Retrospective Analysis of Habitat Selection by Boreal Caribou in the Prince Albert Greater Ecosystem, Saskatchewan, Canada

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Abstract

Recent caribou research in Saskatchewan has focused on faecal DNA analyses, which provide valuable information on caribou population size and connectivity but limited information on habitat use and selection. The delineation of Caribou Habitat Management Areas (CHMAs) and associated tiered management objectives are based in part on habitat potential mapping derived from an expert-based model. This study used telemetry data collected from caribou in the Prince Albert Greater Ecosystem (PAGE) during 2005-2010 to model caribou habitat empirically in a manner that aligns with provincial ecosystem mapping standards and current conceptions of habitat disturbance. This modelling can be used to inform possible revisions to CHMA boundaries and management objectives as the Action Plan for the SK2 Central Administrative Unit is revised. Caribou in the PAGE study area demonstrated selection for black spruce, tamarack, and shrub bog/fen habitats, as well as pine-lichen stands, although the latter is very rare in the study area. All other habitats were avoided, especially deciduous and mixedwood stands. Caribou avoided areas of recent wildfires and forest harvest, and avoided buffered anthropogenic disturbance (composed primarily of roads). The modelling suggested possible updates to the habitat potential mapping that would shift several lowland habitats from the *Moderate* to *High* category, generating more continuous blocks of caribou refugia. CHMA boundaries and objectives could be adjusted to better align with how different habitats are functioning in the caribou system. The habitat selection model could also be used to map current habitat suitability to help identify restoration priorities.

1 Introduction

A range plan for the SK2 Central Administrative Unit was prepared in 2019 (Saskatchewan Ministry of Environment 2019) and after 5 years, a revision is pending. This revision could include changes to boundaries of Caribou Habitat Management Areas (CHMAs) and objectives associated with the three management tiers. To help inform such changes, I conducted a retrospective analysis of caribou habitat use, based on telemetry data collected during the Prince Albert Greater Ecosystem (PAGE) caribou study (2005-2010). The retrospective analysis is intended to augment more recent caribou inventory work, which has focused on faecal DNA analyses. While the DNA work has provided information on population size and connectivity, it is not designed to generate detailed information about habitat use and selection.

The PAGE caribou study generated two theses; one focused on historical habitat changes and implications for caribou (Arlt 2009) and the other focused on calving habitat selection (Dyke 2008). Both generated habitat models based on logistic regression analyses of categorical habitat types (stand type by age class, recent burns, cutblocks, roads, water). Since that time, the ecological classification system for the Province was completed and predictive mapping to the ecosite level was developed for forested ecosystems (McLaughlan et al. 2010).

The delineation of CHMAs for the Action Plan was informed by an expert-based model of caribou habitat potential that ranked ecosites and their suitability as caribou habitat for different life requisites. Therefore, ecosite mapping is now foundational to Saskatchewan's current approach to both identifying and managing caribou habitat. Also since the PAGE study, the federal government completed its recovery strategy for the boreal population of woodland caribou in Canada (Environment Canada 2012). The strategy identified obligations for jurisdictions to protect Critical Habitat, including by limiting habitat disturbance by fire and anthropogenic activities.

The purpose of this study was to model caribou habitat selection using telemetry data directly in relation to ecosite mapping and measures of habitat disturbance, to provide a stronger empirical basis for identifying important caribou habitats in a manner aligned with provincial mapping standards and federal obligations. This modelling can be used to inform possible revisions to CHMA boundaries and management objectives.

2 Methods

2.1 Study Area

The study area for the analysis was the PAGE study area (Figure 1), which was located entirely within the Boreal Plains ecozone (McLaughlan et al. 2010).

2.2 Data Preparation

For base data, I used the current, publicly available predictive ecosite, map[1] which provides a rasterized estimate of the spatial distribution of ecosites found in provincial forests.

I used telemetry data available from the Saskatchewan Conservation Data Centre and deleted any points that were located in water or outside the bounds of the ecosite mapping. Five locations from one caribou gathered in 2013 were also deleted because they occurred after a 3-year gap in telemetry records. I detected and corrected one error in the telemetry database where two caribou had been assigned the same ID (21 for collars 314 and 485).

I used harvest information available to 2005, assigning a time since logging to each polygon by subtracting the year of harvest from 2005. For anthropogenic disturbance I buffered all existing (as of 2005) logging roads, major roads, and cutblocks by 500 m.

I downloaded the National Burned Area Composite (NBAC)[2] for 1972-2024 and selected polygons intersecting the PAGE study area and then deleted fires more recent than 2010. I then calculated time since fire by subtracting the fire year from 2005.

