Assessing caribou vulnerability to oil and gas exploration and development in Eagle Plains, Yukon

A report submitted to Yukon's Department of Energy, Mines and Resources

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Shadow Lake Environmental

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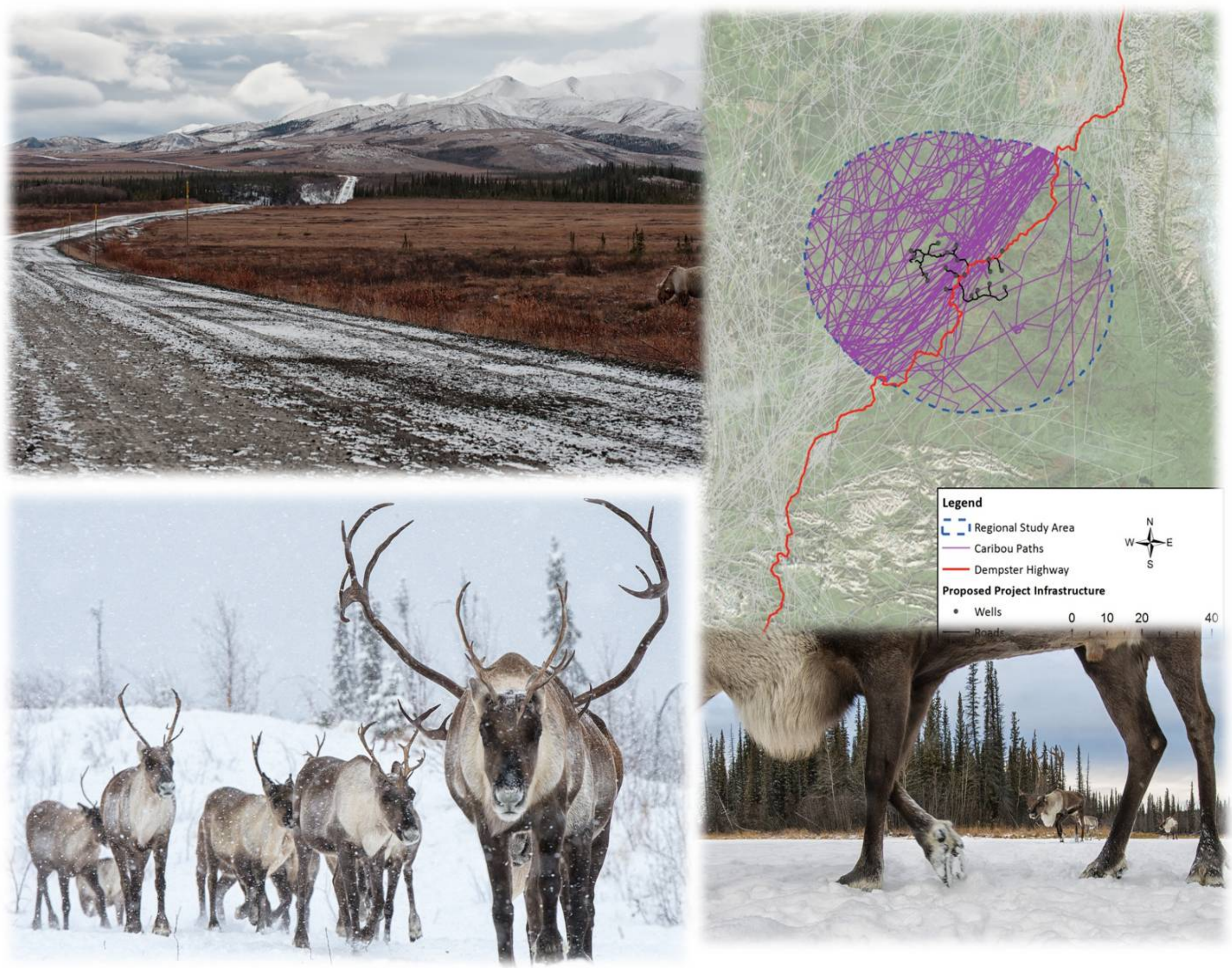

Frontispiece

Dempster Highway, fall migration (photos Peter Mather) and map showing 1985-2016 pathways of PCH collared caribou, the Dempster Highway and a proposed oil and gas project

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1 Executive Summary

Introduction: In February 2016, the Yukon Environmental and Socio-economic Assessment Board (YESAB) released its decision on Northern Cross Yukon's (NCY) "Eagle Plains multi-well exploration and development permit." Their decision was essentially that due to knowledge gaps, including impacts on the Porcupine herd and the aboriginal groups that depend on the herd for subsistence needs, YESAB was unable to assess environmental and socio-economic impacts for the project. Given a number of deficiencies and data gaps that were identified throughout the whole review process, EMR and the Vuntut Gwitchin First Nation (VGFN) felt it important to assemble information available on potential impacts, mitigation and best practices for caribou interacting with oil and gas development, both with respect to the NCY and other potential future development in the region.

We realized that an underlying issue was uncertainty about how information on the Porcupine herd 'fitted' with the 'applied' questions about reducing and managing impacts of development. Thus we organized the information following the structure adopted by the International Panel on Climate Change in assessing vulnerability (to impacts of climate change on the environment) generalized to assess the vulnerability of caribou to industrial exploration and developments (IPCC 2007). IPCC (2007) described Potential impact as a function of the *sensitivity of* a particular system to change (climate and industrial exploration and developments) and its *exposure to* those changes. The capacity to adapt to those changes is modified by herd and habitat management as well as mitigation of the industrial activity. Monitoring is the feedback between impacts and mitigations (adaptive mitigation).

Potential impacts: Potential impacts are the outcome of the exposure of the caribou to an industrial development and their sensitivity to environmental changes. Our review of potential impacts covers the spatial gradient from caribou standing alerted by a road watching trucks to caribou changing their movement's kilometres away from a road or drill site. We identify what is known about the mechanisms that explain how small changes in caribou behaviour can accumulate to reduce their productivity. We describe how caribou are integrating their responses to disturbance with changes in habitat caused by oil and gas exploration and a cascade of changes including increased predation. Caribou respond to disturbance in a similar way as they do to predators by avoidance and flight and selecting habitat to minimize their risk of exposure to risk. A gap in our knowledge about potential impacts is the role of memory and learning which allows caribou to save energy by responding less (habituation and tolerance). We review specifically the potential impacts based on studies on the Porcupine Caribou herd. We identify four issues stand out as where our knowledge is inadequate for describing direct impacts.

- Avoidance of roads and traffic is measured for some herds but the underlying mechanism is uncertain, raising questions about how to design mitigation.

- The extent to which hunting interacts with the responses to road traffic and increases the responsiveness is uncertain which reduces the predictability of caribou responses to oil and gas and appropriate mitigation.
- While behavioural observations can be used to measure the responsiveness of caribou, the observations are not integrated with the movement rates and directions of caribou fitted with satellite or GPS collars.
- We lack studies with adequate sample design to describe barren-ground caribou behavioural responses to the sequences of seismic lines, drilling or extended flow testing which is essential to be able predict responses to exploration.

Sensitivity: The increase, decline and increase of abundance for the Porcupine herd recorded since the early 1970s is characterized by relatively low rate changes (-4% to +4%). The herd trend appears to strongly correlate to adult cow mortality, as pregnancy rate remained relatively stable throughout the population cycles. At the physiological level, the PCH accumulates the lowest fall back fat among herds with comparable data. One interpretation is the herd has evolved with a relatively favourable winter environment either because of: 1) availability of favourable snow conditions either from lower snowfalls or a diverse topography so caribou can space away from adverse snow: or 2) an overall predictable winter environment. The probability that a cow will get pregnant follows a sigmoidal relationship with fall body weight. Both the steepness of the curve and the relative weight that is associated with a 50% chance of getting pregnant has been suggested to relate to the vulnerability (the steeper the more vulnerable) and the productivity (the lower the relative weight the more productive). Among herds with comparable data, the PCH is one of the least productive but is also the least vulnerable, suggesting that it will never increase or decline dramatically and never "erupt" to high population densities.

In comparison to migratory tundra herds across North America, the PCH experiences warm early spring conditions (high June 10 growing degree days) and cool moist summers, resulting in low drought conditions and relatively deep snow accumulations in winter. This suggests a prolonged plant phenology profile, higher quality summer forage, and lower mosquito and oestrid fly harassment indices. Winter snow depths are relatively high compared to other herds but the diverse terrain allows the herd to seek shallower snow area during bad winters.

Thus with respect to the adverse potential impacts of human activity, we speculate that the Porcupine Herd has evolved in a favourable environment resulted in larger calves but low winter reserves. Thus with low inherent productivity, the introduction of significant industrial activity could, without dramatically affecting pregnancy rate or cow mortality, prevent the Porcupine herd from recovering during a decline phase or significantly reduce the rate of increase during population expansion.

Exposure: The current and potential future exposure of the PCH to proposed NCY infrastructure was assessed using a path analysis of collars from April 1985-January 2016. We used a 30-km buffer zone to determine use, movement rates and residency time. The number of satellite collars available varied considerably among years, peaking at 45 in 2015. Caribou that interact with the 30-km buffer in fall follow a migration route south along the west side of the Richardson Mountains, turning southwest just north of Eagle River, although in the year when most collars passed through the buffer zone (2013), caribou moved south from Old Crow, directly through the Eagle Plans area via Johnson and Chance Creeks (M. Suitor, pers. comm.). Visual examination of fall movement paths suggests the Dempster Highway may be acting as a barrier movement to winter ranges south of the highway in the mid Peel River, Hungry Lakes area. It is possible however that this movement pattern may reflect habitat differences so caution should be taken until further analysis is complete. The consequence of these movement paths with respect to Northern Cross is the significantly higher use of the Chance Creek area and lesser use of proposed well sites and roads southeast of the Dempster Highway.

Caribou first arrive in September and are essentially gone by May (only two paths recorded in May). There is a progressive decline in per cent use from October (44%) to April (15%) based on the per cent of years that caribou intercept the buffer zone. Based on the monthly average, per cent of paths October (4.1%) and December (4.5%) had the highest use between 1985 and 2016. However, both months were influenced by a single year (1990 for December; 2015 for October).

Movement rates in the buffer zone declined from September (14.5 km per day) to March (2.0 km/day) increasing in April (6.4 km/day) as spring migration begins. With respect to residency time, caribou during March spent on average 16.8 days in the buffer, during fall migration residency time increased from September (4.2 days) to December (14.3 days).

Using climate data downloaded from the 30-km buffer zone we note a declining trend in snow depth and an increasing trend in July drought. From previous analysis lower snow means higher probability of use in Eagle Plains but higher drought means higher probability of fire, less lichens and thus lower use.

There is a need to integrate the cumulative effects of existing and potential future changes within the range of the PCH. We present an existing model structure that has been applied to other migratory tundra herds.

<u>Adaptive capacity:</u> Adaptive capacity is what needs to be done to reduce the potential impacts. Thus within the concept as applied to oil and gas development and the PCH, adaptive capacity includes habitat and harvest management and project-specific mitigation. Further, to improve the project-specific mitigation, the effectiveness of mitigation measures needs to be monitored and deficiencies identified, mitigation adjusted and implemented – the adaptive monitoring cycle. Thus, there needs to be a collaborative caribou technical advisory group to oversee the process.

In our review, we found that the distinction between Best Management Practices and mitigation is unclear. As a generality, Best Management Practices are normally in place thorough policy or legislation and their goal is to “avoid” and/or “minimize” industry effects on caribou. Typically, they are broad-level recommendations at the regional scale. We provide an example of BMP for Mountain Caribou in northern B.C. that covers all the main topics that need to be addressed for barren-ground caribou (see Appendix C). Taking the topics to a more detailed level constitutes a project-specific mitigation plan. We provide an example related to timing of operations with respect to sensitive life cycle periods for the PCH.

What we know the least about Best Management Practices is how they are implemented and reviewed. For example, within the existing BMP for seismic operations, we do not know how they work in practice, as there appears to be no feedback reporting on how they are implemented or how adaptive mitigation for specific developments would provide feedback on any gaps in the seismic BMP.

Potential impacts include that caribou avoid roads and traffic at variable distances depending on vegetation, observation methods, predation and hunting. However, the results of reducing those impacts through monitoring and mitigation are uncertain. We found many proposed actions based on speed, stopping distances etc but almost no follow-up to determine effectiveness. The same general point can be made about other proposed mitigation and thresholds to modify mitigation through monitoring. While much information is available on best practices and mitigation, it is mostly for boreal and mountain caribou and there is less information for migratory tundra caribou. This leads us to suggest that a more collaborative approach, integrating baseline information on movements with environmental variation, would be the basis for best practices and mitigation.

The key to relying on collar locations is having confidence in collars representing caribou abundance at the spatial and numerical (# of caribou) scale that decisions need to be made. A few studies have addressed this problem on large migratory caribou herds. However, how many collars are needed to be representative for a herd will vary seasonally as the seasonal ranges vary greatly in size. We discuss methods and results of three studies relevant to large migratory herds. In Labrador, Otto et al., 2003 determined the number of satellite collars required to successfully mitigate impacts of low jet overflights on the George River herd. Rettie (2008) used computer simulations to evaluate how many collars would be necessary to be 80% confident that distribution would have 90% of the groups during calving or post-calving census surveys. Adamczewski and Boulanger (2016) working on the Bathurst Caribou Herd argued for an increase in the number of collars on the herd to satisfy a number of uses including assessing female survival, and confidently representing winter distribution to aid in harvest management and detecting interactions with development infrastructure.

The small sample sizes of collared caribou are typical of barren-ground caribou monitoring and the consequent low encounter rates restricts relying on only collared caribou for monitoring. The only example we found was designed to address the need for mobile protection areas in the winter and migration ranges of the Bluenose East Caribou Herd (Gunn and Poole 2011). They concluded that the satellite-collared cow locations were, within the scale of their pilot project, relatively predictive of the overall numbers of caribou within the buffer zone and the zone of influence. However, the use of the collars alone without aerial surveys could result in either unnecessary restrictions or loss of protection for caribou. We propose that there needs to be a more rigorously designed research project that adds ground-based surveys to Gunn and Poole's (2011) protocols. In reviewing the project proposal and information requests we note the lack of any clear link between collar location, track surveys and height of land surveys. We also discuss the use of new technology, for example using the VHF collars on the herd by developing innovative ways to monitor movements near the proposed development with the use of towers or drone technology.

Access management is an important issue that has potential impacts with respect to: 1) caribou encounters with development, 2) timing, distribution and quantity of harvest and 3) how caribou may react to human activity. We provide some of our thoughts on Access management and the benefits of a caribou technical Advisory group, providing a sample Terms of Reference as an appendix. We conclude the mitigation section with our perspectives of key knowledge gaps to better mitigate and monitor impacts on caribou:

- Adaptive management
- Habituation and learning
- Stress
- Implications of collective behavior
- Environmental trends and variation
- Linking different scales of abundance monitoring

Habitat management: The Porcupine caribou herd is fortunate in respect to the amount of protected lands within their range, however stronger protection is primarily on calving grounds and summer range. For areas not under some tenure of protection (such as the Eagle Plains), the North Yukon Land Use Plan (NYLUP) has stratified the landscape with respect to sensitivity to caribou and potential for development. The current lease by Northern Cross Yukon falls under Area designated as high potential for development. As a safe guard the Plan also sets thresholds for linear and surface disturbance. In reviewing comments from outside groups the main concern was the elimination of a number of older seismic line (non-forested and likely to have recovered), which dropped the current linear and surface disturbance well below threshold values. Without reducing those seismic line the NCY project would raise current linear and surface disturbance to "cautionary" or "critical" levels with respect to the thresholds. We propose a "verification test" that would determine if the elimination of those lines alters our current knowledge of the Zone of Influence around seismic lines. We also offer a note of caution with respect to habitat protection after the election of Donald Trump and the control of both the Senate and House of Representative in the U.S. A long-standing issue may come to a head with the opening up of the Alaskan portion of the PCH's calving grounds to oil and gas development.

Harvest management: There is a well-developed strategy for Harvest management coordinated by the Porcupine Caribou Management Board. The Board did express concern about new access provided by the NCY project and wished that a better system were in place to track the magnitude and spatial extent of harvest. We provide an example of Agnico Eagle's project in Nunavut and how they were able to quantify the redistribution of harvest after an all season access road was constructed.

Finally we highlight eight recommendations:

1. Creation of a Technical Working Group to oversee the mitigation/monitoring cycle for Northern Cross
2. An appropriate Committee to draw up Best Management Practices for Yukon caribou
3. Need for a data repository
4. Undertake a cumulative effects analysis
5. Project to relate caribou on the ground relative to satellite
6. Monitor harvest in new access through a harvest study similar to Agnico Eagle study or through a revitalized hunter check station along the Dempster.
7. Update analyses to predict fall and winter movements from climate – especially snowfall and estimate the range of natural variation.
8. Validate the exclusion of non-forest seismic from threshold calculations.

2 Introduction

In February 2016, the Yukon Environmental and Socio-economic Assessment Board (YESAB) released its decision on Northern Cross's "Eagle Plains multi-well exploration and development permit." Their decision was essentially that due to knowledge gaps, including impacts on the Porcupine herd and the aboriginal groups that depend on the herd for subsistence needs, YESAB was unable to assess environmental and socio-economic impacts for the project. As a result of this uncertainty the project was referred to the Executive Committee of the Yukon government. Currently that YESAB decision is under a judicial review.

In its decision YESAB identified six issues that would have helped inform their decision:

1. *Access to and use of the PCH by First Nations and the Inuvialuit in relation to the project area and potential zones of influence from project activities;*
2. *The relationship between barren-ground caribou and land use activities, with focus on range utilization in response to surface disturbance and linear density*;
3. *Baseline data to assess cumulative effects and developmental thresholds (e.g. cumulative surface disturbance impacts and potential effects on habitat quantity and quality);*
4. *Cumulative impacts of exploration and development activities on access to and use of the PCH by First Nations and the Inuvialuit*;
5. *Development of Best Management Practices as guidance to oil and gas activities in*

relation to the PCH; and

6. *A process to establish safe operating distances and critical numbers for the PCH.*

Given a number of deficiencies and data gaps that were identified throughout the whole review process, EMR and the Vuntut Gwitchin First Nation (VGFN) felt it important to assemble information available on potential impacts, mitigation and best practices for caribou interacting with oil and gas development.

After follow-up meetings (Oct. 18 and Nov. 21) with EMR and VGFN Lands Branch representatives, we agreed that the focus of the contract would be **"to assess the vulnerability of the PCH to changes in its environment with specific focus on potential oil and gas development on the Eagle Plains."**

While we have focused on assessing the vulnerability of the Porcupine Herd, we have provided information using EMR's list of tasks (Table 1) to guide the structure of the report. We have identified information gaps as well as what we know, and what still needs to be done to mitigate any effects of development.

Table 1: List of tasks identified by Energy Mines and Resources relative to Northern Cross's 2015 Eagle Plains proposal.

Compile and review existing scientific knowledge regarding direct and indirect industrial impacts and focus on barren ground caribou where possible;
Gather information on the expected effects, impacts, and mitigations relative to the Porcupine Caribou Herd's ecology;
Consider differing levels of intensity for each set of activities
Review the YESAB application made by the proponent and the submissions of others during the Designated Office Review or any subsequent YESAB process if the contract is in effect at that time. Particular emphasis will focus on any comments made about the Porcupine Caribou Herd (PCH) and possible mitigative measures.
Review and comment on: • *the specific recommendation of the North Yukon Regional Land Use Plan to determine "safe operating distances"; and* • *the YESAB Northern Cross Yukon 30 seismic program recommendation to determine "significant numbers".* • *Thresholds of caribou abundance for activity*
Identify knowledge gaps in any best management practices that exist, including gaps that will inform BMP development.
Identify and comment on relevant sections of the land use plan and existing PCH conservation management measures that exist within the range of the PCH that may mitigate the proposed drilling program.
Discuss with the Department of Environment's proposed mitigation plan for PCH with

respect to the proposed Northern Cross Project.
Specific questions the Contractor is to consider and address: • *should the drilling be completed in fewer years or over time?;* • *what are the pros and cons of seasonal drilling i.e. summer only versus winter?;* • *what are the suggested BMPs for a herd migrating or residing in the area of activity versus a herd; that chooses to reside within the area of industrial activities?; and* • *what is an effective mechanism or process for meaningful inclusion of affected First Nations and co- management bodies in an adaptive management framework?*

The questions of Best Management Practices and mitigation for caribou are being addressed in different jurisdictions across Canada. Conservation status has prompted the need to conserve caribou habitat in western Canada, which has led to mitigation for oil and gas development. We have referenced as much of the relevant applicable approaches for caribou in the Yukon. The conservation status of boreal and mountain caribou has encouraged the development of Best Practices in BC and Alberta. Yukon's caribou are Northern Mountain caribou, which are assessed as Special Concern except the Porcupine Herd is assessed as barren-ground caribou and in 2016, was listed as Threatened. Industrial development was ranked as one of several interacting threats for barren-ground caribou. Species of Special Concern require a management plan to prevent them from becoming Threatened or Endangered (Environment Canada 2012).

3 A review of scientific knowledge of direct and indirect industrial impacts

We realized that an underlying issue was uncertainty about how information on the Porcupine herd 'fitted' with the 'applied' questions about reducing and managing impacts of development. Thus we organized the information following the structure adopted by the International Panel on Climate Change in assessing vulnerability (to impacts of climate change on the environment) generalized to assess the vulnerability of caribou to industrial exploration and developments (Figure 1; IPCC 2007). IPCC (2007) described Potential impact as a function of the *sensitivity of* a particular system to change (climate and industrial exploration and developments) and its *exposure to* those changes. The capacity to adapt to those changes (Figure 1) is modified by herd and habitat management as well as mitigation of the industrial activity. Monitoring is the feedback between impacts and mitigations (adaptive mitigation).

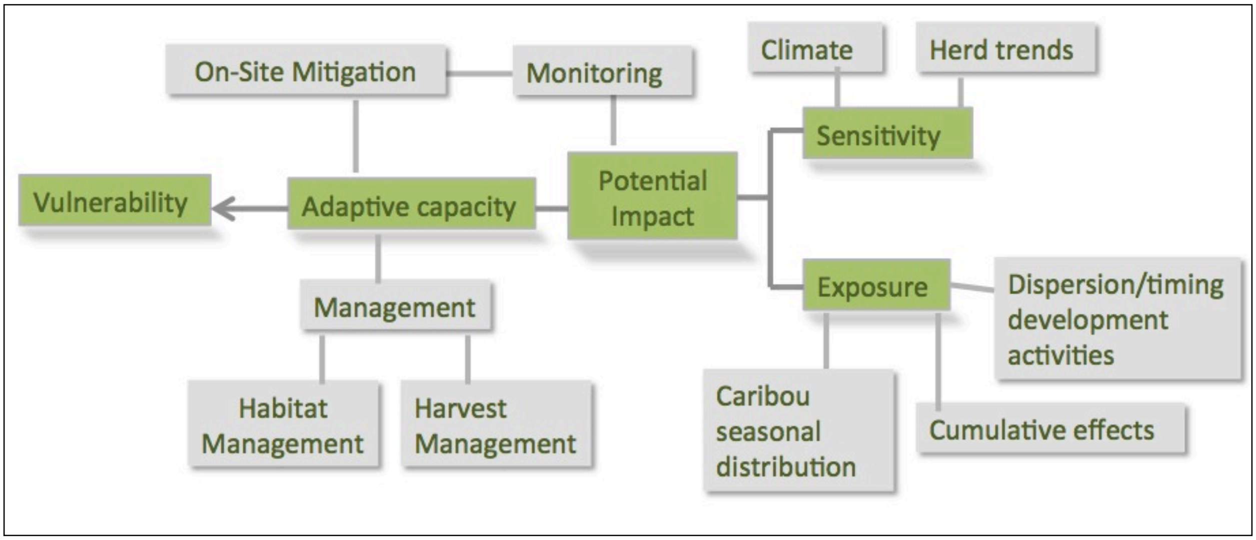

Figure 1 Approach to assessing effects of industrial change on migratory tundra caribou.

3.1 Potential industrial impacts: a review

Potential impacts are the outcome of the exposure and sensitivity of the caribou to an industrial activity such as roads, seismic lines and drilling. By integrating exposure with the sensitivities, in this case, for the Porcupine Herd (Section 5), we can better predict potential impacts and how to mitigate them (Figure 2).

The state of knowledge about direct and indirect impacts of industrial and human activities on caribou is large and varied which reflects the diverse ecology of caribou and changes in techniques and analyses over some 40 years of studies. Reviews are available for the behavioural responses of barren-ground caribou and so we have not repeated them (for example, Bergerud et al. 1984; Wolfe 2000; Stankowich 2008; ABR and Braund Associates 2014). Instead, we summarize what is known about responses of the Porcupine herd to industrial disturbance and findings from recent studies.

3.1.1 Direct Impacts

The theoretical framework for describing direct impacts (Figure 2) is based on that caribou have a similar repertoire of direct responses to people and vehicles as they do to predators (Frid and Dill 2001). The caribou through vigilance and movements minimize the risk of predation even at the expense of reduced foraging. Human disturbance and predation risk indirectly impact caribou survival and reproduction through trade-offs between perceived risk and energy intake from foraging. Information on how caribou reduce their foraging time first came from studies at the Prudhoe Bay oil field, Alaska (Appendix A) where caribou in the vicinity of drill sites reduced their foraging and lying time. When insect harassment was absent, caribou moved faster and spent 25% less time lying and more time standing in the vicinity of the road and pipeline and were the most reactive within 600m (Murphy and Curatolo 1987).

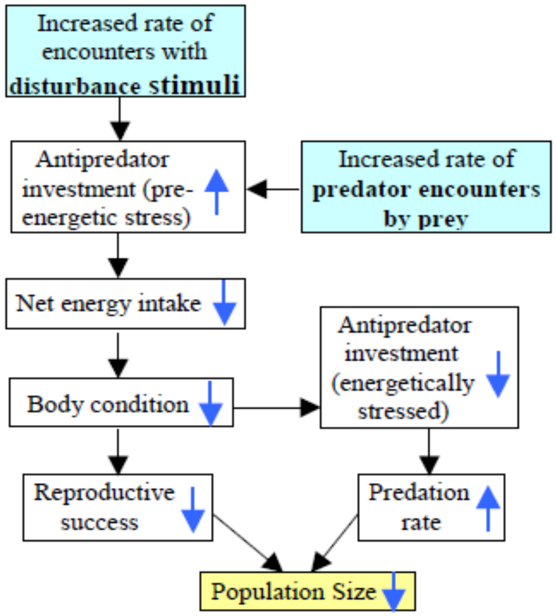

Figure 2 Conceptual model outlining behavioural mechanisms by which increased rates of human disturbance could cause population decline (from Frid and Dill 2002). The blue arrows indicate a positive (up) or negative (down) response.

The duration and frequency of caribou responses partially depends on the intensity of disturbance: for example, Russell and Martell (1985) did not find altered activity budgets (except less sparring) for Porcupine Herd caribou close to the Dempster Highway in fall and winters 1979-81. However, traffic was infrequent as the highway had only officially opened in 1979. The distance from the Dempster Highway at which caribou reacted (to a truck) depended on the truck's speed and if the approach was directly toward the caribou (Horesji 1981).

As well as daily activities, caribou also changed their distribution relative to disturbance. Caribou distribution recorded during aerial surveys was less than expected within 4 km along a recently constructed road in the oilfield on the calving and summer range of the Central Arctic herd (Cameron *et al.* 2005). The avoidance within 4 km of roads was also reported for wild reindeer in Norway (Nelleman *et al.* 2001). However elsewhere, there is variability in the distances at which the caribou avoid the roads (Appendix B summarises findings for boreal caribou). This is similar to findings from Norway where the responses of wild reindeer fitted with GPS collars varied at 1, 5, and 10 km scales (Panzacchi *et al.* 2013a). The wild reindeer's avoidance was strongest for tourist cabins and roads. Boulanger *et al.* (2012) measured a Zone of Influence (a zone with reduced caribou distribution) of 11-14 km around an open pit mine (with haul roads 23 km in length) on the summer and fall range of the Bathurst herd using presence or absence data from aerial surveys.

Increasingly, use of satellite-collared caribou has added to our understanding of responses to roads and traffic including avoidance, deflection and reduced crossing success. For example, Johnson and Russell (2014) used the 27 years of collaring in the Porcupine herd to estimate avoidance distances for the Porcupine herd. The avoidance distance from the Dempster Highway declined from 30km in 1985–1998 to 18.5 km during 1999–2012. However, Johnson and Russell (2014) also noted that the level of industrial exploration had slowed by 1985 and then remained low on the winter range of the Porcupine herd. While the traffic on the Dempster had increased 1994-2008, the fall and winter traffic had remained relatively stable (Figure 3).

