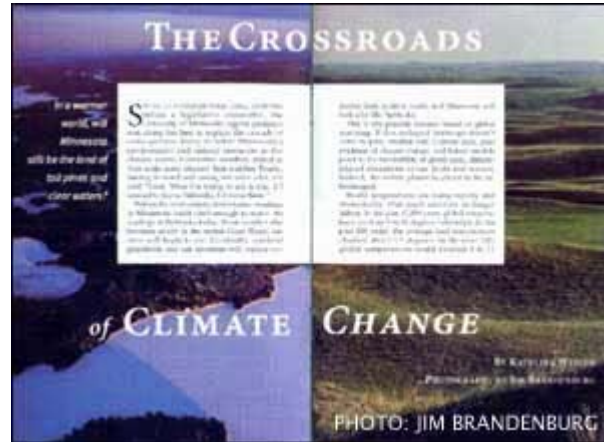


The Crossroads of Climate Change

In a warmer world, will Minnesota still be the land of tall pines and clear waters?

By Kathleen Weflen

Sitting at a polished wood table, testifying before a legislative committee, the University of Minnesota regents professor was doing her best to explain the cascade of consequences likely to befall Minnesota's environment and natural resources as the climate warms. Committee members stirred in their seats; some checked their watches. Finally, leaning forward and raising her voice a bit, she said, "Look. What I'm trying to say is this: If I wanted to live in Nebraska, I'd move there."



Within the next century, temperature readings in Minnesota could climb enough to match the readings in Nebraska today. If our weather also becomes as dry as the central Great Plains, our trees will begin to die. Eventually, semiarid grasslands and oak savannas will replace our forests from south to north, and Minnesota will look a lot like Nebraska.

This is one possible scenario based on global warming. If this reshaped landscape doesn't come to pass, another will. Climate data, past evidence of climate change, and future models point to the inevitability of grand-scale, climate-related alterations to our lands and waters. Indeed, the entire planet is about to be re-landscaped.

World temperatures are rising rapidly and dramatically. That much scientists no longer debate. In the past 17,000 years, global temperatures went up 8 to 10 degrees Fahrenheit. In the past 100 years, the average land temperature climbed about 1.5 degrees. In the next 100, global temperatures could escalate 4 to 11 degrees, according to the United Nations Intergovernmental Panel on Climate Change.

Carbon dioxide, methane, and other greenhouse gases are increasing. Along with water vapor, the gases hold heat in the atmosphere, keeping earth at a balmy 59 degrees on average. Since the Industrial Revolution, however, these insulating gases have piled up like extra blankets, trapping more heat. Carbon dioxide has increased nearly 30 percent. Methane has more than doubled.

During the past two decades, most springs in Minnesota have arrived earlier than usual--sometimes by a week or more. Eight of the 20 warmest years in Minnesota have been recorded since 1981. While the mid-1990s brought some unusually harsh winters, never in recorded history has Minnesota had three benign winters in a row as it did with record high-temperature years occurring in 1997, 1998, and 1999. Many Minnesotans have mixed feelings about the near demise of winter. One question on our minds: How will our state change if spring comes earlier every year?

If warming continues, Minnesota's components of boreal forests could fade away. For uncertain reasons, spruce along North Shore streams have already declined in recent decades. Within two or three decades, the shift from conifers to hardwoods could become obvious, but it probably won't be pretty. After all, one mature forest won't simply give way to another. And even when new forest matures, it will look different from today's mix. One species, such as sugar maple, could dominate. Flora and fauna would be less diverse than they are today.

Noting that average winter temperatures in northern Minnesota have gone up 3 to 5 F in the past century, University of Minnesota forest disturbance researcher Lee Frelich says, "If this rise in temperature continues, the Boundary Waters will change to oak and pine, similar to what you see now on the bluffs at Taylors Falls in Interstate State Park."

