Need and opportunity for a North American caribou knowledge cooperative

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The importance of migratory caribou (*Rangifer tarandus*) to northerners, the increasing pressure to extract non-living resources, and predicted global climate change have led researchers, managers and resource users alike to focus on how to improve our knowledge of this unique northern ungulate. Unprecedented threats to caribou sustainability, along with the increasingly acknowledged value of indigenous hunters' contribution to caribou research, pose the additional challenge to innovate research methods that accommodate differing cultural perspectives and facilitate communication among groups. This paper surveys the state of scientific knowledge of the eleven major northern mainland herds of North America. We recommend an approach to improve our working knowledge of barren-ground caribou in order to assess better future impacts. The transfer of knowledge gained from years of research and indigenous experience on many aspects of caribou ecology should be evaluated and, where applicable, transferred to herds with more modest databases. The establishment of a North American Caribou Monitoring and Assessment System, based on a synthesis of local knowledge and research-based science, is recommended as a tool for improved communication and collective learning.

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There are currently over three million migratory caribou in North America occupying range from the Western Arctic Herd (WAH) in Alaska to the George River Herd (GRH) in the Ungava Peninsula (Fig. 1). These populations are the most important terrestrial wildlife subsistence resource in northern North America (Burch 1972; Klein 1987, 1989). The annual movements and distribution of these herds take them from the forested winter range in the taiga to the treeless tundra adjacent the Arctic Ocean. Deep snow, rate of spring melt, timing of plant growth, and summer insects have been shown to be important driving forces in regulating herd numbers (Russell, Martell et al. 1993). Primarily Native communities harvest over 70 000 caribou across North America annually.

In the distant past, advancement of indigenous knowledge of caribou focused on human survival in conditions of limited material resources and regular subsistence shortfalls. From the early 1900s until the early '80s, caribou biologists focused on manipulating population levels through harvest management (Urquhart 1989). Hunter–research conflicts emerging from these efforts reflect the significant uncertainty surrounding existing knowledge of caribou and the disparity in cultural perspectives between the two groups. The recent establishment of formal co-management in Canada represents an institutional response to these problems (Usher 1986; Osherenko 1988). These arrangements have modified previously strained relations by providing opportunities for improved communication. In several cases, however, these arrangements have been limited in drawing Native and researcher perspectives together to address common problems (Kofinas 1998; Kruse, Klein et al. 1998). It is