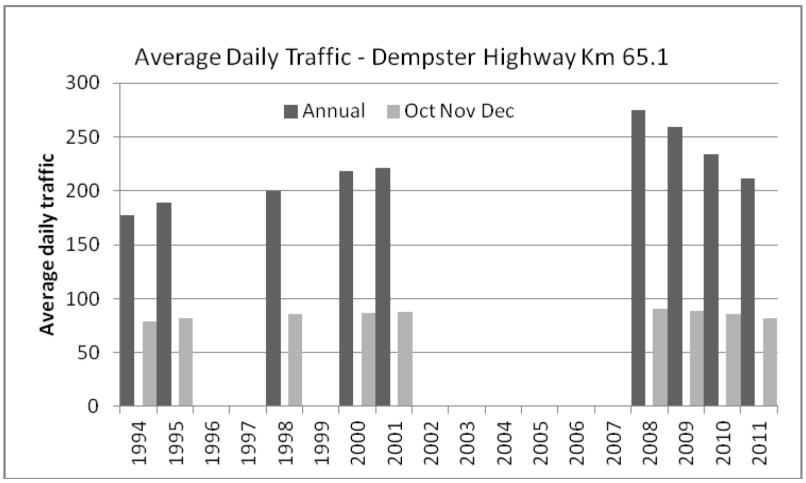

Figure 3 Average daily traffic for the Dempster Highway (downloaded February 2017': www.hpw.gov.yk.ca/pdf/traf2011.pdf)

While Johnson and Russell (2014) measured the distance of reduced density of the Porcupine Herd caribou with respect to the Dempster Highway, Wilson *et al.* (2016) measured the *rate of movement* as caribou of the Western Arctic herd as the caribou approached a mine road. The Western Arctic herd during fall migration approaches the 85 km-long private haul road built for the Red Dog mine (Dau 2015). The road has been in operation since 1989 and haul trucks make about 49 round trips per day (4 vehicles per hour). For most of the length of the road there is no hunting as it is a private road (ABR and Braund Associates 2014, Wilson *et al.* 2016). Wilson *et al.* (2016) report that some caribou slowed as they approached the road and took an average of 33.3±17.0 (SD) days to cross the road compared to 3.1± 5.5 days for normal crossers. After crossing the slow crossers moved >1.5 faster than normal crossers.

In Norway, pregnant wild reindeer were migrating to their calving ground and had to cross a highway with an average of 500 vehicles/day (21/vehicles/h). The cows changed direction and paralleled the road for ca. 5 days before crossing when traffic frequency was lowest after midnight. During fall migration, traffic frequency was lower (12 vehicles/h) and the reindeer crossed the road directly (Panzacchi et al. 2013b). In summer at the Prudhoe Bay oilfield, Murphy and Curatolo (1987) reported that when the traffic frequency was 15 to 32 vehicles/h, caribou crossing success of a road was low (the road was paralleled by an elevated pipeline).

The seasonal exposure and different sensitivity by sex and age class and experience contribute a large part of the variation to the different levels of responses by caribou to industrial development. Another source of variation is how the responses were measured. For example, at the Ekati open pit mine in the Northwest Territories on a 21-km all-weather ore haul road, 55-60% of the barren-ground caribou tracks deflected from the road based on snow tracking (2002-2011). However, based on remote cameras, the deflection rate was 1-2% (ERM Rescan 2014), which likely reflected the field of view of the cameras being different from the area sampled along the road by the track surveys. Further if caribou are typically deflected from crossing a road, they likely would have deflected much further out than remote cameras positioned along the road surface.

The exposure of caribou to industrial disturbance varies with seasonal migrations and distribution. For example, the Porcupine herd is exposed to the Dempster Highway and oil and gas exploration during fall and spring migration and winter (Section 5) and winter distribution annually varies with snow conditions (McNeill *et al.* 2005). In contrast, the Central Arctic and increasingly, the Teshekpuk herds are exposed to oil exploration and development during calving and post-calving. Caribou differ in sensitivity to disturbance during different seasons: for example, Cameron *et al.* (2005) reported that parturient females had stronger avoidance of oil field structures than non-parturient females in the Central Arctic herd (Appendix A). The orientation of the road relative to migration is likely another factor contributing variability. Nicholson *et al.* (2016) using GPS collars did not find the Central Arctic herd avoided the Trans Alaska Pipeline and Dalton Highway during 2003-06 but the fall and spring movements largely paralleled the structures.

Caribou are not only responding to human activities but also the presence of predators as well as forage availability and weather (Avgar et al., 2013, 2015, Hebblewhite and Merrill 2009; Ciuti et al., 2012). Recently, we have started to understand how memory and learning ability affects habitat selection, which adds variability to caribou responses to development (Van Moorter et al., 2009, Oliveira-Santos et al*.,* 2015). Johnson and Russell (2104) raised the question of whether the reduced responses observed were not a reduction in the intensity of disturbance but that the caribou were habituating to the road and traffic. Habituation is the learnt reduction in behavioural responses such as to traffic and roads or off-road vehicles (Colman et al., 2001, Haskell et al*.,* 2006, Reimers and Colman 2006, Haskell and Ballard 2008). Reimers and Colman (2006) suggested that caribou habituate to off-road vehicles travelling on predictable trails. However, mountain caribou exposed to intense snowmobile activity did not habituate (Seip *et al.* 2007). Valkenburg and Davis (1985) noted the greater reaction to aircraft overflights elicited by the Western Arctic caribou compared to the Delta caribou. They concluded that the Delta herd had habituated to aircraft and, for the most part do not perceive aircraft as a threat. The Western Arctic herd, on the other hand, had either not the time to habituate to the sound or perceived every motorized sound as a threat, because snowmobiles were almost always associated with hunting activity in the Western Arctic herd.

Hunting has a strong effect on behaviour and those behavioural responses are complex and animals differentiate between human activities such as hunting relative to predation (Ciuti *et al.* 2012a and b). Elk's individual experience and learning also allowed them to adjust habitat selection relative to the risk of hunting (Thurfjell *et al.* 2017). The advances in understanding how elk behave relative to hunting, predation and roads predicts that memory and experience likely play a role in caribou behaviour and leadership. Caribou are typically in social groups, which influence their responses to disturbance as their behaviour affects each other. Probably, only a few individuals set the direction and pace of migration and respond to the roads and the other caribou in the group follow them (Johnson and Russell 2014; Wilson *et al.* 2016). This is also the underlying premise for the concept of 'let the leaders pass' which has been PCMB's management approach to hunting along the Dempster Highway (Padilla 2010).

We currently are aware of three examples where hunting may influence caribou responses to a road and traffic. The first example is the Porcupine herd and the Dempster Highway (Section 6.3). The reduction in the Porcupine caribou's avoidance distance may be due to a decline in hunting level 2000-2012 (Johnson and Russell 2014). Surrendi and DeBock (1976) reported that the Porcupine herd caribou were more responsive to traffic on the Dempster Highway when it was associated with hunting activity. The caribou's exposure to hunting would have changed as hunting access changed through different "no-hunting" corridors and 'letting the leaders pass' policies (Padilla 2010). The avoidance of well sites and seismic lines also declined during the same two periods from 11km to 6km in 1985–1998 and 1999–2012, respectively which may also have been the result of natural vegetation recovery (Johnson and Russell 2014).

The second example of hunting affecting response to roads is on the fall and winter range of Leaf River herd, the caribou's fall migration brings them to a major all-weather road with traffic mostly related to hydroelectric infrastructure, but the road is a focus for sport hunting during fall and winter (Plante *et al.* 2016). Landscape characteristics better explained caribou vulnerability to sport hunting than habitat selection of caribou and hunters, or their co-occurrence. Caribou were more vulnerable if close to hunting infrastructures (e.g., roads, outfitter camps) than elsewhere, but caribou strongly avoided the road. Most harvest sites were within 10 km of the nearest road, but caribou were 7 times more likely to be harvested a few meters from a road than at 10 km from it.

The third example of the interaction between hunting and responses to road traffic is preliminary and awaiting a more detailed analysis. An all-weather road to connect an open pit mine to the community of Baker Lake was opened to hunting from all-terrain vehicles and subsequently the satellite-collared caribou appear to be deflected from the road by 2015 (Agnico-Eagle 2015).

We have described how caribou respond at different distances to disturbance and the responses are variable and the reasons may be complex and interacting at different scales. Four issues stand out as where our knowledge is inadequate for describing direct impacts.

(i) Avoidance of roads and traffic is measured for some herds but the underlying mechanism is uncertain, raising questions about how to design mitigation. The behavioural responses (changes in movements) to traffic do not appear to be the only mechanism given the distances over which avoidance occurs. While learned behaviour including memory is a likely mechanism, there also may be habitat changes. The avoidance of open pit mines (about 15 km) and their associated roads coincided with the extent of changes in lichen chemical composition consistent with fine particle dust deposition (Rescan 2011,Boulanger et al., 2012).

(ii) The extent to which hunting interacts with the responses to road traffic and increases the responsiveness is uncertain which reduces the predictability of caribou responses to oil and gas and appropriate mitigation

(iii) While behavioural observations can be used to measure the responsiveness of caribou, the observations are not integrated with the movement rates and directions of caribou fitted with satellite or GPS collars. Integrative studies could lead to adaptive monitoring such as the utility of creating predictable gaps in traffic for caribou to cross the roads. Integrative studies would also address gaps in describing responses to differing levels of intensity for the different disturbance activities such as traffic frequency or spacing of seismic lines

(iv) We lack studies with adequate sample design to describe barren-ground caribou behavioural responses to the sequences of seismic lines, drilling or extended flow testing which is essential to be able predict responses to exploration.

3.1.2 Indirect impacts

Habitat: Indirect impacts from oil and gas exploration and development have been most studied in boreal forests. The indirect impacts are sufficient that fears about declines and oil and gas development have been realized for boreal and mountain caribou in Alberta and northeast BC, as seen in their declining status (COSEWIC 2014). Comparing the amount of modified boreal forest to the rate of change in boreal caribou abundance has led to thresholds for habitat loss and rates of linear features on the landscape.

Boreal caribou ecology differs from migratory tundra caribou in the scale of migratory behaviour and the extent of gregarious (collective) behaviour, which likely plays a role in determining impacts of oil and gas development. Boreal caribou group size is typically < 50 animals, with the smallest group size during calving and the largest during the rut and winter (COSEWIC 2014). Boreal caribou use relatively small home ranges: average movement was 37-53 km between winter and summer range in the Ontario Shield Ecozone (COSEWIC 2014). Boreal caribou adapt their behavioural decisions over time of day to compromise between risk avoidance (predation or disturbance) and their forage requirements to balance their survival (Beauchesne *et al.* 2013).

The indirect impacts that reduce boreal caribou abundance appear to be changes to predation rates on caribou, as seismic lines, roads and drill camps remove the original habitat and then the subsequent plant succession benefits moose and deer which in turn supports wolf predation as the roads and seismic lines also favour movements of wolves (COSEWIC 2014). Avgar *et al.* (*2015*) analysed movements of GPS collared caribou every 5 hours and described how the caribou sense their vicinity and use their spatial memory. Individual variation was high but 30% of the caribou avoided both wolves and moose habitat because the greater risk of exposure to wolves in the moose habitat.

Energy costs: Behavioural responses such as being alert and moving away from perceived risk reduce time spent foraging and cost the caribou energy, and if the responses are frequent enough, the caribou's body reserves are reduced. For a nursing cow, a reduction in body reserves translates into smaller fall going into winter and a reduced probability of pregnancy. Thus these are the links between the behavioural responses to herd productivity and changes in caribou herd size (summarized in White *et al.* 2014).

The relationship between forage intake, behavioural responses and their energy cost led to a quantitative approach to estimate the cumulative costs of the behavioural responses (Russell 1976). The Porcupine Caribou Technical Committee in 1988 laid the groundwork when they requested computer simulation models. The models were to "aid in evaluating present data, help guide future research, and provide some insights into the potential impact of alternate development scenarios" (Kremsater *et al.* 1989). Consequently, researchers determined estimating the chances of a cow becoming pregnant relative to the cow's responses to disturbances (Hovey et al., 1989; Kremsater et al., 1989; Whitten et al., 1989; Murphy *et al*., 2000, Russell et al., 1996, White et al., 2014).

Initially, the models focused on oilfield development on the Alaskan North Slope (Murphy et al., 2000) including for the Porcupine herd (http://www.pcmb.ca/resources) but subsequently was applied to project direct impacts of open pit mining on migratory tundra caribou (Russell 2014a, b and c). The model uses measureable differences in activity patterns due to disturbance within about 500 m from the source of disturbance. Those differences based on observations are a reduction in foraging time of 6%; an increase walking and running by 3 %; and a reduction of their eating intensity by 3 % due to vigilance behaviour (i.e., reducing the per cent of the foraging period spent actually ingesting food). Those reductions while seemingly small can add up to reduce the amount of weight that caribou gain (White 1983; Section 5).

3.2 Potential Impact Summary

Potential impacts are the outcome of the exposure of the caribou to an industrial development and their sensitivity to environmental changes. Our review of potential impacts covers the spatial gradient from caribou standing alerted by a road watching trucks to caribou changing their movement's kilometres away from a road or drill site. We identify what is known about the mechanisms that explain how small changes in caribou behaviour can accumulate to reduce their productivity. We describe how caribou are integrating their responses to disturbance with changes in habitat caused by oil and gas exploration and a cascade of changes including increased predation. Caribou respond to disturbance in a similar way as they do to predators by avoidance and flight and selecting habitat to minimize their risk of exposure to risk. A gap in our knowledge about potential impacts is the role of memory and learning which allows caribou to save energy by responding less (habituation and tolerance). We review specifically the potential impacts based on studies on the Porcupine Caribou herd. We identify four issues stand out as where our knowledge is inadequate for describing direct impacts.

- Avoidance of roads and traffic is measured for some herds but the underlying mechanism is uncertain, raising questions about how to design mitigation.
- The extent to which hunting interacts with the responses to road traffic and increases the responsiveness is uncertain which reduces the predictability of caribou responses to oil and gas and appropriate mitigation.
- While behavioural observations can be used to measure the responsiveness of caribou, the observations are not integrated with the movement rates and directions of caribou fitted with satellite or GPS collars.
- We lack studies with adequate sample design to describe barren-ground caribou behavioural responses to the sequences of seismic lines, drilling or extended flow testing which is essential to be able predict responses to exploration.

4 Expected impacts, and mitigations relative to the Porcupine Caribou Herd's ecology

We broadened the approach based on vulnerability of ecosystems to climate change (Figure 1) to the PCH and included environmental changes with oil and gas development in the context of cumulative effects (Figure 4). The "sensitivity" of caribou is determined from past trends in herd size and vital rates, functional responses between body condition and pregnancy rates, and climate trends. Sensitivity of the PCH is further assessed in comparison to other migratory tundra herds. "Exposure" focuses on caribou seasonal distribution and how they interact (through encounter rates) with project-specific (e.g. Northern Cross) and cumulative development. Sensitivity and exposure are a basis to determine potential impacts on caribou. Ideally this assessment will be quantitative (preferably at the herd level) rather than qualitative. Potential impacts can be ameliorated by built-in adaptive capacity within the system. Thus habitat and harvest management can offset impacts while adequate project-specific mitigation can reduce impacts of the project on the productivity of the caribou herd. Further, by developing a monitoring program to assess the effectiveness of the mitigation program, we can implement an adaptive management approach, to improve mitigation. At the end of the process the "vulnerability" of the herd can be assessed. Thus this section on the Porcupine herd is based on the IPCC assessment approach (Figure 1) with how topics highlighted in red boxes (Figure 4) link to the primary components.

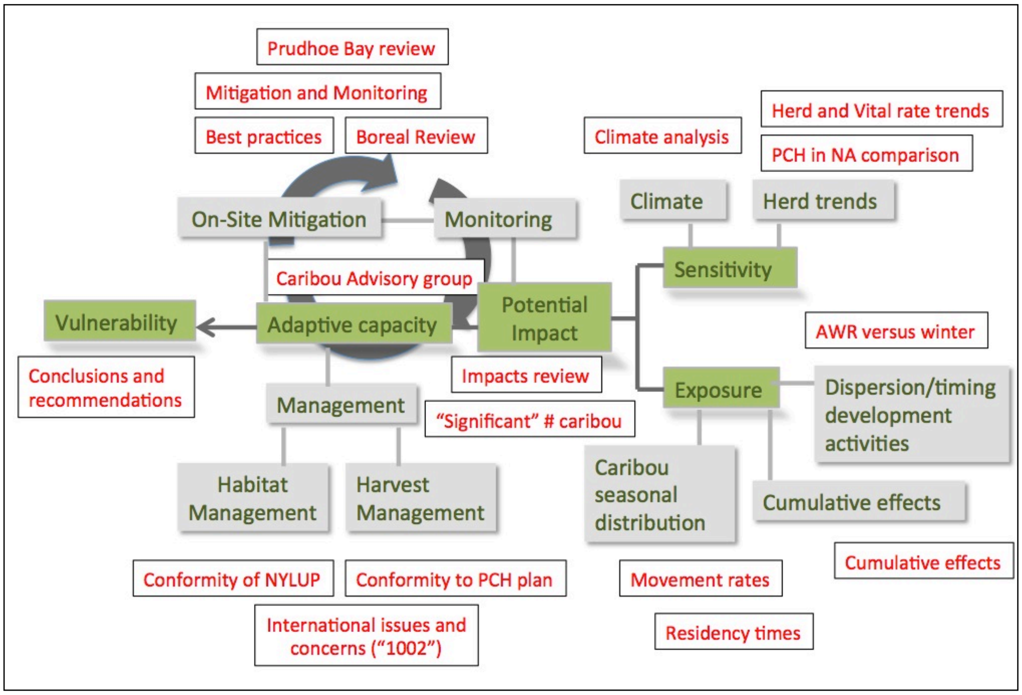

Figure 4 Topics discussed in this report (in red) linked assessment components.

5 Sensitivity

5.1 What is Sensitivity?

Sensitivity is the degree to which caribou are affected, either adversely or beneficially, by changes in their environment. For example daily warmth especially in June affects the amount of plant growth, which in turn affects the caribou productivity, and impacting how they respond as individuals and herds to industrial development. A cumulative effects analysis for the Bathurst herd (Figure 5) shows how the loss of caribou is highest when plant growth is low.

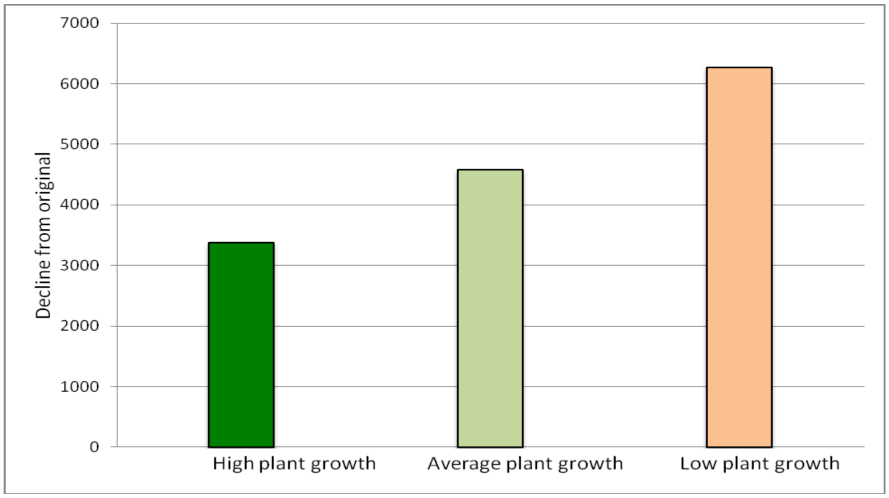

Figure 5 Relative decline in the Bathurst caribou herd under 3 scenarios of early summer plant growth (Russell, unpub).

Migratory tundra caribou evolved strategies to enable them to buffer environmental change to survive. From an evolutionary point of view, those strategies offer clues to energetic bottlenecks, largely reflecting seasonal environmental conditions that are both adverse and unpredictable. A good example is fall back fat. Caribou store fat reserves to offset periods of negative energy balance. Thus herds that typically put on large back fat reserves in the fall either have one or more combinations of adverse winter conditions: 1) deep unpredictable winter snow; 2) homogeneous landscapes with few options to distribute away from adverse snow conditions; or 3) typically poor or unpredictable food resources. Among herds with comparable data, the PCH deposits the least back fat by fall (Figure 6)

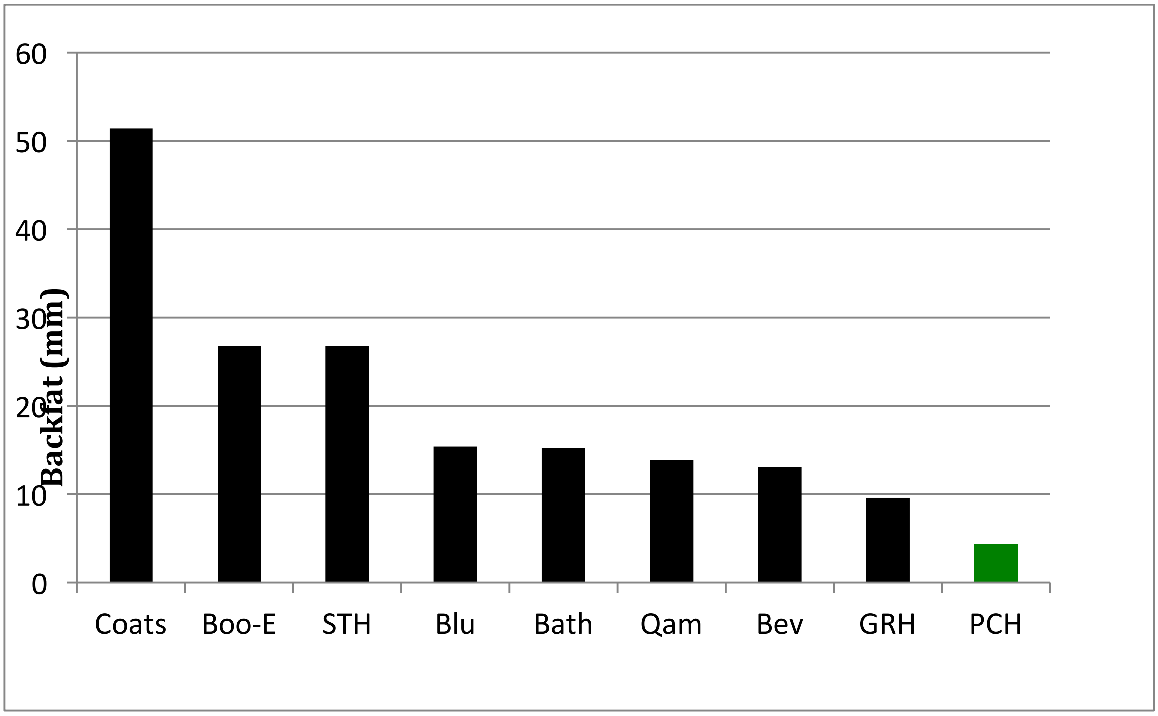

Figure 6 Fall back fat for North American arctic caribou herds. (Boo-E- Boothia East, STH – Southampton, Blu Bluenose East, Bath – Bathurst, QAM – Qamanirjuaq, BEV - Beverly , GRH – George River Herd, PCH - Porcupine Caribou;)

Low back fat deposits have both positive and negative implications with respect to potential impacts of oil and gas development. On the one hand, we have some confidence that fall, winter and spring conditions for the PCH are good compared to other herds. However having evolved to not physiologically prepare for adverse conditions during these seasons, individuals may have lower tolerance for "new adverse conditions" such as disturbance and displacement from oil and gas development.

5.2 Trends in herd productivity

The PCH population trend has been estimated from photographing post-calving aggregations since 1972 when the herd was estimated at 100,000 animals. The herd then increased at 4% per year until reaching a peak in 1989 (178,000). From 1990-2001 the herd declined at about 3.5% per year estimated at 123,000 in 2001. The herd was not counted again until 2010 when 169,000 were estimated. The last survey in 2015 was 197,000, the highest recorded from this herd in five decades. However, reports from harvesters through the Arctic Borderlands Ecological Knowledge Co-op (Russell and Svoboda, in prep.) may hint that the herd is at its peak as caribou "size" is declining, which is known to precede a peak in herd abundance.

Estimating calving location, parturition rate and early calf survival is based on a sample of collared females. On average 81% of the PCH cows give birth annually and on average 72% of the calves survive the first month. There is a strong relationship between early calf survival and forage as indexed by the growing degree days June 20 on the calving grounds (Russell, unpublished). By spring, composition counts indicate that approximately 35 calves per 100 cows are present at the onset of spring migration. During the decline of the herd adult cow mortality was estimated at about 16-18% annually compared to less than 10% during the increase phase. Adult cow mortality is the most important determinant of PCH herd productivity.

5.3 Trends relative to other North American Herds

Herds across North America are declining following almost universal increases in the 1970s and 1980s. The Porcupine herd was one of the earliest herds to reach its peak in 1989 and then began to decline. Generally herds in the NWT and Nunavut began to decline in the mid 1990s and are currently still declining or are stable at very low numbers. However the PCH was the only herd that began another increase phase in the 2000s, and all other herds continue to decline or remain at very low numbers. Further Figure 7 shows that even in decline the PCH dropped only 35% from peak numbers compared to as high as 98% in herds east of the Mackenzie River.

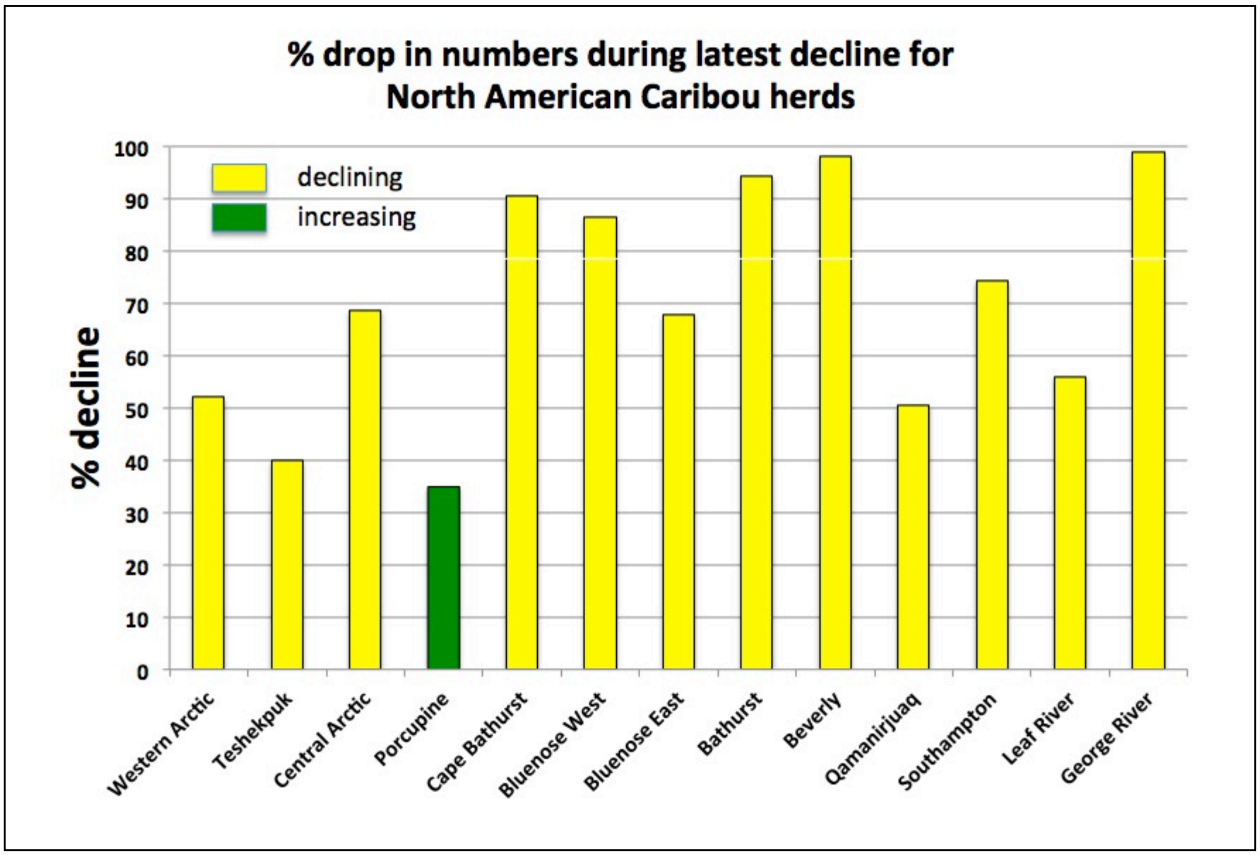

Figure 7 Per cent decline during most recent declines in North American herds. Bar colour represent current status of the herd (green increasing; yellow declining or stable).

