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Disrupting the Harmony

Effects of Climate Warming on Arctic Terrestrial Ecosystems

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Introduction **- Climate warming and associated environmental changes are occurring at a rapid rate throughout much of the Arctic region. Terrestrial ecosystems in the Arctic are highly vulnerable to these changes because of their simplicity and high sensitivity. The effects of a warming environment are thus stronger and more profound in the Arctic than in ecosystems at lower latitudes.**

How will the spatial distribution of ecosystems change?

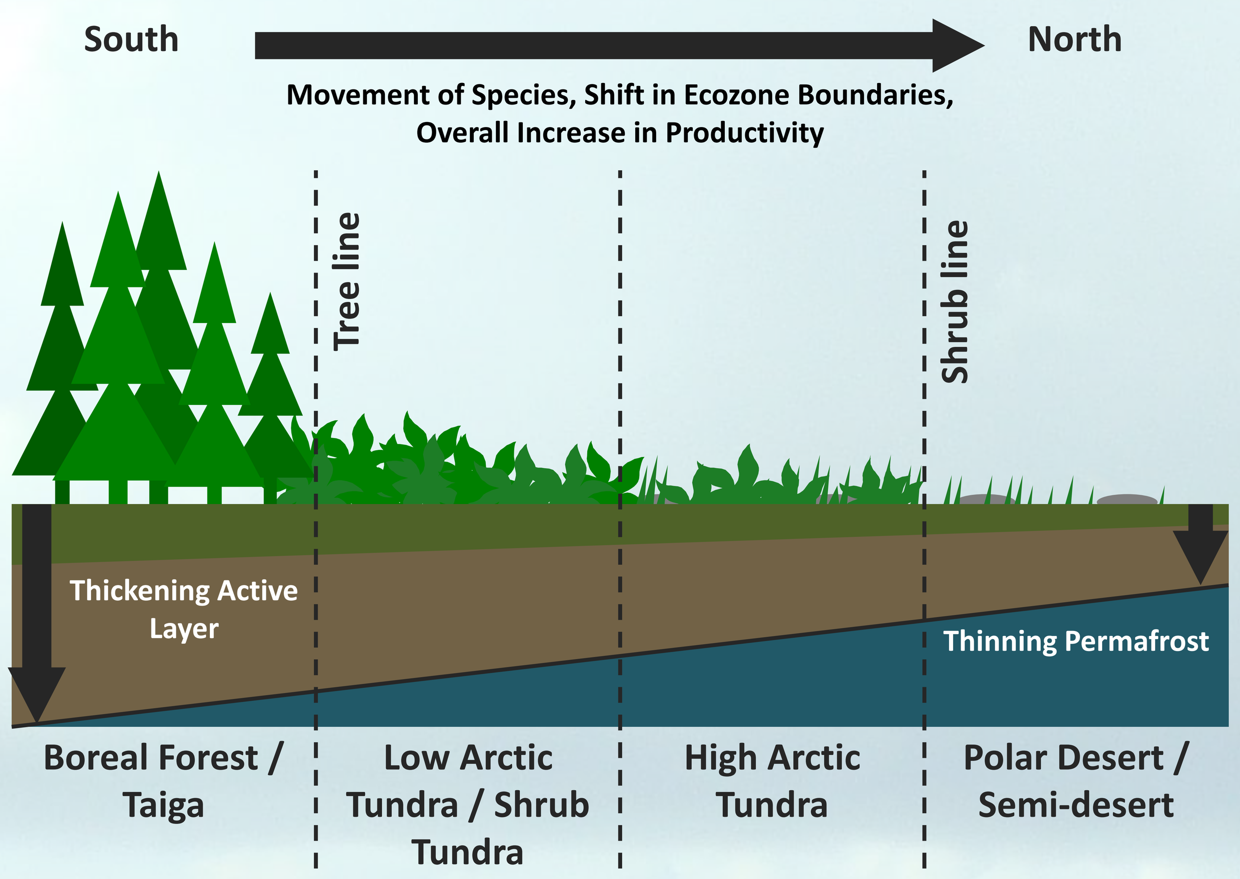

Figure 1: Arctic warming is causing a northward shift in ecozone boundaries or ecotones, like the tree line and shrub line, through the gradual movement of vegetation communities[1]. Southern animal species will also move north to exploit newly suitable habitat, often at the expense of Arctic-specialist species[2].

