# Modeling Cumulative Effects in Barren-ground Caribou Range: Proceedings of a Workshop in Yellowknife, February 2008

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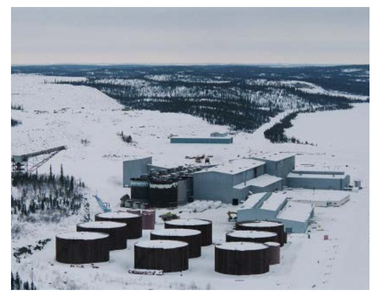

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# PREFACE

A number of events, including the rapid decline of the Bathurst caribou herd and associated management, prevented the finalization of this report until 2013.

# ABSTRACT

The declines in caribou populations between 1996 and 2006 aroused considerable concern in NWT communities because caribou have been a resource of great value to people in the north for many generations. Possible explanations for the declines include: a natural cycle, variation in weather and forage conditions, predation, hunting, disease, and industrial development. Of these factors, some are beyond immediate control, but effects due to direct human influence, like hunting and development, can be managed. The impact of development on caribou is usually not due to single roads, mines, cut-blocks or seismic lines; rather, it is the cumulative effect of many habitat alterations over time that affects caribou numbers and distribution. Concerns over effects of development on caribou have been raised in environmental assessments, particularly by Aboriginal groups, for many years, but progress on assessing them has been limited. To be objective, assessment of cumulative effects must account for other factors, including hunting and natural variation in weather.

Due to the need for overall knowledge of a caribou herd's complex ecology in assessing cumulative effects, biologists have turned to computer models to help track multiple variables and relationships, and to look at “what if” simulations. While these models cannot predict the future, they can help users understand how various factors interact and what likely consequences of particular management decisions might be. In the 2006-2010 NWT Caribou Management Strategy, a commitment was made by the Government of the Northwest Territories (GNWT) to develop a modeling approach that could assess the impacts of development in its proper context of natural variation. In this report we summarize the presentations and participant responses at a public workshop held in February 2008, Yellowknife, NWT, on modeling cumulative effects in the range of the Bathurst herd. In addition, we report on progress towards a demonstration project initiated at the February 2008 workshop.

PHOTO A. GUNN

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## INTRODUCTION

The issue of cumulative effects of development on barren-ground caribou is complex but important for agencies, co-management boards, industry and others concerned with the management of caribou in the Canadian and Alaskan north. Caribou have been a resource of great value to Aboriginal people in the north for countless generations. Studies from Alaska on barren-ground caribou and oilfield development (Cameron et al. 2005), infrastructure development and reindeer in Norway (Nellemann et al. 2003), and woodland caribou population and range losses in southern Canada (e.g. Schaefer 2003, Wittmer et al. 2007) have shown that intensive development can result in displacement, range loss and declines in caribou and reindeer numbers. While losses have been clearly established in woodland caribou (Schaefer 2003), the effects have been more difficult to show for barren-ground caribou. These effects remain the subject of dispute, given that caribou in general have some ability to habituate to developed landscapes (e.g. Haskell et al. 2006, Joly et al. 2006). Part of the problem in clearly linking development to changes in barren-ground caribou numbers or distribution is that *“anthropogenic (human-caused) effects on caribou must be identified and assessed within the framework of a variable natural environment”* (Cameron et al. 2005). Similarly, Wolfe et al. (2000) concluded that *“clear separation of cumulative effects of development from natural variation in caribou habitat use and demography will be difficult”.* In effect, a strong knowledge of natural variation in habitat use and demography of a herd is needed before additional effects of development can be clearly understood.

Barren-ground caribou herds vary widely in numbers over time (Legat et al. 2001, Zalatan et al. 2006, Bergerud et al. 2008). Over the period of 1996-2006, declines of 40-86% were documented in NWT barren-ground caribou herds (*Barren-ground Caribou Management Strategy for the NWT 2006-2010* [BGCMS] 2006-2010). The ecological conditions influencing individual herds vary and declines may have multiple causes. For example, timing of spring green-up on the Porcupine herd's coastal calving grounds varies from year to year, and this influences calf survival (Figure 1). The challenge of assessing effects of development in barren-ground caribou, while accounting for other factors affecting them, is substantial. However, an overall approach to assessing cumulative effects is needed and was committed to in the 2006-2010 BGCMS.

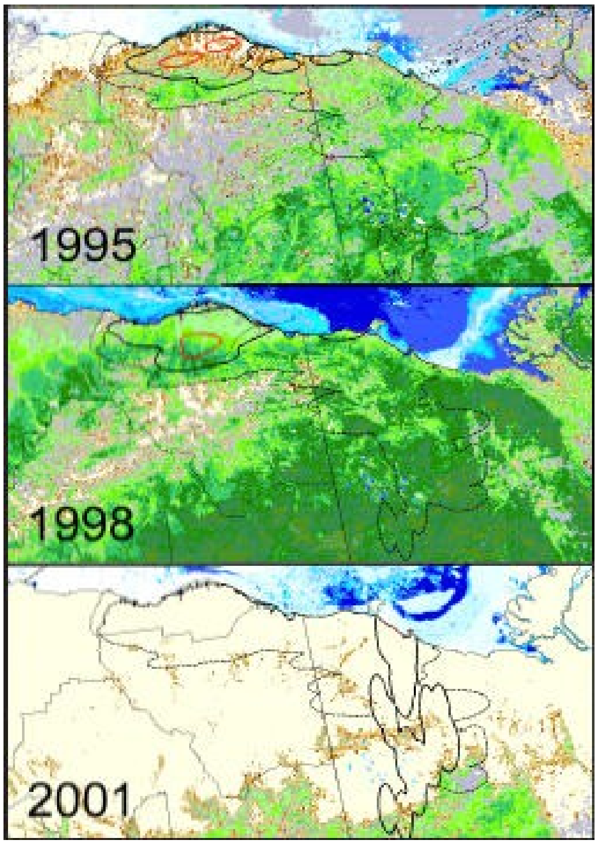


**Figure 1:** Variation in greenness (Normalized Difference Vegetation Index [NDVI]) in first week of June on Porcupine caribou calving grounds, from Griffith et al. (2002). In 2001 much of the herd calved far from the normal coastal calving grounds.

Previous work on assessing cumulative effects in the Bathurst caribou range was carried out by Gunn et al. (2001) using linked energetics and population models developed by D. Russell and colleagues for the Porcupine herd, and by Johnson et al. (2005) using spatial modeling with resource selection functions (RSFs). The herd's calving, summer and winter ranges together take up about 350,000 km$^2$ in northern Canada. In addition, the ALCES model has been used in a number of applications to model boreal woodland caribou persistence in heavily developed landscapes of Alberta and southern NWT, Dehcho region. Gunn et al. (2004) combined technical and TK of boreal woodland caribou in a study of habitat use. The work described here was designed to build on the understanding gained through these programs.

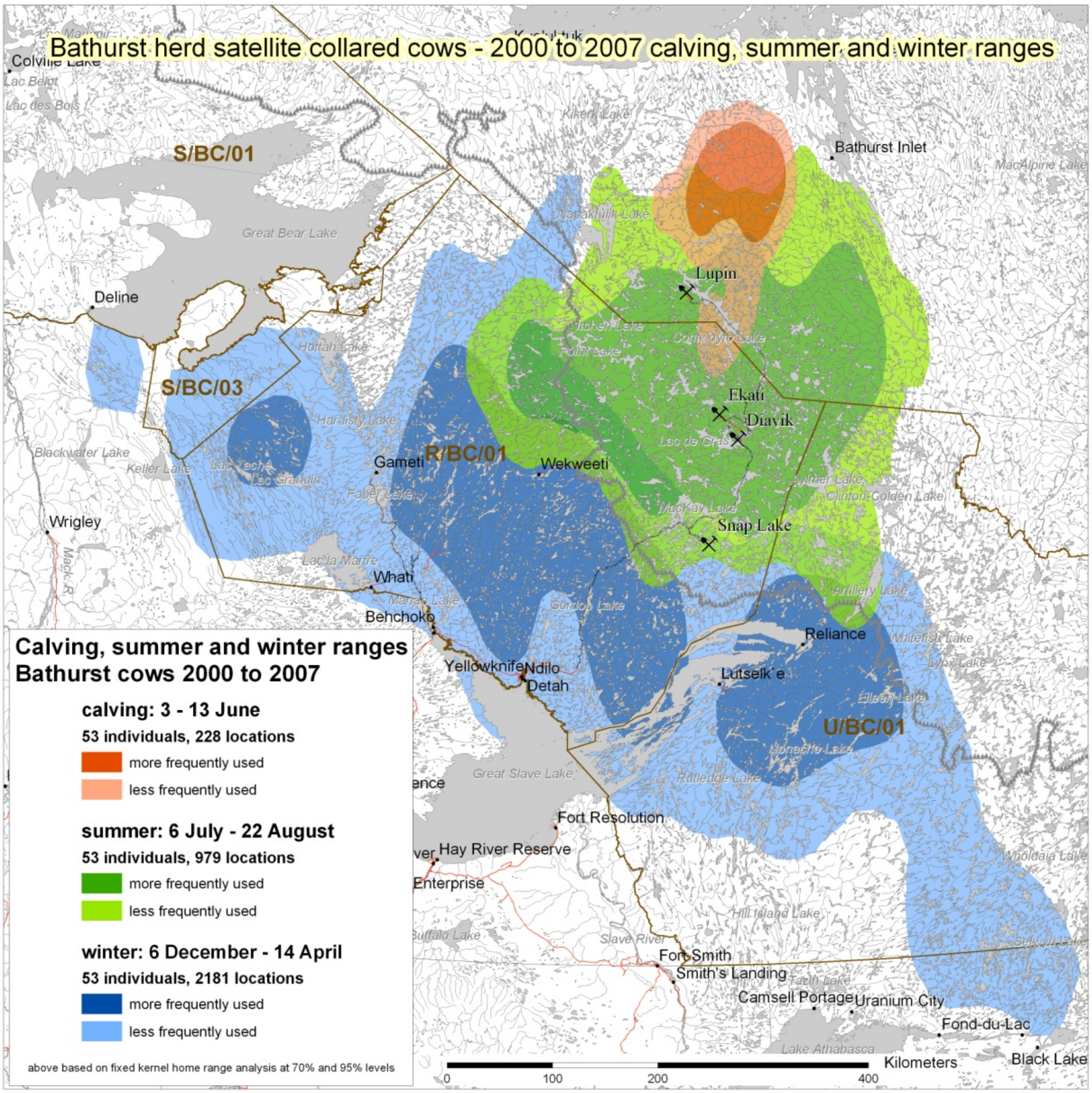


**Figure 2:** The Bathurst caribou herd's calving, summer and winter ranges based on accumulated satellite collar locations from 2000 to 2007. The diamond mines referred to in the text (Ekati, Diavik, Snap Lake) are in the summer-fall range.

A public workshop on assessing and modeling cumulative effects in barren-ground caribou range was held February 21-22, 2008 in Yellowknife, NWT. The Bathurst herd was used as a case study, although knowledge gained from other herds was also considered. We report here on the presentations and discussions at this workshop. In addition, a technical follow-up meeting was held in Calgary on July 17-18, 2008 to build on the February workshop. The focus of the July meeting was to plan a demonstration project on modeling cumulative effects in the summer range of the Bathurst herd, using three modeling approaches and elements of Tłįchǫ TK. This report centers mainly on the February workshop, but also summarizes the discussions at the July meeting, as well as information from speakers that was not covered at the February workshop.

Our objectives are to:

- Provide an overview of information on the Bathurst herd, including scientific and traditional knowledge,
- Outline three models that have been used in studies of caribou and development,
- Consider an integrated modeling approach that would use all three models to evaluate development in barren ground caribou range, using technical and traditional knowledge,
- Outline comments and discussion from the participants of the February workshop, and
- Describe a demonstration project underway to assess the feasibility of integrated modeling.

The report does not follow the agenda of the February workshop exactly, as the order of presentations had been re-arranged slightly for a more logical flow. The main text has brief summaries of each presentation with the author's name listed, to keep the report relatively concise. More complete versions of presentations may be requested from individual speakers.

PHOTO J. ADAMCZEWSKI

# BATHURST CARIBOU – REVIEW OF WHAT WE KNOW

## Caribou Issues and Concerns (T. Blondin)

Detailed notes from T. Blondin's presentation on February 21, 2008 at the caribou & cumulative effects workshop were not available at the time of writing this report. Mr. Blondin spoke about the importance of including TK along with scientific knowledge in wildlife research and management, and about the great importance of caribou to Aboriginal people – who in some cases have known and depended on caribou for thousands of years. He has worn many hats in his career and remains active in a number of programs on behalf of Tłįchǫ people. He provided an overview of the West Kitikmeot Slave Study (WKSS) program, which was a multi-year partnership between industry, government and Aboriginal groups. One of the hallmarks of the WKSS program was support of a number of studies of TK, some referred to in a presentation by A. Legat and M. Chocolate (next section). WKSS also supported some scientific studies of Bathurst caribou by A. Gunn and colleagues.

PHOTO T. ANTONIUK

## Tłı̨chǫ Elders' and Hunters' Knowledge: Barrenland Caribou (A. Legat and M. Chocolate)

Between 1997 and 2001, a research team from the four Tłı̨chǫ communities documented Tłı̨chǫ elders' knowledge of barren-ground caribou that migrate within the Môwhì Gogha Dè Nı̨ı̨tłèè, as defined in the Tłı̨chǫ Agreement. The team documented oral narratives, harvesting information dating back to the early 1900s, and elders' explanations of caribou behaviour. Oral narratives were documented from more than 40 elders at least 75 years old. Details on the research can be found in Legat et al. (2001, 2008). In this summary we provide an overview of some of the key findings and comment on how this knowledge may be useful to modeling and management.

**Figure 3:** Members of the Tłı̨chǫ Regional Elders' Committee. (PHOTOS A. LEGAT)

Top left to right: Jimmy Martin, Angelique Mantla, Madelaine Drybone, Harry Simpson. Bottom row, left to right: Louis Whane, Mary Adele Moosenose, Ronie Wetrade, Robert Mackenzie, Pierre Beaverhoe, Joe Migwe, Adele Wedawin, Alexis Arrowmaker, Elizabeth Michele.

### *Monitoring Caribou*

Traditional methods of monitoring focuses on observations and statements made by a group of knowledgeable harvesters and elders. It is the hunters who observe, and along with the elders, put their observations into context, while youth listen. Without adequate knowledge, the elders emphasize, people lack the ability to understand indicators of change and whether the change is part of a cycle, or if the indicators should trigger community concern. As elder Amen Tailbone from Gamètì said, *"You must know the caribou and observe the caribou and if the caribou does something that is different than you expect, then you must watch them even more intensely so you understand why it did not behave the way you expected it to."* (Legat et al. 1995).

Tłįchǫ people continue to travel the trails that extend throughout the Môwhì Gogha Dè Nı̨ıtłèè so youth will know these trails and significant sites (Zoe 2007). Youth are told that if caribou are in the region, they will probably frequent specific locations where fences were traditionally built to harvest caribou in the spring (Legat et al. 1995) and where natural water crossings can be found in the autumn (Legat et al. 2001). Numbers of caribou frequenting these locations suggest distribution patterns for that year; however, it is only after discussions with other hunters and elders that distribution becomes clear.

Harvesters and elders also monitor the state of caribou habitat, through observation based on experience. They discuss the abundance of lichen, grasses and sedges, the degree to which a fire has destroyed caribou winter habitat, and the amount of dust that has accumulated on vegetation near mines and from other industrial activities. Knowledge of what caribou eat is gained while observing them forage and from what is found in the mouths and stomachs of harvested caribou (Figure 4). According to Tłįchǫ harvesters, caribou can locate rich sources of food with their strong sense of smell. However, the strong smells around mines and larger communities can cause confusion for caribou moving towards lush habitat (Legat et al. 2001). Forest fires that have destroyed preferred winter habitat causes caribou to migrate elsewhere.

