Losing the Boreal:

A View of How Climate Change Could Shift Alberta's Ecosystems

By Carolyn Campbell, *AWA Conservation Specialist.*

Every now and then you learn something that really shifts your world view. That happened for me in autumn 2013 when I saw University of Alberta biologist Rick Schneider present the first phase of his work modelling what Alberta could look like under a range of likely climate change effects. I've followed the UN's Intergovernmental Panel on Climate Change (IPCC) reports since 1997 and so I've been aware of some of the global food, water, and political implications of what we are leaving to future generations. The revelation in Schneider's work is literally how close to home it hits: it allows us to glimpse how Alberta's regions have changed in response to climate change in the past and to imagine how our touchstone landscapes in Alberta could shift in the next 80 years – the average life expectancy of a baby born in Alberta today. Most importantly, this work can help inspire us to act to conserve them.

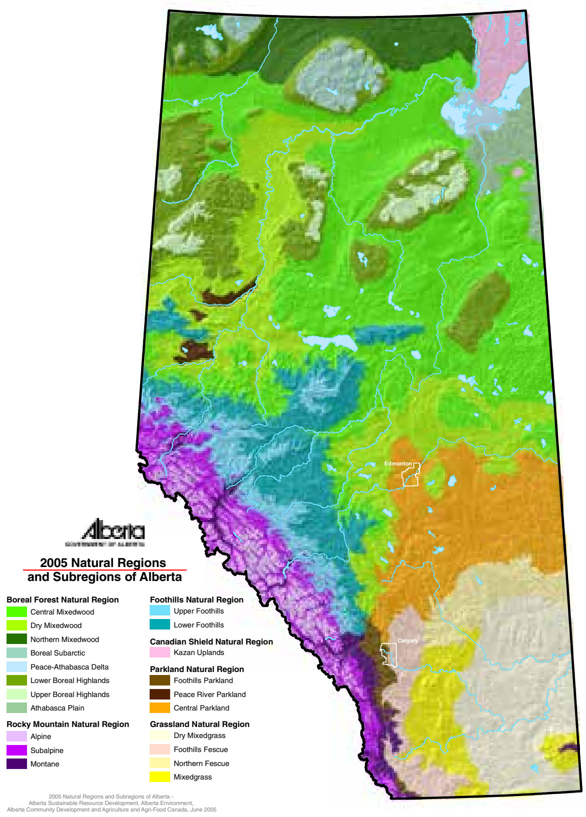
Schneider published the paper *Alberta's Natural Subregions Under a Changing Climate: Past, Present, and Future* in August 2013. It is the first of three studies he will undertake as part of the Biodiversity Management and Climate Change project led by the Alberta Biodiversity Monitoring Institute (ABMI). This first study outlines how our Natural Regions and Subregions might change by the end of this century. The second study, now near completion, looks at options for adapting to climate change and setting objectives for biodiversity conservation in light of climate change. His third study, starting in April 2014, will focus on the design of a protected areas network in the face of climate change.

In summary, Schneider considers drier future scenarios more likely than wetter ones. On the most likely trajectory, grasslands and parkland climates will shift at least one Natural Subregion northwards by the 2050s, and water will become scarcer across the enlarged parkland and grassland regions. The rate at which wetland areas and forests would be displaced by grasses would depend on fire, insect outbreak, drought, and the rate at which species migrate. There is potential to reach a tipping point by the end of the century where our vast Mixedwood Boreal Forest, consisting of extensive peat wetlands and mixed aspen and conifer forests, would be transitioning towards a much drier parkland ecosystem or even towards grasslands. Though Schneider does not dwell on this, the potential for such dramatic loss of species in Alberta leaves a deep impression of why it is so important for us to reduce global greenhouse gas emissions.

Understanding the Present

Schneider clearly explains why Alberta looks the way it does now in terms of the essentials of elevation, temperature, and precipitation. Of all our Natural Regions, the Rocky Mountains and Foothills receive the most precipitation; there, vegetation changes with altitude and, in some areas, directional aspect. Outside the mountains and foothills, precipitation follows an arc: roughly speaking, the most falls in the middle of the province and amounts decrease as you move north and south. Following this pattern and to my surprise, Medicine Hat gets roughly the same precipitation as the northern boundary of Wood Buffalo National Park.