Rainfall is a critical variable, but a difficult one to predict for a changed climate, says Frelich. "If it becomes warm and dry, then there will not be much forest left in Minnesota. The state will be like Nebraska. If it becomes warm and wet, then the state could still be forested, like Ohio, for example." But, again, Minnesota would not be beautifully reforested any time soon. New species would take years to arrive, mature, and reproduce. Beech trees, for example, don't begin seed production for 40 years.

Crossing Boundaries

Minnesota's place on earth makes it particularly sensitive to change in the climate. The state sits at the continental crossroads of three major biomes--prairie, deciduous forest, and northern coniferous forest--caused in large part by three major air masses--relatively dry Pacific air, humid air from the Gulf of Mexico, and polar air. John Tester, ecologist and author of Minnesota's Natural Heritage, says this location probably gives Minnesota the greatest climate changes in the shortest distances and times in North America, except for mountainous areas. Perhaps this is why we Minnesotans seem to be so obsessed with climate and weather: It's not so much that we live in a remarkably cold and snowy place; it's that our climate is variable in the extreme.

You can see this variability in climate and biomes if you drive north from Minneapolis to Duluth on a summer day. Around Hinckley the air cools and cornfields give way to maple, elm, ash, and other hardwoods. This is the climate boundary where warm, humid air coming up from the Gulf of Mexico veers eastward. Another 30 miles north near Barnum, you cross the southern boundary of the polar air mass. Here cooler air has coaxed spruce and fir out of wet lowlands into the uplands, and you begin to see aspen and birch.

If current warming trends persist, we could see a striking shift in these climate and landscape boundaries, says John Pastor, research ecologist with the Natural Resources Research Institute, University of Minnesota?Duluth. "Move the climate of Minneapolis to Duluth, and you'll get Minneapolis vegetation," he says. "And that could happen in 50 years."

A Matter of Degrees

Could a few degrees of warming cause such a big shift? Tester uncovered a clear example. He wondered why vegetation changed abruptly from forest around Itasca State Park to prairie in Mahnomen County just 50 miles west. Examining

weather records, he found similar January temperatures in forest and prairie, but an August mean of 65.1 F in the forest and 69 degrees in the prairie. He noted annual precipitation averaged 25.1 inches in the forest and 19.6 inches on the prairie. His conclusion: Shifts of less than 4 degrees in temperature and 6 inches in moisture created this forest-prairie border.

The places where the biomes meet will be the first locales to feel the heat of global warming and undergo alterations in flora and fauna. Minnesota is especially vulnerable to warming because of its extensive transition zones. What's more, northern latitudes show the greatest seasonal change, and these places will likely experience some of the most pronounced changes due to climate.

Some climate change is, of course, natural. Climate has been shifting Minnesota's landscape for thousands of years. Peering through microscopes at grains of pollen extracted from muddy lake bottoms and bogs, scientists have seen the evidence that 12,000 years ago spruce trees covered most of Minnesota. About 10,000 years ago, when the glaciers had melted back into Canada, pines, oaks, and other deciduous trees replaced spruce.

Between 8,000 and 5,000 years ago, the summers became warmer and drier, and water levels fell. According to pollen records, prairie plants took root in western Minnesota around this time. Birches and pines moved north as prairie plants pushed eastward into Wisconsin. As the climate began cooling around 6,000 years ago, the trees began migrating south and west again. The prairie-forest border shifted westward and remained fixed from about 500 years ago until 1850, when Euro-Americans arrived with their axes and plows. Agricultural weeds, such as ragweed, become common in the pollen records from this time, while the percentages of forest and prairie species decline.

As Minnesota's climate changes again, time will be of the essence. Habitats could shift hundreds of miles north within decades. Now, instead of thousands of years, species might have a few decades to colonize new areas with suitable climate. If species can't transplant themselves to new habitat, the population size could drop--perhaps too low to reproduce successfully--and extinctions could occur.

