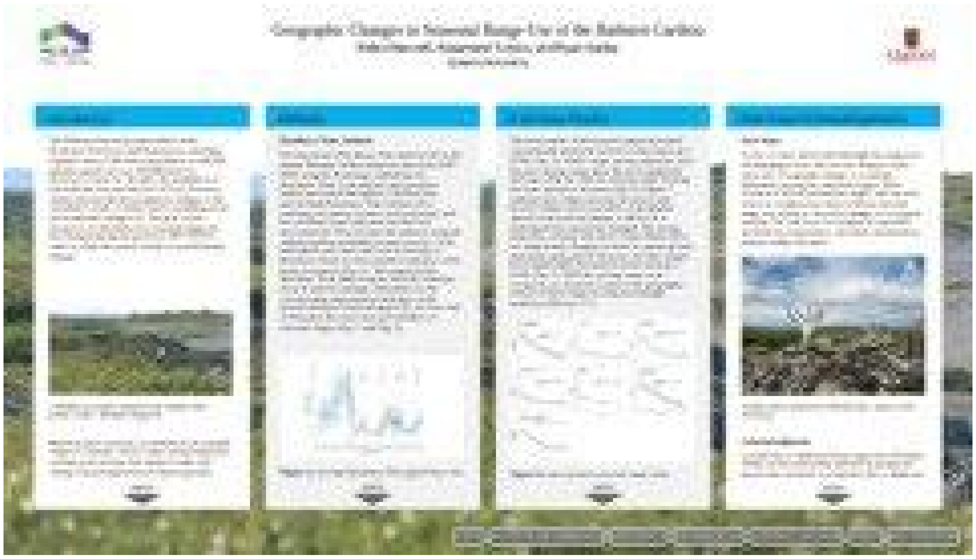
Geographic Changes in Seasonal Range-Use of the Bathurst Caribou



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INTRODUCTION

The Bathurst barren-ground caribou in the Northwest Territories and Nunavut are a herding ungulate that in 1996 had a population of 349,000 animals spread out over 390,000 km2 (1). However, in past two decades, the population of this herd has now declined by 97% (1). Previous studies discuss that this population collapse is the cumulative result of many factors, including recent environmental changes (1). The goal of this research is to determine how seasonal range-use has changed during the period of 1997-2019 in order to relate directional trends to environmental change.

A Bathurst caribou spotted near Yamba lake - photo credit - Michael Stefanuk

Based on prior research, we defined seven seasonal ranges to examine: *winter range, spring migration, calving, post-calving, late-summer range, fall rutting, and fall migration* (2). Barren-ground caribou winter below tree- line where their activity levels are most sedentary (3). In late April these animals conduct a massive migration north into the tundra to reach their *calving* grounds where they give birth (3). After *calving* these animals move south into their *summer range* (still above tree-line) and spend their time foraging (2). They congregate in October and conduct their *fall rut* (2). After *fall rut* they migrate south back into their *winter range* (2). Each one these seasonal events happens at different places within their greater home range and is also characterized by different levels of movement (3). By determining how these caribou are moving with a Residence Time analysis (4) and Lavielle segmentation (5), we can determine the exact timing of these events each year.


An esker and tundra landscape within the summer-range of the Bathurst caribou - photo credit - Joel Koop

METHODS

Residence Time Analysis

We performed a Residence Time analysis (4) on the annual Bathurst caribou telemetry data from 1997-2019 using the R package *Adehabitat* (5). Residence Time is an analysis that quantifies animal movement throughout a defined time period. High Residence Time indicate slow sedentary movement in more restricted areas, and low residence times indicates fast directed movement (4). We performed the analysis using all collared caribou available for each year (n = 8-32 individuals each year) and took an average of Residence Times to create profiles indicative of the herds movement (Fig. 1). We segmented the Residence Time data using the Lavielle technique (6) in R with the package *Adehabitat* (5). By corroborating segmentation with data on the general timing of seasonal ranges (2), we were able to determine the exact start and end dates of seasonal ranges (Fig. 1 and Fig. 2).

