The effect of oil and gas development in the Arctic National Wildlife Refuge on Porcupine Caribou

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**INTRODUCTION**

Barren-ground caribou (*Rangifer tarandus groenlandicus; R.t granti*) are an iconic sub-species of caribou occurring in tundra ecosystems across the circumpolar regions of the world. In North America, barren-ground caribou are found across the Canadian Arctic (14 subpopulations) and one herd (i.e., Porcupine Caribou herd) occurs in the Alaskan Arctic. Barren-ground caribou occur in large herd sizes (e.g., upwards of 200,000-400,000 individuals; Griffith et al., 2002) and are of high cultural and economic value to indigenous communities who rely on caribou for subsistence hunting. Caribou are the dominant herbivore in tundra ecosystems and occur over vast ranges in their annual cycle that encompasses several hundred thousand square kilometers. Caribou are exposed to extreme climactic conditions and varying snow conditions from year-to-year which alter migratory routes and calving locations in order to access high quality vegetation (Russell et al., 1993; Whitten, 1996). Caribou herds naturally fluctuate in high and low abundance making them an ideal candidate to study the temporal variation in population dynamics.

In recent years, the debate to extract oil in the Arctic National Wildlife Refuge (ANWR) has been renewed leaving the future of the Porcupine Caribou herd (PCH) in jeopardy. The PCH is a large nomadic herd of barren-ground caribou (~200,000 individuals) that migrates every spring to distinct calving grounds located in the coastal plain of the ANWR The proposed drilling operation occurs over a large proportion of the PCH calving grounds and could dramatically alter the access to quality vegetation, and large expenses of land required during the calving period. Caribou avoid areas of human disturbance during the calving period (Cameron et al., 2005), and access to quality vegetation has been found to increase calf birth weights and overall survival of calves (Chan-McLeod et al., 1994; Cameron et al., 2005). Proposed drilling could be problematic for a herd that has a lower reproductive rate compared to other caribou herds and could cause long-term population decline (Russell et al., 1993; Whitten, 1996; Griffith et al., 2002). Given the low reproductive rates, how will the PCH respond to proposed oil and gas developments on their calving grounds? Here we simulate the effect of proposed oil and gas development on the PCH by implementing an age-structured population model that tests the effect of lower calf survival on long-term population dynamics. We simulated the effect of a 5%, 10%, and 20% reduction in calf survival rates. We assumed that oil and gas developments would have a negative impact on calf survival since previous studies have shown shifts in calving locations in response to land use changes (Cameron et al., 2005). We also assumed if the PCH calving location is displaced outside of the coastal plain due to human disturbance predation would increase and the access to high quality forage required for lactation would decrease thus causing a lower survival for calves.

**LIFE HISTORY**

The PCH are a large herd of (~200,000) migratory caribou that winters in the Brooks Range of Alaska and Ogilvie Mountains of Yukon, Canada, which is located just south of the tree-line. The PCH calving grounds is located on the coastal plains of the ANWR in Alaska and encompasses ~ 6,000 km2 on the arctic tundra (Russell et al., 1993; Whitten, 1996; Griffith et al., 2002). Migration to the calving grounds starts in April and continues into mid-May, and the departure from the calving grounds to the wintering range starts in late-June and early-July. Caribou do not have pre-determined migratory routes to their summer and winter ranges, and migration routes are largely dependent on environmental conditions (Russell et al., 1993; Whitten, 1996; Griffith et al., 2002). During the migration to the calving grounds spring snow melt dictates the year-specific calving locations. If spring snow melt is late migration could be stalled resulting in calving locations occurring on the migratory route in the mountains and foothills rather than the coastal plain. The coastal plain of the ANWR, which is the core area of the calving grounds, has a lower predator density than the surrounding foothills and mountains and thus calves born in the coastal plain have a higher survival rate (Russell et al., 1993; Whitten, 1996; Griffith et al., 2002). Wolves (*Canis lupus)*, grizzly bears (*Ursus arctos horribilis)*, and golden eagles (*Aquila chrysaetos*) all prey on calves but the majority of predation occurs on the edges of the core area (Whitten et al., 1992). Since caribou are nomadic and have unpredictable calving locations predation is not consider a major influence on the population (Whitten et al., 1992).

