MEETING ECOLOGICAL SOCIETY OF AMERICA

Tracking Vanishing Mammals and Elusive Nitrogen

BALTIMORE—More than 3000 ecologists gathered here 2 to 6 August for the Ecological Society of America's annual meeting. Besides getting a look at the city—which itself is an urban ecology research site—scientists heard talks ranging from mammal extinctions to the potential greening of the U.S. Southwest.

Miocene Survivors: Armed to the Teeth?

The land where buffalo roam and deer and antelope play is a pale shadow of an earlier time, at least for hoofed species. Ten million years ago in the Miocene, the North American continent was home to an array of grazing mammals, including camels, rhinos, and as many as 20 different species of horses. Most of these species died out about 6 million years ago, probably because of a sudden climate shift. At the meeting, paleontologist Steven Stanley of Johns Hopkins University aired a provocative view as to what may have helped cause the extinction: scratchy grass.

In the new climate, Stanley suggests, softer grasses gave way to more abrasive plants, so that only certain horses and other grazers with teeth able to withstand tough chewing survived.

Stanley's idea attempts to explain a mammalian mystery: The species that survived the Miocene are almost all animals with very high-crowned molars, while those that died out have lower-crowned teeth. That pattern was laid out in a 1993 *Paleobiology* paper by Richard Hulbert of Georgia Southern University in Statesboro. Vertebrate paleontologists David Webb and Bruce MacFadden of the Florida Museum of Natural History in Gainesville, who helped document the extinction, have an explanation for why most browsing mammals—low-crowned animals such as some camels and deerlike species that nibbled on soft leaves on trees and shrubs—might have died out. They argue that in the new, drier climate at the end of the Miocene, the savanna—a grassland with scattered trees—became only grassland. But that doesn't explain why many grazing animals vanished, which should have been able to survive on grasses alone, too.

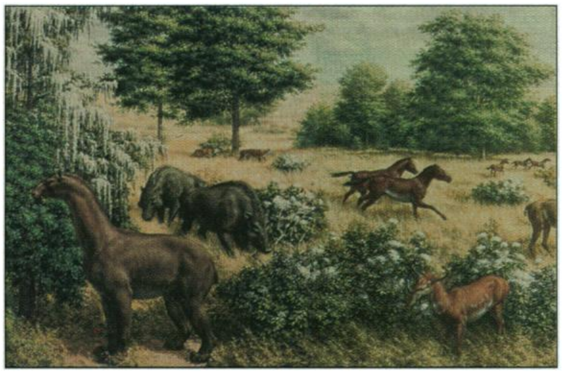
Stanley put this puzzling extinction data together with other recent clues to the vegetation changes of the time. By looking at carbon isotopes in the teeth of more than 500 horselike species and other fossil mammals, Thure Cerling, a geochemist at the University of Utah in Salt Lake City, and others sought clues to animals' diets and thus their habitats. As Cerling's group reported in *Nature* last September, the teeth reveal a major shift across North America, and much of the rest of the world, in the composition of late-Miocene plants: Wheat, bluegrass, and other plants known as C3 (because of their photosynthetic pathway) gave way to tougher C4 plants, such as crabgrass and Bermuda grass, which prefer a drier, more tropical setting. The reason, the group suggested, might be a global drop in atmospheric carbon dioxide levels, which would have favored C4 plants.

Stanley now links this switch to C4 grasses to the mammal extinctions. Paleontologists generally think that grazers evolved high-crowned teeth so they could tolerate the wearing effects of grasses. Stanley's hunch: Horses with shorter teeth died young because their teeth were worn down by the even more abrasive C4 grasses. He says he "dug around in the literature to try to test this idea" and found support: Botany papers showed that C4 grasses, which have more veins than C3 plants, produce more than five times as many abrasive silica bodies by leaf area.

Stanley concludes that the grass change doomed animals that were not long in the tooth. "If you need long teeth to eat grass with silica, then you need longer teeth to eat grass with more silica," he says. Stanley says this could also explain another twist to the mystery noted by Webb, MacFadden, and Hulbert—that a pocket of shorter-toothed grazers persisted on the U.S. Gulf coastal plain, which stayed moister than the rest of the continent and still supported savanna where grazers could supplement a C4 diet.

Although Hulbert calls Stanley's idea "plausible," he and others say it's not yet convincing. Other theories could also explain the demise of the short-toothed grazers, notes paleontologist Paul Koch of the University of California, Santa Cruz. For example, the new mix of grasses would have had less protein than C3 grasses, so horses would have had to chew more of it—putting longer-toothed horses at an advantage regardless of the grass' silica content. One strategy to test Stanley's hypothesis might be to study the tooth wear rates of modern species, says Hulbert—for example, by comparing the teeth of U.S. bison to those in Canada, where there is more C3 grass. These modern grazers might offer clues to why their ancestral cousins weren't so lucky.