For plants, what matters is how much moisture stays in the ground. In simplified terms, Alberta can be divided into regions that are forested and those that are not. The moisture is driven out of the soil in warm



Map of Alberta's Current Natural Regions
CREDIT: GOVERNMENT OF ALBERTA.

Medicine Hat, so grasslands prevail. In the much cooler boreal forest region, which covers about 60 percent of the province, the soil retains enough moisture to support trees. Soil moisture levels are fairly uniform across large portions of Alberta's boreal, an exception being the cooler, wetter areas of boreal hills such as the Birch Mountains. Such relative uniformity implies that once a tipping point in temperature change is reached, it will affect most of Alberta's boreal forest.

Glimpse into a Warmer Past – the Hypsithermal Period

An early section of Schneider's report reconstructs how Alberta's Natural Regions and Subregions responded to a warmer temperature period in the mid-Holocene era called the Hypsithermal period. It occurred 4,000 to 8,000 years ago. His reconstruction draws on previous research based on pollen obtained from lake and pond sediments from across the province. Schneider states that the Hypsithermal period is of particular interest because Alberta summer temperatures were 1.5 to 3° C warmer than at present; that is at the low end of what is expected later this century as a result of global warming. The Hypsithermal also had colder winters than what current predictions suggest so it's not a perfect match. Nonetheless it reveals how our Natural Regions responded in the past to growing season changes arising from warmer summers.

Subregions occurred approximately one Subregion to the north of their present locations. There is limited data from the Parkland and the Grassland but, in both of these regions, it is clear there was a significant decrease in available water. Most lakes in these two regions, except those fed by deep groundwater sources, were largely dry during the Hypsithermal. This suggests that from the Edmonton area eastward and southward, what is now the aspen-grass Central Parkland would have mainly supported grasses and more extensive sand dunes.

In the Dry Mixedwood Subregion of today's Boreal, Central Parkland characteristics existed during the Hypsithermal period. At lower elevations, Dry Mixedwood Boreal characteristics replaced what is now the largest Subregion, the moister Central Mixedwood. In the Foothills, the water table also was lower and the fire rate and proportion of pine increased at the expense of spruce. In the Rocky Mountains, many southern Alberta glaciers melted (to be re-established in later millenia), the treeline moved up 200 metres and there was some upslope movement of tree species.

Looking at a Range of Future Climates

Today the atmospheric CO^2 concentration is nearly 397 parts per million (ppm), about 25 percent more than the 320 ppm of 1965. Levels of greenhouse gas emissions over the next 80 years are uncertain. They will depend in large part on future population growth, rate of economic development, and the effectiveness of policies to curb emissions. Predictions vary on how increased greenhouse gas emissions will affect future temperatures and precipitation. Schneider uses the range of those predictions to try to identify the likely results for Alberta. I'll briefly describe that process.

Schneider selected one higher (A2) and one lower (B1) standardized or well-accepted scenario of greenhouse gas emissions levels. B1 projects CO^2 concentrations of 488 ppm in 2050 and 549 ppm in 2100. For those same years, A2 projects CO^2 concentrations of 532 and 856 ppm, respectively. He then looked at 24 climate models (Global Circulation Models or GCMs) developed by different teams of scientists that have been used to generate temperature and precipitation responses to emissions for western North America.

The average across all 24 models is for the Mean Annual Temperature for Alberta to rise by 4.2° C by the end of the century under the high-emission A2 scenario and by 2.8° C under the lower B1 scenario. These predicted increases are relative to the average temperature for the "baseline" period of 1961 to 1990. Notably, not one model projects an increase of less than 2.0° C. Such a temperature increase will increase growing degree-days by between 33 and 56 percent, mainly through an earlier spring season.

None of the models predicts a decline in Mean Annual Precipitation (compared to 1961-1990) but 21 out of 24 models predict Alberta will become substantially drier in the coming decades. This is because warmer temperatures increase evapo-transpiration from soils and vegetation and reduce winter snow cover duration. They combine to produce a longer period of evaporative moisture loss. As well, in the middle of summer when moisture stress is greatest, precipitation is expected to decline from today's levels.