[1] https://geohub.saskatchewan.ca/maps/b85cca37951349578432754fc0848688/about
[2] https://cwfis.cfs.nrcan.gc.ca/datamart

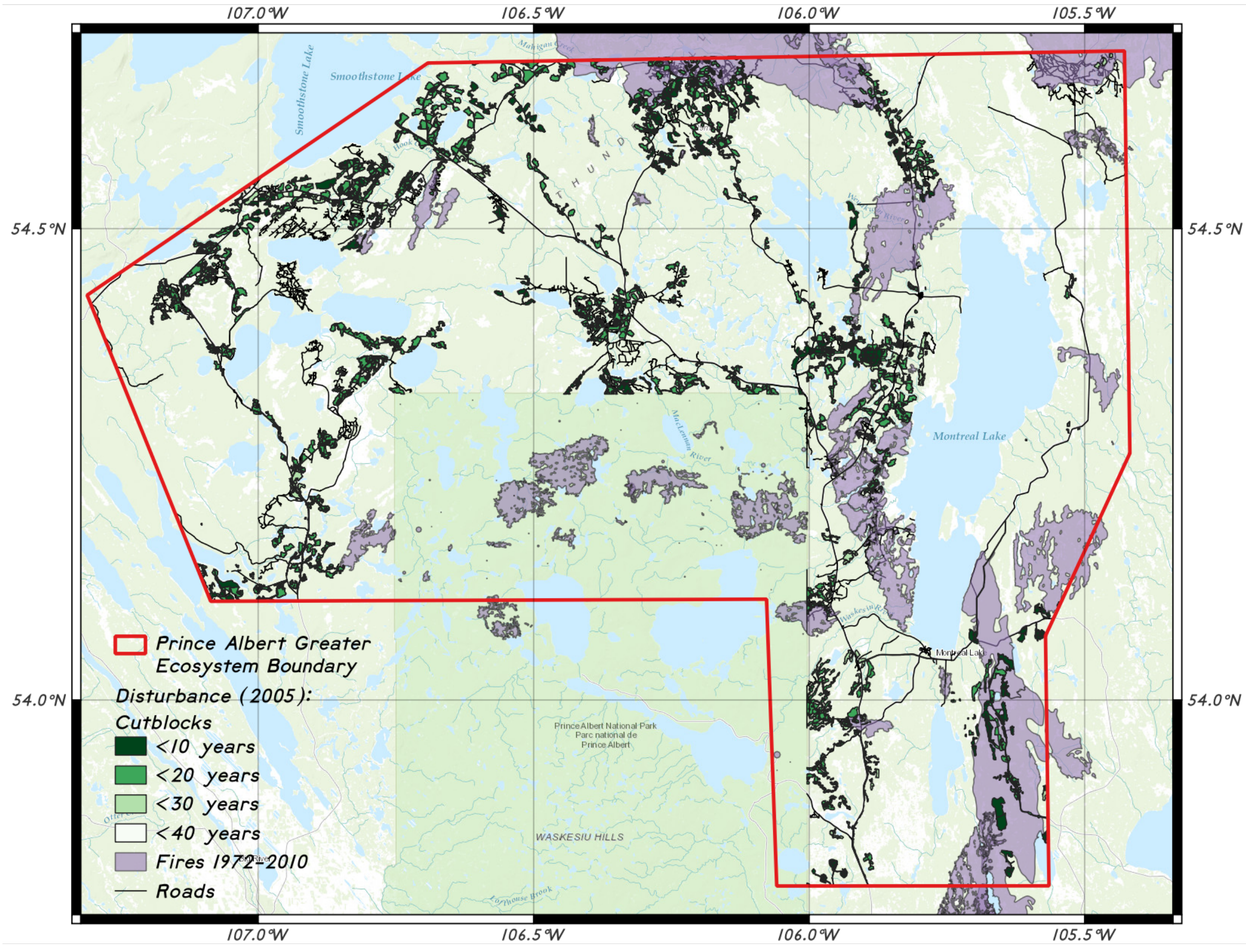

Figure 1: Greater Prince Albert Ecosystem study area and habitat disturbance circa 2005.

2.3 Caribou Selection by Ecosite

I first examined habitat selection by caribou of different ecosites via selection ratios. A selection ratio is calculated by dividing the proportional use of a habitat type by its availability (Manly et al. 2002). In this case I divided the proportion of telemetry locations (pooled among animals and seasons) falling within each ecosite by the proportion of the PAGE study area composed of each ecosite. Ratios >1 indicated selection for an ecosite relative to its availability while those <1 indicated avoidance. The states of ecosites used or available to caribou in relation to harvest or fire history were not considered in this initial analysis.