University of Minnesota ecologist Margaret Davis has studied lake-sediment pollen records to determine the rate at which trees can relocate. Though spruce and beech trees are not endangered, their rate of movement illustrates how species or genotypes might fare as their climate range shifts northward at unprecedented speed. Spruce hold the record for fastest dispersal. During the period of rapid warming 10,000 years ago, spruce moved 60 miles per century into northwestern Canada. A northward-flowing river might have helped disperse their seeds. Beech trees, on the other hand, managed to move only 10 miles in a century, as jays carried their nuts a few miles and buried them in the woods. With the predicted doubling of carbon dioxide concentrations around 2060, geographical range limits would move about 300 miles per century, too fast for some species to keep up.

Soil and Water Mix

At the root of how species might react to climate change is soil. Pastor and his research team created computer models to simulate tree species in northeastern forests on two soil types--heavy clay and sand. They bumped up temperatures 3.6 F and doubled carbon dioxide. On clay, which retains water, northern

hardwoods such as maple and yellow birch displaced conifers. These less cold-hardy species grow faster and larger than spruce and fir. And their leaf litter contains more nitrogen and breaks down faster, thus adding more soil nitrogen and productivity as warming lengthened the growing season.

Sandy soil holds less water, and coniferous-hardwood forest in sandy soil gave way to stunted pine-oak forest. Thus, the climate model suggested, the sand-plain forests around Brainerd, north of Duluth, and in the Boundary Waters Canoe Area would likely be replaced by oak savanna, brush, and grasslands.

Room to Move

One complication of predicting the consequences of warming is this: Climate change is being imposed on lands and waters that have already been altered by human activities. John Almendinger, ecologist with Department of Natural Resources Forest Assessment, studies the paleohistory of vegetation to look for patterns of change. Though the warmer, drier climate of 8,000 to 5,000 years ago suggests how our land might change again, he says the historic link breaks down for two reasons: We've suppressed fires, and we've fragmented the landscape.

Historically, fires set the stage for natural regeneration of conifers. In the absence of fire, says Almendinger, native pines, tamarack, and black spruce have been decreasing since logging caused the initial loss. Most of the former conifer forests are being managed for aspen or are succeeding to fire-sensitive hardwoods. Fire-sensitive balsam fir is the only conifer that has increased its populations.

The ability of plants and animals to relocate and to maintain genetic variability will depend in part on how isolated they are. Species currently in northern Minnesota might fare better than those to the south where farmland, cities, and other barriers surround fragments of habitat. Wind-carried seeds, spores, and pollen enable some plants to colonize and crossbreed despite fragmented landscapes. But other plants depend on animals to disperse their seeds or pollinate their flowers. These interdependent species may need more direct routes--green corridors--to move from one habitat to another.

"We should ask if we have landscapes that are sufficiently intact to let nature take its course," Almendinger says. The DNR Conservation Connections program helps address that question. It aims to connect natural areas, creating travel corridors for plants and wildlife. Says Almendinger, "That's pretty clearly the right direction."

Green corridors might not be enough to help rare species, such as the Minnesota dwarf trout lily, which evolved in a particular environment and has an insular range. This diminutive woodland flower grows in three watersheds in Minnesota--and nowhere else in the world. Though it occasionally forms seeds, it appears to reproduce only by sending out runners. Being an endemic species with vegetative reproduction means double trouble--the dwarf trout lily is crippled in both its ability to disperse and its ability to adapt genetically, unlike seed reproducers that have the opportunity for sexual recombination.

Climate change might already be stressing dwarf trout lily populations. After the past two nearly snowless winters, DNR biologists have noted crashes in both the number of colonies and the number of plants.

Winners and Losers

For some wildlife populations, the climate news is more heartening. White-tailed deer, for example, would not be perturbed if Minnesota looked like Nebraska. They can find food and shelter just about anywhere--from boreal forests to southern grasslands. And they tolerate heat. Heat has a big bearing on a deer's weight, as it does for many mammals. The nation's smallest deer live in Florida, while northern boreal forests have the largest. Thus, a warmer Minnesota might have more but smaller deer to hunt. Pheasants and wild turkeys, also at the northern edge of their range in Minnesota, could multiply too.

Black bears would probably be able to take the heat. Their range from Alaska to Mexico shows their adaptability. They are generalists in their food selection but prefer wooded cover. If more oak trees were to grow in a warmer Minnesota, bears would feed more heavily on fall acorns. Then well-fattened young bears would mature and reproduce sooner. Populations could increase in number if forest habitat is available.