Examining the temperature-precipitation outputs from the emission scenarios and models, Schneider focussed his research on scenarios representing a range of five climate outcomes. These scenarios are "Wet," "Cool," "Median," "Hot," and "Dry," based on the defining feature of each profile. Next Schneider used the "climate" output from these five models to model how vegetation would respond in those Alberta Natural Subregions with a strong causal relationship between climate and ecosystem type. He could not do this for several Subregions where non-climatic factors (for example, extensive delta or bedrock) dominate the ecosystem (such as in the Peace-Athabasca Delta, or the Kazan Upland in Alberta's Canadian Shield region). But he could do it for most Subregions.

Less Likely "Wet," More Likely Drier

The effects of increased precipitation predominate in the "Wet" scenario (24 percent higher precipitation, a 4° C temperature increase by the end of the century). Vegetation succession under a hotter and wetter climate is difficult to predict. It would be something like Minnesota's climate, which doesn't exist anywhere in Alberta now. In this scenario, Schneider believes that plant communities would shift due to warming and increased climate variability. But species best suited to the climate would be too far away to out-compete most native species.

Species from more distant warmer regions would eventually arrive but major changes in ecological composition would be unlikely to occur before the dawn of the 22nd Century. Schneider concludes that "Wet" is unlikely because only three of 24 GCMs support this outcome. He does not develop it in as much detail as the scenarios where higher temperature effects dominate.

Of the four scenarios where increased temperature effects dominate, "Dry" is at the other precipitation extreme from "Wet," with zero precipitation change from the baseline and a 4° C temperature increase. "Cool" (a nine percent precipitation increase and an almost 3° C temperature increase) is not really cool but it involves the least change along a range of "in-between" precipitation outcomes. Those in-between outcomes also include "Median" (a nine percent precipitation increase and a 4° C temperature increase) and "Hot" (a six percent precipitation increase and a 6.5°C temperature increase). These three scenarios follow a common pathway of vegetation change, with the main uncertainty being how fast and how far Alberta's Subregions shift along that path.

Schneider produces a series of fascinating maps portraying the modelled shifts in various Natural Subregions for the "Cool," "Median," "Dry," and "Hot" models (there are maps of "Wet" in the Supplemental Map appendix). In the text, he focuses most on describing vegetation shifts under the "Cool" and "Hot" models, which bound the minimum and maximum amount of change expected by the year 2100. He emphasizes how vegetation succession would occur instead of specific endpoints because of the many uncertainties about the timing of changes.

The Drying and Expansion of the Grasslands

Today's Parkland region is the most densely populated region in Alberta, containing Edmonton and Red Deer. Of the four Grassland Subregions, Calgary is now located in the most westerly, the Foothills Fescue. That Subregion extends in a corridor south to the US border and includes the areas around Nanton, Pincher Creek, and Cardston. Precipitation and elevation levels generally decline as we move eastward through the Mixedgrass and Dry Mixedgrass Subregions, with the Northern Mixedgrass Subregion now arching east through Rockyford, Drumheller, and Coronation.

In the "Cool" model, representing the least amount of predicted climate change, Grassland and Parkland Subregion climates shift roughly one Subregion northward by the 2050s. Plant communities preferring the warm and dry end of the spectrum within a given Subregion will flourish, at the expense of communities on the cool and wet end of the spectrum, mainly through competition. Presumably, the Calgary area will remain in Foothills Fescue, but would favour plant communities now found closer to the US border. The Northern Mixedgrass (now in the Hanna-Coronation-Sullivan Lake area) acquires a Dry Mixedgrass climate. Southeast Alberta's Dry Mixedgrass would shift to more closely resemble conditions in northern and central Montana.

In the "Hot" model, the same Grasslands changes as predicted in "Cool" are likely to occur up until the middle of the century. After that, species now outside Alberta that are better suited to dry conditions will be needed for colonizing. A big question is whether species migration can match the rate of climate change, especially under the hottest and driest scenarios. Alberta's current Dry Mixedgrass Subregion in the southeast would have a 2080s climate similar to the driest parts of Wyoming and southern Idaho, suited to sage brush adapted to extreme aridity and with more active sand dunes.

Across today's Grassland and Parkland regions, as in the Hypsithermal period, the average water level of "prairie pothole" wetlands and lakes will decline. Seasonal wetlands will remain dry for longer periods. The change will be proportional to the increase in temperature.