# Vegetation in Stomach and Mouth

## Fall Migration

| Tłı̨chǫ | Times Mentioned | English | Latin |
|---|---|---|---|
| ʔadzìì (575 times) | | | |
| ʔadzììdegoo | 335 | Various type of white lichen | Several types found, not identified |
| ʔadzìì | 158 | General term for lichen | |
| Tł'o (192 times) | | Term for grasses and sedges | |
| Tł'o | 126 | | |
| Tł'oghǫa | 62 | Type of sedge | CYPERACEAE Carex bigelowii ?? |
| Tł'odzìì | 4 | "Old grass" | CYPERACEAE Carex sp. ?? |
| Daàghoo | 52 | Type of tree lichen | Not identified |
| ʔı̨t'ǫ̀ʔı̨t'ǫ̀ | 29 | Cranberry leaves | ERICACEAE sp. |
| Kwetsı̨ | 12 | "black rock lichen" | UMBILICARIA Muhlenbergii |
| K' òòʔı̨t'ǫ̀ | 7 | Willow leaves | SALICACEAE Salix sp. |
| Gots'ǫkàʔı̨t'ǫ̀ | 7 | Cloudberry leaves | ROSACEAE Rubus chamaemorus |
| Hozìıı̨t'ǫ̀ | 5 | "Barrenland Leaves" | Salix sp. |
| Dzìewàʔı̨t'ǫ̀ | 2 | Blueberry leaves | ERICACEAE Ledum decumbens |
| ʔetł'edegoo | 1 | Not identified | Not identified |
| Degaet'ìì | 1 | Not identified | Not identified |

## Spring Migration

| Tłı̨chǫ | Times Mentioned | English | Latin |
|---|---|---|---|
| ʔadzìì (326 times) | | | |
| ʔadzììdegoo | 78 | Various type of white lichen | Several types found, not identified |
| ʔadzììdezǫ | 22 | Black lichen | Several types found, not identified |
| ʔadzìì | 6 | General term for lichen | |
| ʔadzììdekwo | 5 | Yellow lichen | Not identified |
| Tł'o (74 times) | | | |
| Tł'o | 34 | Term for sedges and grasses | |
| Tł'odzìì | 24 | "Old grass" | CYPERACEAE Carex sp. ?? |
| Tł'oghǫa | 15 | Type of sedge | CYPERACEAE Carex bigelowii ?? |
| Tł'ot'aà | 3 | Type of grass or sedge | Not identified |
| Hozìıı̨t'ǫ̀ | 10 | "Barrenland Leaves" | Salix sp. |
| Daàghoo | 8 | Type of tree lichen | Not identified |
| ʔı̨t'ǫ̀ʔı̨t'ǫ̀ | 8 | Cranberry leaves | ERICACEAE sp. |
| Kwetsı̨/Kwetsǫ̀ | 8 | "black rock lichen" | UMBILICARIA Muhlenbergii |
| Gots'ǫkàʔı̨t'ǫ̀ | 5 | Cloudberry leaves | ROSACEAE Rubus chamaemorus |
| Dzìewàʔı̨t'ǫ̀ | 5 | Blueberry leaves | ERICACEAE Ledum decumbens |
| K'òòʔı̨t'ǫ̀ | 1 | Willow leaves | SALICACEAE Salix sp. |
| Dlòodìì | 1 | General term for mushroom | Not identified |

**Figure 4:** Caribou foods during fall and spring migration periods, based on elders' knowledge. (PHOTO M. CHOCOLATE)

### *Tłı̨chǫ Laws Governing Human Behaviour*

Human behaviour is monitored by most Tłı̨chǫ and discussed with elders and leaders. It is common knowledge that human behaviour impacts caribou populations and distribution. How one behaves is usually related to the level of knowledge one has; according to the elders, destroying caribou habitat around the mines suggests a lack of knowledge. A lack of knowledge is usually tied to a lack of respect for caribou, meaning the caribou are less likely to return. As elder Johny Nitsiza from Whatì said, "*We don't just kill caribou. We only kill what we need… We know some people kill caribou, without needing it for food. I, myself, think it is disrespectful for* *caribou to be treated this way. Some people only take the part they want and throw away the rest. It is wrong…*"

The survival and continued annual migration of caribou are dependent on the respect shown to them by humans. The laws about respect discussed by Tłı̨chǫ elders can be categorized as follows:

- To assist and care for others - human and non-human,
- To minimize waste, and
- To correctly and thoughtfully dispose of bi-products.

PHOTO A. LEGAT

**Figure 5:** Philip Zoe preparing caribou hide.


PHOTO A. LEGAT

**Figure 6:** Barrenland caribou trails, Tłı̨chǫ camps, and hunters on the land.

Tłı̨chǫ traditional laws governing human behaviour affect caribou distribution, caribou health, and the caribou's will to return. The Tłı̨chǫ have experienced and therefore acknowledge that the following consequences will occur when traditional laws, such as the following, are broken:

- If people lack knowledge and destroy the caribou's food sources, caribou will disappear,
- If people waste by taking more than they need and not sharing, caribou will disappear,
- If people waste by not using all that the caribou provide, and by throwing their bones and hair in inappropriate places, the caribou will disappear, and
- If people lack knowledge of the weather, and the amount of caribou food available, they will not know when the best time is to hunt or where the caribou may migrate.

### *Linkage to Modeling*

Linking specific details associated with knowledge of caribou such as distribution patterns, fitness in spring and autumn, number of young observed, and number of caribou using particular locations can be linked to data in scientific models. However, the significance of considering the oral narratives in totality cannot be overstated. Tłįchǫ knowledge in these narratives explains the caribou's relations with place, humans, wolves, snow-depth, time of freeze and thaw, and everything else that interacts with caribou. The oral narrative links past and present, and is vital if we are to understand cumulative impacts and monitoring (Legat 2012). The story itself is a model that needs to be considered separately from scientific models.

### *Linkage to Decision-Making and Management*

Among Tłįchǫ elders and hunters, humans behave properly if they have knowledge, and if humans lack knowledge they lack respect for the land, of which caribou and humans are an integral part (Legat 2012). The Tłįchǫ Elders' Committee stressed the importance of elders teaching youth about caribou to ensure that they show respect by knowing caribou and the habitat on which they depend. At the modeling workshop on February 21, 2008, Madeline Chocolate explained that she and her husband were only taking caribou they needed and that all people should think carefully about what they need, and not be told what they could or could not take by government.

The intricacies of using TK are best left to those Tłįchǫ who understand the oral narratives that weave the past with the present. People in the communities know who these individuals are; they know who has the knowledge; they know who thinks about the future well-being of caribou and the future well-being of community members.

## Traditional Knowledge and Bathurst Caribou Cycles (D. Beaulieu)

I am descended from Francois Beaulieu, who came north in 1752 and married a Chipewyan woman from Fort Resolution. When I was growing up, my parents, grandparents and elders told me stories of when caribou numbers were high and low in the Rocher River and Fort Resolution area. I learned about the cycle of caribou from TK taught to me by my grandmother and grandfather, my mother and father, and the elders of Rocher River and Fort Resolution. The caribou cycle described in the TK of this family is diagrammed in Figure 7.

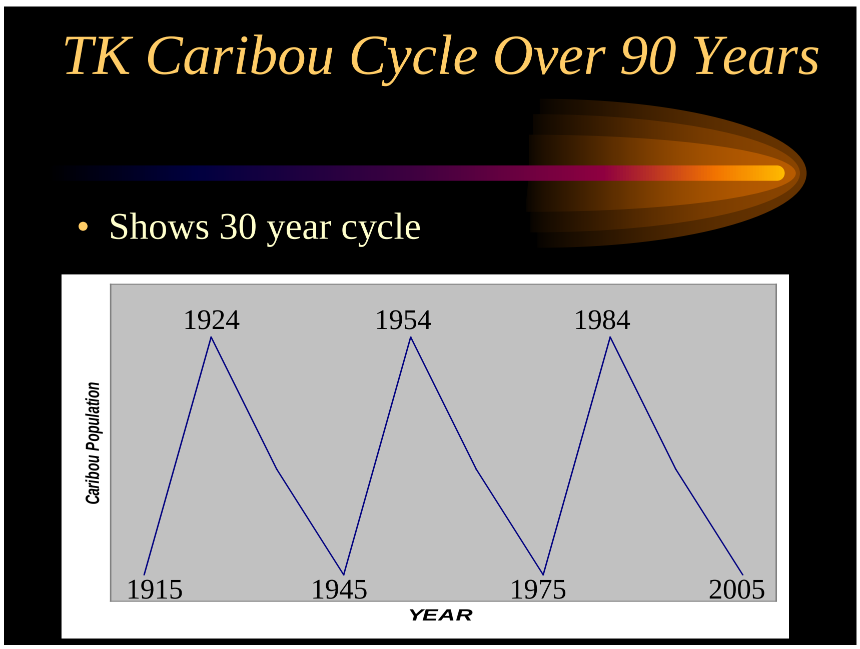


**Figure 7:** High and low Bathurst caribou numbers from 1915 to 2005, based on TK in D. Beaulieu's family.

In 1915, numbers were low and people told of hard times as caribou couldn't be found even when the Chipewyan people traveled towards the tundra to hunt in winter. My grandfather told me that during the First World War there were no caribou to be found in the Rocher River area. My grandmother told me that when her younger brother John was born in 1924, her dad told her that it sounded like thunder and the ground shook because there were so many caribou. After the Second World War, my parents said there were no caribou; again, people had to travel to treeline to try to find caribou.


PHOTO D. BEAULIEU

When I was born in October 1953, my father said there were lots of caribou in the Rocher River area that winter. My auntie Dorothy and uncle Angus Beaulieu told me in the '50s there were caribou on the prairies west of Fort Resolution and on the ice on Fort Resolution Bay. In 1975, I was working in the mine at Pine Point and my father was a wildlife officer in the South Slave region. He told me that the caribou numbers were low. Caribou were far away and there were no winter roads; people who could afford it were flying out to hunt caribou. There were few resident hunters and no caribou outfitters so the harvest was low. In 1984, I was back trapping and living up the Taltson River. There were lots of caribou again around Rocher River and I hunted caribou in Taltson Bay. After 1984 caribou moved further to the northeast and we had to travel farther each year to hunt caribou.

In 2005, caribou numbers were again low. TK says that as caribou numbers increase, they expand the range used. TK also demonstrates that over the past 100 years, the caribou cycled up and down every 30 years (Figure 7). The next peak for caribou numbers should be 2014 and the next low will likely be in 2035. TK tells us that caribou herds increase quickly and decline more slowly. Counts and studies by biologists have documented roughly the same cycle since 1975.

Today, there are additional pressures on the caribou such as mines, winter roads, outfitting, snowmobiles, airplanes and collaring caribou. The caribou can no longer hide from us. If these pressures are not reduced over the next few years to help caribou numbers recover, caribou numbers will not come back as strong as before. We also need a management plan for 2035 when caribou numbers should once again be low. In 2044 caribou numbers will peak again; I'll be 90 and I'll be around if you want more advice.

PHOTO NWT ARCHIVES, COURTESY OF D. BEAULIEU

## Biological Monitoring of the Bathurst Herd (A. Gunn)

The Department of Environment and Natural Resources (ENR) has been monitoring the Bathurst herd of migratory barren-ground caribou using standardized methods since the early 1980s. The primary focus is on monitoring herd trend (increasing, decreasing or stable) and population size. Heard and Williams (1990 and 1991) offered an analysis and rationale for barren-ground caribou monitoring in the NWT with the emphasis on tracking trend in the abundance of breeding females. This approach to monitoring the Bathurst was strengthened in the early 2000s through consultations for Bathurst herd management planning and most recently in ENR's *Barren-Ground Caribou Management Strategy for the NWT 2006-2010* (BGCMS). Calf survival, harvest, pregnancy, adult survival, and sex ratio are monitored in addition to the abundance of breeding females, to provide supporting and explanatory data for population trends.

The trend in breeding females is measured on the calving ground as close to the peak of calving as possible. The first step is a systematic reconnaissance survey to map relative densities and to group them as survey blocks with similar densities. Those survey blocks are flown by an aircraft specialized for photography at a relatively high altitude (1,000 m). The aircraft takes 2,000-3,000 photographs along transect lines. The caribou are later counted from the photographs. The use of photographs increases the survey's accuracy as it is easier to see and count the caribou, and the counts can be verified. The allocation of sampling effort (number of photographs), relative to caribou density, increases the precision of the resulting estimated number of caribou. The third step for the census is sampling the breeding status and sex-age class of the caribou on the calving ground. This information is used to adjust the total number of caribou counted on the calving ground to an estimated total number of breeding cows. Breeding cows are identified from a calf at heel, a distended udder or that the cow still is antlered (antlers are shed shortly after calving). Non-breeding caribou may be barren cows, yearlings and some younger bulls. The estimated number of breeding females is extrapolated to total herd size using pregnancy rate and adult sex ratio. The adult sex ratio is estimated from one or more fall composition surveys, as all sex and age classes mix during the rut. The trend in numbers of female caribou on the calving grounds of the Bathurst herd is shown in Figure 8.

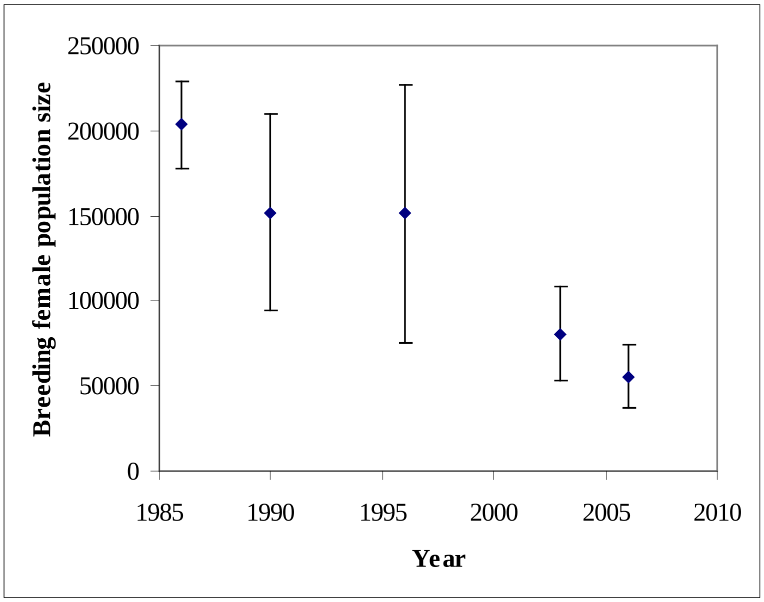


**Figure 8:** Trend in numbers of female caribou on the calving grounds of the Bathurst herd, based on surveys 1986-2006 (Boulanger and Gunn 2007).

Calf survival is indexed by measuring the ratio of calves to cows during observations from the ground at different times of year. As the index is a ratio, it is influenced by pregnancy rates, cow mortality as well as calf survival. Calf counts in late winter (March/April) are used to index recruitment (the proportion of calves surviving to one year of age) which is a measure of the potential growth rate for a herd. In the Bathurst herd, typically, calf survival is measured on calving grounds (initial calf survival for few days to one week) during the periodic censuses and annually on late winter ranges. Recently (2004-2008), calf survival has also been measured on fall ranges, which indexes summer survival.

For calf survival estimation, sampling has to be systematically dispersed across the herd's range to minimize unrepresentative sampling when the caribou distribution is segregated by age and sex. Obtaining precise estimates is relatively easy to maximize by obtaining enough samples (20 sites or groups). Typically, calf survival varies annually (possibly because of breeding pauses in cows) and given the variability, trends over several years are more important than differences between pairs of years. Demographic modeling indicates that annual variation in calf survival influences trends in herd size less than variation in adult female survival. However, sustained trends in annual calf survival do influence trends in herd size.

In the Bathurst herd, late winter calf survival, as measured by calf:cow ratios, declined by almost half since 2001-2004 compared with 1985-1996. Calf survival was markedly low during summer 2004 but subsequently calf:cow ratios were higher during 2006, 2007, and 2008. Calf:cow ratios measured in late winter for the Bathurst herd from 1985 to 2008 are shown in Figure 9.