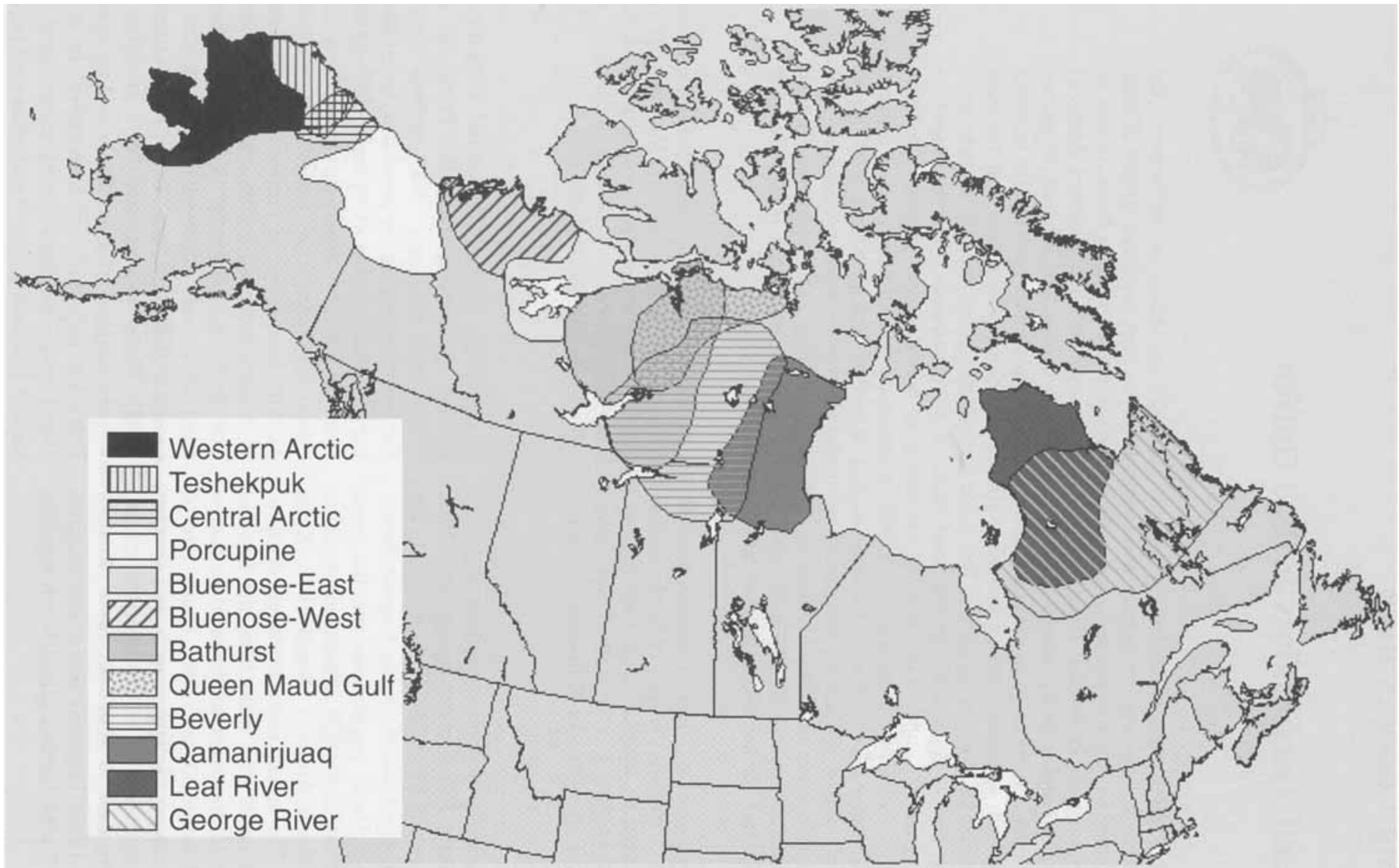

Fig. 1. Major North American mainland caribou herds: annual ranges of barren-ground caribou.

noteworthy that co-management board transactions, which facilitate contact between biologists and community representatives, are orientated primarily on public policy issues, and therefore function with crowded agendas and limited time for in-depth local knowledge–science exchanges (Kofinas 1998).

Since the 1980s, proposed and actual industrial development within the range of North American herds has resulted in many environmental impact studies, which have largely been uncoordinated. Currently, a number of large industrial development proposals are in various stages of planning. The Western Arctic Herd (WAH), numbering over 400 000 animals, and the Teshekpuk Herd, which overlaps in range with the WAH, are the subject of considerable regional concern from ongoing mining activities and US Congress plans to open up portions the National Petroleum Reserve to oil exploration and development. The Central Arctic Herd (CAH), a small herd of 20 000 animals, has been affected by development within its range at the Prudhoe Bay oil field. As the scale of the development expands, significant impacts on herd productivity are being documented (Cameron et al. 1992). Lessons from research in the Central Arctic Herd have been applied on the adjacent Porcupine Caribou Herd (PCH), which currently numbers 130 000 individuals. For the last 15 years, the threat of oil development in the calving grounds of Area 1002 of the Arctic National Wildlife Refuge has resulted in considerable research on the PCH. Recent leasing for mineral exploration within the summer and calving range of the Bluenose Herds (BLU), just east of the Mackenzie Delta, has focused studies on defining better caribou population parameters in the region. (The Bluenose Herd has recently been genetically separated into three herds [Nagy, unpubl. data].) The 350 000-strong Bathurst Caribou Herd (BAT) has multiple proposed and ongoing industrial development activities within its range. Broken Hill Proprietary Ltd. (BHP) and Diavik are constructing several diamond mines with significant infrastructure and transportation corridors within their range. Meanwhile, considerable debate has occurred over encouraging mineral exploration and constructing new transportation corridors within the calving ground of the Beverly (BEV) and Qamanurjuaq Herds (QAM), west of Hudson's Bay. Heavy metal discoveries in the Voisey Bay region of Labrador, hydroelectric development and proposals in the James Bay/Churchill Falls region, and low altitude military jet flights from NATO training facilities may have significant impacts on the largest North American herd, the 700 000-strong George River Caribou Herd (GRH).

Concurrently, an emergent interest in the "traditional ecological knowledge" of indigenous people (Inglis 1993; Berkes 1999), along with the specification of indigenous rights for involvement in Arctic wildlife management, has raised community expectations that locals' knowledge will have standing in research and environmental assessment processes. In several regions (e.g. Yukon, Northwest Territories and Nunavut) these expectations are backed with new legally binding provisions requiring that the knowledge of each region's indigenous people be incorporated into all phases of management.

During this current period of increased pressure from industrial development and institutional change, global climate change is expected to have significant impacts, particularly in the North. Warmer summers, deeper snow in winter and earlier spring melt, combined with high annual variation in these parameters will all affect the delicate balance of the northern environment, and all may have direct and indirect impacts on large migratory caribou herds. In some areas these climate-mediated changes have already occurred. For example, polar orbiting NOAA satellites have been used to monitor vegetation green-up (via an index called NDVI) in the North. Recent (1981–1991) patterns of NDVI in the western Arctic have shown an earlier plant green-up in spring and delay of plant senescence in fall (Myneni, Keeling et al. 1997; Myneni, Tucker et al. 1998). This pattern has been especially pronounced at high latitudes, 45°–70°N, and is putatively associated with increases in CO_2 profiles in the Arctic and considered indicative of climate warming on the seasonal availability of green plant biomass. At the local level, caribou hunters report a northward advance of the treeline, a general "drying" of river systems and more erratic weather events (Kofinas et al. 1997).

