4. Arctic Tundra

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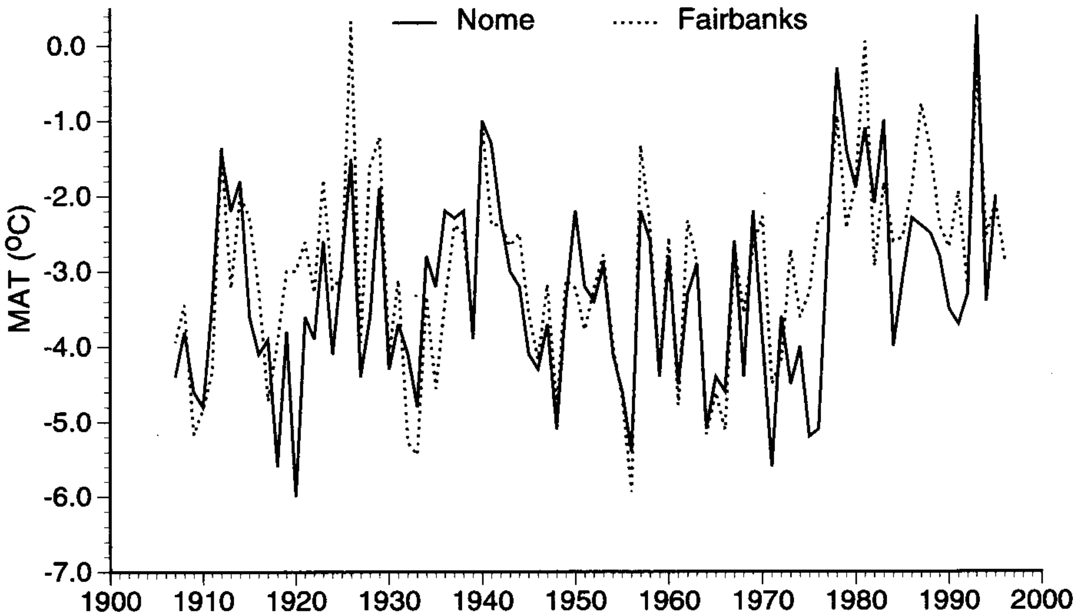
4.1 Introduction

Arctic tundra is made up of low growing lichens, shrubs, grasses, sedges, and other flowering plants adapted to a cold climate with a very short growing season. The arctic tundra region forms a belt around the polar regions of the northern hemisphere continents. Arctic tundra is a wildlife habitat of international significance, especially for caribou and migratory birds. The arctic tundra contains a large amount of stored carbon in frozen soils, but it has still not been determined whether the tundra is a source or a sink of atmospheric CO_2 now and under climate change scenarios. The Arctic tundra cannot shift northward with climate warming in Alaska, Canada, and Russia because it is bordered to the north by the Arctic Ocean, so it may be geographically squeezed under global warming scenarios. The arctic tundra contains major deposits of oil and natural gas that represent a significant portion of the national reserves of arctic nations. Petroleum construction, operations, and transportation take place in a sensitive tundra environment that itself will be affected by climate change. The most extensive land use in the arctic tundra is subsistence harvest of wildlife and secondarily of plants. Subsistence resources are major items in the daily diet of arctic residents, and the subsistence way of life is at the foundation of the identity, culture, and spiritual values of many arctic peoples. Some threatened and endangered species occur largely in the Arctic, but several migratory wildlife species of conservation concern find critical habitat in the Arctic.

