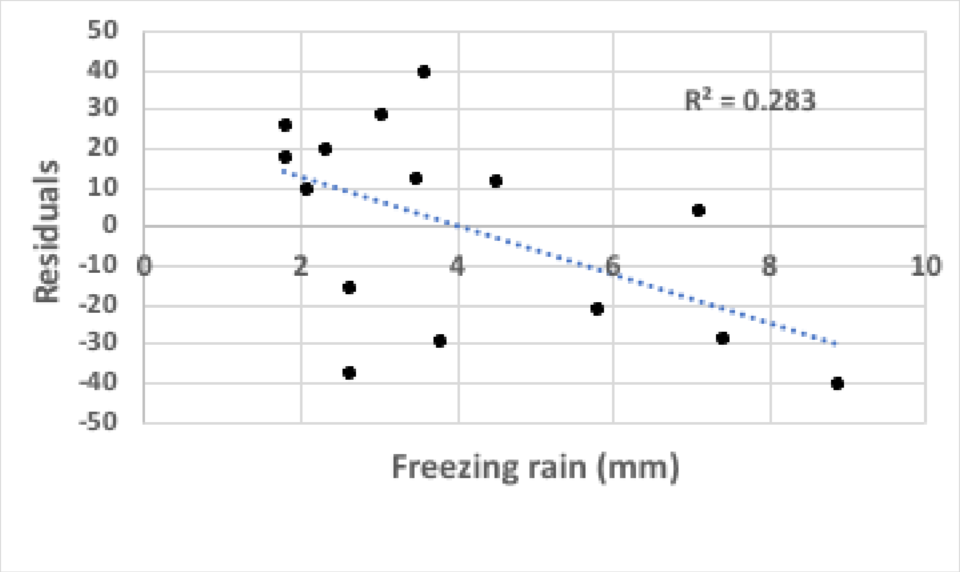


Figure 57. Correlation between freezing rain and the residuals from Figure 56 in the PCH.

Together the multiple regression accounted for 46% of the variability in Fall body (F=5.1, p=0.025).

Spring Body Condition:

There was a negative correlation between Spring Body Condition and cumulative freezing rain from September to December the previous year (r^2=0.46; p=0.001; Figure 58). The climate variable that accounted for most of the residuals was the 2-year running average for July temperature in year$_{t-1}$ (r^2=0.46, p=0.004; Figure 59).

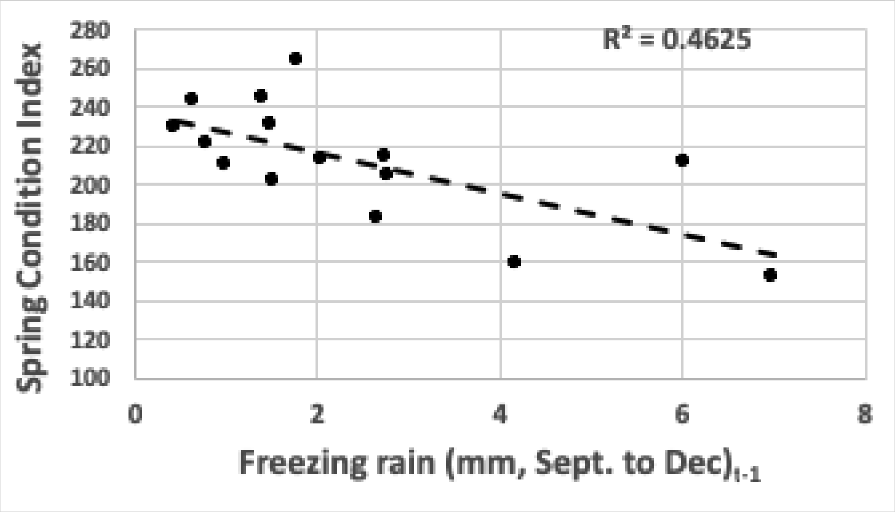


Figure 58. Relationship between spring body condition and cumulative freezing rain from September to December the previous fall in the PCH.

