Evaluating arctic tundra system responses to grazing disturbances: a modeling approach

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Introduction

Arctic terrestrial ecosystems are assumed to be one of the most sensitive systems, enduring low temperatures, short growing seasons and freeze-thaw dynamics. The comparatively slow rates of productivity and decomposition may make it particularly difficult for these systems to recover from disturbances. One major disturbance in arctic terrestrial systems is grazing by caribou and reindeer, and different grazing intensities and climate regimes may result in different productivities and plant species compositions

Objectives

This study is to evaluate how tundra ecosystems with different grazing patterns will respond to warming and how the combinations of climate change and grazing may affect system response. It is unclear whether climate warming or grazing is the dominant factor that controls this system.
Our hypotheses are:

- Warming will increase total productivity
- Warming and grazing effects are at the plant functional level
- Heavy grazing affects plant functional types such as lichens and deciduous shrubs and decreases total productivity

Methods

We applied a nutrient-based transient vegetation dynamics model (ArcVeg) to simulate how typical arctic tundra ecosystems respond to different degrees of grazing. Two different herbivore grazing regimes in tundra systems were considered and compared in this study: managed reindeer herds and wild caribou herds. Grazing intensity was represented by the combination of annual probability of grazing and percentage of biomass removed by grazing. We used three parameter combinations: (0.1, 25%) or low grazing intensity indicating the system would be grazed every ten years, and 25% of plant biomass was removed by grazing, (0.5, 50%) or medium grazing intensity, 50% of plant biomass removed every two years, and (1, 75%) or high grazing intensity, 75% removed by grazing each year. The first scenario is more similar to caribou grazing, whereas the latter two are indicative of managed reindeer herds.
We also manipulated climate in model warming scenarios. The warming scenario for our simulation was assumed to be a 2°C temperature increase linearly ramped over a 50-year period.