2.4 Grouping Ecosites

Ecosites were aggregated for further analyses based on similar ecological characteristics and the results of the analysis of selection ratios. This was a required step to make the multivariate modelling approach tractable, by reducing the size of conditional probability tables and reducing the occurrence of sparse cells (see below). This resulted in seven ecosite groups:

- *Black spruce tamarack or shrub bog/fen*;
- *Pine-lichen*;
- *Non-treed bog/fen*;
- *Mesic forest*;
- *Mixedwood*;
- *Deciduous*; and,
- *Grassland*.

2.5 Multivariate Caribou Habitat Selection

2.5.1 Theoretical Background

I modelled habitat selection by caribou using a causal Bayesian Network (BN). BNs are directed acyclic graphs (DAGs) composed of nodes (random variables) connected by directed edges (arrows). Random variables are encoded as a series of discrete states (i.e., values that the random variables can take) and directed edges representing the conditional dependencies among variables (Marcot et al. 2006). For nodes with two or more "parents," (i.e., incoming edges) the conditional probability distribution of the states defines the probabilistic distribution of outcomes.

"Causal" BNs assume that the directed edges do not just encode statistical associations but represent direct causal relationships. Therefore, a causal BN encodes explicit causal assumptions about how systems are structured (Pearl 2009). The structure of causal BNs are usually defined based on expert knowledge and then parameterized with data, where available, whereas non-causal BN structures can be directly learned from the data.

BNs are an alternative to using Resource Selection Functions (RSFs) (Burnham and Anderson 2011) for modelling the contrast between "used" (i.e., telemetry) and "available" point distributions on landscapes defined by one or more habitat-related factors (Wilson et al. 2022). BNs provide several theoretical and statistical advantages over logistic regression-based methods, such as RSFs, including:

- BNs model "used" versus "available" habitat selection directly, rather than the binary "used" versus "unused" assumption of logistic regression, thereby avoiding the problem of zero contamination that occurs when some subset of "available" locations have likely been "used" (Johnson, Nielsen, et al. 2006);
- BNs avoid the necessity of coding categorical variables as a series of dummy variables in contrast with a baseline category, which complicates interpretation; and,
- BNs are nonparametric and therefore don't have to meet the assumptions of regression analyses.

2.5.2 Model Structure

The following habitat-related factors were included in the model:

1. *Ecosite group* - ecosites aggregated as above by ecological similarity into seven groups;
2. *Time since harvest* - discretized as *<40 years* and *No harvest history*;
3. *Time since wildfire* - discretized as *Recent* (i.e., <40 years) and *No history*;
4. *Anthropogenic buffer* - either *In* or *Out*.

I also defined causal relationships between factors. That is, the factors are not independent but are at least in part caused by another factor in the model:

1. *Ecosite group* → *Time since harvest* (i.e., where harvest occurs depends in part on ecosite);
2. *Ecosite group* → *Time since wildfire* (i.e., fire susceptibility differs by ecosite);
3. *Time since harvest* → *Anthropogenic buffer* (i.e., where the anthropogenic buffer occurs partly depends on where harvesting occurs);
4. *Season* → *Ecosite group* (i.e., caribou use in different seasons manifests primarily in use of different ecosites).

I included *Season* in an initial model, assigning seasons to each telemetry location, as defined by Rettie and Messier (2000):

- Post-calving: 16 May - 30 June;
- Summer: 1 July - 15 September;
- Autumn: 16 September - 30 November;
- Early winter: 1 December - 28 February; and,
- Later winter/spring: 1 March - 15 May.

This initial model was used to determine whether caribou selection of different habitats differed among seasons.

The target node (dependent variable) of the network was labelled *Location*, with two states: *Telemetry* and *Available*. After model fitting, the model predicted the probability that a point drawn from the sample of *Telemetry* and *Available* locations was a *Telemetry* location, based on the underlying habitat-related factors. For example, if a location was equally likely to be a *Telemetry* or *Available* point, conditional on the habitat characteristics at that location, the output probability would be 50%. If a set of habitat characteristics was more often associated with *Telemetry* than with *Available* points, then the output probability would be >50%.

2.5.3 Analysis

Using the structure of the initial model containing season, I learned parameters from a database of telemetry points and an equal number of random points drawn from within the PAGE study area. I assessed whether the outcome *Location* (i.e., the probability of a given point from the database being a *Telemetry* or *Available* location) was conditionally dependent on seasonal shifts in the use of *Ecosite groups*, harvested (*Time since harvest*) or burned areas (*Time since wildfire*). I did this by comparing marginal mutual information (MI) to MI conditional on *Season.* MI measures the association between variables in a manner similar to a correlation coefficient in parametric statistics, and expresses the extent to which uncertainty in a child node is reduced by information known about its parent (Scutari and Denis 2021). If the MI shared by the predicting factors and the outcome *Location* changes substantially when conditioned on *Season*, it suggests that habitat selection by caribou varies by season.