—JOCELYN KAISER



Teeth-grinder. Shift to abrasive grass may have rubbed out many short-toothed Miocene grazers.

THE AGE OF MAMMALS, A MURAL BY RUDOLPH F. ZALLINGER/PEABODY MUSEUM OF NATURAL HISTORY, YALE UNIVERSITY

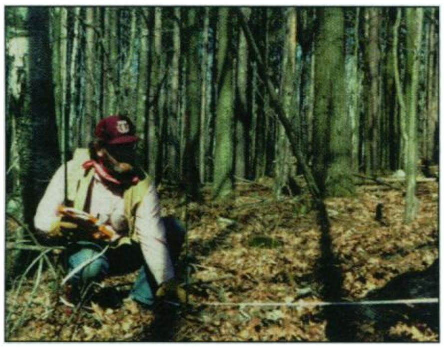
Nitrogen as Forest Fertilizer Falls Short

From car exhaust to agricultural fertilizer runoff, nitrogen pollutants are blitzing Earth's ecosystems, triggering fish-choking algal blooms and other ecological problems. But environmentalists have had at least one reason to cheer this nitrogen glut: The nutrient should fertilize tree growth, spurring forests to soak up human-made carbon dioxide that would otherwise fuel global warming. Such an effect has been a leading explanation for where a big chunk of the world's carbon emissions disappear to—a mystery known as the "missing sink."

At the meeting, however, ecologist Knute Nadelhoffer of the Marine Biological Laboratory in Woods Hole, Massachusetts, described experiments in the northeastern United States and Europe that suggest nitrogen isn't spurring much forest growth at all. His group and others traced the path of nitrogen compounds added to experimental forest plots and found that, at least in the short-term, the nitrogen winds up mostly in soils, not in trees. If the finding holds up, "it has some pretty big implications" for trying to find the missing sink, says terrestrial ecosystem modeler Alan Townsend of the University of Colorado, Boulder.

Over the last several years, scientists have traced the fate of about 75% of the carbon dioxide pumped into the atmosphere each year by human activity. But a whopping 1.8 petagrams of carbon remains unaccounted for. Global carbon dioxide measurements suggest that the carbon is disappearing into the land, not the oceans (*Science*, 24 July, p. 504).

One leading idea: As vegetation is plied with more and more nitrogen, it grows faster and thus takes up more carbon dioxide. The amount of the nitrogen falling onto the Earth's surface as rain and soot has more than doubled since the 1960s, fed by fossil-fuel burning and ammonium nitrate from



MARTHA DOWNS/MARINE BIOLOGICAL LABORATORY

Where's the nitrogen? Nadelhoffer sampling foliage in the Harvard Forest.

manure and fertilizers (*Science*, 13 February, p. 988). Townsend has estimated that if 80% of deposited nitrogen goes into tree biomass, it could account for up to 1.3 petagrams of the missing carbon.

But there's been a dearth of data on the fate of nitrogen once it hits the ground. That's what Nadelhoffer's team set out to gauge in the Harvard Forest's red pine and oak stands. In 1991 and 1992, the group sprayed four 900-square-meter plots every month with water doped with nitrogen-15, a stable isotope found naturally only in minute amounts. The researchers traced where the nitrogen went by feeding wood, root, and soil extracts into a mass spectrometer, which measures isotopic composition. The results, now in press at *Ecological Applications*, were a surprise: At more pristine plots, the nitrogen stayed mostly in the soil, with as little as 5% of the nutrient ending up in the trees within 2 years after spraying began. In plots that had already been heavily fertilized since 1988—at levels comparable to polluted parts of Europe—as much as 25% of the nitrogen showed up in the wood within 2 years. But that's far less than levels that would account for even half the missing sink, points out Nadelhoffer. "We thought we might see a much higher level," he says.

A similar experiment by Nadelhoffer's group in a Maine conifer forest yielded comparable results, and he reported at the meeting that other teams in six European forests are finding nitrogen uptake levels in trees running no higher than 30%. Nadelhoffer thinks that most nitrogen gets bound up in organic complexes in soil humus that would become accessible to tree roots only slowly.

These nitrogen experiments aren't the final word, Nadelhoffer cautions, because there could be some lag in the time it takes trees to absorb nitrogen from the soil. Townsend also notes that the sites didn't cover all forest types. "We need a few more years of data and sites to really put the nail in the coffin," he says. And forests may still be taking up the extra carbon dioxide, but not because of extra nitrogen, he adds. If nitrogen fertilization is ruled out, says Townsend, "we're going to have to start looking somewhere else." –J.K.