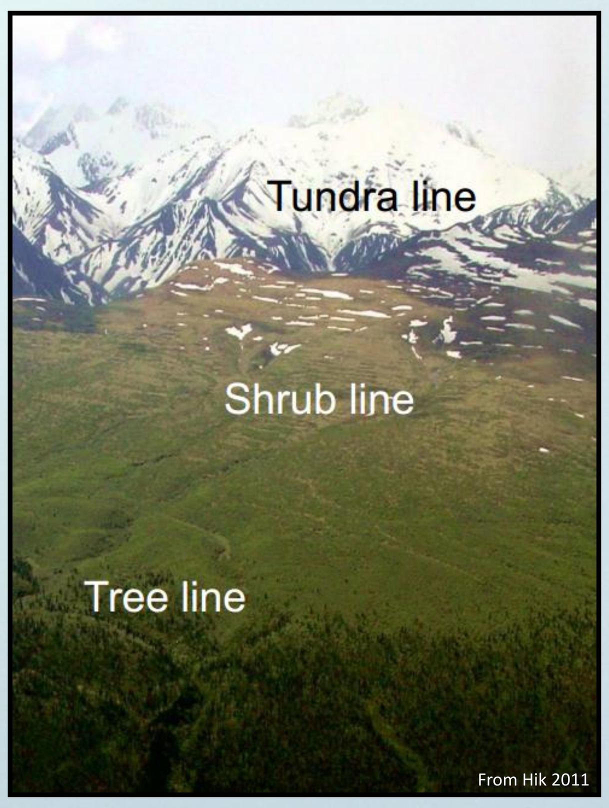

Figure 2: Arctic alpine environments, such as the mountains of Canada's Yukon Territory (pictured), are particularly vulnerable to climate warming. The ecotones on mountains are shifting upwards, effectively crowding out the tundra and near-barren habitat typically found at high elevation[1,3].

How will Arctic soil processes change?

