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THE CIRCLE

MAGAZINE

4.2025

The Arctic wanderers: CARIBOU IN A CHANGING NORTH



THE ARCTIC WANDERERS: CARIBOU IN A CHANGING NORTH

COVER: Caribou roam near the George River in Labrador, Canada.

Photo credit: © GaryAndJoanieMcGuffin.com / WWF-Canada

THIS PAGE: A single caribou stands in a field of cottongrass on a hillside adjacent to the Hulahula River in the Arctic National Wildlife Refuge.

Photo credit: lexis Bonogofsky, Public domain

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Our failure to act will be the demise of the caribou

HOW DO I express the central importance of caribou for Indigenous Peoples and Arctic ecosystems in a 500-word editorial? It's impossible, because it's a matter that resides in the bloodstream, not in a document. It's about knowing the caribou are near by the appearance of new flies on a windowpane. Of being able to field-dress the animal in minutes, blindfolded. Of honouring ancestral near-relatives who starved in years when the caribou didn't come. These are matters of the heart, not the mind.

In 2014, at the request of WWF's Global Arctic Programme, I authored the (frankly prescient) Circum-Arctic Conservation Plan for Migratory Tundra Caribou and Wild Reindeer. This plan outlined a *pre-emptive approach* for relatively abundant caribou, such as the Porcupine herd that calves in Alaska; a *precautionary approach* for herds in decline or at population lows, which describes the majority of herds in the Arctic; and a *recovery approach* for populations at severe risk, such as High Arctic Peary caribou. The goal for all these strategies was to ensure that caribou populations could fluctuate sustainably, under relatively natural conditions, for the long term.

The conclusion of my proposed plan read: "Without immediate action, there is a real danger that wild caribou/reindeer, by virtue of their perceived abundance, could be largely ignored and left to fend for themselves. The result would almost certainly be serious degradation of herds and populations, leading Arctic nations in a decade or so to resolve to do something when it is too late."

So...how are we doing 10 years later? I believe we



MONTE HUMMEL was President of WWF-Canada from 1978 to 2004 and is the author of six books about the Arctic, including *Caribou and the North*.

Sámi reindeer herder Mikael Vinka and his favourite reindeer, Ammarnäs, Västerbotten, Lapland, Sweden.

I believe we are presiding—our generation, right now, in real time—over the potential loss of this circum-Arctic cultural and ecological treasure.

are presiding—our generation, right now, in real time—over the potential loss of this circum-Arctic cultural and ecological treasure. The evidence is before us in the form of synchronous, dramatic population declines for most herds worldwide.

In my country, Canada, where all the great migratory caribou herds are now formally classified as "threatened," the best hope for protecting at least some critical habitat is to approve the 2023 Recommended Nunavut Land Use Plan—the

largest land-use plan in the world. Yet, after 18 years, five previous drafts, and hundreds of local consultation meetings, the recommendations of community-based Inuit remain stalled in the political and bureaucratic systems of both Indigenous and non-Indigenous "decision-makers." While the plan languishes, areas that have been recommended for protection by Inuit, such as caribou calving areas, are being compromised through extensive mineral staking and other proposed industrial developments.

Looking around today, I'd say that caribou matters of the heart have been stymied by disconnected matters of the mind. In his mandate letter to all recently elected federal government officials, Mark Carney, Canada's new prime minister, wrote: "You will be expected and empowered to lead...and to bring decisive action to your work." It is long past time to bring the spirit of this directive to bear on the plight of caribou—not just in Canada, but throughout the Arctic. □



CLIMATE CHANGE

Are heat waves the new norm in Nordic countries?

THE SUMMER OF 2025 was one of the warmest on record, with heatwaves across Europe and North America—and the usually cooler Nordic countries weren't spared. In mid-July, a two-week-long heatwave gripped Norway, Sweden and Finland. Temperatures in parts of Norway and

Sweden reached up to 35°C, while Finland had its longest heatwave on record.

According to a study by World Weather Attribution, human-caused climate change made the Nordic heatwave at least 10 times more likely and around 2°C hotter than it would have been in a world without

climate change. The study warns that similar heat events will become five times more frequent by 2100 unless there is a rapid shift away from the use of fossil fuels. It also found that the probability of prolonged periods of heat has almost doubled since 2018.

The heat resulted in a

A burnt forest in Kårböle, Sweden. The heat wave resulted in more wildfires.

Photo credit: European Union 2018, Pavel Koubek, CC BY-NC-ND 2.0 via Flickr.com

NEW PROJECTIONS

A bleak future for Arctic caribou

ARCTIC CARIBOU COULD decline by as much as 80 per cent by 2100 under an emission-intensive scenario at the high end of the range of future pathways, according to a new study led by the University of Adelaide and the University of Copenhagen. The study found that climate change

could cause steep declines in caribou and reindeer numbers and distribution—and that North American caribou populations are most at risk.

The international team of researchers used fossils, ancient DNA and computer models to reconstruct changes in reindeer and caribou

numbers over the past 21,000 years at unprecedented resolutions. They examined how reindeer responded to past climatic events and used this information to model how they might cope with future changes.

Climate change contributed to the loss of nearly two-thirds

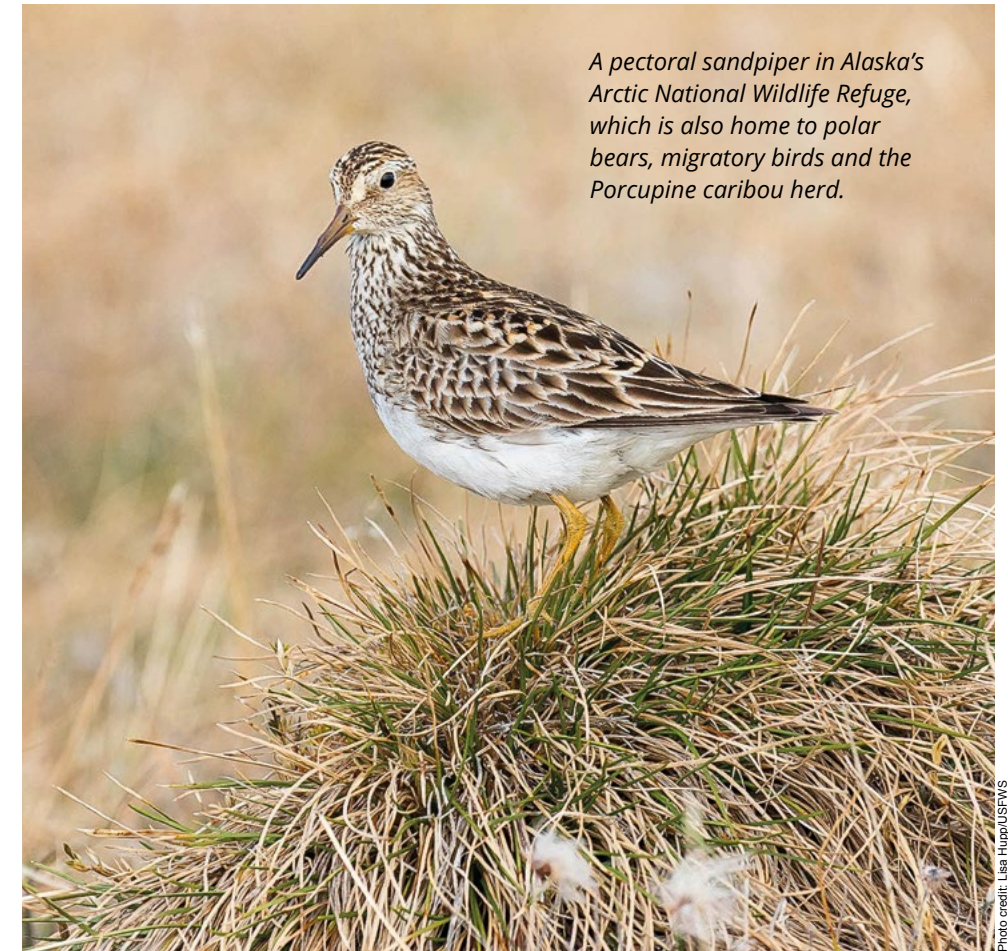
of the world's populations of wild reindeer and caribou over just the last three decades. The researchers warn that the situation will get much worse without major cuts to greenhouse gas emissions and increased investment in wildlife management and conservation.

HOOF HEALTH

Bacteria linked to livestock hoof disease found in Arctic caribou

A TEAM LED by the Universitat Autònoma de Barcelona has detected *Treponema* bacteria in the hooves of migratory Arctic caribou without any signs of disease. The team took tissue samples from 48 caribou with no visible hoof lesions and identified three species of *Treponema* known to cause digital dermatitis—a painful hoof disease found in cattle and sheep worldwide. In recent years, scientists have discovered these bacteria in wild elk in the US Pacific Northwest, suggesting that they can be found in both domestic and wild animals. Caribou depend on healthy hooves for long migrations, and while hoof diseases are common, it is hard to investigate them due to the remote locations that caribou inhabit in the Arctic.

The bacteria were found in hoof tissue collected during the cooler months of early spring, which suggests they can persist in Arctic conditions and may be more widespread in wild herds than previously thought. The discovery underscores the possibility that pathogens normally associated with livestock diseases could also circulate in Arctic wildlife. Further study is needed to understand what role these bacteria may play in caribou health and how climate change could influence their activity.



A pectoral sandpiper in Alaska's Arctic National Wildlife Refuge, which is also home to polar bears, migratory birds and the Porcupine caribou herd.

Photo credit: Lisa Hupp/USFWS

DRILLING IN THE ARCTIC

Oil and gas development plans threaten Porcupine caribou and Gwich'in People

THE TRUMP ADMINISTRATION is pressing ahead with its plans to open the entire coastal plain of Alaska's Arctic National Wildlife Refuge to oil and gas leasing following a federal court decision earlier this year that reinstated seven previously cancelled leases. The refuge, some 78,000 square kilometres in size, is home to polar bears, migratory birds and the Porcupine caribou herd, whose calving grounds are sacred to the Gwich'in People of Alaska and northern Canada.