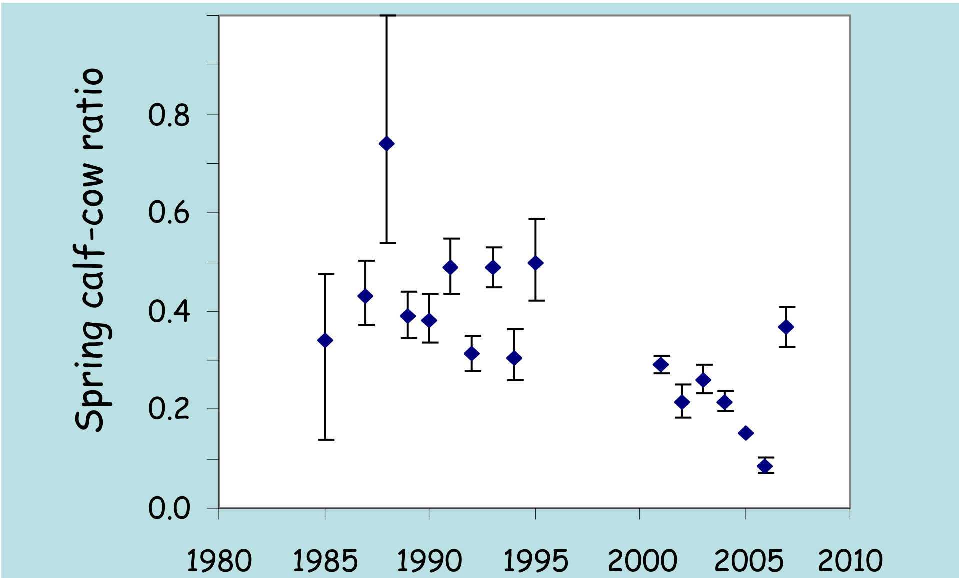


**Figure 9:** Calf:cow ratios measured in late winter for the Bathurst herd.

Pregnancy rates are measured on calving grounds (from counts of cows with calves, distended udders or hard antlers) or directly from harvested cows during community-based monitoring of hunts. Pregnancy rates were once thought to be relatively constant but more recently, it is apparent that cows undergo reproductive pauses depending on their physical condition. Demographic modeling indicates that variation in pregnancy rates can have a moderate effect on trends in herd size. In the Bathurst herd, pregnancy rates have not been regularly monitored until recently. The rate was 63% in March 2005 when 150 cows were examined during harvesting. The following year, the condition of cows without the energetic costs of pregnancy and lactation had improved and pregnancy rates had recovered to 80% in 2006. For comparison, pregnancy rates for the Porcupine herd averaged 0.81 (range 0.71-0.92) for 1983-2001 (Griffith et al. 2002).

Until 2004, the adult sex ratio was not directly measured for the Bathurst herd, but was extrapolated from the Beverly herd and estimated to be 66 bulls:100 cows in 1985 (Heard 1985). The lower observed bull:cow ratios of 31-36 bulls:100 cows in 2004, 2006, and 2007 suggest that mortality is higher in male caribou during declines.

Resident and non-resident harvest levels are reported annually, but there is less information for subsistence harvesting. Some harvest is monitored at winter road check stations and via community reporting. In 1988-93, harvesters were interviewed in the Dogrib communities. Their monthly reports were extrapolated to estimate caribou harvested. Harvesting is the ideal time to collect seasonal data on physical condition and health, as hunters rate caribou condition in a comparable way to biologists, thus harvesting can effectively contribute to herd monitoring (Lyver and Gunn 2004).

Seasonal and annual adult female mortality was estimated from satellite telemetry based on how long individual collared cows live. The mean adult female survival rate was 0.81 for the

Bathurst herd for the period 1996-2006 and did not change over that time. Modeling suggests that herd trend is sensitive to slight changes in adult female survival (Fancy et al. 1994, Boulanger and Gunn 2007) although it is difficult to detect small changes in survival.

Satellite telemetry, aerial surveys, and observations from hunters and communities are all used to monitor caribou distribution. For the Bathurst herd, satellite collars in the late 1990s numbered ten or less; more recently 15-20 collars have been in place, somewhat limiting the extent to which the collars represented herd movements. During the peak of calving, a comparison of the survey blocks of calving caribou and the satellite collars suggests that collars have been representative of the main areas of calving concentration. In the context of cumulative effects, radio collars are useful to estimate probability of exposure of caribou to the zone of influence around mines (Boulanger et al. 2004). From fall 2008 on, satellite radio collars on Bathurst caribou have GPS (global positioning system) accuracy and a higher frequency of locations, allowing more detailed studies of habitat use to be made.

This summary has focused on demographic monitoring of the Bathurst herd by GNWT, but ENR biologists have also invested time and effort into research on the herd's basic ecology, often in partnership with university researchers like Chris Johnson (University of Northern BC, Prince George). Currently, there are graduate students studying the herd's winter range and effects of insect harassment in the summer. Work continues on evaluating the effects of changing weather in spring and summer on NDVI (Normalized Difference Vegetation Index, a measure of greenness and vegetation productivity) in the herd's spring and summer ranges. In addition, a developing project led by C. Johnson will assess fire history and ecology on the herd's winter range.

## Traditional Knowledge and Science Working Together – Examples from the NWT (J. Adamczewski)

A number of participants at the February 2008 cumulative effects workshop stressed the importance of using TK together with knowledge gained from scientific studies. Biologists in the NWT have carried out studies of caribou where scientific and TK have both been used in caribou programs. Below we provide examples where TK and scientific studies have been used in complementary ways.

Boreal woodland caribou have been listed nationally as *threatened* by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) due to widespread declines across southern Canada. In the Dehcho region of the NWT, Gunn et al. (2004) modeled the occurrence of boreal caribou and habitat attributes along with a database of harvest kill sites by hunters in the Dehcho region to determine areas with the highest likelihood of having boreal caribou. An aerial survey in March 2002 showed boreal caribou occupation had not changed at the regional level. Boreal caribou were strongly associated with black spruce and lichen-rich habitats. In this study, modeling based on technical criteria concurred with patterns shown in the Dehcho database – hunters in this region knew the areas and habitats likeliest to have boreal caribou.

Zalatan et al. (2006) measured an index of caribou abundance by the frequency of hoof scars on spruce roots along migration trails of the Bathurst and Beverly herds. The record provided by this means dated back to the early 1900s, although a few roots dated back to 1760. Based on these records, caribou numbers in these herds were high in the mid-1940s and 1990s and were low during the 1920s, 1950s to 1970s, and in the beginning of the 21st century. These patterns correlated strongly with TK of Tłı̨chǫ elders and in the most recent decades, with population surveys of the Bathurst herd. We noted earlier the value of hunters' ratings of caribou condition during harvest periods and the correlation of these ratings with condition indices measured by biologists (Lyver and Gunn 2004). Using hunters' condition assessments can increase the number of cows assessed substantially and strengthen estimates of herd pregnancy rates.

In the present report, D. Beaulieu defined periods of caribou abundance and scarcity from his family's observations from 1915 to 2007 and found recurring periods of scarcity in 1915, 1945, 1975 and 2005, along with periods of high numbers in 1924, 1954 and 1984. Surveys by GNWT biologists began in the 1970s, and since that time, have been generally consistent with the cycle defined by D. Beaulieu. It is also worth noting that Bergerud et al. (2008, see p. 136) re-constructed periods of abundance and scarcity of the George River herd from reports of high and low caribou numbers, and in some cases starvation of Aboriginal hunters in particular areas, back to the 1700s. Bergerud et al. (2008) believed that the extent of the herd's seasonal ranges contracted and increased with population size in a predictable manner. D. Beaulieu's reconstructions of caribou abundance and scarcity used a similar model – caribou could be expected in more peripheral areas at high numbers, but not at low numbers.

PHOTO C. JOHNSON

## The Three R's: Respect, Responsibility and Resilience – Cumulative Effects in a New Light? (A. Gunn)

Cumulative effects have been talked about for at least 15 years but still agencies and industry struggle with assessing them. For example, critics of current cumulative effects assessments have listed failures, such as the limited area over which effects are considered or the lack of accounting for natural environmental variation (Kennet 1999, Duinker and Greig 2007). For caribou, the cumulative effects of human activities will vary according to the state of the individual and herd. How caribou cope with additional stresses, such as mines or roads, depends on the level of natural environmental stress they are experiencing. Caribou already cope with aspects of their environment such as late or early springs, hot or cool summers, variable summer nutrition, and insect harassment. Their resilience to further man-caused stresses is poorest during periods of decline, when the animals are usually in the poorest condition and have low recruitment.

PHOTO A. GUNN

Measuring responses of caribou to human activities requires adequate recognition of natural environmental variation as well as human effects such as hunter harvest. Range-wide (landscape) objectives and possible thresholds for regional and project-specific cumulative effects needs to be integrated within an overall framework for caribou management. Although we collectively know much about caribou ecology, and are concerned about the welfare of caribou, we have not integrated our information sufficiently. We suggest that the three R's: Respect, Responsibility and Resilience will be key to helping us measure and monitor the cumulative effects of development on caribou, and ultimately to manage them.

Respect for caribou and people include being knowledgeable and sharing knowledge, both key to understanding cumulative effects. Responsibility is a reminder that everyone with a stake in Bathurst caribou, or caribou in other populations, has some measure of responsibility for their welfare. The responsibility is shared between developers pursuing individual projects, environmental assessment agencies, land and wildlife management agencies, co-management boards, and governments (territorial and Aboriginal). Collectively we have a responsibility to ensure that cumulative effects assessments include natural environmental variation, consider human influences at variable time and space scales, and integrate projects across the scale of the herd's annual range.

Resilience describes the ability of caribou to cope with environmental changes, including human land uses. Environmental variation, such as levels of insect harassment, can reduce or increase resilience of an individual caribou which then changes the same individual's response to human activities. Resilience also applies at the herd scale; a herd with poor average condition or low recruitment will be less resilient to additional stresses. The application of resilience as a concept will allow us to integrate project-specific effects assessments and range-wide monitoring to better understand the cumulative effects of human activities on the Bathurst caribou herd.

Ecological resilience is measured by the amount of disturbance that can be coped with before the individual (or herd) changes its behaviour (Holling 1973). Resilience links to respect – our knowledge about the adaptability of caribou. It is also intuitive – we know that there are limits to adaptability. It is flexible in data needs and/or use and can deal with both responses to human activities and environmental variation.

Caribou ecology is complex. Figure 10 illustrates how it looks when we identify some of the factors that influence a caribou herd; for most of the variables and relationships, we have data from the Bathurst herd and for others, we can borrow relationships or data from other herds, especially the Porcupine herd. We can look at how individual factors influence caribou, and then examine how other factors affect these relationships and how they link to herd-wide trends.

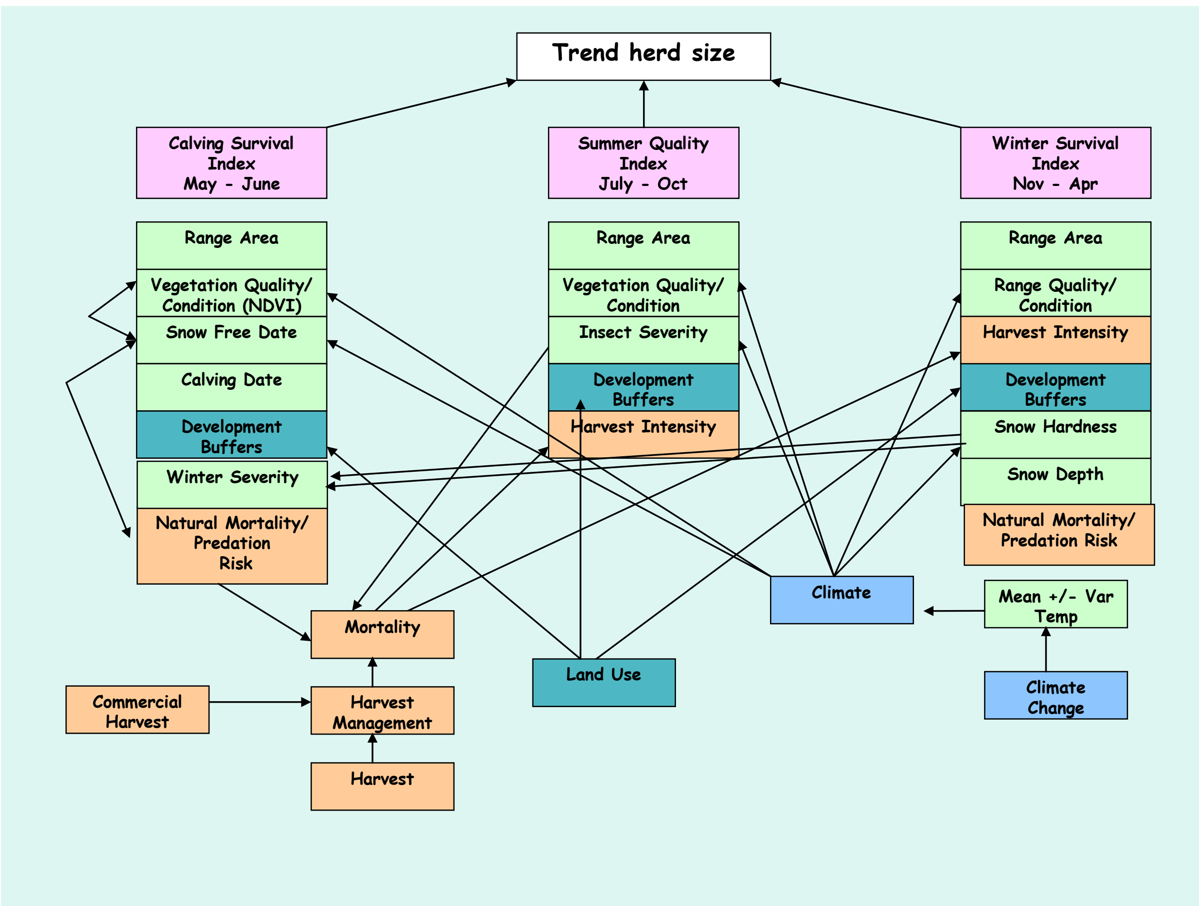


**Figure 10:** Diagram illustrating known factors influencing caribou health and condition. We have data for the Bathurst herd for most of these factors, or can borrow data from other herds.

As an example, the fatness of an individual caribou is a measure of its resilience. A cow requires a certain amount of fat and protein (often called her condition) before she will conceive in the fall. If her condition is well above these threshold levels, she can lose a fair amount of condition and still become pregnant. A lean cow, however, is near the threshold levels and a small loss in condition might reduce her chances of becoming pregnant. If a lean cow reduced her foraging time 14% during the summer because of warble fly harassment, then reduced her foraging time a further 2% being alert checking out aircraft, that 2% would be inconsequential in a year when she was fat. In a year when she is lean, the 14+2% would be enough to reduce her chances of pregnancy (not enough fat) by 10%. If many cows in the herd are lean, then these small changes in feeding behaviour may have significant herd-wide effects on productivity.

Resilience works in a hierarchical manner moving between individual and herd scales, and in time between seasons, years and decades. At the herd scale, high calf survival suggests that the herd has the potential to increase. However, demographic modeling has shown that population trend is highly sensitive to small changes in cow mortality rates (Fancy et al. 1994, Crete et al. 1996, Boulanger and Gunn 2007). With low recruitment and reduced cow survival, herd resilience to additional stresses is low. Figure 11 illustrates the relationship between the herd and individual scales.

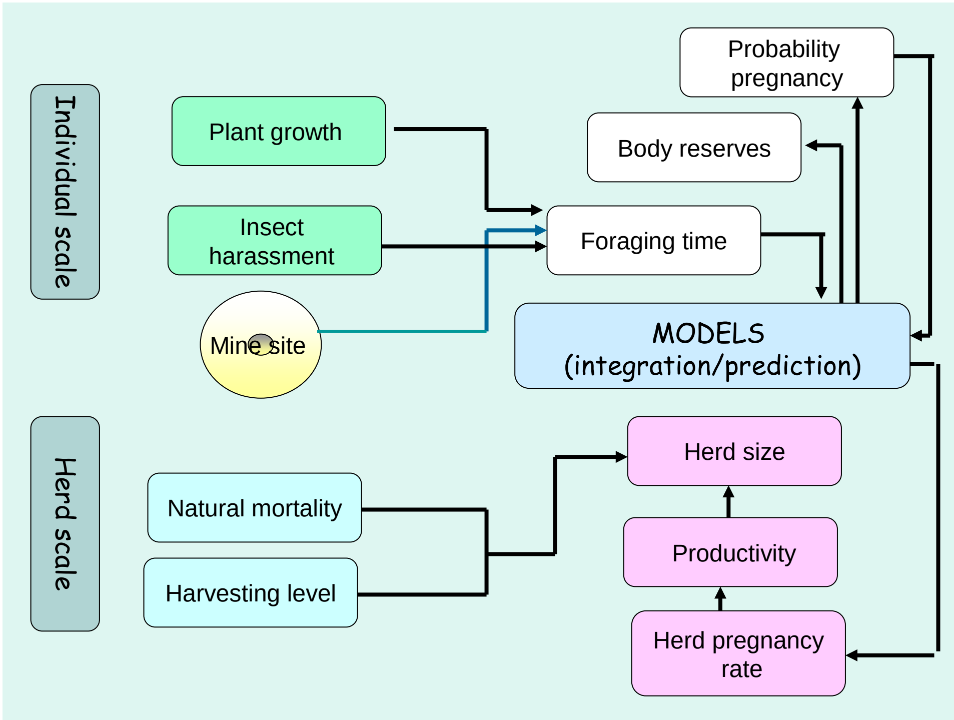


**Figure 11:** Diagram illustrating relationships between monitoring at the level of the individual and the herd level, relative to describing cumulative effects.

