Environmental Studies 30 -- The Global Ecosystem
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LECTURE 13: Tundra

Climate

The Tundra Biome (see Figure 13.1 for distribution) is the most poleward of all the earth's ecosystem, so, not unexpectedly, mean temperatures are very cold. Winters are extreme and summers short and cool. Generally, every month has frost at night. Tundra climates have less cold mean annual temperatures and less cold extreme than many stations in Taiga to the south. Bordering the Arctic Ocean, tundra climates are moderated a bit by maritime influences, even though the Arctic Ocean is mostly frozen. Nevertheless, this climate is, in one sense, colder as far as plants are concerned than the Taiga stations. During the short, frosty growing season, temperatures are somewhat lower than in the more seasonal Taiga; this critical period is colder. Rainfall is very low in the Tundra, often around 200 mm/yr., but evaporation is very low as well, so the climates are humid so far as the plants are concerned.

Soils

Tundra soils are permanently frozen to great depths. During the summer the upper part of the soil profile thaws, but only a thin layer, a few centimeters to a meter or so thick, is available for the rooting of plants. The ice in the subsoil, of course, inhibits drainage; this together with low evaporation rates ensures that Tundra habitats are wet, except when rainfall is very low indeed.

The freeze-thaw cycle is the most important soil forming process in these soils. The expansion of water as it freezes has a tendency to slowly churn the upper soil layer. On level topography, rocks are pushed upward and to the side, and frost-heaved hummocks are common. On hillsides the soil mantle oozes downhill. Leaching is nearly absent, and chemical weathering is very slow due to low temperatures, but the freezing of water in cracks in soil particles, and the stresses set up in rocks by alternate heating and cooling very effectively break parent materials into clay-sized particles.

Determination of Tree-line

The Tundra-taiga ecotone is a fairly broad one with tongues and islands of forest extending into the tundra zone. Frost desicration damages trees exposed above the snow in the wintertime, and short, cool growing seasons limit summer time photosynthesis which might repair the damage. Trees penetrate deepest into the Tundra in valleys protected from the drying winter winds and having snow accumulation or along northward-flowing rivers that warm local areas in the summer. Finally, production becomes so low that trees can produce few seeds and those few have difficulty establishing themselves in the Tundra vegetation mat.

Plant Adaptations

I. Shrubs

Dwarf shrubs of willow or birch dominate tundra communities in more moist but well-drained areas. These plants take advantage of the protection of snow cover to protect them from desicration during the winter period. During the summer, the low growth habit also keeps leaves and stems in a warm micro-climate as temperatures very close to the ground are about 10°C warmer than at a meter above the surface.

II. Perennial Herbs

A good fraction of the tundra vegetation consists of these plants. Grasses and sedges (grass-like plants related to bullrushes) as well as broadleaved forbs are important. Annual plants

are relatively unimportant because short growing seasons do not allow many plants to complete their life cycle in one year. Rather, most plants must store several years' production before they are able to begin to reproduce. Storage organs are common, and many tundra plants reach great ages, even 100 years for herbs. One interesting adaptation of some tundra herbs is <u>aperiodism</u>, an ability to go into dormancy at any stage of growth. These plants can flower at any part of the short summer season, following a variable number of years of growth. Such plants are oddly reminiscent of the aperiodic species of the Tropical Evergreen Forest. Other herbs produce flower heads in one season and over-winter in a condition to flower immediately after snow melt the next summer. Just to flower, effect pollination, and ripen seeds may take the whole of the short, cool summer.

A large fraction of tundra plants disperse by dropping ripe seed on the surface of the Fall snow and letting the wind scatter them to new locations.

III. Lichens

On excessively well-drained uplands, lichens, symbiotic associations of algae and fungi, dominate. Unlike other common encrusting lichens of rocks in the temperate zone, tundra lichens have an upright, branching life form. The shallow soil mantle above permafrost holds very little water if it happens to be sandy or stony. Higher areas also have thinner or absent snowcover because of winds. Lichens are generally much tougher (drought and cold resistant) than higher plants and thus dominate such habitats.

IV. Mosses

Mosses form mats reminiscent of the <u>Spagnum</u> bogs of the lower latitude forests in the Tundra, although the species are different. Productivity is too low for massive quantities of peat accumulation.