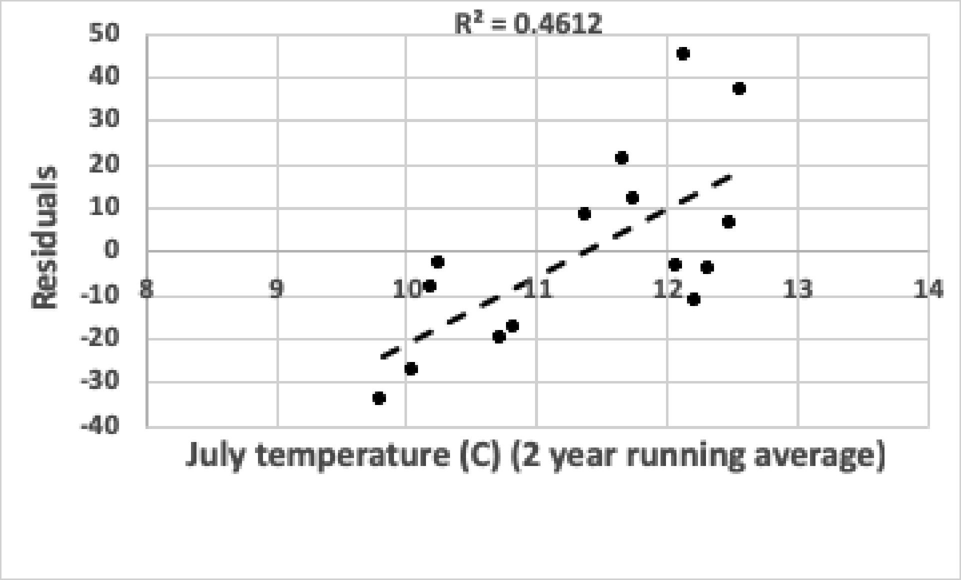


Figure 59. Correlation between 2-year running average of July temperature in year t-1 and residuals from Figure 58 in the PCH.

Together the multiple regression accounted for 85% of the variability in Spring body condition (F=15.8, p< 0.0001).

Condition links to vital rates:

Fall Condition:

There were no significant correlations between fall body condition and Porcupine caribou vital rates.

Spring Condition:

There was a strong correlation between current year spring recruitment (calves:100 cows) with the previous year spring body condition ((r^2=0.77; p=0.01, n=6; Figure 60), despite the small sample size for spring recruitment.

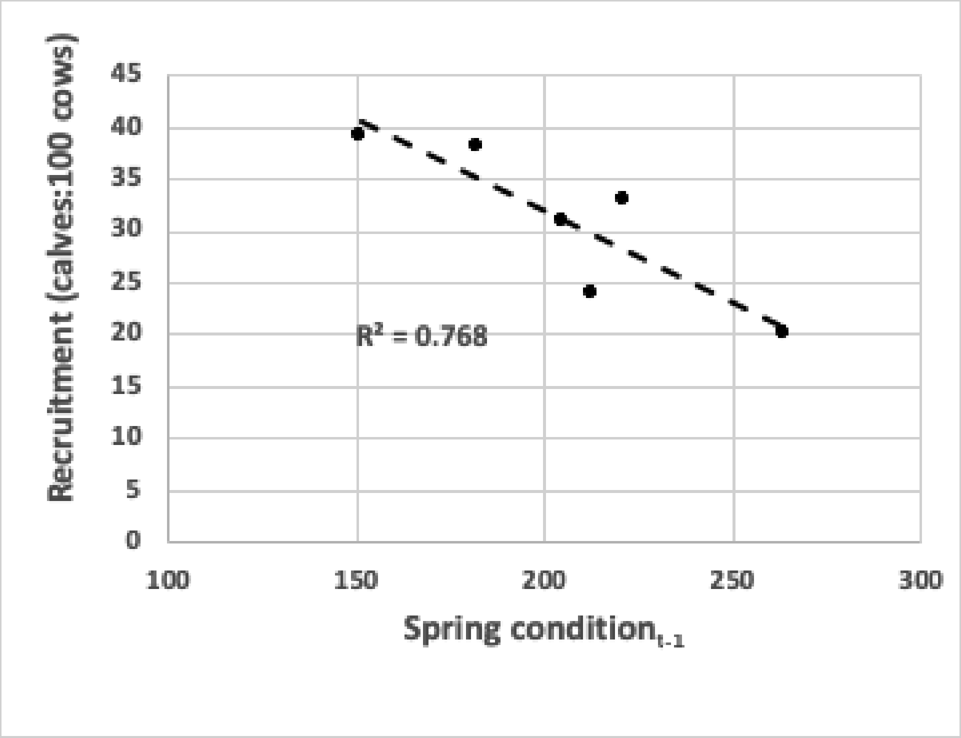


Figure 60. Correlation between spring recruitment (calves:100 cows) and spring body condition in year$_{t-1}$ in the PCH.

The regression accounted for 77% of the variability in spring body condition ($F=8.7$, $p< 0.01$).

Central Arctic Herd

Vital Rates:

Data for the CAH (Lenart 2015) included adult cow mortality (1998-2015, n=18), parturition rate (1994-2014, n=20), and June calves:100 cows (1994-2014, n=21). Adult mortality is reported for the period July 1 through the following June and thus mortality 2010, for example, represents mortality of adult cows from July 2009 to June 2010. In addition to those data provided in agency reports we estimated early calf survival (June calf:cow ratio)/(parturition rate), similar to data presented for the PCH (Caikoski 2015). Our analysis regarding early calf survival ignored estimates for 1995 and 1997 which indicated over 100% survival (112 and 123 % respectively.