In addition to multiple scales of time and individual/herd scales, a third scale to consider is space – namely seasonal and annual ranges.

What is a resilient landscape? How much change can caribou cope with? An exploration of the answers lies in taking what we know, working respectfully together, and integrating our knowledge through the use of models. We have good information on many of the variables and relationships, but we need to improve the integration of our knowledge. Resilience conceptually links project-specific and regional cumulative effects assessments with individual, herd and landscape-scale responses of caribou.

## Caribou Monitoring at Diamond Mines (J. Virgl)

The goal of this presentation is to provide an overview of the mitigation and monitoring that occurs at the Ekati, Diavik, and Snap Lake diamond mines. Consistent with the theme and objectives of the workshop, the presentation provides a summary of the information that the mines collect over different scales of space and time. A brief description of the types of analyses used to determine mine-related and natural effects is also provided.

**Figure 12** Aerial view of Diavik diamond mine, central Northwest Territories. (PHOTO DIAVIK DIAMOND MINES INC.)

### *Mitigation*

Managers at each mine site use a number of mitigation measures or environmental management policies and procedures to limit or reduce impacts to caribou and other wildlife which include:

- Education of staff and contractors to increase awareness about the importance of wildlife conservation,
- Communication of presence of approaching caribou or caribou on site to environmental technicians who monitor their movement through the project area,
- Giving all wildlife right-of-way,

- Watering roads to reduce the amount of dust from vehicles and equipment,
- Installation of mufflers on equipment to reduce noise levels,
- Early initiation of reclamation studies to determine which methods might work best for the natural growth of vegetation on disturbed areas,
- Not allowing hunting by mine staff and contractors at the mine-sites,
- Sorting and managing garbage to limit the presence of food waste that can lead to an increase in predator numbers in the area, and
- Enforcing speed limits on roads and posting signs to warn drivers of frequently used caribou travel routes where the animals are likely to cross the road.


**Figure 13:** Caribou are given the right of way at mine sites. (PHOTO GOLDER ASSOCIATES)

### *Monitoring*

Each mine site has a number of different types of monitoring programs. Community-based monitoring programs include groups and organizations such as the Tłı̨chǫ Government, Yellowknives Dene First Nation, North Slave Métis Alliance, Kitikmeot Inuit Association, and Lutselk’e Dene First Nation. Many Dene people work in the environmental departments at the mine sites. Each year, the mines produce annual reports on wildlife monitoring that are reviewed by independent environmental monitoring agencies such as the Independent Environmental Monitoring Agency (for Ekati), the Snap Lake Environmental Monitoring Agency, and the Environmental Monitoring Advisory Board (for Diavik), and government agencies. These agencies provide feedback and direction for the monitoring programs.

Site monitoring includes daily monitoring activities such as reporting wildlife incidents, deterrent actions that may be required, and wildlife mortalities. Caribou that travel through the mine site are monitored along roads, near the processed kimberlite areas, and on the airstrip. The information is used to determine the level of reaction of caribou to different stressors such as blasting, light vehicles, heavy equipment, and aircraft.

Vegetation classifications and habitat monitoring are completed at each mine site. Vegetation classifications are generated using the ecological landscape classification system developed by ENR (previously RWED) for the Slave Geological Province. The system produces a standardized habitat layer that enables precise estimates of cumulative changes to the amount, fragmentation, and quality of habitat for caribou and other wildlife. Having a standardized habitat layer also enables direct comparison among project-specific analyses for effects on caribou distribution and behaviour. Direct vegetation loss is monitored through measuring changes in the vegetation classification associated with the mine footprint. Other changes to caribou habitat such as the number and abundance of different plant species are determined through vegetation studies. Dust level is also monitored, and the concentrations of metals in lichens are analyzed.

Environmental conditions at each mine site also are measured with meteorological stations. The data provide an index of insect level activity, and estimates of rainfall, wind, and temperature. This information has been used to explain some of the natural variation in caribou behaviour.

Other data used for monitoring include satellite collars, aerial surveys, and ground observations of caribou behaviour. Data from satellite and GPS-collared female caribou (courtesy of ENR) provide information on the coarse-scale movement, habitat selection, and distribution of caribou herds. The data provide the mine sites with notice that caribou are approaching the study area, which helps determine the timing of surveys. Other analyses of collar data include: 1) time of year or season when caribou are most likely to be influenced by the mines and other developments within their annual range, 2) large-scale resource selection functions (RSFs), 3) year-to-year variation in seasonal range distributions, and 4) the proportion of time caribou spend in the zone of influence during each season and over the years.

Aerial surveys provide smaller scale information on caribou as they move closer to the mine sites, and how their response may change as the level of activity at the mine changes over time. Data collected include estimates of group size, group composition, number, dominant behaviour of group, and distribution (probability of occurrence). Surveys are flown along pre-determined transects at altitudes of 150 to 200 m above ground level at speeds of 130 to 160 km/hr during the northern and post-calving migration periods. Some aerial survey results for caribou presence near the Snap Lake mine are shown in Figure 14. The approach provides good visibility for detecting caribou groups and determining group composition, which is important for analyzing the effect of development on caribou distribution. Mine and environmental variables include distance to mine, year, phase of development (e.g. construction, operation), habitat, and season.

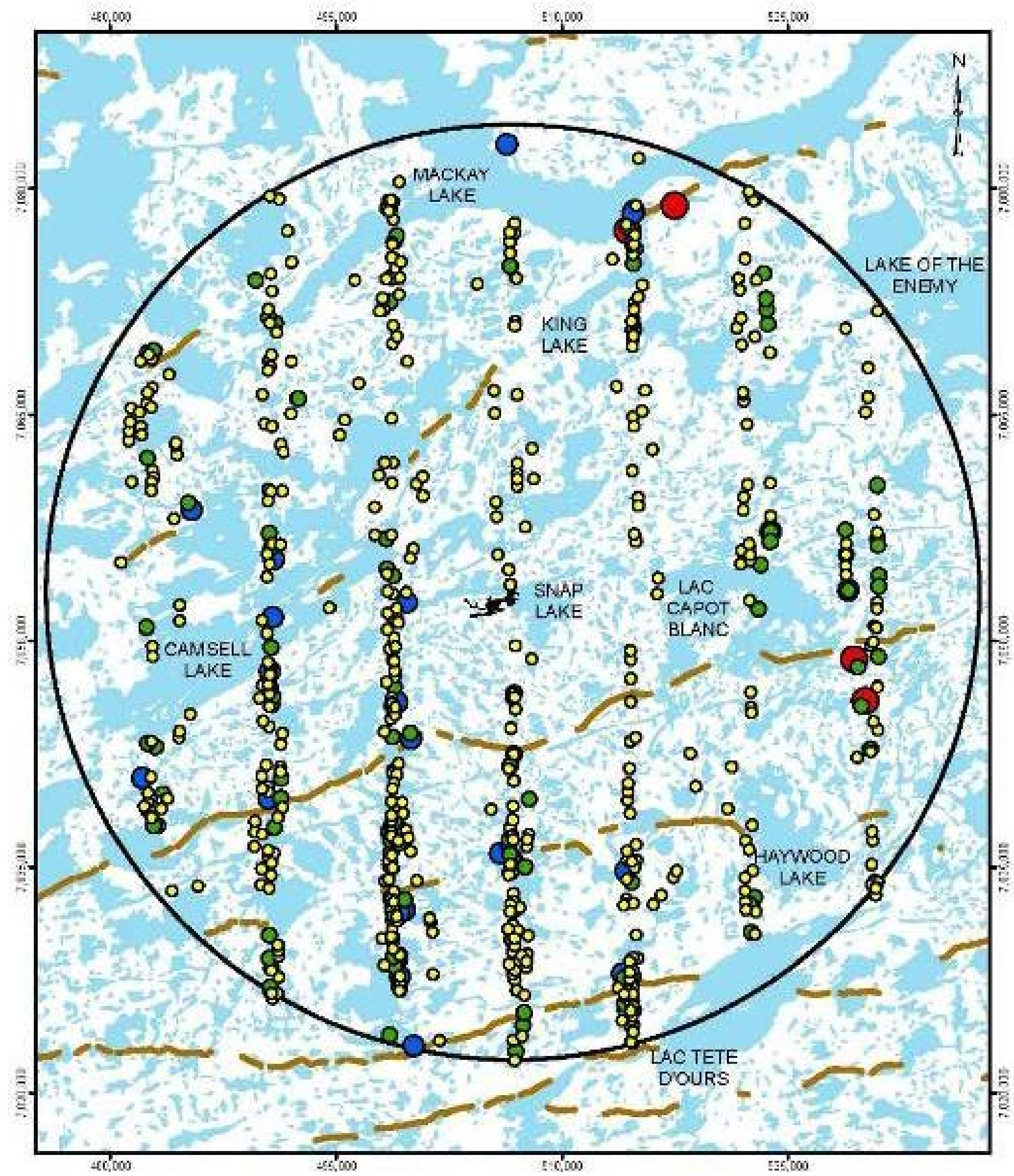


**Figure 14:** Aerial survey transects in the Snap Lake mine-site area, with caribou groups seen.

Scanning observations of ungulates from the ground is an established and accepted method for estimating the time individuals spend among various behavioural activities (e.g. feeding, resting, and walking). Observations are recorded near the mine site and up to 25 km from the mine. Data are recorded every eight minutes and an attempt is made to observe caribou for at least 1-1.5 hours; multi-hour observation periods are rarely possible because caribou are most likely to be near the mines when on the move north or south. Analyses of these data have provided valuable information on the smaller-scale responses of caribou to mine development. Analysis is done separately for groups with calves and groups without calves to determine if the proportion of time spent among behaviours is related to distance from the mine, year, and environmental variables such as insect levels and weather.

### *Summary*

With help from the communities, ENR and mine environmental staff, data has been collected on the responses of caribou to mine sites and natural factors over different scales of space and time. The independent environmental monitoring agencies have provided feedback and direction for the studies. Some general patterns have been observed and the results have varied from year to year, and at the different mine sites. This is not surprising when we consider the different levels of activity and area of footprint associated with each mine, the different topography and landscape features within each study area, changing weather patterns, and natural changes in caribou population size. There is still much to learn, and government and mine site staff are very busy, have many demands, and limited resources for research and monitoring, and the barrens can be a difficult place to work. Getting at the answers will not be easy and will take the cooperation of everyone who wants to conserve caribou for our future generations.

PHOTO GOLDER ASSOCIATES

## Information Sources on Bathurst Caribou Herd (Contributions from Various Speakers)

The following table is meant to provide an overview of the kinds of information available for the Bathurst caribou herd and the potential for cumulative effects modeling. An earlier version was filled in at the February workshop from speakers' notes and a few items have been added since then by authors of this report. Table 1 is not an all-inclusive list; readers looking for more detailed information may want to consult some of the references or contact workshop speakers. We recognize that TK about caribou is held by Aboriginal groups other than the Tłįchǫ and Chipewyan people.

With the exception of caribou abundance indexed by spruce root-scars, most information gathered by biologists for the Bathurst herd dates back to the 1970s or later, and is usually at the scale of the herd or one of its seasonal ranges. TK about caribou in the Bathurst range has a long time-fame, often dating back hundreds of years or longer through oral narratives passed down over generations. Information gathered by diamond mines begins in the late 1990s or early 2000s and is focused at a relatively small spatial scale (30 km) around the mine sites.

**Table 1.** Information on the Bathurst caribou herd: sources and scales.

| Information Type | Source (Who collects it?) | Spatial Scale of Information | Time Scale of Information | Comments/Notes |
|---|---|---|---|---|
| Becoming knowledgeable | Tłı̨chǫ elders; documented by TK research team | Large (Traditional Territory) | Extensive (Tłı̨chǫ cultural history) | Knowing how to behave with caribou requires a strong knowledge base |
| Habitat monitoring | Tłı̨chǫ elders | Large (Traditional Territory) | Extensive (Tłı̨chǫ cultural history) | |
| Caribou water crossings | Tłı̨chǫ elders | Large (Traditional Territory) – small | Since the caribou came | |
| Caribou distribution (seasons/years) | Tłı̨chǫ elders | Small–Large | 1920s – 1990s | |
| Caribou preferred vegetation | Tłı̨chǫ elders | Small–Large | 1920s – 1990s | |
| Trend in caribou numbers (cycle) | Chipewyan elders | Large (herd) | 1915 – 2006 | D. Beaulieu presentation – peak every 30 yrs. |
| Relative abundance of caribou | Tłı̨chǫ elders (oral history); biologists (spruce root scars) | Small–Large | 1800s – 2000s | Example of TK and science agreement |
| Monitoring and managing human behaviour | Tłı̨chǫ elders | Large (traditional territory) | Extensive – passed via oral narratives | |
| Location of caribou fences | Tłı̨chǫ elders | Small–Large | Extensive – passed via oral narratives | |
| Herd size | GNWT | Large (herd range) | 1986–2006 (5 surveys) | Expensive; variance can be high |
| Calf survival (Calf:cow ratio) | GNWT | Large (herd range) | 1985–1995 and 2001–2007 | Trend indicator |
| Pregnancy rate | GNWT/hunters | Medium–Large (herd range) | 1980s – 2000s (some years) | Trend indicator Available from calving ground surveys or hunters |
| Adult sex ratio | GNWT | Large (herd) & individual | 2004, 2006, 2007 | |
| Cow survival rates | GNWT | Large (herd) & individual | 1996–2007 | From radio collars; limited numbers |

| Information Type | Source (Who collects it?) | Spatial Scale of Information | Time Scale of Information | Comments/Notes |
|---|---|---|---|---|
| Caribou condition assessment | GNWT, hunters, elders | Large (herd) & Individual | Starting 2005 Also 1990–92; longer via elders | |
| Hunter harvest | Co-management boards, communities | Large (herd) | Some years 1990s, 2000s | Incomplete information |
| Distribution, movements, fidelity | GNWT | Large (herd), seasonal, individual | 1995 – 2000s | Satellite collars; limited sample, all cows |
| Environmental variation – insect harassment | University partners & GNWT | Medium–Small (individuals, groups) | Starting 2007; trend indices 1950s–2005 | Shown important for Porcupine caribou |
| Environmental variation – Range condition | University partners & GNWT | Large – seasonal herd ranges | 1985–2007–NDVI on calving and summer ranges | Shown important for Porcupine caribou; uses remote sensing |
| Diet | GNWT | Medium–Small (individuals, groups) | Calving 1998–99; summer 1990–92 | |
| Caribou distribution (all groups, cow-calf groups) | Diamond Mines | Local (Mine study areas – 30–40 km from mine site) | Started late 1990s or 2000s | Standard method for all diamond mines |
| Caribou behaviour near mines | Diamond Mines | Local (Mine study areas) | Started late 1990s or 2000s | Standard methods for two mines |
| Environmental variation – insect harassment | Diamond Mines | Local (Mine study areas) | Started late 2005 based on index | Standard methods for one mine |
| Environmental monitoring – dust | Diamond Mines | Local (Mine study areas) | Started 2000s | Standard methods for three mines |
| Environmental monitoring - metals in lichens | Diamond Mines | Local (Mine study areas) | Started 2000s | Standard methods for all mines |

# MODELING CARIBOU AND DEVELOPMENT

## What are Models? – A Way to Integrate Data & Knowledge (J. Nishi)

When asked last year whether industry and caribou could co-exist in the north, Fred Sangris, (Chief, Yellowknives Dene) said, “When the buffalo went from the plains, the people of the plains, the Cree, the Dakota – their culture died, their spirit died. Here, we have a chance to save it.” By evoking the near demise of bison, Chief Sangris drew a powerful lesson from history. His comparison of bison and caribou underscored two important points: 1) there is a strong cultural link between Aboriginal peoples, wildlife and the land, and 2) abundance of wild animals today is no guarantee to their future survival.

The comparison between bison and caribou has also been made by biologists – in 1984, Tom Bergerud and co-authors concluded, *“But, adaptable as the caribou is, it still has the same problems as the buffalo – overharvest and the need for space.”* Wildlife managers’ concern about hunting is usually greater when herds are declining, particularly in the present-day when few places are still truly remote.