To determine the causal influence of the habitat-related factors on *Location*, I calculated Average Causal Effects (ACE). ACE is calculated by intervening on each factor, setting evidence on each state in turn, and observing the change in expected value of the *Telemetry* state in the outcome variable *Location.* Formally:

$$ACE_{t,0} = E[Y|do(T = t)] - E[Y|do(T = 0)]$$

That is, the average causal effect is the effect of intervening on treatment T to impose the state t, minus the effect of the baseline of no intervention ($T = 0$). In this case, ACE is the change in probability of a point location being classified as a *Telemetry* location rather than an *Available* location, based on a change in a predicting factor from one state to another, independent of other factors.

In addition to determining the causal effect of individual states on an outcome, ACE can also be used to characterize causal effects at the factor level, although there is no single metric that completely captures this. Instead, I calculated four, related metrics of factor-level causal effects:

1. **Maximum absolute ACE**: The maximum ACE on the outcome among any of the states of the factor;
2. **ACE range**: The maximum minus the minimum ACE among the states of the factor;
3. **ACE standard deviation**: The standard deviation of the ACEs among the states of the factor; and,
4. **Mean absolute ACE**: Mean of the ACE values of each state of the factor.

3 Results

3.1 Landscape Characteristics

Based on available data, 12.1% of the PAGE study area was composed of recent burns in 2005, although data were unavailable before 1972. An additional 5.6% of the study area had been harvested.

The oldest cutblocks in the database current to 2005 were 36 years old. Buffering existing roads and cutblocks resulted in an anthropogenic buffer covering 31.2% of the study area.

3.2 Caribou Selection of Ecosites

The telemetry dataset included 147,702 locations collected on 25 caribou from 10 January 2005 to 29 March 2010. Caribou locations were detected in all boreal plains ecosites occurring in the PAGE study area except *BP8 - Trembling aspen - white birch/mountain maple: fresh sandy clay loam*. This ecosite was deleted from all subsequent analyses.

Of ecosites associated with selection ratios >1, all but one were part of the *Black spruce tamarack or shrub bog/fen* ecosite group (Table 1). Collectively, these ecosites comprised 57% of the PAGE study area. The only other ecosite associated with a positive selection ratio was *Pine-lichen*, which was very rare in the study area (<1%). *Deciduous* and *Mixedwood* ecosites tended to have the lowest selection ratios.

Table 1: Proportion of ecosites in the PAGE study area in relation to caribou use, as estimated by selection ratios (proportion of locations in an ecosite divided by the proportional representation of the ecosite in the study area), ordered from most selected to least. Ecosites were aggregated into seven groups based on ecological similarity for subsequent analyses.

Ecosite	**Ecosite proportion**	**Selection ratio**	**Ecosite group**
BP23 - Tamarack treed fen: Wet fibric organic	0.082	2.908	*Black spruce tamarack or shrub bog/fen*
BP19 - Black spruce treed bog: Moderately wet peat	0.122	2.480	*Black spruce tamarack or shrub bog/fen*
BP2 - Jack pine/lichen: Moderately fresh sand	0.005	1.914	*Pine-lichen*
BP24 - Leatherleaf shrubby poor fen: Wet fibric peat	0.018	1.689	*Black spruce tamarack or shrub bog/fen*
BP18 - Black spruce - tamarack treed swamp: Wet mesic	0.099	1.421	*Black spruce tamarack or shrub bog/fen*
BP20 - Labrador tea shrubby bog: Wet fibric organic	0.003	1.280	*Black spruce tamarack or shrub bog/fen*
BP25 - Willow shrubby rich fen: Wet humic organic	0.036	0.967	*Black spruce tamarack or shrub bog/fen*
BP27 - Open fen: Wet fibric organic	0.000	0.875	*Non-treed bog/fen*
BP21 - Graminoid bog: Wet fibric organic	0.000	0.745	*Non-treed bog/fen*
BP14 - Black spruce/Labrador tea/feathermoss: Very moist sandy clay loam	0.214	0.727	*Black spruce tamarack or shrub bog/fen*
BP26 - Graminoid fen: Wet humic organic	0.008	0.721	*Non-treed bog/fen*
BP28 - Seaside arrow-grass marsh: Very moist humic organic	0.006	0.524	*Non-treed bog/fen*

