Modeling cumulative effects on summer range of the Bathurst caribou herd: a demonstration project

31 March 2009

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Report prepared by J. Nishi, A. Gunn and J. Adamczewski on behalf of the collaborating partners.

1. Description of program/project and deliverables:

a. *Background and Objectives*

The potential cumulative effects of development (mines, pipelines, roads, etc) on barren-ground caribou are an important and long-standing issue in northern Canada. Caribou numbers in most herds are declining which increases concerns as declining herds are less resilient . Assessment of cumulative effects on the long term well-being of the Bathurst caribou herd has been recognized as a knowledge gap during environmental reviews of diamond mines in the central NWT. Development must be assessed in the context of natural variation in caribou numbers and distribution (Cameron et al. 2005). The challenge to describing cumulative effects is considerable as weather, hunting, and other factors will continue to affect caribou, along with development. Environmental variation has not previously been well addressed in cumulative effects assessment (Duinker and Greig 2007).

To describe, understand and manage cumulative effects on large landscapes, resource agencies are looking for ways to engage in multi-stakeholder processes. Success has come elsewhere in Canada with computer models as tools to explore realistic land use scenarios (Duinker and Greig 2007). The 2006-2010 GNWT Caribou Management Strategy commits to developing cumulative effects modeling for barren-ground caribou. To help address the ongoing issue of cumulative effects and to follow through on commitments in the 2006 NWT Caribou Management Strategy (GNWT 2006), we are building a collaborative program to develop modeling tools for assessing cumulative effects on barren-ground caribou, with the initial focus on the Bathurst caribou herd.

The approach builds on initial steps taken previously in the NWT. Firstly an energetics and demographics models built for the Porcupine herd and adapted to the Bathurst herd was tested for the Diavik diamond mine (Gunn et al. 2001). Secondly, a conceptual use of habitat selection models was applied to the Bathurst herd, grizzly bears, and wolves (Johnson et al. 2005). And thirdly, In Alberta, modeling a number of industries and their effects on woodland caribou has made use of the landscape simulation model ALCES® (e.g. Schneider et al. 2003), an approach applied more recently to boreal caribou range in the southern NWT (Nishi et al. 2007).

These three modeling approaches were explored with a broad audience during a workshop in February 2008 in Yellowknife. A commitment was made to developing a demonstration project by early 2009 that would involve all three models and focus on assessing diamond mines and other developments in the Bathurst herd's summer range, with use of Traditional Knowledge (TK). A commitment was made to include existing mapped traditional ecological knowledge, using an approach used previously in boreal woodland caribou studies (Gunn et al. 2004). At a technical meeting in Calgary in July 2008, biologists, modelers and a TK specialist (A. Legat) reviewed the integrated approach further and planned next steps toward the demonstration project.

The advantage of an integrated modeling approach is being able to use the strengths of all three models. The linked energetics and demographics models have a strong base in caribou biology at the level of the individual and the population. Foraging behaviour of individual caribou potentially altered by disturbance is linked to diet, then to body condition, which in turn is linked to population productivity in the demographic model. The habitat selection models (Johnson et al. 2005) estimate use and avoidance of habitat and landscape features by caribou and can also include spatial aspects of traditional knowledge about caribou range. The output of the habitat model can be used to estimate a caribou's seasonal diet, which is the link to the energetics and population models. By developing these types of linkage, we can assess how individual feeding behaviour and habitat use and avoidance at a seasonal range scale may be related to population-level changes in caribou. By modeling different levels of environmental variation (e.g. early vs. late green-up, and good vs. bad insect years), we can simulate the effects of natural environmental variation with the effects of human activity on caribou at the level of the individual and the population.

ALCES® is a landscape model which can simulate environmental and anthropogenic changes and track a wide variety of indicators as landscape change unfolds. ALCES has been used effectively to help broad groups of stakeholders understand the trade-offs from landscape change and industrial development at a regional scale and to pose "what-if" scenarios. As barren-ground caribou are an important indicator species, we think there is value in considering longer term development scenarios which have implications to landscape change and habitat quality for caribou. As we develop the modeling links between caribou behaviour, habitat use and avoidance, and population-level responses, these relationships can be integrated into ALCES to help people understand the trade-offs between industrial development on the landscape and the risk of reduced resilience in caribou populations.