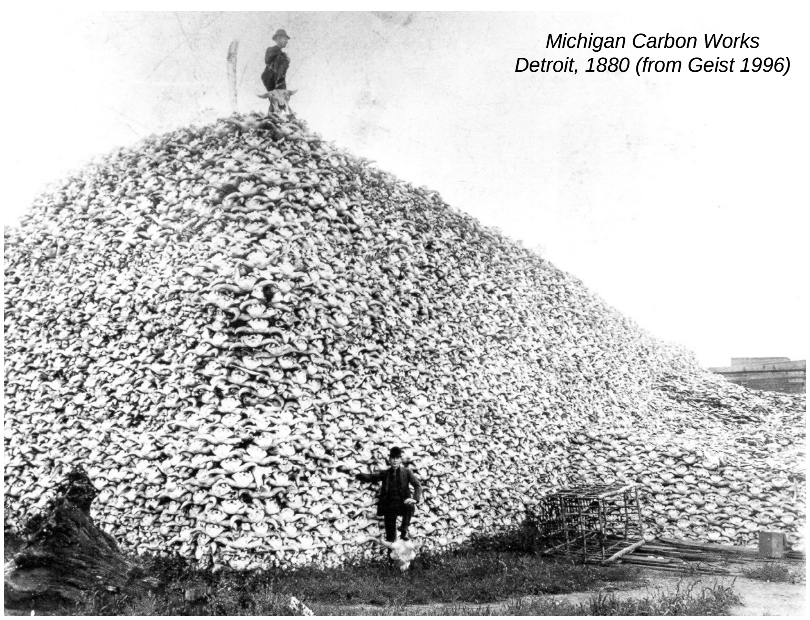


**Figure 15:** A mountain of bison skulls in Detroit, 1880. Plains bison once numbered in the millions in North America, but will never reach similar numbers again.

My objective for this presentation is to introduce you to the concept of modeling by touching on three general themes: 1) a definition of models, 2) computer-based simulation models, and 3) modeling concepts.

### *What is a Model?*

The concept of modeling may seem abstract and not very relevant to caribou management. However, I suggest that modeling is something we all do in our daily lives.

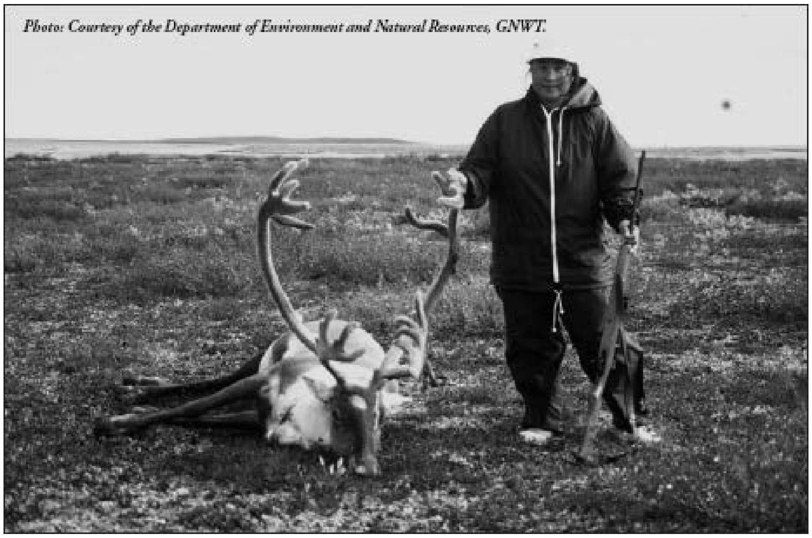


**Figure 16:** Caribou have been important to NWT hunters for many generations. (PHOTO ENR)

For those of us who hunt caribou, the very act of hunting involves thinking and planning, which are essential parts of the modeling process. Thinking is the basis for good modeling. A hunter uses his own knowledge and understanding of where caribou might be on the land. Before a hunter goes out on the land, he will have already run through “what if” scenarios to help him plan where to go, when to go, and what to take. Another important part of good modeling is communication of ideas and thoughts. In the hunting example, we think and communicate to improve our understanding based on our own direct experiences and those of others. The three components of modeling – thinking, communicating and learning – are activities that we all do every day.

Models are important because they help us visualize and understand complex relationships. Models allow us to "use what we know" to help us make decisions. Models also help us better understand what we do not know, and how the uncertainty in our knowledge may affect our decisions. Models can show us new ways of thinking and new perspectives. Models can be thought of as imitations of real life objects, situations, or processes. In the context of wildlife management, we need to think of models as tools to help us make better decisions. The value of a model is not how accurate it is, but whether it contributes to making better, more informed decisions.

With respect to cumulative effects and caribou, there are at least four general factors that affect the ability of caribou to respond to changes in their environment: 1) natural environmental variation, 2) harvesting and predation, 3) climate change, and 4) human land use. When we try to understand how cumulative effects may impact caribou, we need to think about how caribou will be affected by all these factors over time.

### *Computer Simulation Models*

An important part of modeling is thinking through "what if" scenarios. When applying models to cumulative effects on caribou, it is more efficient to use computers to run scenarios. The advantage of computers is that they can conduct thousands of complex calculations simultaneously in minimal time and help identify the most sensitive relationships and indicators. In Alberta, the computer model ALCES has been used to simulate multiple land uses and monitor environmental indicators as well as social and economic variables that are important to people. The model has helped decision makers understand ecological and socio-economic consequences of different land uses.

### *Modeling Concepts*

**What models are and are not:** Models do not make predictions of the future, but they can help us understand the likely consequences of particular decisions. Computer models and their outputs (simulations) are learning tools that help us understand important ecological processes. People make decisions, and models do not.

**The importance of scale:** The concept of scale in time and space is important in modeling. Some models operate at a very fine scale, while others operate at a larger landscape scale. Models can simulate short time frames, to longer periods of 100 years or more. To be useful decision support tools for land use, models need to work at broad spatial and temporal scales. In this context, 'strategic' refers to taking a broad or large-scale perspective, while 'tactical' refers to a narrower perspective. Figure 17 is a pair of photographs that demonstrate the different between strategic and tactical views.

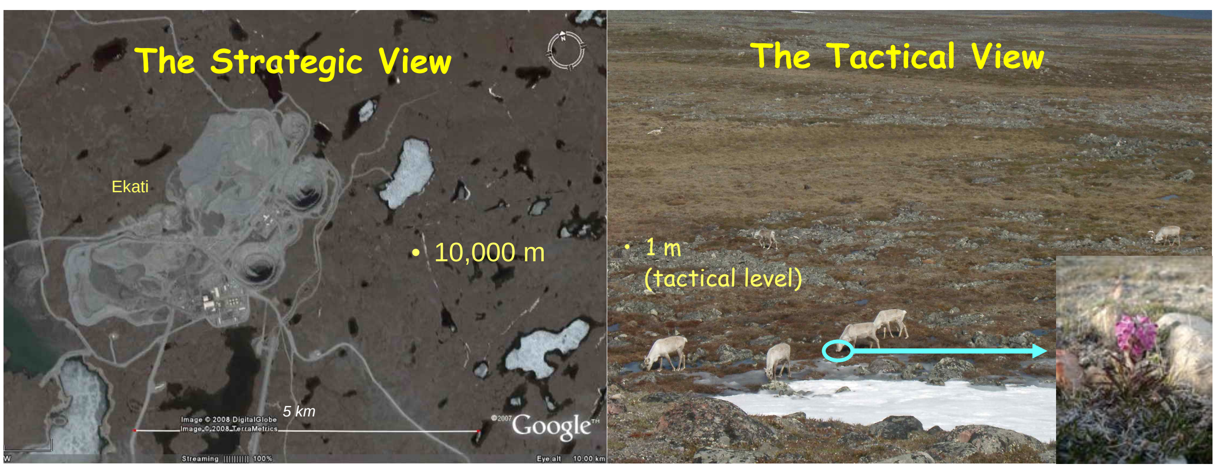


**Figure 17:** Aerial views of the Diavik mine in Bathurst range at 10,000 feet (left) and ground level view of caribou (right) on the Bathurst range in the spring. (PHOTO J. NISHI)

The aerial view of Diavik mine at 10,000 meters illustrates a strategic perspective, which allows us to see broad landscape patterns, but does not allow us to see fine details on the ground. Conversely, a tactical perspective is shown by the ground-based view of caribou on the tundra. From this perspective we cannot see large scale patterns on the landscape, but we can see with excellent precision and detail the type of habitat caribou are using and the types of plants they are eating.

**Spatially explicit versus spatially stratified:** A final key modeling concept is the distinction between spatially explicit and spatially stratified. If we were to ask a hunter where he shot a caribou, he would be able to show us exactly where the caribou was on a map. We can say that the hunter's knowledge of the caribou kill is spatially explicit because it has a specific point location. On the other hand, if we were to ask the hunter where he was going to shoot caribou in the future (i.e. next week, next month, or over the next ten years), he would not be able to give us the exact locations of his future caribou kills. However, he would be able to say where he would expect to kill caribou in the future. He would be able to draw (or stratify) an area on a map to show where he would expect to find caribou. The point locations of the future caribou kills would likely occur within that spatially stratified area.

In conclusion, I will leave you with two final thoughts before the next three presentations. Firstly, *"the best explanation (i.e. model) is as simple as possible – but no simpler."* (Albert Einstein). Secondly, think outside the box. In addition to understanding the individual speakers and their specific models, look for similarities, differences, and linkages between the respective models.

### Resource Selection Functions (RSFs) as a Tool to Plan for Cumulative Effects (C. Johnson)

Cumulative effects are an important but challenging component of the environmental assessment process. Although the definition of cumulative effects is intuitive and easily understood – the incremental environmental, social or economic effects resulting from past, present, and future development activities – the techniques available for measuring these effects are complex and often confounded by the temporal, spatial, and behavioural scales of observation. Past efforts to define and measure cumulative effects were limited by: 1) difficulties in defining the extent and incremental impacts of temporally and spatially separated projects, 2) a lack of large-scale strategic guidance, 3) few standardized and defensible methods, and 4) limited empirical data describing valued ecological components, such as sensitive wildlife. We developed and applied a quantitative technique, RSFs, to a large landscape that included the seasonal ranges of the Bathurst caribou herd (Johnson et al. 2005). This method can assist land managers and resource planners conducting broad-scale environmental assessments.

Resource selection functions are statistical models that integrate animal locations and spatial data to quantify the magnitude of use or avoidance of habitats or other environmental features, including human disturbances. Relative to other broad-scale techniques for measuring habitat selection, RSFs have a number of advantages:

- RSFs accommodate spatially explicit inputs (i.e. GIS data) and produce maps representing the strength of selection or avoidance of habitats and human use features across landscapes,
- RSFs are quantitative, providing measures of precision and uncertainty,
- RSFs are based on well-established statistical and ecological theory, and
- RSFs are general enough to accommodate any animal or plant species dependent on resources that vary spatially.

Figure 18 shows the types of variables that can be used to create an RSF model.

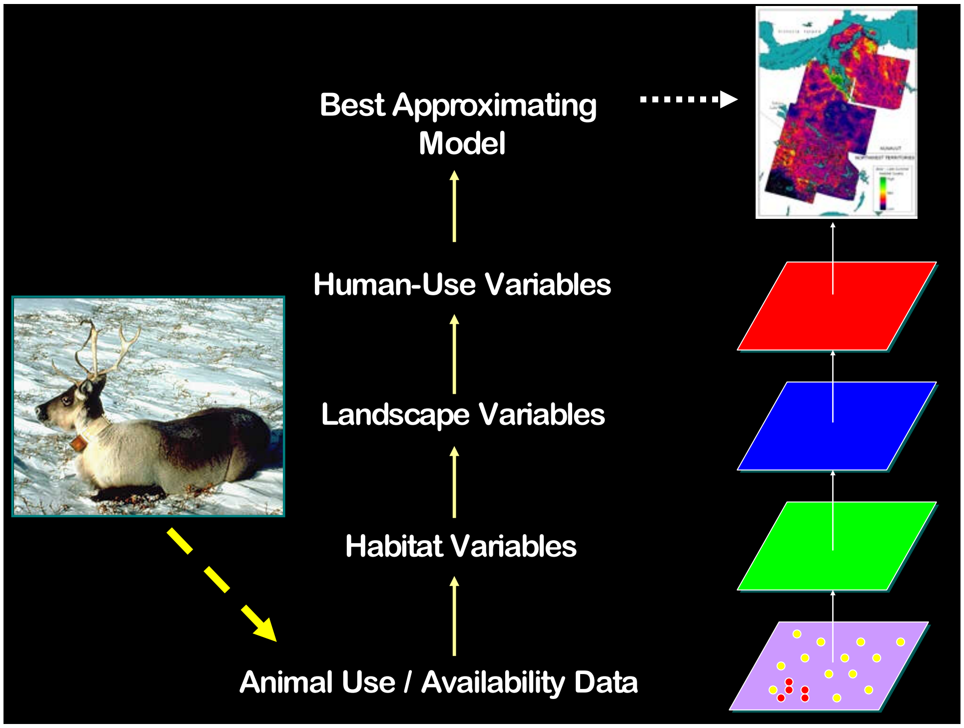


**Figure 18.** A schematic view of Resource Selection Functions. Various kinds of spatial information, including mapped traditional knowledge, can be used to measure animal use, habitat quality and the effects of human activity on animal use. (IMAGE C. JOHNSON)

In response to recent increases in industrial activity, we constructed RSF models for sensitive and valued wildlife of the Canadian Central Arctic. The development of diamond-bearing kimberlite deposits across the Northwest Territories and Nunavut has led to unprecedented levels of mineral exploration and extraction. Figure 19 demonstrates how cumulative effects can change the landscape at a diamond mine over time. The cumulative effects of these and other industrial activities are now an issue of concern for regulatory agencies, conservationists, wildlife managers, and communities. Regional planning initiatives are being developed to guide and monitor the rate of industrial development, but few tools are in place to quantify current and future effects.

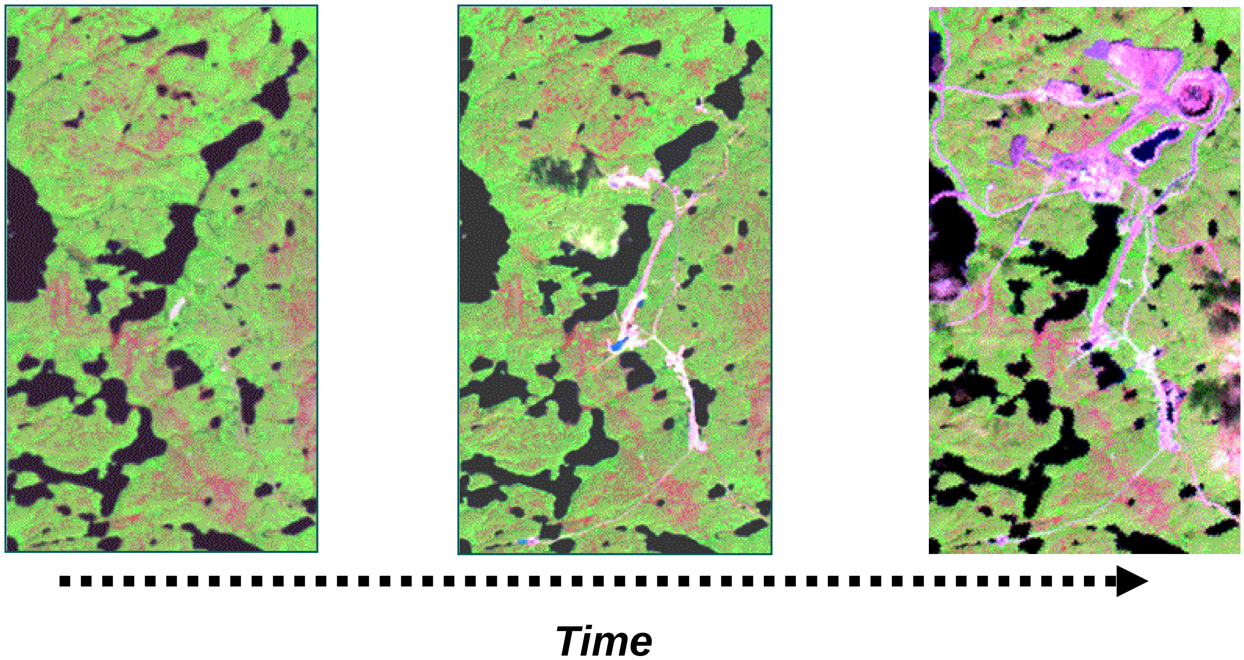


**Figure 19:** Changing landscape at the Ekati diamond mine in the Bathurst caribou range. Each small road segment or other man-made change by itself has little effect, but the accumulated effects over time may be significant. (PHOTOS C. JOHNSON)

As the first step in meeting some of the information needs of regional planning initiatives, we generated resource selection models that statistically related the observed distribution of radio collared barren-ground caribou, gray wolves, grizzly bears, and wolverines to vegetation, interspecific interactions, and human disturbance features. Across all models, mines and other major developments had the largest negative effect on species distribution, followed by exploration activities, and outfitter camps; however, our models did not suggest strong avoidance by all radio collared individuals during all seasons to each disturbance type. We used a geographic information system (GIS) to extrapolate each seasonal resource selection model to the study area and then performed risk assessments to quantify the loss of high-quality habitats for each species as a function of modeled resource selection function coefficients and hypothetical zones of influence and accompanying disturbance coefficients. Modeled co-efficients were estimated from the observed movements of collared animals, and hypothetical zones of influence and disturbance co-efficients were taken from the scientific literature. In general, human disturbances had the largest negative influence on the availability of grizzly bear and wolf habitats, followed by caribou and wolverine habitats. The largest seasonal effect was recorded for caribou, where model coefficients suggested a 37% reduction in high-quality habitats and an 84% increase in low quality habitats during the post-calving season.