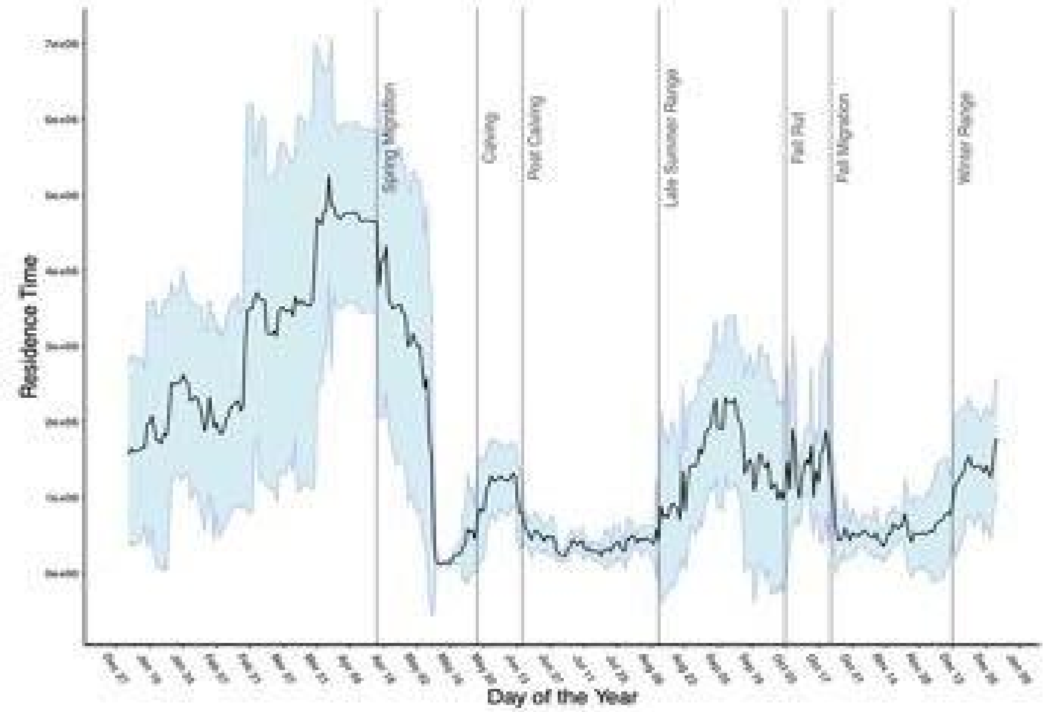

Figure 1: *Average Residence Time (black line) with standard deviation (blue ribbon) of 20 female caribou collared in 2011 plotted against day of the year. Residence Time was calculated using the AdeHabitat package in R (5). The Lavielle method of segmentation was used to separate homogenous types of movement (6). Each segment indicates the start of the seasonal range in 2011.*