Green Thumb for the Southwest

In the U.S. Southwest, color arrives and vanishes suddenly, as fleeting wildflower blooms paint the stark desert. But this dramatic landscape may not last forever. New data presented at the meeting suggest that global warming could shift the Southwest from a chiefly desert biome to one overrun by grasses and shrubby trees.

The new view stems from efforts to examine how vegetation will shift with rainfall patterns following increased atmospheric concentrations of carbon dioxide (CO_2). For 20 years, climate change models have suggested that global warming will alter rainfall in many regions of the world. One often-cited example is the Southwest, home of summer rains dubbed the Arizona monsoon. Ecologists would like to know how plants will respond—and migrate—if such storm systems intensify over the next 50 to 100 years.

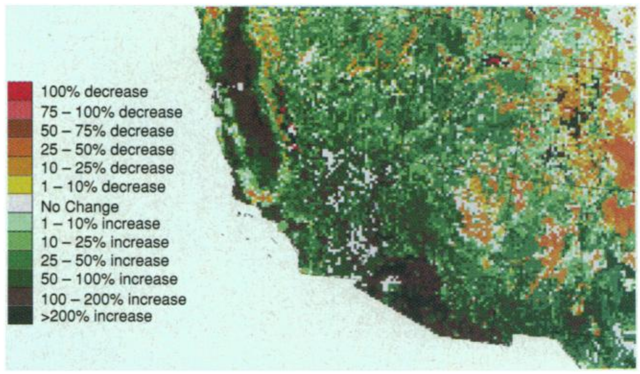
Ecologists Jake Weltzin at the University of Notre Dame in South Bend, Indiana, and Guy McPherson of the University of Arizona in Tucson tested how the shrubby oak *Quercus emoryi*—which dots lower tree lines across the Southwest—might respond to higher average summer rainfall. Working at Arizona's Fort Huachuca Military Reservation from 1994 to 1996, the duo watered oak plots—sheltered from precipitation by plastic film and cut off from groundwater by film-lined trenches—with various amounts of rain collected nearby. They found that high summer "rains," or 5.25 millimeters of precipitation per day, produced three times as many oak seedlings as dry summer conditions—1.75 millimeters per day. Similar increases in watering in wintertime had no such effect.

Even if prolonged droughts punctuate increased precipitation from global warming in the Southwest, shrubby trees should still thrive: Higher atmospheric CO_2 levels typically favor woody plants, which respond by growing more and evaporating water more slowly, says Wayne Polley of the Agricultural Research Service in Temple, Texas. In greenhouse experiments reported at the meeting, Polley found that increasing CO_2 concentrations from 370 ppm to 700 ppm doubles the number of honey mesquite seedlings that survive drought. A one-two punch of summer rains and CO_2, therefore, could lead to an explosion of shrubby oaks and other woody plants, McPherson says. "We're talking about these plants going from less than 5% to more than 30% of the canopy cover in many areas of the Southwest," he says.

Woody plants aren't the only likely desert invaders. In a third talk, ecologist Ronald Neilson of the Forest Service in Corvallis, Oregon, predicted that U.S. grasslands could spread into the Great Basin and grow denser in California and Texas. Neilson unveiled new, more finely resolved analyses of vegetation changes predicted by the Mapped Atmosphere-Plant-Soil System (MAPSS) computer model under a doubling of atmospheric CO_2. According to Neilson's conclusions—some of which appeared in the June issue of *Global Change Biology*—the Bermuda high, a tropical air mass that fuels the Arizona monsoon, would intensify. As a result, plants such as love grasses and grama grasses could eat away at low-lying desert, Neilson says.

Ecologists and atmospheric scientists alike welcome the new data, but they stress that pinning down any link between climate change and vegetation is tricky. During a global warm-up 11,000 years ago, "the various vegetation types didn't just migrate [en masse] around the map of North America," says James Brown of the University of New Mexico in Albuquerque. Jerry Meehl of the National Center for Atmospheric Research in Boulder, Colorado, adds that the Southwest's complex landscape of mountains and desert makes forecasting regional climate change difficult. "There is a chain of uncertainty that runs through links between CO_2, rainfall, and vegetation," Meehl says. "But to get at actual ecosystem impacts, these are the kinds of studies you have to do. This type of research can be very useful." –**KATHRYN S. BROWN**

Kathryn S. Brown is a writer in Columbia, Missouri.



NEILSON & DRAPEK/GLOBAL CHANGE BIOLOGY 4, 505 (1998)

Retreating desert. The U.S. Southwest gets much greener according to one MAPSS simulation based on doubled atmospheric CO_2 levels.