Cumulative impact is a term widely used to address the effects of development or climate change on caribou populations, but it is rarely defined explicitly. In our definition, cumulative impact can take several temporal and spatial forms. For example, for an individual animal, daily and seasonal changes in foraging opportunities, energy expenditure and predation risk will *accumulate* throughout the year as the animal moves among seasonal ranges. Depending on their individual movement patterns, on some days and in some ranges there may be a *cost* or a *benefit* of exposure to industrial development or climate change to an individual. The annual summation of daily energy costs/benefits is the cumulative effect on the individual animal and is expressed as survival, weight gain and reproduction of the individual. The cumulative effect at the population level is the average annual and spatial summation of the daily cost/benefit that results from exposure to development and/or climate change. If dramatic, the cumulative effect at the population level may be detected as changes in population survival rate, average weight gain or parturition rate from one year to the next. When the cumulative effect is mild, it may take many years to detect a temporal cumulative effect at the individual (e.g. a cow's frequency of breeding pauses) or the population (e.g. trend in parturition rate) level.

Beyond herd level effects is a broad set of potential impacts on human societies. These include changes in local access to hunting grounds and hunting patterns that may result from periodicity of river freeze-up and break-up, rate and depth of snowfall and melting, and shifts in household demand for caribou as a consequence of new employment patterns and changing community demographics (Kofinas & Braund 1998; Berman et al. 2000).

A quantitative and qualitative assessment of cumulative effects on caribou and people, whether from industrial development, global climate change or both, increasingly requires a database and research approach that allow decision makers the ability to determine the likelihood of impacts at the caribou population level. It is no longer acceptable to limit an assessment to disruption of activities or displacement from favoured habitats and extrapolate caribou population effects. Unless cumulative impacts can be demonstrated to affect herd productivity, then environmental assessment panels, co-management bodies and agency managers are left to speculate about the significance of the disruption to a herd's population and communities who depend on caribou resources. As well, focusing on the population allows for an assessment of cumulative impacts when a number of industrial development activities are proposed within seasonal ranges. To assess cumulative impacts at the caribou population level, an ideal data set would reveal:

- herd movements and seasonal distributions
  - we need to know frequency and variation in distribution and movements patterns;
- characterization of habitat including plants, snow, climate and insects
  - we need to characterize habitats and relate their use to annual variation in plant growth, snow accumulation and melt rate, and insect harassment;
- role of habitat on caribou diet and activity
  - it is necessary to document seasonal activity budgets and diets, and the linkage between these variables and changes in snow and insects must be quantified;
- role of diet, activity on animal growth
  - the energy needs of animals under varying diets and activities will allow us to determine the energy balance of an individual;
- role of reproduction on herd growth
  - relate demographic parameters to temporal trends in habitat, independent of development;
- role of growth and fat deposition on reproduction
  - we must link growth and fattening that result from annual energetic cycles to reproductive parameters (pregnancy, survival);
- role of mortality (predation and harvest) on herd growth;
- how industrial development may alter habitat, predators, harvest, activity and diet;
- how climate change may alter forage quality, predation, harvest, caribou activity and diet.

It was against this "ideal" data set that we developed a simple questionnaire to assess the relative state of science-based knowledge regarding the major North American mainland caribou herds.

In this paper, we

a) report the results of a survey of the present state of knowledge of these herds;
b) outline research priorities that were identified for each herd;
c) provide an overview of the research tools developed for the Porcupine Caribou Herd, the herd with the richest database;
d) recommend transferring knowledge about herds with more complete databases to those herds with modest baseline information;
e) propose the establishment of a monitoring and assessment tool for North American caribou.

Table 1. Individuals interviewed in relation to each herd.

Herd	Researcher(s) interviewed
Western Arctic Herd (WAH) Teshapuk Lake Herd (TLH)	Pat Valkenburg, Alaska Dept. Fish and Game
Central Arctic Herd (CAH)	Ray Cameron, University of Alaska; Beth Lenart, Alaska Dept. Fish and Game
Porcupine Caribou Herd (PCH)	Don Russell, Canadian Wildlife Service; Dorothy Cooley, Yukon Dept. Renewable Resources
Bluenose Caribou Herd (BLU) Bathurst Caribou Herd (BAT) Queen Maude Gulf Herd (QMG) Beverley Caribou Herd (BEV) Qaminuriak Caribou Herd (QAM)	John Nagy, NWT Dept. Renewable Resources Anne Gunn, NWT Dept. Renewable Resources
Leaf River Herd (LRH) George River Herd (GRH)	Micheline Manseau, Canadian Parks Service