However, industry interest in the

refuge remains weak. A congressionally mandated lease sale in January 2025 attracted no bids, echoing the poor response to an earlier auction. Even so, Alaska's state development agency now retains leases, and the US administration has committed to expanding leasing across the refuge as part of its broader Arctic energy agenda.

Indigenous leaders warn that drilling would fragment critical caribou habitat and threaten food security.

Same species, different stories

GETTING THE FACTS STRAIGHT ABOUT CARIBOU AND REINDEER

If you wanted to see a reindeer, your best bet might be to head to northern Scandinavia. But what if a caribou was on your bucket list? Are the two really that different? And what challenges are these deer-like animals facing in the Arctic? To answer these and other questions, *The Circle* spoke to **JAN ADAMCZEWSKI**, a former wildlife biologist with the Government of Northwest Territories in northern Canada. He's been studying and working with caribou since the early 1980s.



What's the difference between caribou and reindeer?

They both belong to the same species: *Rangifer tarandus*. But reindeer are found mainly in northern Europe and Siberia, where they exist both as wild herds and semi-domesticated animals that have been herded by people for thousands of years. Caribou are native to North America and remain wild. The word “caribou” describes wild populations in North America, while “reindeer” usually refers to the wild and semi-domesticated herds of Eurasia.

A main difference is that reindeer that are semi-domesticated are pretty tolerant of people, whereas wild caribou and wild reindeer are not. There are some semi-domesticated reindeer herds in Alaska as well as one in northern Canada.

There are several subspecies of caribou, such as the Peary caribou, the smallest, palest caribou, found in the High Arctic islands of Canada, and the larger barren-ground caribou, found in the tundra regions and boreal forest of mainland Canada. We also know there have been many instances of caribou and reindeer interbreeding.

What traits do caribou and reindeer share?

Physically, they're similar. Both are the only deer-like animal where the females have antlers. Caribou tend to be larger, with longer legs for migrations. The Peary caribou are the smallest of them—if you put one beside a barren-ground caribou, it would look almost like a calf.

Caribou, Labrador, Canada.

The Dolphin-Union caribou, a unique ecotype of barren-ground caribou named for its location in the western Arctic, is a little bigger than Peary caribou but smaller than barren-ground caribou. They have fairly big hooves, which helps with walking on snow and with swimming.

European reindeer have many of the same characteristics as caribou. Their body sizes vary, but fundamentally, these are all the same animal.

In the winter, most caribou and reindeer eat the same food: lichen, which can make up 80 to 90 per cent of their diet. Lichen is a moss-like substance made of a fungus and alga living together, often found on rocks and trees. When spring comes, they will eat less lichen and start eating different plants. They are very good at finding the plants and plant parts that have high nutrient contents. The mating season is usually in October, and pregnant females will typically give birth in May or early June. Normally, they will have one calf. But if the conditions are not so good—for example, if food is scarce, the winter has been harsh, or the effects of climate change have disrupted their migration or access to calving grounds—they may not breed every year.



Jan Adamczewski

Do all caribou and reindeer migrate?

No. European reindeer have seasonal migratory movements, but they don't travel on the same scale as the migra-

tory caribou herds of North America. In Siberia, wild reindeer do migrate—much like North American barren-ground caribou—while semi-domesticated reindeer often move with their herders instead of following long natural migrations. In both cases, calving grounds remain central, with females congregating there to give birth.

How important are these animals to Indigenous Peoples?

It's hard to exaggerate the importance of caribou—and the ability to hunt caribou—in Indigenous cultures across northern North America. There's archaeological evidence showing that Indigenous Peoples were hunting caribou as far back as 8,000 to 10,000 years ago. And there are Indigenous cultures that identify with caribou—not just as something to put on the table, but they identify as caribou people, culturally and spiritually. Hunting is very important for elders to pass on traditional knowledge and practices.

And the Sámi have been herding reindeer for many, many generations. This relationship differs from the caribou hunting cultures in North America, but there is a very close relationship between the people and their reindeer.

How is climate change affecting caribou and reindeer?

They're a cold weather animal, so a warming climate is a major concern. Temperatures are warming faster at high latitudes, where caribou and reindeer are largely found. But climate is not having just one effect—there are many effects, some negative and some positive.

Spring tends to come earlier than it once did, which can mean that females that have just given birth and are nursing young calves have good access to green growth. But the vegetation is changing in some areas, with less lichen and more shrubs, which are harder to digest and less energy-rich. A warming climate also means that some parasites and pathogens can increase their range northward, which increases caribou's and reindeer's exposure.

Precipitation patterns are also chang-



Reindeer, Kebnekaise, Sweden.

ing—and one thing that's really not good for these animals is warm winter temperatures followed by freezing. When you get a rain-on-snow event, the frozen ice crust that results locks the animals' vegetation under ice. Freezing vegetation in winter has been associated with die-offs in Peary caribou and likely also affects other caribou and reindeer populations.

How the weather affects the insect season is also important. Historically,

the insect season has been mostly confined to July. But these days, it can start in June and go well into August. The severity of the bug season is one of the major effects of warming weather on caribou. Caribou are vulnerable to biting flies, like black flies, mosquitoes and horseflies—and the ones that really seem to bother them are the warble and bot flies, which are parasitic. If the bugs are particularly bad, then instead of feeding and rebuilding their body

reserves, the caribou will run around trying to get away from these pests. If the females don't feed well in summer, then when breeding season arrives, they're quite lean and less likely to be pregnant that winter.

What other threats are caribou and reindeer facing?

The threats that have become increasingly important in the last decades are human-caused: roads, seismic lines,

Boreal versus migratory tundra caribou

Caribou and reindeer are the same species even though their genetics, behaviours, appearances and habitats differ across their ranges. For the purposes of conservation and management in North America, they are divided into ecotypes that are based on habitats and behaviours rather than genetics.

Migratory tundra caribou roam the Arctic and sub-Arctic tundra in massive herds and undertake some of the longest land migrations on Earth—often covering thousands of kilometres each year. They are typically smaller and paler than other ecotypes, adapted for long-distance travel and endurance in extreme

environments.

Boreal caribou, on the other hand, inhabit mature, lichen-rich boreal forests and are predominantly sedentary. They occur in small, isolated groups and generally migrate only short distances—about 50 to 150 kilometres annually. Physically, they are larger and darker, with broader, denser antlers and longer legs and heads than their tundra counterparts.

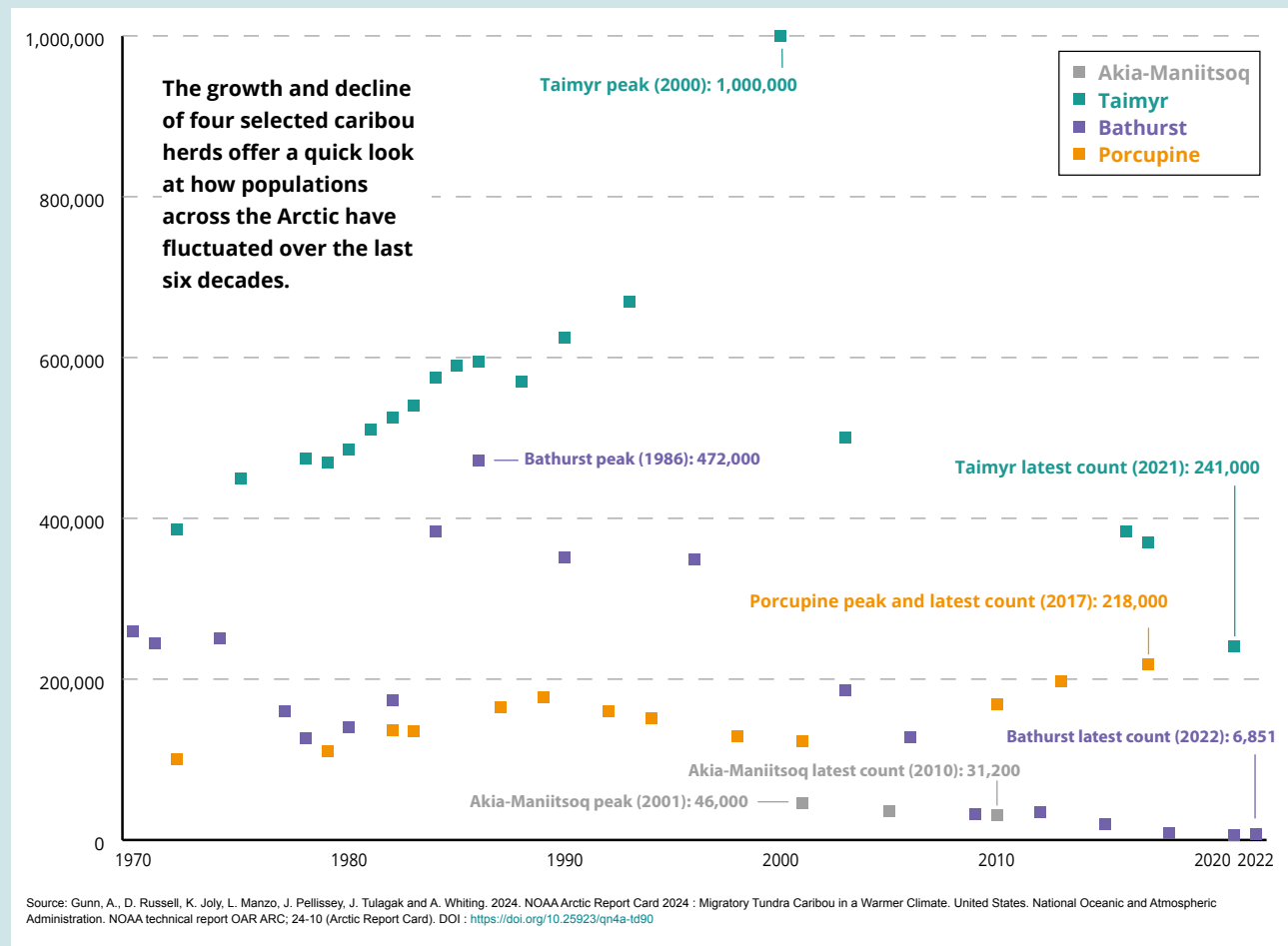
In Canada alone, experts recognize more than a dozen distinct caribou ecotypes—ranging from mountain caribou in British Columbia to the tiny Gaspésie herd in Québec—each with different habitats, behaviours and conservation challenges.



