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Facing a Future of Change: Wild Migratory Caribou and Reindeer

Migratory wild reindeer and caribou numbers have dropped by about one-third since populations peaked in the 1990s and early 2000s. Four of five major herds in Russia and one of two herds in Greenland are declining. Several large Canadian herds monitored sufficiently to measure abundance trends have declined by 75–90%, and the declines have recently accelerated. For example, the Bathurst herd has declined from over 450 000 caribou in 1986 to fewer than 50 000 in 2009. The Beverly herd, one of Canada's best-known herds, had 270 000 caribou in 1994, but fewer than 100 breeding cows in 2009. Farther west in Alaska, the large Western Arctic and Porcupine herds are also declining.

Some herds, however, are not declining. East of Hudson's Bay, the George River and Leaf River herds total close to one million animals. The George River herd peaked early (~1992), while the Leaf River herd was still increasing at the last count, in 2002. On Alaska's Arctic coast, the Teshekpuk Lake and Central Arctic herds are still growing at an average rate of 7% per annum (both populations were last estimated in 2008). In Norway and Finland, where herds are small, wild reindeer are stable or increasing.

Historically, migratory tundra caribou herds have undergone well-defined and largely synchronous periods of abundance and scarcity, likely driven by continental climate switches such as the Arctic Oscillation. Populations that were almost universally low in the late 1960s and early 1970s increased to peak levels in the late 1980s and throughout the 1990s. Prior to the population lows in the late 1960s, aboriginal elders spoke of earlier periods of abundance and scarcity, and with scarcity, of human hardship and starvation. The variability in timing of population peaks is undoubtedly related to the timing and severity of nutritional and ecological bottlenecks for each herd and to the heterogeneous nature of climate impact on the range conditions of those herds.

Across their circumpolar ranges, many herds are being exposed more frequently to industrial exploration and development, leading to concerns about the cumulative effects of such exposure. For example, caribou change their habitat use in the vicinity of roads, oilfields, and mines. Additionally, a shift to wage earning in user communities can affect harvest levels by increasing the demand for caribou meat. Increased income allows harvesters more choice in harvesting methods, such as taking advantage of winter and all-season roads, and technological advances allow caribou to be located more easily. The post-calving ranges of the Beverly herd have recently seen a boom in uranium exploration, raising strong concerns about the effects of those activities on caribou abundance. In the 1990s, high levels of exploration for diamonds on the post-calving ranges of the Bathurst herd culminated in the construction of four diamond mines. Currently, there is a concern about oil and gas exploration activities on the winter ranges of the Bluenose East and Bluenose West caribou herds in the Northwest Territories.

Climate trends interact with and may alter the typical cyclic behavior of caribou abundance. Examples of climate trends are the warming temperatures for the ranges of the central Canadian herds, such as the Bathurst and Bluenose herds, with average increases of 3° to 6°C for winter and correspondingly more freeze-thaw cycles. Other environmental trends on the Bathurst ranges since the mid-1980s include a greater loss of lichen-dominated forests to forest fire; a decline in snow depths as fall temperatures increase; an increase in the number of freeze-thaw days; and a decrease in snow cover during spring migration. Warmer temperatures in summer are increasing the amount of plant biomass, but this gain is counteracted by a decrease in plant nutritional quality and an increase in insect harassment, especially by warble flies.

Climate changes are not uniform across the circumpolar North. The regionalization of global climate was a strong point made during the Arctic Council's *Arctic Climate Impact Assessment* (2005). We raise this point because there are examples of extrapolating herd-specific studies to all herds across the entire circumpolar North. It is counterproductive to paint all drivers of global change as detrimental to the long-term viability of caribou herds. In this context, we recognize a need to help the media understand the weakness of studies that consider only one of various possible outcomes, for example, assuming that climate change is always negative for caribou. To understand how climate trends will influence caribou abundance, we must first understand how caribou cope with the natural range of variation in their environments.

On the North American mainland, caribou have evolved diverse ecological strategies to adapt to their environments, which vary from west to east and north to south. The proportions of tundra and

taiga in the ranges vary greatly between herds: the Western Arctic herd has 30% of its annual range below the tree line, while the George River herd has 90%. Some herds on Alaska's North Slope, Canada's northeast mainland, the Hudson Bay islands, Baffin Island, and Greenland have year-round ranges on the treeless tundra. Tundra ranges are themselves diverse, as they can be continental or maritime; this difference affects local weather, especially winter snow and ice conditions.