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Ecosite	Ecosite proportion	Selection ratio	Ecosite group
BP12 - Jack pine - spruce/feathermoss: Fresh loamy sand	0.090	0.438	*Mesic conifer*
BP15 - Balsam poplar - white spruce/feathermoss: Very moist silty loam	0.018	0.222	*Mixedwood*
BP3 - Jack pine/feathermoss: Moderately fresh loamy sand	0.051	0.204	*Mesic conifer*
BP4 - Jack pine - trembling aspen/feathermoss: Moderately fresh sand	0.43	0.192	*Mixedwood*
BP5 - Trembling aspen/prickly rose/grass: Fresh sand	0.002	0.158	*Deciduous*
BP9 - White spruce - trembling aspen/feathermoss: Fresh sand	0.011	0.098	*Mixedwood*
BP17 - Manitoba maple - balsam poplar/ostrich fern: Moist silty clay loam	0.000	0.091	*Deciduous*
BP13 - White spruce - balsam fir/feathermoss: Fresh sandy clay loam	0.067	0.082	*Mesic conifer*
BP10 - Trembling aspen - white spruce/feathermoss: Fresh silty loam	0.035	0.057	*Mixedwood*
BP7 - Trembling aspen - white birch/sarsaparilla: Fresh loamy sand	0.032	0.055	*Deciduous*
BP11 - White birch - white spruce - balsam fir: Fresh sandy clay loam	0.008	0.054	*Mixedwood*
BP1 - June grass - mountain goldenrod grassland: Moderately fresh loamy sand	0.000	0.048	*Grassland*
BP22 - Open bog: Wet humic organic	0.000	0.048	*Non-treed bog/fen*
BP16 - Balsam poplar - trembling aspen / prickly rose: Fresh clay loam	0.014	0.036	*Deciduous*
BP6 - Trembling aspen/beaked hazel/sarsaparilla: Fresh loamy sand	0.036	0.018	*Deciduous*

3.3 Multivariate Caribou Habitat Selection

Based on the very small difference between marginal MI and MI conditional on season for the predicting factors in relation to the outcome *Location*, I concluded that caribou habitat selection did not differ significantly among seasons and the variable was omitted from further analyses (Table 2). The final structure of the causal model is presented in Figure 2.

At the factor level, *Ecosite group* had the strongest causal effect on *Location*, followed by *Anthropogenic buffer*, *Time since wildfire*, and *Time since harvest* (Table 3). Within the factor *Ecosite Group*, the *Black spruce tamarack or shrub bog/fen* and *Pine-lichen* ecosites had the strongest, independent causal effect on caribou habitat selection, while all others had a negative effect, with *Deciduous* and *Grassland* having the strongest negative causal effects (Figure 3). Being located outside the *Anthropogenic buffer* also had a strong positive effect on caribou habitat selection while being in areas outside recent wildfires or with no harvest history had weaker effects.

Table 2: Comparison of marginal Mutual Information (MI) versus MI conditional on *Season* for factors predicting *Location*.

Factor	Marginal MI (bits)	Conditional MI (bits)	Reduction by *Season*
Ecosite group	0.134	0.138	-0.004
Time since harvest	0.017	0.018	-0.001
Time since wildfire	0.036	0.037	-0.001
Anthropogenic buffer	0.108	0.108	-0.000

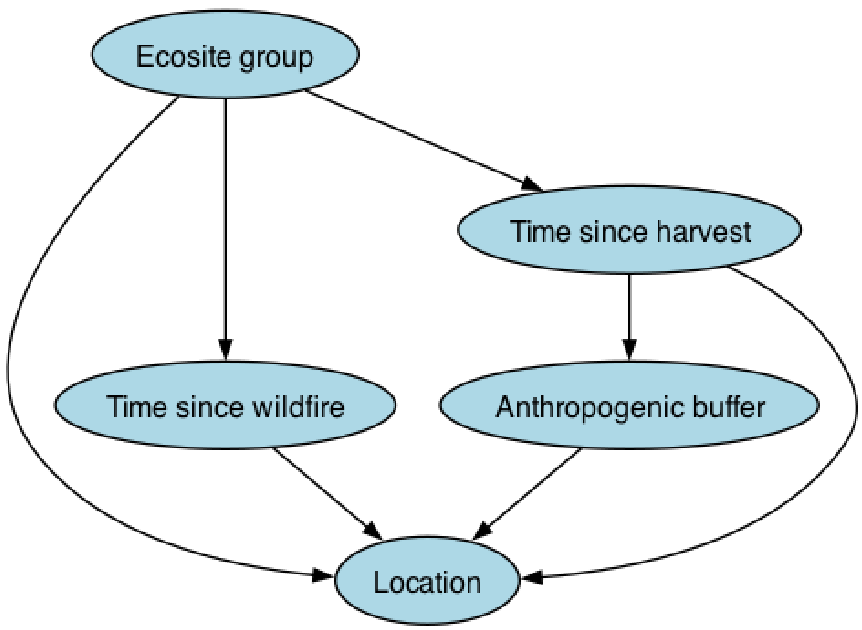

Figure 2: Structure of the causal Bayesian Network predicting the probability of a point being a *Telemetry* versus *Available Location*.