Woodland caribou, Ontario, Canada.



Barren-ground caribou, Nunavut.



Five decades of data

According to data collected since 1970, wild caribou and reindeer herds across the Arctic have shown dramatic swings in population over the past five decades.

While large fluctuations are natural, this Arctic herbivore has lost nearly two-thirds of its global abundance in the past three decades. Several of the largest North American herds, such as the Western Arctic and Bathurst

herds, peaked in the 1980s and 1990s before declining sharply—for example, the Bathurst population fell from about 470,000 caribou in 1986, max fewer than 7,000 in 2022.

In contrast, the Porcupine herd has grown steadily, doubling from around 100,000 in the 1970s to more than 200,000 in recent years. Herds in Greenland have been relatively stable, while Siberian herds, such as the

Taimyr, continue to rank among the world’s largest, despite having experienced a huge decline to currently only a quarter of its previous size.

Smaller herds everywhere remain vulnerable, with some numbering only a few thousand.

Overall, the data highlight both the resilience and fragility of Arctic caribou in the face of changing conditions.

mines and development in general. But it’s different for different herds. In the Canadian North, we generally have less development—so far—but there are lots of roads proposed. In the Northwest Territories, for instance, there is a winter road season to support active mines, and there is often a big truck coming every 30 seconds or so when this winter

road season is running. As soon as you put in a road like that, you’re putting a barrier across the caribou’s range. We have already seen—from the ground and satellite collars on caribou—that caribou don’t cross those roads when the traffic is running at full speed. Roads can also make it much easier for hunters to find and hunt caribou and reindeer.

We have known for some time that only migratory herds of caribou and reindeer are able to reach numbers in the tens and hundreds of thousands; migration allows them to avoid some of their predators, find the best forage seasonally, and avoid some parasites. Their migratory habit is what allows them to reach those big numbers. The fear

is that the more roads and other infrastructure we build, the more we will inhibit their ability to move freely on the landscape—and somewhere along the line, that may mean smaller herds.

Are caribou and reindeer on the decline everywhere?

Sometimes one herd will be declining while a neighbouring herd is increasing in number. Since about 2000, most of the migratory herds in the Northwest Territories were either declining or at fairly low numbers. But over the last few years, a number of herds have stabilized—and some are actually growing at this point. So, each herd has its own conditions.

For example, there’s one herd called the Bluenose-East that has a calving ground in Nunavut, west of the community of Kugluktuk. From 2000 to 2018, this herd went through a major decline, from about 120,000 to about 19,000. But then from 2018 to 2021, it stabilized, and since then, it has actually shown quite an increase. So, after years of talking to people in nearby communities about limiting their harvest, it was wonderful to find that the herd is doing really well now.

What does the future hold for caribou and reindeer across the Arctic?

I think these are adaptable animals. They’ve persisted through all kinds of challenging climate conditions—even through the last ice age. In fact, the oldest caribou fossil known is something like 1.6 million years old. So I think they will be able to adapt as long as we don’t limit their ability to make whatever changes they need to survive. If we can really limit new development in key areas like calving grounds, including roads—and keep giving caribou the option to move freely on the landscape—then I think they’ll be able to adapt.

But if we start constraining their ability to move and change where they calve, then the likelihood of smaller herds increases. Ultimately, the healthiest caribou and reindeer are those with minimal human disturbance. □



A reindeer herd in Finnmark, Norway.

From the tundra to the cloud

SÁMI REINDEER HERDERS MAP CLIMATE CHANGE

The Climate Change Impacts on Terrestrial Ecosystems (CITE) project co-developed a digital tool with Sámi reindeer herders to document observations of changing land, climate and ecosystems. As **MÁRET J. HEATTA** writes, by combining herders’ knowledge with scientific data, the tool strengthens decision-making, biodiversity stewardship, and adaptation strategies—ultimately supporting Sámi livelihoods and fostering resilience to climate and environmental change across Sápmi.

THE LAND IS changing. Sámi reindeer herders, whose lives and culture are tied to the rhythms of the seasons and the



MÁRET J. HEATTA is a project leader in the Arctic Environmental Unit of the Saami Council who specializes in co-production methods and Indigenous data sovereignty in climate change research.

movements of their herds, hope their way of life will continue to thrive. Yet as the climate warms, weather grows less predictable, and multiple pressures intensify, Sámi worries deepen and the question becomes urgent: How can reindeer husbandry—and the relationships to land and animals that are at its centre—continue in ways that reflect Sámi culture and values?

Climate change is reshaping life across Sápmi. Warmer winters, sudden ➤

Oops, watch out for reindeer! Kilpisjärvi, Lapland, Finland.



that shifting seasons bring a range of challenges, from ice crusts that block access to grazing to unstable snow and ice conditions that disrupt herding and travel. These patterns mirror scientific projections of shorter winters, later snow and more frequent freeze-thaw events.

A key benefit of merging herders' knowledge with scientific tools is that it empowers Indigenous communities, helps clarify how policies affect livelihoods, and creates context-sensitive solutions grounded in local landscapes.

COMPOUNDING PRESSURES

Scientific studies also show that the growing season is lengthening, allowing plants more time to grow. This may push tree lines and shrubs northward and higher up mountains, threatening Arctic biodiversity. It also allows new animal and insect species to migrate into the area, potentially carrying unfamiliar diseases.

Herders, too, are noticing these shifts on the land. They observe that the vegetation is changing, with tree lines moving upwards into tundra landscapes. They are reporting concerns about alien species and diseases as well as the increasing presence of predators—all of which adds pressure to reindeer survival and herding. The flexibility to use and move through the land in response to the shifting weather conditions is greatly diminished by other land uses. Forestry, wind power, mining, tourism and expanding infrastructure reduce grazing resources, fragment areas, and create barriers to moving with the herds. At the same time, growing predator populations add stress and losses. All these pressures are acting simultaneously, forcing difficult choices.

Forestry, wind power, mining, tourism and expanding infrastructure reduce grazing resources, fragment areas, and create barriers to moving with the herds.

Reindeer herders' knowledge and observations are crucial for understanding climate impacts, but without the protection of grazing lands, the ability to adapt and sustain Sámi reindeer husbandry is at risk.

Safeguarding both the land and Indigenous knowledge is essential for ensuring that reindeer herding—and the culture, livelihoods and values embodied in it—can continue to endure for future generations. □

Co-creating a digital tool with reindeer herders

The Climate Change Impacts on Terrestrial Ecosystems (CITE) project is a co-creative initiative between Sámi reindeer herders and researchers in northern Sápmi to address climate change and biodiversity impacts on reindeer herding.

Regular dialogue allowed the project design to adapt to reindeer herders' needs and schedules, respecting their seasonal demands and building trust among participants. Running from 2022 to 2024, the project resulted in an open-access mapping tool by and for herders to record their observations. The data remain owned by the herders, and the project stands as an example of embracing flexibility and successfully weaving knowledge systems.

thaws, refreezing ice, shifting vegetation and unpredictable snow directly affect reindeers' health and ability to undertake seasonal migrations. Together with threats from competing land uses, these pressures create mounting challenges for Sámi reindeer herders. Each community experiences these changes differently, making it difficult to predict local impacts or find simple solutions.

CLOSING GAPS IN THE CONVERSATION

For generations, herders have carried deep knowledge about how environmental conditions influence reindeer survival and well-being. This knowledge is closely tied to culture, land and values, but has rarely been documented in ways that connect with scientific data. As a result, much of what herders know is missing from broader conversations

on climate adaptation.

To close this gap, Sámi reindeer herders and researchers came together in the CITE project, funded by the Nordic Council of Ministers, to codesign a digital tool.

The tool allows herding communities to systematically record their observations and experiences of environmental change and competing land use.

Designed to be simple and practical for everyday use, the tool is available in several Sámi and Nordic languages as well as English and has been tested in pilot areas across Sápmi and refined using feedback from the test group.

These observations are combined with scientific data to create a fuller picture of how climate change is unfolding on the ground. Herders have observed



From 2017 to 2020, the number of caribou crossing the river went from tens of thousands to zero. The caribou had abruptly shifted their winter range by more than 500 kilometres.

The caribou remember

COLLECTIVE MEMORY AND SURVIVAL

Migration is a calculated risk for caribou, who maximize their chances of survival by balancing the energy they need to migrate against seasonal shifts in food availability. As **ELIE GURARIE** and **ANNA BROSE** write, unpredictable weather conditions caused by climate change are making it harder for caribou to find that balance—but a phenomenon known as social memory is helping. ►

Caribou swim across the Kobuk River in Alaska.

AS FAR BACK as most people can remember, the Western Arctic caribou herd—historically the largest migratory herd in Alaska—would cross the Kobuk River at a wide bend called Paatitaaq (Onion Portage). In early October, tens of thousands would flow across the Kobuk on their southwest migration to spend the winter on the Seward Peninsula. In fact, archaeological evidence shows that both caribou and humans have returned to that site repeatedly over the last 10,000 years or more.

For most of those years, there was no better place to be a subsistence hunter—



ELIE GURARIE is the primary investigator on the Fate of the Caribou Project.



ANNA BROSE is the project's program and communications manager.

or a caribou biologist. Get there in late September, take a seat in the fields of wild garlic (after which the portage was named), and invariably, the caribou would come.

Until, suddenly, they didn't: from 2017 to 2020, the number of caribou crossing the river went from tens of thousands to zero. The caribou had abruptly shifted their winter range by more than 500 kilometres, staying north of the Kobuk River and deep in the Brooks Range mountains, considerably north and east of their historic wintering areas.

A MYSTERIOUS SHIFT

To find out why, we analyzed GPS movement tracks from hundreds of caribou over more than a decade of monitoring and conducted an intensive evaluation of caribou deaths over that same period. Our analyses of temperature, snow depth and wind largely failed to explain the range shift. But when we started to consider the caribou as *social* and *cognitive* beings—that is, as animals that carry with them and transmit a collective knowledge of their landscape and

experiences—a story emerged.