4.2 Past effects of climate change

The Bering Straits region has attracted a great deal of interest from investigators of paleoclimates and paleoecology because of the area's role as a critical land interchange between North America and Eurasia and in the peopling of North America (Hopkins et al. 1982). The sequence of climate and vegetation events has been reconstructed from both coastal exposures and inland lake records which are discontinuous and sometimes difficult to cross match. Recent findings of intact plant communities which were buried under volcanic ash and lava flows offer exceptional new opportunities to reconstruct past environments on the Seward Peninsula. Sometime before 10,000 B.P. a transition occurred from herbaceous tundra to a dwarf birch tundra (Ager 1983). In the earliest stage of the transition, or prior to that, balsam poplar may have extended westward of current tree limits. Compared to other areas of Alaska, there is relatively little evidence of major vegetation response to climate change on the Seward Peninsula up to historic times. Nome was one of the major gold rush sites in the late 1890s, and continuous climate records are available for Nome from the earliest years of the 20th century. The 20th century record of mean annual temperature at Nome is nearly identical to Fairbanks (Figure 4.01), including most of the fine points of major cold and warm years. Fairbanks is boreal forest and Nome is in a tundra region, however, because summers are much cooler and winters warmer in Nome than in Fairbanks. These are optimum conditions for the development of productive tundra vegetation. In general, trees have been unable to grow or reproduce on the Seward Peninsula because of insufficient summer warmth, even though mean annual temperatures have been comparable to areas such as Fairbanks.