Between 1997 and 2012 there was an increasing trend in adult cow mortality in the CAH ($r^2=0.38$, $p=<0.004$; Figure 61) but no trend in parturition rate or late June calf:cow ratio.

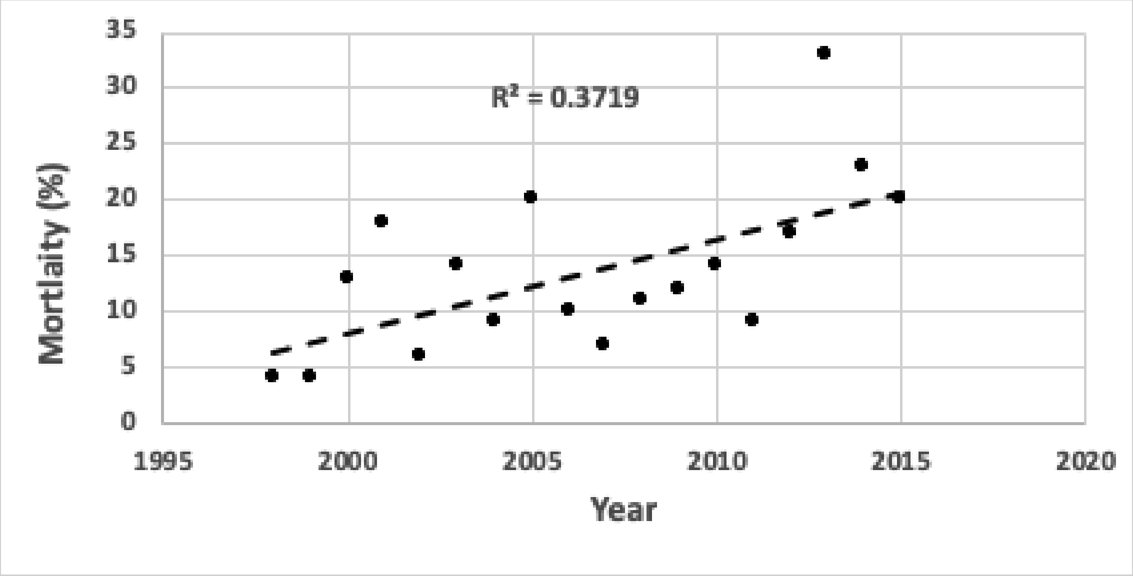


Figure 61. Trend in adult cow mortality from 1998-2015 in the Central Arctic Herd.

Correlations among vital rates

There was a negative relationship between adult cow mortality and the 2-year running average for late June calves:100 cows in year$_t$ (r^2=0.54, p<0.001: Figure 62).

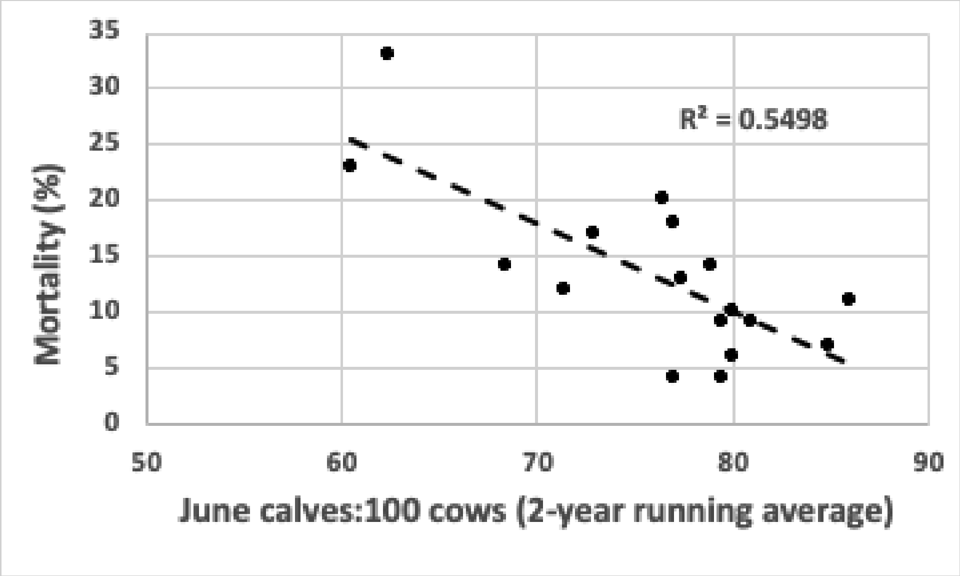


Figure 62. Relationship between June calves:100 cows (2-year running average) and adult cow mortality in the Central Arctic Herd.

