MEETING ECOLOGICAL SOCIETY OF AMERICA

Getting to the Roots of Carbon Loss, Chili's Gain

SPOKANE, WASHINGTON—Some 3500 ecologists gathered here from 8 to 12 August for the annual meeting of the Ecological Society of America. Discussions ranged from the link between ancient deforestation and greenhouse warming to a sizzling ecological explanation for why peppers are hot.

Chili Idea Gets Warm Reception

From red-hot chicken wings to kimchi, many spicy foods get their sinus-clearing zing from hot peppers. For some ecologists, chili peppers have posed a burning question: Why are they hot? The fruit owes its spiciness to a chemical called capsaicin, and plants generally put energy into producing such toxins for a reason, such as to deter enemies. At the meeting, a researcher offered intriguing evidence suggesting that chilies wield their sting with the precision of a stiletto: to target seed-chewing mammals while leaving birds unscathed. Birds swallow the seeds but don't digest them, essentially acting as vessels for carrying chilies to new turf.

The idea that plants make chemicals to deter predators isn't new, and many plants rely on animals to spread their seeds. But this may be the first well-documented instance of a plant using a chemical selectively, to repel some animals without affecting others that boost its chances to reproduce. "That seems to be the first very good case where you can poison your enemies but not your [friends]," says ecologist Judith Bronstein of the University of Arizona, Tucson. "It's a great story."

The story begins in South America, where chilies and their relatives—from jalapeños to poblanos and bell peppers—originated. With the exception of stoic humans, mammals don't care for capsaicin, which stimulates neurons that sense pain. That's why the chemical is a key ingredient in pepper spray and a growing number of other concoctions for warding off belligerent backwoods bears and backyard rodent pests. Birds, by contrast, seem to be impervious to capsaicin, apparently because they lack the right shape of a receptor—an ion channel—on their mucous membranes. Capsaicin binds to the ion channel and causes it to open, allowing ions to flow in and trigger nerve impulses the brain interprets as pain. Gary Nabhan, a plant ecologist at the Arizona-Sonora Desert Museum in Tucson, and grad student Joshua Tewksbury of the University of Montana, Missoula, speculated that the plants learned, so to speak, to exploit capsaicin's ability to set a mammal's tongue, but not a bird's, afire.

To find out which wildlife eats chilies (*Capsicum annuum* var. aviculare), Tewksbury studied 150 hours of videotape collected last summer of around 25 chili bushes in 2500 hectares of mesquite shrubland in southern Arizona—the northern edge of the plant's natural range—which the U.S. Forest Service last spring designated a protected chili reserve. They found that the pea-sized fruits were eaten only by birds, mainly the curve-billed thrasher. The chilies were ignored by desert packrats and cactus mice foraging in adjacent bushes for hackberries, another red fruit that isn't spicy.

Put into cages, five packrats and five mice

turned up their noses at chilies, although they readily ate an altered version that wasn't spicy—but after showing up in the feces, the seeds failed to germinate. The same kind of nonpungent seeds fed to birds germinated just as well after being expelled as those planted by hand. And spicy seeds eaten by birds germinated three times more often, although the researchers don't know why. Capsaicin also acts as a laxative in birds, helping them spread the seeds, Tewksbury says.

That's not the only benefit chilies derive from being bird feed. Chili plants grow best in shade, as Nabhan and Tewksbury found out when they transplanted some to sunny spots. But not just any shade—the chilies usually turn up near hackberry bushes and other shrubs with small fruits dispersed by birds. Being clustered with other fruit-bearing shrubs lures more birds, which ensures that more of the chili fruit gets eaten, the researchers found.

The duo hasn't yet tied up all the loose strings. For one, they plan to try the same experiments in Bolivia, where chilies first evolved, to see if the same patterns show up there. But Tewksbury thinks he and Nabhan can fairly conclude that for Arizona's wild chilies at least, "there's a strong benefit to being hot."

The North's Voracious Carbon Past

Burned prodigiously since the industrial revolution, fossil fuels are the main source of the rising levels of carbon dioxide in the atmosphere in recent decades. But land conversion—logging, burning, and plowing over natural greenery—is also a big factor, contributing about 20% of the annual CO_2 surfeit from human activity, mostly from slash-and-burn agriculture in tropical forests. The tropics, however, weren't always the only hot spots for forest destruction. A new analysis presented at the meeting suggests that vegetation razed by people throughout history, largely in northern countries, pumped an enormous amount of carbon into the air—on par with the billions of tons added by burning fuels since.

The numbers drive home the fact that civilizations began spewing out greenhouse gases centuries ago and underscore the importance of land cover—as both a source and sink for carbon—in discussions today of how to implement the Kyoto Treaty, which is supposed to limit CO_2 emissions. "People are so fixated on fossil fuel emissions. They aren't putting land-cover conversion into the equation as well," says remote imaging expert Steven Running of the University of Montana, Missoula.

The study, by geographer Ruth DeFries of the University of Maryland, College Park, and ecologist Chris Field of the Carnegie Institution of Washington in Stanford, California, is the first attempt to sum up all the carbon added to the atmosphere since people began to leave a significant mark on Earth's vegetation, chopping down forests, turning

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savanna into desert, and converting woods to farmland or, eventually, into parking lots. The researchers started out with a map of the world's potential vegetation at the dawn of civilization—based on factors like climate and soil type—and simulated a satellite map to compare with actual satellite maps of global vegetation today.