Our first goal in this cumulative effects demonstration project is to modify, apply and integrate existing models for barren-ground caribou to show how the models will be applicable as learning and decision support tools for governments and wildlife co-management boards in the Northwest Territories, and potentially elsewhere in the north. The initial focus is on the Bathurst caribou range but we hope that the approach can be used for other herds and regions.

Our second and longer-term goal, is to provide the basis for collaborative learning about cumulative effects and barren-ground caribou with a broader group of government, industry, and community representatives. This will use modeling tools, principally ALCES but also other models, and emphasize a "management-by-objective" approach to improve our collective understanding of ecological and socio-economic interactions and trade-offs when considering human activities on caribou range. We will draw on relevant experience from previous programs such as the North Yukon Planning Commission (NYPC 2008).

Objectives:
1. Update and refine the habitat selection models (Johnson et al. 2005) for the Bathurst caribou summer range, incorporate Tli Cho traditional knowledge on caribou habitat use, and assess potential displacement of caribou by development from preferred habitats and ranges. Knowledge gaps and technical issues and their solutions will be explicitly addressed;
2. Re-visit and run linked energetics and demographics models (Gunn et al. 2001) with newer ecological data for the Bathurst herd, to explore behavioural, nutritional and demographic consequences of caribou responses to disturbance and natural environmental variability.
3. Populate ALCES with landscape and footprint data from Bathurst summer range, and modify its structure to accept updated RSF coefficients for Bathurst caribou;
4. Develop the linkages between the models; and
5. Review the demonstration cumulative effects modeling with a broad audience and plan next steps collaboratively.

This CIMP project is part of a larger project – the Bathurst Caribou cumulative effects demonstration project. CIMP support was sought for Objective 1 (Habitat selection modeling) which is a key part of the overall demonstration project. The habitat modeling uses resource selection functions (RSF) to quantify the population-level effects of habitat (Mace et al. 1996, Seip et al. 2007). Using caribou locations from satellite-collared caribou and satellite mapping of their ranges, the model allows us to identify the strength of habitat relationships where strong selection or suitability is indicated by high RSF values (Johnson et al. 2004). When related to disturbance features, such as mines or exploration activity, the RSF analyses can quantify the avoidance response of caribou. This empirical response function will allow us to delineate a zone of influence which is a key component for identifying current and future cumulative effects (Johnson et al. 2005), and for simulating the effects of displacement and disturbance in the energetics model and land use scenarios in ALCES.

The data from the CIMP component will be integrated into the larger project. For our integrated cumulative effects modeling approach, the RSF weighting coefficients and maps are the inputs into the caribou energetics and demographics models and the cumulative effects simulator (ALCES). The RSF analysis estimates the probability of caribou being in a specific habitat class, which subsequently allows us to estimate a caribou's seasonal diet. We can assess how individual feeding behaviour and habitat use and avoidance at a seasonal range scale may be related to population-level changes in caribou. By modeling different levels of environmental variation (e.g. early vs. late green-up, and good vs. bad insect years), we can simulate the effects of natural environmental variation with the effects of human activity on caribou at the level of the individual and the population.

Personnel

This demonstration project is coordinated by J. Adamczewski for GNWT ENR, in association with K. Clark at the Wekeezhii Renewable Resources Board. J. Nishi has been the project manager for the demonstration project, with help from A. Gunn. Collaborators are C. Johnson (UNBC) who undertook the habitat selection analyses, with collaboration on TK from A. Legat (WRRB) and D. Taylor (GIS consultant). D. Russell, C. Daniel, M. Carlson and A. Gunn are key collaborators on the energetics modeling. J. Nishi, A. Gunn and J. Adamczewski are lead collaborators on report production. GNWT Bathurst caribou biologist B. Croft is engaged in several of these activities.

Methods:

a) What training was completed? The habitat selection model project was carried out by a small team. Training will be an outcome of the overall cumulative effects project which will engage aboriginal governments, co-management boards and stakeholders with an interest in caribou and development. The project will empower those groups to learn and choose among combinations of development and key environmental variables such as caribou. The training started with the Feb. 2008 Yellowknife workshop when the participants were exposed to the range of models and how they can be used.