Mortality rate

After detrending there was a strong positive correlation between adult cow mortality and the 2-year running average of freezing rain from September to December in year$_{t-1}$ (r^2=0.35; p=0.009; Figure 63). After detrending the climate variable that accounted for most of the residuals was the 3-year running average of July temperature year$_t$ (r^2=0.36, p=0.008; Figure 64).

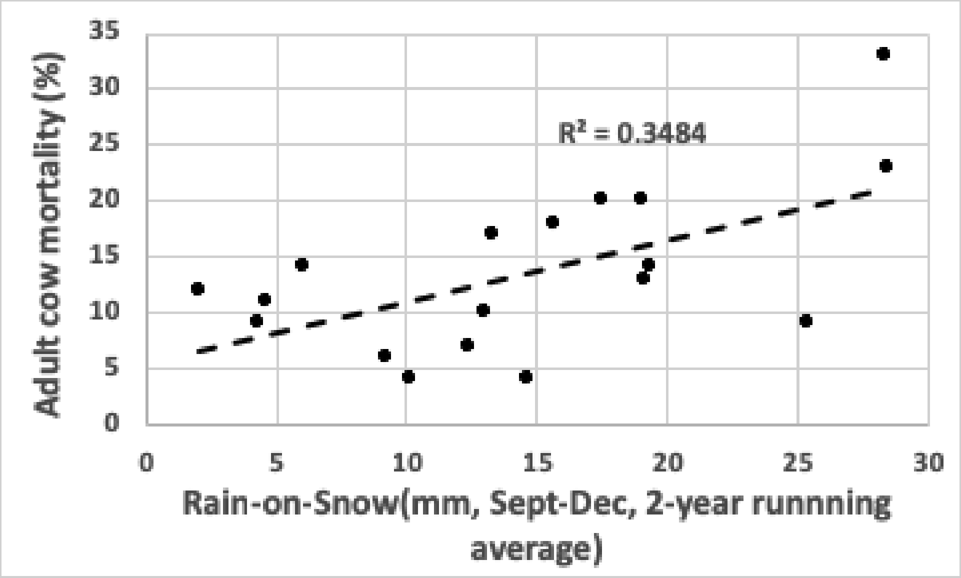


Figure 63. Relationship between 2-year running average of fall rain-on-snow versus adult cow mortality in the Central Arctic Herd.

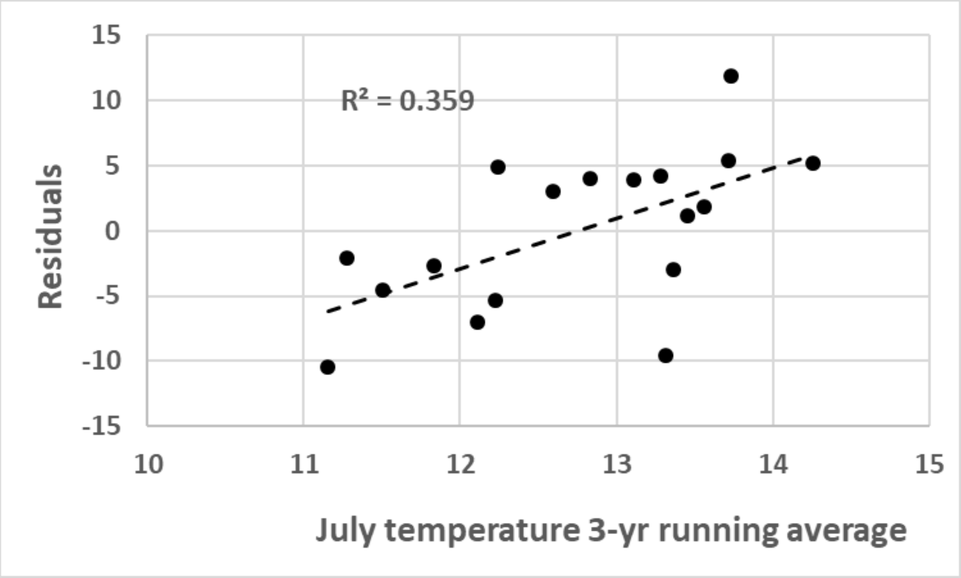


Figure 64. Relationship between 3-year running average of July temperature and the residuals from Figure 63 in the Central Arctic Herd.

Together the multiple regression accounted for 59% of the variability in adult cow mortality in the CAH (F=28.6, p<0.001).

Parturition

There was a positive correlation between parturition rate and average September temperature in year$_{t-1}$ (r^2=0.48; p=0.001; Figure 65). No other climate variable was significantly related to the residuals of this relationship.