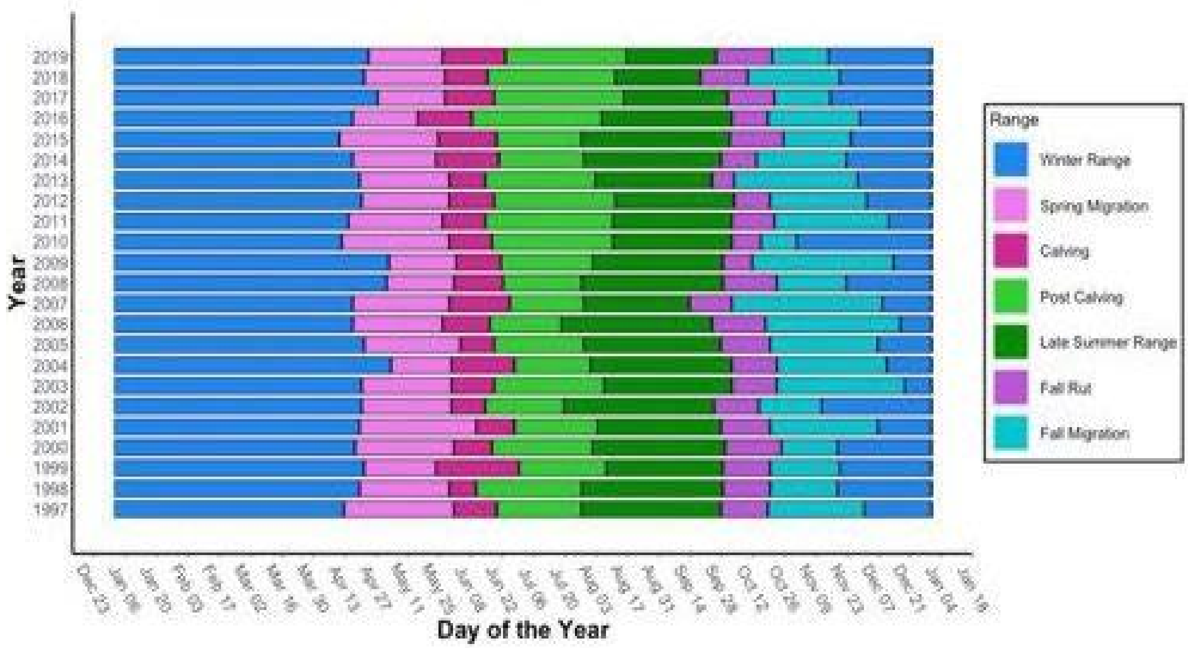

Figure 2: *Timelines of seasonal ranges each year against day of the year. Timelines indicate the start, end, and duration of each seasonal range by year. Information on timing of these events was dervied through our Residence Time analysis (5) and Lavielle segmentation (6).*

Brownian Bridge Mapping

To create maps of seasonal ranges we used Brownian Bridge mapping techniques (7) on our collar data. Point- data from telemetered collars are highly correlated as each successive point or observation is the result of a previous location. We used Brownian Bridge mapping as it also accounts for correlation in animal movement (7;8) and outperforms traditional kernel density mapping methods (8) (for example see Fig. 3).

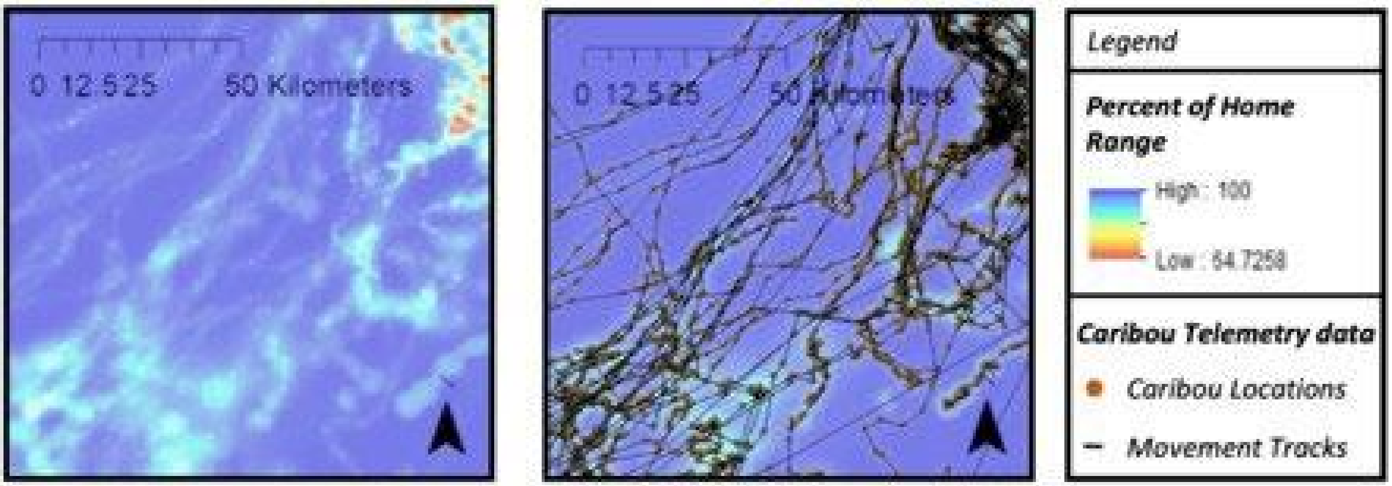

Figure 3: *An example of a Brownian bridge probability map without telemetry tracks overlaid (left panel) and with telemetry tracks overlaid (right panel). Each pixel in these maps indicates percent of total probability captured within a contour. The example illustrates how the Brownian Bridge method estimates probability in the direction the caribou are moving, rather than just producing fuzzy boundaries around individuals points.*

We first separated our telemetry data based on the annual timing of ranges according to our Residence Time analysis and Lavielle segmentation (Fig. 2). We then mapped the ranges based on observed separations. In total 161 (23 years x 7 seasonal ranges) distinct seasonal maps were created (for example see Fig. 4).