Method

A 28-question survey (Appendix) was developed to assess the state of science-based knowledge on reproduction (Q1–Q9), harvest (Q10–Q11), movement (Q12–Q14), habitat (Q15–Q18), diet and activity (Q19–Q23) and growth and fattening (Q24–Q27) and to identify managers' research priorities (Q28). Managers and researchers most associated with individual herds and with significant research backgrounds were selected for an interview (Table 1). To quantify our results, points were assigned to the level of information available for each aspect of knowledge about caribou (excluding Q28). Additional communications with key informants were conducted to identify recent and current ecological studies – indigenous or western-scientific – of North American caribou.

Results

General comparisons: Across North America, the most abundant information is available on herd movements (61% of maximum possible score, Table 2), harvest (59%) and habitat use (57%); the poorest information concerns growth (28%), diet (35%) and reproduction (41%). This is not

Table 2. Results of herd status questionnaire.

Herd	Movements	Habitat	Diet	Growth	Reproduction	Harvest	Total score
WAH	10	14	7	5	12	11	59
TLH	8	16	2	0	3	8	37
CAH	10	9	8	4	11	10	52
PCH	10	14	17	11	20	13	85
BLU	7	11	5	0	5	13	41
BAT	3	11	4	2	7	5	32
QMG	1	4	0	0	0	3	8
BEV	4	8	3	4	11	5	35
QAM	2	8	5	2	11	5	33
LRH	3	9	2	3	0	10	27
GRH	9	16	12	3	14	15	69
Max. score possible	10	19	17	11	21	15	93
Avg. % of max.	61	57	35	28	41	59	

surprising as traditionally managers must delineate herds for management purposes (movements) and assess the harvest pressure on the herds. Habitat information is often available independent of other caribou research.

Herd comparisons: Major differences were noted among the caribou herds, with knowledge about the Queen Maud Gulf Herd being least complete (score = 8) and that for the PCH being most complete (score = 89) (Table 2). The quality of the database on an individual herd appears to be related to the level of real or proposed development now and in the past, the financial resources available within the jurisdictions for research, and the history of university interest in the specific herds. For example, the CAH has had considerable research information available largely as a result of impact assessments from Prudhoe Bay oil development. In contrast, the more modest information about herds in the NWT and Nunavut primarily reflects the number of herds within their jurisdiction, as well as the resources available and the lack of past major development activities within their ranges. The two largest herds in North America, the WAH and the GRH, have a considerable database available, in large part due to the priority given these herds by government wildlife agencies, as well as significant involvement of university researchers within their respective ranges. The herd with the highest score, the PCH, has all three elements present: development proposals, financial resources and academic interest. Much of the research activity on the PCH has been primarily in response to proposed large-scale development projects. These include the Arctic Gas Pipeline of the early 1970s, the Dempster Highway of the mid- to late 1970s, the Beaufort Sea oil and gas activity of the early 1980s, and potential development of Alaskan North Slope oil resources in the Arctic National Wildlife Refuge from 1980 to the present. Because the Porcupine Herd is international, ranging across three state/territorial jurisdictions, there has been a consistent flow of resources available to conduct research activities by management and research agencies.

Reported research priorities: There is a consistent trend in research priorities in relation to the level of knowledge about the herd. Managers reporting on herds that were scored as being known only to a poor or fair extent (Teshekpuk Lake Herd, BLU, BAT, BEV, QAM, Leaf River Herd) indicated a need for very basic herd-specific information: seasonal movements, herd delineation, calving ground ecology, population estimates and impacts of developments. Priorities for herds with a good level of information (WAH, CAH, GRH) focused on the need to integrate data sets, monitor animal condition, determine range conditions (e.g. role of herd in range degradation), understand natural population cycles and evaluate the extent of possible herd interchanges. For the herd about which the most is known – the PCH – priorities involve more ecosystem-level questions, such as the role of caribou in the ecosystem (nutrient cycling etc), the development of monitoring protocol and the transferability of knowledge and relationships to the study of *Rangifer* internationally.

Traditional knowledge caribou studies: The recent proliferation in traditional ecological knowledge (TEK) research in North America has resulted in several caribou-specific studies. While the presence of caribou TEK is clearly independent of TEK studies, it is recognized that formal documentation of local knowledge is important in preserving elders' understanding of caribou and in facilitating an interface with TEK and western science. A review of recent and current TEK research indicates that while research funding is being allocated to conduct work in these areas, most projects are conducted for finite periods with little, if any, commitment to ongoing data collection and analysis (e.g. West Kittikmeot/Slave Study caribou projects). Caribou TEK projects are most often focused locally or regionally on documentation of historical range use, migration patterns and descriptions of hunting patterns, e.g. Ferguson et al.'s (1998) thorough treatment of Inuit knowledge of population change on Baffin Island. Few address locals' interpretation of ecosystem dynamics, and fewer extrapolate findings to project future conditions. Still fewer projects have formalized the interaction of researchers and community experts to assess jointly the state of knowledge and together address research questions.