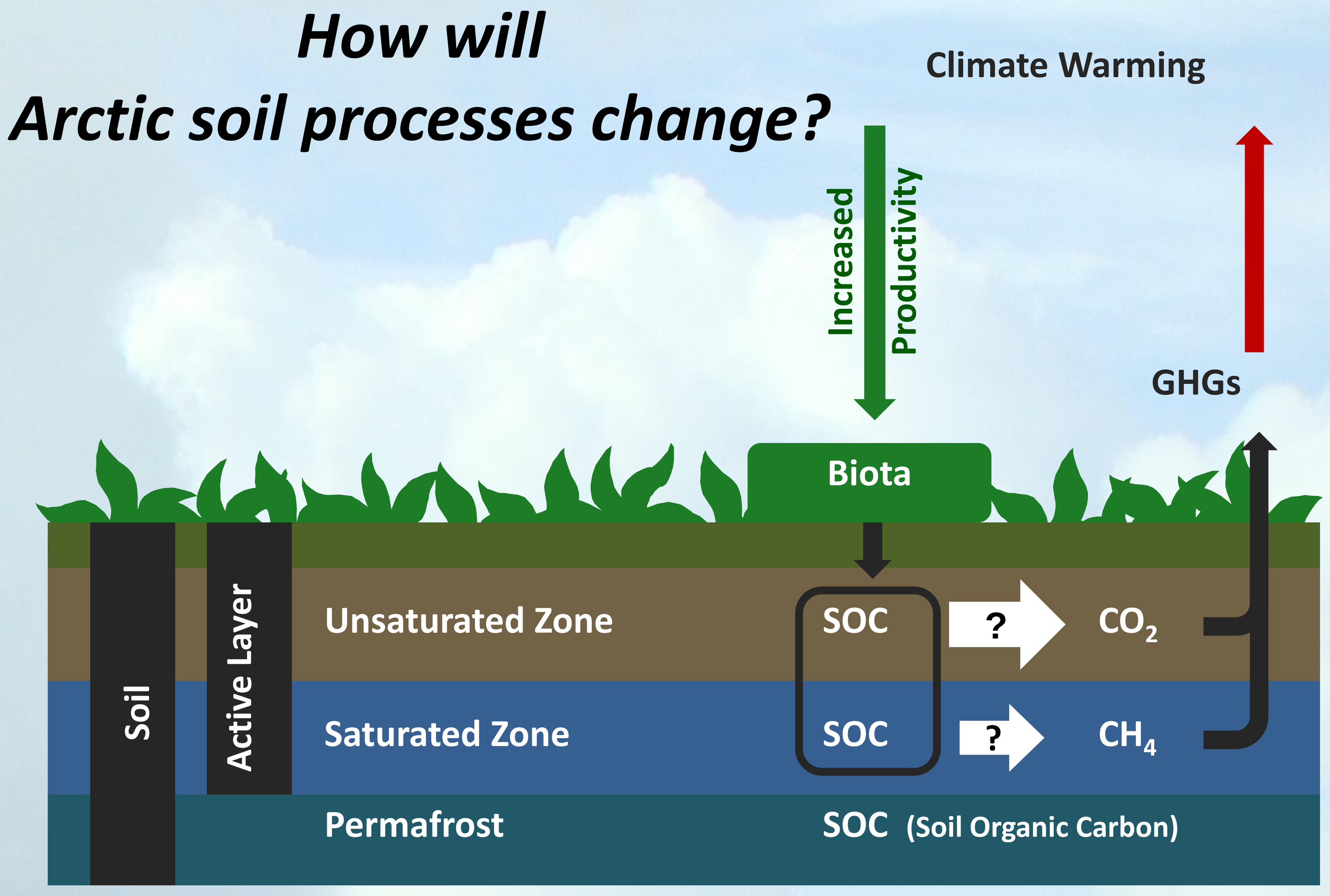

Figure 3: Arctic soil ecosystems are likely to change rapidly in response to climate warming, with potentially massive implications for the global carbon balance[4]. Increase in soil temperature will accelerate the microbial respiration of organic matter (white arrows), resulting in greater carbon fluxes to the atmosphere, but this may be counteracted by increases in carbon sequestration by plants[4, 5].