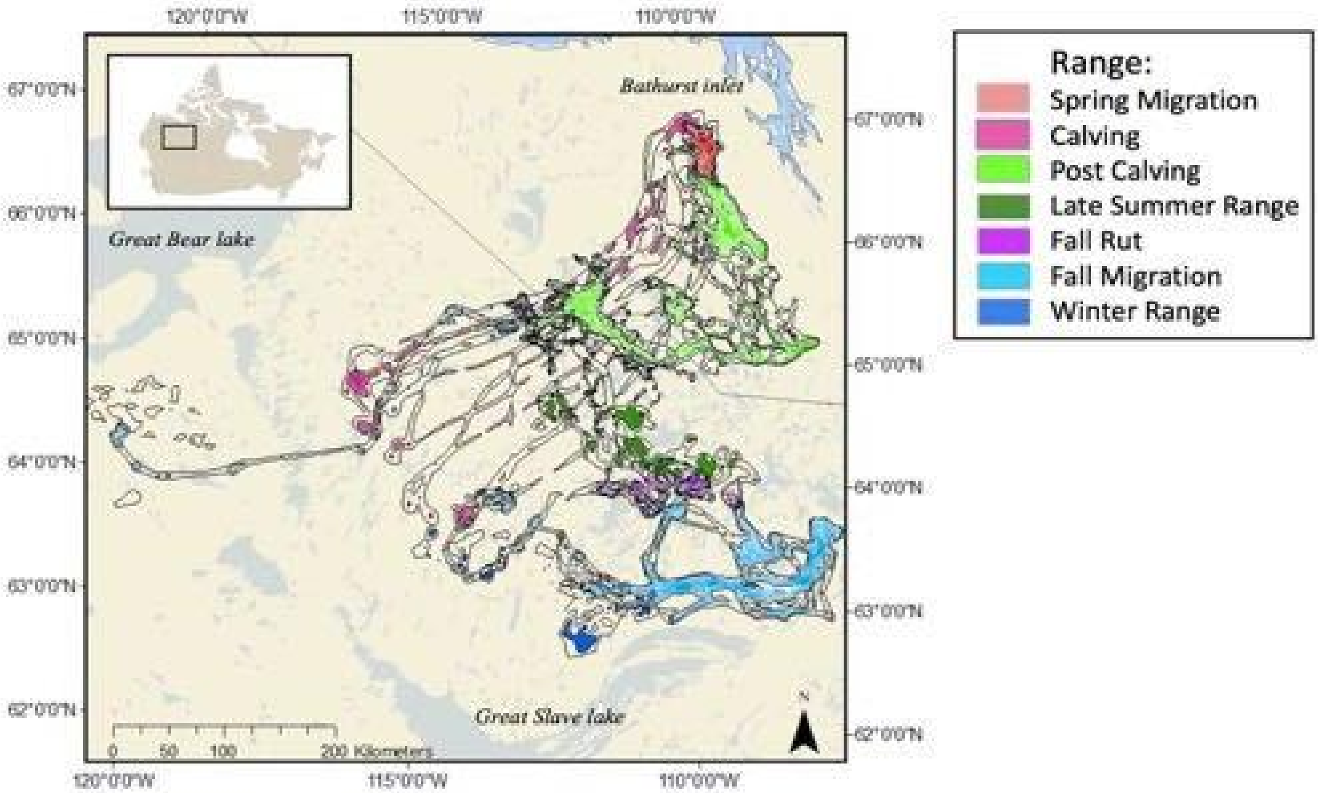

Figure 4: *Map of seven distinct ranges from 20 collared caribou from the Bathurst herd in 2011. Using collar data provided by the Government of Northwest territories, the 2011 dataset was segmented based on start and end dates of seasonal ranges derived from our Residence Time analysis (5). Maps were produced using Brownian Bridge probability estimation (7) on individual caribou trajectories and an average was then taken for each range. Each range is displayed at the 95% of the probability level (in colour) and at the 99% with a black line surrounding each range.*

Geographic Distribution Analysis

We used the function directional distribution within ArcGIS (version 10.5)(10), on our annual seasonal ranges to calculate the standard distance of a caribou in the *X* and *Y* direction of a polygon to create ellipses displaying standard distances (Fig. 5).