Discussion

There is a need across North America to look critically at the range components of all herds and their sensitivity to disturbance. For most herds, calving and post-calving grounds have been the focus of protection measures. But are all herds equally dependent on seasonal ranges for nutritional needs or is it possible to have limited human activities, depending on a particular herd's nutritional dependence? Will the importance of seasonal ranges be enhanced or diminished under predicted climate change? These are questions that are increasingly asked, particularly as indigenous decision makers try to balance their need to maintain subsistence with the desire to provide regionally based economic opportunities for residents.

No individual government agency nor Native organization has sufficient resources to collect the full suite of data needed to detect long-term trends in climate or other global changes, the potential cumulative impact of industrial activity, their combined potential impacts on biological resources, and the implications for human cultures that depend on these resources. To overcome this, we must capitalize on the rare long-term databases that include relevant and concurrent abiotic and biotic variables. Where such databases do exist, it is critical that they be used to: 1) investigate the sensitivity of caribou population performance to global changes; and 2) test hypotheses regarding causal mechanisms of population response to global change, and identify and quantify spatial and temporal scaling to other hierarchical levels of cumulative impact (e.g. individual > local population > continental populations; or day > physiological season > annual > decadal trends).

Global changes are expected to be at least decadal in extent; we need decadal data to detect potential effects and cannot wait for new research initiatives to provide long-term data. Applying research and databases that exist for the PCH provides the best opportunity to accomplish the objectives listed above.

Second, we must create systems through which the knowledge of researchers is made accessible to communities and policy makers, and the ecological and cultural knowledge of indigenous hunting people is brought to bear on science-based research and management.

The Porcupine Caribou Herd data set

A largely unbroken series of research projects over the last 25 years has focused on the implications of potentially large, energy-related development projects for the health and population size of the PCH. Using this extensive research base, we have developed two models that successfully link weather and climate to herd productivity (the CARIBOU models) (Russell, White et al., in prep.). The first – the ENERGY model – simulates the body condition of an individual caribou facing an array of habitat conditions throughout its annual cycle. The second model – POPULATION – projects herd productivity and community harvest into the future. Linkage between the models is through a series of validated relationships between individual animal performance and probability of reproductive success (e.g. pregnancy, birth, survival etc.).

These models have been utilized to assess the energetic and population impacts of community harvesting (Hanley & Russell in press), climate change (Griffith, Douglas et al. 1998; Griffith, White et al. 1998; Griffith & Russell 1999; White et al. 1999) and oil development (Murphy et al. 1998; Griffith & Russell 1999) within the range of the PCH. The models have been linked with a vegetation model (Epstein et al. in press) to explore the implications of a greener North over a 40 year horizon. In the process, a comprehensive data set was developed linking plant quality with plant biomass (Johnstone et al. 1999). In addition, an algorithm has been developed to predict diet shifts with changes in plant community (White et al. 1999). These two achievements allow us to extrapolate our models to other herds or to assess implications of future vegetation change.

Concurrent with this modelling activity, we have utilized remote sensing as a tool to monitor PCH range conditions, particularly in spring, summer and fall. Historical habitat and population data from the PCH supports our use of Normalized Difference Vegetation Index (NDVI) (Myneni, Keeling et al. 1997; Myneni, Tucker et al. 1998) as a range condition monitoring tool. NDVI is highly correlated with total green plant biomass in the Arctic (Hope et al. 1993; Markon et al. 1995; Shippert et al. 1995). We have documented a significantly increasing trend ($r^2 = 0.70$) in estimated NDVI on 21 June 1985–1996 (Griffith, Douglas et al. 1998) that paralleled increasing summer temperatures on the calving grounds during the same period. This calving ground trend in NDVI was consistent with the global trends observed by Myneni, Keeling et al. (1997). In addition, we have shown that the annual pattern of NDVI values is strongly correlated with calf survival during June ($r^2 = 0.85$) (Griffith, Douglas et al. 1998).