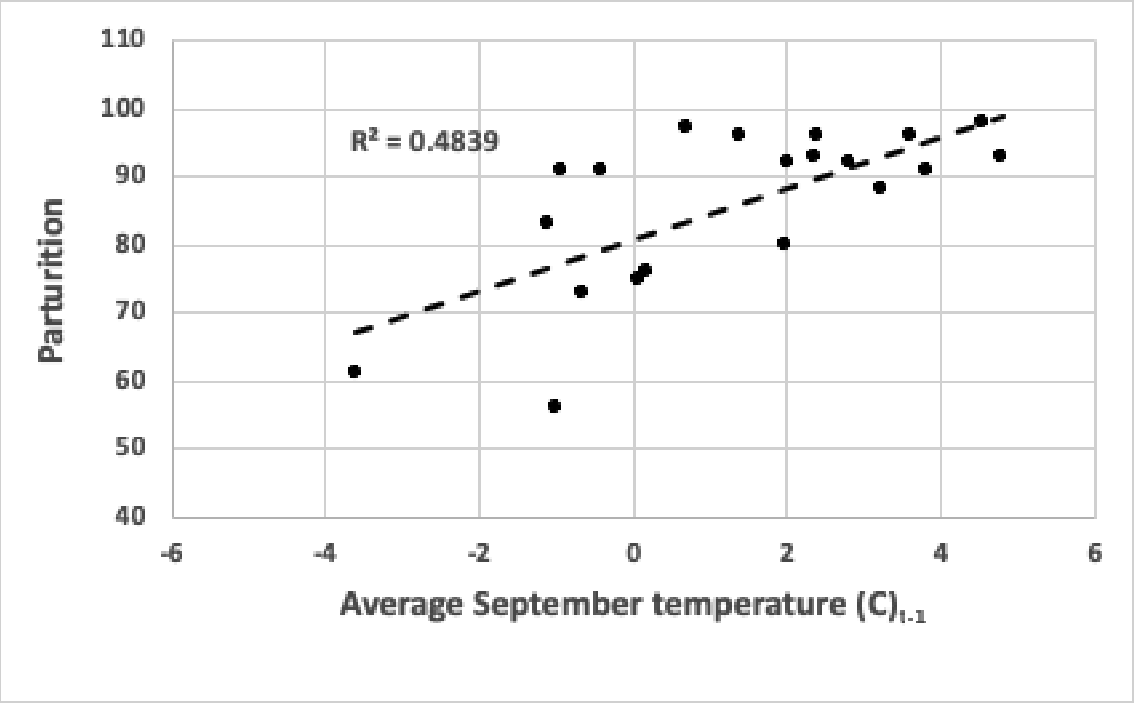


Figure 65. Relationship between average September temperature and parturition rate in the Central Arctic Herd.

The simple regression accounted for 48% of the variability in parturition rate in the CAH (F=7.3, p=0.008).

June calves:100 cows

There was a positive correlation between late June calves:100 cows and October 31 snow depth in year_{t-1} (r^2=0.48; p=0.001; Figure 66). The climate variable that accounted for most of the residuals was 2-year running average for July temperature in year_{t-1} (r^2=0.20, p=0.042; Figure 67).

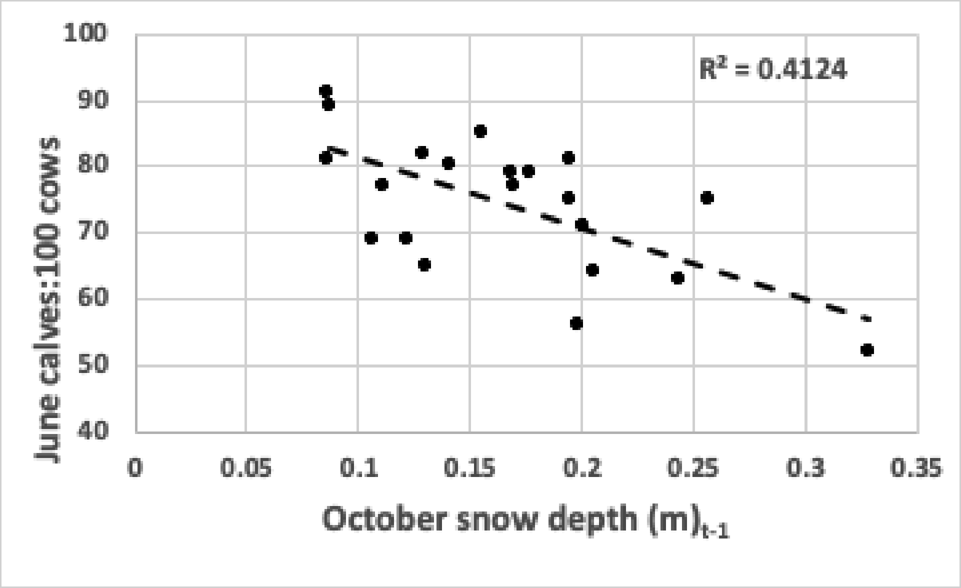


Figure 66. Relationship between October snow depth and June calves:100 cows in the Central Arctic Herd.

