

Migratory Tundra Caribou in a Warmer Climate

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Headlines

- Arctic migratory tundra caribou populations have declined by 65% overall over the last 2-3 decades. More recently, the relatively smaller coastal herds in the western Arctic are showing signs of recovery while the larger inland herds are either stable or continuing to decline.
- Warmer summer and fall temperatures, changes in winter snowfall, and an increasing human footprint collectively stress Arctic caribou, altering their distribution, movements, survival, and productivity.
- The extent of recent herd declines and onsets of recoveries varies regionally, consistent with regional climate trends. Arctic regions of greatest projected summer warming are projected to see the largest continued population declines.
- Sharing knowledge is essential, as those charged with managing caribou endeavor to more fully understand climate impacts on herd health and implement strategies that encourage herd growth, while accommodating the cultural, nutritional, and spiritual relationships northern people have with caribou.

Introduction

Climate influences almost every aspect of caribou ecology, which means the Arctic's rapid warming will have far-reaching, cascading, and complex impacts. The Arctic climate is strongly regional, such as differences between coastal and interior climates. Besides climate, geological influences on vegetation add to the regional differences which, in turn, complicate predicting how cold-adapted caribou (and their Eurasian counterpart, wild reindeer) can balance beneficial and adverse impacts of a warmer climate. Caribou spend about 3/4 of their day foraging and digesting, so how climate interacts with forage quality and quantity is key. However, climate impacts on arctic vegetation are complex; grasses, sedges and shrubs are likely to increase while many plant groups are relatively resilient to climate change (Callaghan et al. 2022).

Historically, the caribou's cyclic abundance (Gunn 2003) anchored their central role in arctic tundra food webs and Arctic Indigenous cultures through spiritual and nutritional sustenance. Migratory tundra caribou numbers increased to peak values in the 1990s and early 2000s (Table 1) but have since declined 65%, from 5.5 million to 1.88 million with timing varying regionally (Gunn 2016; Russell et al. 2018; CARMA unpubl. data). In the western Arctic, the coastal herds (Table 1) are, in general, smaller and

recovery has been underway for 6-16 years for 4 of the 5 herds. The five largest herds are inland (Taimyr, Bathurst, George River, Qamanirjuaq and Western Arctic), with peak herd sizes of close to or above 500,000 caribou. These herds have not yet started to recover and are either stable at low numbers or continuing to decline (Table 1, Fig. 1). Concerns are heightened for those herds as Indigenous Elders state that numbers have never been so low. Why caribou have declined is complicated: natural cycles have played a role but so has the changing landscape due to a greater human footprint and climate change.

Table 1. Trends among migratory tundra herds since recent peak numbers. In this table increasing and decreasing were assigned if there was a trend for 3 surveys in a row. Herd codes are: Teshekpuk Lake (TLH), Central Arctic (CAH), Cape Bathurst (CBH), Bluenose West (BNW), Porcupine (PCH), Western Arctic (WAH), Taimyr (TAI), Bluenose East (BNE), Bathurst (BAH), Qamanirjuaq (QCH), Leaf River (LRH), George River (GRH), and Kangerlussuaq-Sisimiut (KSH). The significance of Sedimentary versus Precambrian Shield geology relates to contrasts in vegetation communities and surficial hydrology. The herds labeled as either Coastal or Inland spend their calving and post-calving seasons in coastal or inland ranges, respectively.

