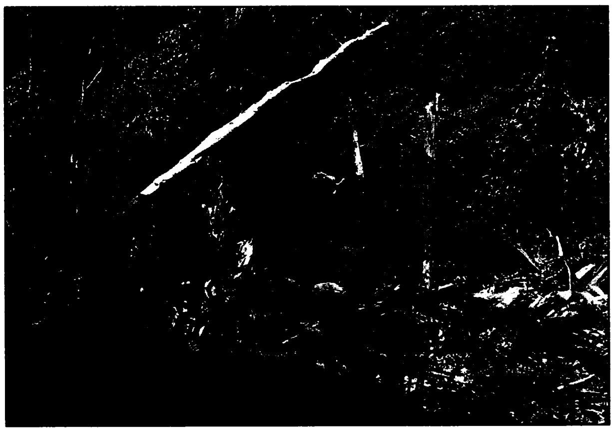
ing to an analysis now being carried out in Panama, Malaysia, and nine other tropical locales by a team from Harvard University and the Smithsonian's Center for Tropical Forest Science. These researchers, including Harvard's Panayotou and the Smithsonian's Elizabeth Losos, are monitoring the growth of every tree in a series of 50-hectare plots and recording their responses to catastrophes, both natural and those caused by human activities, such as logging. These and other studies show that tropical forests can sequester as much as 200 metric tons of carbon per hectare, says forest economist Marco Boscolo of Harvard. This is about one and one-half to two and one-half times the storage capacity of forests of mid- and high latitudes.

The problem will be in realizing the vast sequestration potential of the tropics, given the ongoing deforestation there. Still, there are signs that deforestation can be curbed, if governments make the necessary commitment. "Although reducing deforestation in the tropics may appear to be difficult, it is happening in countries such as Brazil, India, and Thailand," says Brown. Strong forest legislation, a large reforestation program, and community awareness are responsible for the turnaround, she says.

In some cases, electrical utilities are helping out, partly because it may help them win the permits they need to expand production. Because carbon dioxide can travel around the world, U.S. utilities can be recognized for reforestation done abroad. For example, a group of utilities including Wisconsin Electric Power and the PacifiCorp is spending $3.5 million to protect about 2500 hectares of forest in Belize. And in Sabah, Malaysia, that state's largest logger, the Innoprise Corp., is cooperating with the Forest Absorbing Carbon Dioxide Emissions Foundation, a group started by the Dutch Electricity Generating Board, to rehabilitate 25,000 hectares of degraded, logged forests with a mix of long-lived local trees, known as dipterocarps, and forest fruit trees. The goal is to increase the carbon sequestered in those areas by at least 200 metric tons of carbon per hectare.

Similar projects are under way at home. For example, the Klamath Cogeneration Project, which beat out two competitors to build a new, gas-fired power plant in Klamath Falls, Oregon, plans to reforest 1000 hectares of Oregon grassland, pasture, and scrub—at a cost of $1.5 million—to offset some of the plant's carbon dioxide emissions.

Even as these efforts are getting started, researchers are beginning to test novel ideas about how forests can be managed to soak up even more carbon. A computer-modeling effort by Gregg Marland and his colleagues in the Environmental Sciences Division of the Oak Ridge National Laboratory in Tennessee indicates, for example, that actively managed, fast-growing forests that are harvested and replanted can tie up even more carbon than mature, protected forests that are left alone. That's because harvesting wood for use in long-lived products, such as home construction, takes the carbon out of circulation, in effect creating a new carbon sink. Moreover, wood fuels can substitute for fossil fuels, such as coal and oil, that throw more carbon dioxide into the atmosphere.



ELIZABETH LOSOS

Carbon storehouse. Reduced-impact logging, as in this forest in Sabah, Malaysia, may help reduce atmospheric carbon dioxide.