Results of our research can contribute to the development of a regional environmental assessment for sensitive wildlife that will assist with the preparation and review of project-specific cumulative effects analyses. Furthermore, small scale maps generated from resource selection models are an excellent tool for visualizing animal habitat relationships and sensitive areas. When analyzed with GIS, maps provide a consistent measure by which to assess the effects of proposals from different resource sectors over large geographic areas.

Proponents may use selection coefficients to situate or time temporary and permanent mining activities to reduce the level of disturbance across important seasonal habitats. Regulators may restrict development or demand remediation based on the total area of impact, the availability of high-quality habitats, or the potential for species decline following some increase in disturbance activities. Recognizing the uncertainty in predicting the pace of development and the impacts to the environment, these methods could be applied to various scenarios representing a range of development intensities or variation in disturbance effects.

Our findings (Johnson et al. 2005) were based on a relatively small sample of animals extrapolated to a large study area with few disturbance effects. Future increases in industrial development across the central Arctic or a different sample of animals could result in markedly different disturbance effects. Furthermore, the logic of the risk assessments and our inferences to habitat quality is dependent on a link between the coefficients generated with our selection models and the value of habitats to the focal species. We assumed that the disproportionate use of resources correlated with animal fitness. Considering that the results of resource selection studies are often congruent with more detailed and mechanistic site investigations, that assumption appears valid for many cases. However, as demonstrated by species such as the grizzly bear, we may observe strong selection for a food resource associated with human habitation that ultimately results in decreased survival. Resource selection studies are not without criticism, but the technique can provide useful guidance to conservation and management, where model coefficients and resulting maps are carefully interpreted and inferences are constrained to the sample data.

PHOTOS C. JOHNSON

**Figure 20:** Information on fires on the caribou winter range and abundance of key forages like lichens can be used in RSF modeling.

### *Data Needs for RSF Modeling With Caribou*

RSF modeling has been applied to a variety of wildlife species. Because it is spatial, RSF modeling requires data that are either map based or that can be converted to a spatial format. Listed below are basic requirements for RSF modeling with caribou.

### *Caribou Data*

Analysis requires repeated, accurate, and precise locations of individual caribou:

- A minimum of 100 locations per caribou, and
- Spatial error of each location should be <200 m; poor quality locations from satellite collars will reduce the strength of any relationship between caribou distribution and environmental and anthropogenic features.

### *Environmental Data*

Models require reliable GIS data for environmental attributes that might influence the distribution of caribou; example data include:

- Vegetation occurrence – maps with cover types that can be related to caribou ecology (e.g. do forest types differentiate areas where terrestrial lichens are found?),
- Vegetation productivity and quality – absolute NDVI values or difference in NDVI values across a season,
- Human disturbance – linear features (e.g. temporary and permanent roads, trails), point features (e.g. mine sites), area features (e.g. areas of intense or repeated exploration activity, areas that outfitters frequent),
- Natural disturbance – spatial location of burns or other natural disturbances that may affect the use of habitats by caribou,
- Predation risk – surface illustrating predator distribution or abundance (if researchers or community feels that caribou distribution is directly influenced by predators at large spatial scales), and
- Other – any spatial data can be proposed as a hypothesis that might influence the distribution of caribou: density of caribou in an area, snow conditions, density of vegetation patch types, and distance to major water bodies (i.e. use for movement corridors).

## Energetics and Population Models for Porcupine Caribou (D. Russell)

Development can affect caribou in a number of ways, among them reduced feeding time or displacement from preferred habitats for feeding. Linked energy balance and population models were created for the Porcupine caribou herd (PCH) to assess how these kinds of effects might influence a female caribou and calf at the scale of the individual, and how effects on many individuals might affect the population. Although effects on individual caribou feeding patterns might seem almost trivial, their accumulation over time in many caribou, particularly in a summer with severe insect harassment, can have significant effect on the herd. Similarly, displacement by industrial development may result in cows calving on ranges with poorer forage and higher predator exposure. Figure 19 shows an overview of linked energetics and population models for the PCH.

PHOTO A. GUNN

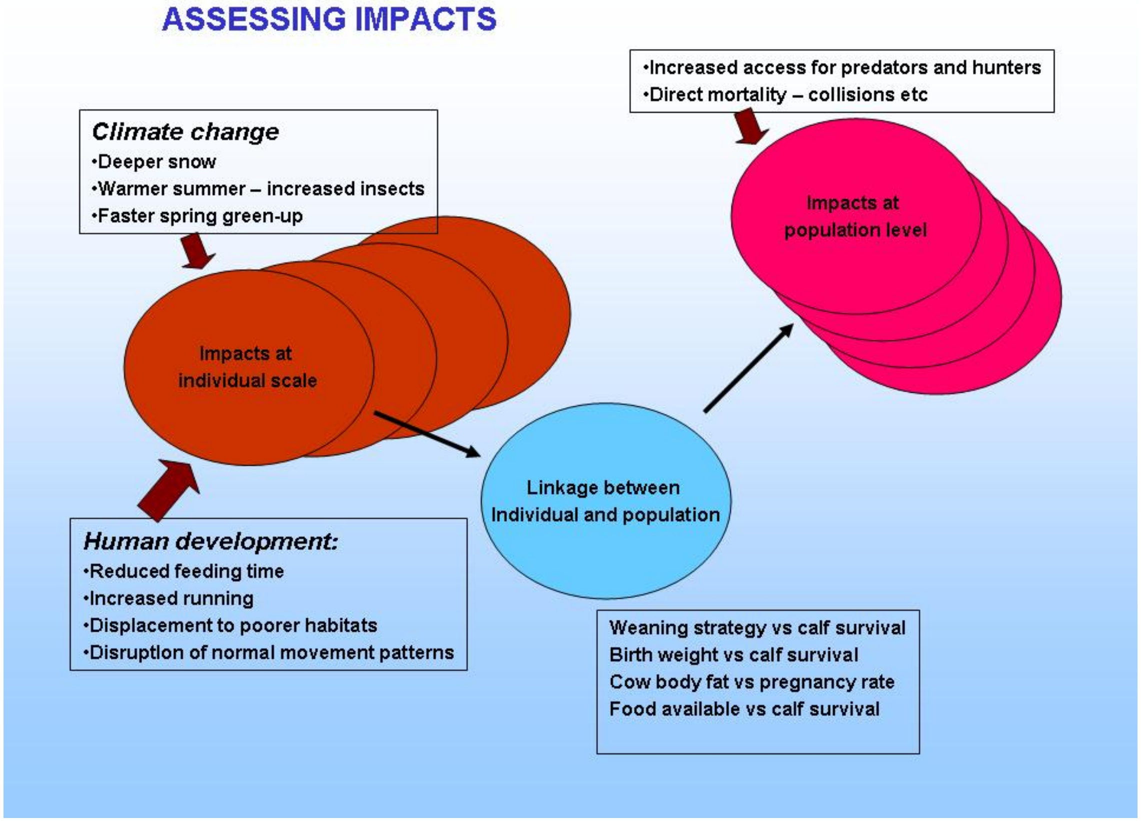


**Figure 21:** Overview of linked energetics and population models for the Porcupine caribou herd. (IMAGE D. RUSSELL)

The energetics model predicts the daily body weight and body composition change of a caribou cow, her milk production, and the daily body weight change of her calf as a function of milk intake. State variables driving these outcomes are daily activity budgets, diet, forage quality, and forage quantity. The energetics model consists of two submodels. The first is the energy submodel which predicts daily changes in a cow's metabolizable energy intake (MEI) by calculating the cow's food intake and then simulating the functioning of the cow's rumen and her digestive kinetics on an hourly basis. The MEI predicted by the energy submodel is then transferred to a growth submodel which calculates the cow's energy expenditure, her energy balance, and her subsequent daily change in weight, milk production and hence the daily change in weight of her calf.

The energy submodel asks the question: how do changes in activity budgets, diet, forage quality, and forage quantity affect the energy intake of a female caribou? In particular, it is designed to predict effects of environmental conditions on MEI. Specific objectives of the energy submodel are:

- To show effects of environmental conditions and movement patterns (as reflected by changes in activity budgets, forage quality, and forage quantity) on MEI by female caribou,
- To evaluate effects of human and natural disturbance (e.g. oil development, insect harassment) on MEI, and
- To evaluate winter severity (as reflected by snow depth) on MEI.

The broad purpose of the growth submodel is to evaluate effects of changes in seasonal activity budgets and MEI on the energetic and reproductive status of a female caribou.

The growth submodel has two specific objectives:

- To evaluate the impact of changing activity costs, maintenance costs, and MEI on the cow's energy balance and subsequent change in body composition and growth, and
- To evaluate effects of the cow's energy balance on the growth of her foetus during pregnancy and her calf during lactation.

PHOTO A. GUNN

**Figure 22:** Caribou aggregated tightly during the insect season. Warm calm weather can lead to disrupted foraging at a time of high forage quality.

### *Linkage between Energetics Model and Population Model*

A “body condition” table is generated for females of different ages and reproductive histories and for their calves. This table consists of two body condition indicators for calves (rate of weight gain for the first 21 days of life, and total body weight in the early fall), a cow protein gain indicator and a cow fall fat weight indicator for females of different ages and reproductive histories. These reproductive histories match the population cohorts within PopModel and link to overall herd productivity by weaning strategy, calf mortality, and probability of pregnancy.

Weaning in caribou appears to be a dynamic process responsive to the condition of the cow and calf. Because the energy cost of lactation is great, caribou employ a weaning strategy based on the need to trade-off the survival of the cow, survival of the calf, and the ability of the cow to conceive later in the autumn when calves are five months old.

Post-natal weaning occurs when biomass during the first week in June and rate of plant growth over the next three weeks are insufficient to maintain growth rates in the calf. Upon weaning, the calf dies and the cow increases her probability of getting pregnant in autumn. The post-natal survival rate is a function of the average daily weight gain of calves over their first three weeks of life.

Summer weaning of calves results when cow protein reserves fail to get replenished. The most likely cause is accidental injury, disease or severe summer conditions in the cow, as we consider nitrogen availability not limiting in the summer range of the Porcupine caribou herd. The proportion of summer lactators is determined from the average daily protein gain of the mother through the early summer.

Early autumn weaning occurs when the fat reserves of the cow are below a specified threshold primarily due to a combination of the factors listed above and a particularly bad insect year. As a result, the survival rate of the calf declines and the age of first reproduction of the calf are likely advanced. For the cow, this strategy enhances her survival through winter and increases the chance of getting pregnant. However, we assume that calf survival through winter is compromised.

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

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

The proportions of summer lactators that are early, normal, and extended weaners are calculated as a function of the distribution of early fall calf weights. For each cohort of summer lactators, the model tracks the mean calf weight for that cohort and a standard error for this fall calf weight.

### *POPMODEL – Projecting to the Population Level*

We developed a herd population model which simulates the herd size trajectory of the PCH over a period of 40 years. The herd population model is stochastic (incorporates random variation) in order to estimate and quantify the risk that the herd will decline by a certain amount over this time-frame. It operates with an annual time step, and assumes that herd size responds each year to climate variables, summer habitat, oil development, and harvest levels. The primary climate variables are winter snow depth, represented by three categorical levels (shallow, medium and deep), and average summer temperatures, again categorical, which are a proxy for insect harassment level being low, medium or high during the sensitive post-calving season. Summer habitat and vegetation changes are represented only indirectly in PopModel, since forage biomass and forage quality are already taken into account in the energetics model CARIBOU. Based on an analogy with the central Arctic herd, oil development and the associated industrial activity is assumed to displace caribou from the high quality calving ground forage, thereby reducing calf survival. Harvest levels in each community depend on the herd's movements and are therefore related indirectly to climate because snow depths influence caribou movement patterns across the herd range. We assume that the total number of animals harvested by a given community depends on how close the caribou were to their community in a given year.

### *Model Structure and Processes*

The herd is represented in the model by eight cohorts: yearlings (male and female), two year olds (male, barren female and pregnant female), and adults three years and older (males, barren females and pregnant females). The time step begins at the end of May (i.e. just before the cows give birth in the first two weeks of June), so the model does not need an age class for newborn calves. Parturition rates depend on the cows' autumn fat reserves, which in turn influence the energetics model outlined above. In each year, the combination of environmental conditions (snow depth and insect harassment) give certain parturition rates for the four female cohorts capable of getting pregnant during the following rut: barren one year olds (probabilities ranging from 3-15% depending on combination of snow and insects), barren two year olds (72-78%), three year olds (82-84%), and pregnant three year olds (25-78%). The rates for the fourth cohort essentially specify the probabilities of a cow being pregnant two years in a row and since this group of caribou accounts for between half and two-thirds of all females, the significant variation in parturition rates for different environmental conditions can have a substantial impact on herd productivity.

As described above, calf survival rates are affected by the weaning strategies that cows follow in summer and fall, and these strategies are determined by the body condition of both calves and cows. In the model, calf survival is further reduced by the degree of oil development.

This represents caribou being displaced from the optimally nutritious forage and by increased predator exposure in the areas to which they are displaced.

Initial total herd size and proportion of the herd in each of the eight cohorts is set by the user. We started our population runs with a total herd size of 130,000 animals, and set the initial cohort sizes according to the long-term averages from running the population model to equilibrium from various non-equilibrium starting conditions.

### *Model Output*

The population model is linked to the energetics model through the output table generated in the energetics model. Annual climate is randomly generated and appropriate body condition indices are used from the table to determine appropriate productivity values. The modeller can assess impacts of different development scenarios by choosing from a drop-down menu in the model interface.

Output of each scenario simulation is a frequency distribution of final population size after 200 iterations of the model. A histogram is displayed indicating the probability that the herd will increase, remain stable or decline under the scenarios; shifts in the relative probability among classes are used to compare scenarios. As with other models, the outcomes are not predictions but the likelihood of a significant effect on the herd can be gauged from the outcomes of many model runs. Figure 21 shows sample outputs from inputting varying conditions (e.g. climate change, development) into the model.

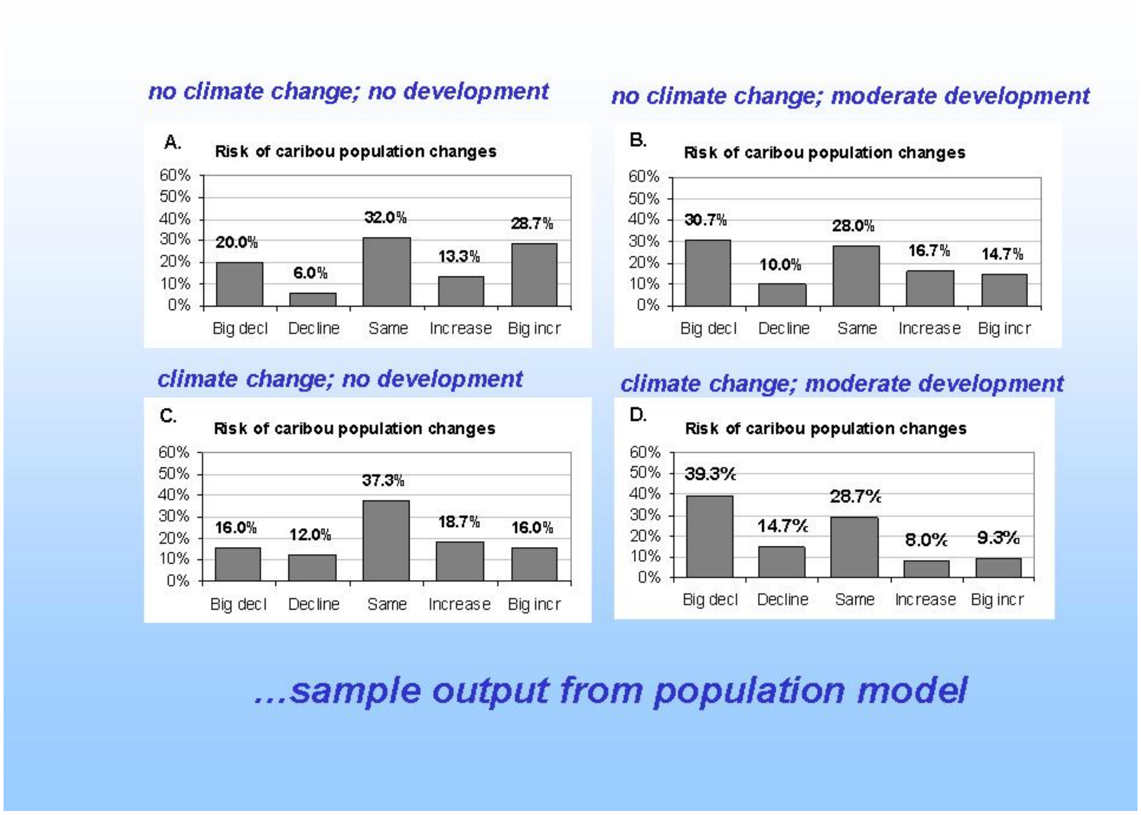


**Figure 23:** Sample output from population model of many simulations with varying conditions. The results are expressed as probabilities of a change in population size; as with all models the results are not predictions.