Year	Sedimentary Geology					Precambrian Shield Geology							
	Coastal Calving/Post-calving					Inland Calving/Post-calving							
	Peak < 100,000					Peak > 100,000							
	TLH	CAH	CBH	BNW	PCH	WAH	TAI	BNE	BAH	QCH	LRH	GRH	KSH
2024													
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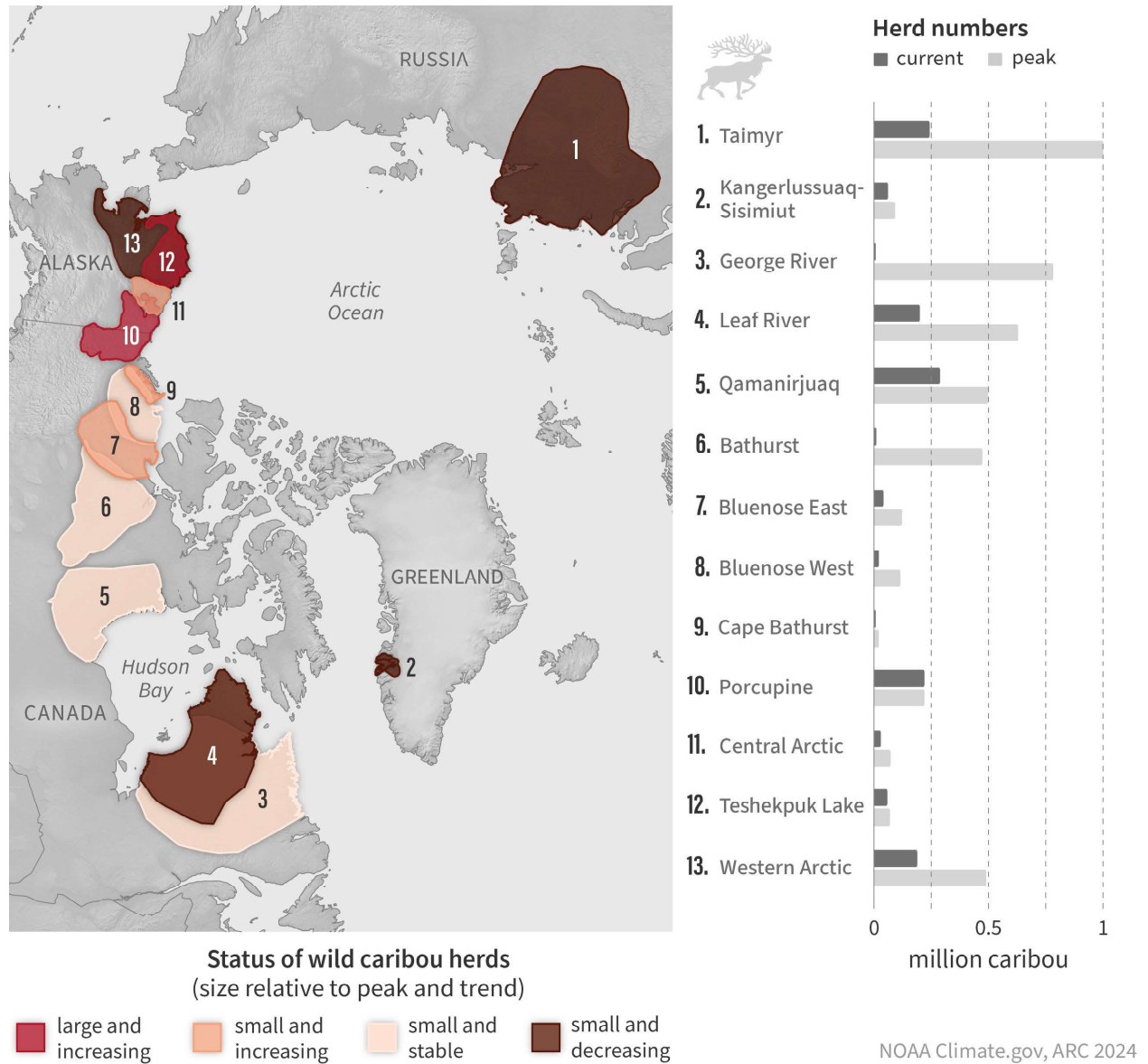


Fig. 1. Trends and herd size status among migratory tundra caribou herds since peak numbers in the 1990s and early 2000s.

Current and projected signals of the warmer climate for caribou

Since 1980, the fall warming trend across the Arctic is the most consistent climate signal (Russell et al. 2024). Warmer falls are correlated with increased risk of icing on winter ranges. The western coastal herds have earlier and warmer springs while the central continental herds have drier and warmer summers. Warmer and drier summers reduce adult survival (Russell et al. 2024) and Indigenous Knowledge emphasizes that caribou are healthy during cool, wet summers (Tłı̄chq Government 2022). The Western Arctic Herd in western Alaska has declined 70% since numbering 490,000 in 2003, which harvesters attribute partly to climate change. Although the herd has a maritime arctic climate, the herd calves and summers inland from the coast (Fig. 2). Communities have observed that reduced summer snow patches have impacted the herd’s ability to avoid insect harassment. On the winter ranges, days with freezing rain and rain-on-snow will likely increase as the fall temperature increases. Ice layers can

lock away terrestrial forage that overwintering caribou rely upon, impacting body condition and survival. For example, for the Western Arctic herd, an extreme midwinter thaw with rain in December 2005 left many caribou in poor body condition and cow survival declined to 70%.



Fig. 2. Caribou in fall range of the Western Arctic Herd of Alaska. Photo credit: K. Joly.

