



The blue pearl. A yak searches for vegetation near Lake Hovsgol.

CLIMATE CHANGE

The Big Thaw Reaches Mongolia's Pristine North

As warmer temperatures affect plants, animals, and human society, researchers ask whether ecological changes can be reversed

LAKE HOVSGOL, MONGOLIA—The shortcut through the forest was the only way to get back to base camp before dark. But now Tumorsuk and his passengers may not make it home tonight at all. The burly forest ranger steps on the gas pedal, and the wheels scream as the jeep sinks deeper into the muck. Tumorsuk mutters in Mongolian, kills the engine, and climbs out. The fading daylight casts a blue hue on fresh snow covering every pit, branch, and boulder. Wolves will soon be on the prowl.

“He wants us to get out,” ecologist Bazartseren Boldgiv says calmly. He and his Ph.D. student Lkhagva Ariuntsetseg, both at the National University of Mongolia in Ulaanbaatar, peer under the jeep; its belly is flush with the ground. Ecologist Clyde Goulden, visiting from the Academy of Natural Sciences in Philadelphia, Pennsylvania, scans the evergreen taiga forest. The trees tilt at drunken angles. Some have toppled over. “This is climate change,” Goulden says. Higher average temperatures in summer are thawing the layer of permanently frozen soil, or permafrost, and disturbing the soil structure around the shallow tree roots.

Global warming is not a uniform process. Mongolia, particularly at the high altitudes around Lake Hovsgol, has been warming more than twice as fast as the global average. Unique ecosystems are feeling the heat. Here at the transition between steppe grassland and taiga, plants and animals are confronted with a changing environment—and the outlook is not good for the herders who are crowding up from the south. Since the end of communism early in the last decade, the steppe has seen an explosion in livestock numbers—expanding up to threefold over the past 2 decades alone. The grasslands are on the verge of ecological collapse, says

Goulden. “The environmental problems are closing in on two fronts at once.”

Tumorsuk’s breath clouds his broad, ruddy face. He orders the scientists to gather stones. Then he pulls an ax from under his seat and disappears into the woods.

A blue pearl on ice

Sidelined by a chronic back injury, Goulden watches as his colleagues pile rocks next to the jeep, following Tumorsuk’s mysterious order. If he’s worried, he doesn’t show it. Then again, Goulden, 70, is no stranger to hardship in the most sparsely populated country on Earth. Since helping launch long-term ecological studies of the Lake Hovsgol region in 1994, Goulden has dealt with many hassles. In 2006, fierce winds sank a motorboat that shuttled his team 100 kilometers to the northern shore. Fortunately, no one was injured. Sans boat, they now make a bone-rattling drive—8 hours in ideal conditions, 4 days at worst—to get supplies and scientists to field sites.

Hovsgol’s forbidding location makes it an ecological wonderland. Of the world’s 17 ancient lakes—those with the geologic fortune of existing continuously for millions of years—Hovsgol is the most pristine outside of Antarctica. The “blue pearl,” as Mongolians call it, is untouched by the pollution that has spoiled most Eurasian lakes, and arid Mongolia wants to keep it that way.

Tumorsuk—who, like many Mongolians, does not use a last name—is one of 14 rangers charged with patrolling the Connecticut-sized nature reserve encompassing the lake. One of his main jobs is to track the hooves arriving from the south. Nomadic herders have plied the steppe since antiquity, grazing horses, yaks, goats, and sheep for a few months in one valley before

pulling up the poles of their felt-lined gers and moving on to the next. But the steppe has never supported the present horde: 35 million head of livestock, more than 10 times the human population of Mongolia. Tumorsuk must constantly cajole the herders not to overgraze the steppe around the lake.

While people around the world are giving up agrarianism for the city life, Mongolians are streaming in the opposite direction. During 8 decades of communism, a nation of herders was forcibly modernized. The results are a mixed bag: Although Mongolians enjoy one of the highest literacy rates in the world, their shamanistic traditions were all but exterminated, and the cities swelled, particularly Ulaanbaatar, where a third of Mongolians now live. But when the Soviet Union crumbled in 1991, newly democratic Mongolia suddenly lost its economic *raison d’être*. Bustling trade routes to Russia ebbed. Unemployment skyrocketed in the mid-1990s. Relations with China remain cautious.

“They fell back on what they know,” says Goulden. “The problem is that most of the new herders don’t have the know-how.” The flow of traditional knowledge from one generation to the next—how to avoid conflicts with other herders, keep animals healthy, and avoid overgrazing, for instance—was severed. The limits of sustainability are being tested on a grand scale.

If land-use patterns were the only change, Mongolia’s predicament would not be so dire. But now the land itself is changing. Winter temperatures in Mongolia have increased a staggering 3.6°C on average during the past 60 years. “The mountains are losing their snowcaps, and the glaciers on the northern shore are shrinking,” says Goulden.

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This is no boon for agriculture. Although global warming has shifted the start of the growing season from June to May, precipitation is more erratic, Goulden says. Four of the worst drought years on record in Mongolia occurred in the past decade. And during the same period, intense storms have grown more frequent, according to a 2005 report by the United Nations Environment Programme. Flash floods erode the overgrazed steppe topsoil. But the worst weather condition is the dreaded dzud, an ice crust that forms over vegetation when rain freezes or melted snow refreezes. From 1999 to 2002, dzuds were a death sentence for 10 million animals that were unable to forage. The livestock losses spurred a wave of suicides among herders.

Where theory meets dirt

Dusk is settling on the taiga. Tumorsuk returns to the jeep, huffing as he lugs a 3-meter-long section of tree trunk on his shoulder. He drops it next to the jeep and digs around the sunken wheels with a shovel, clearing out sloppy muck. As they stand by helplessly, the ecologists' fingers and toes grow numb.