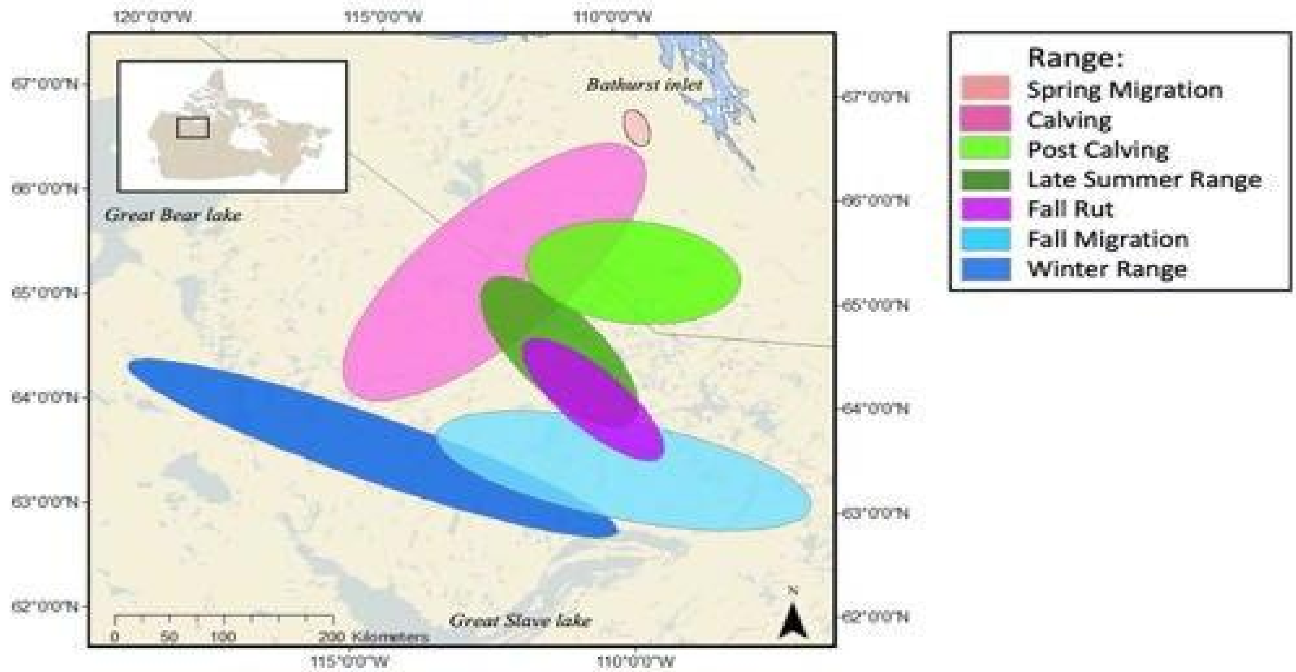

Figure 5: *Standard deviation ellipses of each seasonal range produced through Brownian Bridge techniques in 2011 (Fig. 3). Ellipses were produced using the function directional distribution in ArcGIS version 10.5(10) on each range polygon. This function determines the standard distance in both the X and Y direction and creates an ellipse based on the spread of your data. From these ellipses you gain information on area and centre of the ellipses.*

We used the centers of these ellipses to create a point file; which we converted to tracking files within ArcGIS (version 10.5; movies 1-7), allowing us to better visualize how the epicenter of these ranges have changed with time.

PRELIMINARY RESULTS

The areal extent of all seasonal ranges decreased exponentially during the period of observation ($p \leq 0.001$; Fig. 6). *Winter range, spring migration, and the post calving range* show the most significant decreases (Fig. 6); with the *calving range* showing the least amount of decrease (Fig. 6). Figure 7 indicates how ellipse area has decreased, and because ellipse area is a product of geographic spread of the seasonal ranges, it allows us to understand how spread has changed. The *spring migration*, calving, and *winter range* ellipses have not significantly changed in terms of spatial-spread during the study period. However, all other ranges have significantly decreased in areal extent ($p \leq 0.001$; Fig. 7). With the *calving range* as an exception, we observed a trend of the geographic centers of these ranges moving increasingly northwest (Movies 1-7).