From our research an interesting difference between the PCH and herds to the east is the functional response between probability of getting pregnant and relative body weight (Russell et al in press). In the fall, the body condition of the cow indicates the probability of getting pregnant. Figure 8 gives us 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. The figure was generated by the CircumArctic Rangifer Monitoring and Assessment (CARMA) Network body condition database and each curve was significant ($p<0.01$). We interpret the curves to indicate how resilient the herd is to change (steepness of the curve) and how potentially productive the herd could be. 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).

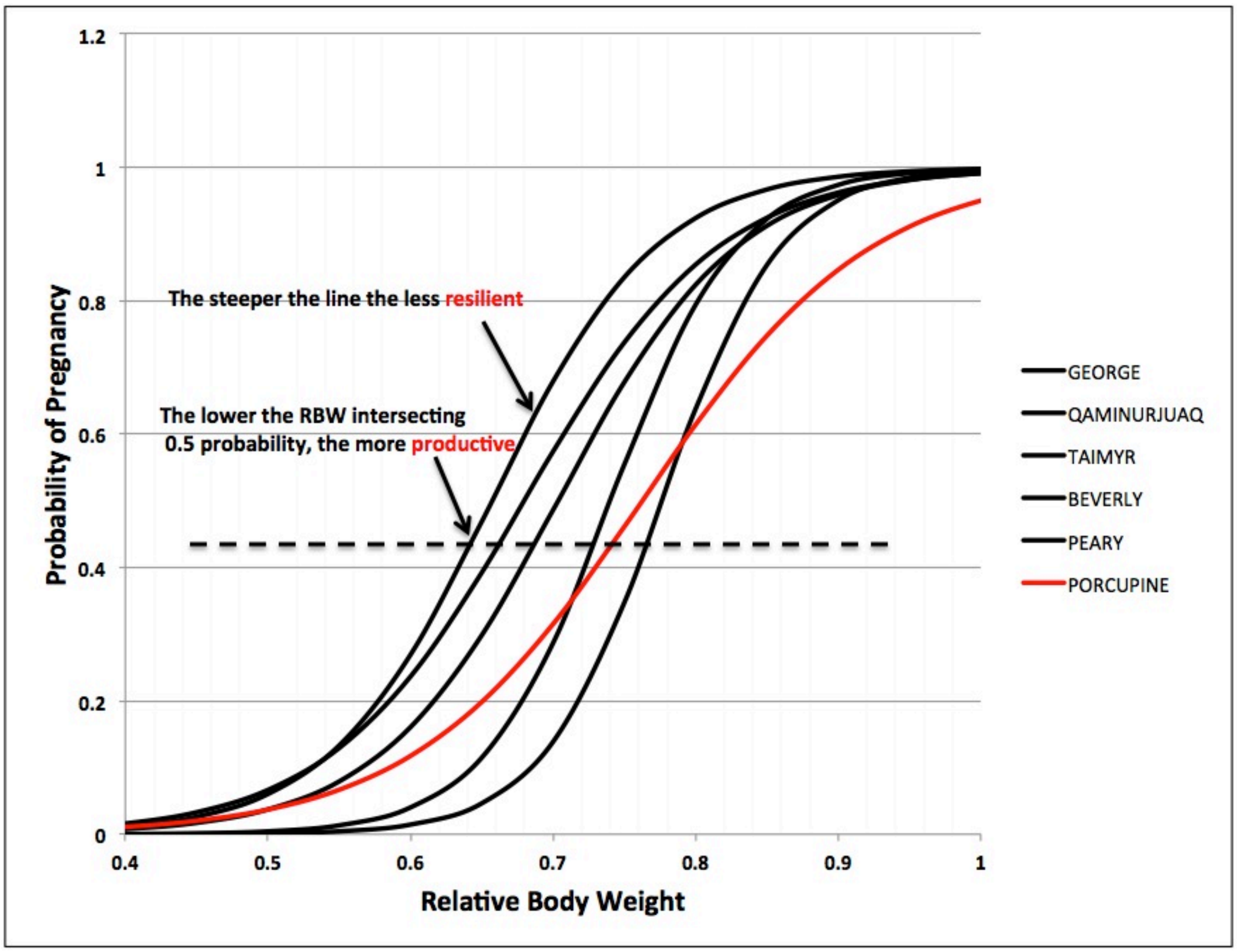

Figure 8 The probability of pregnancy versus relative Body Weight for North American herds. Black dashed line delineates 0.5 probability of getting pregnant.

5.4 Climate within PCH range relative to other North American Herds

In comparison to migratory tundra herds across North America (Figure 9), the PCH experiences warm early spring conditions (high June 10 growing degree days); cool moist summers, resulting in low drought conditions; and relatively deep snow accumulations in winter. Spring snowmelt is average. From these conditions, we would expect early green-up where calving cows have access to nitrogen-rich forage when demands for milk production is high. The cooler moist July conditions indicate that plant phenological changes would be slow and plant senescence delayed, again making higher digestible forage extend later in the season. Compared to the migratory tundra herds on the Canadian Shield where topography is relatively homogeneous, the PCH's summer and winter ranges are topographically diverse with much younger geological formations. Thus during winter, although snow depths are on average higher than eastern herds, the dissected terrain means that regions and landscape feature (e.g. ridges) with lower snow accumulations are available when deep-snow winters occur.

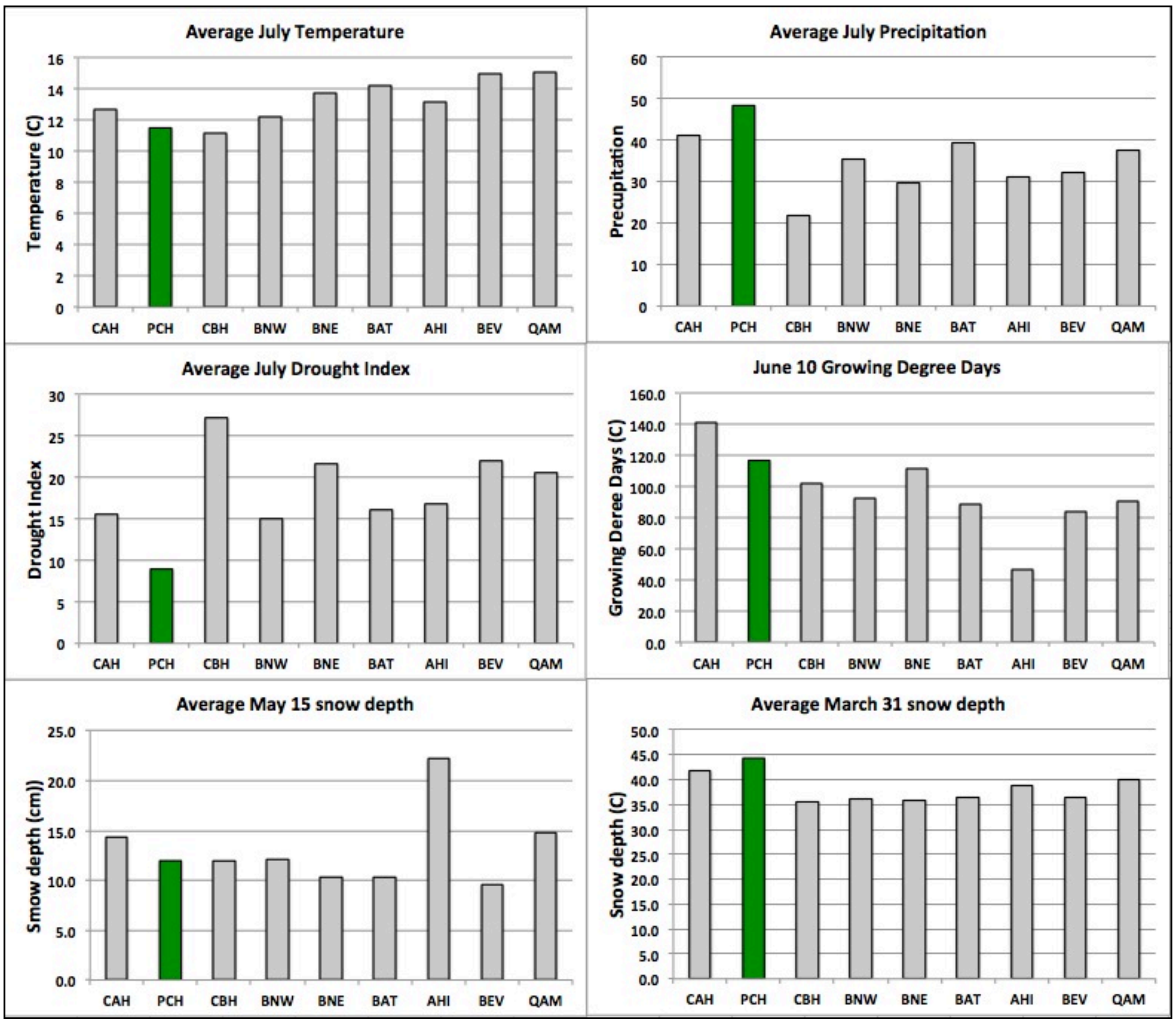

Figure 9 Average climate conditions for North American Herds. (CAH-Central Arctic; PCH - Porcupine Caribou; CBH - Cape Bathurst; BNW - Bluenose West; BNE - Bluenose East; BAT - Bathurst; AHI - Ahiak; BEV - Beverly; QAM – Qamanirjuaq (source: CARMA Climate database – see Russell et al., 2013).

5.5 Sensitivity Summary

The increase, decline and increase of abundance for the Porcupine herd recorded since the early 1970s is characterized by relatively low rate changes (-4% to +4%). The herd trend appears to strongly correlate to adult cow mortality, as pregnancy rate remained relatively stable throughout the population cycles. At the physiological level, the PCH accumulates the lowest fall back fat among herds with comparable data. One interpretation is the herd has evolved with a relatively favourable winter environment either because of: 1) availability of favourable snow conditions either from lower snowfalls or a diverse topography so caribou can space away from adverse snow: or 2) an overall predictable winter environment. The probability that a cow will get pregnant follows a sigmoidal relationship with fall body weight. Both the steepness of the curve and the relative weight that is associated with a 50% chance of getting pregnant has been suggested to relate to the vulnerability (the steeper the more vulnerable) and the productivity (the lower the relative weight the more productive). Among herd with comparable data, the PCH is one of the least productive but is also the least vulnerable, suggesting that it will never increase or decline dramatically and never "erupt" to high population densities. A caution however is that as the herd declines, the likelihood or rate of any recovery may be compromised if climate or anthropogenic changes become significant in their environment.

In comparison to migratory tundra herds across North America, the PCH experiences warm early spring conditions (high June 10 growing degree days) and cool moist summers, resulting in low drought conditions and relatively deep snow accumulations in winter. This suggests a prolonged plant phenology profile, higher quality summer forage, and lower mosquito and oestrid fly harassment indices. Winter snow depths are relatively high compared to other herds but the diverse terrain allows the herd to seek shallower snow area during bad winters.

Thus with respect to the adverse potential impacts of human activity, we speculate that the Porcupine Herd has evolved in a favourable environment resulted in larger calves but low winter reserves. Thus with low inherent productivity, the introduction of significant industrial activity could, without dramatically affecting pregnancy rate or cow mortality, prevent the Porcupine herd from recovering during a decline phase or significantly reduce the rate of increase during population expansion. Further documented climate trends may reduce the predictability of favourable environmental conditions.

6 Exposure

6.1 What is Exposure?

It is important to quantify exposure to changes in a caribou herd's environment, whether natural or man-made changes. This can be a climate trend, a road or a tourist lodge and ultimately the cumulative changes throughout the range of the herd, whether socio-economic or environmental. Migratory tundra caribou exposure to oil and gas exploration occurs where sedimentary basins with potential or proven oil and gas reserves underlie the annual ranges of the herds west of Great Bear Lake (Cape Bathurst, Bluenose West and East; Porcupine, Western

Arctic, Teshekpuk and Central Arctic herds). Only the Prudhoe Bay oilfield is developed (APPENDIX A). Baseline information about responses to oil and gas development was compiled for proposed pipelines in the early 1970s and again in the 2000s along the Mackenzie River corridor (Joint Review Panel Report of Environmental Review 2010). The Mackenzie Valley is the eastern and western edge of the annual ranges of the Porcupine and Bluenose West and East herds. Although oil and gas exploration occurred on the winter ranges of the Bluenose West herd in the early 2000s (INAC 2016), studies were not undertaken.

Alaska coastal caribou ranges are within lands designated for oil and gas leases but not yet explored or developed fields (National Petroleum Reserve-Alaska). The exception is the Central Arctic herd, which calves partially within intensively developed oil fields (NRC 2003). The Porcupine herd calves and summers on lands of as yet undetermined tenure (oil and gas development or wilderness). The northeast corner of Alaska was set aside as ANWR in 1960 as a wilderness area, except for the coastal plain. In 1980, Congress in Section 1002 directed the "coastal plain" (hence the 1002 area) be studied as to whether it should be designated as wilderness or opened for oil and gas leases (Corn et al., 2006, BLM 2012).

At the individual herd and caribou level, we can measure exposure through seasonal and daily movement patterns based on the use of satellite and GPS collars. This allows us to measure seasonal exposure and how long caribou spend in the vicinity of a project. In this section, we will first examine the exposure to the PCH from the proposed well drilling program of Northern Cross Yukon (NCY). We reviewed NCY environmental impact analysis and soon realized the analysis was too superficial to allow us to adequately assess potential exposure of the PCH to the NCY proposed development. Thus we conduct specific analysis that allow us to better understand and quantify potential impacts and to provide information needed to make decisions with respect to mitigation and monitoring. Next, we looked at climate trends for this region of Eagle Plains and discuss possible implication of future exposure to the NCY project area. Finally, we outline a possible cumulative effects assessment approach to integrate exposure to movement patterns, energy protein dynamics and to population productivity.

6.2 Northern Cross (Yukon) Ltd. proposed project

The Northern Cross proposed program is within the fall, winter and spring ranges of the PCH. The project descriptions adequately address likely interactions between the NCY project and the PCH, although the state of the current data analysis does not allow us to quantify impacts. To provide more information than was available in the proposal, information requests and public comments, we used GPS and satellite collar data from April 1985 to January 2016 to develop needed exposure related indicators. Our goal was to create datasets that could, in the future, quantify the PCH exposure to the NCY project and that could be used to translate to population level impacts. We took a similar approach on Baffin Island (Russell 2014a) and within the range of the Qamanirjuaq herd (Russell 2014b) and are further developing the approach for the Bathurst Caribou Herd (Russell et al., 2015). For a detailed treatment of our cumulative effects assessment approach see Section on "Cumulative Effects".

6.3 Path analysis

6.3.1 Caribou distribution

The number of satellite collars available varied among years (Figure 10), peaking at 45 in 2015. Although data for 2010 exists, for some reason, they are missing in our database. The absence of collars in 1996 is because there were no collars. It is important to note that earlier satellite collars tended to document course scale movements (providing location data more on a weekly scale than a daily scale), thus interpolating a daily location is much less exact than that available with current GPS collars.

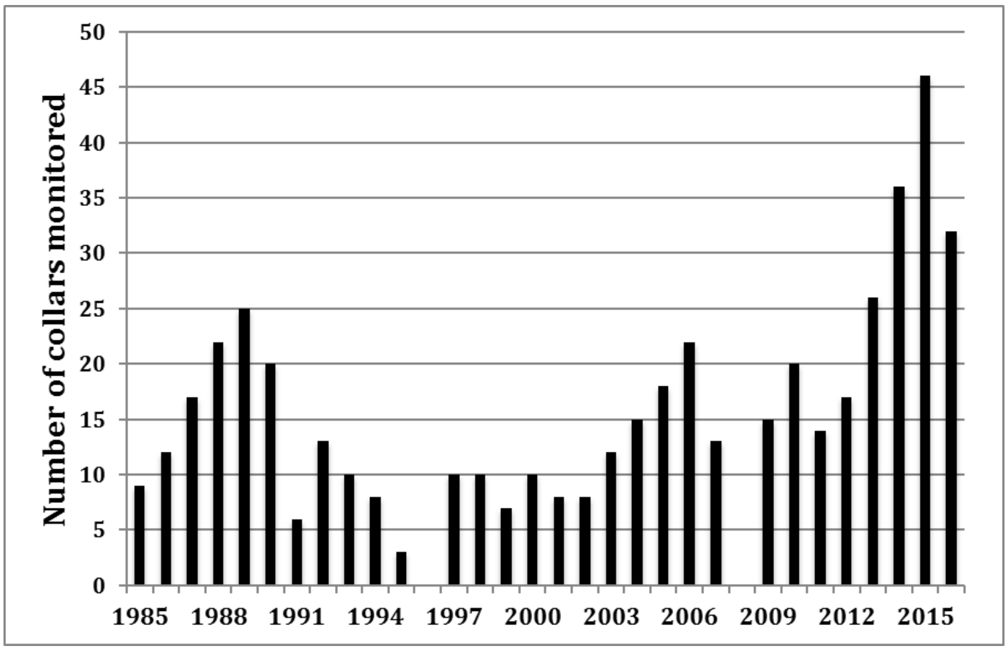

Figure 10: Maximum number of collars monitored between April 1985 and January 2016.

We created a 30-km buffer around the proposed NCY well sites and access roads. Thirty kilometres was chosen as most interveners and the company felt that the first early warning indicator of caribou getting closer to the development site was if a collared caribou was located within 30 km. Figures below illustrate all collared caribou paths (shortest line between two consecutive locations) from April 1985 to Jan 2016 in the whole range (Figure 11) and within the 30-km buffer (Figure 12). In all 59,157 paths were drawn and of those only 1.3% (774) were within or intersected the 30-km buffer zone. The NCY buffer zone is in the southeast corner of the PCH annual range. More than 500 of those paths were recorded in the fall and winter of 2015-2016. Figure 12 does illustrate that paths are not randomly occurring in the buffer zone with the vast majority of paths north and west of the Dempster Highway. The dense linear path concentration just north of the highway was from the winter of 2015-16. Paths outside of the buffer zone are visible as very light coloured lines.

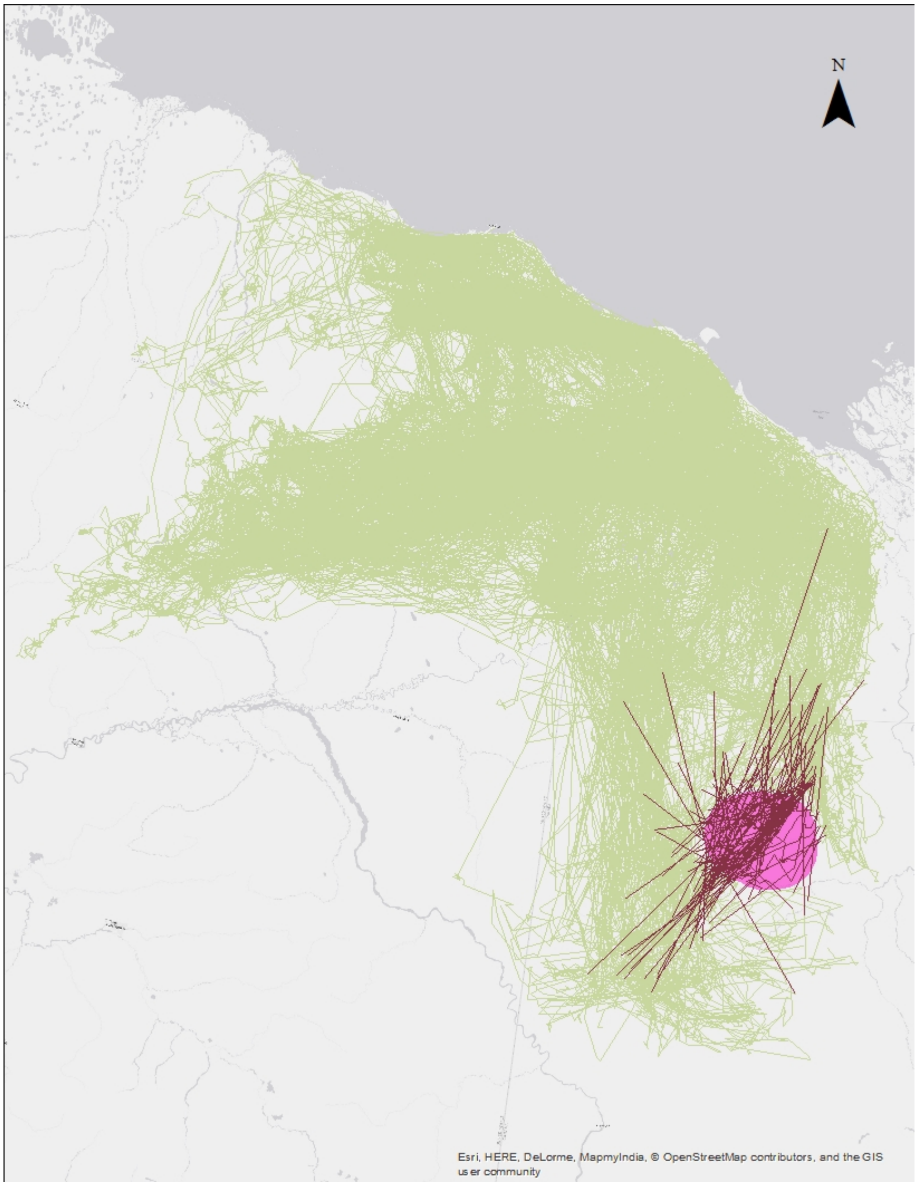

Figure 11 Movement paths of the PCH from 1985-2016. Purple zone is 30-km buffer around NCY proposed infrastructure. Brown paths intersected or fell entirely within the 30-km buffer.

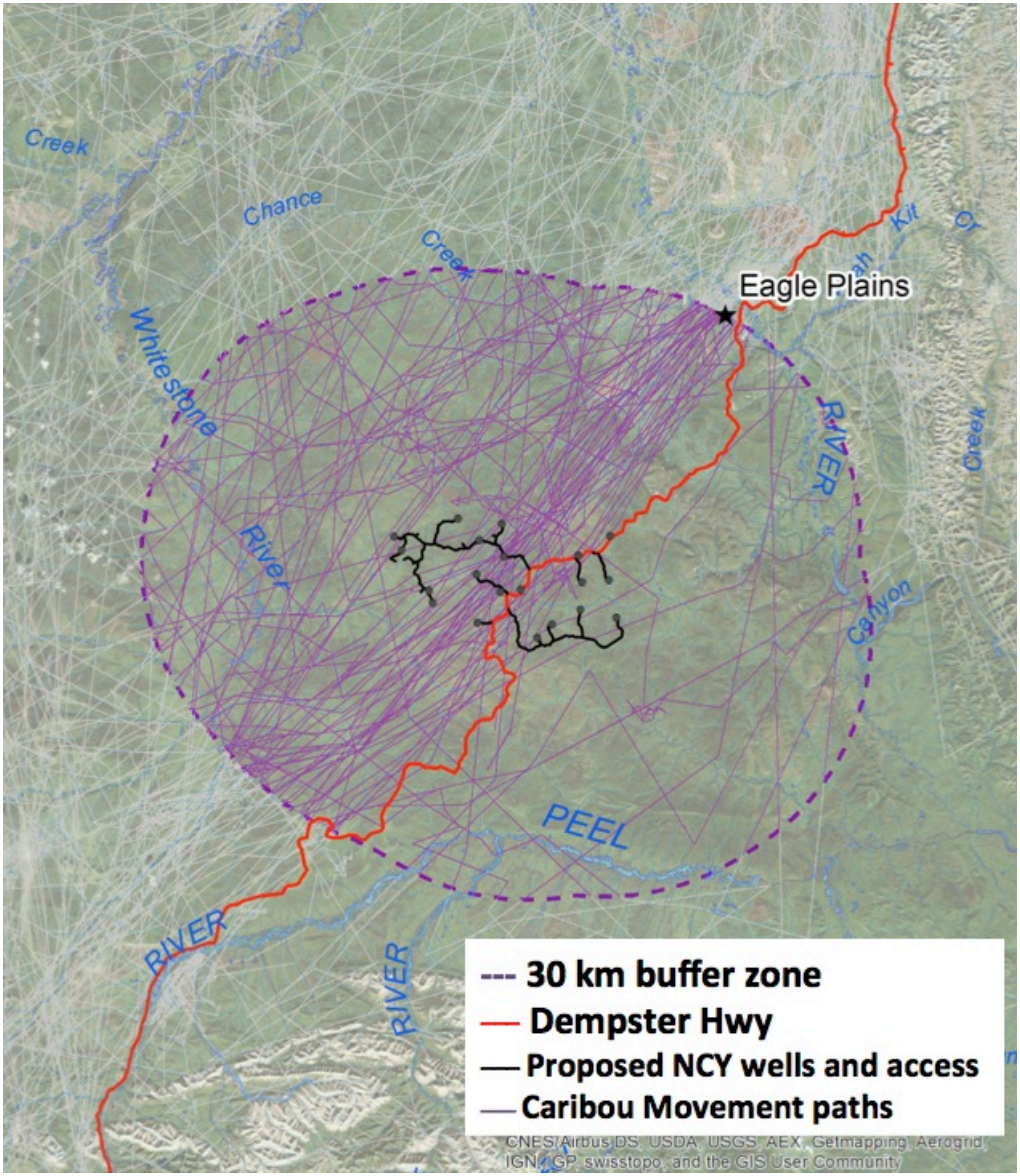

Figure 12 Movement paths that intersected a 30-km buffer around NCY proposed project infrastructure 1985-2016

6.3.2 Timing and degree of use of the 30-km buffer zone

To calculate the monthly per cent "use" of the 30-km buffer zone, we divided the number of paths that intersected or fell within the buffer zone by the total number of paths for a given month and year to overcome the annual differences in number of collars available and frequency of relocation fixes (Figure 13). Caribou are most frequently found in the buffer zone in October and least in May. The average per cent use shows a similar pattern although December had the highest per cent use. However, the very high use (48%) occurred in the winter of 1990-91 but that was when there were few collars being monitored. In recent years, the highest collar use of the buffer zone was the winter of 2015-16 in that 18% of all October movements occurred in the buffer zone, which would represent more than 36,000 animals.

Caution should be used in interpreting the results, especially for years when the total number of collars (Figure 10) was so low that we cannot confidently conclude the collars adequately represented the herd. A good example is the high per cent use of the buffer zone in the winter of 1990-91 (Figure 13). The maximum number of collars monitored from October 1990 to March 1991 was seven collars. Coincidentally the senior author captured 60 caribou in the spring of 1991 using Eagle Plains as a base and noted many caribou in the Eagle Plains area. This does make the point that other knowledge such as harvesting and local knowledge of caribou distribution can be used to build a picture of annual exposure of caribou.