The most conspicuous ecological strategy is seasonal migration. These migrations are the key for wild reindeer and caribou to take advantage of the shifting patterns of forage availability while at the same time spacing themselves to reduce exposure to predation and parasitism. For the few herds for which we have enough data, we are just starting to appreciate how other ecological strategies vary between herds, especially those that link movements and foraging to survival and reproduction. The Porcupine caribou herd, migrating across the borders of the Yukon, the Northwest Territories, and Alaska, enters its winter range with relatively little back fat, having devoted summer resources to raising relatively large calves. These caribou are able to remain successful despite their small overwinter reserves because of the typically low snow and abundant lichens in the region. However, once north of the tree line on spring migration, the pregnant cows leave lichen areas and feed on evergreen shrubs and moss until fresh green vegetation emerges from under the snow. The emergence of new vegetation typically occurs at or within a week of calving, when their nutritional demands peak. The cows arrive on the calving grounds with low body reserves, and the timing and progression of green-up largely determines the fate of their newborns within the first month after birth. The rapid green-up after snowmelt offers nursing cows abundant nitrogen-rich forage, essential for milk production, and we have already seen that warmer springs have increased early calf survival in the Porcupine herd.

By contrast, cows of the Bathurst herd on the central barrens of Canada raise relatively small calves and put on moderate amounts of fat during the summer. Their lichen-rich winter range has considerably more snow than the range of the Porcupine herd, and its terrain makes it more vulnerable to large forest fires. In spring, the pregnant cows are able to use lichens all the way to the calving grounds, where fresh green vegetation is initially scarce as snowmelt and green-up occur later than they do farther west. The lactating Bathurst cows must draw down on their fat and protein reserves to produce milk and quickly leave the calving grounds to find nitrogen-rich forage and start to replenish their reserves. Thus the fate of their newborns is more dependent on the reserves of the mother than on the accessibility of fresh green vegetation.

Other factors, such as the severity of warble fly harassment (and probably the intensity of internal parasitic infections), as well as behavioral responses to land-use activities (such as mines and exploration camps), influence the amount of nutritious forage available to cows in summer. The cows must balance the amount of fat they need to survive the winter and the amount of milk production required for calf growth. Calf growth is reflected in body size, which is directly related to the overwinter survival of the calf. There is a lot of variation across North America in the amount of back fat individuals of a herd typically have and in the fall body size of their calves. This variation is likely related to the long-term severity of the winter and early spring range. Herds with harsher winter ranges tend to accumulate more fat in the summer.

So how can cows control this allocation in response to annual differences in quality of their summer ranges? Control of milk production and ultimately the weaning date is an important way to balance cow and calf survival: it ensures cow survival, then calf survival, and finally successful conception during the fall breeding season. In some herds, notably the Central Arctic herd, cows exercise this control by having a target body weight they attempt to attain prior to the breeding season. If they enter the summer in poor shape, they tend to gain more weight than the cows that entered the summer in good shape. Both body fat and body protein reserves are involved in body condition. Whereas the probability of getting pregnant is strongly dictated by the amount of fat reserves of the cow, and therefore by the fat amassed during summer, calf birth weight and survival are dependent on body protein reserves entering winter, and therefore on the amount of protein amassed during summer. Low body reserves can have differential effects on fecundity and survival of the individual.

The ability of caribou and wild reindeer to survive in an environment characterized by unpredictable variations in weather is obvious by their abundance and diversity. We are starting to understand how caribou are able to buffer the impacts of annual environmental variation—a measure of their resilience. A measure of resilience of the individual cow is related to her long-term reproductive output; however, environmental effects that lead to reduced calf production or survival of the cow will result in low resilience. Within a population, the resilience of females likely varies depending on age,

cohort, and recent reproductive output, amongst a range of factors. When a sufficient proportion of individual females exhibit low resilience, then the population may be at a tipping point, becoming vulnerable to other factors such as predation and harvest.

We are also learning about the relationship between caribou survival and reproduction, caribou foraging strategies, and increasing our understanding of how they use seasonal ranges. Use patterns allow caribou to cope with environmental variation—put simply, if one area is unfavorable, the caribou can move to a more favorable area— as long as land-use activities do not restrict their movement. We are realizing how those ecological strategies reveal the vulnerability of caribou to environmental changes added to human-caused changes because the strategies have limits—they can cope with only so much change.

The factors outlined above are important considerations in caribou management. In Canada, and to various degrees elsewhere, caribou management is now a joint responsibility of governments and local users through co-management boards. In some regions, co-management of caribou is relatively new and already challenged to deal with rapid environmental change, declining wildlife, and the taxing question of harvest allocations. Despite the challenges, co-management has the most potential for the future of caribou, as it involves those who have the most to gain and the most to lose if conservation fails.