Due to agricultural settlement, few native vegetation areas now remain in Alberta's Parkland region. Under the "Cool" model, conditions will favour Northern Fescue grassland vegetation now seen in the Castor-Coronation area to take over in the Edmonton area (which is now Parkland) by the 2050s. In the "Hot" model, a shift to the Oyen-Medicine Hat Dry Mixedgrass climate will occur in the Edmonton area by the second half of the century. This is a striking change. Schneider's paper does not focus on possible effects to agriculture but there undoubtedly would be important impacts. Where native vegetation persists, the drier climate would reduce the ability of the Parkland's characteristic aspen to withstand drought and insect attack and would favour a transition to grass depending on the temperature change.

Upward Migration in Foothills and Mountains

In the elevation-sensitive Foothills and Rocky Mountains, climate change effects will mean that current low elevation plant communities will mix with and gradually displace higher elevation plant communities. The Foothills under the "Cool" scenario should remain forested because of its high precipitation. Present even-aged lodgepole pine stands will transition to more complex communities including aspen and possibly Douglas fir from the Montane. In the "Hot" scenario, the southern Lower Foothills (north of Cochrane and just west of Sundre and Caroline) will be moisture-limited by the 2050s, and the entire Foothills will be moisture-limited by the 2080s. At that point, a northern expansion of Grasslands from the Foothills Parkland (where Cochrane and Turner Valley are situated) and Foothills Fescue (where Calgary is situated) is likely. Due to the expected time required for grasslands succession, there may not be widespread forest loss by 2100, but the change will be underway.

In the Rocky Mountain Subalpine and Alpine, species will generally move upslope, but at different rates due to local site conditions. The pace of succession will be slow due to the short growing season but eventually Alpine communities will be less able to shift upwards because of slope steepness and lack of soil. Vegetation communities of

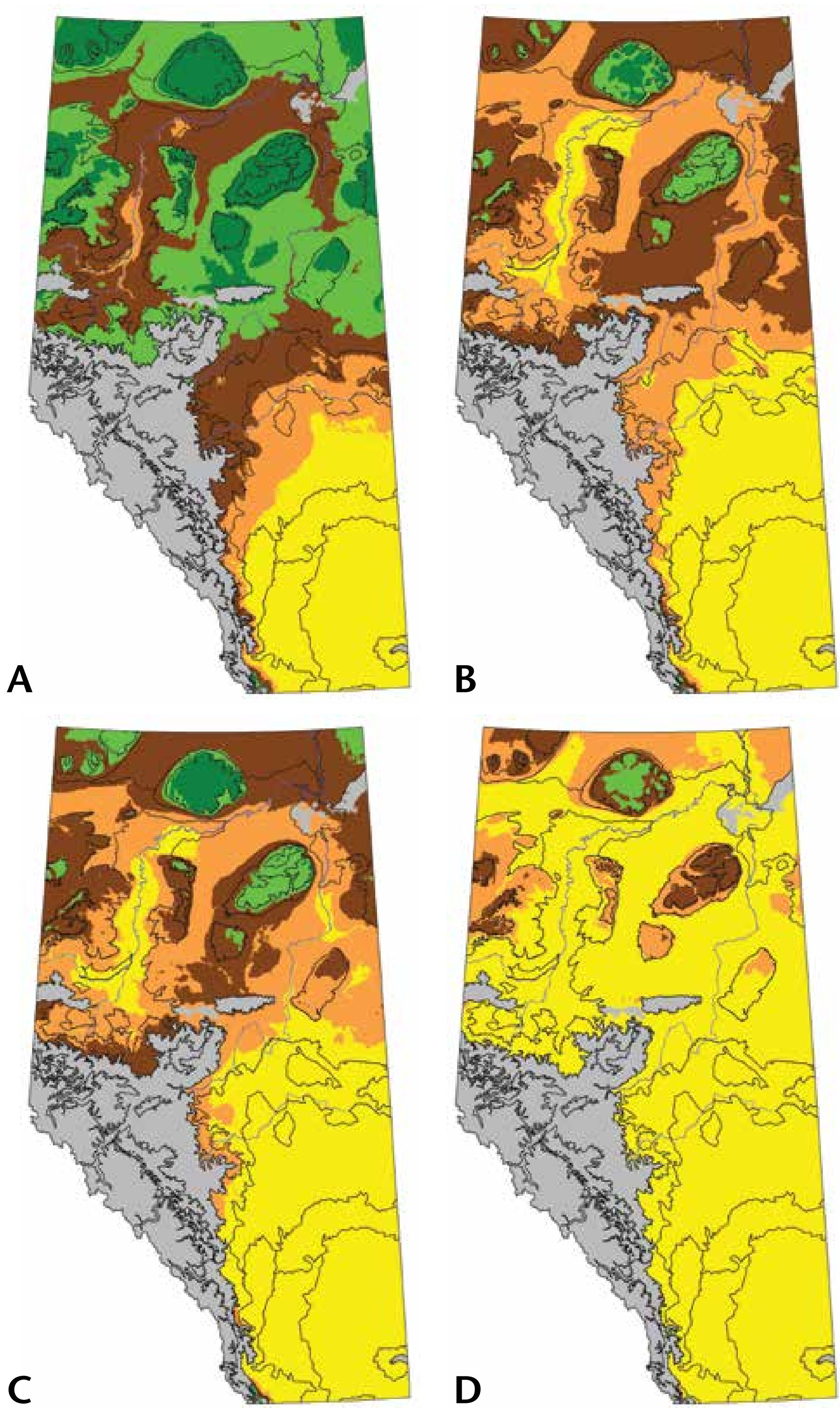
Montane, Subalpine, and Alpine may mix to an extent. Today's Montane area west of Turner Valley and Cochrane consists of open forest and grasslands. At least some Montane forest will remain in the "Cool" model but, under the "Hot" scenario, it will likely transition to Grassland.