Results

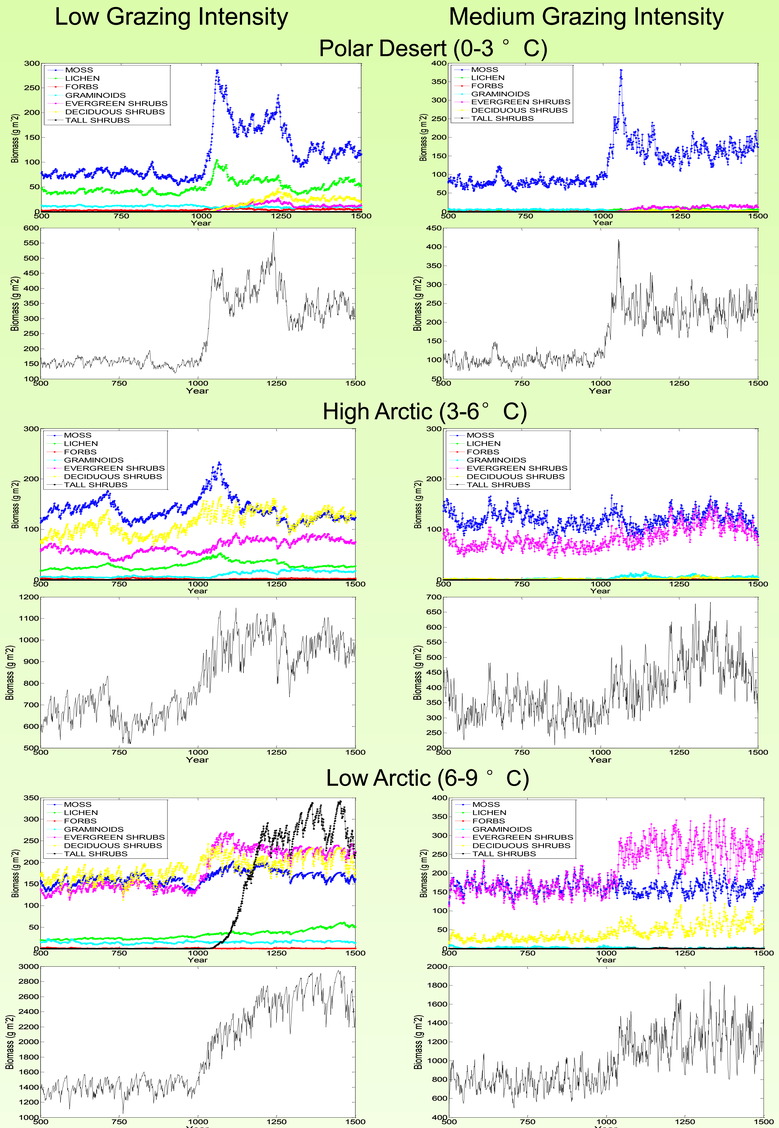

Figure 1: Comparison of total biomass and above ground biomass of each Plant Functional Type change over time with warming and different grazing regimes

Grazing and temperature have opposite effects on system productivity, with higher grazing intensity resulting in lower productivity and warmer temperatures leading to greater productivity. Under **similar grazing regimes**, the modeled biomass increased as a result of warming by approximately 130% in Subzones A and B (polar desert and High Arctic), while only about 50% in Subzones C, D and E (Mid- and Low-Arctic). Under the **same climate regime**, biomass for Subzones C, D and E decreased about 30% more than Subzones A and B due to increasing grazing intensities, indicating that Subzones C, D and E may be less resistant to grazing disturbances.

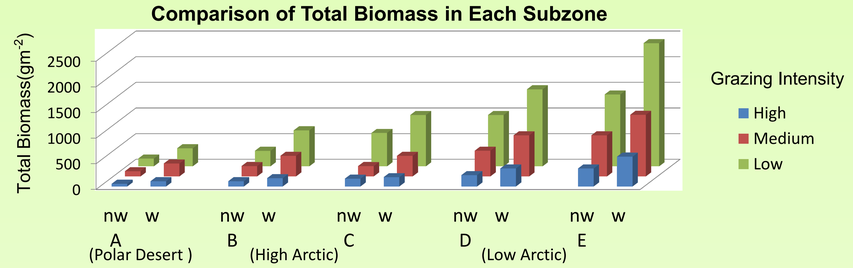

Figure 2: Total biomass comparison among subzones along a grazing gradient from high to low under no warming(nw) and warming(w) assumptions

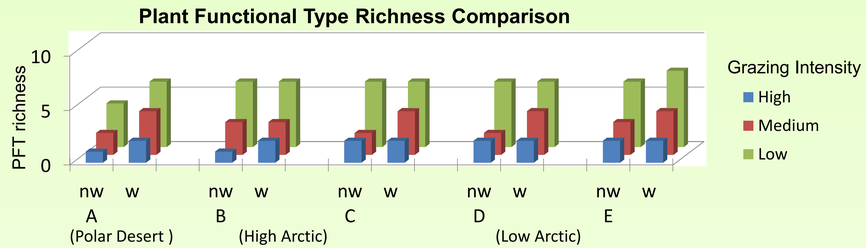

Figure3: Summary of plant functional type richness with different grazing regimes (from High to Low) under no warming(nw) and warming(w) assumptions

Conclusions

Generally speaking, heavy grazing decreases Plant Functional Type richness and total biomass while warming in general increases total biomass. Compared to systems without warming under the same grazing regime, systems enduring warming may be more resistant to grazing due to higher biomass. Heavy grazing removes most lichen and deciduous shrubs, potentially altering nutrient cycling of that system, since lichens can have associated nitrogen-fixers. Reducing nitrogen input to tundra ecosystems may cause such nitrogen-limited systems to be more easily affected by other disturbances.

References

Epstein, H.E., J.O. Kaplan, H. Lischke, and Q. Yu. 2007. Simulating future changes in arctic and sub-arctic vegetation. **Computing in Science and Engineering** 9:12-23.
Epstein, H.E., M.D. Walker, F.S. Chapin III and A.M. Starfield. 2000. A transient, nutrient-based model of arctic plant community response to climatic warming. **Ecological Applications** 10:824-841.
Walker, D.A., and the CAVM Team. 2005. The circumpolar arctic vegetation map. **Journal of Vegetation Science** 16:267-282.

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