Figure 4.01 Nome and Fairbanks Mean Annual Temperatures, 1907-1995

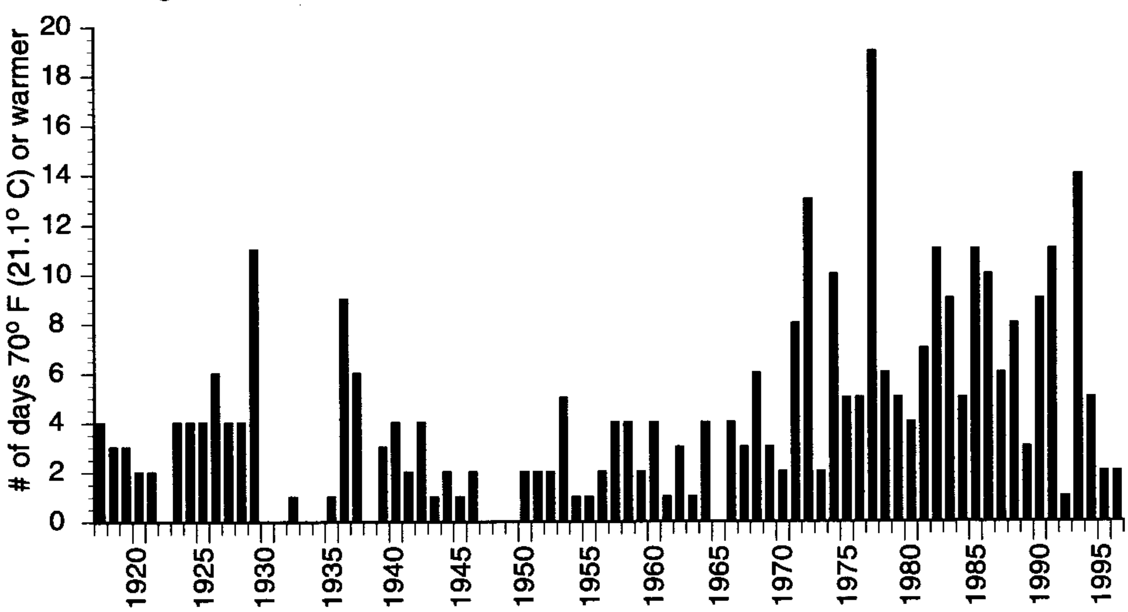


The tundra region is persistently cool and seldom experiences intense dry conditions during the short growing season but extreme warm and dry periods can occur, leading to large tundra fires (Racine 1979). During the past four decades, spring has arrived earlier and earlier in Alaska's arctic tundra. Data from Alaska's most northern weather station at Point Barrow indicate a trend toward earlier dates of snow disappearance and warmer temperatures during the spring months of May and June. Functionally, the warming trend appears to be associated with longer vegetation growing seasons, as evidenced by observed increases in the amplitude and timing of the seasonally cyclic atmospheric carbon dioxide concentrations measured at Point Barrow (Keeling et al. 1996). Similarly, historical satellite imagery indicates increased photosynthetic activity of arctic vegetation, suggesting increases in plant growth associated with the longer active growing seasons (Myneni et al. 1997). These relationships infer direct linkages between spring temperatures and phenological characteristics of vegetation growth in the arctic tundra. For example, the warmest spring in the May-June Point Barrow temperature record occurred in 1990. That year was accompanied by the earliest date of snow disappearance (14 May), a peak in the amplitude of annual carbon dioxide flux, and the highest June vegetation greenness index on the Alaska north slope as measured by satellite. The timing of snowmelt and the greening of vegetation is one of the most crucial factors in the health and survival of caribou, especially because it coincides with calving (Jorgenson and Udevitz 1992). The growth and condition of tundra vegetation is also strongly influenced by the timing of seasonal events (Shaver and Kummerow 1992).

4.3 Future changes

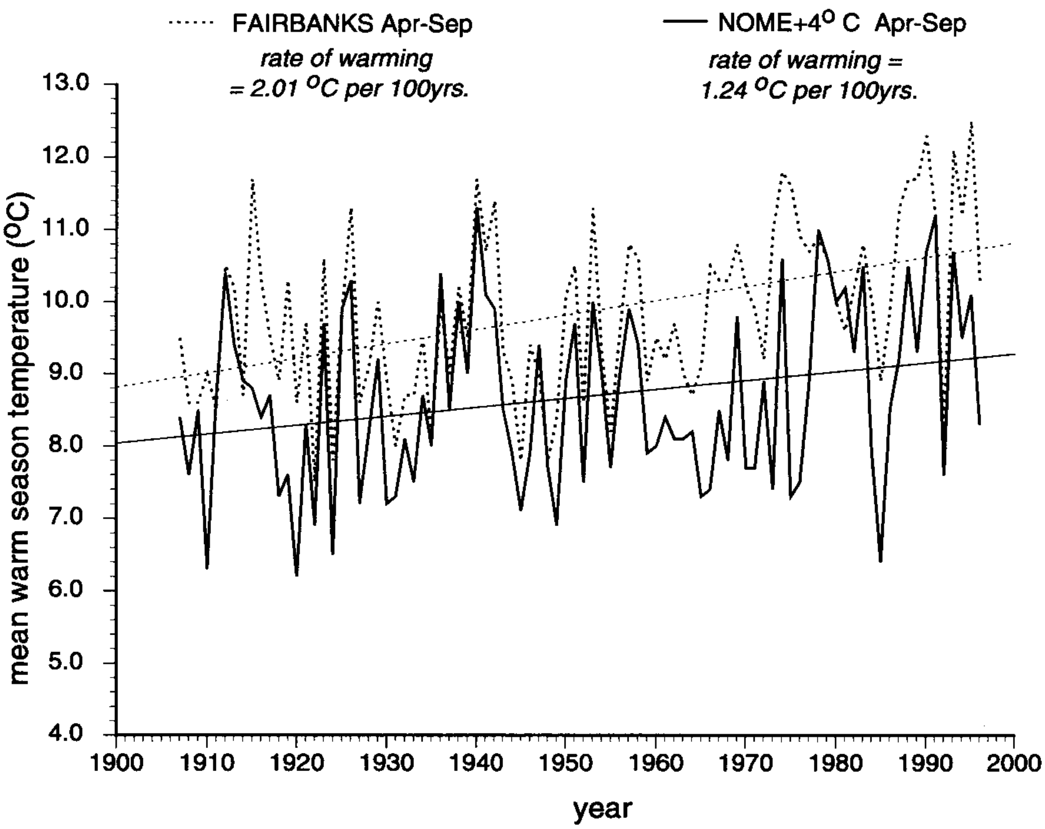
Forest vegetation currently occupies the base (eastern portion) of the Seward Peninsula, but further west where the summer atmosphere is cooled by the cold Bering Sea, trees are currently unable to grow. However, the number of the warmest summer days at Nome has increased dramatically in the last 20 years compared to the earlier 20th century (Figure 4.02). The number of warm days is beginning to approach the threshold that would permit tall shrub and trees to develop. Furthermore, Nome is a coastal station, and the effect of summer warming should be even more pronounced further inland. If summer temperatures of the 20th century in Nome were warmed by 4°C, the level of warming given in the scenario of Weller et al. (1995, Chapter 2), the summer climate at Nome would closely match that of Fairbanks (Figure 4.03). The Fairbanks area supports some of the most productive sites documented in the Alaska boreal forest. It is reasonable to infer, then, that well before Nome reached the level of Fairbanks summer warmth, (1) the existing tundra vegetation would be climatically stressed, (2) a significant risk of tundra fire would occur, and (3) tree invasion of the tundra would begin. Essentially, all but the highest elevations of the Seward Peninsula would support boreal forest. A greater frequency of winter ice storms would be likely as well.