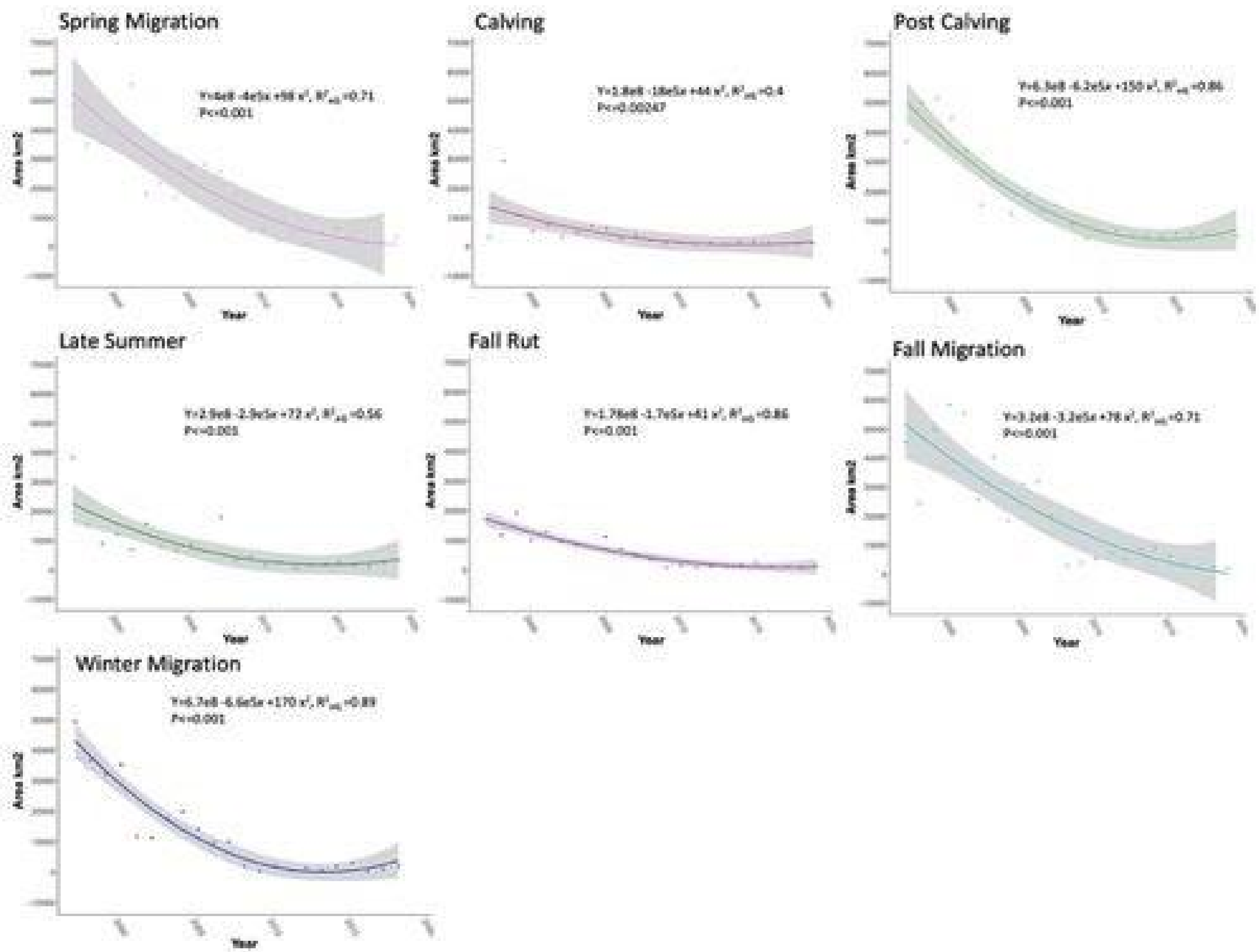

Figure 6: *Area of each seasonal range of the Bathurst Caribou in km2 by study year (1997-2019). Area is the total area at the 95% level derived from our Brownian Bridge maps (Fig. 4 is an example). We fitted data with exponential models and included standard error, equations, adjusted R2, and p-values in each panel.*