Roughly, the story goes like this: When the caribou crossed the Kobuk River and headed southwest to the treeless but lichen-rich tundra on the Seward Peninsula, as they tended to do from 2010 to 2015, their survival rates were excellent: more than 95 per cent made it through the winter. The caribou who remained north of the Kobuk River were less likely to survive, and ended the winter in poorer health, likely due to differences in their access to lichen.

But then, in the winters of 2016 and 2017, caribou survival on the Seward Peninsula fell by 15 per cent. These were notably warm winters. The sea ice was at record lows, and more winter precipitation came down as rain (remarkably, for the Arctic Ocean) than as snow. Perhaps that made it harder for caribou to migrate. Perhaps the freezing rain events created an impenetrable ice layer over the lichen. In any case, caribou on the Seward Peninsula fared much worse, while their cousins that had opted to winter in the north did as they usually do—which is to say not great, but not so bad.

After this collective experience, a great number of caribou that had previously crossed the Kobuk River chose instead to join those that were toughing it out in the mountains.

COLLECTIVE SOCIAL MEMORY

We came to two major conclusions: First, the range shift was a smart move. Fewer caribou overall have been dying in the winter than would have if they had continued wintering south and west. Second, the choice was driven by past experiences: when collective survival was poor in the south, individuals were much less likely to head that way. This is evidence—long reflected in Alaska Native knowledge of caribou behaviour—that these large-scale movements are informed by the herd's collective social memory.

Caribou have survived great climate and population fluctuations in the past because they have many astonishing features and adaptations: hollow insulating hairs, wide-splayed hooves, eyes that change from blue in the winter gloom to gold in the summer sun, stomachs that glean enough from

woody threads of lichen to stay fat and happy through the severest winters. But perhaps the greatest tools they have for navigating some of the harshest environments on Earth are their mobility and their sociality.

Even as the climate in the Arctic changes faster than anywhere else on Earth, caribou are seeking solutions to the challenges posed by unpredictable weather and shifting resources by poking and prodding the landscape at vast scales.

Since our study was published, some caribou have already resumed swimming across the Kobuk River at Paatitaaq, headed to the Seward Peninsula—having determined, perhaps, that the effort of wintering in the mountains was not worth it after all, and aiming to try their luck on the lichen tundra once more. Only time will tell whether this gambit succeeds.

But whatever happens, the caribou will remember. □

This is evidence—long reflected in Alaska Native knowledge of caribou behaviour—that these large-scale movements are informed by the herd's collective social memory.

A distant view of caribou in the Brooks Range.



Reindeer inhabit almost all areas without glaciers in the Svalbard archipelago. The coastal populations are much smaller in size and experience more winter rain and snow, with harsher foraging conditions.

Against the odds

WHY SOME SVALBARD REINDEER ARE THRIVING DESPITE CLIMATE CHANGE

Svalbard reindeer live at the top of the Earth in one of the most rapidly changing Arctic environments. As **ÅSHILD ØNVIK PEDERSEN** writes, this cold-adapted, endemic species inhabits almost all vegetated areas of the archipelago—and unlike populations elsewhere in the Arctic that have seen declines, their numbers doubled from the 1980s to 2015 (the last survey date). But some Svalbard populations have declined or remained stable in size while others have grown more than threefold. What’s going on?

TO ANSWER THAT question, scientists are turning to one of the longest-running wildlife studies in the Arctic, covering nearly 50 years of data. Researchers with the Climate-Ecological Observatory for



ÅSHILD ØNVIK PEDERSEN is an Arctic ecologist and senior researcher at the Norwegian Polar Institute. She leads the Climate-Ecological Observatory for Arctic Tundra (COAT) in Svalbard.

Arctic Tundra (COAT) have been tracking Svalbard reindeer by counting them, noting their age and sex. They are also marking and recapturing individual animals to follow their survival, reproduction and movement over time. These long time-series allows scientists to link reindeer health and numbers directly to shifts in weather and climate.

Svalbard reindeer live on the northern edge of the species’ range. Like their relatives elsewhere, they shape the tundra by grazing, fertilizing and trampling vegetation. They are also an

important part of the Arctic tundra food web: when they die, scavengers like the Arctic fox rely on them for food.

But while the Svalbard reindeer are all part of a single subspecies, their fortunes differ according to whether they dwell mainly in the archipelago’s coastal or inland areas.

WINNERS AND LOSERS IN A CHANGING CLIMATE

Climate change has brought both benefits and challenges to these reindeer: icing episodes caused by winter rain can trap plants beneath ice, making it hard to get enough food. On the other hand, longer snow-free seasons give them more time to feed and store energy before winter. The body mass of females is crucial for reproduction and survival and explains nearly 90 percent of the variation in population size from year to year. Body mass variations are connected to winter conditions, reproduction and competition among reindeer for food when population densities are high. ➤

While the Svalbard reindeer are all part of a single subspecies, their fortunes differ according to whether they dwell mainly in the archipelago’s coastal or inland areas.

Rapid climate change effects and reindeer responses are revealing uncertainties and new concerns about how this cold-adapted species will cope as the pace of change accelerates.

When rainy winters create icy pastures, locking plants beneath a frozen basal ice layer, starvation can result in mortality, especially among the youngest and oldest reindeer. Few calves are born the following summer, leading to population declines.

These icing episodes can cover large areas of land. But the combined effects of these events and changes in summer conditions lead to different outcomes in our two core monitoring areas, home to coastal and continental reindeer populations. The explanation likely lies in small but important differences in weather, climate and how the reindeer themselves respond.

SAME ISLANDS, DIFFERENT EXPERIENCES

At the meteorological station in Ny-Ålesund, on the west coast of Spitsbergen, the largest island of the Svalbard archipelago, the annual amount of winter rain has been considerably greater than at the Svalbard Airport station in central Spitsbergen. This has caused more severe icing events and harsher conditions for coastal reindeer. But inland, warmer summer temperatures have promoted plant growth, partly offsetting the negative effects of winter rain. As a result, population trends have diverged: while reindeer numbers have not increased on the coast, they have grown more than threefold in central Spitsbergen.

The COAT observatory shows that even within a single Arctic archipelago—in

this case, Svalbard—climate change can shape populations in very different ways, with local weather patterns tipping the balance between growth and decline. Put simply, in inland Spitsbergen, the positive effects of summer warming have outweighed the negative effects of winter warming, leading to a steep rise in population size, while on the west coast, the opposite appears to be the case.

Rapid climate change effects and reindeer responses are revealing uncertainties and new concerns about how this cold-adapted species will cope as the pace of change accelerates. The big question is whether Svalbard's reindeer—and other Arctic wildlife—can keep adapting to a climate that is reshaping their world so quickly. □

COAT: Norway's Arctic early-warning system

The [Climate-ecological Observatory for Arctic Tundra \(COAT\)](#) is a Norwegian program that tracks the effects of rapid climate change in the far north. COAT uses extensive fieldwork, satellite and drone imagery, weather stations, and automated sound and photo monitoring to document shifts across entire ecosystems—from plants to predators. Reindeer are a key focus: COAT researchers track population trends, forage quantity and quality, and the cascading effects of climate warming

on reindeer health and survival. This work helps explain how changing snow and vegetation conditions influence reindeer movements and the wider tundra food web.

Since 2010, COAT has grown into an international research hub, contributing data to nearly 300 publications, including Arctic Council reports. By revealing how ecosystems are transforming, COAT aims to equip Norway and the global community with the knowledge needed to manage and adapt to the climate crisis.

The reindeer population in Adventdalen, close to the main settlement of Longyearbyen, has been monitored since 1979. The reindeer are counted by age and sex in late June, when they are still in winter fur and easy to spot. The population here has increased more than threefold since the late 1970s.



The summer siege

MOSQUITOES, FORAGE AND THE FUTURE OF ARCTIC CARIBOU

Climate change in the Arctic is altering summer forage and insect conditions for migratory caribou. Warmer, earlier summers can mean increased forage quantity, but reduced quality. At the same time, these conditions can trigger earlier, more intense periods of insect harassment. As **HEATHER JOHNSON** writes, these changes are associated with shifts in migratory caribou behaviours and distributions, along with their ability to survive and reproduce.

UNDER THE MIDNIGHT sun, the Arctic tundra is transformed. The frozen, dark, windswept landscapes of winter are remade by blooming cottongrass, the arrival of millions of birds, the buzzing of mosquitoes, and the return of thousands of migratory caribou. These caribou have just completed one of the longest land migrations on Earth, travelling hundreds of kilometres to reach their calving and summer grounds at the top of North America.

Researchers initially speculated that warmer summers in the Arctic would benefit migratory caribou. After all, these are herbivores that spend most of the year in extreme winter conditions, surviving on lichens and dead vegetation. Shouldn't a longer, warmer summer be better for them?

However, paradoxically, we are seeing the opposite. Even as the Arctic has become "greener," with more productive growing seasons, most migratory

caribou herds across North America have declined. This pattern has raised urgent questions about the influence of summer habitat on caribou and how their populations may be affected in the future.

CHANGING SUMMER CONDITIONS

The Arctic summer provides caribou with an abundance of fresh, green plants that supply the fat and protein they need to recover from winter and fuel the next generation of calves. Although summer is an important time for accumulating these nutrients, it is also when caribou are harassed by insects—primarily mosquitoes and oestrid flies (bot or warble flies). When harassment is severe, caribou spend less time eating and more time fleeing to cooler, windier areas.

The problem: while these areas offer relief from the bugs, they also offer less food.

Both summer forage and insect harassment shape caribou behaviour—and both, in turn, are strongly affected by climate conditions. Longer, warmer Arctic summers alter the abundance, quality and timing of summer forage available for caribou while also



Caribou cow and calf, Archimedes Ridge, Alaska.

likely reducing their opportunity to eat because of earlier, more intense periods of insect harassment.