Table 3: The Average Causal Effect (ACE) of different factors causing caribou habitat selection, as measured by Maximum Absolute ACE, the range of ACE, the standard deviation (SD) of ACE, and the mean absolute ACE of states within factors.

Factor	Max abs ACE	ACE range	ACE SD	Mean abs ACE
Ecosite group	0.430	0.537	0.211	0.246
Anthropogenic buffer	0.298	0.378	0.189	0.189
Time since wildfire	0.291	0.312	0.156	0.156
Time since harvest	0.240	0.243	0.121	0.122

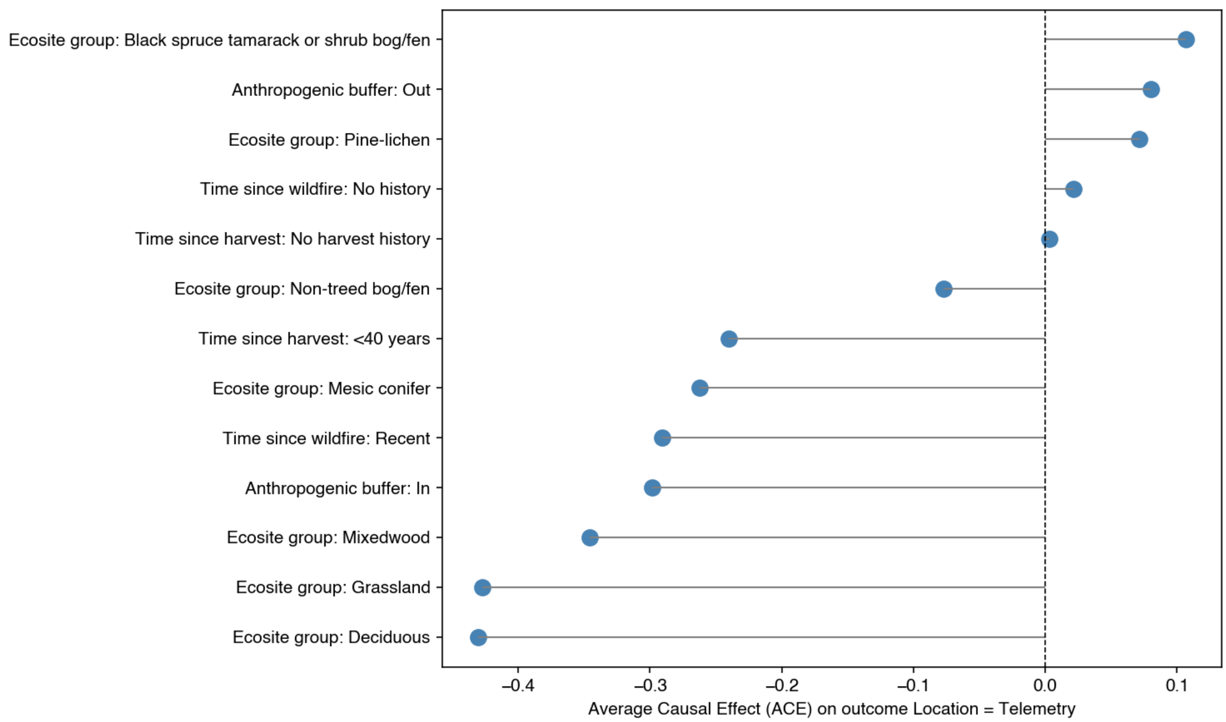

Figure 3: Causal effect of factor states on caribou habitat selection, as measured by Average Causal Effect (ACE). A positive ACE score indicates selection by caribou and a negative score indicates avoidance.

4 Discussion

Results of the habitat selection analyses generally aligned with previous studies of boreal plains caribou in Saskatchewan. In the first telemetry study of caribou in the Province, Rettie, Rock, et al. (1998) reported that caribou in central Saskatchewan selected peatland habitats throughout the year. Arlt (2009) found that caribou selected treed muskegs and mature jack pine while avoiding hardwood and young conifer stands. Dyke (2008) focused on the calving season and again found that caribou occurred closer to treed muskegs and jack pine stands than random locations while mixedwood stands were not used at all. These results are broadly similar to those reported for boreal caribou in western Canada in general (Environment Canada 2012).