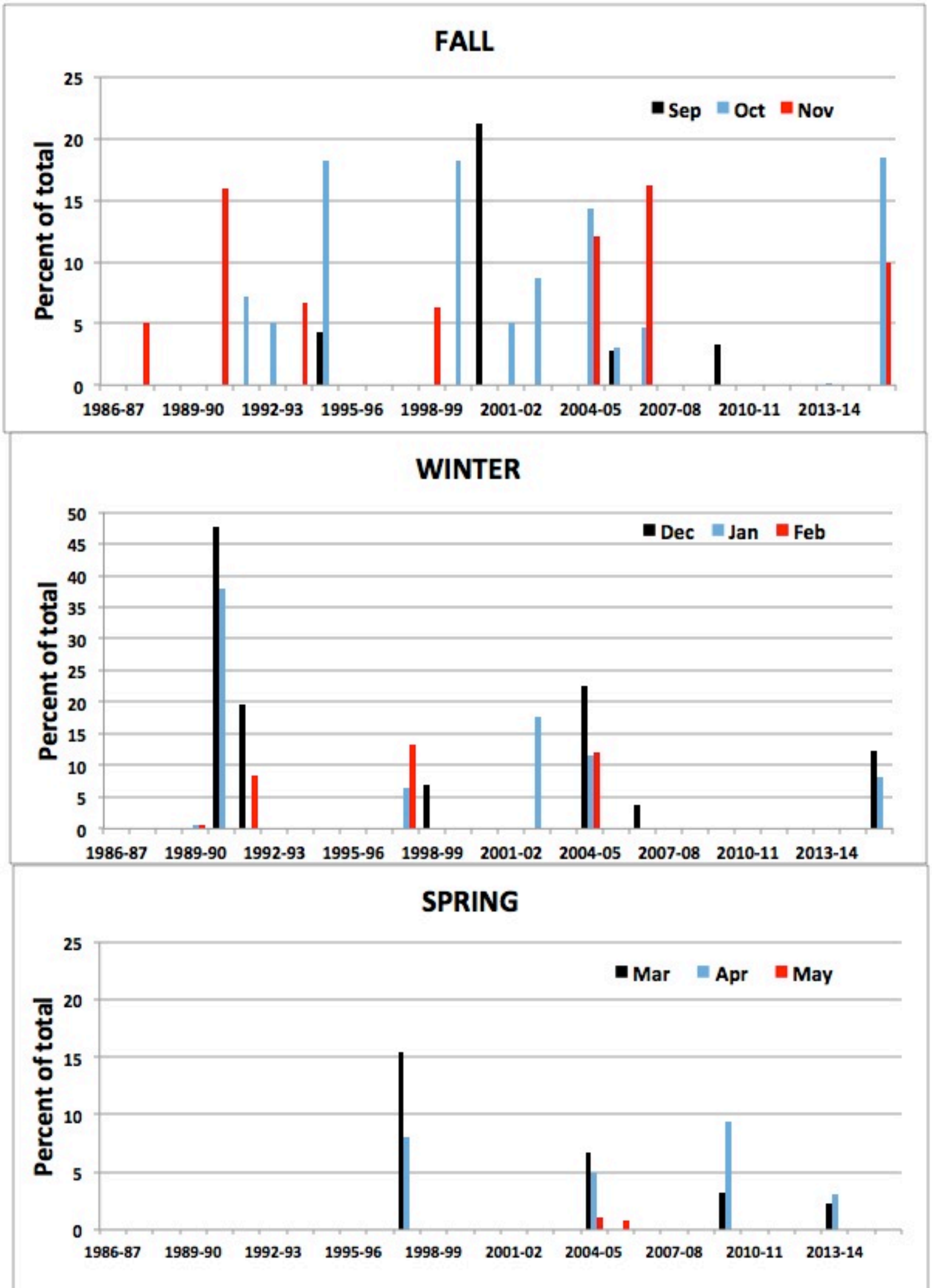

Figure 13 Per cent of total paths that intersect a 30-km buffer around proposed NCY infrastructures in fall, winter and spring.

Figure 14 summarizes the use of the 30-km buffer zone with respect to the per cent of years collared caribou are found in the zone (Figure 14A) and the average monthly per cent use of the zone (Figure 14B) defined as the per cent of total paths that intersected or were within the 30-

km buffer zone. With collar sample size in mind, Figure 14 shows of pattern of decreasing use from October through winter and least with use in spring. There were no collars recorded in the buffer in June, July and August and only two collars were ever recorded for May.

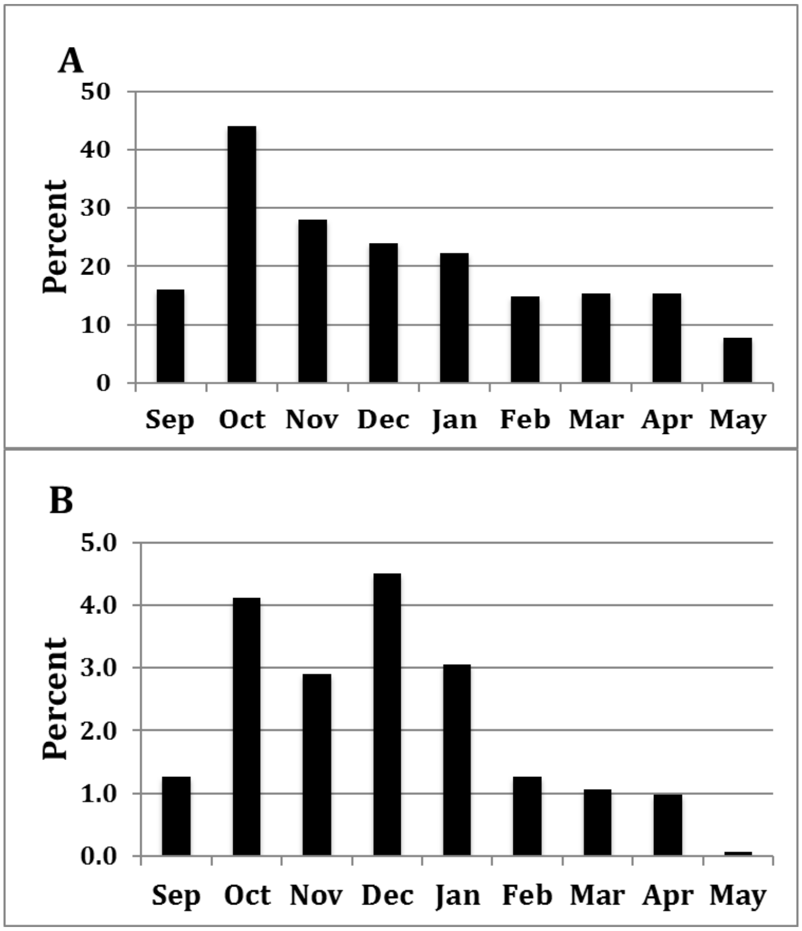

Figure 14 Caribou use of the 30-km buffer zone: A) per cent of years caribou present; and B) average per cent of herd using the 30-km buffer zone.

It is important to distinguish between the timing of caribou movements through the buffer zone and the likely timing of oil and gas activities. Depending on snow accumulation, winter operations are not likely to begin until November, missing the October movement of the herd. Thus from Figure 14A instead of 44% of the years with a collared caribou (October) the likelihood that a collared caribou would be in the area is closer to 28% of the years (November). Oil and Gas activity in late winter and spring would likely have collars in about 15% of the years representing about 1% of the monthly movement paths (Figure 14). But note that biologists have seen a shift towards a later migration towards winter range in recent years and even major reversals in movement direction that have resulted in a lot of caribou still moving in November (M. Suitor pers. comm.). If this trend continues than we would expect much more interaction between fall migration and oil and gas activities.

6.3.3 Movement rates and Residency time

The movement rates of caribou and how long they spend in the 30-km buffer (residency) are important for mitigation and monitoring protocols. To this end we calculated the average monthly movement rate for collars in the 30-km buffer (Figure 15). Rates declined from September to March and increased in April as spring migration began. The high rate for May was with two animals, perhaps delayed in leaving winter areas and in a hurry to reach the calving grounds.

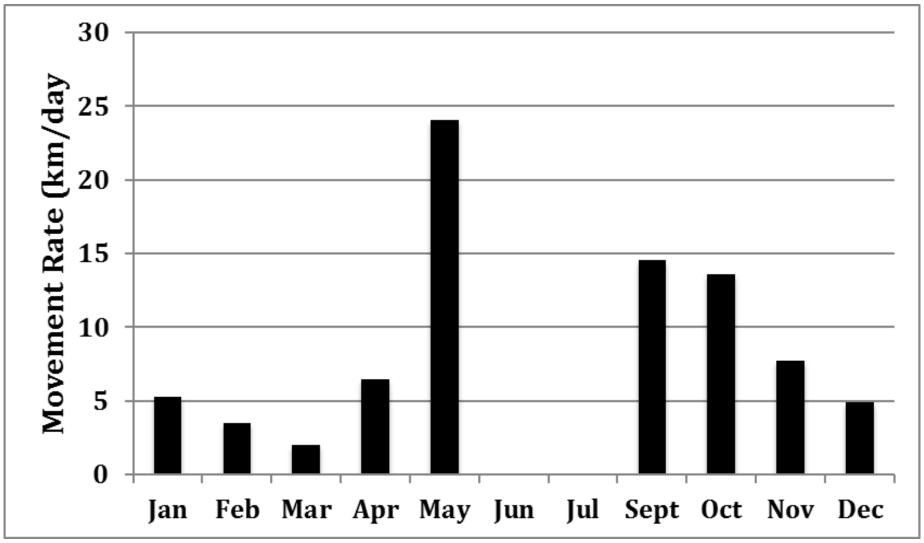

Figure 15 Monthly average movement within 30-km buffer zone (1985-2015).

A GIS-based path-line approach was developed to estimate the time spent by collared female caribou in the 30-km buffer from NCY proposed infrastructure. Path-lines (defined as a straight line connecting two telemetry point locations) were generated from telemetry point locations and overlaid on the 30-km buffer zone to determine the spatial relationship of the buffer boundaries between the two locations. Path-lines were attributed with duration of time (both within and outside the buffer) using the proportion of line length in combination with re-location interval. For example, Figure 16 displays two path-lines within a hypothetical buffer: one path-line entirely within the buffered zone; and one path-line that was split when intersected with the buffer boundaries. Although they have similar line lengths within the buffer (8.9 km vs. 8.8 km), they represent two very different durations within the buffer (24 hours vs. 7.8 hours, respectively), resulting in a more accurate residency estimate compared with using simple line lengths; i.e., accounting for duration increases the influence of lines that were always fully contained within the assessment area because they represent a full day of occupancy.

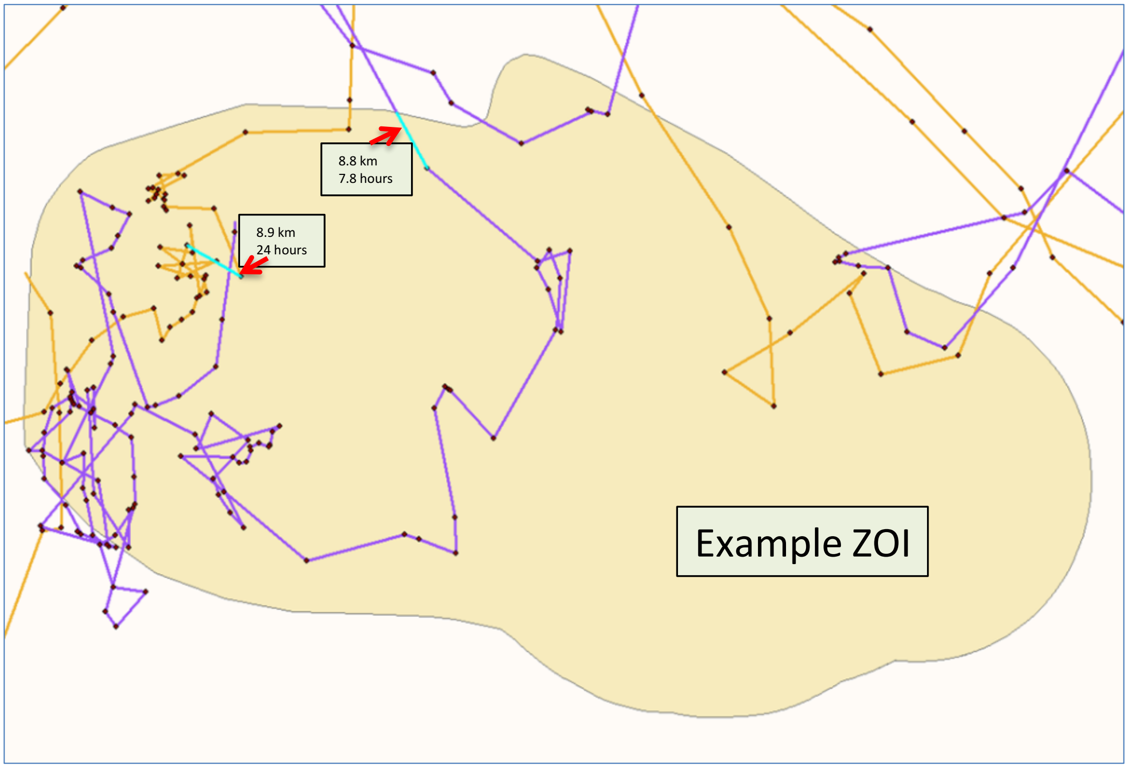

Figure 16 Example calculation of “path-lines” in a hypothetical buffer zone.

All path line durations (hours) within the buffer zone were summed and divided by the total duration of all path lines (within and outside of the buffer) to estimate residency time as a proportion of total collar duty cycle time (time between two consecutive locations; Figure 17). Caribou during March spent on average more than 16 days in the buffer; during fall migration, residency time increased from September to December (Figure 17). Again the two individuals in May spent the least time in the buffer zone.

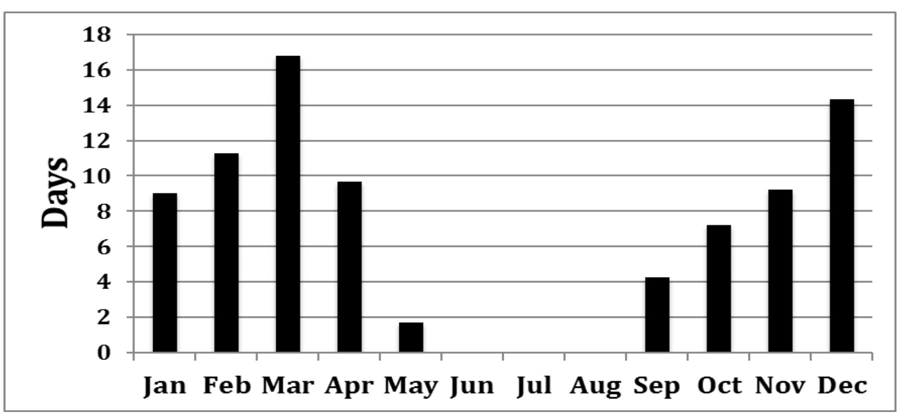

Figure 17 Average residency time per collared animal intersecting a 30-km buffer zone around proposed NCY infrastructure.

6.4 Climate trends in the 30-km buffer zone

Using the same CARMA MERRA climate database discussed under Sensitivity section, we extracted climate data from only those cells that fell within or overlapped the 30-km buffer zone. Our intention was to look at snow conditions and summer fire weather index (our Drought Index) to see if any trends emerged. Caribou tend to use the Eagle Plains area in winters with shallower snow because the region typically has higher snow than the Richardson Mountains or the Ogilvie basin (Russell et al 1993) but has higher lichen biomass (in non-burned areas). Figure 18 shows that in the 30-km buffer there is a significant negative trend in March 31 snow depth, indicating that if the trend continues exposure to the area may increase in winter as lower snow depths make foraging in the region more attractive. Observations of caribou even feeding in burn areas (M. Suitor, pers. comm.), especially near moist creek bottoms where burns were patchy, still containing sufficient lichen biomass for caribou. Using the three-year running average eliminates the annual variability and allows us to better observe trends. Snow depth increased from 1981 peaking in 1991 and generally declined to 2008. In the last seven years, we see another increasing trend.

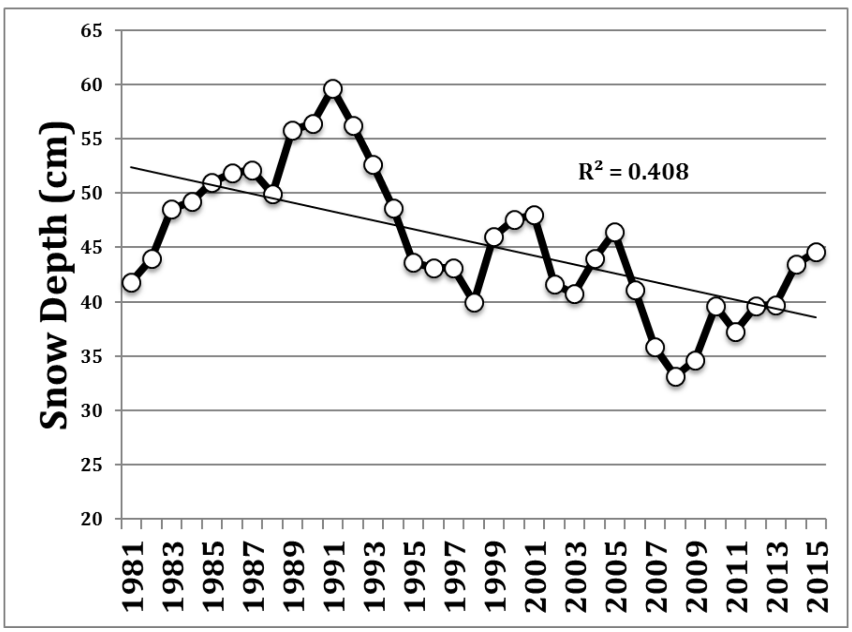

Figure 18 March 31 snow depth in a 30-km NCY buffer area (three-year running average).

Our July drought index (equivalent to fire weather index) show the opposite trend (Figure 19), with increasing drought conditions interrupted by three years of low drought conditions in the early 2000s. As our drought index is correlated to the number of fires in central Yukon (Russell, unpublished), we can expect more frequent fires in the regions (see also Gustine et al 2014). The study area has already had about 1/3 burnt forest since the 1990, 1991 and 2005 fires (NCY Environmental Conditions 2014). Thus we can speculate from the snow and drought conditions that on one hand caribou will have more winter access to the area, but drier summers may reduce lichen abundance as the probability of forest fires increases.

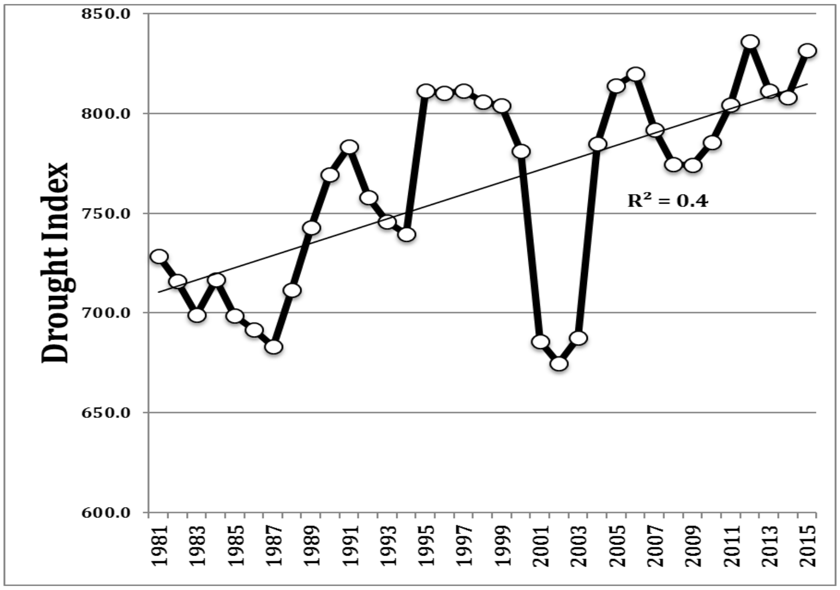

Figure 19 July drought index in a NCY 30-km buffer zone (three-year running average)

6.5 Predicting fall migration patterns from weather

Clearly, it is advantageous for seasonal planning of oil and gas activities to be able to know what the probability is of a significant number of caribou entering the development zone within the seasonal window of operations. For the Porcupine herd there have been three research projects that attempted to link climate to Porcupine Caribou distribution and movements.

Eastland (1991) notes that PCH autumn migration does not follow distinct routes, but rather are "part of a continuous corridor that connects summer and winter components of the range." He refers to September movements as "a form of migratory restlessness," and October movements suggesting that caribou were coordinated, and directional. Weather was among the driving factors that influenced autumn movements and selection of wintering range. Eastland (1991) suggested that spring migration is driven by the onset of calving, but "braked" by snow conditions that influence traveling and foraging.

McNeil et al., (2005) showed, using satellite collar data, that climate variation can partly explain seasonal variation in caribou distribution. Their analysis related average seasonal distribution patterns between sets of years to different weather-related environmental conditions, e.g., shallow vs. deep winter snow, or early vs. late spring snowmelt. For each season, McNeil et al., (2005) identified one key environmental factor influencing caribou distribution, informed by local knowledge and expert scientific opinion. They used available climate data relevant to that seasonal factor's annual state to divide the years into two classes based on ranking of the years. For example, they defined early or late snowmelt as the key driver for spring migration, indicated by whether or not the snowpack measured on May 1 at Old Crow had declined by at least 30 cm from that measured on March 1. For fall migration, they determined that the key driver for that season was whether snowfall was early or late, based on whether September snowfall at Old Crow was greater or less than 4.5 cm (McNeil et al.' 2005).

Nicolson et al., (2013) built on the earlier work (Eastland 1991, McNeil et al 2005) to further address the spatial and temporal sequences of movement. McNeil et al., (2005) did not account for the possibility that caribou presence in a zone one season could be influenced by the distribution of animals in the previous season. Nicolson *et al.* (2013) modelled the probability of animals moving between consecutive seasons into adjacent zones and how climate drove the movements. The model most consistently predicted the distribution of animals accurately during calving, when caribou are highly concentrated, and least consistently predicted correct locations during spring migration, when caribou are moving rapidly and are highly dispersed. During the rut and late fall (Oct 8-Nov 30), early snowfall increased the probability that caribou that had been in the Porcupine Basin in August and September would move to another zone, i.e., it reduced the probability that they would remain in the Porcupine Basin. During winter, deep snow increased the probability that animals located in the Richardson Mountains would stay in that zone.

Both McNeil et al (2005) and Nicolson et al (2013) were relying on 1985-2003 collar data (collectively 68 collar years) and both attempted to account for all seasonal movements and distribution over the entire range of the PCH. Although beyond the scope of this contract, we would recommend that a more focused analysis be conducted in the Eagle Plains area for fall, winter and spring seasons. The research conducted so far is a credible methodology and approach. Currently we have approximately five times that many collar-years available (~342). Further, both previous studies relied on weather station data often far from caribou distribution. Using CARMA's spatial climate database (Russell et al., 2013) we now have available daily weather data from 1979-2015 at a much finer scale (MERRA grid size is ½ degree latitude by 2/3 degree longitude) and with many more caribou-relevant climate indicators.

6.6 Modelling Cumulative effects

Cumulative effects were highlighted in two of the six issues YESAB identified as needing more information to make a decision. In our experience, reliance on a single proponent of a development to undertake a cumulative effects analysis is unrealistic and a collaborative approach between stakeholders is more effective. Consequently, cumulative effects analysis seldom precedes or is inadaquately integrated into an environmental assessment. Yet one of the most frequent concerns about the future of migratory tundra caribou is the impacts of the cumulative effects of changing climate and land-use activities across herd's ranges. Gunn et al., (2011) and Johnson & St.-Laurent (2011) commented on the lack of a methodological framework as reason for slow progress on cumulative effects. They suggested a collaborative approach using a framework based on the scaling from individual to population, the relative frequency, and magnitudes of effects and their regulation.

We know quite a bit about individual caribou responses to human activities – interruptions to foraging and displacement of individuals at various distances from the disturbance (Aastrup, 2000; Cameron et al., 2005; Boulanger et al., 2012). To scale up the individual's behavioural responses to the population requires being able to estimate the costs to the individual and whether those costs will affect its reproduction and survival. Estimating the costs of a behavioural response is not straight forward; as well as the energy costs of movement and interruption in foraging time, there may also be an effect on diet (energy/protein intake) if a displacement puts the individual in a different habitat. Understanding and integrating those relationships between behaviour, habitat selection, energy and protein intake relative to reproduction and survival is data intensive and interdisciplinary as the understanding is based on ecology, nutritional ecology and modelling.

The CARMA network (Russell et al., 2013) has developed an approach and associated tools for cumulative effects assessment (Gunn et al., 2013, 2014). The Caribou Cumulative Effects (CCE) model framework has 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 caribou biology. The sub-models in the CCE model are: 1) a model tracking movement patterns of a caribou herd with respect to past present and future development; 2) a model for the change in an individual caribou's body condition over time; and 3) a model of the caribou herd's population dynamics Figure 20). The movement model tracks historic caribou migration patterns across the herd's range, and the subsequent consequences of this daily movement pattern on caribou behaviour and available forage; the movement model also tracks changes in exposure to harvest risk. The body condition model takes output from the movement model, combined with future projections of vegetation change, to predict changes in body condition of an individual caribou over time. The output of the body condition model is then used to predict changes in caribou fecundity and survival which, along with the harvest risk projections of the movement model, are fed into a population model to project the future size and composition of the caribou herd.

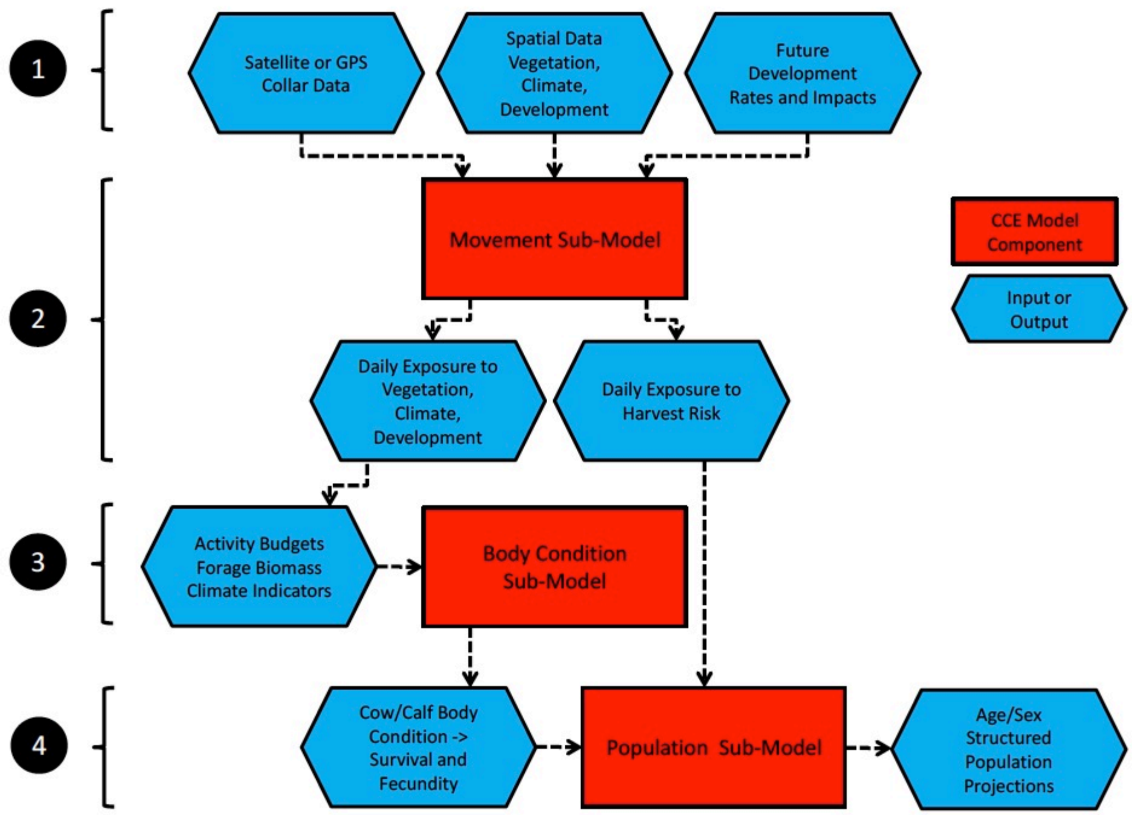

Figure 20 Schematic of the Caribou Cumulative Effects (CCE) model showing sub-model components in red and various sub-model inputs/outputs in blue.

The initial inputs (1) 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 zone of influence (ZOI). These inputs then feed into (2) the caribou movement sub-model, which produces output on the daily environment and harvest risk experienced by an individual caribou. Output from the movement sub-model feeds into (3) estimates of activity budgets, forage biomass and climate indicators which are inputs for the individual caribou body condition sub-model; the outputs of the body condition sub-model are the body condition of a cow and her calf which can be interpreted in terms of fecundity and survival rates. These demographic parameters, together with the harvest risk exposure from the movement sub-model, are inputs to (4) the population sub-model, which produces estimates and confidence intervals for age/sex structured population projections.

We have applied these models on a number of migratory tundra herds, initially looking at climate impacts but also in relation to industrial development (Murphy et al., 2000; Russell 2012, 2014a, 2014b; Russell *et al.* 2015). Further over the last decade, the PCMB has taken a lead role in developing the capability to undertake a full cumulative effects assessment of the

PCH. Although relying heavily on the CCE model described above to address energetic impact of disturbance, the PCMB has initiated discussions on ensuring that the full range of cumulative effect impacts on the herd are recognized (e.g. displacement and changes in migratory routes).

6.7 Exposure Summary

The current and potential future exposure of the PCH to proposed NCY infrastructure was assessed using a path analysis of collars from April 1985-January 2016. We used a 30-km buffer zone to determine use, movement rates and residency time. The number of satellite collars available varied considerably among years, peaking at 45 in 2015. Caribou that interact with the 30-km buffer in fall follow a migration route south along the west side of the Richardson Mountains, turning southwest just north of Eagle River. Visual examination of fall movement paths suggests the Dempster Highway may be acting as a barrier movement to winter ranges south of the highway in the mid Peel River, Hungry Lakes area. It is possible however that this movement pattern may reflect habitat differences so caution should be taken until further analysis is complete. The consequence of these movement paths with respect to Northern Cross is the significantly higher use of the Chance Creek area and lesser use of proposed well sites and roads southeast of the Dempster Highway.