To project what a warmer climate may mean, we applied an existing model (Russell et al. 2021) for a coastal herd (Fig. 1; Central Arctic Herd), an interior continental herd (Bathurst Herd), and the central Siberian Taimyr Herd (Russell and Gunn 2024). Under the optimistic scenario (global temperature increases $<1.5^{\circ}\text{C}$ by 2100), the Russian and Alaskan coastal herds' summer range temperatures by 2100 remain between the historic mean daily and historic maximum daily temperature (historic period as 1980-2019) while the interior Bathurst Herd's average summers will be as hot as the historic maximum daily mean. Specifically, the annual average number of days $>19^{\circ}\text{C}$ is projected to increase from the historic period 14 days to 38 days by 2100 on the Bathurst Herd's summer range compared to 7 to 11 days for the Central Arctic Herd and 3 to 6 days for the Taimyr Herd. The hotter days cause caribou to reduce their forage intake partly in response to mosquito harassment but also to reduce internal heat generated by digestion (Trondrud et al. 2023). Resulting daily forage intake would be 8% less for the Bathurst Herd, 2% less for the Taimyr Herd, and unchanged for the Central Arctic Herd (Russell and

Gunn 2024). Forage intake impacts cow body weight in the fall, which dictates pregnancy rates and calf survival. For the optimistic scenario, the additional costs of climate change are that the Bathurst and Taimyr herds would decline to 71% and 67% of current herd size, respectively, but the Central Arctic herd would slightly increase (4% higher). However, under the pessimistic 2100 scenario (~4.4°C global warming by 2100), all three herds are projected to decline by 64%, 32%, and 9% of current levels for the Bathurst, Taimyr, and Central Arctic herds, respectively (Russell and Gunn 2024).

A warmer climate and the people who depend on caribou

Arctic caribou are adapted to annually variable weather, but projections of when their adaptability could be exceeded are uncertain, especially as there are other cumulative impacts on caribou seasonal ranges. For example, a warmer climate, landscape changes (including mining, roads, and railways), and increasing predation are driving reindeer herding in Finland toward tipping points when adaptive mechanisms reach their limits (Landauer et al. 2021). Adaptive mechanisms include caribou avoiding extremes in weather, such as icing on their winter ranges, by shifting their migratory pathways, but they are at risk if roads and railways limit their free passage. The observations of people who share the caribou's landscape emphasize that a warmer climate is already part of a changing landscape creating threats for caribou health and productivity and adding to the food security threats faced by the people who have long depended on them. Caribou will shift their ranges to adapt to a changing climate but that can have unexpected impacts when they encounter other uses of the landscapes. Inuit hunters are observing unexpected shifts in the Qamanirjuaq Herd's calving grounds after decades of calving in a relatively fixed location. The location of calving is partly tied to vegetation green up, which is now progressively earlier (Mallory et al. 2020; Cameron et al. 2020). Inuit hunters reported that the shift brought calving to the edge of an operational gold mine (NIRB 2023), which was unanticipated and a strong concern for the neighboring communities who depend on the Qamanirjuaq herd.

Indigenous Elders are afraid for the future of the Bathurst Herd, which they have depended on for thousands of years. They identify how the herd's hotter climate, mining, and associated roads are changing the herd's movements. The herd has declined 97% since the mid-1990s and the Wek'èezhìi Renewable Resources Board, a co-management body, has worked with communities, Indigenous governments, and the Government of the Northwest Territories to eliminate caribou harvesting and increase wolf harvests. The decline was partly a natural cycle but warmer summers, roads, traffic, and mines have contributed. Alarmingly, conservation actions have not led to herd recovery, which raises fears for its future given the predictions of a hotter climate across its interior range.

While the hotter climate projections are not encouraging for the long-term health and vitality of many of the Arctic caribou herds, the signals of a warmer climate are already measurable on the Arctic caribou ranges. Understanding when caribou reach the limits of their adaptability will require the observations and knowledge of people who share the ranges, as well as scientific monitoring. Sharing knowledge among all stakeholders is essential for the bodies charged with looking after caribou as they endeavor to contribute to the resilience for caribou and people across the Arctic landscapes.

Methods and data

We used estimates of caribou abundance from aerial surveys 1970 to 2023 (Gunn 2016; Russell et al. 2018; unpublished CARMA database). We derived seasonal herd-specific climates from the National Aeronautics and Space Administration's Modern Era Retrospective Analysis for Research and

Applications climate indicators clipped to herd-specific ranges (Russell et al. 2013). For future climates, we focused on average monthly temperature projections for late spring to fall for mid-century (2050) and end-century (2100) from the Coupled Model Intercomparison Project Phase 6 (CMIP6) global climate models with an optimistic SSP1-1.9 scenario (below 1.5°C global warming by 2100) and the pessimistic SSP5-85 (high emissions; ~4.4°C global warming by 2100) scenarios. We applied relationships of climate, population dynamics, and forage ecology for spring to fall to quantify climate change impacts using an existing integrative Caribou Cumulative Effects model (White et al. 2014; Russell et al 2021; Russell and Gunn 2024). Russell and Gunn (2024) presents a novel quantification of the regional impacts and the authors will make the report, the data inputs, and model output available on request. A journal publication of this report is in preparation.

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