The Rocky Mountains and Foothills are our headwaters lands, generating over 80 percent of the annual flows of the North and South Saskatchewan River systems. Groundwater "base flows" and seasonal runoff patterns of the main tributaries and mainstems of these rivers, driven by Mountain and Foothills precipitation and temperature, are vital to downstream urban settlements, irrigated agriculture, and many other industries across Alberta, Saskatchewan, and Manitoba. Since Schneider is focusing on native vegetation change he does not model flow variation of major rivers expected from these climate change scenarios. Other groups such as the Prairie Adaptation Research Collaborative are working on this important topic.

The Contraction of the Boreal

When I interviewed Rick Schneider to ask him what the key climate change impact of his research was, he stated, "The biggest story is the potential for Alberta's boreal to reach a tipping point. We should prepare for it." According to Schneider's modelling, it will only take a couple of degrees' increase in temperatures to reach that tipping point. Because of the large area of relatively uniform boreal forest climate, this implies the potential for a massive change.

The Dry Mixedwood Subregion makes up 22 percent of Alberta's boreal region today (it's shown as "Deciduous" in Schneider's map simulations). It includes the towns of Athabasca and Bonnyville in the northeast and stretches along much of the Peace River up to High Level. Where it has not already been cleared for agriculture, it is primarily aspen forest and roughly 15 percent wetlands. The "Cool" model predicts transition to an aspen-grass Parkland climate over the next few decades. As moisture levels



Maps of four models of potential Alberta Natural Region climate conditions in the 2080s. All the maps show in varying degrees the expansion of Grasslands and contraction of Boreal Forest climate conditions compared to today.
Panel A= Cool model;
Panel B = Median model;
Panel C = Dry model;
Panel D = Hot model.
CREDIT: SCHNEIDER (2013), P. 42.

decline, they eventually limit aspen regeneration and promote grasslands. Strikingly, the "Hot" model predicts Medicine Hat's Dry Mixedgrass climate will be established across the Dry Mixedwood by the latter half of the century. After the 2050s, depending on the rate of fire and insects, aspen regeneration would decline and widespread transitions would occur beginning with south and west-facing slopes.

The Central Mixedwood is by far Alberta's largest Subregion today, covering 44 percent of the Boreal or a quarter of the entire province. In the northeast, the Central Mixedwood extends from Lac La Biche to about 100 kilometres north of Fort McMurray, where the drier, sandier Athabasca Plain begins. In north central Alberta, it extends from Lesser Slave Lake to Wood Buffalo National Park, interrupted by several boreal hill systems. In the northwest it includes a wide area around the Hay-Zama Lakes, bounded by Boreal Highlands.