To better understand how these conditions may affect caribou in the future, the US Geological Survey worked with partners to conduct research on the

Central Arctic herd on the North Slope of Alaska. We collected data on the quantity and quality of important summer forage (plants like willow, dwarf birch and tussock cottongrass) and how these changed throughout the season while also modelling mosquito activity based on wind and temperature data. Additionally, we put GPS tags on adult female caribou to see how their move-

ments, habitat use, survival and reproduction responded to annual changes in summer conditions.

CARIBOU RESPONSES

We found that earlier, warmer summers were associated with greater quantities (in terms of biomass) of some forage plants for caribou, but also with

Female caribou survived better when they had access to higher forage biomass, and they were more likely to produce calves after summers with higher forage protein. But greater mosquito harassment reduced both female survival and reproduction.



HEATHER JOHNSON is a research wildlife biologist with the US Geological Survey.



Photo Credit: Alexis Bonogolsky

Mosquitos swarm above a field of cottongrass in the Arctic National Wildlife Refuge.

reduced forage protein—important for reproduction. Also, earlier, warmer summers were predicted to come with earlier and more severe periods of mosquito harassment. Importantly, we found that caribou behaviour, survival and rates of reproduction responded to changes in summer habitat conditions.

Early in the summer, caribou sought areas with higher forage quality, especially protein. Later in the summer, after plants had matured and protein declined, caribou shifted to areas with higher forage biomass, enabling fat storage. They also avoided areas predicted to have higher mosquito harassment—more than doubling their movement rates when harassment was high as they sought insect relief.

In fact, intense mosquito harassment hindered caribou from foraging effectively and reduced their use of high-quality plants. These responses drove major shifts in caribou distributions, with the herd moving north to cooler, windier coastal areas early in the summer and shifting to southern inland areas later in the season.

We also found that year-to-year changes in summer conditions had

consequences for caribou survival and reproduction. Female caribou survived better when they had access to higher forage biomass, and they were more likely to produce calves after summers with higher forage protein. But greater mosquito harassment reduced both female survival and reproduction. In addition, we found that summers with both low forage protein and high harassment had a particularly pronounced effect at reducing calf production the following year. These conditions, associated with earlier, warmer summers, are expected to occur more frequently in the future.

Our research is showing how climate change is affecting summer habitat for migratory Arctic caribou, leading to shifts in their behaviour, distributions and demographics. We are continuing to investigate these relationships in other caribou herds, using additional data types and new technologies. Collectively, this work will be used to anticipate how caribou populations may respond to future environmental conditions and to identify important management and conservation strategies. □

Sea ice signals

USING ARTIFICIAL INTELLIGENCE TO KEEP CARIBOU ICE HIGHWAYS CLEAR



A small cabin stands isolated on a frozen lake on the south coast of the Victoria Islands, surrounded by snow-covered tundra and ice ridges.

IceNet trains its models on decades of satellite observations. By learning from this vast historical dataset, the model can understand how sea ice develops in response to a wide range of atmospheric and ocean variables.

Every autumn, the Dolphin and Union caribou herd undertake a perilous sea ice crossing from Victoria Island in the Canadian Arctic to the mainland coast of Nunavut and the Northwest Territories in search of better winter foraging. But the impacts of climate change and mounting icebreaker traffic in the area are threatening this vital route. **ELLEN BOWLER** and **LISA-MARIE LECLERC** explain how sea ice forecasts that use artificial intelligence (AI) could help predict caribou crossing times and inform proactive conservation.

IT'S ALREADY THE start of the fall migration season in the north, and the Dolphin and Union caribou herd is gathering on the south coast of Victoria Island. The caribou are waiting for a stable platform of sea ice to form a bridge that will allow them to journey south to their mainland winter pastures: connectivity between the caribou's summering and wintering ranges is critical to their ability to thrive and reproduce. But a warming climate and transiting icebreaking vessels—which create open water leads—can delay the formation of these essential ice highways.

On the frontlines of this issue, local teams and Indigenous communities are developing solutions to manage the pressures on caribou and people that use the same ice highways. Vessel awareness is also a top priority during the open-water season, given that large ships pose serious risks to everyone navigating the changing Arctic seascape. Communication between multiple groups, including Hunters and Trappers Organizations, governments and vessel operators, is crucial.

A few initiatives have already been

launched—for example, a Notice to Mariners system now recommends that ship captains communicate with community contacts during caribou migration times to find out about the risks. The system also recommends that ships adopt safe transit speeds to avoid disrupting the migration.

DEALING WITH UNPREDICTABILITY

But a major challenge remains: the timing of the caribou's crossing is highly variable. Caribou are known to begin crossing as soon as the sea ice is stable, but that timing varies annually.

As a result, advisories must cover wide time frames and may not precisely reflect the actual migration timing in any specific year. These advisories could prove even more insufficient as the climate continues to change. We need to know with greater certainty when the ice will form each year.

But sea ice forecasting is a notoriously difficult task that traditional physics-based models have struggled with. The models often fail to produce predictions at an accuracy or resolution that is relevant for people in the Arctic, despite requiring huge

Local teams and Indigenous communities are developing solutions to manage the pressures on caribou and people that use the same ice highways.



ELLEN BOWLER is a machine learning researcher with the British Antarctic Survey's AI Lab.



LISA-MARIE LECLERC is a regional biologist for the Kitikmeot region of Nunavut.



A herd of barren-ground caribou move through a snowy landscape in Wapusk National Park, Manitoba, Canada.

Photo credit: © Peter Ewins / WWF-Canada

computing resources and large teams to deploy.

This is where IceNet, a cutting-edge sea ice forecasting initiative based on AI and led by the British Antarctic Survey and Alan Turing Institute, can help. IceNet trains its models on decades of satellite observations. By learning from this vast historical dataset, the model can understand how sea ice develops in response to a wide range of atmospheric and ocean variables. It has not only proved to be more accurate than leading physics-based models, but also produces forecasts in seconds on a normal laptop—a game-changer for time-sensitive decision-making.

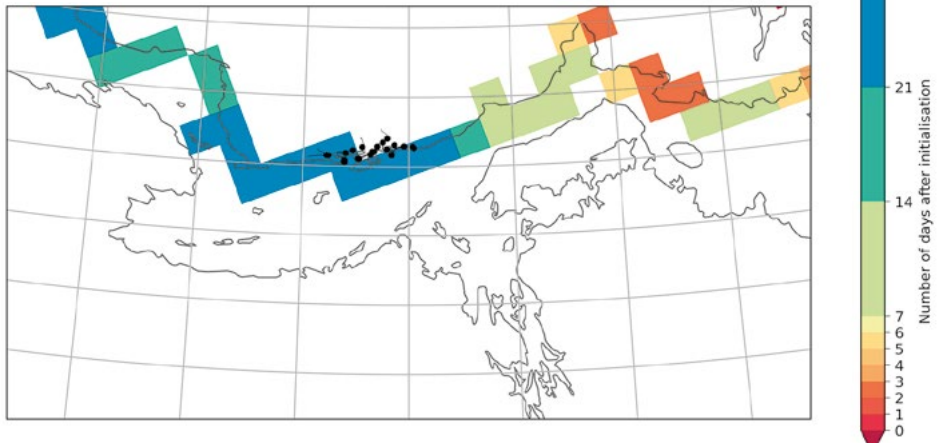
AI MEETS LOCAL KNOWLEDGE

To create a tool for caribou conservation, we combined IceNet's forecasting abilities with local expertise. For decades, the Government of Nunavut has conducted extensive research on the Dolphin and Union caribou using GPS collars, building up a wealth of telemetry data. By fusing these data with satellite observations of sea ice, we were able to build a deeper understanding of how migration timing relates to ice formation.

Now, instead of just forecasting sea ice, we can use IceNet to predict when the caribou are most likely to begin migrating. The software tools allow experts to review forecasts and migration predictions and integrate the information into other knowledge and data streams. These early-warning alerts and tools could lead to more finely tuned conservation measures, such as by refining estimates of when icebreakers should avoid an area or giving ship operators advance notice so they can adjust their plans, ensuring safe passage for caribou.

For people who live in the Arctic, where culture is deeply intertwined with caribou, developing problem-solving tools that can inform strong conservation measures alongside future economic development will be vital as the climate continues to change. This AI-based framework could play a part in the future of conservation and management in the region. For example, beyond its uses to protect the Dolphin and Union caribou, the technology could be adapted to predict when polar bears are likely to come ashore near communities and alert residents of potential conflicts. It could also be

Countdown to safe sea ice for caribou



This example of an IceNet early-warning map, generated with a start date of October 17, 2022, predicted how long it would take from that date for the sea ice to start reaching a safe crossing level for caribou (red indicates sooner, blue indicates later). The black dots are the real-time GPS locations of caribou on the date the map was generated. In this example, even though the herds were already gathered at the coast, IceNet predicted that it would be two or three weeks before safe ice formed. Conservationists can use IceNet information to alert icebreaking vessels to high-risk times and places.

tapped to help protect whale migration corridors and safeguard large walrus haul-out sites from increasing human pressures.

In the face of rapid climate change, combining local expertise with innovative technology is crucial to building

adaptive measures. By developing tools like IceNet in collaboration with people who live and work in the Arctic, we can build solutions for people and wildlife as they adapt to a swiftly changing ice world. □

Eating grass, slowing climate change

CARIBOU AND MUSKOXEN SHAPE THE PAST AND FUTURE ARCTIC

In the rapidly warming Arctic, grasslands are shrinking and shrubs are spreading, speeding up permafrost thaw and global climate warming. As **JEFF KERBY** writes, some researchers wonder if one solution might lie with the tundra's few remaining giants—caribou and muskoxen—whose grazing and trampling could help hold the line.

I SPENT MY first summer in Greenland 15 years ago camped on a patch of grass overlooking a glacial lake rimmed by rocky ridges. Back then, as a student, I was tracking caribou and muskoxen demographics and noting how plants raced through their growth stages in the short Arctic summer.

These days, when I return with students of my own, I can still find that campsite. But shrubs have grown to block the lake view, and years of warm, wet summers have turned the firm, grassy ground into a mossy patch that oozes brown water with every footstep.



JEFF KERBY is a geographer and landscape ecologist at the University of Cambridge (UK) & Dartmouth College (US) who works with interdisciplinary teams and local communities to better understand how large herbivores shape landscapes and ecosystems.