Already some co-management boards and communities in both the Northwest Territories and Nunavut have made the difficult decisions to restrict or even stop harvesting caribou. The extent of the declines in caribou and wild reindeer with environmental changes means that co-management boards, as well as the public and governments, will face increasingly tough choices about caribou management, including not only questions of harvest management, but also questions about land use and the pace of development.

One approach to describing how climate change varies regionally, which effects of climate change will be negative or positive, and which strategies caribou use to buffer environmental change is to undertake comparative and comprehensive assessments. Those assessments require a range of expertise from community knowledge holders, remote sensing experts, social and policy scientists, biologists, and veterinarians. Instead of working individually in our respective regions and disciplines or coming together only at conferences to share "findings" in the conventional way of doing science, a group of "caribou people" sought an alternative approach. They recognized the need to draw on collective experience and knowledge to understand the complex problems facing wild reindeer and caribou and the people who depend on them. They also recognized that collaboration that crosses cultural, geographic, and disciplinary boundaries is the only really workable solution.

The result of this collaboration was the establishment of the CARMA (CircumArctic Rangifer Monitoring and Assessment) Network, which formally started in 2004. Its beginnings, however, go back to February 1999, when scientists, reindeer and caribou users, and resource managers gathered in Rovaniemi, Finland. CARMA has built itself on a grassroots approach, involving a wide range of experts, from hunters to biologists, social scientists, veterinarians, and remote sensing experts. It is important to acknowledge that we, the authors of this opinion piece, have a role in CARMA, although we have written this article from our perspectives of a long involvement with caribou and the caribou people.

CARMA is a coordinated effort at standardizing protocols, implementing monitoring programs, sharing information, and conducting comprehensive assessments. Each herd will experience a variable array of weather, level of industrial development, institutional arrangements, and harvesting practices, with variable consequences for caribou demography and distribution. Circumpolar caribou managers, academic researchers, and traditional caribou users have already started to work together through CARMA. By building on shared information and experience, CARMA contributes to a circumpolar perspective for assessing implications of change and informing management alternatives for individual herds. In addition to developing monitoring protocols and syntheses, CARMA's partners are working with governments and co-management organizations to develop decision support tools that will help in focusing discussions and making decisions.

During the current herd declines, people are asking whether the herds will again recover as in the past or whether the combined threats of climate change, increased industrial development, greater access, and more efficient hunting technology will delay recovery or prevent it altogether. The question becomes, given changing environmental conditions, is the past a secure guide to the future?

We argue that, given the nature of the declines, the management actions to foster recovery need to be set in a context different from the conventional approach to caribou management. The typical

management interventions are those that influence caribou mortality: harvest and predation. However, the threats to caribou from climate change and a shift in land use toward industrial exploration and development have subtle and interacting effects on caribou, reducing measures of individual resilience such as body condition, calf survival, and pregnancy rates.

The future focus of management should be to foster resilience in caribou herds, to increase their capacity to cope with climate change and the changing economic and social settings. This focus requires defining resilience with performance-based criteria to ensure that management is adaptive, effective, and measurable. CARMA's tools and comprehensive herd assessments will contribute toward monitoring and understanding those effects whose total is summarized as resilience—the capability of individual caribou or the herd to cope with environmental change, as well as the capacity of the co-management system to translate findings into a collective will to act. Individual measures include levels of fat reserves, or rates of pregnancy and calf survival, while frame-size measures are indicative of population responses. Landscapes (seasonal ranges) where caribou are not impeded from freely undertaking both seasonal migrations and local movements, either to reduce exposure to predators and parasites or to forage efficiently, will be crucial to building individual and herd resilience. Fostering resilience in herds is tied to institutional arrangements that are collaborative in approach and adaptive.

Global warming and the heterogeneity of regional conditions raise questions about our current capacity to make assessments useful in caribou management, pointing to the uncertainty that has always been a part of sustaining human-caribou relationships. We are concerned not only about how the herds themselves are coping with their changing environment, but also about how human communities that rely on caribou will be able to cope. It is from the shared perspective of caribou and people that we seek to learn from the successes and failures of others.

We recognize that problems of caribou conservation, like those of conserving other once-numerous migratory species, such as the Atlantic cod or the Plains bison, are not simple; nor are there simple solutions. Individually and collectively, we need to use our knowledge and experience to drive forward the policies needed, such as regulation of land-use activities to ensure that caribou have the space they require. We should ensure that harvest policies do not shortchange caribou herds already coping with fast-changing trends in their environment. We need to make sure that harvest and land-use policies are designed in ways that provide for caribou adaptation in the face of global-scale changes. Through the passion of science and wealth of indigenous knowledge, Northerners have much to contribute and much to share. Our shared responsibility and concern is that the circumpolar North remain one of the few places in the world where the sheer scale of the wildlife migrations will persist.

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