Arctic Food Web

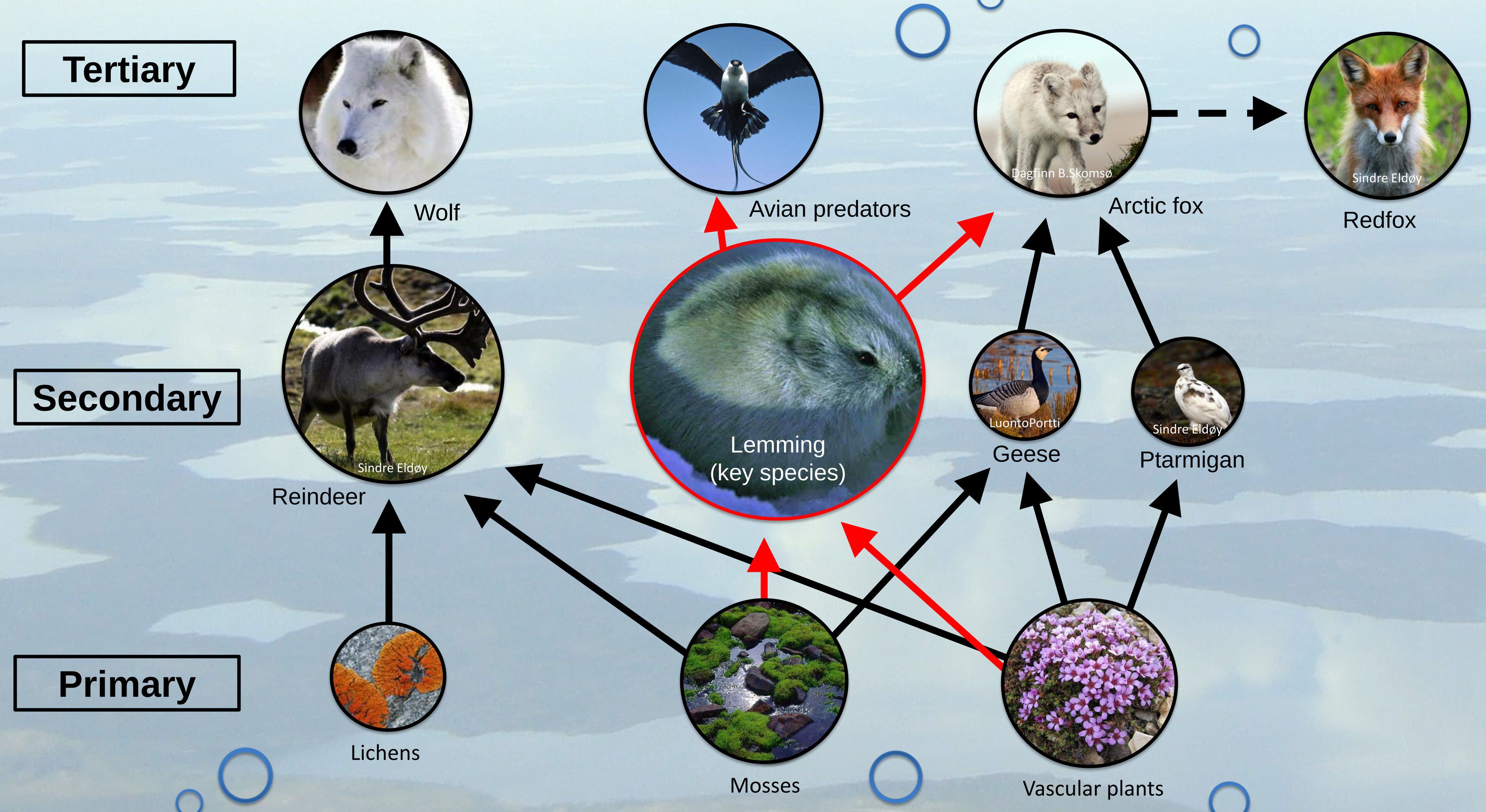

Figure 4: A simplified terrestrial food web from a northern Arctic area[6,7]. There are differences between the summer food web and the winter food web in the Arctic because of migratory species, birds in particular. The terrestrial food webs are closely linked to marine, invertebrate and microbial food webs, and are much more complex than shown above[6]. Lemming (*Lemmus* spp.) is shown as a key species. The dashed arrow indicates the competition between the Arctic fox (*Vulpes lagopus*) and its expanding competitor, the red fox (*V. vulpes*)[2].