Selecting low-productivity habitats such as treed bogs is consistent with the hypothesis that caribou are selecting habitats primarily for their value as refugia from predation (Rettie and Messier 2000; Bradshaw et al. 1995). Low productivity sites provide limited forage for early seral ungulates such as moose (*Alces alces*) and deer (*Odocoileus spp.*) that drive the broader predator-prey system. Moose and deer select habitats that provide abundant herbaceous shrub and tree forage such as upland deciduous, mixedwood, and riparian forests (e.g., Darlington et al. 2022; Johnson and Rea 2024; Shackleton 2013). These species generally respond positively to forest harvesting or fire disturbances in productive habitats because of the flush of suitable forage that results. However, these relationships are not absolute; moose will select denser conifer forests in winter (Johnson and Rea 2024), and "spillover" of white-tailed deer into adjacent low productivity habitats has been documented (Latham et al. 2011). Additionally, disturbances such as linear features can reduce the effectiveness of caribou refugia by increasing the penetrability of these habitats by wolves (*Canis lupus*) (DeMars and Boutin 2018). These broad relationships point to possible approaches to managing the working land base, whereby suitable caribou refugia are protected from disturbance while forestry is directed elsewhere and managed to mitigate early seral habitat and subsequent population responses of moose and deer.

Results of this study were also consistent with work highlighting the importance of anthropogenic disturbance in influencing caribou habitat selection, with the *Anthropogenic buffer* factor being second only to *Ecosite group* in driving habitat selection. Arlt (2009) found that caribou in the PAGE study area avoided cutblocks and linear features and Dyke (2008) found that caribou occurrences during the calving season were located farther than expected from roads. Avoidance of linear features is a consistent result in studies of caribou habitat selection (e.g., Dussault et al. 2012; James and Stuart-Smith 2000; Viejou et al. 2018). Clearly, managing caribou refugia effectively will require managing linear features in these habitats.

Time since wildfire was a less-important driver of caribou habitat selection than *Ecosite group* or *Anthropogenic buffer*. The relationship between caribou and fire is complex, with studies generating conflicting results on the importance of burned areas and unburned residuals on caribou habitat use and survival (e.g., Dalerum et al. 2007; DeMars, Serrouya, et al. 2019; Konkolics et al. 2021; Skatter et al. 2017). While wildfire was included in the federal government's aggregate disturbance metric because it was correlated with juvenile recruitment among boreal ranges (Environment Canada 2012), more recent work suggests that it is a less important driver of caribou demographics than anthropogenic disturbance (Johnson, Sutherland, et al. 2020; Wilson 2025).

Time since harvest was the least important factor affecting caribou habitat selection, although only 5.6% of the PAGE study area had been harvested during the era analyzed, perhaps limiting its effect on selection. Research suggests that caribou avoid cutblocks overall, but that they can select them in some seasons for their forage value, although this might be maladaptive because of the higher risk of predation in such sites (Dussault et al. 2012).

Finally, I found no evidence that habitat selection varied significantly between winter and snow-free seasons. Rettie and Messier (2000) analyzed habitat selection in the region among five seasons and found limited differences, discernible only when considering available forage at fine spatial scales.

4.1 Comparison with the Expert-based Habitat Potential Model

Differences between the results of the habitat selection analysis and the expert-based habitat potential model that informed the delineation of CHMAs suggested that many of the ecosites ranked *Moderate* in the expert-based model could be reclassified to *High* based on the habitat selection results. Specifically BP23, BP24, BP18, and BP20, all included in the *Black spruce tamarack or shrub bog/fen* ecosite group, were used more than expected based on their availability in the study area. Other ecosites in that group were not strongly selected (BP25 and BP14, see *Limitations* below).

Other ecosites ranked *Moderate* in the expert-based model were avoided in the habitat selection analysis, but generally not as much as those ranked *Low*, suggesting a reasonable correspondence. Mapping revised groups of ecosites, broadly informed by caribou habitat selection characteristics, resulted in a revised habitat potential map with much less *Moderate* habitat and larger, relatively continuous blocks of *High* habitat, compared to the mapping developed for the Action Plan. These blocks often aligned reasonably well with existing CHMA boundaries (Figure 4).

4.2 Limitations

The predictive ecosite map is estimated to have an accuracy of 40-60%,[3] which could affect the results of the habitat selection analysis at the ecosite level and results should be interpreted with caution. However, spatial accuracy of the ecosite groups was likely higher than the average accuracy for individual ecosites because prediction errors are generally more likely for ecosystems that are most similar, and those were grouped together for the multivariate analysis.

Grouping ecosites involved some subjective decisions that could have influenced results. For example, while the *Black spruce tamarack or shrub bog/fen* ecosite group was selected by caribou, the group contained one ecosite that was included because of ecological similarity (BP14 - *Black spruce/Labrador tea/feathermoss: Very moist sandy clay loam*) but was avoided by caribou (Table 3). Because a significant proportion of the PAGE study area was composed of this ecosite (21.4%), the decision to include this ecosite reduced the estimated selectivity of caribou for the broader group.

Of course all such analyses are limited by potential biases in collaring data; perhaps most significantly the preference of collaring adult females, often to meet other study objectives (e.g., to enable recruitment surveys). Differences in movements among other age classes, importantly adult males or perhaps dispersing subadults, is not captured.