The spot I once knew is gone.

Satellite images over the past 40 years show similar changes across tundra regions of the rapidly warming Arctic. The question many researchers are now asking is: can large herbivores—like caribou and muskoxen—slow or even reverse what is being lost?

Tundra, the verdant but treeless land north of the boreal forest, has always been shaped by large herbivores. Although only caribou and muskoxen remain today, dozens of species roamed its grasslands during the last ice age. These animals are also central to the human history of the Arctic, sustaining peoples who followed the retreating ice millennia ago and remaining today as pillars of northern cultures and economies.

NATURE'S GRAZING GUARDIANS

For the past three decades, my colleagues and I have combined ecological observations and field experiments to

study how herbivores are responding as warmer and wetter conditions that alter the timing and amount of plant growth in the tundra of West Greenland. We ask how animals might push back against vegetation change in the landscape—such as through grazing and altering snow and soil conditions.

These simple questions have complex answers, but the emerging picture is clear: animals at this study site are slowing the shift from grasslands to shrublands—though at their current numbers, they don't seem to be stopping it.

When grasslands diminish, populations of caribou and muskoxen often decline, either by moving elsewhere or having fewer surviving offspring. The proliferation of tall shrubs also changes how the tundra functions in several ways. First, shrubs are darker than grasses, so they absorb more heat from the sun and accelerate permafrost thaw. They also trap more snow, which (perhaps counter-intuitively) keeps the ground warmer in winter by insulating it from air that drops below -40°C . Shallower annual freezes allow microbes living in the Arctic soils to start breaking down the region's immense stores of organic matter earlier in the summer, giving them more time to release greenhouse gases like carbon dioxide and methane that had been locked away in permafrost.

All these changes promote a warmer Arctic and reinforce positive climate feedbacks that affect the entire planet.

What could slow these patterns? Some researchers suggest the answer is simply more large herbivores—caribou and muskoxen, or even the animals that once roamed the north during the

last ice ages (the Pleistocene), such as horses and bison. Collectively, the larger and more diverse the population, the more they buffer the area against shrub expansion and the accelerated climate warming this brings. This is because grazing keeps shrubs short and promotes grasses, trampling breaks up snow and compresses the soil so the ground stays colder and drier, and droppings can fertilize grasses—all influences that tip the balance toward grassier landscapes that reflect more sunlight and slow permafrost thaw.

At high enough densities, the foraging and other impacts of large herbivores could even promote grassland expansion that would, in turn, support even more animals. This could benefit both local and international stakeholders.

Most of the attention on this idea has focused on experiments in Siberia, but the concept remains largely untested at scale and across the Arctic. Or does it?

CLUES ON THE TUNDRA

In the 1960s, muskoxen were introduced to West Greenland, a place they had not lived for dozens of millennia, if ever. Since then, their numbers have grown to more than 10,000, and the animals have become a core component of the local economy and culture. They now coexist with caribou, much as they did 15,000 years ago across broad

areas of the European, Asian and North American Arctic. In a time of rapid warming, we've found that their greater presence has slowed some of the shrubification under way in West Greenland. But we still don't know by how much across the region, or where in the landscape their impacts are strongest.

Not everywhere is shrubifying. In West Greenland, when I walk the tundra, I see more caribou and muskoxen in areas that have more grass. Are they causing this? Or are they simply following the shifting landscapes to places where change is slower or more sensitive to herbivores? Or is it both?

It's a chicken and egg problem that needs study across larger areas than traditional field projects. New tools—such as satellites, tracking collars and drones—are just now making this feasible. The stakes are high, both for Arctic communities and people far away

who may not even know what a muskox is, but stand to benefit from a slowdown in the pace of climate warming.

Scientific research can raise questions about management choices, but it must also embrace a core truth: northern peoples did not cause the greenhouse gas emissions that are now reshaping their homelands. Any exploration of the role of herbivores in moderating Arctic change must align first with the interests and involvement of the people who live there. There is no other way.

There is promise here—both in learning how herbivores might slow climate change, and in doing so through approaches led and coordinated by northern communities. Whether large herbivores like caribou are a solution to challenges at this scale is uncertain. But if explored responsibly, it offers a rare chance at a win for the Arctic environment, northern communities and the entire planet. □

Although only caribou and muskoxen remain today, dozens of species roamed Arctic's grasslands during the last ice age.

Muskoxen in Ilulissat, Greenland.

The Fortymile caribou herd diet

HUNGRIER SUMMERS MEAN HARDER WINTERS

Caribou—iconic symbols of the northern wilderness—are facing steep population declines as climate change reshapes their habitats. **LIBBY EHLERS** studied Alaska’s and Canada’s Fortymile caribou herd using GPS video camera collars to capture “bite-sized” views of their foraging behaviour. She explains what the research revealed about how competition, insects and shifting vegetation are affecting their survival and reproduction.

ACROSS THE SWEEPING alpine tundra landscapes of Alaska and Canada, the Fortymile caribou herd moves continuously, heads down, constantly searching for food beneath endless skies. During their two-month summer, swarms of mosquitoes and flies swirl in the heat, driving the animals to windswept ridges that provide needed relief from harassment but offer little to eat.

Traditionally, shrubs and lichens have carpeted these lands, but their availability to caribou is shifting as wildfires, warming and competition for high-quality summer foods change the landscape. For Indigenous Peoples, scientists and wildlife managers alike, caribou are more than animals—they are a vital thread in northern ecosystems. Understanding what, where and how these animals search for and find quality foods in summer has become a pressing question in a rapidly changing Arctic.

For many northern Indigenous and rural communities, caribou remain the most important land animal for food, clothing and cultural traditions. But many herds continue to decline. By



LIBBY EHLERS is an applied ecologist who is currently working with the California Department of Fish and Wildlife in the US.

2024, the Fortymile herd, which lives in east-central Alaska and west-central Yukon, had dropped to about 30,000 animals, down from 80,000 in 2017.

CHANGING FOOD SOURCES AND MORE INSECTS

One of the biggest reasons for this recent decline is climate change. Warmer temperatures, changing precipitation patterns, and stronger and more frequent wildfires are modifying the plant communities that make up the tundra. Shrubs and trees are spreading into open areas where lichens—the main winter food source for caribou—once thrived.

Unlike shrubs, lichens grow very slowly, sometimes taking decades to recover if they are damaged or eaten too heavily. This means that even if caribou find enough shrubs to eat in summer, they may struggle to survive in winter, when lichens are scarce.

Insects are also making life harder for caribou. Scientists estimate that in Alaska alone, there are trillions of mosquitoes in summer. These and other flies harass caribou so severely that they spend less time eating and more time trying to escape.

Warmer temperatures and changing wind patterns caused by climate change may exacerbate this problem, extending the duration and intensity of the insect season and leaving caribou in a

weaker nutritional state and potentially challenged to rebuild their bodies, give birth, and feed and raise their young during the short, demanding summer season.

A NEW WAY TO STUDY CARIBOU

To better understand how these pressures are affecting the Fortymile caribou herd, researchers from the University of Montana and a team of partners—including the Bureau of Land Management, Alaska Department of Game and Fish, Yukon government, and U.S. National Park Service—used a new technology: GPS video camera collars. These collars were fitted on caribou and recorded short video clips showing exactly what the animals were eating throughout summer and where they were feeding.

With help from community scientists and botanists, the team analyzed more than 18,000 videos and identified more than 7,000 food items. I led the team to build mathematical models to predict how caribou decided where to feed, considering food availability, weather, insect activity, wildfires and competition with other caribou.

The results showed clear patterns. When many caribou were packed into the same area, they ate fewer lichens—likely because competition between animals had already reduced the amount available. As a result, they turned more often to shrubs, especially willows, which are a higher-quality food in summer. Willow leaves provide proteins in summer and can regrow quickly after being eaten. This shift makes sense for short-term survival, but there are long-term risks if lichens are depleted in areas used year-round. Because the Fortymile herd’s summer and winter ranges largely overlap, heavy use in summer can damage lichens needed for winter, compromising survival and reproduction over time.

HOPE FOR THE FUTURE

Despite these challenges, our study points to constructive steps that can be taken. We used our data to build detailed seasonal maps of the herd’s range, showing areas where caribou



Researchers fitted GPS video camera collars on caribou from the Fortymile herd to find out where and what they ate throughout the summer. This image captured them munching on bearflower (Boykinia richardsonii).

were most likely to find high-quality foods in summer. These maps are now being used by wildlife managers to guide conservation and land-use decisions. This project also relied on extensive collaborations between scientists, government agencies and volunteers who classified thousands of video clips. By combining advanced technology with community involvement, we are finding new ways to understand and protect caribou.

The story of the Fortymile caribou herd is both a warning and an opportunity. It shows how climate change and shifting food communities can push an iconic species toward decline. But it also shows how creative tools, teamwork and diverse knowledge systems can help us find solutions. Protecting the spaces and

foods that caribou need to survive in a rapidly changing Arctic is not only vital for the animals themselves, but for the northern people and ecosystems that have always depended on them.

Caribou are truly adapted for the north. They are lifelines for people, indicators of ecosystem health, and symbols of resilience in a rapidly changing world. The story of the Fortymile caribou herd shows us that what caribou choose to eat today shapes whether they, and the communities that depend on them, can thrive tomorrow. Protecting their habitats and food sources now is the key to keeping this species—and the systems that thrive with them—alive for generations to come. □

We used our data to build detailed seasonal maps of the herd’s range, showing areas where caribou were most likely to find high-quality foods in summer. These maps are now being used by wildlife managers to guide conservation and land-use decisions.

Three herds, four scenarios

Regional differences in climate and vegetation will shape how Arctic caribou herds respond to rising temperatures.