### *Data Requirements for Energy and Population Models*

Computer models depend on sound data for input into the models. The basic data needs for the paired energetics and populations models are listed below.

**Energy Model:**

- Activity budgets – present model has 15 annual time periods but structure is flexible:
  - Foraging, lying, standing, walking, running, pawing intensity, eating intensity,
  - Baseline, and
  - For any development scenario.
- Diet (by plant group),
- Forage (by plant group and time period):
  - Biomass,
  - NDF (Neutral Detergent Fibre, a measure of plant fibre content),
  - Nitrogen content, and
  - Digestibility.

- Initial starting conditions:
  - Caribou body condition at start of run.

- Snow depth (by time period).

**Population Model:**

- Initial population structure:
  - # Age classes,
  - Age and sex structure, and
  - Starting population.

- Cohort mortality rates,
- Harvest rates,
- Pregnancy rates (calculated in energy model).

PHOTO J. ADAMCZEWSKI

## ALCES®: A Decision Support Tool for Cumulative Effects (T. Antoniuk & J. Nishi)

The ALCES® model was developed in the 1990s by biologist Brad Stelfox to serve as a way of exploring cumulative effects of industrial activity such as forestry, oil and gas extraction, agriculture, and peat mining on large landscapes in Alberta. Combined with scenarios for climate change, ALCES® has helped managers and stakeholders better understand how human activity on northern landscapes can affect environmental indicators such as numbers of woodland caribou. A pilot project is underway to use ALCES® in assessing development in woodland caribou range in the Dehcho region. The ALCES® simulation model has also been adapted to various species of wildlife in other landscapes in Canada and the United States (Alaska). ALCES® is meant to work at a strategic scale with large landscapes and over extended time periods.

### *What is ALCES?*

ALCES® is a computer model designed to help people understand what natural and land use changes could mean for the environment, communities, businesses, and governments. It can help answer questions like:

- Where have we come from?
- Where are we now?
- What are some likely trajectories we will travel along in the future?
- How do identified indicators (caribou, social, economic, other ecological) respond to land use trajectories and disturbance regimes through time?
- What are some key strategic opportunities and challenges that require our attention?
- Which land use trajectories provide optimal outcomes (e.g. more caribou harvest, more economic benefits)?

Figure 22 shows how ALCES can be used to explore future cumulative effects for caribou herds, considering varying conditions and processes.

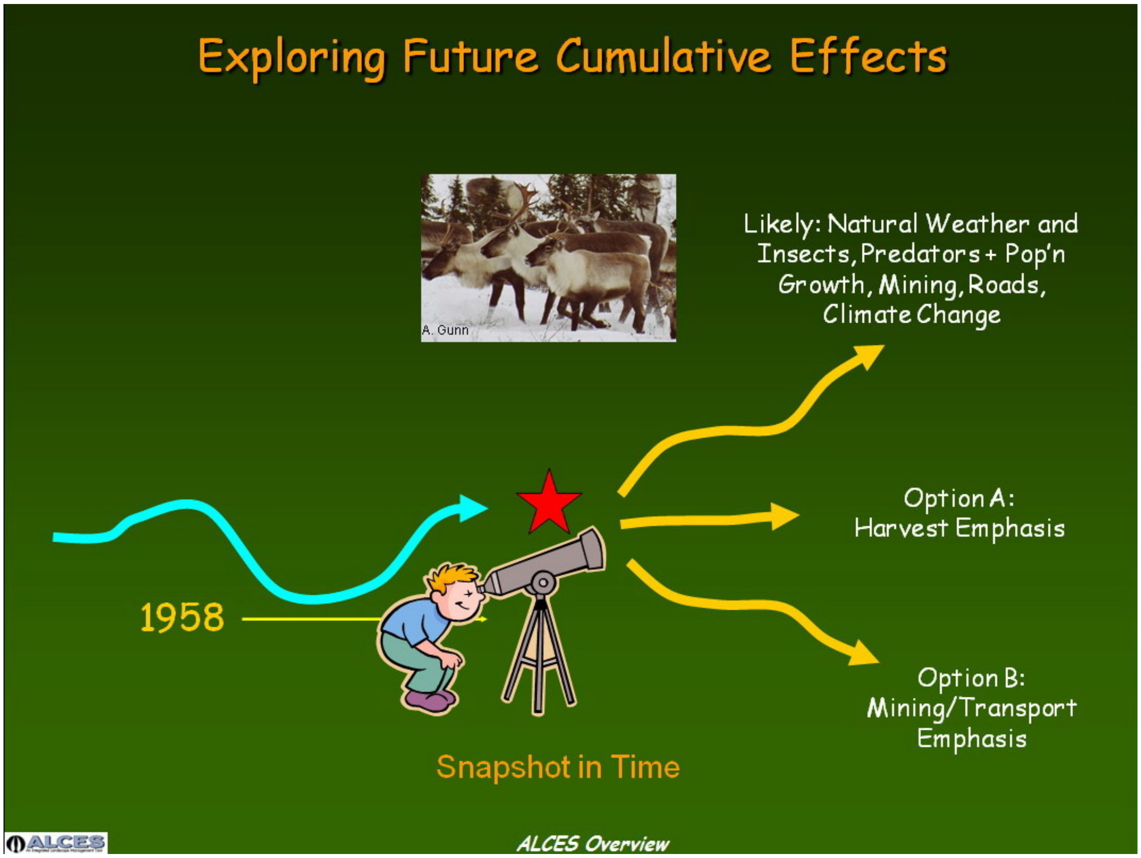


**Figure 24:** ALCES® allows communities and stakeholders to assess likely effects of varying initial conditions and priorities.

ALCES tracks and simulates an array of land use practices and associated anthropogenic footprints including mining, energy, transportation, human settlements, tourism and recreation, hunting and trapping, Aboriginal land use practices, parks and protected areas. ALCES users can explore the consequences of individual or multiple co-occurring land uses and define all land uses as either deterministic or random future trajectories. The natural ecological processes tracked by ALCES include meteorology, fire and insect outbreak regimes, plant community dynamics, carbon pool dynamics, and the dynamics of wildlife habitats and populations. The basic physical engines of the ecological systems, namely climate and fire, can be run either deterministically or stochastically, allowing the ALCES user to explore the effects of random variation on all dependent ecological attributes.

ALCES has been used in many areas of North America, usually for large regions (e.g. caribou seasonal and annual ranges). It is built with a spatially-stratified Stella stock-flow model. The kinds of information entered into the model are existing GIS (spatial) values, with future land use trends set or preferred by the user. The output includes annual landscape, land use, and indicator conditions, presented as tables and graphs, and sometimes maps using the MapNow component.

### *Using ALCES*

The general steps used for ALCES projects are:

- Identify the study area, stakeholders, and key indicators. To ensure a balanced reporting on the performance of the study area, one must select indicators for each of the social, economic, and environmental areas,
- Describe current landscape and land use conditions; initialize ALCES with GIS data for the designated study area,
- If desired, incorporate data that describe historical land use patterns; involve stakeholders and other experts,
- Introduce "reasonable" land use trajectories that define the desired land use practices for the study area. Stakeholders and other experts are involved. To ensure that the trajectories being run in ALCES are viewed as being conservative, we recommend that proposed development rates at the low end of the anticipated range are used,
- Incorporate the appropriate metrics that define the natural disturbance regimes (fire, climate, insect outbreaks, etc.). Stakeholders and other experts are involved,
- Conduct the simulations and report on the chosen indicators, and
- Revise simulations to consider other options or outcomes if indicator levels are unacceptable.

Active and ongoing participation of stakeholders and industry, community, and government experts is critical to a successful project. Future landscape, land use, and indicator conditions can be visualized using charts, tables, and representative maps (MapNow). The MapNow program produces maps that depict possible future conditions. Care must be taken when using these maps because they do not show what the future will be; only what it might be.

PHOTO J. ADAMCZEWSKI

## *Using ALCES for Barren-ground Caribou*

ALCES is already able to track three of the four components of barren-ground caribou resilience (Natural Environmental Change, Land Use, and Climate Change). The fourth component, Predation and Harvest, has been built in for other projects, so this could be done for barren-ground caribou. ALCES already uses RSF models described by Chris Johnson, and barren-ground caribou equations could be easily incorporated. TK could be included directly in relationships modeled by ALCES or indirectly by using a Habitat Suitability approach. The new work that would be required for barren-ground caribou would be linking inputs or outputs with the Porcupine caribou energetics model. The advantage of using one model like ALCES for evaluating trade-offs between land use, predation, and mortality, is that the effect of a wide range of different management options could be quickly and easily simulated.

## *Data needs for ALCES model application*

Like other models, ALCES works best with strong supporting data sets. Basic data needs for an ALCES application to barren-ground caribou are listed below.

**Defined study area:**

1. Consistent land cover and landscape classification and associated spatial files for study area,
2. Land use feature classification and associated spatial files for study area,

3. Mathematical (RSF) or ‘Expert Opinion’ (HSI) based relationships between caribou use, mortality, land cover, landscape, and land use features,

4. If link to energetics and population dynamics is desired, information on relationships between environmental conditions (i.e. temperature, precipitation, insect harassment, NVDI) and adult and calf survival, and

5. Projected human population, energy (mining) exploration and production, and transportation growth and reclamation scenario(s) for defined study area.

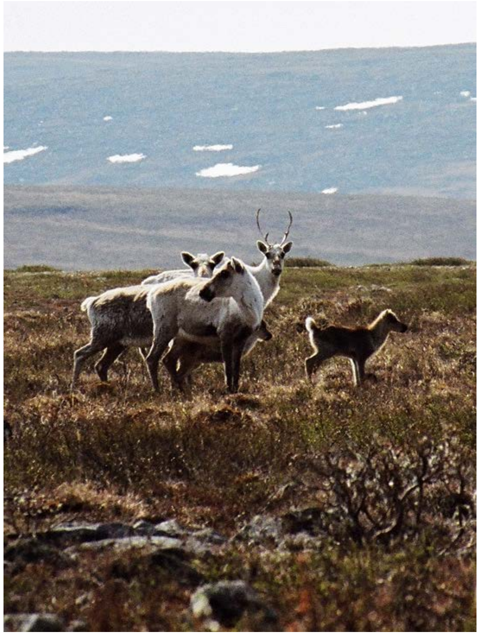

PHOTO A. GUNN

## An Integrated Modeling Approach (J. Nishi, T. Antoniuk, and A. Gunn)

Our main objective is to show that an integrated modeling approach is a useful and innovative way of incorporating essential components of the three models that were presented this afternoon. Our second objective is to seek your support for development of this integrated modeling approach. We have organized this presentation in two parts. The first part is meant to recognize that the integrated model is a decision-support tool that needs to be considered in a broader context of an adaptive co-management system. Secondly, we will outline steps for developing the integrated model.

Integration occurs at two levels:

1. At the broad level, integration means recognizing that a cumulative effects model is part of a larger decision making process. This system of decision making includes a broad group of partners and stakeholders including governments, co-management boards, and other parties, and
2. At a finer level, integration refers to the components of a systems model and the issues of how those components would be linked. We need to recognize from the earlier talks that these linkages will span across scales.

From a systems perspective, the model should reflect our current knowledge and understanding of caribou ecology as a means to understanding cumulative effects on caribou. Monitoring and research on caribou distribution, abundance and behaviour contributes information and helps us evaluate how well the models represent the real world. A third building block recognizes the decision rules that managers consider when recommending best management practices. Anne Gunn spoke earlier about the three R's (i.e. Respect, Responsibility and Resilience); we would like to now add a fourth R – Rules. In this context, Rules represent management practices that would reduce impacts or mitigate against cumulative effects. Together, these building blocks (shown in Figure 23) are parts of a larger system - an adaptive co-management system.

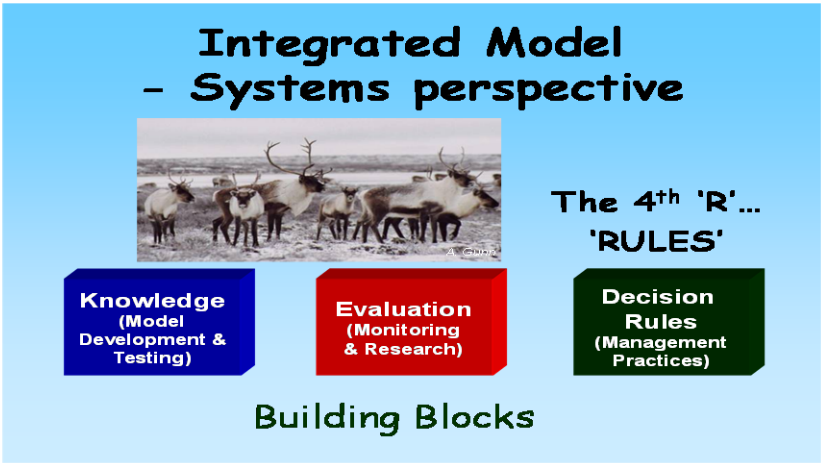


**Figure 25:** An integrated model from a systems perspective.

The linkages between technical, administrative and political expertise reflect our overall capacity to understand and evaluate issues and to make good decisions to manage and/or mitigate cumulative effects. Simulation models can improve our technical expertise and can be useful learning and decision-support tools in the administrative and political decision-making arenas. As a decision-support tool, an integrated cumulative effects model should be developed and understood in the context of how to manage cumulative effects.

We need to consider two important issues when we develop integrated models. The first issue is the concept of scale; the second issue is the process of connecting model components. Scale is a reflection of benchmarks in time and space. With respect to cumulative effects, we need to determine the appropriate scale by which to understand, monitor and manage cumulative effects. The seasonal range of Bathurst caribou can be simplified into three seasonal ranges; spring calving (orange), summer (green) and winter (blue), shown in Figure 2.

The next step in the integrated approach is to combine the seasonal ranges with the potential effects that caribou may experience on the landscape. There are four general categories by which cumulative effects might change the resilience of caribou herds: 1) Natural

Environmental Variability, 2) Climate Change, 3) Human Land Use, and 4) Predation and Harvest.