Local knowledge, ecosystem monitoring and models as discussion tools

Drawing on ten years experience in Porcupine Caribou co-management, we have also experimented with methods for improving communication and learning among researchers, agency managers and caribou hunters. Using simulation models to integrate research findings, we have engaged Porcupine Caribou hunting communities in discussions about the assumptions, relationships and predictions of caribou research through an innovative regional ecosystem monitoring programme called "the Arctic Borderlands Ecological Knowledge Cooperative" (see www.taiga.net/coop/about.html). Drawing on both research-based science and the local knowledge of indigenous communities, the "Knowledge Co-op," while in its nascent stages of development, is proving to be a valuable tool in advancing our collective knowledge base for the range of the PCH. Posing the question, "What is changing and why?", the Arctic Borderlands monitoring programme initiated a community-based monitoring component with two key assumptions:

a) locals who have a long-standing relationship with the land and its caribou can become the eyes and ears of a regional ecosystem monitoring programme; and

b) hunting people's knowledge can contribute to building a database of on-the-land observations, and to interpreting important relationships between caribou and weather.

Community-based ecosystem monitoring offers promise in achieving systems that are both ongoing and are respectful of differences in western and indigenous traditions of knowing (Kofinas et al. 1997). The Knowledge Co-op experience also shows that a community ecosystem monitoring programme focused on caribou offers considerable potential in synthesizing hunting people's observations and interpretations of ecological dynamics to reflect a range-wide understanding of current conditions and change, regional variation and behavioural responses of caribou to direct or indirect human interference, particularly with respect to weather and climate.

Table 3. Porcupine Caribou hunters' indicators of good quality caribou: body condition and overall health (Kofinas 1998: 166).

Things hunters look for when selecting caribou	• size of rump • gait or waddle of walk • whiteness of mane • size of rack • symmetry and overall shape of rack • number configuration of points on rack • size and shape of antler shovel • greyness of rack • social role of individual in group • posture of animals when moving
Post-mortem indicators of caribou health	• quantity of "backfat" (i.e. rump) • quantity of stomach fat • colour of marrow • tone and colour of lungs (e.g. lungs stuck to chest indicate poor health) • colour of kidneys and liver • presence of pus bags on kidneys • absence of "water" in muscles ("water" being produced when animal is worked) • contents of stomach (e.g. grass-filled indicates sick animal) • presence of parasitic larvae in kidneys

Among the elements of local knowledge on caribou offering great potential in future monitoring research is hunters' acute and detailed observations of body condition (Kofinas 1998: 166) (Table 3). In a parallel monitoring project within the range of the WAH, work with the communities of Kiana and Kotzebue of Alaska is serving to develop a hunter-based protocol for evaluating the body condition of harvested caribou, and linking local observations as inputs to the energetic CARIBOU model.

Building on these models and the cooperation achieved within the Knowledge Co-op, we have recently completed multi-disciplinary research that produced a web-based "Possible Futures" model. The purpose of this model is to engage stakeholders in a dialogue to evaluate implications of policy alternatives in relation to industrial development and climate change (Nicolson et al. 1999). Although models have many advantages, people other than their designers seldom understand them, which leads to distrust of model results (Parson 1995; Risbey et al. 1996). Two important goals in building a common assessment tool are therefore *transparency* (people understand how it works) and *utility* (people find it useful as a vehicle for communicating and exploring ideas) (Kruse, White et al. 2000). We have developed a "Possible Futures" model that addresses these two goals to help users retrace events depicted in a simulation and to prompt a discursive process of learning among researchers and local communities (see www.taiga.net/sustain).

Central to the Knowledge Co-op and the Possible Futures Model has been an exchange of ideas across cultural boundaries. These have resulted in new directions for researchers' analyses (i.e. generation of new hypotheses), better access to current research findings for community hunters, and a better appreciation of others' knowledge. Moreover, these collaborations demonstrate how complex societal level impacts, commonly of great concern to users but beyond the scope of caribou research, can be articulated and elaborated through a process of information exchange.

Recommendation

There is a need to coordinate research and enhance communication among managers, researchers and community members throughout northern North America as they grapple with large-scale industrial development, the cumulative impacts of sets of smaller-scale human activities, and concurrent climate-mediated change on caribou ranges of large migratory herds. Such an initiative could facilitate regional comparisons of all these components of change that are currently unavailable, and result in new continental-scale understandings of caribou.

The following questions should be addressed by coordinated, continental research.

Caribou ecology:
1) What knowledge is currently available on our caribou herds?
2) What are the similarities and differences among North American caribou herds, and what is the significance of these similarities and differences for impacts of climate change and industrial activity?
3) Are all calving and post-calving grounds of equal within-herd value for population dynamics?

Local knowledge study methods:
1) What aspects of cumulative effects of development on caribou are indigenous hunters best suited for monitoring?
2) How can current qualitative research methods be modified to document past and current local/indigenous knowledge on caribou?
3) How should body condition assessment programmes of harvested caribou be implemented to insure they are unobtrusive for local hunters, relevant to regional ecosystem monitoring and caribou modelling exercises, and comparable among programmes?

Assessment and communication tools:
1) What predictive, management or decision making tools can be established to monitor a changing northern environment?
2) How can models enhance interaction while respecting of cultural differences and advancing collective learning?
3) Can a generalized approach to assessing climate change and industrial development be developed for large migratory caribou herds across North America? If so, what is the best venue for comparing observations and discoveries among herds and regions?