Figure 4.02 Number of warm summer days at Nome, 1917-96



In the arctic tundra vegetation of northern Alaska, under conditions of projected global warming, experimental results indicate probable changes to the species composition of plant communities. Increased temperatures leading to greater depth of soil thawing, deeper soil active layers, and increased nutrient availability (Nadelhoffer et al. 1991) creates favorable conditions for some tundra plant species and unfavorable conditions for others. At the Toolik Lake Long Term Ecological Research site, located on the Alaska north slope, a combined experimental treatment of increased temperature and increased nutrient availability within a tussock-tundra community over a 9-year period resulted in a substantial decrease in the growth and biomass of cotton grass (Eriophorum vaginatum), a 90% increase in the total vascular biomass of a common dwarf-birch shrub species (Betula nana; Chapin and Shaver 1996), and a 30%-50% loss in species diversity, primarily in moss, lichen, and forb species (Chapin et al. 1995). This trend also agrees with historical pollen records that show decreased sedge abundance during warm periods of the Holocene (Ritchie and Cwynar 1982).

Figure 4.03 Comparison of actual Fairbanks summer temperatures and Nome summer temperatures warmed by 4 °C, 1907-1996



The primary expected or potential mid-term and long-term changes in arctic tundra due to global warming include:

- Higher rate and magnitude of temperature change compared to more southern latitudes.
- Warmer spring temperatures, earlier snowmelt, and longer growing seasons.
- Permafrost remaining dominant but with deeper soil active layers, increased available soil nitrogen, and increased decomposition of soil carbon.
- Increased dominance of shrubs, decreased abundance of grasses and sedges, and overall decrease in floral diversity.

- Southern areas of arctic tundra replaced by forest, including most of the Seward Peninsula.
- Loss of some shallow arctic tundra ponds and lakes.
- Increase in the frequency and extent of tundra fires, especially if warming is accompanied by summer drying.
- Changes in the abundance and/or distribution of wildlife species resulting from changes in the seasonal availability, quality, and/or distribution of tundra habitats.
- Changes in accessibility for subsistence users resulting from changes in snow and ice conditions on traditional travel routes.
- Changes in the environmental mitigation practices used by the petroleum industry resulting from changes in the dynamics and distributions of permafrost, ground water, and seasonal runoff.

4.4 Additional research needed

- Monitor the growth, development, and expansion of forests at the edge of the tundra on the Seward Peninsula.
- Monitor the expansion of shrub dominance on the north slope of Alaska.
- Document and monitor post fire recovery and recolonization of tundra habitats.
- Document changes to the seasonal availability and nutritional quality of forage species used by caribou, reindeer, and muskoxen.
- Document changes to the seasonal availability and quality of critical aquatic habitats used by fish and waterfowl populations.

4.5 Mitigation and adaptation measures

- Ensure adequate conservation and protection of the more northern arctic tundra habitats (include international cooperation with Canada and Russia) to accommodate refugia for plant and animal populations that become displaced northward as tree and shrub species expand into southern tundra regions.
- Implement fire suppression or fire prescription practices, depending on how various tundra habitats recolonize following fire (research need 4.4.3 above).

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