CENTRAL ARCTIC

- Oceanic climate
- Cooler summers
- Rich tussock tundra vegetation



BATHURST

- Continental climate
- Hotter summers
- Sparse tundra on bedrock



CURRENT SITUATION

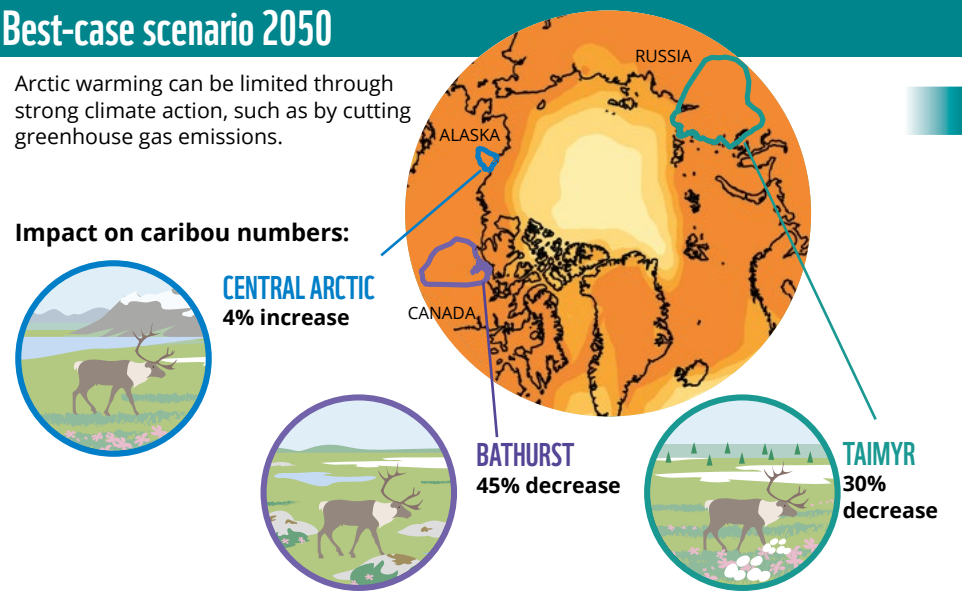


TAIMYR

- Continental climate
- Cooler summers by the seas
- Shrub and moss-rich tundra

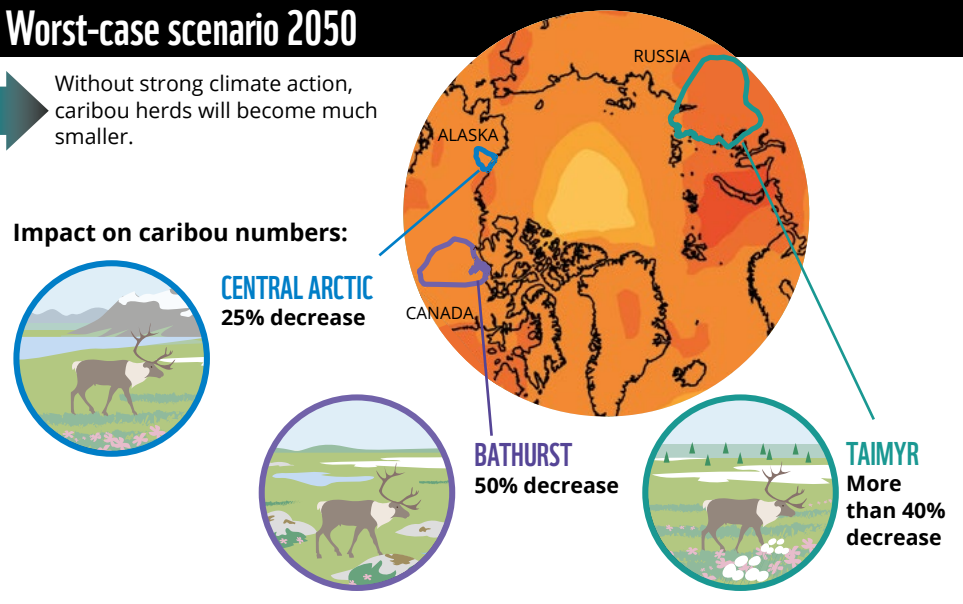
Best-case scenario 2050

Arctic warming can be limited through strong climate action, such as by cutting greenhouse gas emissions.



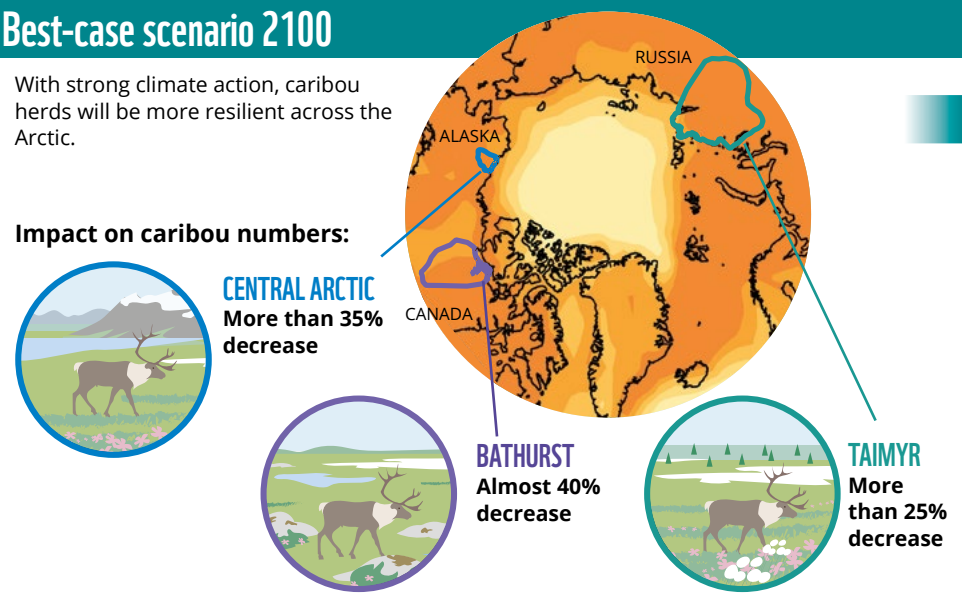
Worst-case scenario 2050

Without strong climate action, caribou herds will become much smaller.



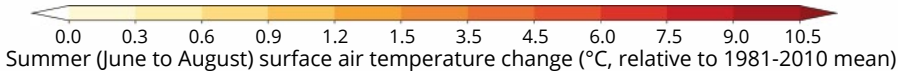
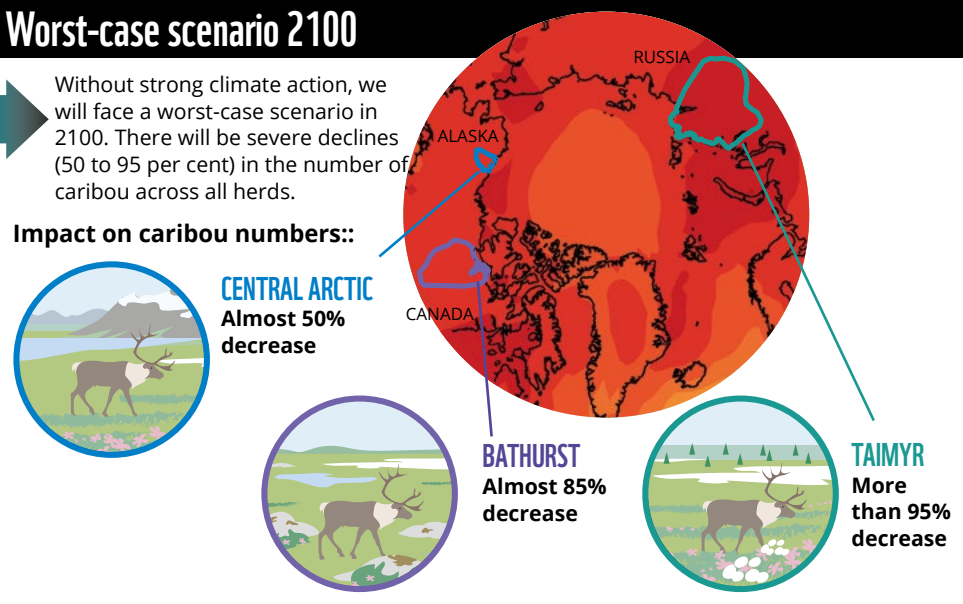
Best-case scenario 2100

With strong climate action, caribou herds will be more resilient across the Arctic.



Worst-case scenario 2100

Without strong climate action, we will face a worst-case scenario in 2100. There will be severe declines (50 to 95 per cent) in the number of caribou across all herds.



Energy modelling

WHAT THE FUTURE MAY HOLD FOR ARCTIC CARIBOU

There's no question that a warmer climate is mostly bad news for Arctic caribou. By causing heat stress, increasing insect harassment in summer, and making it hard to find food after rain-on-snow events in winter, climate changes constitute a looming black cloud on the caribou's horizon. On the other hand, warmer summers also benefit Arctic plants, especially shrubs—which means more food for caribou—and climate varies regionally across the Arctic.

So, just what does the future look like for migratory tundra caribou herds across the Arctic? The Caribou Futures project is trying to answer that question.

THE WWF GLOBAL Arctic Programme asked two Canadian caribou biologists, Anne Gunn and Don Russell, to discuss the future of Arctic caribou in a warmer climate and specifically how regional climate variations and their effects on vegetation will influence how caribou herds respond.

"The project is trying to give us a glimpse into the future for different migratory caribou herds to see how they might develop under different climate change scenarios," explains Ronja Wedegärtner, a project lead with WWF. "It's also about giving policymakers and the public a sense of what to expect so they know how and where to act."

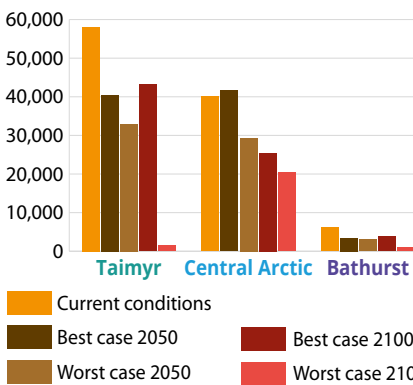
PROVIDING A SNAPSHOT OF CARIBOU'S FUTURE

Gunn and Russell examined how three migratory tundra caribou herds in different regions—with different climates and vegetation—might fare under best- and worst-case warming scenarios.