In some parts of Minnesota, observers have noted the appearance of new wild neighbors that could be reacting to climate change. Cardinals have flown north to Duluth. Raccoons now range north into Canada. Opossums have ambled north into Minnesota. True katydids, an eastern and southern U.S. species, recently arrived in the Twin Cities.

As habitat changes, so will its inhabitants. Species adapted to specific habitats are most vulnerable to shifts. The disappearance of boreal forests would dislocate boreal species such as pine marten and fisher. Unlike whitetails, moose cannot tolerate heat and need boreal vegetation to survive. Their range would shift northward, out of Minnesota.

Birds, of course, are the wild creatures best suited for long-distance travel to new grounds. Perhaps 36 bird species may no longer show up in a warmer Minnesota, says Jeff Price, director of the American Bird Conservancy's climate studies. Pine siskins, boreal chickadees, and other north-woods species are projected to shift northward. Dark-eyed juncos and evening grosbeaks may no longer turn up at bird feeders. And it may be no use listening for the songs of white-throated sparrows or a host of now-native vireos and warblers.

Few ducks may answer the calls of hunters in western Minnesota's prairie potholes, part of North America's most important waterfowl breeding area. A 1998 study led by Lisa Sorenson of Boston University tested 12 hotter-weather scenarios in the pothole region and found that 11 would lead to drought. By 2050 the numbers of ponds and ducks could drop by about half their current averages. Hunters hoping to head north to find ducks in Canada might be sorely disappointed: Ducks breeding farther north may be less productive, and wetlands there may also suffer drought.

As some bird species leave the declining forests of the Arrowhead region, a couple dozen more might move into newly suitable habitat as their former ranges shift. As grasslands expand, Minnesota might attract more meadowlarks, field sparrows, grasshopper sparrows, and the like. Painted buntings, great-tailed grackles, and a few other species could colonize the state.

Timing as well as distance may be a telling factor in how birds and other species adjust to new habitats. What happens, for instance, if migratory species arrive on their spring breeding grounds before food sources show up, that is, before key

plants flower or insects hatch? And what happens to plants, in turn, if birds, bats, butterflies, or other pollinators don't synchronize their arrival with blooming?

Warming Waters

Minnesota's fish and other aquatic organisms are bound by three great drainage systems--northeastern lands drain into the Great Lakes, the north and northwest into Hudson Bay, central and southern into the Mississippi. Waterfalls, dams, and other barricades impede species migration and dispersal along rivers and streams within each system's watersheds. With little room to move, species will need to adapt to survive changes in their waters.

What will happen to lake and stream levels as the climate warms is as unpredictable as rain. With carbon dioxide doubling, evaporation would increase and could lead to the loss of 8 to 12 inches of lake water, in addition to current evaporative losses. Precipitation, particularly in summer, could offset the loss. With more evaporation and evapotranspiration, more precipitation will likely fall somewhere on earth--but not necessarily in Minnesota.

Lake and stream temperatures may change too. Maximum weekly stream temperatures in summer would rise about 3 to 4 F, according to projections based on a doubling of atmospheric carbon dioxide sometime in the future. If a stream loses its shade trees due to climate change, its water could heat up another 11 to 14 degrees. Eventually, even the groundwater-fed streams of the southeast could warm, because shallow aquifers are related to mean annual air temperatures. Some, or even many, streams could lose their trout and become bass or catfish waters. In other words, they might resemble the streams of Missouri.

Like forests, streams will change slowly but surely if warming continues. For example, picture a 10-mile stretch of a cold, spring-fed stream that empties into a warm-water river such as the Zumbro. Over the course of many years, as waters warm, trout would gradually creep up into cooler water closer to the source. Trout anglers would have to go upstream seven or eight miles to find fish. Later they might find only isolated pockets of trout. Eventually trout could vanish from those streams fed by limited quantities of groundwater.