<u>Animal Adaptations</u>

The extreme cold stress and short growing season of the Tundra greatly reduces the diversity of animals and imposes special adaptive constraints on the remainder. Poikilotherms are especially scarce; the few reptiles and amphibians penetrate only the more favorable areas of the Boreal Forest. Phytophagous insects are quite rare, although mosquitos are quite thick and a few bumblebees are available to pollinate flowers.

Even resident birds and mammals are very few in species, though voles (lemmings) are quite abundant. Lemmings are well known for their periodic population fluctuations in which population density rises and falls by factors of 10 or more in 3-5 year cycles. Other high latitude animals have similar fluctuations (e.g. Arctic Hare). Ptarmigan, snowshoe hares, caribou, and Arctic foxes are among them. Most of these animals require at least a little forest for cover in the winter time, and other primarily forest species move onto the Tundra in summer (e.g. bears, wolves). More dramatically, a variety of birds migrate onto the Tundra from temperate latitudes to breed, including songbirds, wading birds and waterfowl.

<u>Ecosystemic Characteristics</u>

Tundra ecosystems do not have particularly high primary production, perhaps 1.5 tons/ha/yr. on the average. However, like the Steppes and Savannas, the low growing vegetation is very exposed to herbivore activity. The voles, migrating birds and large mammals may, between them, consume 70 to 80% of each year's net plant production. Thus the animal biomass and production are higher than might be supposed.

Human Uses

I. Hunting and Gathering

The very long cold winter of the very high latitudes is not congenial to humans, a basically tropical species. Further, the Tundra Biome is almost entirely lacking in edible plant resources for humans. A nearly pure hunting mode is required. As a result, only very late, very sophisticated, very specialized hunter-gathers finally penetrated this biome. Groups like the Eskimo apparently arrived in the Tundra only in the last 20 thousand years or so. The lack of high-latitude human foraging adaptations seem to explain why the Americas were settled so recently (most authorities hold that humans have been in the New World only since about 12,000 years ago). Before the last few thousand years, a Bering land bridge would have had no one around to cross it.

Many high latitude foraging populations, especially the Eskimo, are basically shore peoples. The climate of the coast is milder and sea-mammals and fish are richer and more reliable resources than caribou and other inland herbivores. Some Eskimo and Indian populations and some Siberian hunters did live entirely in the Arctic interior, however. The life of the barren ground Eskimo and Naskapi Indian hunters seems to have been among the most marginal human adaptations. The mean productivity of caribou and other big game was high enough to support hunters, but the animals gather in huge migratory herds, which are difficult to find. A little bad luck in locating the herds could easily result in starvation and extinction, especially with a long winter and few plant foods to fall back on.

There is some suspicion that the tundra habitats of the glacial parts of the Pleistocene were quite different, and perhaps more productive, than the modern biome. Larger hunting populations may have existed on the Tundra in the past.

II. Agriculture

Ordinary agricultural production is absent in the Tundra. Only the highly specialized adaptation of reindeer (caribou) herding is present here. This practice arose in Eurasia (date uncertain) and has been adopted by a variety of high Arctic peoples, including Lapps, various Siberian groups, and some Eskimos.

III. Human Impacts

The Tundra Biome is one of the least impacted by modern humans. Populations remain very low almost everywhere. It is a fairly fragile habitat, so when modern populations come to exploit particular resources (e.g. oil or other minerals), impacts can be severe. The slow growing vegetation takes a very long time to recover from disturbance, for example. Construction activities are difficult and have to take into account the peculiarities of permafrost soils. Roads built on Tundra tend to melt the permafrost and turn into mud puddles. Luckily, such difficulties of operating in the Tundra restrict mineral extraction to the most valuable resources, and large areas are likely to remain wilderness. The main danger is like that to the Tropical Evergreen Forest. Ill-advised exploitation schemes may destroy large areas of Tundra, perhaps without even net short-term benefits.