The project did not require fieldwork because we used existing data from satellite-collared caribou, previously-gathered Tlicho knowledge and satellite imagery. Recently gathered data on Bathurst caribou behavior from graduate student L. Witter (UNBC) was used in the modeling, as well as recent additional radio-collar data.

What methods were used? The methods were computer-based analyses of existing data. The first step was to collect, screen and process satellite derived vegetation maps , NDVI (greenness) satellite data, and spatial disturbance (locations of outfitter camps, mineral exploration (land use permit and mineral lease site) and data on major existing developments (operating mines). Considerable effort was expended on comparing the attributes of existing vegetation classifications including the West Kitikmeot Slave Study (WKSS), Land Cover Map of Northern Canada (NLC), Canada Land Cover (CLC) and Earth Observation for Sustainable Development of Forests (EOSD) land cover classification. A decision was made to use a combination of the NLC and the EOSD land cover classification because these two classifications and an agricultural classification will form the basis of a Canada wide land cover dataset to be published by the federal government within the next few years. The land cover classes in the NLC were modeled from the Circumpolar Arctic Vegetation Map (CAVM). This connection to the CAVM classification may improve the ability of the merged land cover classification to extend geographically to other caribou ranges. Additionally the other classifications had more limited geographic range or had lower resolution.

Anthropogenic footprints on the Bathurst summer range were categorized as i) existing mines, ii) land use permit applications, iii) mining claims and mineral leases, and iv) outfitter and ecotourism camps. Mine footprint data were requested and compiled for Lupin, Ekati, Diavik, Snap Lake and Kennedy Lake sites. Land Use Permit (LUP) application files were requested from the Mackenzie Valley Land and Water Board (MVLWB), Wek'èezhìi Land and Water Board (WLWB) and Indian and Northern Affaires (INAC) Yellowknife regional office. Several agencies in Nunavut were contacted but no similar territorial databases were found. Based on responses from respective agencies, a common geospatial dataset was created for LUP sites which was error checked for duplication. A spatial dataset on mining claims and mineral leases was acquired through INAC. In addition a database on outfitter and ecotourism camps was developed from separate database administered by INAC and ENR.

Johnson et al. (2005) completed and published a series of RSF analyses for Bathurst caribou and other sensitive species found across the study area. Those methods and findings served as the starting framework for this second iteration of analyses. We used both 12 years of satellite collar data and TK to relate the observed distribution of caribou to vegetative habitats and the known footprint of existing mines, exploration areas, outfitter and ecotourism camps, roads, communities, and traditional hunting areas. Impacts of disturbance were generalized to one of three types: energetic costs of altered behaviour or increased movement, lost or isolated habitat, and direct mortalities resulting from human-wildlife interactions. The RSF approach was limited largely to those developments that leave a spatial footprint on the landscape and can be quantified relative to an assumed change in animal distribution.

Weighting coefficients for each covariate (e.g., habitat, mines) in the RSF model were applied to GIS data resulting in maps of the predicted distribution of Bathurst caribou across the summer range. As a stand-alone product, these maps can be used to illustrate future developments and show the amount of important habitats that may be influenced by industrial activity. For our integrated cumulative effects modeling approach, the RSF weighting coefficients and maps will serve as important inputs into the caribou energetics model and the cumulative effects simulator (ALCES).

The RSF analysis has produced coefficients for each combination of habitat type and development zone (i.e., zone of influence) that will be incorporated into the energetics model. The RSF coefficients are used to calculate an odds ratio (or relative probability) of the caribou selecting each habitat type, relative to the availability of each of habitat types on the landscape, and also with respect to whether the habitats occur within or outside a zone of influence associated with an anthropogenic footprint.

The RSF coefficients have been provided to the caribou energetics modeling team and we anticipate preliminary results by mid April. Since this work is ongoing, the next steps are briefly summarized below briefly.