Caribou first arrive in September and are essentially gone by May (only two paths recorded in May). There is a progressive decline in per cent use from October (44%) to April (15%) based on the per cent of years that caribou intercept the buffer zone. Based on the monthly average, per cent of paths October (4.1%) and December (4.5%) had the highest use between 1985 and 2016. However, both months were influenced by a single year (1990 for December; 2015 for October).

Movement rates in the buffer zone declined from September (14.5 km per day) to March (2.0 km/day) increasing in April (6.4 km/day) as spring migration begins. With respect to residency time, caribou during March spent on average 16.8 days in the buffer, during fall migration residency time increased from September (4.2 days) to December (14.3 days).

Using climate data downloaded from the 30-km buffer zone we note a declining trend in snow depth and an increasing trend in July drought. From previous analysis lower snow means higher probability of use in Eagle Plains but higher drought means higher probability of fire, less lichens and potentially lower use.

There is a need to integrate the cumulative effects of existing and potential future changes within the range of the PCH. We present an existing model structure that has been applied to other migratory tundra herds.

7 Adaptive capacity

7.1 What is adaptive capacity?

Adaptive capacity is what needs to be done to reduce the potential impacts – building adaptive capacity at the project and herd management scale will lessen the vulnerability of caribou

(Figure 1). If no actions were available to reduce the potential impacts of oil and gas activity on caribou, then we would conclude that the system has no adaptive capacity to reduce the potential impacts. Thus adaptive capacity, in this report, is the suite of actions that all stakeholders (industry, territorial, federal and aboriginal governments, and co-management boards) can use to minimize impacts on, and the vulnerability of, caribou.

For the Porcupine herd, the need to reduce impacts is recognized in the identification of sensitive habitats (International Porcupine Caribou Board 1993). For Northern Mountain caribou, Environment Canada's (2012) management plan recommends following best practices guidelines. At a development project-specific level, mitigation and monitoring actions ensure that operations are conducted to minimize impacts on caribou. Mitigation effectiveness is monitored and, if not effective, changes to mitigation are enacted. This cycle, called an adaptive management cycle improves the adaptive capacity of the system (Figure 21).

Because all stakeholders in PCH conservation have an interest in reducing impacts and all groups bring their knowledge to the table, we suggest the mechanism to implement the adaptive management cycle is a collaborative Technical Working Group (TWG). A collaborative TWG reduces the need to get the project-specific mitigation right from the onset, improvements will evolve throughout the life of the project and the end result can become the initial mitigation and monitoring plan when the next oil and gas development is proposed.

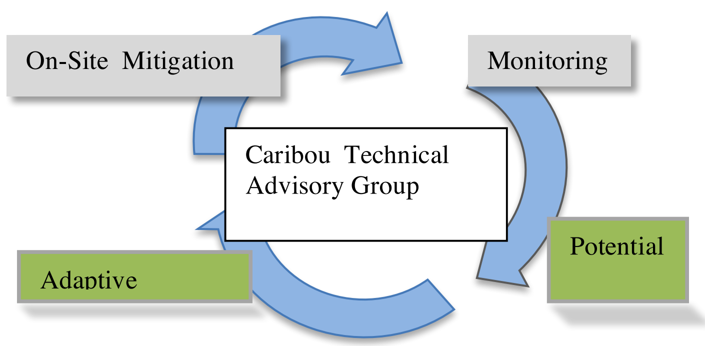

Figure 21 The adaptive management cycle is an important component in vulnerability assessment

A level of mitigation actions is already built in at the landscape scale for the Porcupine herd. The North Yukon Land Use Plan (NYLUP) has designated certain regions for more or less protection for the PCH based on current seasonal movement patterns, knowledge of sensitive habitats and resource potential. Along with these regional designations, the NYLUP sets general thresholds for linear and surface disturbance that triggers accelerating levels of concern. The thresholds trigger cautionary approaches to the intensity of development, which would also be flagged as increasing the sensitivity of caribou. It should be noted that similar Land Use Plans for the Dawson and Peel regions have not been completed, but both of which contain Porcupine Caribou range.

Governments have already agreed since the 1987 Agreement between the Government of Canada and the Government of the United States of America on the Conservation of the Porcupine Caribou Herd to existing protection measures for how the PCH should be managed. The Porcupine Caribou Management Board and the International Porcupine Caribou Board were created to implement a within-Canada and an international agreement, respectively. A good example of how these agreements lead to action is the creation of a Porcupine Caribou Harvest Management Strategy that is designed to ensure harvest is managed strategically, taking into account the best current monitoring information on the status and health of the herd and added pressures on the herd with respect to industrial development, all balanced by the subsistence needs of aboriginal communities.

7.2 Best Management Practices versus mitigation

In our review, we found the distinction between Best Management Practices and mitigation is unclear. As a generality, Best Management Practices are normally in place thorough policy or legislation and their goal is to “avoid” and/or “minimize” industry effects on caribou. Typically, they are broad-level recommendations at the regional scale. For example, a common best practice, and one adopted by the NYLUP, is “to minimize the construction of all season roads.” Best Management Practices act a general set of guidelines for project-specific mitigation.

An example of Best Management Practices for barren-ground caribou are from the Northwest Territories, where the *2014 Wildlife Act (NWT)*, requires for industrial projects likely to disturb wildlife or habitat, the proponent has to produce monitoring and mitigation plans according to the 2015 Wildlife & Wildlife Habitat Protection Plan and Wildlife Effects Monitoring Program. The Program’s Guidelines set out the procedures rather than detailed mitigation and so are equivalent to Best Management Practices. Then, the Mackenzie Valley Impact Review Board (and Nunavut Impact Review Board) reviews the proponent’s monitoring and mitigation plans and use the equivalent of a case-law approach with proponents and interveners accumulating experience for mitigation and monitoring through successive environmental assessments.

7.2.1 Best Management Practices – what we know.

The Yukon government in 2013 described Oil and Gas Best Management Practices as “A range of practices that can reduce the time, intensity or duration of the footprint on the land base – not usually prescriptive.” The goals are general and include “to conserve wildlife and fisheries habitat.” (http://www.emr.gov.yk.ca/oilandgas/best_management_practices.html). The web site explains that at this time (2017), the Best Management Practices are available for seismic, historic resources and wilderness tourism. The Yukon Chamber of Mines compiled a 2010 Yukon Mineral and Coal Exploration Best Management Practices and Regulatory Guide http://www.yukonminers.ca/images/BMP_RG_October28_REVISED_WebFile_Apr15.pdf.

We know that Best Management Practices are available for boreal and Northern Mountain caribou in BC and Alberta. Appendix C lists those developed for Northern Mountain caribou in B.C., which we view as a “straw dog” for Yukon caribou as consultation is essential for developing credible BMPs. The topics for B.C.'s BMPs include the following, which cover activities such exploration drilling, access management (construction, use, decommissioning), timing of activities, waste and drill site management and camp operation:

- Identify the impacts of proposed activities on caribou and caribou habitat.
- Avoid or minimize new disturbance to and the loss of important habitats.
- Avoid increasing the density of linear disturbances within or in proximity to caribou habitat.
- Avoid displacing caribou and minimize direct and indirect mortality on caribou populations.
- Avoid increasing the predation risk for caribou populations.
- Avoid contaminating caribou habitat.
- Restore habitats to a condition that provides a similar level of functional caribou habitat as before any industrial activity took place.
- Develop a monitoring and adaptive management plan to monitor the effectiveness of measures to avoid, minimize and restore.

We note that these Best Management Practices overlap with those proposed in the NYLUP and by Environment Yukon for the NCY proposal. Appendix C refers to seismic, exploration drilling, access management and camp operations. The Best Management Practices for Seismic (YTG 2006) are similar to those recommended for BC and we did not identify any gaps. However, we did not have access to a current study on wildlife and seismic lines in the Yukon (K. Simpson and M. Suitor pers. comm. 2017), which may better inform possible recommendations for seismic operations. We did not find any studies that describe the implications of the concentration of lines in 3-D seismic.

Timing: British Columbia applies a risk window approach to encourage avoidance of impacts by establishing caribou seasons when the risk is least. Least-risk windows divide a calendar year into critical, cautionary, and low risk windows based on the species ecology. Critical and cautionary timing windows cover the time when a species is most sensitive to disturbance, and when development should be avoided. Low-risk timing windows are defined when species are least sensitive to disturbance; development activities should be planned for low risk windows whenever possible. We have modified the Least-risk window approach developed for barren-ground caribou in Nunavut by including the dates for the Porcupine herd (Table 3).

Best Management Practice for migratory caribou (Northern Mountain and barren-ground caribou) may require balancing effects through timing. For example, activities can be timed for the seasons when the habitat is not occupied: for example, requiring summer drilling and camps on a caribou winter range will reduce caribou behavioural responses. However, those activities may require an all-season road, which can have effects from increased access throughout the year.

Table 2: Seasons, risk category, timing and caribou susceptibility developed for barren-ground caribou in Nunavut (Kivalliq Inuit Association 2016) with the dates for the Porcupine herd (PCMB 1993)

Season	Risk category	Timing	Caribou susceptibility and behaviour
Spring migration/ pre-calving	Cautionary	1 April – 31 May	Narrow corridors of cows often rapidly moving together with occasional staging in large aggregations
Calving	Crucial	1-10 June	High densities of cows at annually lowest part of condition cycle; cows and newborn calves more responsive to disturbances
Post-calving/ insect season	Crucial	10 June - 15 July	Cows and calves aggregating into large groups and calves susceptible to abandonment and loss from disturbance; aggregations susceptible to disturbance at traditional water crossings
Summer/insect season	Cautionary	16 July-7 August	Cows and calves aggregating into large groups; aggregations susceptible to disturbance at traditional water crossings
Fall migration/ pre-rut	Cautionary	8 August-7 October	Caribou often more dispersed and regaining body condition prior to breeding
Rut/Fall Migration	Low	8 October – 30 November	Caribou either migrating or staging
Winter	Low	1 Dec-31 March	Caribou in aggregations over a large area and less movement

7.2.2 Best Management Practices- what we do not know

What we know the least about Best Management Practices is how they are implemented and reviewed. For example, within the existing BMP for seismic operations, we do not know how they work in practice, as there appears to be no feedback reporting on how they are implemented or how adaptive mitigation for specific developments would provide feedback on any gaps in the seismic BMP. While we know enough from the experience of other jurisdictions to produce general guidelines, we suggest the knowledge gaps are more in the specific details of mitigation such as discussed in Section 8 (this report).

EMR has asked us in this report to identify knowledge gaps in any BMPs that exist including gaps that will inform BMP development. We suggest that a bottom-up approach (resolving uncertainties in mitigation) will inform the development of Best Management Practices rather than constructing the general guidelines first. We also suggest that from the experience particularly in BC for Northern Mountain caribou, enough information on Best Management Practices already exists and as we have suggested, Appendix C is a straw dog for a collaborative group to initiate discussion.

7.3 Mitigation

Mitigation is a hierarchy of site- or project-specific actions designed to implement the broad-level recommendations to reduce the effects on caribou. Thus, if for example, an oil well drill program is permitted (through an environmental assessment review) to have an all -season road, project-specific mitigation will determine how it is designed and operated to minimize impacts on caribou (Figure 22). The project is designed and operated to 'avoid' effects; if effects are unavoidable mitigations should 'minimize' the effects and if residual effects are still significant, mitigations should 'offset' effects ('Offset' is equivalent to 'Compensate'). Based on the "precautionary principle," it follows that gaps in baseline information describing exposure and sensitivity will require stronger mitigation to ensure that potential impacts are not missed. Typically, mitigation actions should be designed to escalate in direct response to the exposure and or sensitivity of the caribou (Figure 22).

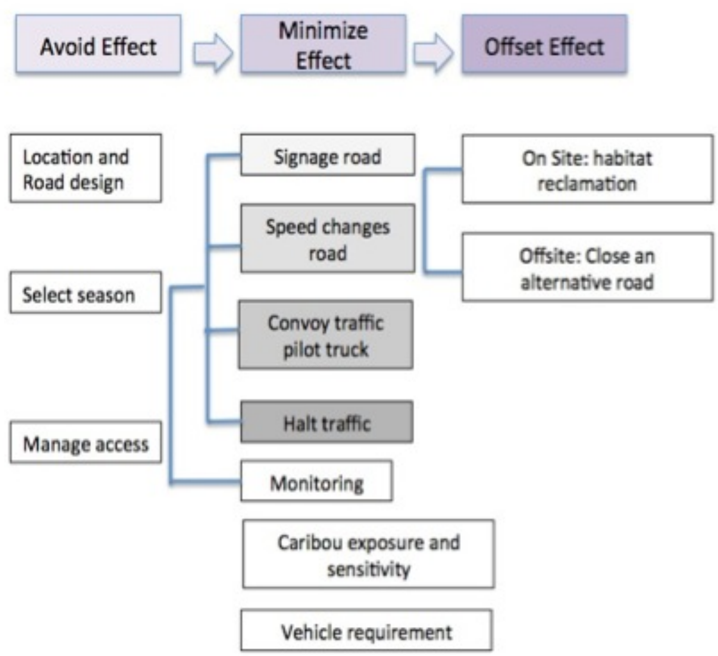

Figure 22 An example of escalating mitigation for road and traffic use

The hierarchial approach to mitigation is well-established (Jakle 2012). An example is the rapid and extensive oil and gas development on the range of the Greater Sage Grouse that was a factor when the US Fish and Wildlife Service determined that the bird was a candidate for protection under the *US Endangered Species Act*. The reasoning was because threats included habitat loss and a lack of regulatory mechanisms to prevent future impacts (USFWS 2010 in Kirol et al., 2015). Subsequently, collaboration between industry, government and non-government undertook mitigation with measured and documented successes (Kirol et al.,2015).

Most examples of an escalating mitigation approach follow the flow diagram in
. To illustrate this approach and general application, Figure 23 shows how adaptive management and monitoring can improve project-specific mitigation.

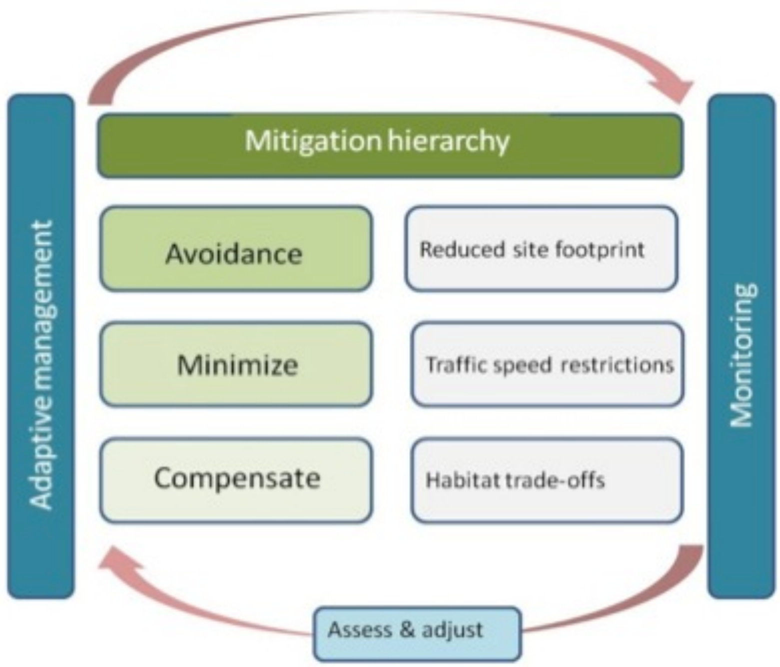

Figure 23 The adaptive mitigation - monitoring cycle incorporating escalating mitigation concept

In this section we highlight links to environmental assessment websites that have on-site mitigation plans for migratory tundra caribou. In the NWT, the Mackenzie Valley's Environmental Impact Review Board (MVEIRB) is a co-management body responsible for the environmental assessment review process (except on Inuvialuit Lands). MVEIRB lists 34 completed environmental assessments and 6 on-going assessments since 2000 (http://www.reviewboard.ca/about/). All assessments contain mitigation plans at various levels of detail and mostly termed Wildlife Monitoring and Mitigation Plans. Similarly, for Nunavut, the Nunavut Impact Review Board (NIRB) allows searches of their registry and final environmental assessment documents include the detailed proposed monitoring and mitigations that NIRB's project certificate may list as binding conditions.

The lists of mitigations tend to be broadly similar between mitigation plans and do not show much evidence for a linear progression over time; in other words, what has worked and not worked and where refinements are needed. For example, Table 3 is for the proposed Kiggavik mine and is more detailed than those measures proposed by, for example, Northern Cross.

However, we lack the knowledge to know which speeds and stopping times relative to group size are appropriate.

Table 3: Vehicle protocols when encountering caribou, developed for the AREVA's proposed Kiggavik mine, Nunavut.

Distance of caribou from the road	Less than 10 adults in a nursery group	More than 10 adults in a nursery group
Less than 200 m	Driver to remain stopped for 30 minutes, then may proceed at 20 km/hr if behaviour is unchanged and caribou are not moving towards the road	Driver to remain stopped until caribou are greater than 500 m from the road
200–500 m	Driver to remain stopped for 10 minutes, then may proceed at 20 km/hr if behaviour is unchanged	Driver to remain stopped until caribou are greater than 500 m from the road
In sight & >500 m	Driver to proceed at 30 km/hr	Driver to proceed at 30 km/hr

Both B.C. and Alberta have seen considerable oil and gas development on the ranges of boreal and Northern Mountain caribou which has led to best practices and mitigation. Detailed mitigation plans are available for individual development projects through the environmental assessment process (http://www.eao.gov.bc.ca/ea_process.html).

Other useful websites dealing with mitigation are:

http://www.env.gov.bc/emop/(lists documents with policies and procedures)

http://www.env.gov.bc.ca/wld/speciesconservation/bc/documents/boreal_caribou_biol_rationale_may8_2009.pdf

http://www.env.gov.bc.ca/wld/frpa/uwr/approved_uwr.html

http://www.env.gov.bc.ca/wld/BMP/bmpintro.html (Interim Operating Practices for Oil and Gas Activities in Identified Boreal Caribou Habitat in British Columbia (IOPs))

http://open.alberta.ca/publications/caribou-protection-plan-guidelines-and-caribou-calving-information (Alberta's draft plan for caribou recovery in North and Central Alberta, 2016)

http://aep.alberta.ca/fish-wildlife/wildlife-management/caribou-management/default.aspx

Alaska: Increasingly over the last 10 years and in response to extensive oil and gas development in the U.S., mitigation is being treated as a hierarchy with avoidance, minimization, remediation and offsetting, similar to B. C. (Lutz et al., 2011; Jakle 2012, Clement et al., 2014). In Alaska, the migratory tundra Central Arctic Herd (CAH) has been exposed to decades of oil development and exploration leases have been granted for the neighbouring Teshekpuk herd (Appendix A) also for calving and summer ranges on the coastal plain. The herd's current management reports that the management goal to “Minimize the adverse effects of development on CAH caribou” is being met but the details on mitigation for caribou are unreported (Lenart 2015). However, Braund et al., 2013 surveyed mitigation undertaken for seven oil development projects in the vicinity of Nuiqsut, a small community on the western extension of the Prudhoe Bay oilfield. The survey lists the specific mitigation for caribou and local residents’ comments about whether the mitigation was ineffective.

Mitigation is now proposed for oil development on the neighbouring Teshekpuk herd’s ranges where the National Petroleum Reserves are being opened for leasing (Appendix A). However, mitigation details are lacking as the development is not yet operational. The initial environmental assessment for the leasing recognized a lack of baseline for movements, which has led to a detailed analysis of movements using collared caribou to determine pathways for insect relief to avoid conflict with the oil structures (Carroll et al., 2007).

In 2012, the U.S. Department of the Interior released an updated Integrated Activity Plan/Environmental Impact Statement comparing alternative areas and development and listing mitigation measures for public comment. The Teshekpuk Lake Special Area and the Utukok River Uplands Special Area are excluded from leasing until 2018 and 2014, respectively. However, the plan does acknowledge that exploration activity (seismic and test drilling) may occur on the winter range of the Teshekpuk herd. When the lands are offered for leasing, environmental effects are assessed and mitigation is prescribed, but not in detail. For example, pipelines shall be designed and constructed to minimize alteration of caribou and other large ungulate movement and migration patterns. Exploratory drilling operations may be restricted during the fall caribou migration (August 1 through October 31) in certain river valleys to allow for subsistence hunting.

7.3.1 Mitigation summary

Potential impacts include that caribou avoid roads and traffic at variable distances depending on vegetation, observation methods, predation and hunting. However, the results of reducing those impacts through monitoring and mitigation are uncertain. We found many proposed actions based on speed, stopping distances etc. but almost no follow-up to determine effectiveness. The same general point can be made about other proposed mitigation and thresholds to modify mitigation through monitoring. While much information is available on best practices and mitigation, it is mostly for boreal and mountain caribou and there is less information for migratory tundra caribou. This leads us to suggest that a more collaborative approach integrating baseline information on movements with environmental variation would be the basis for best practices and mitigation.

7.4 Monitoring

The Northern Cross seismic program in 2014 was an opportunity to test the relationship between observed numbers of caribou and the number of collars. The unknown relationship between collars and caribou on the ground suggests that other monitoring methods are essential. As well as mitigation, recent environmental assessments provide alternative approaches to monitoring. Instead of relying solely on the satellite collars, aerial surveys or snow track surveys, there are other options. These options have the advantage providing quantitative information that relate to thresholds for mitigation. We note that during the hearings for a gold mine in Nunavut (Sabina project), the approaches to monitoring for along a road are possibly relevant to Northern Cross (Table 4).

Table 4: Three options for monitoring wildlife encounters along roads derived from proposed monitoring for Sabina's Back River project.

Option 1: Observation Blinds
An observation tower with a blind at the top will be constructed at the observation points. When active monitoring is triggered, caribou monitors will visit the observation blind during daylight hours and scan for caribou. The distance to caribou will be estimated using markers or a laser rangefinder.
Option 2: Tower Cameras
A remote-controlled camera on a tower at the observation posts will be able to record caribou out to the trigger distance. An example is from Infinity Optics, which produces surveillance cameras (http://www.infinitioptics.com/).
Option 3: Vehicle-Based Monitoring
Caribou monitors will survey the tundra from vehicles on project on-site roads at vantage points that allow a good view of the surrounding tundra. Methods will follow those for the observation blinds.

7.5 Significant number of caribou

In reviewing NCY's mitigation and monitoring plans as well as reactions to those plans from public, boards and governments there is no agreement on what "significant" number of caribou are required to trigger escalating or de-escalating mitigation and monitoring actions. As well, there was disagreement on what monitoring techniques are needed to quantify caribou abundance in vicinity of oil and gas activities (summarized in Table 5).

Table 5: Collar and caribou thresholds for escalating mitigation Levels and associated monitoring methods for the Northern Cross project. Groups are NCY - Northern Cross Yukon; Env. Yukon - Environment Yukon; and PCMB - Porcupine Caribou Management Board.

LEVEL	Group	# collars/distance	# caribou/distance	monitoring method
1	NCY	1/30 km	>500/30km	collars; height-of land: track surveys
	Env Yukon	1/30km	>500/30km	collars; height-of land: track surveys
	PCMB	1/30km	>500/30km	collars; "ground"; monthly aerial
2	NCY	1/6km		collars
	Env Yukon	1/6km		collars

	PCMB	1/6km	>250/6km	collars; "ground," monthly aerial
3	NCY	2/6km		collars
	Env Yukon	2/6km		collars
	PCMB		25/600m	collars; "ground," monthly aerial

Given this variation in thresholds and methods, we discuss:

- What is known about how many collars are required to adequately represent the distribution of the herd:
- How to transfer collar distribution to caribou abundance on the ground; and
- How to utilize/link different scales of monitoring to better index caribou abundance in the vicinity of development activities.

7.5.1 Number of collars required to represent herd distribution

The key to relying on collar locations is having confidence in collars representing caribou abundance at the spatial and numerical (# of caribou) scale that decisions need to be made. A few studies have addressed this problem on large migratory caribou herds. However, how many collars are needed to be representative for a herd will vary seasonally as the seasonal ranges vary greatly in size. The next step after determining how many collars may represent herd seasonal distribution is to estimate the likelihood that collared caribou will encounter a specific location such as seismic lines or a camp within a seasonal range (Section 5.3 and 6.4.)

In Labrador, Otto et al., 2003 determined the number of satellite collars required to successfully mitigate impacts of low jet overflights on the George River herd. They used herd size, kernel density analysis, a distribution buffer of approximately 30 km (area around collars that constituted a no-fly zone) and average seasonal group size to determine the number of collars required to “protect” caribou at specific levels of protection. Otto et al., 2003 defined protection probability as the chance that any one randomly selected caribou would be “captured” within one of the caribou “groups” found inside the associated Kernel Home Range. For fall migration protection probability levels of 95%, 75% and 50% would require 184, 26, and 18 collars respectively. The number of collars would be 64, 49, and 34 for winter and for spring 97, 44 and 35 collars. When Otto *et al.* (2003) completed their analysis, there were an estimated 700,000 caribou in the George River herd with range requirements higher than the PCH.

Rettie (2008) used computer simulations to evaluate how many collars would be necessary to be 80% confident that distribution would have 90% of the groups during calving or post-calving census surveys. He used this procedure for the Cape Bathurst, Tuk Peninsula, Bluenose West and Bluenose West herds (NWT). He concluded the number of collars required would be (population size in brackets): Bluenose East = 38 (63,600), Bluenose West = 81 (18,000), Cape Bathurst = 35 (1,400), Tuk Peninsula = 21 (3, 000).

Adamczewski and Boulanger (2016) working on the Bathurst Caribou Herd argued for an increase in the number of collars on the herd to satisfy a number of uses including assessing female survival, and confidently representing winter distribution to aid in harvest management and detecting interactions with development infrastructure. By simply creating a Minimum Convex Polygon, essentially making the smallest possible polygon around location points, and randomly reducing the number of points they showed the change in the estimated distribution of the herd relative to the number of collars. They argue for 50 cow and 15 bull collars on the Bathurst herd to be able confidently describe winter distribution to be able to assign a harvested caribou to the Bluenose East Herd or the Bathurst Herd.

There are currently around 40 satellite and/or GPS collars in the PCH. To be able to assign a confidence in detecting seasonal distribution specific to the PCH would require a separate analysis. From the studies above, 40-50 collars on females adequately represent seasonal distribution; collars beyond 50 marginally improve confidence.

7.5.2 Translating collars relative to caribou abundance on the ground

Even though the number of collars to represent a seasonal distribution can be estimated, it is typically a low number relative to the number of caribou likely to encounter a specific location such as a camp. For example, for the Porcupine herd (April 1985 to January 2016), only 1.3% of the 59,157 collar paths was within or intersected the 30-km buffer around Northern Cross's proposed drilling (Section 5.3.2.). A similar problem of low encounter rates within seasonal distribution was described for the Teshekpuk and Western Arctic herd approaching the Red Dog mine haul road during fall migration (Wilson *et al.* 2016). The study involved 216 caribou collared between 2004 and 2013 which had 263 migration paths. Only 12% (32) came within 15 km of the road during autumn migration and 9% (24) collared caribou crossed the road.

The small sample size of collared caribou is typical of barren-ground caribou monitoring and the consequent low encounter rates restricts relying on only collared caribou for monitoring. We found little effort to link the location of collars to abundance of caribou on the ground. The only example we found was designed to address the need for mobile protection areas in the winter and migration ranges of the Bluenose East Caribou Herd (Gunn and Poole 2011). In their study, eight hypothetical exploration sites were identified within the Bluenose East herd range. When collars were located within an early warning zone, aerial surveys were conducted from the exploration site to the outside edge of the buffer zone (Figure 24).

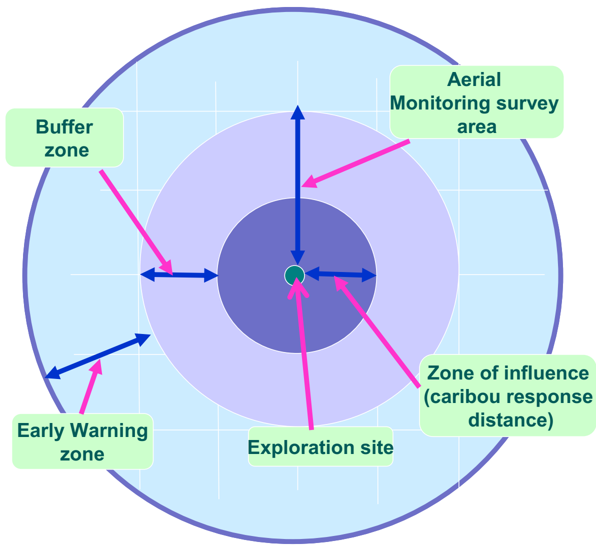

Figure 24 The study design showing Early Warning, Buffer and Zone of Influence around a hypothetical exploration site. From Gunn and Poole (2011).