5 Recommendations

The following are recommendations and possible next steps arising from this study:

- Revise the caribou habitat potential map to better reflect the habitat selection characteristics of caribou, as indicated by this analysis;

[3] https://geohub.saskatchewan.ca/maps/b85cca37951349578432754fc0848688/about

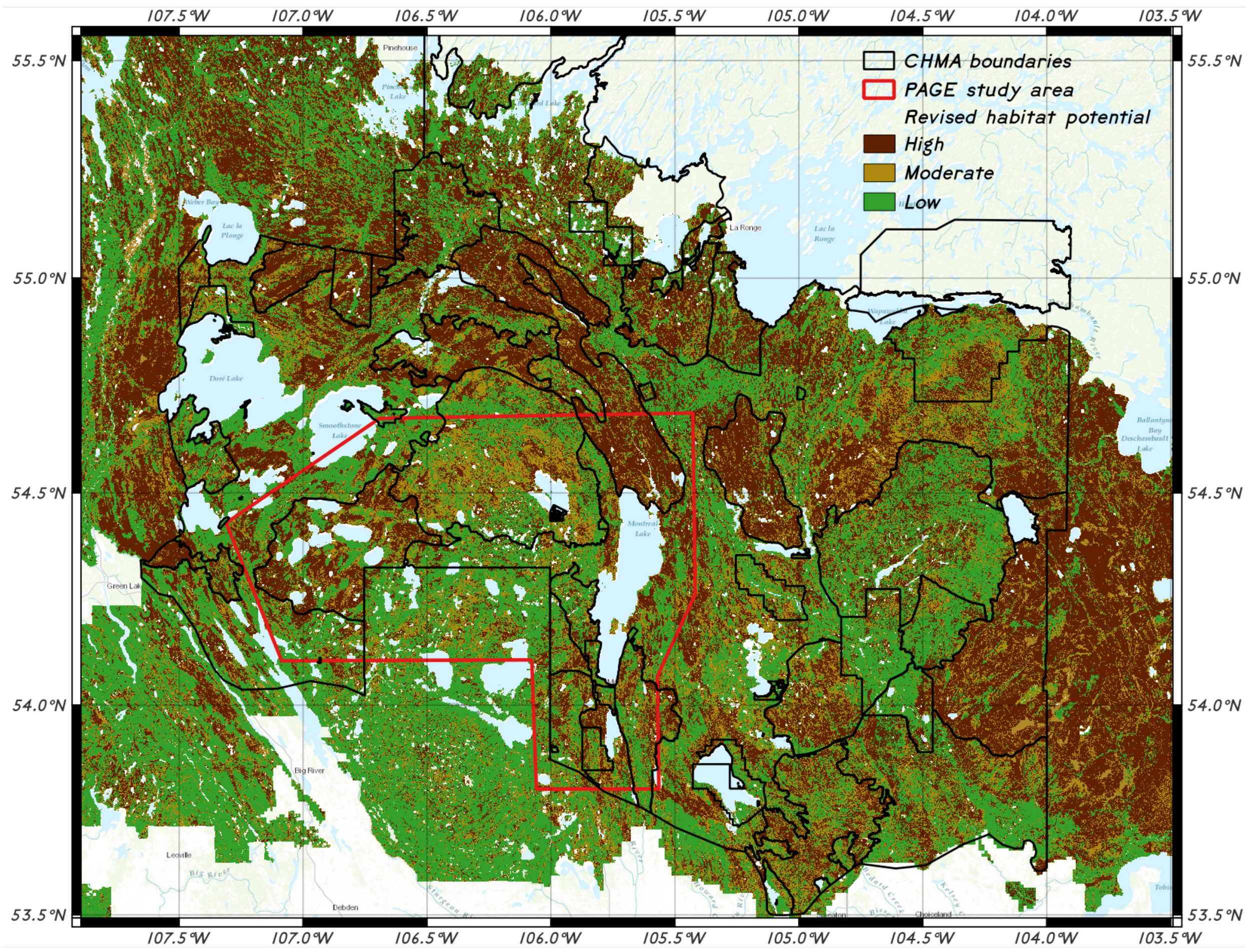

Figure 4: Proposed, revised caribou habitat potential in the SK2 Central Administrative Unit, derived from telemetry based habitat selection results from the PAGE study area.

- Use the revised habitat potential map to revise boundaries for CHMAs, where necessary;
- Use the habitat selection model to map the current distribution and abundance of suitable habitat in the SK2 Central Administrative Unit;
- Use the map of current suitable habitat to identify possible priorities for habitat restoration and protection;
- Revise objectives for habitat tiers to better align with the functioning of the habitat potential categories (i.e., *High* habitat potential = caribou refugia: priority for protection, *Low* potential = primary prey habitat: priority for predator-prey mitigation).

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