- Determine Caribou Use of Landscape Strata: The next step will be to determine the probability that each RSF stratum (i.e. combination of habitat type and development zone) will be encountered by the individual caribou for each day of the simulation. This can be estimated from the seasonal RSF coefficients using the following equation:

$$P_{i,d} = (RSF_{i,d} * Area_{i,d}) / \sum_i (RSF_{i,d} * Area_{i,d})$$

where

$P_{i,d}$ = probability of animal selecting stratum i on day d
$RSF_{i,d}$ = RSF odds ratio for stratum i on day d
$Area_{i,d}$ = total area in stratum i on day d

- Develop Body Condition Model Inputs: All of the model inputs required by the body condition model will be developed through literature review and expert opinion; for those inputs with significant uncertainty in their values, a range (or distribution) of values can be provided as input. The full suite of model inputs will be stored in a single Excel spreadsheet, with accompanying documentation, similar to the approach used by Gunn et al. (2001).

- Run the Body Condition Model: The model will be run stochastically – i.e. for multiple Monte Carlo simulations – in order to capture the effects of uncertainty in the inputs on model predictions. For each Monte Carlo simulation the model will do the following:
  - For those days of the simulation period that occur either before or after the RSF analysis, assume that the caribou encounters average conditions for habitat and development when selecting body condition model inputs corresponding to that day.
  - For those days within the RSF analysis period, randomly select the RSF stratum used by the individual caribou that day based on the probability distribution ($P_{i,d}$) outlined above. Once a daily RSF stratum has been selected, convert this to its corresponding body condition stratum using a crosswalk from one classification system to the other. For any model inputs that vary by habitat type (i.e. forage availability and activity budgets), select the suite of input values that correspond to the body condition stratum selected for that day's use.

- Repeat Runs for Alternative Scenarios: Additional model simulations will be conducted to compare different scenarios against the "current condition" scenario, which will be based on average conditions for all input parameters. For example, to predict the body condition that would result from a "no development" or "2X development" scenario, the area associated with each development zone would change, which in turn would alter the calculated use probabilities ($P_{i,d}$); this would then change the available forage and activity budgets experienced by the animal. Additional scenarios will be run to evaluate the potential effects of climate change. To demonstrate the concept of cumulative environmental and anthropogenic effects, we propose to run the following 9 scenarios as a first series of preliminary runs in the energetic model:

Scenario	Development	Climate
1	None	Average
2	Current	Average
3	2X Current	Average
4	None	Worst-case (high snow, high insect, short greenup)
5	Current	Worst-case (high snow, high insect, short greenup)
6	2X Current	Worst-case (high snow, high insect, short greenup)
7	None	Best-case (low snow, low insect, warm greenup)
8	Current	Best-case (low snow, low insect, warm greenup)
9	2X Current	Best-case (low snow, low insect, warm greenup)

This list should provide some indication of the sensitivity of model predictions to a range of possible assumptions regarding development and climate.

- Predict Change in Population Parameters: Once the preliminary runs are completed, a next step will be to relate predicted changes in body condition to changes in one or more population parameters. For example in the 1999 Diavik analysis, a relationship between fall body fat content and conception rates was used to translate body condition predictions into demographic effects. A similar approach would be used in this analysis to generate a relationship between pregnancy rate of the herd as a function of the level of development, the prior-winter snow depth and the summer insect level.

- Links to ALCES: The inclusion of RSF coefficients in to the Energetics model allows us to estimate the ways by which broad scale habitat use by caribou may be linked to body condition indices and demographic parameters such as fall pregnancy rates, under varying environmental conditions and changing amounts of anthropogenic footprint. By running stochastic simulations in the Energetics model within a factorial design, we will then be able to generate output that could define preliminary functional relationships that would be used to drive demographic parameters of caribou within the ALCES model. Since ALCES is fundamentally a land use simulation model, the outputs from the RSF-informed Energetics model have valuable implications for developing the linkages between natural variability, anthropogenic land use, and demographic resilience of barren ground caribou.

b) **Describe how the communities/organizations were involved.** The aboriginal organizations were involved during the February 2008 meeting when the approaches were initially described. The Wek'eezhii Renewable Resources Board is one of the lead organizations on the current project. At this stage of computer modeling, community members were not part of the project team but longer-term objectives for the program will likely include work with elders and community members, and a follow-up workshop.