Along the North Shore, another story would unfold. Here trout streams drain from warm-water lakes. Dense canopies of spruce create cool microclimates along the streams. When it comes to cooling these critical habitats, aspen and other tree species just don't cut it, says Mark Ebbers, DNR trout program coordinator. Logging of streamside spruce stands could help explain the disappearance of brook trout from the Temperance River. Reports from 50 to 75 years ago claimed anglers found brook trout aplenty. Today water temperatures are above brook trout tolerance. If Minneapolis weather moves up the North Shore and spruce decline, all of these streams would likely lose their trout.

Perhaps the DNR could stock smallmouth bass in the vacant niche. Bass and sunfish are among the species that would find warming to their liking.

Walleyes and crappies would probably increase in cold northern trout lakes. Trout and cisco would decline in all but the deepest, coldest northern lakes.

Why Act Now?

The earth's temperature will continue to rise even if we stabilize carbon dioxide emissions today, says Peter Ciborowski, the Minnesota Pollution Control Agency's expert on climate change. That's because we'll still be adding 3 to 4 billion metric tons of carbon per year to the atmosphere.

What's more, the full impact of emissions is being masked, Ciborowski says, because oceans are absorbing some of the extra heat, storing it, and releasing it years later--perhaps delaying the onset of atmospheric warming by 30 to 40 years. Eventually, the oceans may warm to the point that they stop draining away heat.

In 1997 in Kyoto, Japan, more than 150 nations agreed on the need to reduce greenhouse-gas emissions. Ciborowski is drawing up a list of options for reducing Minnesota's carbon contribution of about 0.5 percent of the world's total. If nations take action within the next decade, Ciborowski believes we could stop increasing emissions from large industrialized countries, slow the growth elsewhere, and then begin to reduce them. That effort will require worldwide planning and local action.

Reducing emissions is "not about giving up your car," says Michael Noble, director of Minnesotans for an Energy-Efficient Economy. Instead, he says, it's about galvanizing public demand to put energy-efficient technology into use now. Just as the world has embraced information technology--cell phones, personal computers, the Internet--in the past 15 years, so can people transform the use of energy technology, he says. "It's not a mystery how to fix this problem," says Noble. "Every change in energy technology has led to an improvement in the quality of life--wood to coal, coal to gas . . . now to solar cells, wind turbines, fuel cells."

Research ecologist John Pastor insists that people need to view both the causes and consequences of warming in personal terms. How we use our land, cities, and highways affects the climate as surely as the climate affects us. If we drive fuel-efficient cars and reduce our annual mileage, for example, we keep tons of carbon out of the atmosphere.

Though we must continue to investigate the impacts of warming, Pastor says, we cannot afford to wait any longer before we act. "Once we see broad-scale changes happening in vegetation," he says, "it's too late." Natural systems will collapse.

Humans might be able to adapt to new habitat in a warmer world, but what are we willing to give up? At risk is our natural heritage, Pastor says, our sense of place. And we could lose that identity soon. While they skied together near their home in Duluth, Pastor's college-age son asked him to estimate the speed of change. Pastor calculated a possible time line based on his own age of 48. "I'll live out the rest of my life in these north woods I love. You will not," he told his son. "By the time you die, this is not going to be here. Your children--my grandchildren--will only live a small part of their lives here. And my great-grandchildren probably will not see this at all."

Learn More

Here are three of many web sites on climate change:

[Minnesotans for an Energy Efficiency Economy](#) (Minnesota perspective)

[EPA's Global Warming Site](#) (federal government)

Global Change and Environmental Education Resources (educational resources)


Rocky Mountain Institute (practical advice for individuals)

Two recent books on climate change are:

The Change in the Weather, William K. Stevens. Delacorte Press, 1999.

Weather: How It Works and Why, Arthur Upgren and Jurgen Stock. Perseus, 2000.

From Jan. 8 through April 22, the Science Museum of Minnesota in St. Paul will feature Polar Thaw: Global Warming in the Arctic and Antarctic. The exhibit chronicles the impacts of global warming at high latitudes.

For more information, call 651-221-9444 .

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