The relatively flat topography of the Central Mixedwood means that excess water tends to pool in low lying areas. Since the last glacial period, slow decomposition in these wetlands due to cool temperatures has led to the accumulation of peat wetlands (fens and bogs) over almost half the Central Mixedwood landscape. These wetlands include extensive areas of black spruce fens. On the uplands there are aspen, mixedwood, and white spruce forests, with jack pine stands on the sandier soils to the east. Though Schneider does not address wildlife impacts in his paper, the Subregion supports a range of fur-bearing carnivores, dozens of migratory bird species during their breeding season and, in its intact peatland complexes and old growth forests, populations of boreal woodland caribou.

For both "Cool" and "Hot" models, climate change effects in the Central Mixedwood will begin first in lower areas, and widespread change across the higher elevation areas will follow. In the "Cool" scenario, Dry Mixedwood characteristics would appear along the Peace and Athabasca Rivers by the 2020s and extend across most of the Subregion by the 2050s. After 2050, a Parkland climate would be established, and most white spruce would be lost from low elevations by the end of the century. At higher elevations in the Central Mixedwood, there would be minimal permanent loss of white spruce before 2050; after that, the shift would be driven by forest fires. Total surplus surface water will decline, peat formation will stop, and most wetlands will eventually transition to Parkland characteristics, albeit with a significant lag. The availability of groundwater is an uncertainty; it may slow this transition, or not. Even this change, from Central Mixedwood to Parkland under the "Cool" scenario, would involve an astonishing loss of Alberta's species diversity in the lifetime of today's young children.

In the "Hot" scenario, almost the entire Central Mixedwood experiences a Grassland climate by the 2050s. The transition to a moisture limited system happens quickly, and fire would be the main factor in the succession rate. Additional tree mortality could occur from prolonged drought. Forest loss can also be expected from ongoing forest clearing by the petroleum industry and from harvesting by the forest industry if efforts at regeneration prove unsuccessful in the dry climate of the "Hot" model. Because of the large amount of water now stored in the Central Mixedwood, Schneider notes that a transition of wet sites to grassland by the end of the century is unlikely. It is unclear what the intermediate stages might be, but eventually, most wetlands will transition to grassland characteristics. The remaining water bodies will eventually be those either fed by groundwater or those whose waters are deep enough to sustain summer outflows and evaporation.

In the uplands, the transition to grassland would be affected by the limited number of dry-adapted grass species available in forested areas, and possibly by soil type as well. Invasive grass species could become abundant given the extensive road network in the Boreal and the relative absence of native grass species. A forest industry response may be to plant non-native dry-adapted tree species, which could also affect succession patterns.

The Upper and Lower Boreal Highlands make up 18 percent of the Boreal, and include the Chinchaga region, Birch Mountains, and Caribou Mountains. Their succession pathway is similar to the Central Mixedwood, only delayed because of higher elevations. Under the "Cool" model, Central Mixedwood climate conditions are achieved by the 2020s or 2030s. In the "Hot" scenario, the climate conditions reach the current Dry Mixedwood by the 2050s, and the lower hills eventually transition to a Parkland or even a Grassland climate.

In the Northern Mixedwood that now covers eight percent of the Boreal, permafrost thawing is likely to be complete by the end of the century under the "Hot" model, but some permafrost patches may remain under the "Cool" model. This thawing initially favours the formation of bogs and fens, which then dry as temperatures warm. Again, because of the water now stored in this Subregion, Schneider considers it unlikely to change much beyond a wetland stage by the end of the century. Under the A2 scenario, greenhouse gas emissions do not stabilize by 2100. If humanity goes down that path, climate warming and associated forest transitions would continue. This would eventually expose most of Alberta's boreal forest to a grassland climate. This would indeed mean a profound transformation of the Alberta we know now.

Understanding how Natural Regions and Subregions may well change in the next 80 years will hopefully strengthen our resolve to work to slow down the likelihood of this change by reducing global greenhouse gas emissions. It should also inform our conservation planning and adaptation efforts. Edmonton and area members can get a preview of Schneider's work to date on this topic at our Edmonton Talk that he will present on April 7 (see Events section). We will also keep our readers posted as more instalments of these landmark studies are completed.