Describe how traditional knowledge was used, if applicable. The knowledge of elders was an essential part of the habitat modeling project. It was based on interviews undertaken as part of a WKSS project (Legat et al. 2001). The maps from those interviews were scanned, geo-referenced and incorporated into subsequent analyses of caribou locations and geospatial data to determine habitat selection by caribou.

Results:

The data sources for the habitat selection model revealed consistencies and inconsistencies across various datasets regarding land use activities on the Bathurst summer range. For the satellite-based vegetation maps, the Canada Land Cover (CLC) 90m classification had the best coverage, but there were two apparent issues that came out of the RSF analysis: i) in some areas the caribou selected for forests (this is likely a result of misclassifying forests for shrub communities), and ii) there is a scene artifact, i.e., different classifications between adjacent Landsat scenes. Although the NLC and CLC classifications could be merged that would not address the issue of accuracy which can only be addressed properly with ground truthing. The NLC appears to have fewer errors than the CLC classification.

The data collection and reporting methods for permit areas are different between land use permit versus the showing report. The criteria to define the start and end of a permit year were inconsistent. There is no single reliable source of data that describes exploration and mining activities. For example, the INAC (Indian and Northern Affairs Canada) land use permit database has uncertainty about the type and level of activity that is associated with each data point (i.e., point data are not equivalent to point-source activities). In Nunavut, the INAC database does not include Inuit-owned lands. The Mackenzie Valley Land and Water Board and INAC datasets are inconsistent.

The traditional knowledge used in the habitat selection model (RSF) was 88 caribou harvest locations which were in 5-year increments. The model used 287 locations of trails near Lac de Gras and 13 caribou water-crossings. The Traditional Knowledge had a good predictive performance based on cross-validation technique. Caribou water crossings in the TK dataset were robust predictors of caribou distribution.

Which CIMP category did this project support; “Monitoring and Research” or “Capacity Building and Training” or both? This project supported monitoring and research, in particular integrating existing data from various sources to modeling cumulative effects for barren-ground caribou.

If this project was a monitoring / research project, which Valued Component did you study and why? The Valued Component is barren-ground caribou, identified by most NWT communities as the single most important wildlife species for them, and known as a valued cultural resource through many generations. The larger modeling program will also address in part components such as climate change, vegetation and community wellness.

How did the results of this project educate people on cumulative impacts?
The outputs of the habitat selection (RSF) model include maps which, in our experience, are effective in sharing results with people to increase understanding about cumulative effects. The output of the integrated model will include maps and presentations to facilitate shared learning by diverse groups of participants, and we hope to facilitate such learning via periodic workshops, reports and the opportunity to choose future landscapes through "management by objective" modeling.

If results outlined in the report are preliminary, please explain how 'final' results will be accessible. The results are preliminary as the habitat selection (RSF) model is part of the overall demonstration project. The final results will be presented at a meeting with community representatives and available as a technical report, posters and maps.

Discussion / Conclusions:

a. Describe how the results of this project will further knowledge of cumulative impacts.
    - *Do you plan to do more work like this in the future?*

As outlined earlier, the demonstration project described here is intended as a pilot project to test the practicality of an integrated modeling approach using 3 distinct models. Possible further steps may include extending the modeling to the Bathurst herd's entire seasonal range (i.e. calving, fall and winter ranges in addition to the summer range) and application to other herd ranges. Work to date has been carried out with a view to developing methods that will be useful for other caribou herds and other regions. There is interest from biologists who work with the Porcupine and Beverly herds in applying the methods used in this project.

Nearly all of the Northwest Territories is within the range of one or more barren-ground caribou herds. Interest in mining of several minerals, road construction, a pipeline in the Mackenzie Valley – these will be issues of continuing importance in the NWT. Assessing and managing for potential impacts of these developments will need the kinds of tools that the current project is helping to develop.

b. Describe how results of the project were communicated to the communities and other groups.
    - *Did you have a community meeting? Was a report written?*
    - *Will the report be made available on a website?*

At present the intensive modeling is still in progress, so community meetings would not yet be appropriate. We expect to generate a report styled after GNWT ENR manuscript and file reports, and this will be posted on the GNWT ENR web-site. We will present results at meetings to be determined with the WRRB.

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