Arctic summers are short, and the window for access to high-quality green vegetation is even shorter. Caribou rely on high-quality forage to overcome winter nutritional stress, and access to high-quality forage can vary from year to year due to environmental conditions (Whitten et al., 1992; Russell et al., 1993; Whitten, 1996; Griffith et al., 2002). Since caribou occupy large summer ranges they are able to travel to new foraging patches to acquire enough resources to meet their energetic demands if a foraging patch is depleted of it resources. The impact of high quality forage abundance and weather conditions are a major limiting factor to caribou population growth. Similar to other ungulates (e.g., mule deer—*Odocoileus hemionus*; Merkle et al., 2016), PCH has evolved to time their arrival to the calving grounds with vegetation green up. Females that are parturient (i.e., about to give birth) are in poor body condition when they arrive to the calving grounds and require high protein plants to produce quality milk (Chan-McLeod et al., 1994; Cameron et al., 2005). The synchrony in arrival and vegetation green up is a key life-history component of caribou that dictates access to plants with high protein content. Females that are able to forage longer on protein rich plants, such as cotton grass (*Eriophorum sp*.) which occurs in high abundance within the coastal plain of the ANWR, produce calves that weight more at weaning. Additionally, access to high protein plants predicts calf birth weight the following the year thus clarifying the importance of calving grounds to the performance of the PCH long-term (Chan-McLeod et al., 1994; Cameron et al., 2005).

**MODEL DESCRIPTION**

To simulate the effect of oil and gas developments in the ANWR on PCH calf survival we implemented an age-structured population model. We constructed our analysis in four parts 1) we used distance sampling to estimate initial population abundance, 2) we projected population trends under a no development scenario, 3) we projected population trends under a oil and gas development scenario, and 4) we calculated elasticities and lambda values to understand which vital rates had the most influence on population dynamics. To do this we first extracted known fecundity and survival rates (Walsh et al., 1995) on the PCH. We used 13 age classes (calves, 1yr old, 2yr old, 3yr old, 4yr old, 5yr old, 6yr old, 7yr old, 8yr old, 9yr old, 10yr old, 11yr old, and 12yr old). We then used prior simulations (Walsh et al., 1995) age-class proportions and multiplied those values by the estimated abundance (see ‘Table 1.’) to get the first year abundance for each age-class.

Under the no development scenario we allowed the survival rates for calves (mean = 0.6, sd=0.01) to vary randomly and we drew samples from a normal distribution. We assumed that under a no development scenario calf survival rates would still fluctuate around the reported mean value with a low standard deviation for each sample survival rate. We then used the formula:

to project the population size for the first age class, where is the population size of the first age class at time stamp ‘t+1’, is the current population abundance of the first age class at time ‘t’, and is the fecundity for the first age class. For age classes 2-12 we used the formula:

x x

where is the second age classes abundance at time stamp ‘t+1’, is the abundance of the first age class at time ‘t’, and is the survival for the first age class.

Next, for the oil and gas development scenario we simulated the effect of a 5%, 10%, 20% reduction in calf survival. This gradient represented scenarios in which calf survival was minimally impacted, moderately impacted, and severely impacted. We used the same formula as stated above to project the population size, but we manipulated calf survival rates to reflect the 5% (mean= 0.57, sd=0.01) 10% (mean= 0.54, sd=0.01), and 20% (mean= 0.48, sd = 0.01) reduction scenarios when drawing random samples from a normal distribution. We allowed survival for calves to fluctuate since we know year-year environmental fluctuations could cause an increase or decrease in calf survival even in the presence of oil and gas development. We calculated the proportion of simulations that resulted in decreasing probability trends using the formula:

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We interpreted () as low risk, as moderate risk, and as high risk of population decline.

Lastly, we wanted to understand how changes in vital rates could impact population growth. We implemented a sensitivity analysis that estimated elasticities (i.e., the proportional change in lambda values with changes in survival rates) under the no development and development scenarios, and we also estimated the asymptotic lambda value. We did this by constructing a Leslie matrix and using the function *eigenanalysis* in the R package ‘*popbio*’ (Stubben and Milligan, 2007). We excluded density-dependence from this analysis since the data surrounding density-dependence in the PCH is limited and several studies have suggest that environmental conditions are the biggest influence on population growth (Whitten et al., 1992; Russell et al., 1993; Whitten, 1996; Griffith et al., 2002).