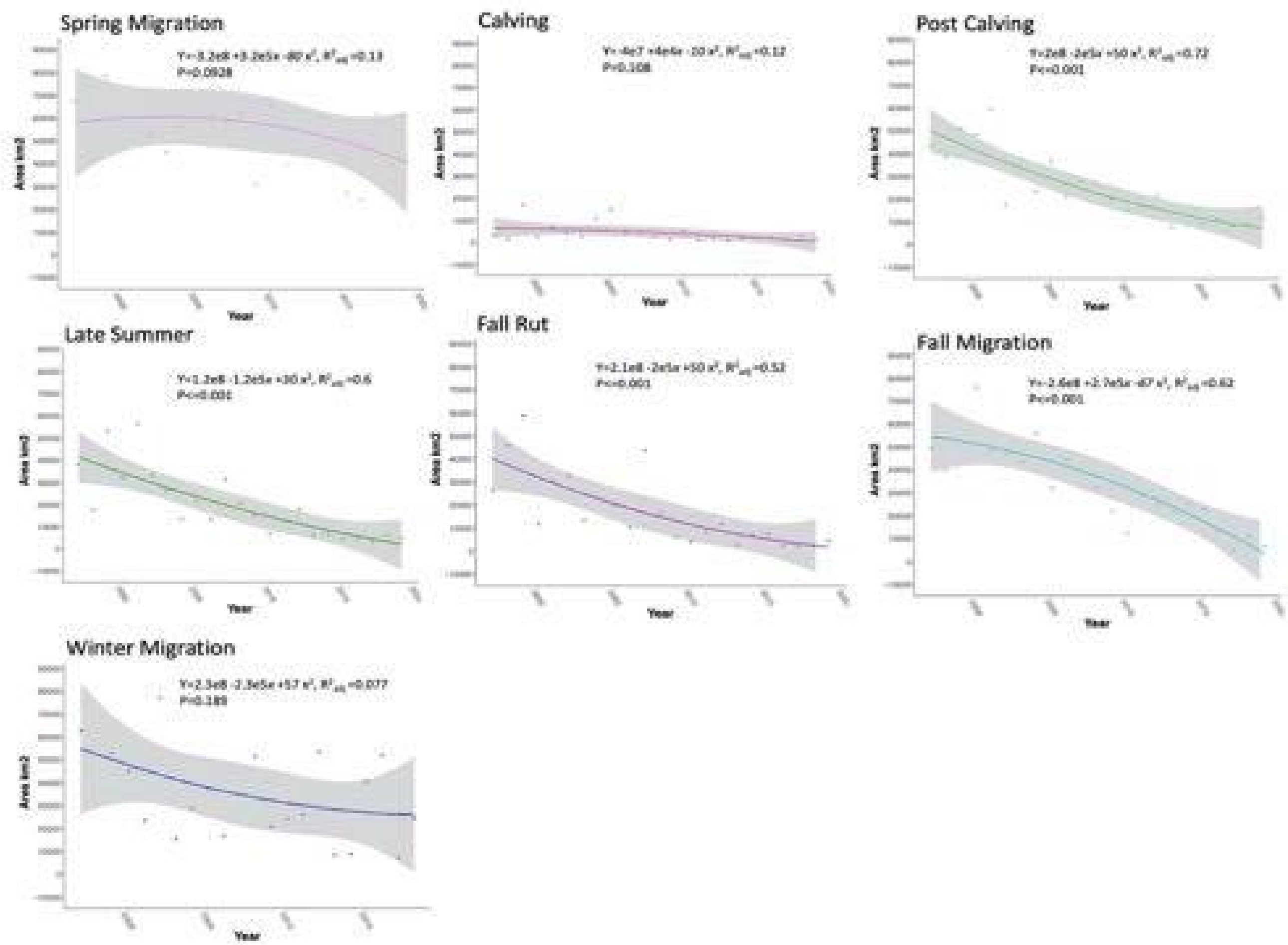

Figure 7: *Area of each seasonal directional distribution Ellipse calculated on each seasonal range of the Bathurst Caribou in km2 by study year (1997-2019). Ellipses are created using the function directional distribution in ArcGIS desktop version 10.5 (10). The function calculates the standard deviation in both the X and Y direction of the maps. Therefore, these figures indicate the degree geographic spread is changing. We fitted data with exponential models and included standard error, equations, adjusted R2, and p-values in each panel.*

[VIDEO]
https://www.youtube.com/embed/mjrOf4vN8eM?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

Movie 1: *Each successive point location represents the centre of the Bathurst caribou spring migration ranges from 1997-2019. Each location is derived from the centre of a directional distribution ellipse. These ellipses calculate the standard distance in both x an y direction of a seasonal range map.*

[VIDEO]
https://www.youtube.com/embed/_9VmfLAbcsU?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

Movie 2: *Each successive point location represents the centre of the Bathurst caribou calving ranges from 1997-2019. Each location is derived from the centre of a directional distribution ellipse. These ellipses calculate the standard distance in both x an y direction of a seasonal range map.*

[VIDEO]
https://www.youtube.com/embed/46COHbmXD30?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

Movie 3: *Each successive point location represents the centre of the Bathurst caribou post calving ranges from 1997-2019. Each location is derived from the centre of a directional distribution ellipse. These ellipses calculate the standard distance in both x an y direction of a seasonal range map.*

[VIDEO]
https://www.youtube.com/embed/JAMjYjgunAo?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

Movie 4: *Each successive point location represents the centre of the Bathurst caribou late summer ranges from 1997-2019. Each location is derived from the centre of a directional distribution ellipse. These ellipses calculate the standard distance in both x an y direction of a seasonal range map.*