Gunn and Poole (2011) set the threshold for temporary suspension of land use activities as 25 caribou in the zone of influence. The threshold was exceeded at three of the eight sites (Figure 25). The threshold of 50 caribou in the buffer zone was exceeded at four sites, and for two of those sites those caribou numbers would have justified notice to the exploration manager and the land use inspector of a potential suspension should caribou enter the zone of influence. Once threshold exceeded number required to suspend operations, then survey could be cancelled to reduce flying time.

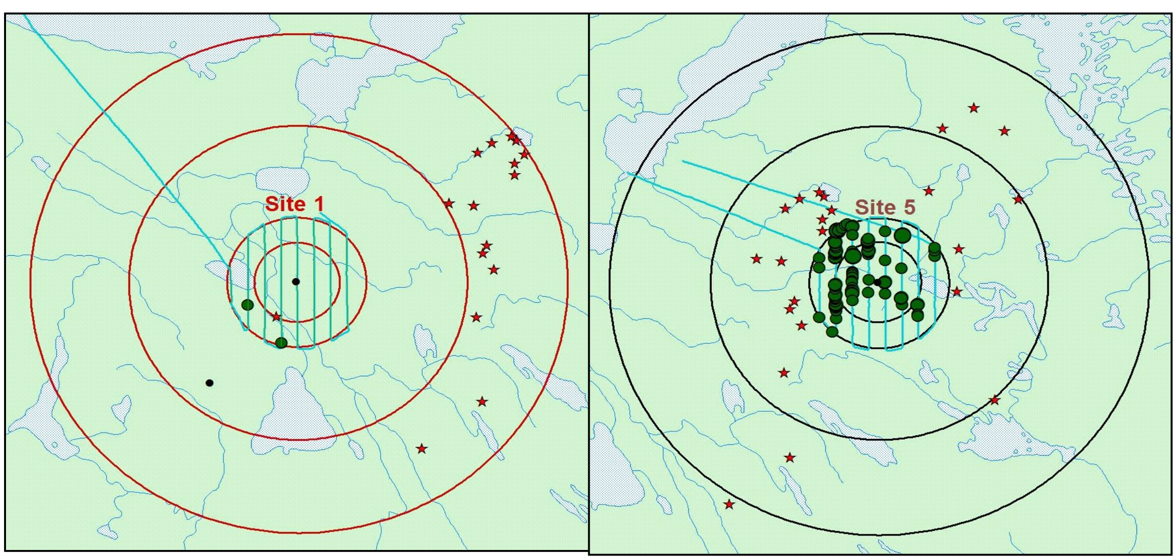

Figure 25 Two examples of the results of collar location and aerial surveys from study by Gunn and Poole (2011).

Gunn and Poole (2011) concluded that the satellite-collared cow locations were, within the scale of their pilot project, relatively predictive of the overall numbers of caribou within the buffer zone and the zone of influence. However, the use of the collars alone without aerial surveys could result in either unnecessary restrictions or loss of protection for caribou. The collars are predictive of regional, not site specific distribution at the scale of 10s of kilometres. However, this could change depending on the type of collars as a shift to GPS collars could increase the acquisition of finer scale locations.

An improvement on this study would be to conduct simultaneous ground surveys (height-of-land, truck sightings or snow track) so that data would be available at three scales. Calibrating the scales and determining the effects of sightability of the caribou can precede any actual drilling program. In the review of the NCY project and intervener comments, the main concern was the reluctance of the operator to start aerial surveys and their total reliance on collars as a trigger to escalate mitigation measures. NCY plans to conduct incidental road observations, height of land surveys and track surveys around the development zone but there is no clear quantitative link to calibrate between those surveys and number of caribou. NCY proposed to suspend snow track surveys if a collar came within 6 km of the development. In relying on collars NCY do recommend increasing the number of collars from ~50 to 100 to better represent caribou abundance at a finer scale. In their submission however, PCMB indicated that would cost an additional $300,000 a year, a sum that was hard to justify. Concern was also raised about the costs to the caribou themselves.

PCMB and others recommended aerial surveys be done monthly once collars are in the 30-km buffer zone. From our analysis most of the collars pass through the 30-km buffer zone in October and November and from Figure 17 we determined that average residency time in those months are 7 and 9 days respectively with ~30% of the collars moving though the buffer zone in less than 5 days.

There is a need to employ a more operational methodology to assess caribou abundance and to be able to adapt the methodology as technology changes – for example for GlobalStar or Iridium collars (M. Suitor pers. comm.). We propose that there needs to be a more rigorously designed research project that adds ground-based surveys to Gunn and Poole's (2011) protocols. Hypothetical development (surrogate) sites can be chosen anywhere (although the terrain should be similar), as the caribou do not need to be in the vicinity of the proposed NCY development. The resultant linkages of the monitoring methods to estimate caribou abundance could be the basis to begin operations but the goal in the initial development years is to better refine the methodologies.

7.5.3 VHF collars

In the Porcupine herd VHF collars have been the primary collar type in use. Only in recent years have satellite/GPS collars begun to match the number of VHF collars. The advantage is cost, VHF collars cost about 20% of satellite collars; the disadvantage is you have to be within range of the collar to get a location (most often from aircraft). Thus instead of currently 45 collars on PCH females there are close to 100 collars if we include VHF collars (the # suggested by NCY). In recent years a number of studies using towers (US Forest Service; http://www.fs.fed.us/pnw/starkey/tracking.shtml) or drones (http://diydrones.com/profiles/blogs/trackerbots) are finding low cost ways of monitoring VHF collars in smaller regional areas. We suggest that doubling the number of collars will increase confidence in tracking movements and abundance of caribou in the 30-km buffer zone. Equipped with a video camera and a VHF receiver routine drone flights may serve as a collar location-monitoring tool, height of ground and track survey all-in-one. We note that currently satellite based collars are exclusively deployed and thus the number of active VHF collars will decline over the next few years.

7.6 Access management

Access management is a relatively well-researched question – for example, B.C. has an extensive literature review (see a review by Wilson and Hamilton (2001)). However we have included it as a knowledge gap in this report, as although best practices for access management is being developed for the North Yukon Land Use Plan, there currently remains gaps in techniques and understanding relative to traditional harvesting and education and to the inter-relationship between caribou responses to harvesting and development.

Northern Cross listed a series of mitigations in its 2014 Road Access Plan for the six points of access of winter or all-season roads with the Dempster Highway (Table 6). As well as road access, the roads will facilitate off-road access, which is a likely issue mostly during winter as travel over the terrain in summer is more difficult. A review of U.S. forestry roads found that locked gates and earth berms were largely ineffective in preventing motorized use on roads designated 'closed' or 'restricted' (Havlick 1999). Research into the effectiveness of signs has focused on warning about the presence of wildlife crossings rather than road closures (Huijer et al., 2009, 2015). However ‘static’ signs have limited effectiveness and changing signs (electronic messages) are more effective.

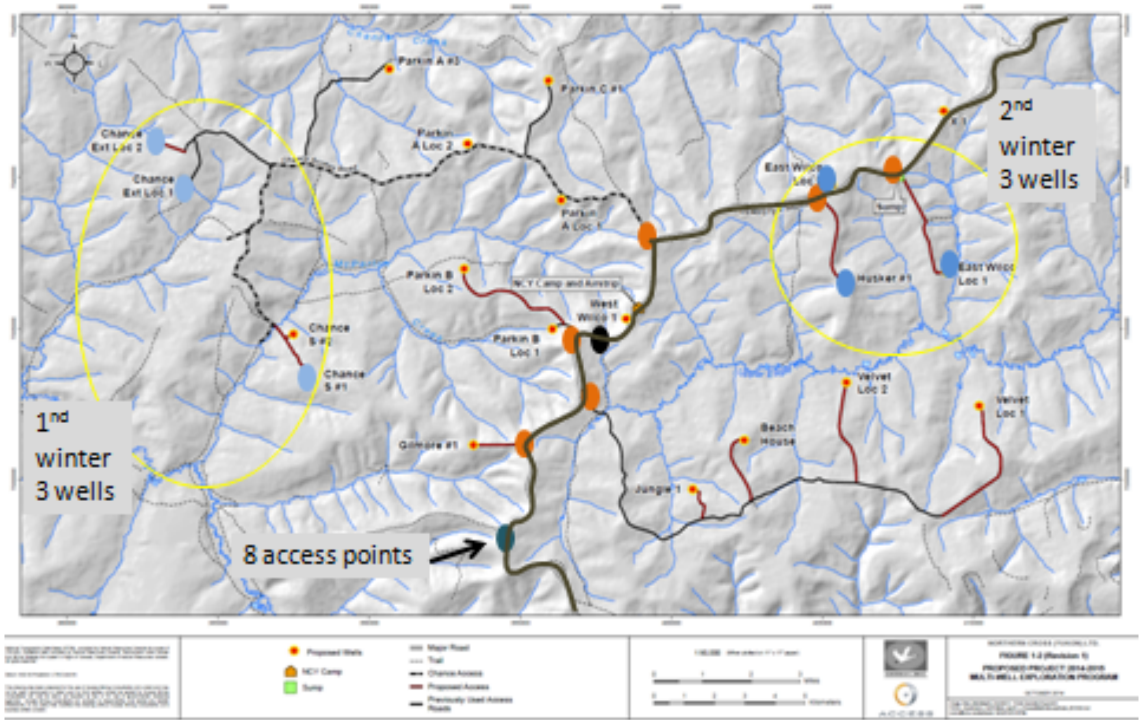

Figure 26 The map shows the six access points (red dots) for the winter or all-weather roads needed to access the drill sites from the Dempster Highway.

Table 6: Components of an Access Management Plan prepared by NCY with comments from VGFN and this report.

NCY 2014 access plan	VGFN comments 2015	This report
NCY has the right to restrict access to authorized project personnel.	VGFN citizens will be granted access on project roads (including the Chance Road) for the purposes of trapping.	To minimize caribou responses, traffic and people should be restricted to minimum
All project roads will be gated, and radio controlled to prevent unauthorized use.	NCY will develop alternative mitigations when gates prove ineffective. The trigger to implement alternative mitigations will be when one gate or decommissioned road is circumvented.	Gates unless manned are typically ineffective; after road is decommissioned, travel surface should be removed or blocked (slash or earth berms constructed to an approximate height of 2 metres
Signs will be positioned at all road access points.		Signs should be updated (electronic) & with an education program
Use pre-existing linear features.		Dog-legs to reduce line of sight (but visibility needed for drivers and wildlife).

Vehicles will be restricted to 50 km/h.		Safe vehicle speed unknown – needs to be flexible.
All wildlife will have the right-of-way on roads and vehicles will stop when wildlife is encountered.		
Additional speed restrictions will be implemented when large numbers of caribou are present.		Also use pilot truck or convoy traffic to create crossing 'gaps in time.'
First 100 m of roads connecting to the Dempster Highway will be made impassable using appropriate methods (e.g. rock fencing and ditches).	All roads and clearings will be decommissioned to state of functional habitat restoration as soon as practical.	Rollback, vegetation planting, mounding, installation of berms or temporary barriers during any shutdowns.
	All project roads that lead off the Dempster Highway will be monitored for public access on a daily basis when caribou are in the area	Manned gates with remote video cameras.
	Snow embankments and windrows will be limited to 1.5 m in height, with breaks every 500 m to facilitate caribou movement. Breaks will be established opposite one another, not offset.	
Education		Explain caribou behaviour especially relative to traffic and unexpected movements.

While we have reviewed impacts of disturbance and mitigation for migratory tundra caribou, we note the lack of analyses on how caribou integrate both environmental affects (sensitivity) and exposure to more than one set of disturbances. In the Western Arctic herd's range, analyses of satellite collars suggest delay and deflection during fall migration at a distance of 50 km from the Red Dog mine haul road (Dau 2015). However, hunting is restricted to one part of the road (Dau 2015) suggesting that the extent of the delay and deflection, which varied annually, requires greater understanding. The Dalton Highway linking Fairbanks to Prudhoe Bay crossing the ranges of the Central Arctic Herd has hunting along the highway but the data have not been analysed on the responses of the caribou to the highway.

In Nunavut, a supply all-weather road between a community and mine started out as private until the community requested to use it for caribou hunting. While hunting in the vicinity of the road increased, the evidence that the overall harvest increased was unclear and but was also suggestive that the fall hunting added to the responsiveness of the caribou to infrastructure and their deflection from the Meadowbank Road.

The Porcupine Caribou Management Board has a Harvest Management Strategy that will need to track any potential changes in harvest levels if Northern Cross access changes the harvest amount. The greater problem lies in how hunting influences caribou behaviour changes to industrial activities, and how to mitigate that effect. There is no evidence-based approach due to lack of analyses and pre-designed monitoring, to comparing responses to traffic before and after exposure to hunting.

We note that the disturbance will have the least effect on the caribou when it is predictable (vehicles travel the roads at consistent times and speeds). More can be done using monitoring to fine-tune the time of day and preferred crossing locations to increase the predictability for the caribou that can then be incorporated into traffic management. This applies even more strongly to people on foot and ATVs.

7.7 Benefits of a technical advisory group

Environmental assessment increasingly leads to recommendations for adaptive monitoring and mitigation. Issues of technical complexity are commonplace and require sharing with communities to empower them to trust and understand how their resources are being cared for. There is also the need to incorporate community values and knowledge during the monitoring and mitigation. A technical advisory working group is ideally placed to ensure collaboration and to act as a go-between for the public and the proponent by providing oversight (watching). In a practical sense, responding to written comments such as reviews of annual monitoring reports can be protracted and difficult to manage especially when several agencies and groups are involved. Face-to-face meetings tend to be more productive in finding common ground on technical issues.

Finalized wildlife and mitigation plans through the environmental assessment process of drafts, information requests and hearings are collaborative. This point was made for example in B.C.'s final mitigation plan for the Roman coal mine proposed within the ranges of a northern mountain caribou herd. The need for timely collaboration underlines the approach taken by Baffinland, which in conjunction with the Qikiqtani Inuit Association (QIA) established a Terrestrial Environment Technical Working Group prior to the finalization of the Final Environmental Impact Statement (FEIS). NIRB's subsequent project certificate supported the continuation of the advisory group to Baffinland's further development of monitoring and mitigation plans for project interactions with the terrestrial environment, including wildlife and wildlife habitat.

NCY's WMMP was designed to be collaborative as it included suggestions from the Porcupine Caribou Management Board, Environment Yukon and the Yukon Land Use Planning Council. However, given the extensive public concerns during the information requests and the uncertain effectiveness of the proposed adaptive management (see following text), further collaboration would be helpful to NCY.

The four diamond mines in the NWT established oversight bodies for monitoring and mitigation during their environmental assessments and subsequent environmental agreements. While the scale of 10-20 drill pads and roads over two years are not the same scale as open pit mining, both types of developments require monitoring and adaptive mitigation and collaborative oversight bodies play a valuable role. Affolder et al., (2011) reviewed three of those NWT oversight committees for the Ekati, Diavik and Snap Lake diamond mines. The Affolder review made the point about the different and sometimes conflicting mandates of the oversight bodies and whether their role is rigorous technical oversight of environmental monitoring or to communicate about community concerns.

Oversight does not mean the power to affect decisions, it is about watching monitoring and mitigation choices and actions, offering technical advice and communicating about community concerns. The exact roles and means of advising are typically outlined in an environmental agreement or in a terms of reference.

Northern Cross established a working group with First Nation governments, territorial government agencies and the PCMB in 2013 as part of the YESAB Decision Document, 2013-0067 for their 3D seismic operation. The working group met several times over the winter of 2013-14 but did not have the time and information to develop a terms of reference or to always reach agreement. In this context of adaptive monitoring and mitigation for the Porcupine Caribou Herd and Northern Cross, we suggest the conclusions from Affolder et al., 2011 of oversight bodies is useful and germane:

> "Models of oversight differ, as do functions. A particular challenge for existing oversight agencies arises where they are tasked with multiple (and potentially conflicting) roles. Some oversight bodies take on mandates of technical oversight and investigation that demand independence and distance to ensure public confidence in their processes and results. At the same time they are charged with communication and bridge-building roles that require a certain embeddedness and closeness to be able to serve as effective conduits between communities and project teams. One conclusion of this report is that this tension needs to be acknowledged. The danger of not admitting to this tension lies in the temptation to seek out some middle ground – a non-independent body tasked with oversight yet lacking robust powers, or, alternatively, a highly-skilled technical body lacking the funding and personnel to effectively communicate community needs. Neither form

may provide the most effective solution to community needs. Careful attention to the question – what form of oversight does the community need to gain confidence in the Remediation Plan – must come before a decision on the form and function of an appropriate oversight body."

Based on experience in Nunavut and the Northwest Territories, we suggest that during at least annual meetings, it is crucial to have access to monitoring data and levels of project activity. If thresholds are approached, the group should meet to review them and then change the mitigation activity. The monitoring protocols, thresholds and monitoring design should be collaboratively decided using all available information.

7.8 Knowledge gaps

From our review and personal experience we highlight a number of knowledge (or process) gaps that could improve our understanding of caribou-industry interactions and better facilitate adaptive mitigation and monitoring plan implementation.

7.8.1 Adaptive management

A clear knowledge gap is the extent to which monitoring and mitigation work together in an adaptive management context. Typically the listed best practices are relatively generalized with wording such as reducing sensory disturbance, or for roads, reduce risk of disturbance or mortality. The fine-tuning of mitigation is through monitoring that can lead to adjustments in the mitigation. This is usually described as adaptive management, which in its most pure sense is "a systematic and rigorous approach for learning through deliberately designing and applying management actions as experiments", (Murray and Marmorek, 2004). In the NWT, the most progress for adaptive management is with aquatics monitoring and mitigation as the thresholds for water chemistry are better quantified (Racher et al., 2010; Figure 27)

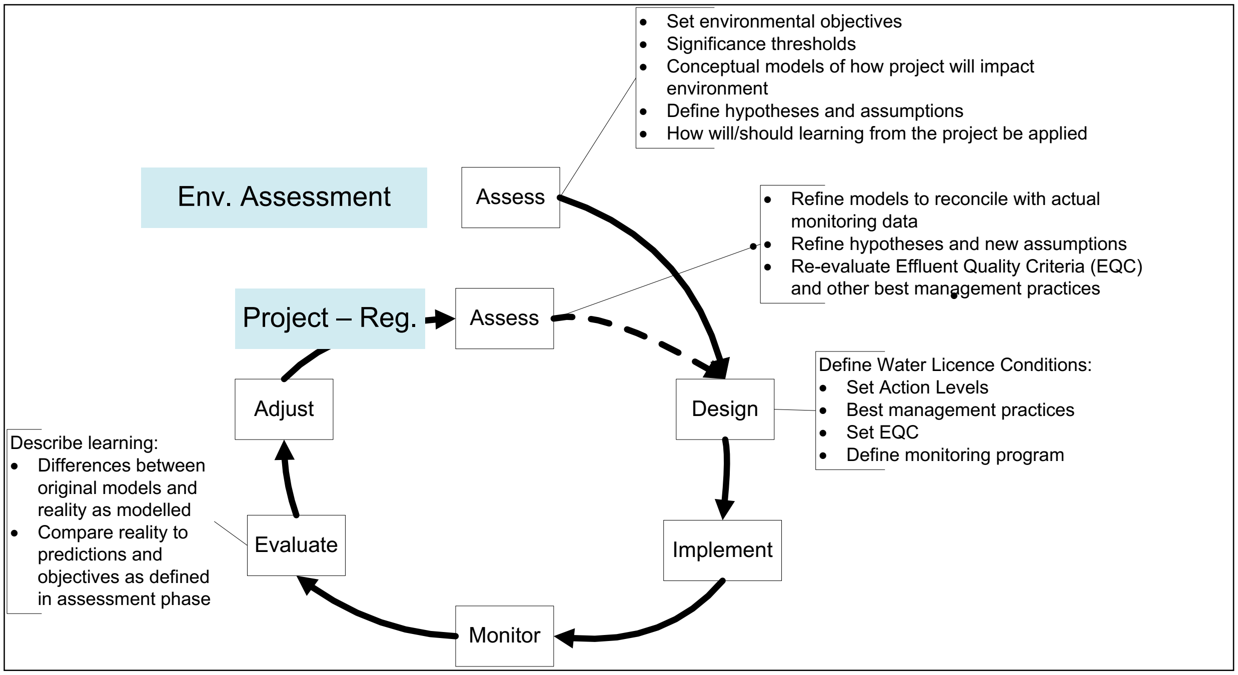

Figure 27 Schematic of adaptive management from Racher *et al.,* 2010

However, in practice, adaptive management is also that alternative treatments (application of mitigation actions) may be sequential rather than be compared at the same time through formal experiments. While most learning about mitigation would preferably be from experimental designs statistically comparing, for example, several levels or types of dust control at the same time, this is not always practical. Shortcomings in the testing of effectiveness of mitigation actions is known. For example, the Joint Review Panel for the Mackenzie Valley Pipeline (JRP 2009) indicated that participants raised doubts about whether monitoring programs were sufficiently well-designed to test the accuracy of impact predictions and effectiveness of mitigation. Another example is that although monitoring and mitigation have been underway since 1996 at an open pit and underground diamond mine in the NWT (Ekati), during an environmental assessment for an extension of the mine, the Independent Environmental Monitoring Agency (the oversight body) asked how monitoring was leading to improving mitigation (MVEIRB 2016). A specific example was whether caribou road crossings were effective and that a quantitative assessment of crossing ramp locations and frequency is needed to determine if current caribou crossing ramps are effective.

The annual reports on monitoring and mitigation typically for N.W.T. and Nunavut mines are sparse on how mitigation is actually triggered and its level reduced or intensified. Specific testing of mitigation effectiveness is rare. An exception was in Alaska, where caribou responses to speed restrictions and truck convoying on a 16-km gravel road serving a drilling well were monitored for three years on the calving and summer range of the Central Arctic Herd. Frequency of traffic was low which may be why traffic convoying (1.5 trucks/convoy and 2.4 convoys/day on average) was ineffective at reducing calving displacement to less than 2.4 km or reducing the disturbance reactions of caribou within 500 m of the road (Lawhead et al., 2004). In general, however, in Alaska oilfield developments, mitigation is not sufficiently monitored to test effectiveness (Braund et al., 2013).

Adaptive management for Northern Cross is an area to be strengthened as much depends on reaching agreement on thresholds that are tied to the sensitivity of the caribou and the type of exposure. Our discussion on the importance of a Technical Working Group (TWG) is also germane to this issue. One of the key roles of the TWG would be to ensure there is an adequate review of the effectiveness of mitigation and to thus improve adaptive mitigation.

7.8.2 Habituation and learning

Although habituation (learning to adjust and reduce behavioural responses) has been suggested for caribou on the Prudhoe Bay oilfield, clear evidence is lacking as few studies were undertaken. Lawhead et al., (2004) did suggest that the low responses from caribou to traffic on one haul road to a drill site compared to a road with a lower frequency of traffic was the from greater opportunities for habituation. However, at least for boreal caribou, memory and 'local knowledge' of their home ranges was found to explain much about the caribou movements and habitat selection (Van Moorter et al., 2009, Oliveira-Santos et al*.,* 2015). The importance of caribou's learning and memory may relate to the initial responses when the caribou become resident in an area for the winter – stringent mitigation to minimize behavioural disturbance and stress may reduce responses for the duration of the residency. This is also an argument for separating harvesting from industrial disturbances.

The Porcupine herd has already been exposed to exploration activities near the Dempster Highway and it is unknown how those experiences have already influenced their behaviour. The Porcupine caribou have been intermittently exposed to oil and gas activity since 1959 and 38 wells (25 on Northern Cross Yukon leases) have been drilled and 4,262 km of 2D seismic lines have been cut since the early 1960s (Anderson et al., 2002). Recently, in 2012 and 2013, NCY drilled four exploration wells and during the winter of 2013/2014, NCY conducted a 325 km^2 3D seismic program which largely overlapped the 1990-91 burn areas - the lines were 75% <2.5 m wide. Although the seismic project was monitored, mitigation was not monitored for effectiveness.

7.8.3 Stress

Little attention has been paid to stress as a response to industrial disturbance although it can be sampled without handling the caribou (Joly et al., 2015). Both nutritional stress and 'fear' stress were found in measurable forms (hormones) in fecal pellets; and in Alaska, higher nutritional stress was found in fecal pellet samples within 16 km of the Red Dog Mine road which is where road dust has affected vegetation (Joly et al., 2015).

Caribou in boreal forest or post-fire shrubs are mostly hidden and activity scans to adequately measure caribou responses are technically difficult. Measuring stress would be a useful monitoring indicator with threshold values to determine whether mitigation to reduce behaviour responses is appropriate.

7.8.4 Implications of collective behaviour

The characteristic of migratory tundra caribou is their collective behaviour – they do things in groups and group size influences their behaviour such as crossing success of roads or pipelines (Lawhead et al., 2006). There are information gaps both in how group size influences crossing success, and how group size or individuals are used to measure crossings and determine thresholds. This tendency suggests that the definition of crossing success based on >50% of the individuals in a group crossing is reasonable (Lawhead et al., 2006). However, ERM Rescan (2014) reported that using cameras at the Ekati diamond mine revealed no effect of group size on susceptibility to heavy or light vehicles (i.e., both large and small groups behaved similar to potential vehicles disturbances). The differences between Alaska and the N.W.T. suggest that more effort is needed to understand how group size affects responses to disturbance and how to set thresholds.

7.8.5 Environmental trends and variation

There is no consistent or recognized way to ensure that climate and weather are included as a contribution to annual and seasonal variations in behavioural responses. Trends in weather and vegetation, especially forage, will influence both the exposure and the sensitivity of caribou to industrial exploration and development. Forage availability made more energetically expensive to acquire or forage quality affected by weather affect the nutritional status of caribou and their responses to industrial activities. Likewise snow depth and condition (density, hardness) will affect caribou timing and rate of travel. However, these relationships are rarely explored in baseline information or how the relationships could modify monitoring and mitigation effectiveness.

7.8.6 Linking different scales of abundance monitoring

There are a limited number of monitoring methods used to document caribou abundance near industrial development and activity. On the ground, there are incidental or systematic road surveys, height-of-land surveys, remote camera and snow track surveys. At a broader scale there are aerial surveys, usually in a defined zone of influence from infrastructure. At the coarsest scale are radio tracking of marked individuals in the herd. A review of most monitoring reports indicates that there are few instances where there is an attempt to link the various scales. In the case of NCY much of the comments are related to significant number of caribou and how to monitor numbers. The most contentious issue was the necessity of conducting aerial surveys, presumably related to cost, given the distance of the project from any fixed-wing base. In the case of NCY if there were a relationship between track surveys, road surveys and collar locations, it would be possible to assign an estimate of the number of caribou within the ZOI with associated confidence limits.

7.9 Habitat Management

The North Yukon Land Use Plan (NYLUP) provides the basis for land use designations for much of the Yukon portion of the summer, fall, winter and spring ranges of the PCH. The yet-to-finalized Peel and Dawson planning initiatives encompass regions south of NYLUP boundaries and we are not aware f the level of protection that will be identified for winter ranges south of the NYLUP boundaries. Lands north of the NYLUP boundaries have strong conservation regimes in place through Ivvavik and Vuntut national parks, Old Crow Flats Special Management Areas and the North Yukon Land Withdrawal, an area that has not been available for land disposition and resource exploration since 1978. The 78,000 sq. km. Arctic National Wildlife Refuge currently protects most of the calving, summer, fall and spring Alaskan ranges of the PCH, although the U. S. Congress can allow development within critical calving grounds with ANWR (see “1002 issue” below).

7.9.1 Conformity to NYLUP

The NYLUP presents landscape at four levels - from Zone I, with the lowest development as the “management intent,” to Zone IV with highest development as its “management intent.” “Surface and linear” disturbance thresholds quantify a zone “tolerance” for development. Essentially there is 10x more development tolerated in Zone IV than Zone I before reaching either cautionary or critical thresholds. The proposed development by NCY falls entirely within the Zone IV designation.

The plan designates cautionary indicator levels as an early warning signal. When these cautionary indicators are reached, the respective governments should share information and review the health of the key ecological values, and if required, determine the management options to minimize and mitigate impacts. Critical indicator levels represent the point where the indicators may have reached or surpassed acceptable levels.