Specifically, we see a need to:
1) Generalize and adapt existing predictive models that link changes in caribou habitat to herd productivity.
2) Conduct an overall assessment of our state of knowledge regarding North America's migratory caribou herds. This will require software that queries the user for specific herd information and develops herd-specific data sets that can be used to easily compare knowledge about different herds and can be utilized by the CARIBOU simulation model.
3) Compare the substance of local/traditional knowledge to elucidate important common principles and important regional and cultural differences.
4) Use remote sensing to compare calving, post-calving and summer habitats across North America.
5) Advance systems to document and incorporate local and traditional knowledge into all stages of caribou research and management.
6) Facilitate collaboration among parties to identify commonal regional monitoring and assessment needs.
7) Develop communication and decision making tools so that knowledge is shared throughout the North. This will involve the creation and development of a "North American Caribou Knowledge Cooperative" that will combine the communica-

tion and tracking elements of the "Arctic Borderlands Ecological Knowledge Cooperative" and the decision making tools modified from the "Possible Futures" model.

8) Transfer knowledge about intensely studied herds, notably the PCH, to the study of herds in Alaska, NWT, Nunavut, northern Quebec and Labrador.

9) Provide a contextual focus for governments and co-management groups to prioritize research projects.

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Appendix: survey of research on North American migratory caribou herds

Reproduction

1) Over what time period are there estimates of population size?
No estimates ______
Less than 5 years ______
5–10 years ______
10–15 years ______
More than 15 years ______
Comments:

2) On average, are these counts
A good guess ______
Somewhat reliable ______
Reliable enough ______
Very reliable ______
Comments:

3) Are pregnancy/parturition rates monitored?
No ______
Yes, but only on specific research projects ______
Periodically ______
Annually ______
Comments:

4) Are age specific pregnancy/parturition rates known?
No ______
Yes, from one research project ______
Yes, based on long-term study of radio collars (i.e. >3 years) ______
Comments:

5) Is post-natal calf mortality (survival to one month) monitored?
No ______
Yes, but only on specific research projects ______
Periodically ______
Annually ______
Comments:

6) Are fall composition counts conducted?
No ______
Only on specific research projects ______
Periodically ______
Annually ______
Comments:

7) Have spring composition counts been done?
No ______
Only on specific research projects ______
Periodically ______
Annually ______
Comments:

8) Are adult mortality rates known?
No ______
Yes, from one research project ______
Yes, based on life table analysis ______
Yes, based on long-term study of radio collars (i.e. >5 years) ______
Yes, based on long-term study of radio collars (i.e. >5 years) and for both sexes ______
Comments:

9) Are calf mortality rates known?
No ______
Yes, from one research project ______
Yes, based on spring composition counts ______
Yes, based on long term study of radio collars (i.e. >3 years) ______
Comments:

Harvest

10) Are harvest levels monitored for the herd?
No ______
Yes, but estimates are poor overall and not every year ______
Yes, but not every year ______
Yes, annually but estimates are a guess at best ______
Yes, annually and reliably enough for management ______
Comments:

11) Is harvest known by age and sex?

No ______

Yes, but estimates are poor overall and not every year ______

Yes, but not every year ______

Yes, annually but estimates are a guess at best for some user groups ______

Yes, annually and reliably enough for management ______

Comments:

Movements

12) How long have radio collars been on this herd?

No collars ______

<5 yrs ______

6–10 yrs ______

11–15 yrs ______

>15 yrs ______

Comments:

13) How many collars are on this winter?

None ______

Less than 10 ______

10–25 ______

25–50 ______

More than 50 ______

Comments:

14) Do you know (0 = no; 1 = yes)?

The peak date of calving ______

The peak date of rut ______

Comments:

Habitats

15) Is there habitat use information available (0 = none; 1 = single study; 2 = a number of studies; 3 = based on years of radio collar locations) for:

Calving grounds ______

Summer range ______

Fall range ______

Winter range ______

Spring range ______

Comments:

16) Have major vegetation types been defined (0 = no; 1 = yes) for:

Calving grounds ______

Summer range ______

Fall range ______

Winter range ______

Spring range ______

Comments:

17) Have major vegetation types been mapped (0 = no; 1 = yes) for:

Calving grounds ______

Summer range ______

Fall range ______

Winter range ______

Spring range ______

Comments:

18) Is spring green-up on calving grounds being monitored through NOAH satellite imagery?