Although they don't have a crystal ball, the pair of biologists used a modelling tool built from field data collected by many people over decades.

"The model is unique—there is no other like it for caribou, or even for any other northern hoofed mammals. This is partly because of its detail, but mostly because it is the only model that considers both forage intake and

Current and projected caribou numbers





Anne Gunn

energy output, such as the cost of seasonal movements or providing milk to a calf,” says Gunn, who coordinates the CircumArctic Rangifer Monitoring and Assessment Network, better known as CARMA, along with Russell.

The model calculates caribou energy budgets and forage intake to predict future caribou population trends under different climate change scenarios. By incorporating data from 50 years of research, it can assess a caribou herd’s food intake and translate it into the amount of energy and protein a caribou cow needs for activities like getting pregnant, growing a calf, producing milk, or replenishing reserves that get depleted during the winter.

LOOKING AT THREE KEY ARCTIC HERDS

To come up with their projections, Gunn and Russell used three representative migratory caribou herds: the Central Arctic herd on Alaska’s coast, the inland Bathurst herd in Nunavut, Canada, and the coastal Taimyr herd in Russia.

What they found was that, while all three herds will likely decline under both the best- and worst-case scenarios, the future doesn’t look the same for all of them.

The biologists modelled two global climate scenarios: the best-case scenario assumes strong global action to reduce greenhouse gas emissions, leading to slower warming and fewer extreme climate shifts. The worst-case scenario assumes emissions continue to rise,



Don Russell

resulting in higher temperatures and more frequent extremes by 2100. Current global trends suggest we are closer to the higher-emissions trajectory, though future policy choices could still alter the path.

For caribou, one herd in the coastal Central Arctic initially fares well enough in the first decades of the optimistic scenario, but declines over the longer term. The Bathurst and Taimyr herds will likely decline under both scenarios, and the losses are steeper and more widespread in the worst case.

Mean monthly temperatures in the worst-case scenario will exceed historic maximums for all three herds by 2100. But the Bathurst herd will likely see the highest number of hot days—a jump from 9 to 95 days with temperatures higher than 20°C—as well as the highest rate of decline in herd size. That’s because higher temperatures mean increased insect harassment and more heat stress, reducing foraging time and making reproduction less likely.

The Bathurst herd also faces a future in which a proposed road could run right through its migratory route—which could be more bad news for the herd’s future.

“Through other work we have been doing in Nunavut, we were able to make some projections in terms of how a road is going to impact that herd. But then we add in the model’s projections for climate change, and we can see that climate is going to play a big role in the herd’s future,” explains Russell, who has studied caribou for almost 50 years.

OFFERING AN URGENT WARNING

Wedegärtner says it can be shocking to look at the projected herd numbers from the model outputs. “It’s really pointing a finger at the issue,” she says. “I think people know climate change is going to do something to caribou, but this project is giving them the space to imagine what that something could be—and from that comes the urgency to act.”

So is all hope lost for Arctic caribou? The simple answer is no. According to Gunn and Russell, there is still time to turn things around—if the world responds to the warnings.

“Since glacial times, caribou have been able to adapt to sweeping climate changes because of their ability to move to ranges where they can survive,” says Russell. “This tells us

that managing roads and developments to keep them permeable to caribou movements is a key management tool to increase the adaptive capacity of caribou faced with a rapidly warming Arctic climate.”

It also comes down to greenhouse gas emissions. Reducing emissions and the effects of climate change to the greatest extent possible will offer caribou herds across the Arctic the best chance.

Still, the model outputs are a stark reminder of what is at risk for caribou—and the people who revere and depend on them—if we don’t act now. ■

While all three herds will likely decline under both the best- and worst-case scenarios, the future doesn't look the same for all of them.



Barren-ground caribou in Nunavut.

Photo credit: Lynne S. Rollin

A shared responsibility

HOPE AND HURDLES FOR THE BEVERLY AND QAMANIRJUAQ HERDS

After 30 years of decline, there is hopeful news for the Beverly and Qamanirjuaq caribou herds in Canada. As **TINA GIROUX-ROBILLARD** writes, the Beverly herd is finally showing a significant increase, and the Qamanirjuaq herd’s decline has slowed.

WHETHER YOU KNOW them as ethén, tuktu, atihk or caribou, the Beverly and Qamanirjuaq barren-ground herds are central to life in northern Canada. Their annual migrations stretch across Nunavut, the Northwest Territories, northern Manitoba and Saskatchewan through the traditional territories of Cree, Dene, Inuit and Métis peoples.

Caribou have long been a vital source of food, culture and community life



TINA GIROUX-ROBILLARD is the executive director of the Beverly and Qamanirjuaq Caribou Management Board.

in the north. Many residents identify themselves as “caribou people”: they are fundamentally defined by caribou, with cultural practices that are inextricable from the animals that have provided food, clothing, teachings and life since time immemorial.

This history is why the Beverly and Qamanirjuaq Caribou Management Board (BQCMB) exists: to unite representatives across the range in safeguarding caribou as pressures from climate change and human activity mount.

HOPEFUL NEWS FOR THESE HERDS

At the BQCMB’s meeting in Rankin Inlet, Nunavut this spring, Government of Nunavut biologists presented encour-

aging results from their 2023 aerial survey of Beverly caribou. The herd is now estimated at 152,000 animals—up from 103,400 in 2018—with nearly 70,000 breeding females. Strong calf recruitment is likely behind this eight per cent annual increase as more young caribou survive to join the breeding population—a key factor for long-term recovery.

Earlier surveys had charted a drop to 103,400 caribou in 2018 from 276,000 in 1994, which makes the recent increase especially noteworthy. Although it is hard to pinpoint exactly what is behind the increase, reasons may include natural population fluctuations (as understood through Indigenous knowledge), favourable forage, or beneficial changes in harvest and predation patterns.

The Qamanirjuaq herd’s latest survey tells a more cautious story. This herd is still declining, although this decline has slowed to two per cent a year, down from five per cent. Cow-to-calf ratios also suggest a continued slowing of the decline, though more assessments are needed to determine the herd’s status.

CHALLENGES AHEAD

Because caribou rely on large, undisturbed landscapes, they are particularly vulnerable to human activity. Arctic development in the form of mines, roads and powerlines has fragmented their habitat, increased human access to caribou, and created migratory bar-

riers. Illegal harvesting and wastage (when animals are killed but not fully used) remain a concern in many range communities, including along winter roads like the one from Tibbitt to Con-twoyto in the Northwest Territories.

Climate change compounds these pressures, altering habitat by thinning ice crossings, changing vegetation, and increasing the frequency and severity of wildfires. Indirect climate effects on caribou are also rising, including threats from new diseases and parasites.

In the face of these pressures, solutions rooted in both Indigenous knowledge and science are guiding the way forward.

SHARED KNOWLEDGE AND RESPONSIBILITY

The Beverly and Qamanirjuaq Caribou Management Plan, titled *Caribou is Life*, is the board’s roadmap for minimizing pressures and sustaining the herds for generations. The plan synthesizes two ways of knowing: Traditional Knowledge shared by Indigenous communities, and scientific insights from surveys, research and monitoring. By combining these systems, the plan helps communities and governments work collaboratively to watch over the herds, respect the land, and pass traditions on to the next generation.

Across the range, community- and land-based programmes are strongholds of caribou stewardship. Guardians’ programmes, monitoring projects, and Indigenous Protected and Conserved Areas (IPCAs) combine culture and conservation.

In northern Manitoba, the Seal River Watershed is well on its way to becoming an IPCA through the efforts of four Dene and Cree Nations. In northern Saskatchewan, the Athabasca Denesūliné are protecting caribou wintering habitat through the Etthén Néné Stewardship Areas. In the Northwest Territories, Thaidene Néné (led by Lutsël K’é Dene First Nation) and the neighbouring Thelon Wildlife Sanctuary safeguard one of the largest protected land areas in North America.

Alongside teaching youth respectful harvesting methods, these initiatives conserve wildlife, ecosystems and cultural connections between caribou, communities and the land. This spirit of collaboration builds on decades of work across regions and cultures.

CARRYING THE WORK FORWARD

For many across the north, caribou are more than wildlife—they are a way of life passed down over generations. As roads and industrial corridors reshape habitat in a changing climate, the work of the BQCMB is pressing.

As we approach our 100th meeting in 2026, our board is investing in youth leadership, Indigenous-led conservation and IPCAs, and expanding the education it offers on respectful harvest.

But stewardship cannot rest solely on the shoulders of the board. It is the shared responsibility of governments, industry, communities, harvesters and individuals alike to ensure the Beverly and Qamanirjuaq herds remain strong for generations to come. □

BQCMB board members and staff in Rankin Inlet, Nunavut:

Joanie Kennah, Manitoba Natural Resources and Indigenous Futures; Dennis Larocque, Camsell Portage, Saskatchewan; Gilly McNaughton, BQCMB wildlife biologist; Fiona Rettie, BQCMB communications specialist; Peter Gazandlare, Hatchet Lake Denesūliné First Nation, Saskatchewan; James Hodson, Northwest Territories Environment and Climate Change; Tina Giroux-Robillard, BQCMB executive director; Atuut Shouldice, Crown-Indigenous Relations and Northern Affairs Canada; Matthew Tokaruk, Saskatchewan Ministry of Environment.

Stewardship is the shared responsibility of governments, industry, communities, harvesters and individuals alike to ensure the Beverly and Qamanirjuaq herds remain strong for generations to come.



THE BQCMB

Created in 1982 amid concerns over declining herds, the BQCMB is the oldest caribou co-management board in North America. It is guided by the simple truth that no single jurisdiction or community can protect migratory caribou on its own.

Over the years, the board has reviewed development proposals, presented a united voice during regulatory processes, advanced community-led, respectful harvest campaigns, and supported Indigenous-led conservation efforts. This foundation of cooperative management shapes today’s efforts to safeguard caribou and their habitat.



Photo credit: National Film Board of Canada/Library and Archives Canada/PA-176850

A northern legacy

Caribou run across a snow-covered landscape in Yukon, Canada circa 1950. Early aerial photographs like this one gave researchers rare glimpses into herd dynamics in Canada's North.



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