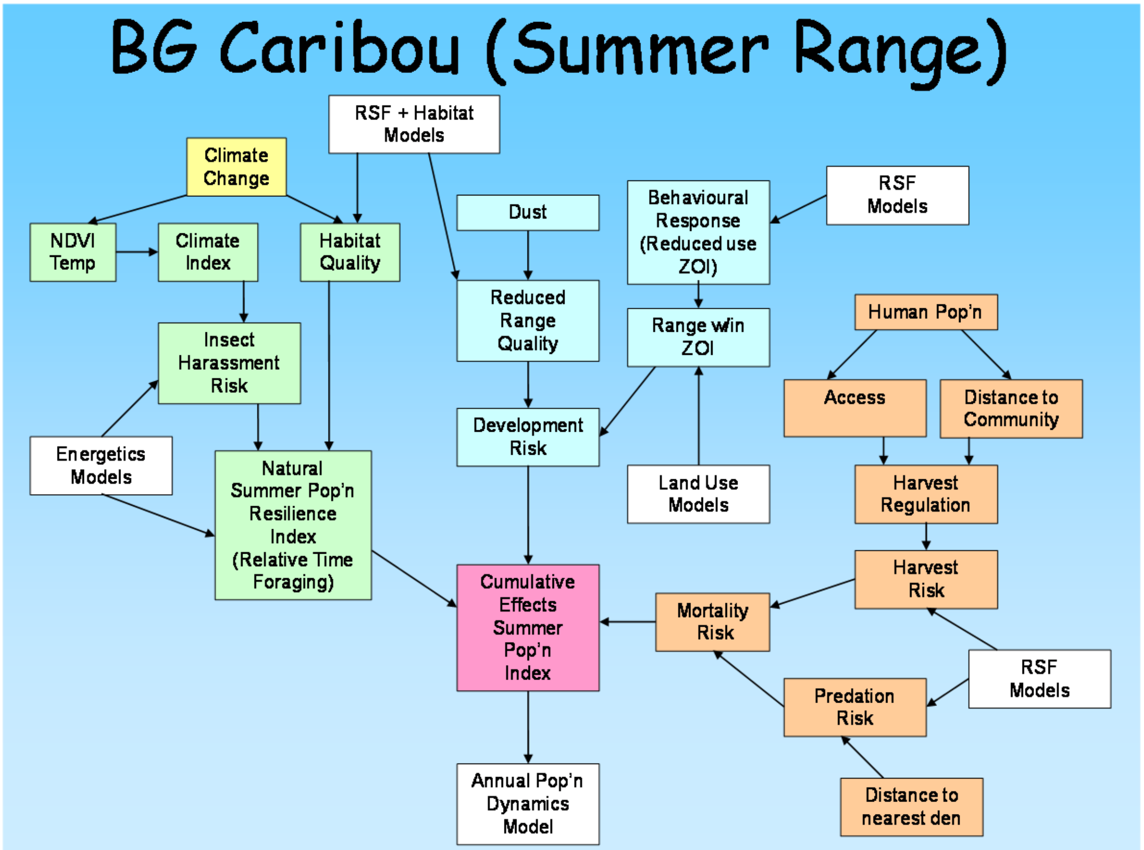


**Figure 26:** Relationships among factors affecting the summer range of barren-ground caribou.

The diagram in Figure 24 focuses on the summer range component of the integrated model. Each box represents a factor that may affect the caribou, while the colors represent the broad categories of effects. The arrows that link boxes show the main relationships or linkages between factors. The color coding refers to the broad categories of effects that may be important to caribou. Green is related to Natural Environmental Variation, yellow shows Climate Change, blue indicates factors associated with Land Use, while tan shading shows factors associated with predation and or harvesting.

In the last half of this presentation, we summarize the linkages between the different modeling approaches and provide a view of how the integrated model might be developed:

- As shown by Chris Johnson, RSFs allow us to link habitat use by caribou with available habitat. RSFs provide a way to integrate the influence of the human footprint on the availability of habitat and the caribou's use of that available habitat,
- Similarly, Don Russell showed that energetics provides both a useful conceptual and empirical approach to linking habitat use with demographic changes in caribou herds, and
- Terry Antoniuk gave us an overview of the ALCES model. ALCES is capable of simulating the human footprint, natural disturbances, climate and other drivers, and helps us keep track of a multitude of ecological and social indicators.

With respect to the RSF approach, habitat availability to caribou can change with a growing human footprint. Available habitat is reduced by the direct footprint of different human developments, subtracted from available habitat in each of the landscape types in which they occur. The second point to understand is the indirect footprint or what many biologists refer to as the zone of influence. The ZOI may also reduce available habitat because the areas which are within a certain distance of a human footprint are used significantly less than other areas.

The value of RSFs is that they help us understand how caribou will use habitats relative to availability. Once we determine the relationships between use and availability, we can project how caribou will respond to additional footprints or disturbances. Spatial models have also proven to be a useful approach for integration of some traditional knowledge – areas of higher or lesser value to caribou, water crossings, and areas used for hunting can be mapped and integrated into RSF models. Maps also have appeal and value to diverse audiences – an important asset in working with partners and stakeholders. Figure 25 shows a map of a simple study area with some portions of the habitat taken up by human land uses.

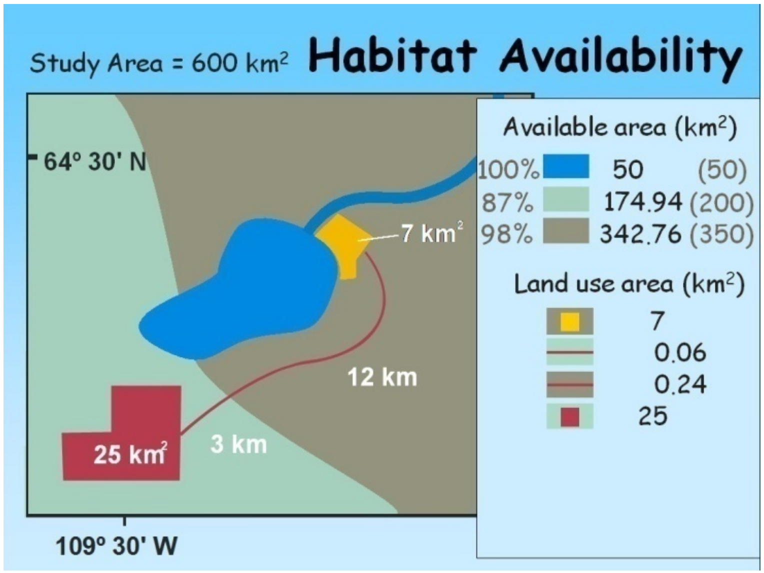


**Figure 27:** A simple study area with some portions of the habitat taken up by human land uses.

The work on energetics provides a strong link between the energy balance of an individual caribou and the population level changes in a caribou herd. Caribou eat plants to get enough energy and nutrients to live and help them gain weight and fat. In female caribou, body condition is a key driver of pregnancy rates. In turn, the pregnancy rate drives herd size through calf production. By linking components of the RSF and energetic models, we can develop links between use and avoidance of available habitat with the energetic costs & benefits to caribou.

ALCES is able to model future changes in the landscape as human footprints change, and is capable of tracking thousands of drivers and indicators. ALCES uses a spatially stratified approach to simulate land use over time and can be used to simulate effects on caribou based on key relationships developed from the RSF and energetic models. A recent innovation with ALCES is "management by objective", which allows participants to explore future landscapes built around objectives and priorities they have chosen.

"Spatially explicit" means that a geographic feature has a specific location on the landscape that can be recorded and found on a map. In this simple study area we can see that each of the human footprints has a latitude and longitude that define their exact locations (Figure 25).

“Spatially stratified” means that the features do not have a specific location but occur within an area of the landscape. This area may be a vegetation community. With spatially stratified data, we can still measure characteristics of a human footprint such as length, area, edge, and corridor density. The features would not have specific locations on the landscape nor would there be measurable distances between individual features.

In summary, we would like to remind you of two main themes to this presentation. The first is to recognize and anticipate the broader context and use of an integrated model in both a political and administrative sense. Political context is the large management arena which involves many stakeholders who need to make informed decisions about caribou and land-use. We use the term ‘administrative’ in the context that the model inputs and outputs should also be linked to current and future monitoring that is done by governments, industry and communities.

The second is to recognize that scale is important in models. The final consideration is that we will not be able to model the detailed intricacies of every single factor that may be affecting the individual lives of all caribou in a herd. As shown by Chris Johnson and Don Russell, there are approaches and models that we can include in an integrated approach that captures the main effects and drivers at a herd or population scale. This is important because we want to build upon and use all the good work that has already been done on caribou and develop something useful for managers.

**Figure 28:** The Ekati diamond mine in the Bathurst caribou herd's summer range (left) and Bathurst caribou feeding in summer (right). (PHOTOS C. JOHNSON)

### Demonstration project: Integrated cumulative effects modeling & Bathurst summer range (J. Adamczewski)

During the February 2008 workshop, a number of the participants discussed the idea of a demonstration project that would make use of all three modeling approaches, include TK, and focus on the Bathurst summer range where there were three diamond mines in 2008. Each of the models has some unique strength that complements the others:

- RSF models are spatial and can work with multiple layers, including spatial TK,
- The paired energetics and population models are strongly grounded in the individual and population-level biology of barren-ground caribou, and
- ALCES is able to track many indicators and is particularly well-suited to large-scale exploration of possible future trends with partners and stakeholders.

The Bathurst herd is a high profile population in the central NWT and during its decline, concerns about possible effects of the diamond mines have been voiced by a number of groups and individuals. The purpose of a demonstration project would be to show that the three models could be used effectively in combination and to use a real-world example that participants of the workshop could see value in. At the time of the February 2008 workshop, the demonstration project was largely at the idea stage; however, there was general support from the workshop participants to proceed with this project.

To move ahead with the demonstration project, a technical meeting was held in Calgary, AB, July 2008. Participants included many of the speakers at the February workshop (A. Gunn, C. Johnson, and A. Legat). The meeting was timed to follow a meeting of the Circum Arctic Rangifer Monitoring and Assessment (CARMA) steering group on the previous two days. Several members of the CARMA group stayed on to contribute to the discussions on cumulative effects modeling. Meeting participants agreed that using all three models was achievable and that outputs of the models could be integrated.

There was agreement at the July meeting in Calgary that the project would include the following elements:

- The RSF work from 2005 by C. Johnson and colleagues would be re-run with newer data,
- Mapped Tłı̨chǫ TK, much of it summarized by A. Legat and colleagues, would be included in the spatial (RSF) modeling,
- The energetics & population models for the Porcupine herd, previously used with Bathurst caribou data, would be re-run with newer data, and possibly using a new version of the energetics model,
- The ALCES model would be adapted to work with barren-ground caribou data and relationships,
- The study area would be the Bathurst herd's summer range; further steps could expand the modeling to the herd's entire annual range and eventually other caribou ranges, and

- The applied focus of the demonstration project would be to assess the effects to date of development in the summer range on the Bathurst herd and to simulate how additional development might affect the herd.

## PARTICIPANT COMMENTS AND DISCUSSION (B. Wooley)

On the first day of the workshop, approximately 75 people attended the public sessions on modeling cumulative effects in the range of the Bathurst herd, held in February 2008, Yellowknife, NWT; most returned on the second day. Participants represented Aboriginal governments, industry, territorial governments, stakeholders and concerned members of the general public. The workshop was facilitated by Bob Wooley (currently with Garner-Lee in Yellowknife). The number and length of presentations on the first day did not allow for in-depth discussion. The second day provided ample opportunities for comments from workshop participants.

The second day of the symposium had originally been intended as an opportunity for a more in-depth technical evaluation of the models that had been discussed on Day 1 of the workshop. Given the broader interest in the discussion on Day 2, the emphasis was shifted towards a discussion of practical applications of the models, specifically focusing on means to integrate TK and western science into the models and taking better advantage of the broad spectrum of experience and knowledge of the workshop participants.

In the morning, participants were asked if they had any questions or comments as a result of what they had heard the previous day. Rather than asking specific questions, the participants provided a number of personal perspectives with respect to the impacts of mining and other development on caribou, and on the past successes and potential for the integration of TK and western science.

PHOTO J. ADAMCZEWSKI

**Figure 29:** Caribou remain an invaluable resource for NWT hunters in the present-day (2008).

Chris Hanks noted that ongoing efforts to collect TK over the recent past have created a body of knowledge that is capable of being integrated into models as described on Day 1. Violet Camsell-Blondin cited Anne Gunn's efforts to demonstrate the data from radio collared caribou along with other GIS data to a group of elders from the Tłįchǫ community. Earl Evans expressed his appreciation for efforts ENR had made in bringing communities together to discuss issues relating to caribou. Jonas Antoine recalled a study of woodland caribou wherein maps of hunting areas created from TK were overlaid with satellite imagery of vegetation cover maps showing habitat most suitable for woodland caribou to guide a study in his area (reported by Gunn et al. 2004).

A number of participants, including Joe Rabesca, Joseph Judas, Earl Evans, Jonas Antoine, Joyce Rabesca and Allice Legat stressed the need to incorporate TK into the models and indicated their willingness to work with the department and the modellers to find ways in which that could be effected.

Danny Beaulieu gave a PowerPoint presentation on historical fluctuations in caribou numbers over the past century, hypothesizing a 30-year cycle as evidenced by historical data that he had gathered from elders and family members. Anne Gunn used data from measures of damage to spruce roots by caribou hooves during migration periods up to 200 years ago, in concert with TK presenting similar evidence of past fluctuations in the caribou population (reported by Zalatan et al. 2006). The similar conclusions based upon two different means of determination were noted as being an example where TK and western science can serve to mutually validate results and conclusions.

The afternoon began with a panel discussion intended to focus on a concrete example of how an integrated model, with elements of all three models presented the previous day, could be used to incorporate TK and model cumulative effects in the Bathurst summer range. The four biologists who had presented models on the first day – Terry Antoniuk, John Nishi, Chris Johnson, and Don Russell – made up the panel. A technical discussion about models and their interactions was planned for the February workshop but was omitted due to time constraints; however, this discussion did take place in July 2008 and details are provided elsewhere in the report.

Throughout the day participants stressed that models are simply tools to guide management decision making processes. They further stressed that the demonstration model be focused and short term to allow for timely results, given the immediacy of the problems of declining caribou numbers and the opportunity to build on the goodwill and co-operation expressed during the workshop. They wanted clarity with respect to what management questions will be answered by the modeling exercise. Concern was expressed that ongoing efforts to deal with the caribou numbers issue not be put on hold pending the results of the model demonstration project.

Participants were keen to have a clear understanding of who was going to initiate and carry out the project and that a source for the funds is identified.

The modellers and the department were urged to proceed with developing the integrated model and get on with the studies in the spirit of the workshop. The initiative was endorsed by individuals such as Joe Rabesca, Chris Hanks, Earl Evans and Violet Camsell-Blondin. After the close of the meeting, participants lingered for some time to speak with the modellers and department representatives about questions or ideas that the workshop had engendered.


PHOTO J. ADAMCZEWSKI

## BARREN-GROUND CARIBOU CUMULATIVE EFFECTS WORKSHOP FEBRUARY 21 AND 22, 2008: LIST OF PARTICIPANTS

Note: We have tried to ensure that all participants' names and affiliations are correct, but we were limited by the information recorded at the time of the workshop. Our apologies for any errors or omissions.

| Last Name | First Name | Affiliation |
|---|---|---|
| Abernethy | David | BHP Billiton |
| Adamczewski | Jan | GNWT ENR |
| Amey | Krista | EBA Engineering Consultants Ltd. |
| Anderson | Nick | University of Northern BC |
| Antoniuk | Terry | Salmo Consulting Inc. |
| Bali | Archana | University of Alaska Fairbanks |
| Barrier | Tara | University of Northern BC |
| Bartlett | John | DeBeers Canada |
| Beaulieu | Danny | GNWT ENR |
| Blondin | Ted | Consultant |
| Campbell | Mitch | Government of Nunavut , Environment |
| Campbell | Darren | Snap Lake Diamond Mine |
| Camsell-Blondin | Violet | Wek'èezhìi Land and Water Board |
| Case | Ray | GNWT ENR |
| Clark | Karin | GNWT ENR |
| Cliffe-Phillips | Mark | Wek'èezhìi Land and Water Board |
| Cluff | Dean | GNWT ENR |
| Croft | Bruno | GNWT ENR |
| Crossley | Doug | Environmental Monitoring Advisory Board |
| Denholm | Eric | BHP Billiton |

| Last Name | First Name | Affiliation |
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| Fraser | Paul | Gartner-Lee Ltd. |
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| Gunn | Anne | Independent Caribou Biologist |
| Haas | Claudia | North Slave Métis Alliance |
| Hanks | Chris | NWT/Nunavut Chamber of Mines |
| Hans | Brenda | GNWT ENR |
| Holder | Joel | GNWT ENR |
| Johnson | Chris | University of Northern BC |
| Johnson | Deborah | GNWT ENR |
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| Mandeville | Lee | Dene Nation |
| Mandeville | Violet | Northwest Territories Métis Nation |
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| Marshall | Rob | Wek'eezhii Renewable Resources Board |
| McCallum | Barry | AREVA Resources Canada Inc. |

| Last Name | First Name | Affiliation |
|---|---|---|
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| Pokiak | Frank | Inuvialuit Game Council |
| Poole | Kim | Independent Environmental Monitoring Agency |
| Rabesca | Joe | Tłı̨chǫ Government |
| Rabesca | Joyce | Wek'èezhìi Land and Water Board |
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| Tae | Maret | Knight Piesold Ltd. |
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| Taylor | Laura | BHP Billiton |

| Last Name | First Name | Affiliation |
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| Wakelyn | Leslie | Beverly and Qamanirjuaq Caribou Management Board |
| Warbanski | Mark | AREVA Resources Canada Inc. |
| Warner | Boyd | Barren-Ground Caribou Outfitters Association |
| White | Dave | Snap Lake Environmental Monitoring Agency |
| Williams | Judy | GNWT ENR |
| Wooley | Bob | Gartner-Lee Ltd. |

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PHOTO J. ADAMCZEWSKI

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