Then, to estimate how much carbon was released as lands were altered, the duo and their collaborators plugged the before-and-after satellite maps into a computer model that converted the greenness of each area into how much carbon was stored in that landscape, be it tundra, grassland, or deciduous forest. The result: Over the course of civilization, land-use changes have liberated about 185 petagrams of carbon—an amount equal to about 75% of that released by burning fossil fuels, the researchers report in a paper in press at *Global Biogeochemical Cycles*. About one-third of the carbon released from altering land happened before 1850, judging from a different research group's estimate of carbon released since then. "It's a very reasonable" conclusion, says Running, who says the number may be even higher according to his own calculated map of prehistorical vegetation.

This dubious legacy of land destruction is, ironically, a boon today: In the United States, for example, regrowth of forests is sucking up a good chunk of the country's fossil fuel emissions (*Science*, 23 July, p. 544). Nowadays it's the tropics where land use is pumping out carbon instead of socking it away. But Field says that's no reason for northerners to gloat: "That doesn't make [today's reforestation] a virtuous thing."

Knowing how much carbon has been lost by altering landscapes also "sets the outer boundary of what reforestation is possible," says Field, because "in concept, the [losses] could be reversed" if in some cases countries can let farmers' fields grow back to their natural state. —**JOCELYN KAISER**

HYDROLOGY

Scarcity of Rain, Stream Gages Threatens Forecasts

Hydrologists warn that the world's network of rainfall and stream gages—often a low priority in science budgets—is slowly eroding

BIRMINGHAM, U.K.—On 1 March 1997, northern Kentucky was drenched with up to 25 centimeters of rain. The Licking River, which meanders through the town of Falmouth, rose a meter in only 3 hours and kept on rising. By evening, Falmouth's emergency siren was wailing and police were shouting evacuation orders through bullhorns. Most of the 2400 residents managed to flee, but the water came so fast, even shoving houses off their foundations, that some had to be rescued from rooftops. Four people in mobile homes drowned.

The river had crested 4 meters higher and 6 hours earlier than the National Weather Service (NWS) had predicted. NWS officials admitted that they had underestimated the danger, but added that their forecasts had been severely hampered by the loss of a crucial gaging station 32 kilometers upriver, which was cut in a budget crisis in 1994. "It was like a flash flood," says Mark Callahan of the NWS's Louisville office. "Without that gage, we were blind."

This kind of uncertainty is not unique. Around the world, the gages that measure rainfall and stream height are slowly disappearing, victims of a slow erosion in funding, according to hydrologists gathered here for the International Union of Geodesy and Geophysics from 19 to 30 July. At the meeting, some 400 hydrologists of the International Association of Hydrological Sciences (IAHS) issued a resolution calling rain and stream gages "an endangered species" and decrying "a severe decline in total quantity of data being collected worldwide."

That decline means that at a time when global warming may be exacerbating weather extremes and water shortages, scientists are less able to monitor water supplies, predict droughts, and forecast floods than they were 30 years ago, says John Rodda, president of the IAHS. And although remote sensing and other technologies offer new sources of climatic data, rain and stream gages remain crucial. "There really isn't any other way of finding out how much water is flowing down a river," says Ed Johnson, NWS's director of strategic planning in Silver Spring, Maryland.

Flooded out. Stream gages like this one near Juliette, Georgia, suffer wear and tear in extreme weather.

CREDIT: USGS

Individual gages aren't terribly expensive when compared to, say, a satellite—new U.S. river stations cost about $35,000 to install and $10,000 a year to maintain and operate. But even in countries with robust science budgets, maintaining aging gages is often low priority, especially when the weather's good. "If you go too long without a flood, people tend to lose awareness of the risk," says Duncan Reed, a modeler at the Institute of Hydrology in Wallingford, U.K. "They ask 'Why are we spending this money?' " Yet scientists need decades of continuous data to predict extreme events such as floods or drought, says Reed. Compounding the problem is the fact that the most critical gages, such as those that monitor rainfall or snowpack in mountains, are often remote and expensive to maintain; therefore they tend to be shut down first. When that happens, says Rodda, "you have the least information from the places you most need."

Many of the countries whose hydrological networks are in the worst condition are those with the most pressing water needs. A 1991 United Nations survey of hydrological monitoring networks showed "serious shortcomings" in sub-Saharan Africa, says Rodda. "Many stations are still there on paper," says Arthur Askew, director of hydrology and water resources at the World Meteorological Organization (WMO) in Geneva, "but in reality they don't exist." Even when they do, countries lack resources for maintenance. Zimbabwe has two vehicles for maintaining hydrological stations throughout the entire country, and Zambia just has one, says Rodda.

In South Africa, although the river gaging system is intact, the number of rainfall stations has plummeted from more than 4000 to about 1700. This is due in large part to urbanization, because daily rainfall reports typically come from farmers. "People are not inclined to do this service free of charge anymore," says Gerhardus Schulze, director of the South African Weather Bureau.

And in countries of the former Soviet Union, the problem is decentralization. The central Soviet hydrological service once collected all rainfall measurements and other data, but the new national hydrological agencies of countries in central Asia have much smaller budgets, notes Manfred Spreafico, director of hydrology with the Swiss Bundesamt für Umwelt, Wald und Landschaft in Berne. About 90% of the stations in the Aral