[VIDEO]
https://www.youtube.com/embed/dRLH5cgj4hA?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

Movie 5: *Each successive point location represents the centre of the Bathurst caribou post fall rut ranges from 1997-2019. Each location is derived from the centre of a directional distribution ellipse. These ellipses calculate the standard distance in both x an y direction of a seasonal range map.*

[VIDEO]
https://www.youtube.com/embed/T-un39qQi1M?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

Movie 6: *Each successive point location represents the centre of the Bathurst caribou fall migration ranges from 1997-2019. Each location is derived from the centre of a directional distribution ellipse. These ellipses calculate the standard distance in both x an y direction of a seasonal range map.*

[VIDEO]
https://www.youtube.com/embed/-Qt9iLaljc8?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

Movie 7: *Each successive point location represents the centre of the Bathurst caribou winter ranges from 1997-2019. Each location is derived from the centre of a directional distribution ellipse. These ellipses calculate the standard distance in both x an y direction of a seasonal range map.*

NEXT STEPS/ ACKNOWLEDGEMENTS

Next Steps

So far, we have shown that although the ranges are all changing in size, they are not doing so at the same rate. Geographic change is occurring differently among the classified ranges. This research is still in preliminary stages, and our next step is to compare how these trends in seasonal range-use relates to observed changes in ecological systems. We will focus on changes in vegetative productivity, temperature, snowmelt, precipitation, and the warble fly index.

Caribou antler spotted near Mackay lake - photo credit - Joel Koop

Acknowledgments

I would like to thank my thesis supervisor Dr. Ryan Danby for his mentorship and help in getting the project this far ahead. I would also like to thank my colleague Rosy Tutton for her signifcant time devoted to helping me with the R coding involved in this project. Finally I would like to thank my funders: Queens University, the Culmaltive Impact Monitoring Program NWT (CIMP), the Association of Canadian Univesities for Northern Studies (ACUNS), and the Northern Scientific Training Program (NSTP).


Sunset on courageous lake: summer range of the Bathurst caribou- photo credit - Robin Mennell

AUTHOR INFORMATION

Hi there!

My name is Robin Mennell, I am a gregarious MSc student currently in my second year at Queen's University. I was born and raised in the Yukon territory and as a result I have a strong passion for ecolgocial issues affecting northerners. I am particualry interested in how researchers can bridge the gap between scientists and community members not often exposed to scientific concepts. I believe the solution to many of the ecological problems faced is the engagment of local youth who can learn new skills, get outside, and take up stewardship roles in their own communities. My current research focuses on barren-ground caribou and their response to ecolgocial changes. Barren-ground caribou are an incredibly important animal to people in the North, and therfore I am incredibly fortunate to be apart of research that will hopefully contribute to conservation of this animal. If you have any questions please do not hesitate to reach out by email or telephone.

Clear Skies,

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ABSTRACT

The Bathurst barren-ground caribou herd has declined from a population of 349,000 animals in 1996 to 8,200 in 2019 (98% decrease). This decline has been shown to be a result of the cumulative effect of several factors including (but not limited to) climate-induced ecosystem changes within their home range. There are two ecosystem-wide changes that may have contributed to population decline: (1) Arctic greening, the proliferation of vegetative biomass in response to climate warming, and (2) phenological changes, which affect the timing of seasonal food resources. This research investigates the impact of these ecosystem changes on the distribution and migration of the herd using remotely sensed data (1997-2017) of the herd's entire range as well as satellite telemetry data available for over 200 collared animals. Using the Adehabitat package in R, we mapped interannual and seasonal ranges by first separating data into distinct seasonal ranges using the Residence Time analysis and Lavielle segmentation and then we mapped these distinct ranges using Brownian Bridge mapping. We show that the extent of the seven distinct seasonal ranges (spring migration, calving, post calving, late summer, fall rut, fall migration and winter range) has steadily decreased in area since 1997. Using the directional distribution function in ArcGIS (version 10.5) we gained a better understanding of the changes in geographic spread during these seasonal ranges. We show that calving, spring migration and their winter range have not significantly changed in areal extent, however the other ranges have ($P \leq 0.001$). Excluding the calving range, our data show that all of the ranges appear to be moving North West and becoming increasing smaller in areal extent. We will expand on this research by comparing these trends in seasonal ranges with observed ecosystem changes to determine their impact, if any, on the decline in Bathurst caribou populations.

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