The Marland team's results are buttressed by the results of a study in which J. Piers Maclaren, Steve Wakelin, and Lisa Morenga of the New Zealand Forest Research Institute Ltd. analyzed that nation's plantations of *Pinus radiata*. They found that a radiata pine plantation that is replanted each time it is harvested puts away 112 metric tons of carbon per hectare by the time the trees mature. "This," says Maclaren, "can be seen as a one-time, permanent movement of carbon from the air to the land surface."

Maclaren calculates that from 2008 to 2026, New Zealand could more than offset its carbon emissions from fossil fuel combustion by intensive forest planting, at a rate of about 100,000 hectares per year. However, carbon sequestration would decrease rapidly after 2045, when plantable land was used up.

Indeed, forestry can go only so far in offsetting global warming, because land for new forests will eventually run short. Kauppi suggests that well-managed forests may serve as a carbon sink only through the end of the 21st century, while Brown sees forests filling a role as major carbon sinks for at least several centuries. Whatever the limits, she says, "it's an opportunity that must be pursued."

–**Anne Simon Moffat**

ECOLOGY

Hybrids Consummate Species Invasion

BOULDER, COLORADO—When biologists think of the comings and goings of species, they often think of war—of new species invading and pushing out the old. In midwestern lakes, however, love seems to be the driving force. In lake after lake, an invading crayfish species is pushing local crayfish to extinction. But biologists at the University of Notre Dame in Indiana are finding that the local crayfish are having their own effect on the invader, as the two species produce a new population of vigorous hybrids.

The finding is a surprise, researchers say, because ecologists often expect animal hybrids to be sterile, unable to play more than a bit part in species invasions. But at the annual evolution and natural history meetings here,* William Perry, a graduate student in the labs of ecologist David Lodge and biologist Jeff Feder, described molecular studies showing that hybrids of Kentucky native *Orconectes rusticus*, or the rusty crayfish, and a native crayfish, *O. propinquus* (the blue crayfish), are indeed fertile. Other work by Perry, Lodge, and Feder suggests that these hybrids are outcompeting both natives and invad-

* Joint meetings of the Society for the Study of Evolution, the American Society of Naturalists, and the Society of Systematic Biologists, Boulder, Colorado, 14–18 June.

W. PERRY

Sleeping with the enemy. Female rusty crayfish (on bottom) courts local male.

ers. The rusty crayfish, it appears, is taking over by assimilation.

That's useful information for conservation, notes Christopher Taylor, a crayfish systematist at the Illinois Natural History Survey, because rusty crayfish and similar intruders are slowly pushing natives to extinction: Of the 340 species of crayfish found in North America, about 30 may soon be completely eliminated by invaders, which usually arrive in new lakes as bait brought by anglers. "If we know how they are doing it," says Taylor, "maybe we can think of a way to slow them down."

Researchers noticed 2 decades ago that some Wisconsin crustaceans are intermediate in color and in the size of various body parts between the larger rusty crayfish—which first appeared in northern lakes in the 1960s—and the blue crayfish. That suggested to Lodge and his colleagues that invading and local species sometimes interbreed. But rusty crayfish themselves vary greatly in form, making it difficult to identify hybrids reliably. So the extent of hybridization remained unclear, and in any case, hybrids were assumed to be less important than other species-replacement mechanisms.

But when Perry collected specimens from some Wisconsin lakes and analyzed enzymes that serve as distinctive species markers, he found that extensive hybridization is under way between rusty and blue crayfish. Further comparisons revealed that backcrosses between hybrids and rusty crayfish were nearly as common as first-generation hybrids, indicating that hybrids are fertile and that they tend to mate with rusty crayfish rather than with each other. Together, the first-generation hybrids and backcrosses accounted for 30% of the crayfish in one lake.

From laboratory observations, Lodge and his colleagues had thought that most of the interspecies matches would be between the large, aggressive rusty males and the blue females. But when Perry examined the hybrids' mitochondrial DNA—which is inherited only from the mother—he found, to his surprise, that 89% were offspring of the opposite match, between rusty females and native blue males. "We were looking for love in all the wrong places," he quips.