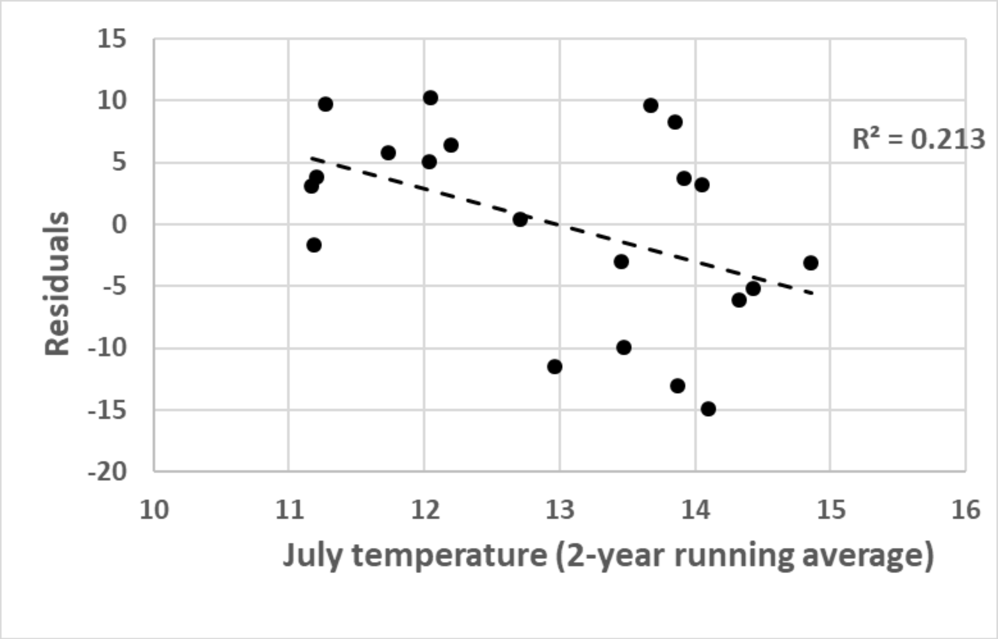


Figure 67. Relationship between 2 year running average of July temperature and the residuals from Figure 66.

Together the multiple regression accounted for 55% of the variability in June calves:100 cows in the CAH (F=10.6, p=0.001).

Early calf survival

Our estimation of early calf survival a positive correlation with October 31 snow depth in year$_{t-1}$ (r^2=0.32; p=0.005; Figure 68). The climate variable that accounted for most of the residuals was the a 2-year running average for September temperature in year$_{t-1}$ (r^2=0.31, p=0.051; Figure 69).

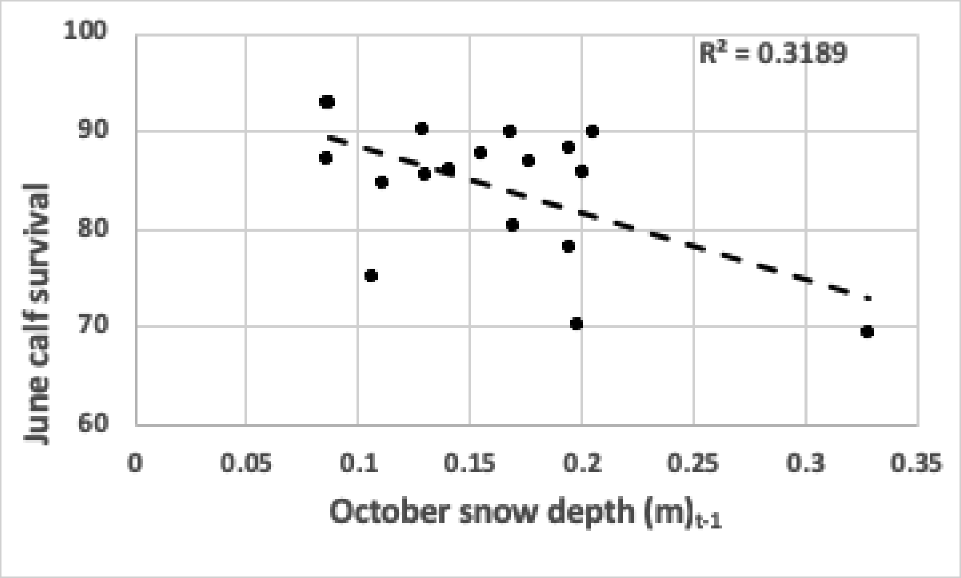


Figure 68. Relationship between October snow depth and June calf survival.