This muck is global warming's battleground. Lake Hovsgol straddles the southern edge of the Northern Hemisphere's permafrost. That edge is receding. As permafrost retreats deeper or disappears, the ground becomes a giant sponge that wicks water away from plant roots. That sets big changes in motion topside. "Taiga and permafrost always go together," says geophysicist Vladimir Romanovsky of the University of Alaska, Fairbanks. "You can't have one without the other." Hovsgol's

taiga forest is growing patchier. And without the insulating tree cover, he says, soil warming accelerates.

Also worrying is a flash point created by drying soil and dying vegetation. Fires are a natural feature here, as shown by periodic dark bands in tree rings. But fires are growing more frequent and fierce, says Boldgiv. The worst-case scenario is that drought and wildfires converge in a regional conflagration. Huge swaths of taiga forest and steppe grasslands could be lost in a single summer, he says. There is no fire brigade out here.

Just what ecosystem might emerge from that apocalyptic scenario is a central question of the Hovsgol project. After a decade of research, ecologists have bad news and worse news. The bad news is that receding taiga and overgrazed steppe tend to leave shrubby wasteland in their wake. Islands of this "semidesert" of sparse plants and few grasses are expanding. Goulden is worried that this may warn of a wholesale transition to semidesert, which would be "disastrous," he says, because it supports a fraction of the animal density that grassland supports. And it could ruin the country's best source of drinking water if topsoil eroding into Hovsgol's tributaries spurs algal growth in the lake.

The worse news: This transformation could be a one-way ticket. A long-standing question in ecology is whether communi-

ties of species can be tipped into "alternative stable states." The steppe grasslands, for example, have proved for millennia to be a robust solution to life in cold, dry Mongolia. But once widespread conversion to semidesert occurs, it might be virtually impossible to reverse, says Goulden. In the taiga, even a temporary loss of permafrost, combined with extreme drought and fires, might be a point of no return, he says. The theory of alternative stable states is a mainstay of modern ecology, says ecologist Peter Petraitis of the University of Pennsylvania. But despite decades of experiments, "it remains just that—a theory."

What is needed is the intense study of a real-world system, he says.

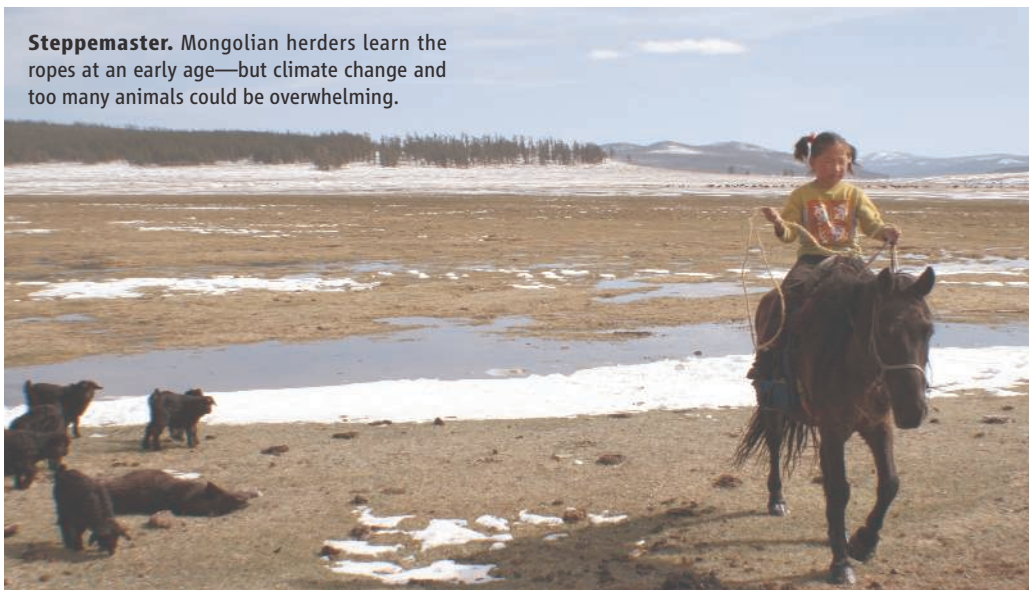
The American-Mongolian collaboration just received a boost to do that. Starting this year, the U.S. National Science Foundation is funding their work in Mongolia with a 5-year, \$2.5 million grant, jointly led by Petraitis, Goulden, and Boldgiv. One task will be to widen the net of environmental monitoring they have established by compiling a map of permafrost, stream hydrology, and plant species distribution. To plug hard data into their ecological models of global warming, they will build chambers over experimental plots and measure the effects of temperature, plant cover, and other parameters on soil moisture and respiration. Also built into the grant is a training exchange between Mongolia and the United States. "The Mongolians know their environment better than anyone," says Goulden. "This must be an equal partnership."

With lightning speed, Tumorsuk carves the end of the log to precisely cup the jeep's wheel axle. Then, using another log as a fulcrum and the three ecologists as counterweight, he constructs an Archimedean lever. One side of the jeep rises from the mud. Tumorsuk grabs stones and plunges his naked hands into the water-filled wheel holes. Repeating the process on the opposite side and driving forward, the jeep moves half a meter before sinking back in. After 2 hours of levering, the jeep finds purchase and the team drives away into the night. The environment has been bested, for now.

—JOHN BOHANNON

Because of its likely impact on animal populations, a wholesale transition to semidesert would be "disastrous."

—CLYDE GOULDEN,
ACADEMY OF NATURAL SCIENCES



Steppemaster. Mongolian herders learn the ropes at an early age—but climate change and too many animals could be overwhelming.