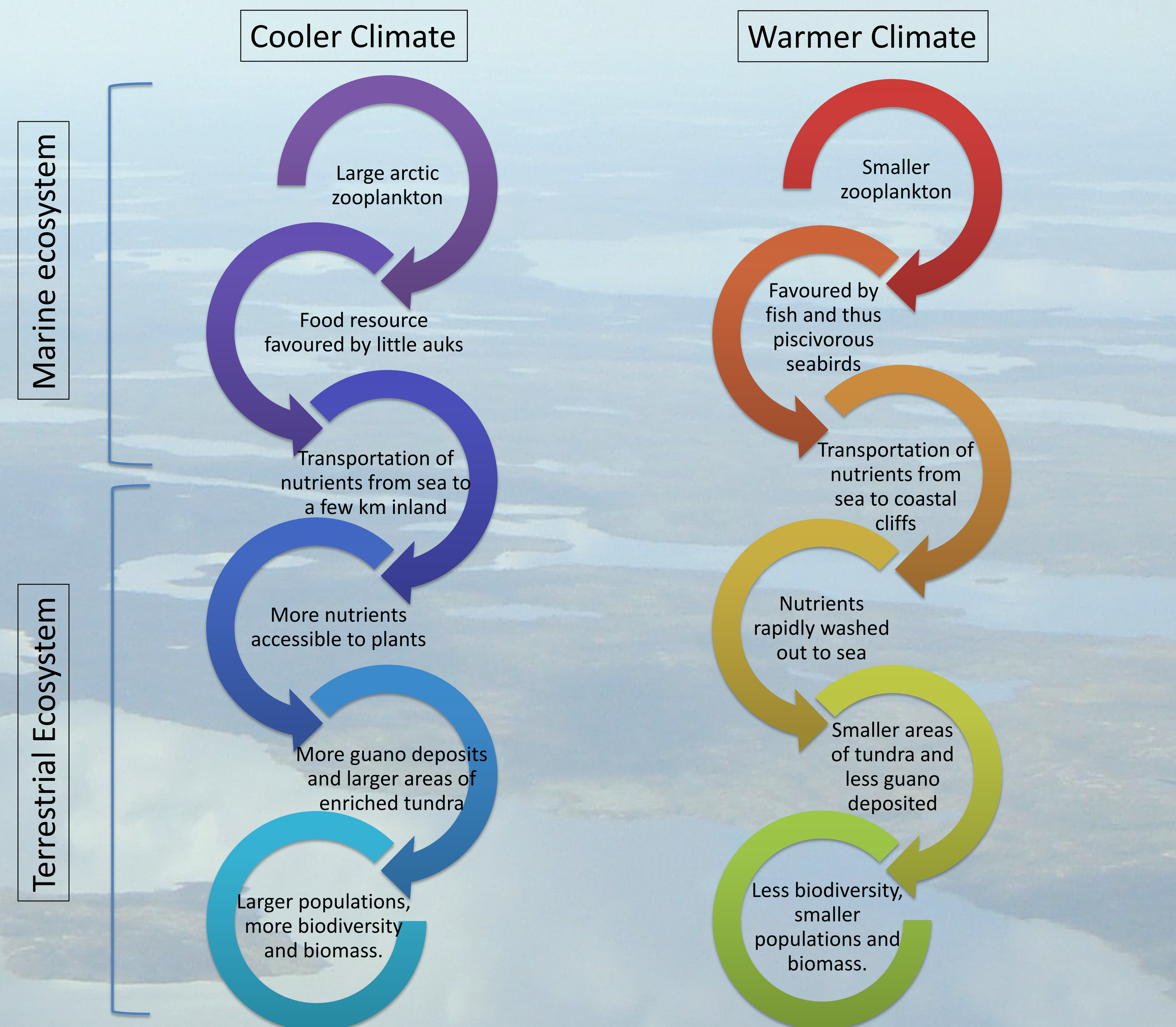

Figure 5: Possible shift in trophic interactions due to climate warming for terrestrial ecosystems dependent on marine ecosystems in the Arctic. In Southern Greenland and Iceland a collapse in little auk (*Alle alle*) populations has already been observed due to changes in zooplankton composition as a result of warmer ocean currents[8].

Changes in seasonal timing

Plant growing season is cued to local temperatures, while the onset of migration in herbivores (e.g. reindeer [*Rangifer tarandus*] and geese) is cued to changes in day length[9]. Due to earlier snow melt in a warming Arctic, the peak of resource availability occurs earlier in the season. This can cause a trophic mismatch for migratory herbivores resulting in higher offspring mortality and lower productivity[9,10].