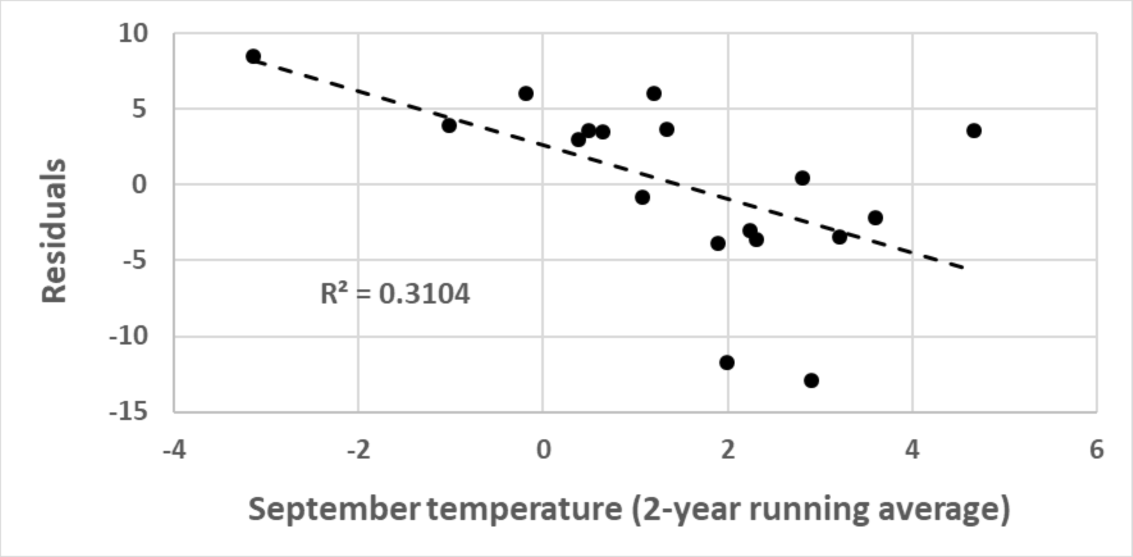


Figure 69. Relationship between September temperature (2-year average) and residuals from Figure 68.

Together the multiple regression accounted for 56% of the variability in early calf survival in the CAH (F=9.4, p=0.002).

Appendix C. Chronology Prudhoe Bay and satellite oilfields and caribou monitoring studies

Oil field		Caribou monitoring		
Year	*Description*	*Year*		*Reference*
1964	State of Alaska issues leases for Prudhoe Bay area			
1967	first successful discovery well			
1969	23 wells drilled two airstrips camps for 1000s of workers	1969	Atlantic Richfield Co. 10-year baseline study	Gavin 1980
1974	Dalton Highway completed			
1975	East-west gravel road across Prudhoe Bay oilfield	1975	Seasonal distribution aerial surveys	Cameron and Whitten 1979
1977	Oil production starts Prudhoe			
1977	Trans Alaska Pipeline completed			
1979 - 81	Spine road extended; Kuparuk field (CPF-1) and pipeline built 40 km west of Prudhoe Bay	1972- 90	(i) Truck surveys and calving to summer counts and behavior; pre-and construction Kuparuk	Smith et al. 1994
1980	Requirement for pipelines 1.5 m height	1981 - 82	(ii) Observational study large groups and pipeline/road Kuparuk	Smith and Cameron 1985
1982	Milne Point Road, wells, Oliktok Road and CPF-2 and CPF-3 built	1978-84	(i) Aerial surveys calving Prudhoe Bay oilfield	Whitten and Cameron, 1985

Oil field		Caribou monitoring		
		1978-84	(ii) Aerial strip transects; 4 years pre and during construction Milne Point Rd	Dau and Cameron 1986
		1980 - 94	(i) Radio-collared cows located summer, quadrat design	Cameron et al. 1995
		1980 - 94	(ii) individual calving sites of radio-collared cows – 14 years; quadrat design;	Cameron and Griffith 1997
			used 1980-94 radio-collars to map the calving distribution	Wolfe (2000)
		1981 - 83	Behavioral observations from fixed points during insect season for crossings pipeline/road Kuparuk	Curatolo and Murphy 1983, 1986
		1993	Ground observations and video behavior gravel pads Prudhoe	Noel et al. 1998
1990	Prudhoe Bay - 220 km gravel roads, 53 well pads, 31 exploration pads, 8 gathering centers	1990-94	Aerial transects, summer, Prudhoe Bay, insects	Pollard et al. 1996 a b
1991	Milne Point 6 more drill pads and 3 more spur roads since 1987	1991 - 2001	Aerial surveys Milne Pt area to compare densities with Dau and Cameron 1986, Cameron et al. 1992	Noel et al. 1998
1997 to 1998	Greater Kuparuk Area – Tarn Project constructed		Calving aerial surveys	Lawhead et al. 2002

