Geophysical Research Abstracts,
Vol. 10, EGU2008-A-12154, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-12154
EGU General Assembly 2008

Evaluating Arctic Tundra System Resilience to Grazing Disturbances: A Modeling Approach

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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, thus altering the system resilience.

In this study, 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. Reindeer as a major food source for nomadic herders, such as the Nenets of the Yamal Peninsula in northwestern Siberia, tend to graze tundra more intensely than wild caribou herds, such as those in Alaska and Canada in North America. 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%) indicating the system would be grazed every ten years, and 25% of plant biomass was removed by grazing, (0.5, 50%) 50% of plant biomass removed every two years, and (1, 75%), 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 modeling warming scenarios. A key assumption of the

model is that with higher temperatures, decomposition rates increase, thus increasing the availability of soil nitrogen for facilitating plant growth. The warming scenario for our simulation was assumed to be a 2˚C temperature increase linearly ramped over a 50-year period. 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 productivity 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, productivities for Subzones C, D and E decreased about 30%, more significantly than Subzones A and B due to increasing grazing intensities, indicating that Subzone C, D and E may be less resilient to grazing disturbances.