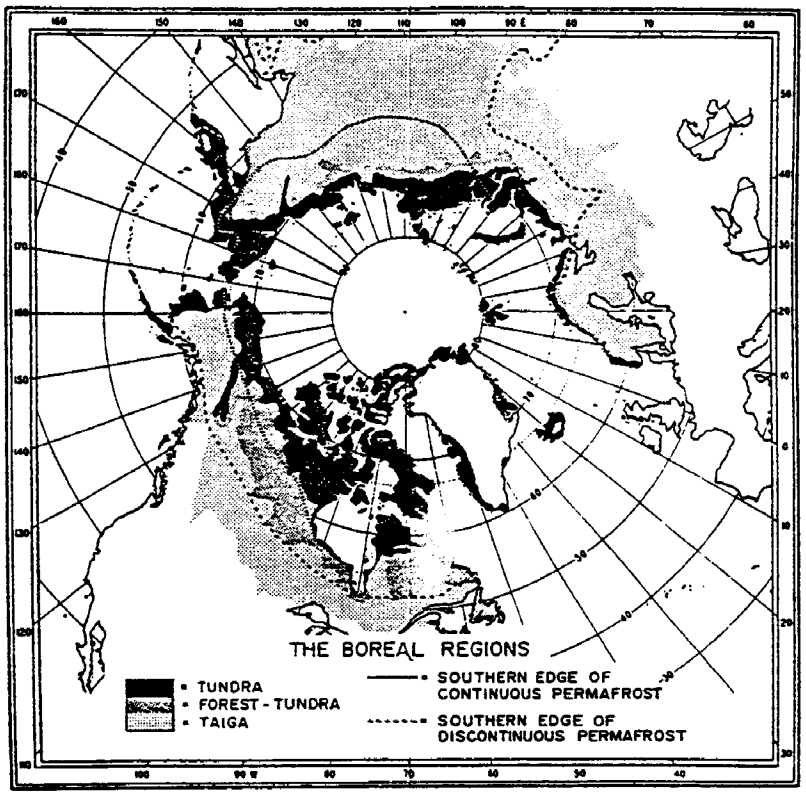
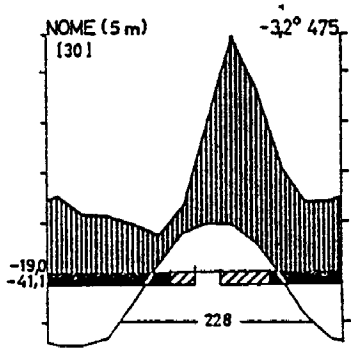


Fig. 1–1 North Polar Projection, emphasizing the Boreal Regions. At this scale boundaries are approximate.



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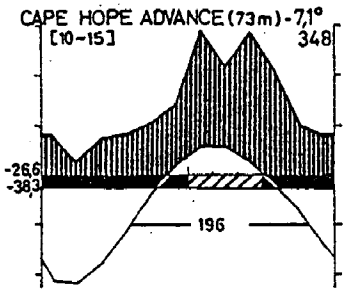

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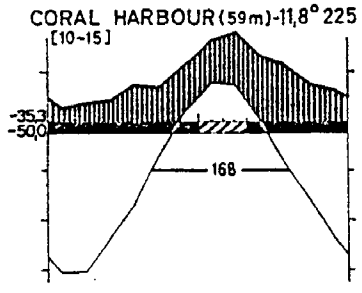

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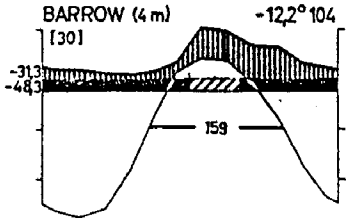

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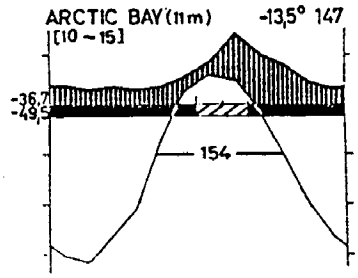

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DISCUSSION QUESTIONS - TUNDRA

1. How can a tundra climate be harsher for plant life than a taiga climate with lower mean temperature?

2. Why do you suppose it took humans so long to achieve the adaptations necessary to exploit the tundra? Do you think genetic or cultural adaptations (or some mixture of both) were involved?

3. During the periods of the Pleistocene with continental ice sheets, cold climates occurred at much lower latitudes equatorward of the ice sheets. How might the climates and biota have differed from the contemporary tundra? Conrariwise, before the global cooling of the last few million years, the polar regions were much warmer. How might this kind of climate have affected plant and animal adaptations?