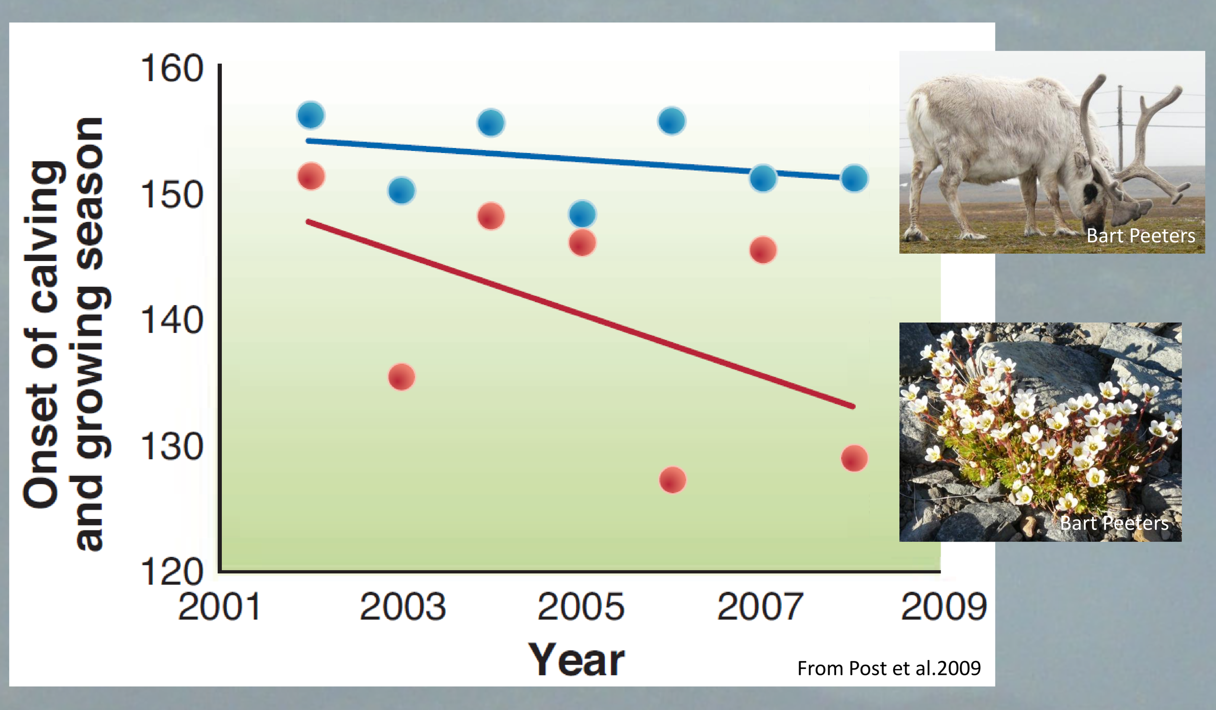

Figure 6: Difference between the timing of caribou calving (blue), and the timing of plant growth (red) in Greenland develops a trophic mismatch[10].

The reindeer herders say mayday

In a warming Arctic, precipitation is expected to increase by 10 – 30%, mainly in the form of wet, unfavorable snow[11]. Freeze-thaw cycles are expected to occur more frequently, producing ice layers in the snow cover, making it more difficult for the reindeer to dig through to their winter forage[11]. This can result in an increased number of reindeer with hoof damages which will increase the susceptibility to infection[11]. Calves born after winters marked by food shortage have been observed to be underweight and with reduced chance of survival[11]. These conditions will affect reindeer herding in Arctic regions[11].

Conclusions

Arctic warming will have a destabilizing effect on Arctic terrestrial ecosystems – a consequence of habitat loss, changes in seasonal timing, and increased competition with southern species.

Regional variation in the response of terrestrial ecosystems to climate change restricts generalization for the whole Arctic region.

References **-** [1]Hik, D. 2011: Aspects of terrestrial ecosystem change in the Arctic (tree line, shrub line, tundra), particularly the relationship to climate and snow. *Summer School in Arctic Atmospheric Science – July 2011* (slideshow presentation). Available online: http://www.candac.ca/create/ss2011/talks/Day2_Hik_L2_Terrestrial.pdf (retrieved July 11, 2012). [2]Killengreen, S. T., Ims, R. A., Yoccoz, N. G., Brathen, K. A., Henden, J.-A. & Schott, T. 2007: Structural characteristics of a low Arctic tundra ecosystem and the retreat of the Arctic fox. *Biological Conservation 135*, 459-472. [3]Harsch, M. A., Hulme, P. E., McGlone, M. S. & Duncan, R.P. (2009). Are treelines advancing? A global meta-analysis of treeline response to climate warming. *Ecology Letters 12*, 1040-1049. [4]Jahn, M., Sachs, T., Mansfeldt, T. & Overesch, M. 2010: Global climate change and its impacts on the terrestrial Arctic carbon cycle with special regards to ecosystem components and the greenhouse-gas balance. *Journal of Plant Nutrition and Soil Science 173*, 627-643. [5]Elmendorf, S. C., Hollister, R. D., Bjork, R. G., et al. 2012: Plot-scale evidence of tundra vegetation change and links to recent summer warming. *Nature Climate Change 2*, 453-457. [6]Jónsdóttir, I. S. 2005: Terrestrial ecosystems on Svalbard: heterogeneity, complexity and fragility from an Arctic Island perspective. *Biology and Environment 105B*, 155-165. [7]Ims, R. A. & Fuglei, E. 2005: Trophic interaction cycles in tundra ecosystems and the impact of climate change. *Bioscience 55*, 311-322. [8]Stempniewicz, L. 2001: Alle alle little auk. *BWP Update 3*, 175-201. [9]Post, E. & Forchhammer, M. C. 2008: Climate change reduces reproductive success of an Arctic herbivore through trophic mismatch. *Philosophical Transactions of the Royal Society B-Biological Sciences 363*, 2369-2375. Post, E., Forchhammer, M. C., Bret-Harte, M. S. et al. 2009: Ecological Dynamics Across the Arctic Associated with Recent Climate Change. *Science 325*, 1355-1358. [11] Bartsch, A., Kumpula, T., Forbes, B. C. & Stammler, F. 2010: Detection of snow surface thawing and refreezing in the Eurasian Arctic with QuikSCAT: implications for reindeer herding. *Ecological Applications 20*, 2346-2358.