**STUDY DESIGN**

To estimate the parameters of the model (fecundity, survival, and initial population size) a two step approach is needed. 1) To estimate female fecundity and calf survival rates we captured 50 pregnant females using a net gun shot from a helicopter on their winter range. We confirmed pregnancy by using an ultrasound and placed a VERTEX Plus camera‐GPS collars (VECTRONIC Aerospace GmbH, Berlin, Germany) on females. This allowed us to estimate survival of calves by creating encounter histories, and calculate fecundity of females by directly estimating the occurrence of stillbirths. We defined fecundity rate as the proportion of collared females that did not have stillbirths. To estimate calf survival a capture mark-recapture approach was utilized by using detections of calves on collar video cameras (placed on adult females) from June-August. We followed similar protocols to Vuillaume et al. (2021) to program collars, and we constructed a weekly encounter history that represented ~12 potential encounters. We fitted into a Cormack-Jolly-Serber model that estimates apparent survival. Some of the assumptions of this model are: every marked individual has the same probability of being captured or resighted, emigration from the sampled area is permanent, independence, and all marked individuals have same probability of survival until sampling period *i*+1.

2) To estimate initial population size we used GPS data from pregnant females (n= 50) to identify year-specific calving areas since calving locations can vary from year-year based on environmental conditions. Next, we generated 100 random starting points for line transects (transect length = 100m, detection on each side of transect= 250m) within the core calving area. We then conducted an aerial survey to complete line transects approximately a week after peak calving. We recorded the total number of caribou on each line transect and the distance at which the caribou were detected. We then used program ‘*distance*’ in R to fit a half-normal model to estimate initial abundance (Miller et al. 2019). We ensured that surveys were conducted in a manner in which animals could not move between line transects, animals were detected with certainty, distance was measured accurately, transects were placed randomly, and detections were independent.

**RESULTS/DISCUSSION**

First we estimated the initial abundance of PCH utilizing distance sampling data. We found the initial abundance was ~100,000 caribou (Table 1) and we used this estimate to project population trends. Next, we conducted an eigen analysis for each scenario to estimate lambda values and elasticities. Under the no development scenario we found the lambda value was 1> (λ=1.004). This means in the absence of oil and gas development the PCH will increase over the 25 year projection. We also found under the no development scenario the survival of calve) and yearlings () had the highest elasticities thus having the greatest impact on population growth. Next, we evaluated oil and gas development scenarios and we found under the 5% reduction in calf survival λ=0.99, 10% reduction in calf survival λ=0.98, and 20% reduction in calf survival λ=0.97. Lambda values were <1 for all three reductions in calf survival (i.e., 5%, 10%, 20%) indicating the population will decline over time across all age classes in the presence of oil and gas development. Similar to the no development scenario, elasticities for the 5%, ), 10%, 0.146), and 20%, ) reductions all resulted in survival of calves and yearlings as having the most influence on the proportion change in lambda.

Next, we used an age-structured model with demographic stochasticity to project population trends. Under the no gas and development scenario we found there was a low risk of population decline (; Figure 1). We found a moderate risk of decline for 5% (0.40; Figure 2) reduction in calf survival, and a high risk of decline for both 10% ( and 20% (reduction scenarions. Managers should focus on mitigating and preventing oil and gas development from occurring on the calving grounds to avoid moderate-high risks of population declines. If oil and gas development occurs, managers should prioritize calf and yearling survival. Food supplementation could improve survival, but studies thus far have only focused on supplementation in the fall and not during the calving period for only woodland caribou (*Rangifer tarandus caribou*; Heard and Zimmerman 2021). Further study exploring the effects of food supplementation on calf and yearling survival would be need prior to implementation of management action.

The strength of this modelling approach is the survival rates fluctuate by drawing random samples. This simulates the year to year variation in vital rates due to demographic stochasticity. The weakness of this approach is the lack of environmental stochasticity incorporated into the model. Since caribou populations are heavily influenced by environmental conditions, the combined effect of decreased survival rates because of oil and gas development and variability in climatic conditions are missing from this model.

**LITERATURE CITED**

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| **Model** | **pbar** | **Abundance** | **SE(N)** | **AIC** |
| --- | --- | --- | --- | --- |
| Half-normal | 0.40 | 100000.20 | 12922.22 | -430.39 |

**Table 1. Results for distance sampling of Porcupine Caribou Herd for half-normal model.**

Diagram

Description automatically generated with medium confidence**Figure 1.** Population projection under a no gas and oil development. Trends show an increase in population size over the 25yr period for all five simulations.

Chart, diagram

Description automatically generated**Figure 2**. Population projections under the gas and oil development for 5% reduction in calf survival. In two out of five simulations population size decreases over a 25yr period.

Diagram

Description automatically generated**Figure 3**. Population projections under the gas and oil development and 10% reduction in calf survival. In all five simulations population size decreases over a 25yr period.

Chart

Description automatically generated**Figure 4**. Population projections under the gas and oil development for 20% reduction in calf survival. In all five simulations population size decreases over a 25yr period.