No ______

Yes, but only on a specific study ______

Yes, routinely ______

Comments:

Diet and activity

19) Is the diet known (0 = no; 1 = yes) for:

Calving grounds ______

Summer range ______

Fall range ______

Winter range ______

Spring range ______

Comments:

20) Has there been nutrient (i.e. nitrogen, Acid Detergent Fiber, Neutral Detergent Fiber) analysis done on major diet plant groups (e.g. deciduous shrubs) (0 = no; 1 = yes) for:

Calving grounds ______

Summer range ______

Fall range ______

Winter range ______

Spring range ______

Comments:

21) Have activity budgets (% time feeding, walking etc.) of groups been documented (0 = no; 1 = yes) for:

Calving grounds ______

Summer range ______

Fall range ______

Winter range ______

Spring range ______

Comments:

22) On winter range has there been an analysis of use in relation to snow depth?

No ______

Yes, we know which regions offer lowest snow depths ______

Yes, we know movement response to snow and its effect on activity and diet ______

Comments:

23) On summer range is the herds response to insect harassment known?

No ______

Yes, we know which regions offer best insect relief ______

Yes, we know movement response to insect and its effect on activity and diet ______

Comments:

Growth and fattening

24) Are body weights of adult cows known?

No ______

Yes, but only as part of specific study ______

Yes, monitored at one time of year, annually ______ If so, what time of year? ______

Yes, monitored routinely more than once a year ______

Comments:

25) Are fat levels in adult cows known?
No ______
Yes, but only as part of specific study ______
Yes, monitored at one time of year, annually ______ If so, what time of year? ______
Yes, monitored routinely more than once a year ______

Comments:

26) Are growth rates or fall/spring body weight of calves known?
No ______
Yes, but only as part of a specific study ______
Yes, monitored periodically ______
Yes, monitored annually ______

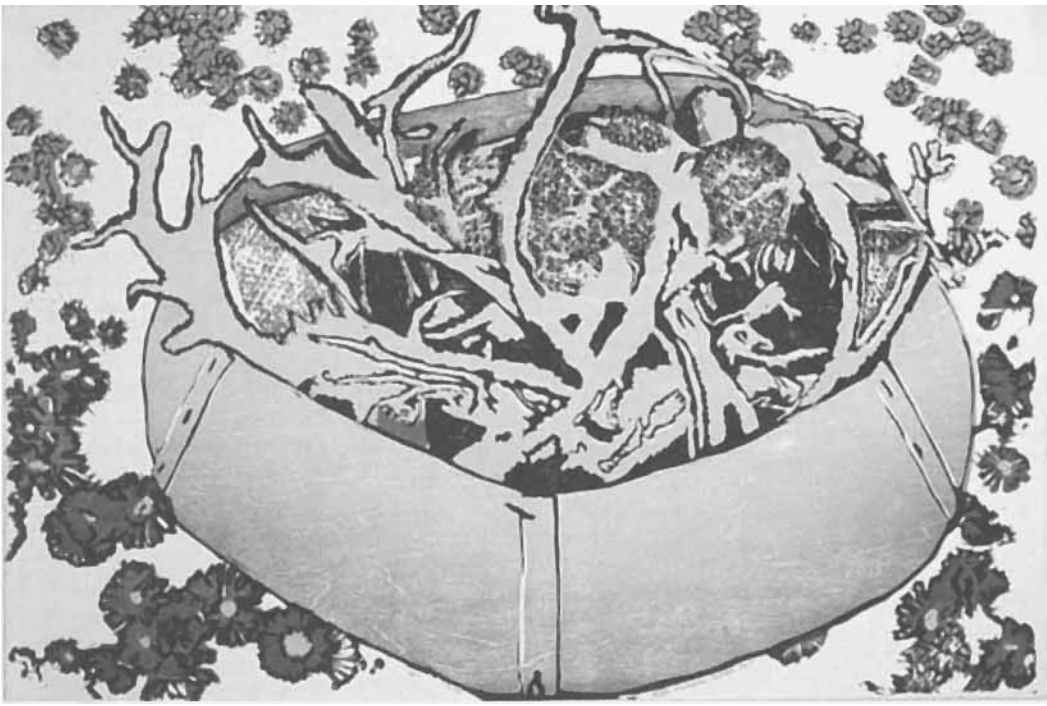
Comments:

27) Do you know (0 = no; 1 = yes) the functional relationship between:
Fall body condition and probability of pregnancy ______
Spring green-up and calf survival ______
Fall condition of mother and weaning date ______
Fall calf weight and over winter survival ______
Spring calf weights and herd productivity ______

Comments:

Research priorities

28) What are the major research priorities for this herd?



"Iglu" is a woodcut print made in 1999 in Baker Lane, Nunavut, Canada, by printmaker Kyra Vladykov Fisher. The image (the original of which is in colour) was inspired by OTCs – open-top chambers that serve as "little greenhouses" to study the effects of global warming on Arctic vegetation, as part of the International Tundra Experiment project. The artist depicts an OTC amid Arctic flowers and filled with caribou antlers, using the microcosm to express the precarious nature of the living world.