In their “conformity check” the Yukon Land Use Planning Council indicated that with the addition of new and proposed development, the region was still well below cautionary or critical thresholds. These sub-threshold levels, however, were possible by assuming 20% of seismic lines were “recovered” and that in non-forested landscapes, linear disturbance was no longer necessary. Specifically the NYLUP states: “…as human-caused surface disturbances, including linear features, recover through natural re-vegetation or active reclamation, they are subtracted from the total amount of disturbed area. As a guide, human-caused surface disturbance is considered recovered when it no longer facilitates travel or access by wildlife and people. In forested areas, a feature can be considered recovered when it contains woody vegetation (trees and shrubs) approximately 1.5 metres in height.” This definition is closely linked with human and predator access and potential effects on Porcupine caribou and moose, key values in the region. Interveners, notably the Nacho-Nyak Dun First Nation, questioned the dramatic (67%) reduction in existing linear features and that if the original values, reported in the NYLUP were used new and proposed developed would reach at least the cautionary level.

Although in general an increase in linear features relate to increased potential disturbance to caribou, the relationship is complex. Caribou react to a zone of influence, which according to Johnson and Russell (2014) is currently 6 km for seismic lines and areas of low human use. Thus the spatial effect of seismic lines (i.e. the area of the landscape that falls within a zone of influence is a more direct measure of potential impacts on caribou. For example, dense linear development in one small section of a defined landscape would have a much lower impact on caribou compared to the same amount of linear development scattered throughout the landscape. In the earlier case much of the ZOI linear features would overlap.

To test whether the removed linear features potential reduce the exposure of seismic lines to caribou, we would recommend duplicating Johnson and Russell's (2014) analysis for: 1) all seismic lines; and 2) non-forested lines removed. If the zone of influence expands with the removal then there is logic in removing non-forested; however if the ZOI stays the same or is reduced then the role of non-forested seismic lines needs to be reconsidered.

7.9.2 The "1002" issue

Superimposed on all these land use designations is an international agreement signed by Canada and U.S. for the conservation of the Porcupine Caribou Herd. The treaty outlines a number of provisions to ensure cooperation and consultation on habitat issues between the jurisdictions.

Conservation provisions in the International Porcupine Caribou Agreement

a. The Parties will take appropriate action to conserve the Porcupine Caribou Herd and its habitat.

b. The Parties will ensure that the Porcupine Caribou Herd, its habitat and the interests of users of Porcupine Caribou are given effective consideration in evaluating proposed activities within the range of the Herd.

c. Activities requiring a Party's approval having a potential impact on the conservation of the Porcupine Caribou Herd or its habitat will be subject to impact assessment and review consistent with domestic laws, regulations and processes.

d. Where an activity in one country is determined to be likely to cause significant long-term adverse impact on the Porcupine Caribou Herd or its habitat, the other Party will be notified and given an opportunity to consult prior to final decision.

e. Activities requiring a Party's approval having a potential significant impact on the conservation or use of the Porcupine Caribou Herd or its habitat may require mitigation.

f. The Parties should avoid or minimize activities that would significantly disrupt migration or other important behaviour patterns of the Porcupine Caribou Herd or that would otherwise lessen the ability of users of Porcupine Caribou to use the Herd.

g. When evaluating the environmental consequences of a proposed activity, the Parties will consider and analyze potential impacts, including cumulative impacts, to the Porcupine Caribou Herd, its habitat and affected users of Porcupine Caribou.

Lands within the Arctic National Wildlife Range in Alaska (1002 lands) contain some of the highest potential for oil and gas reserves in Alaska. The reference for 1002 comes from the *Alaska National Interest Lands Conservation Act (ANILCA)* legislation passed in 1980. Section 1002 of the *Act* states that studies were to be done to determine the value of the area to the PCH (among other resources) and the potential for oil and gas activity. These studies were to be evaluated by Congress, which would then decide whether or not to open the area up for development. Those studies were completed in 1987 (and many are ongoing), but, to date, no Congress could pass legislation to open the area for development.

The relevance of the 1002 lands issue to Eagle Plains oil and gas development is that when the cumulative effects of development are fully assessed for the herd on both sides of the border, stricter management demands may be applied given the potentially large impact of activity within the herd's primary calving grounds. Further, Canada and Yukon and the PCMB, represented on the International Porcupine Caribou Board, will have an opportunity to critically comment on the proposed development and it is important that we have demonstrated due diligence in any developments of this side of the border.

7.10 Harvest management

As well as managing habitats, an effective harvest management strategy can improve the adaptive capacity of the human/caribou system. Harvest management can also be a mitigation strategy as harvesting along a road may intensify the caribou responses to vehicles on the road. Roads can facilitate access for harvesting.

Managing parties in the mid-2000s, assuming the PCH population was in decline but unable to verify because of a series of population count failures, designed and implemented a Harvest Management Strategy which sets thresholds that act as triggers for a set of harvest restrictions. Every year parties meet, exchange monitoring information and make any harvest recommendations they feel warranted with respect to the thresholds established. Managers of the PCH are thus fortunate compared to eastern counterparts in that although harvest regulation has been implemented, those regulations were considerable less stringent than regulations and voluntary restraints imposed on other migratory herds.

Access management necessitated by all season and winter roads was a concern for many interveners during the NCY review process. Although some groups maintained that restricting access to traditional hunting areas was not legal, many felt that access should be gated for safety and conservation reasons. Hunting likely increases the responsiveness of caribou to other human activities including oil and gas support activities.

NCY discussed the development of a baseline study of hunting activity in the Eagle Plains area in the middle of winter. The PCMB maintained that care should be taken to ensure study design is sound and that actual baseline conditions are being captured. Further they said that the study should be long-term and should be developed in conjunction with a Caribou Working Group. In our review we only found one study designed to identify hunting patterns before and after development access was initiated – a spatial harvest monitoring program initiated by Agnico Eagle for its Meadowbank gold mine in Nunavut, east of the community of Baker Lake.

7.10.1 Harvest monitoring case study: Agnico Eagle

In March 2007, Agnico Eagle initiated the Baker Lake Hunter Harvest Study in association with the Baker Lake Hunter's and Trapper's Organization to monitor and document the spatial distribution, seasonal patterns, and harvest rates of hunter kills before and after construction of the Meadowbank All-Weather Access Road (AWAR).

Harvest study staff visits hunters on a quarterly basis to document harvests (which are written on the provided annual hunter harvest calendar), and discuss general hunting trends and observations. Staff also conduct radio addresses and post-promotional material around Baker Lake during the quarterly visits. Agnico Eagle also had the advantage of a 10-yr comprehensive harvest study conducted throughout Nunavut that not only quantified annual harvest rates but also the locations of those harvest. Thus in analysing their harvest data they were able to compare pre-construction (pre 2007) with post-construction.

To determine whether there was a shift in harvest location due to the road, we compared trends in the per cent of Baker Lake harvest within a Local Study Area (2-km zone around AWAR) to a larger Regional Study Area (25-km zone around AWAR). The per cent harvest in the Local Study Area increased from 7% to 34% while in the rest of the Regional Study Area the per cent harvest declined from 60% to 50%. Thus in the entire Regional Study Area (including the Local Study Area) the per cent of harvest trend has been increasing and that per cent increase is disproportionately increasing within the Local Study Area (by 500%).

These results are the clear evidence on the issue of access. In their initial project certificate the road was designated as a private road that would accommodate harvesting. However, under pressure the Baker Lake certificate designation was changed to a public road (although gated and manned). Although there is provisionally a one-km no hunting zone on the AWAR, there was no evidence of enforcement.

8 Specific questions

Energy Mines and Resources asked us four specific questions that are answered in the following section. There is no black and white answers as there are uncertainties and unknowns as identified below. We suggest that a collaborative cumulative impacts analysis examine the different scenarios that should integrate options for the timing and amount of, for example, drilling with annual variations in weather and encounter rates. The resulting projections of individual condition (body weight, survival and pregnancy) and herd size would then guide decisions about the scenarios are the least risky, answers questions about the intensity of development and provide information to help stakeholders.

8.1.1 <u>Should drilling be completed in fewer years or over time?</u>

The answer is conjectural until the baseline information on caribou abundance and trends in, for example, snow depths are integrated. A baseline analyses would describe the annual variation of caribou exposure and for example, if it were a deep snow year and most of the Porcupine herd wintered elsewhere other than Eagle Plains, then it would make sense to drill as many winter wells as possible when the caribou are absent or present in reduced numbers. Caribou migration movements into the project area occur in October through December make decisions more challenging. This period also coincides with a peak in hunting activity.

A question is about Northern Cross's operational flexibility - how quickly can a company tool up or down to adjust to the caribou distribution within a single season? A second question about operational flexibility is whether flow testing can be done in less than 2 years or can be staggered if a large number of caribou were present in the 2nd year. The baseline information also suggests that the caribou encounter rate is reduced east of the Dempster Highway that suggests that timing of the wells east and west of the highway could be used as mitigation. Another factor is whether the caribou are less responsive to a moderate level of disturbance (three drills per winter for 2 years or six wells in one winter) with assumptions about interannual variability in weather such as snow conditions. This could be examined through energetic and population modelling which has not yet been undertaken.

8.1.2 Pros and cons of seasonal drilling

The choice comes down to the potential for disturbing caribou during a winter operation compared to no exposure to caribou during a summer season, but the creation and long term presence of all-season access to portions of the PCH range. Winter operations are projected to start in December and end in mid-April, overlapping with winter residency and spring migration for the caribou. Summer work is early May until late October which would overlap with fall migration. Initially NCY indicated that they would not require all-season roads to drill the wells, however through a series of Information Request sessions their plans slowly shifted to 6 winter wells and 14 summer wells over from 2 to 8 years. Thus based on the proposed operation seasons, caribou would be exposed to activities in both a summer and winter season unless the summer season ended before October it would overlap with fall migration. From our analysis, October is currently the single most frequently occupied month in the buffer zone and with the greatest number of collars. Therefore ensuring no activity in October would allow most of the caribou to enter the development zone without being disturbed.

A significant consideration is issue of the winter or all-season roads and increased access to the area. Winter operations only reduce the length of all-season roads depending on which wells are unsuccessful, as successful wells will require all-season roads for flow testing. The roads are seven metres wide with a 150 m-long passing bay about every 750 m; the 19 spur roads total 65 km and each road averages 3.4 km. All-season roads fragment the caribou winter habitat and the effect on caribou crossing success and habitat use is unknown. Based on out knowledge of caribou ecology there is a stronger preference for short term disturbance compared to long-term access, so we would recommend that Northern Cross stick to it's original plan to exploratory drill in the winter season. Without spatial analysis and risk analysis of the likely exposure of the Porcupine herd to the proposed total 87-km road (605 km^2) within the area is uncertain. It is also uncertain the effects of adding the Northern Cross project traffic to the >200 vehicles/day on the Dempster Highway.

8.1.3 BMPs for migrating versus wintering resident caribou?

Whether mitigation for winter resident caribou compared to migrating (fall or spring) caribou will be different is speculative without a more detailed analysis of the exposure including the daily rates of movement. Migratory movements typically are at a higher daily rate and more directional (toward a destination). However, at the daily time scale, distinguishing between the two types of movement is difficult. The differences for resident versus migratory caribou may be the thresholds for mitigation as the actions are relatively limited (such as the rate and speed of vehicle passage). However, as fall migration is in October-early November before the start of the winter-drilling and the lack of significant movements through the zone during spring migration two mitigation strategies may not be necessary. Fall migration is a different type of exposure than winter residency as it usually involves faster-moving caribou following each other, which imposes a different likelihood of encounter rates. In that case, the priority for mitigation is to let the leaders pass and to minimize disturbance to prevent aversive conditioning of the caribou early in the winter. Access management to reduce the probability of adding to the disturbance would be advisable especially as most hunting is during fall and spring (M. Suiter pers. comm.).

In comparison, resident caribou would likely have a diffuse movement pattern more predictable from the vegetation cover types including burn areas and their effect on snow depth. Resident caribou would have a lower rate of daily movements and more predictable use of their trails in the snow. This suggests a higher degree of likelihood of encounters with Northern Cross activities. The more predictable the drill camp activities, the greater the likelihood that the caribou can habituate, which suggests that off-road activities (people, snowmobiles, etc) should be minimized.

The clumping of the wells to be drilled in winter relative to the mapped movements of the satellite-collared caribou suggests that exposure will likely be different west and east of the Dempster Highway, which will affect mitigation and monitoring. Figure 28 is the cumulative pathways of the collared caribou during fall migration, winter and spring. However, caution is needed as caribou are seen east of the Dempster Highway possibly in part because caribou are more easily seen in the burns to the east of the highway (M. Suiter pers. comm.).

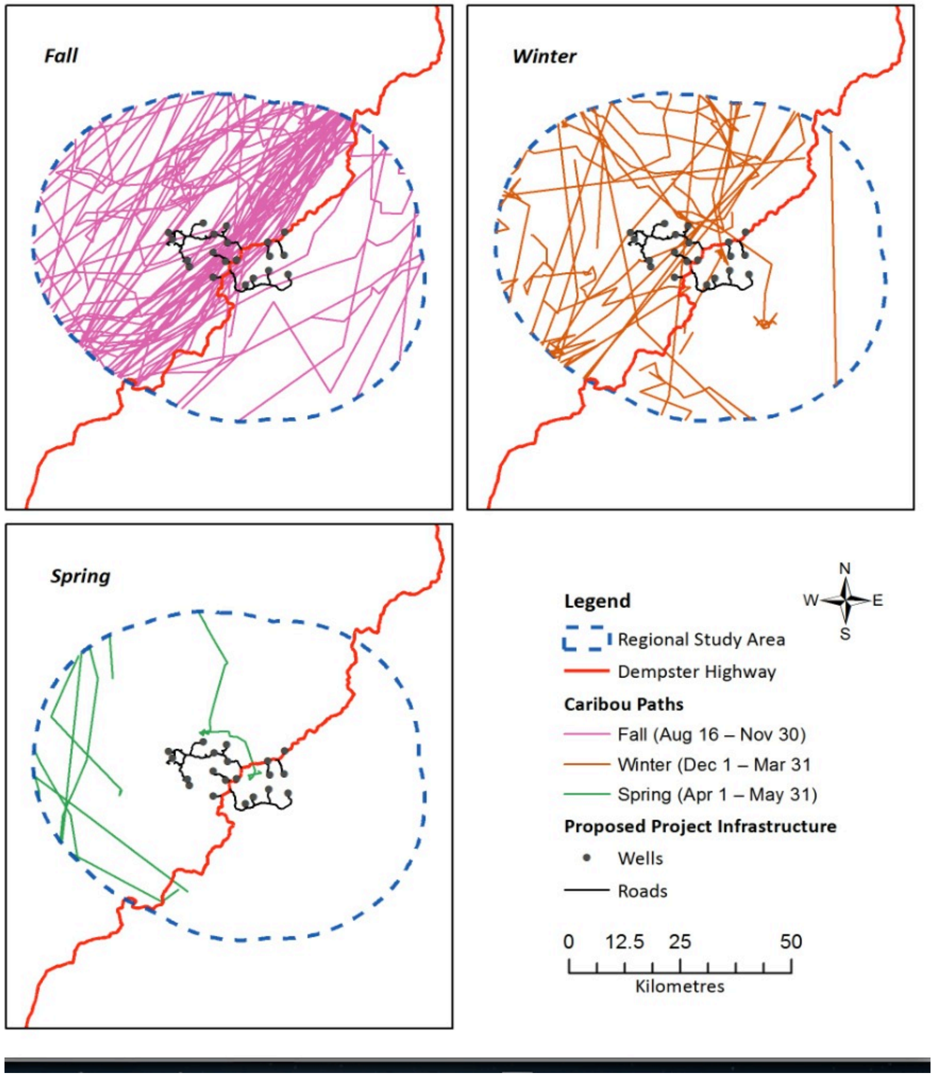

Figure 28 Movement paths of the PCH through a 30-km buffer around proposed NCY infrastructure (1985-2016).

While we have compiled a flow chart (Figure 29) to illustrate progressive monitoring and mitigation drawing on the review comments for Northern Cross, and from our experience with monitoring and mitigation in the literature, we acknowledge that it is illustrative rather than definitive. We suggest that devising monitoring and mitigation is best served by more analysis of the baseline exposure and sensitivity, and then a collaborative approach.

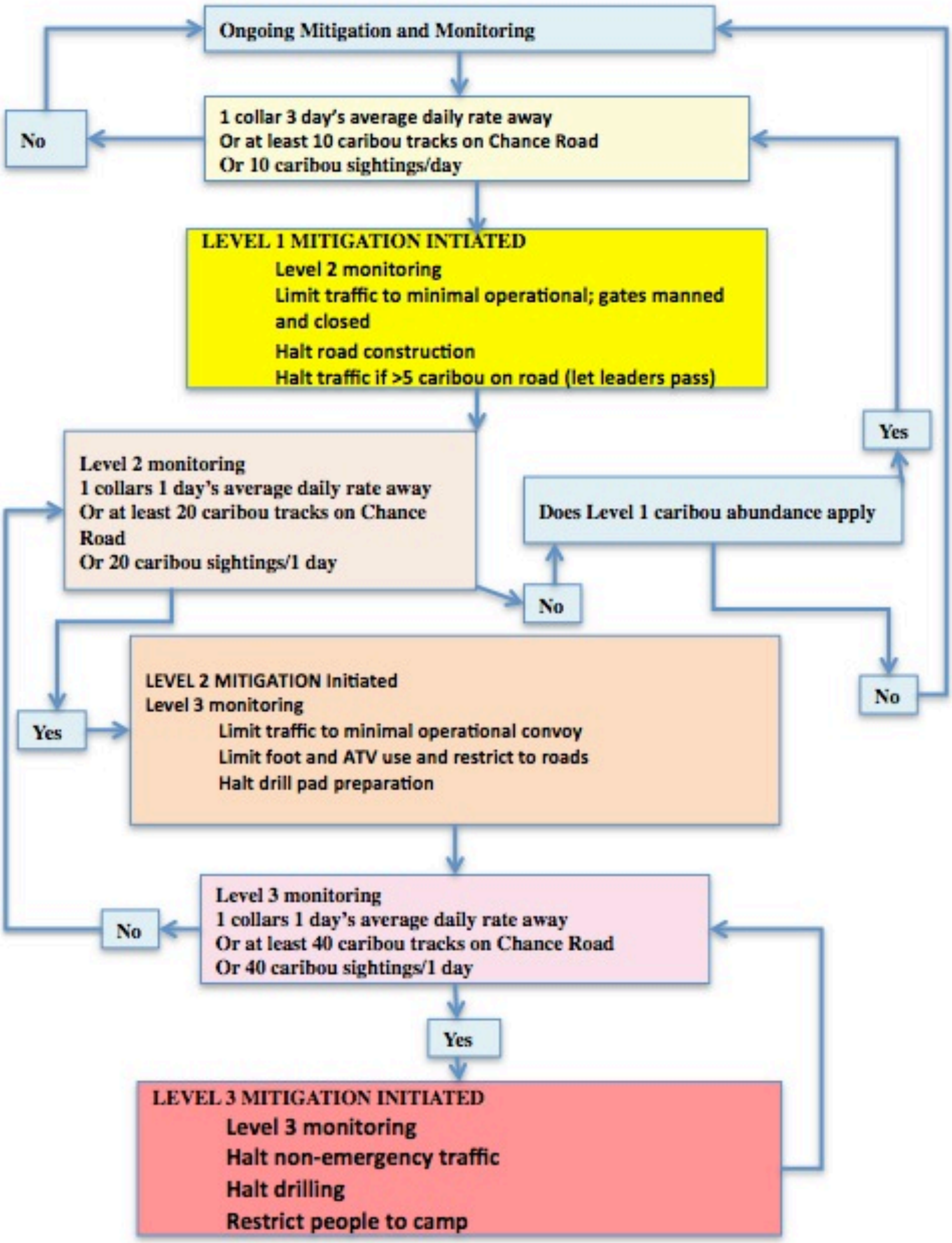

Figure 29 Suggested mitigation flow chart for NCY project

8.1.4 Significant number of caribou and safe operating distance

A survey of the literature found numbers but little objective rationale for safe operating distances in relation to the number of caribou and even less testing of the effectiveness of the proposed thresholds for caribou numbers and distances. The concept is that as caribou approach human activity, the potential for disturbance increases the closer the caribou are to the disturbance (safe operating distance) and the number of caribou approaching (significant number of caribou). We have tried to approach this issue objectively. Thus in Figure 28, we ascribe the early warning trigger as collars that are 3 days travel from the development activity. This value varies seasonally (Figure 28) and, for example can be as high as 42 km in October to as low as 6 km in March. Although the concept is objective, setting the warning zone as 3 days travel may not be appropriate operationally. If the implications of a Level 1 trigger involve adjustments to operational procedures and 3 days is not enough warning, this value may need to be increased. A collar is a sample of the herd and the more collars, the more confidence that the collared samples represent the true distribution of the herd (see section 7.5.2).

Limitations in the reliance on collared caribou mean a need for other monitoring such as aerial surveys. We feel aerial surveys are most useful if specifically designed for determining the proximity of caribou, relative to the number and distribution of collars. However aerial surveys are not practical for the short term monitoring given the vagaries of weather, distance to aircraft base, and movement rates of caribou. A protocol that links ground surveys to collar distribution would be more reliable operational monitoring method. Thus we have referenced a template for a “research” project that could be conducted in the Eagle Plains region to help quantify that link (see section 7.5.2).

From our review of potential impacts, we suggest that the closer the caribou to the source of disturbance, the greater their responses. Height-of-land surveys and track surveys should provide an objective estimate of caribou in close proximity to oil and gas activities. In 2013-14 NCY established an extensive network of 3D seismic lines that surround the current proposed well site operations. We would propose that NCY in consultation with a caribou advisory group design an operational plan to use the 3D seismic lines for track surveys. The seismic lines are suited for this type of survey, although they are used by harvesters despite the narrow right-of-way and poor sight lines (M. Suitor pers. comm.) In our proposed mitigation plan (Figure 29) we input numbers from those surveys that can act as triggers – however, actual numbers would have to be determined by the design of the track surveys and area visible on height-of-land surveys. The key is that the surveys need to be consistent and frequent enough to capture re-distribution of caribou (again tied to seasonal movement rates and average residency time).

8.1.5 What is an effective mechanism for including affected First Nations and co-management bodies in an adaptive management framework?

The answer to this question about Best Management Practices and adaptive mitigation lies partly with those First Nations and co-management bodies themselves as how they want to be involved and how to have access to technical capacity. Our recommendations include one effective mechanism, which is to have a 'body' such as a committee or working group to have the experience of working together to develop BMPs. We have also recommended the need for committee/working group to have access to information (such as a data repository) and the technical capacity to make recommendations.

9 Recommendations

1. Undertake a cumulative effects analysis using the approach of vulnerability and building adaptive capacity to develop monitoring and mitigation relative to herd and landscape management. Varying intensities of development such as summer or winter and multi-year drilling will be examined as different scenarios to integrate climate and vegetation changes. This analysis would provide the framework to support and refine all the various components for Best Management Practices, adaptive mitigation and monitoring and project assessment. Over the last number of years the PCMB has furthered the capability to conduct Cumulative Effects analysis, and thus should assume a lead role in the process.

2. Create a Technical Working Group to oversee the mitigation/monitoring cycle for Northern Cross - could use flow charts as Straw Dog beginning to gain the experience of working together on developing approaches to adaptive mitigation and how monitoring can improve mitigation. Use the output of the cumulative effects assessment to support the Working Group to develop specific recommendations for adaptive mitigations for the Northern Cross Project including Safe Operating Distances.

3. Develop a data repository - in light of the lack of baseline data, inaccessible 3D seismic caribou related data and future data from potential NCY and other north central Yukon oil and gas development, develop a data repository that has open access (a good example is the Wildlife Management Information System (WMIS) data repository in NWT. There needs to be a data management protocol between governments and industry so that data is freely available. We realize that regional offices hold data but there is benefit to have a more centralized data management system.

4. Create a Collaborative Advisory Committee to draw up Best Management Practices for Yukon caribou. This advisory committee could be collaboration between the PCMB (with the mandate for the PCH) and the Yukon Fish and Wildlife Management Board with advisory mandate in other regions of the Yukon.

5. Undertake a retro-active analysis of telemetry to examine relative rates and directions of caribou relative to the Dempster Highway and update analyses to predict fall and winter movements from climate – especially snowfall and estimate the range of natural variation. We recommend that a more focused analysis be conducted in the Eagle Plains area for fall, winter and spring seasons.

6. To prepare for future monitoring, undertake a test of caribou on the ground relative to satellite collars to calibrate the relationships with snow tracks, height–of-land towers, drones and/or observational surveys.
7. Validate the exclusion of non-forest seismic testing from threshold calculations. Incorporate finding from seismic/remote camera study (Yukon Environment and EMR). Conduct a focused RSF analysis with all historic versus reduced seismic lines to see how eliminated seismic lines affect model output.
8. Road management: Implement a harvest study or re-vitalize a check station along the Dempster Highway. This would build a map of harvest locations and caribou sightings to compare with collar locations to re-examine the data suggesting that the Dempster Highway is a factor in Porcupine herd movements.

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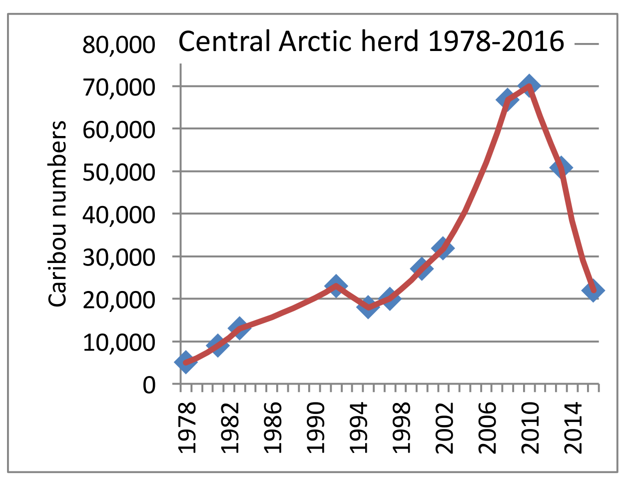
Appendix A: A summary of the Prudhoe Bay oilfield and the responses of the Central Arctic Herd (CAH)



A frequently cited example of whether oil and gas development are compatible with migratory caribou is the relationship between the CAH and the Prudhoe Bay oilfield. The story unfolds over 35 years during which time our understanding of caribou ecology and techniques increased as the oilfield grew. Where available, we have also included a summary of monitoring and mitigation of the effects of the oilfield. While information on the timing and westward spread of the Prudhoe Bay oilfield is readily available since the decline in oil production after the peak in 1989[1], information about what the decline from peak production means in terms of vehicle activity etc is less easily found.

Most all the accounts of caribou behaviour are in relation to roads and pipelines and from calving through summer. The herd migrates inland to the Foothills for winter but encounters seismic operations and the highway with the pipeline. However, responses in fall and winter to seismic operations and the highway are not available. The accounts of caribou responses relate to relatively fine scale distribution changes including fewer cows and calves within 4-6 km of the haul roads and regional shifts in calving. However, methods changed which added to disputed results (Haskell and Ballard 2008, Cameron et al., 2005, Lawhead et al., 2004, NRC 2003 for example).

Prudhoe Bay oilfield (86,418 hectares): The oilfield was the largest oilfield in North America and has more than 1000 wells. It lies on State of Alaska land between National Petroleum Reserve (NPR) to the west and Arctic National Wildlife Refuge (ANWR) to the east. Exploration began in the 1960s, production started in 1968. By 1972, planning was underway for a 1,300-km pipeline to ship the oil to Valdez. Concerns included whether caribou could cross the pipeline and the associated haul road (Dalton Highway). Pipeline construction started in 1975 and was completed in 1977. By 1981, an increasing network of roads and pipelines extended 70 km west of Prudhoe Bay to the Kuparuk and Milne Point oilfields.

In 1996, oil was found west of Kuparak at the Alpine field on the Colville River Delta 54 km west of the Kuparuk Field which started producing in 2000. The Alpine oil is shipped through an elevated pipeline connecting Alpine to the Trans-Alaska Pipeline System (TAPS) via the Kuparuk Pipeline System. Alpine has no permanent road connecting it to other North Slope infrastructure, therefore, in the winter, an ice road is built connecting Kuparuk to Alpine to move in supplies for the rest of the operating year. In any given winter season more than 1,500 truckloads of modules, pipeline and equipment are moved to Alpine over the ice road. Presumably these loads have added to the traffic on the Dalton Highway and through the Kuparuk field. In 2001, ConocoPhillips began development of the Meltwater oil field 16 km south west of Kuparak. Meltwater is on the western edge of calving distribution which raised concerns for the caribou and led to specific mitigation and monitoring program (Lawhead et al., 2004). Lawhead et al.'s 2004 three-year study is, so far, the most detailed study of whether convoying traffic on a 16 km road to a Meltwater drill site is effective in reducing the avoidance of a road on the calving and summer range. However, in 2003, traffic frequency was low - averaging 2.4 convoys (one-way) per day and 1.5 vehicles per convoy. The low frequency of traffic compared with an adjoining road caused moderate behavioural responses especially by groups with calves or yearlings possibly because the frequency was too low for the caribou to habituate.