The apparent prowess of the hybrids may be speeding the invasion. When Perry put rusty and blue crayfish in tanks with similarly sized hybrids, the hybrids beat both species in competition for food—such as insects and aquatic plants—and for shelter under rock piles. "They are actually more competitive than the invader," says Perry. "They're pretty nasty." The crayfish invasion may start with love, but it ends up in war after all.

–Wade Roush

MEETING BRIEFS

How Male Animals Gain an Edge in the Mating Game

COLLEGE PARK, MARYLAND—In the midst of the East Coast's first summer heat wave, some 600 biologists gathered on 21 to 26 June here at the University of Maryland for the annual meeting of the Animal Behavior Society. Among the many talks and symposia were provocative discussions of the lengths male animals have gone—evolutionarily speaking—to find a mate.

Croaking With All Ears

"Jug-o'-Rum," bellows the American bullfrog on many summer evenings to court his mate. The call has long been thought to radiate from the large vocal sac that bulges from under the frog's chin. But Alejandro Purgue, who studies animal acoustics at the University of California, Los Angeles (UCLA), has traced it to a different part of the bullfrog's anatomy: its ears.

"They are acting as loudspeakers," amplifying the sound of the frog's vocal cords, says UCLA neuroethologist Peter Narins. "I would never have guessed that in a million years," says Philip Stoddard, a neuroethologist at Florida International University in Miami. And as Narins reported at the meeting, the bullfrog isn't the only frog that speaks through its ears.

Purgue discovered this unexpected use for bullfrog eardrums while trying to pin down how the frogs use their vocal sacs. As he will describe in an upcoming issue of the *Journal of Comparative Physiology*, he designed a sound-generating device that could be placed inside a frog's mouth to provide a reproducible sound for each test. He then turned on the sound and measured how various body parts amplified it. The vocal sac did pick up the vibrations, but a much stronger response came from the eardrums.

These measurements imply that the frog not only hears, but also calls, through its ears. The ears account for 70% to 80% of the sound output, he estimates, a finding Stoddard calls "absolutely stunning." The sac, for its part, serves primarily to store the air used by the vocal cords, says Purgue.

His finding helped Narins begin to make sense of another frog, *Petropedetes parkeri*, which he had collected in Cameroon to study its odd-shaped ear. Based on a textbook picture, Narins had thought the frog had an enlarged middle ear bone. Not until he and his colleagues caught one did he realize that the protuberance, called a papilla, wasn't a bone at all. "It feels like a sponge," says Narins.

The papilla develops only on males and only during the mating season. Based on preliminary acoustic analyses, Narins and his colleagues now think it tunes the eardrum to resonate at the dominant frequency in the frog's call, amplifying it. The dominant frequency in this frog's call is slightly lower than the natural resonating frequency of the eardrum itself. But "when the papilla is there, [the eardrum] matches the call more closely," says Purgue.

LES MINTER/UNIVERSITY OF THE NORTH, SOVENGA, SOUTH AFRICA

Sounding off. This African frog is thought to amplify its call with the help of eardrums (brown spot) tuned by a protruding papilla (black).

"It looks like it's a unique adaptation," says Andrea Simmons, a neuroscientist at Brown University. She wonders, however, whether it might not be used for a more traditional purpose: tuning the frog's hearing to specific frequencies. "It might be an aid to hearing," Narins agrees. "But we haven't tested that yet."

Bowers as Barriers

Whereas peacocks court by flashing their elaborate tails, male bowerbirds win females by dancing on and around their bowers—platforms or towers made of sticks. Biologists who study these natives of Australia and New Guinea have long thought that the bowers help to wow the females by demonstrating the males' architectural prowess. But evolutionary biologist Gerald Borgia of the University of Maryland, College Park, reported that they serve a different purpose. His data suggest that bowers can provide a kind of screen, allowing the dancing and preening to be more vigorous without frightening off the female.

By correlating features of the bowers with the intensity of the males' displays, says Richard Prum, a systematist at the University of Kansas, Lawrence, Borgia found that "certain bowers have evolved in certain ways [to] allow males to display in a more energetic fashion."