Oil field		Caribou monitoring		
	Alpine stand-alone processing facilities (CD1), a second drilling pad (CD2), and an airstrip/3-mile gravel road connecting the two pads			
1999	Alpine area leased			
2001 to 2003	Meltwater DS-2 drill site and 16 km road/pipeline to CPF-2 constructed		Mitigation (pipeline height, traffic convoy); monitoring–aerial and road surveys	Lawhead et al. 2004
2004	Alpine CD 3 to 7 pads and gravel road to CD-1			
	Alpine satellites – Fiord (CD3) and Nanuq (CD4 producing		80 km west of Prudhoe Bay	
2011	Alpine West/CD5 Project producing			
2015	Greater Mooses Tooth GMT1 permitted; will be connected by 12.5 km road to CD5; up to 33 wells			
2015	Application to develop GMT2 (previously CD7)			
2018	DSEIS issued for GMT2			

Appendix D. Chronology of oil and gas leasing of Teshekpuk herd’s calving and insect relief habitat in the NPR-A

YEAR	Description
1923	Alaskan National Petroleum Reserve created 23 million acres
1977	Teshekpuk Lake Special Area created (1,734,000 acres)
1980	NPR-A leasing for oil and gas authorized by Congress
1998	Northeast NPR–A IAP of 1998 BLM designated the Teshekpuk Lake Surface Protection Area. 588,998 acres unavailable for leasing Plan did not have a preferred alternative. https://www.gpo.gov/fdsys/pkg/FR-2008-07-24/pdf/E8-16894.pdf
2001	Congress directed BLM to “consider additional environmentally responsible oil and gas development, based on sound science and the best available technology, through further lease sales” in NPR-A
2003	Northeast NPR–A Supplemental IAP ROD started to update 1998 plan https://www.gpo.gov/fdsys/pkg/FR-2008-07-24/pdf/E8-16894.pdf
2004	2004 ROD for Northwest National Petroleum Reserve-Alaska Integrated Activity Plan/Environmental Impact Statement preferred alternative for most area for leasing
2005	Northeast NPR–A Amended IAP/EIS completed
2006	BLM issues Northeast NPR–A ROD followed by Northeast and Northwest NPR-A lease sale for Sept. 27, 2006, that included leases on 373,000 acres north and east of Teshekpuk Lake
2006	NGO court challenge and U.S. District Court Judge ruled the 2005 amended plan for Northeast NPR-A did not adequately address the cumulative impacts of oil and gas activities in the 600,000 acres of Teshekpuk Lake area.
2007	BLM initiated the Supplemental IAP/EIS to address inadequacies in the Amended IAP/ EIS. The BLM issued a Draft Supplemental IAP/EIS
2008	Final Supplemental IAP/EIS and ROD identifies 4 million acres for leasing and leasing on 430,000 acres deferred 10 years and additional mitigation measures
2012	EIS for Integrated Activity Plan which is for entire NRR-A: Teshekpuk Special Area deferred until 2018 (400,000 public comments); no alternative identified
2013	ROD for Integrated Activity Plan Teshekpuk Lake and Utukok River Uplands Special Area increased in area; alternative identified to give 52% available for

YEAR	Description
	leasing: established performance-based stipulations and best management practices: monitoring for baseline, compliance and effectiveness of mitigation, created an advisory working group with communities and tribal governments.
2016	NPR-A, a total of 145 tracts available for lease
2017 May	Secretary of the Interior Ryan Zinke NPRA revising the NPR-A 2013 Integrated Activity plan, https://www.doi.gov/pressreleases/secretary-zinke-signs-order-jump-start-alaskan-energy
2017 Dec	NPR-A, a total of 900 tracts available (10.3 million acres), and 80,000 acres sold
2018 Feb	Natural Resources Defense Council went to court against BLM based on the 2016 and 2017 leases partly because BLM failed to develop and compare a reasonable range of lease sale alternatives https://earthjustice.org/sites/default/files/files/Complaint%2C%202-2-2018.pdf
2018 Nov	BLM issues notice of intent to develop a new IAP/EIS (previous complete in 2013) based on Secretarial Order 3352 that directed the development of a schedule to "effectuate the lawful review and development of a revised IAP for the NPR-A that strikes an appropriate balance of promoting development while protecting surface resources."