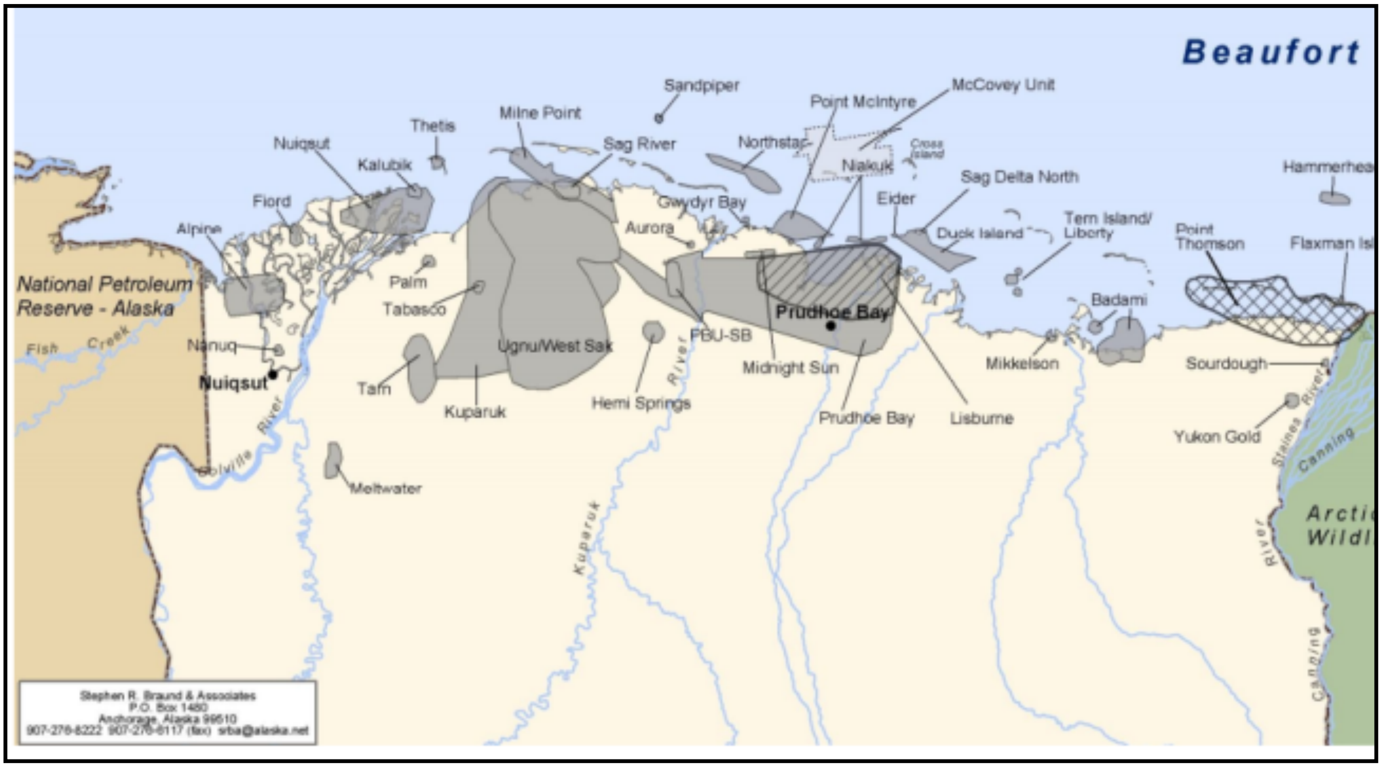


Figure A1. Map of Prudhoe Bay oilfields (from Braund and Associates 2009)

The Central Arctic herd was recognized as a discrete herd with an initial estimate of 5,000 caribou in 1975. The previously continuous distribution of calving recorded in the 1970s had by 1980 become divided on either side of Prudhoe Bay and Sagavanirktok River and the Dalton Highway paralleled by the TAPS as shown by aerial surveys. Within the western calving distribution, the development and use of the Milne Road as the Kuparak oilfield became developed divided the western calving distribution (Cameron et al., 2005). Subsequent analyses based on kernel analysis of collared caribou (2001-2006) showed a large extent of calving with two areas of concentrated calving west and east of the Dalton Highway and Prudhoe Bay. The calving west of Prudhoe Bay that had moved more inland appeared to have less favourable foraging conditions as the calves born on the eastern section were slightly heavier at birth (Arthur and Del Vecchio 2009). Comparing the shifts in calving over time is complicated by changes in techniques. The methods have included aerial surveys in the proximity of roads (summarized in National Research Council 2003, Cameron et al., 2005) and then analysis of radio and satellite collar distribution (kernel analyses) (Arthur and Del Vecchio 2009).

In the 1970s, Child (1973) reported that insect activity and group size influenced the likelihood that caribou would cross under the elevated (two-metre) pipeline. A subsequent review of the height of elevated pipelines and caribou success in crossing under them during calving and summer was initiated as the oilfield expanded west of Prudhoe Bay (Lawhead et al., 2006). The review showed that separating a road from an adjacent pipeline by of >90 m will maintain caribou crossing success in summer (references in Lawhead et al., 2004). Traffic frequency <15 vehicles/hour was associated with higher crossing success. The effect of group size is uncertain as although large groups of caribou have difficulty crossing pipeline/road corridors (references in Lawhead et al., 2006), variation caused by insect conditions and traffic limit conclusions.

For the Central Arctic Herd's calving distribution, the studies were based on systematic aerial surveys. Radio-collared caribou and behavioural studies during calving and post-calving were the evidence for caribou reducing their exposure to the oilfield activities by local redistribution (4-6 km scale) to avoid roads, and the oilfield (summarized Cameron et al., 2005; see also Lawhead et al., 2003). However, the findings were contested (summarized in Haskell et al., 2008). The alternate interpretations were based on differences in techniques (accuracy of locations relative to the scale of avoidance ~ 1 km); whether traffic frequency had changed during the different studies; and the effect of timing of annual snow melt as a factor influencing the distribution of the calving caribou. Lawhead et al., 2006 and Haskell and Ballard (2008) have suggested that reduced behavioural responsiveness of caribou from the CAH over time (habituation) may also be a response to the lack of predation and hunting (Lenart 2013).

After the mid-1990s, the emphasis shifted from documenting caribou behaviour relative to the oilfield to monitoring the changes in herd abundance and vital rates. The research did lead to herd management objectives and mitigation to reduce the effects of the oilfield development. The objectives were to minimize disturbance to caribou and encourage free passage through the oilfield (Lenart 2001) although the success of those measures is unmeasured (Lenart 2013). The objectives also included maintaining a low rate of harvesting.

The herd monitoring revealed that the herd had increased from 5,000 in 1975 to 23,000 caribou in 1992 and 27,000 in 2000. By 1991, as other herds in interior Alaska had declined and the Dalton Highway was opened to public traffic in 1991, the harvests on the CAH increased but remained <2% of the herd. The management for the herd was to work with the oil industry to minimize disturbance to caribou movement from physical barriers and to reduce cumulative stress by reducing hunting adjacent to the oilfield and the haul road. Although the Dalton Highway was opened to the public in 1991, the highway was gated to limit access to the Prudhoe Bay oilfield. Along the highway north to the Yukon River, an eight-km zone on either side of the highway is closed to hunting and the use of off road vehicles (except on the road).

The herd continued to increase after 2000 and likely peaked between 2008 and 2012 at 68,442 (6,420SE) in 2010 (Lenart 2015). The increase was due to low adult mortality including a low harvest level (<3% 2000-2012), high parturition rates (≥85%), and high fall calf survival (≥50 calves: 100 cows) during 1998–2010 (Lenart 2015). However, in May 2013, a late spring was associated with higher adult and yearling females deaths rates, reflected in the 2013 photocensus estimate which revealed a decline to 50,753 (4,345SE), which continued as by 2016 the estimate was only 22,000 caribou.

National Petroleum Reserve-Alaska (NPR-A) : Alaska's National Petroleum Reserve has parallels to Yukon Land Use Plan zones as it is an area with priority for oil and gas development.

In 1923, a large Naval Petroleum Reserve was established in northern Alaska and renamed the National Petroleum Reserve-Alaska (NPR-A) in 1976. The intent of the NPR-A is to allow for oil and gas leasing while providing protection for specific habitats and site-specific resources and uses through lease stipulations and required operating procedures/best management practices. Two Alaskan herds of migratory tundra caribou (Western Arctic and Teshepuk herds) calve and summer within the NPR-A. The Central Arctic Herd calves partially within intensively developed oil fields and the Porcupine Caribou Herd calves within lands of as yet undetermined tenure (oil and gas development or wilderness).

Two Special Areas within the NPR-A relate to caribou: the Teshekpuk Lake Special Area (which included the Teshelpuk herd's calving grounds as well as waterfowl breeding and molting areas); and the Utukok River Uplands Special Area which included portions of the Western Arctic Herd's calving grounds. In those Special Areas oil and gas exploration will be undertaken to "assure the maximum protection of such surface values to the extent consistent with the requirements of the Act for exploration of the reserve" (42 USC § 6504 cited in BLM 2012). The regulations include protection through restricting, or prohibiting the use of and access through a series of land-use plans.

In 1998, the Bureau of Land Management (BLM) completed a plan for the northeast NPR-A which was then amended during the next 7 years. BLM's decision in January 2006 would have opened up the area around Teshepuk Lake (the previously recognized Special Area) for oil and gas leasing. Although the Special Area was open for oil and gas leases, the calving grounds and post-calving coastal areas were included in a Land Use Emphasis Area Caribou Zone. The monitoring and mitigation stipulations (BLM 2005; Integrated Activity Plan and associated Environmental Impact Statement; Appendix E) included the need for a three-year study of herd movements before permanent facilities could be constructed; restrictions on vehicle and aircraft operations; and May 20 and August 20 suspensions of heavy activities.

However, a group of conservation organizations argued in court that the measures would be ineffective and that the Teshekpuk Lake Special Area should not be opened for leasing (Singleton 2006). The conservation organizations which took BLM and the U.S. Fish and Wildlife Service to court raised several issues, but the court was only satisfied with arguments over the inadequate scope of the cumulative effects analyses and ruled against oil and gas leases in the Teshekpuk Lake Special Area (Singleton 2006).

The U.S. Department of the Interior (2012) released an updated Integrated Activity Plan/Environmental Impact Statement comparing alternative areas and development. These documents includes mitigation measures for public consideration and comment. The BLM's record of decision identifies which mitigation measures are required. The Teshekpuk Lake Special Area and the Utukok River Uplands Special Area are excluded from leasing until 2018 and 2014 (?????), respectively. However, the plan does acknowledge that exploration activity (seismic and test drilling) may occur on the winter range of the Teshepuk herd. When the lands are offered for leasing, environmental effects are assessed and mitigation is prescribed. As all fish and wildlife and socio-economics are considered, there is not a great deal of detail:

1g. Pipelines shall be designed and constructed to minimize alteration of caribou and other large ungulate movement and migration patterns. At a minimum, above-ground pipelines shall be elevated seven feet, as measured from the ground to the bottom of the pipe, except where the pipeline intersects a road, pad, or a ramp installed to facilitate wildlife passage. Lessees shall consider increased snow depth in the sale area in relation to pipe elevation to ensure adequate clearance for wildlife. ADNR may, after consultation with ADF&G, require additional measures to mitigate impacts to wildlife movement and migration.

3c. Exploratory drilling operations may be restricted during the fall caribou migration (August 1 through October 31) in the Chandler, Nanushuk, Itkillik, Kuparuk, and Anaktuvuk River valleys to allow for subsistence hunting.

3d. Exploration activities may be restricted during fall caribou migration (August 1 through October 31); and the siting of permanent facilities, except for roads or pipelines, will be prohibited in the Chandler, Anaktuvuk, Nanushuk, Itkillik, and Kuparuk River valleys, unless the lessee demonstrates to the satisfaction of the Director, in consultation with the NSB, that the development will not preclude reasonable subsistence user access to caribou.

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Appendix B: Boreal caribou avoidance of roads

Region	Methods	Comment	Km avoidance	Roads Avoided/ Crossed	Traffic measured	
Mountain		High-use roads	2			Polfus et al.,(2011)
		Low-use roads	1			
Quebec			within 5			Leblond et al.,(2012)
Quebec			beyond 2			Rudolph et al., (2012)
Ontario	114 GPS collars 2009	Forested habitat permeability, predation risk and forage availability; roads not examined	N/A	N/A	No	Avgar *et al.*, 2013
Quebec	48 GPS 2004-10; cows; 4 h intervals	Home range sizes increased than decreased with increasing clear-cuts and roads – increase was search for forage then at a threshold, to reduce effort by trading off risks to expenditure energy	Not addressed	Both	No	Beauchesne et al., 2014
Quebec	49 GPS 2004-10; cows; 4 h intervals	4-35% logged; 0.04 - 1.20 km/km2 minor roads and 0.04 km/km2 for major roads; females avoided crossing clearcut edges and roads at low densities, but crossing increased when disturbance densities increased	Not addressed	Both	No	Beauchesne et al., 2013
NW Ontario	Aerial quadrat survey	Caribou negatively related to wolf occurrence and roads	Not addressed	Avoided	No	Bowman et al., 2010

NE Alberta	1993 (5) & 1994 (15) VHF	Expt exposure propane cannons (seismic): movement rates in response were 2.6 km and 1.6 km in a low and high snow year respectively.	Measured propane cannons	N/A	N/A	Bradshaw et al., 1997
NE Alberta	Used above	Estimated no. disturbances to account for winter mass loss based in reactions to cannons 41-137 events for a 20% loss		N/A	N/A	Bradshaw et al., 1998
North Central Ont	14 VHF, aerial & ground surveys	Expt approach – 25 log haul trucks /24 hours plus private vehicles	2-5km >900m	Avoided	Overall	Cumming and Hyer 1998
Rocky Mt foothills	12 GPS 1998-2000 daily locations	Caribou avoided streams but not seismic lines (80% >23 y) at lower density (0.67 km/km^2); ploughed roads avoided by 100m (but noted small sample size)	<100m	Avoided	No	Oberg
	Behavioural observations	Guided groups people 10-15 m from caribou in open spruce forest; limited number caribou <150; 11 days with and 22 without visitors; some reduction in vigilance				Duchesne et al., 2000
Quebec boreal	24 GPS 3-7 h 1-3 years	Wolves use roads; caribou avoided roads and selected higher elevations (exposed to bear predation)	<1km	Avoided	No	Dussault et al., 2012
Alberta Oilsands	22 GPS 1998 replaced in 1999 + 13 cows	1% study area seismic, roads and well sites; measured decreased use around roads, new drill pads and seismic: rood avoidance declined by 250-500m; .also seismic and wellsites	<500m	unknown	Yes- max 600-800vehicles/day	Dyer et al.,2001

Alberta Oilsands	22 GPS 1998 replaced in 1999 + 13 cows	236 km road; 7111 km seismic 5-9m and modeled similar length roads per home range as controls; roads crossed less than control roads especially in winter x6 fold.			780.0 ± 73.87 SD vehicles / day winter	Dyer et al., 2002
Quebec	Winter tracks aerial surveys	Variability in use of winter range habitats along gradients – avoidance of roads (not in south)	Not examined	Not examined	Not examined	Fortin et al., 2008
NE Alberta	Wolf collars	Wolf use of seismic lines especially in summer increases predation risk to caribou	Not examined	Not examined	Not examined	Latham et al., al 2011
Quebec	59 GPS 2004-2011 2.5-7 h; 1999-2000 28 VHF 3-5 days	37% altered habitat – logging and roads; Probability death in home range scale increased with recent disturbance and active roads; calf death related to recent disturbance; at fine scales surviving individuals avoided roads and disturbed habitat; wolves selected roads	Not examined	Not examined	Not examined	Leblond et al., 2013a
Quebec	53 GPS 2004-2010, 3 or 7h intervals	Tested whether caribou crossed enlarged highway by finding lower rates crossings with surrogate highways; 77% (41/53 did not cross); increased movement rate just before during and after crossing and avoided vicinity highway; 95 km highway crossed ranges and was widened 25 to 90 m over 3 y; increasing disturbance increased rate of movement, and avoidance of road up to 5000m (mean 186 vehicles/hour	Up to 5000m	Yes	Yes	Leblond et al., 2013b

Quebec	24 GPS 2004-2010, 3 or 7h intervals	RSF analysis emphasized hierarchical habitat selection influenced response to roads; 0.75-1.25 km avoidance less than than elsewhere but also constrained by high density roads (1.66 km/km2)	<1.25	Not examined	Not examined	Leblond et al., 2011

Appendix C: Caribou related best practices

(Extracted from B. C. Ministry of Forests. 2014. "A Compendium of Wildlife Guidelines for Industrial Development Projects in the North Area, British Columbia" http://a100.gov.bc.ca/pub/eirs/finishDownloadDocument.do?subdocumentId=9921)

Identify the impacts of proposed activities on caribou and caribou habitat.

3.1. Quantify the amount of habitat lost or adversely affected by project footprint or through sensory disturbance. This should include an evaluation of project footprint against spatial files for caribou (core and matrix habitat).

3.2. Identify duration of sensory disturbance (e.g. only during construction or throughout project timeline) and sources of sensory disturbance (e.g. compressor stations).

3.3. Identify potential impacts of project footprint on predator-prey dynamics. Government and caribou specialists recognize that understanding and controlling predation across the range of woodland caribou is essential to achieving population goals. Include detail, if known, on any expected changes to predator or prey populations or distribution (e.g. whether development footprint is expected to increase forage for bears or ungulates, or facilitate travel for wolves).

3.4. Quantify the increase in the density of linear features (e.g. roads, trails, pipeline right-of-ways, seismic lines) within the regional study area, which is to be determined by the proponent. A supporting rationale for the regional study area determination should accompany any mitigation plan.

Avoid or minimize new disturbance to and the loss of important habitats.

4.1. Relocate all developments outside of designated caribou habitat to minimize overlap of development footprint with caribou values.

4.2. Use previously disturbed areas and existing access, and avoid constructing permanent roads and trails within or to caribou range.

4.3. Employ alternate means of development to avoid and minimize surface disturbance.

4.4. Manage activities to occur in area-based clusters so that vegetation clearing and disturbances occur during as short a timeframe as possible.

4.5. Avoid or minimize vegetation clearing, forest harvesting and development activities that directly reduce or otherwise impact the abundance of arboreal or terrestrial lichens.

4.7. Maintain known and potential wildlife features (e.g. mineral licks and associated wildlife trails) in a natural state and ensure caribou have access to them

4.7.1. Avoid all developments within 250 m of mineral-lick sites and wildlife trails connecting to mineral licks.

4.7.2. Where roads or linear corridors, facilities or other developments cannot be avoided near mineral licks, ensure that connectivity to adjacent forested areas is maintained.

4.7.3. For existing roads or other linear features near wildlife habitat features, minimize use and disturbance during critical-use periods.

4.7.4. Avoid disruptions to drainage and groundwater near mineral licks and wildlife habitat features.

4.8. Maintain visual screening (i.e. forested cover) to provide security and escape cover around mineral lick sites and trails.
4.9. Protect and avoid degradation to wetland habitats.
4.9.2. Place linear developments and associated facilities away from wetlands. Avoid constructing access roads and trails through wetlands.
4.9.3. Maintain a buffer around wetlands to avoid providing direct access between upland habitats and wetland areas used by caribou. This will help to maintain spatial separation between caribou and early-seral ungulates and their predators.
4.9.4. Employ alternate means of development (e.g. horizontal drilling) to avoid and minimize effects on wetland areas
4.9.5 Locate worksites outside riparian areas and manage surface water flows to prevent sediment and contaminants from entering wetlands,
4.9.6. Design, install and maintain wetland road crossings to provide passage of surface and subsurface water. Clear-span bridges are the preferred crossing option.
4.9.7. Use vegetation management control techniques to minimize unnecessary impacts to wetland features and functions.

Avoid increasing the density of linear disturbances within or in proximity to caribou habitat.
5.1. Avoid constructing new linear features (e.g. roads, trails, pipeline right-of-ways, seismic lines) in and near high-value caribou habitat.
5.2. Use helicopter access wherever possible to avoid developing new access corridors.
5.3. Use existing access wherever possible.
5.4. Develop traffic and access management plans for all phases of the project (pre-construction, construction, operation and closure).
5.4.1. Plan roads and design features of roads (e.g. pullouts, construction staging areas, etc.) so that they are not in conflict with important caribou habitat or features.
5.4.2. In areas of high resource road density, co-ordinate the development of roads between user groups.
5.4.3. Plan roads and other linear features to transect, not run parallel to, migration corridors to minimize the utility of new linear features to predators.
5.4.4. Prevent design of loop roads, where linear developments transect previously un-connected road networks.
5.5. Use low-impact seismic lines rather than conventional seismic lines in and near high-value caribou habitat.
5.6. Minimize duration of new access in and near high-value caribou habitat. Fully deactivate and reclaim roads, spurs and trails immediately once use is no longer required (re-contour, de-compact and restore vegetation to original state and species mix by replanting trees and restoring lichen communities).
5.7. Where roads and other linear features cannot be practicably avoided, design temporary structures, including winter roads, wherever possible. Permanently decommission and reclaim all temporary roads, temporarily upgraded roads or structures immediately following industrial activities.
5.8. Fully de-build roads and spurs once use is no longer required by re-contouring, de-compacting and restoring vegetation to its original state and species wherever possible.

5.9. Do not construct new permanent, all-weather roads in core migration areas.
5.10. Retain visual buffers along access routes.

Avoid displacing caribou and minimize direct and indirect mortality on caribou populations.
6.1. Plan all activities in and around caribou habitat to occur only outside risk timing windows for caribou.
6.2. Limit collision-related mortality (e.g. facilitate wildlife movement around roads and post speed limits, particularly in high-wildlife-use areas). Establish and enforce road restrictions and road safety protocols, including traffic calling, speed restrictions, convoying and posting appropriate signage.
6.3. Manage recreational access (motorized and non-motorized).
6.3.1. Avoid providing access to remote or previously inaccessible areas.
6.3.2. Avoid the establishment of road systems with “circle” or “loop” routes.
6.3.3. Limit public access beyond specific control points on a year-round or seasonal basis (e.g. use access control structures, partial or full deactivation, bridge removal or vegetation management to deter unregulated use).
6.3.4. Do not plow or pack access to caribou habitat in winter.
6.3.5. Deactivate temporarily unused roads by leaving them in a condition to discourage motorized access and to make passage by predators difficult.
6.4. Avoid project-related displacement of caribou.
6.4.1. Reduce project-related noise.
6.4.2. Apply best management practices during all phases of development.
6.4.3. Apply best management practices for aircraft operations.
6.4.4. Have a qualified professional on site during construction activities.
6.4.5. Implement a program to monitor wildlife sightings and ensure that a stop work order is in place in the event that caribou are observed within the development area.
6.4.6. Restrict development activities and industrial traffic around known caribou migration corridors during migration periods.
6.5. Apply risk timing windows for all activities.
6.6. To apply a precautionary approach, aerial operations include both helicopter and fixed-wing aircraft. Compliance of pilots and aircraft operators and companies is required.
6.7. Removed [comply with General Wildlife Measures].
6.8. Limit helicopter and fixed-wing flights to:
6.8.1. 2000 m minimum horizontal avoidance from mineral licks.
6.8.2. 400 m above ground level over-flight elevation and no circling for all winter range, mineral licks and for birthing areas.
6.8.3. 100 m above ground level minimum for inventory.
6.8.4. No direct approach to aggregations, animals with young or special features such as mineral licks.
6.9. Implement a program to monitor wildlife sightings, aircraft activities and adaptations.

Avoid increasing the predation risk for caribou populations.
7.1. Limit the amount and distribution of early-seral habitat.

7.1.1. Avoid increasing the amount or distribution of early-seral ungulate or bear habitat within five km of caribou range.
7.1.2. Use vegetation management (e.g. manual brushing) to reduce willow and shrub plant communities on pipeline right-of-ways and other linear features that will be maintained over the long term.
7.1.3. Within the core areas, recreate lichen-bearing habitat, rather than grass or seeding.
7.2. Control predator access.
7.2.1. Do not plow or pack access to caribou habitat in winter.
7.2.2. Fully deactivate and reclaim roads, spurs and trails immediately once use is no longer required (re-contour, de-compact and restore vegetation to original state and species).
7.2.3. Ensure that reclaimed linear features have limited value as moose, deer, or elk habitat.
7.2.4. Ensure that active or reclaimed linear features have limited value for snowmobiles to prevent packed trails to high-elevation habitat.
7.2.5. Avoid constructing roads that provide a corridor into caribou habitat (e.g. from valley-bottom to high-elevation habitat or from upland to wetland habitats).

Avoid contaminating caribou habitat.
8.1. Manage all waste products, during all project phases, so that contamination of water and vegetation does not occur due to development activities.
8.1.1. Waste products include, but are not limited to, all fuels, camp wastes, drilling waste, waste water, herbicides, pesticides, etc.
8.1.2. Consider alternatives to road salts or dust control chemicals where run-off could impact water quality.
8.1.3. Follow appropriate fuel management regulations and guidelines
Restore habitats to a condition that provides a similar level of functional caribou habitat as before any industrial activity took place.
9.1. Restore habitat as soon as possible following development.
9.2. Deactivate linear features as soon as possible after the cessation of development (i.e. at the end of construction phase if possible).
9.2.1. Replant linear features with native species.
9.2.2. Make impassible to predators by creating large, long and frequent rough piles of coarse woody debris, rocks, stumps, etc. along the length of the linear feature until vegetation recovery makes the feature unusable.
9.2.3. Provide visual breaks along edges of linear features until such time as they are fully restored to original condition. Features include berms, dense conifer planting, rough piles of coarse woody debris, rocks, stumps, etc.
9.2.4. Block off linear features at the intersection with pipeline right-of-ways or other linear features to minimize utility to predators.
9.2.5. Reshape slopes, open drainage systems and stabilize for erosion.
9.3. Limit attracting early-seral ungulates and predators to development areas.
9.3.1. Restore native plant communities.
9.3.2. Select less-palatable native plant species for re-vegetation.
9.3.3. Use vegetation management (e.g. manual brushing) to reduce willow and shrub plant communities until natural vegetation and forest recovers.

9.3.4. Avoid use of species that will result in a dense cover of mat-forming graminoids. Where agronomic species are necessary to achieve erosion objectives and/or to prevent establishment of invasive species, ensure the species mix includes only annual, non-mat-forming and non-leguminous species.
9.3.5. Facilitate the re-establishment of lichens in appropriate habitats.
9.4. Explore potential to restore areas not directly affected by proponents' activities (e.g. reduce the density of linear features in area to compensate for increase in linear density associated with pipeline). This could involve establishing agreements with other tenure holders.
9.5. When clearing land, prevent the establishment and spread of invasive species by re-vegetating disturbed areas as soon as possible using native plants, as disturbed ground is often conducive to invasive species. Never plant invasive or non-native plants. As part of the ongoing monitoring of the project, examination of the project area for the occurrence of invasive species must be undertaken and their occurrence addressed.

Develop a monitoring and adaptive management plan to monitor the effectiveness of measures to avoid, minimize and restore.
10.1. The proponent is responsible for carrying out relevant monitoring to ensure that mitigation measures are implemented as planned and are effective at meeting the intended objectives to reduce impacts on caribou and caribou habitat. Planning for monitoring must be done at an early phase of the project and revised as required as the project develops. Monitoring objectives and commitments must be established prior to finalization of the mitigation plan.
10.2. The type and degree of monitoring should be proportional to the degree of risk to caribou and uncertainty around efficacy of mitigation measures (e.g. the greater the uncertainty associated with a mitigation measure, the greater the need to monitor the implementation and effectiveness of the measure).
10.3. Monitoring must be planned and carried out by an appropriately qualified professional knowledgeable in caribou ecology, and all data must be shared with the province to facilitate future management of the subject caribou herds. Further, monitoring results should be used to improve the approach to mitigation for the current project activity or development and, if appropriate, future mitigation opportunities.
10.4. Generally, monitoring of implementation and effectiveness of mitigation measures should include the following considerations:
10.4.1. Focus on changes over time to all caribou components and indicators. Monitoring plans should be designed to identify project effects as distinct effects from other projects or stochastic events.
10.4.2. Use a before-and-after control study design.
10.4.3. Use modelling as part of the monitoring suite of tools.
10.4.4. Prioritize monitoring based on an assessment of the likelihood of the effectiveness of proposed mitigation and the severity of the impact on caribou and caribou habitat.
10.4.5. Employ principles of adaptive management to improve effectiveness of mitigation and to mitigate unforeseen impacts.