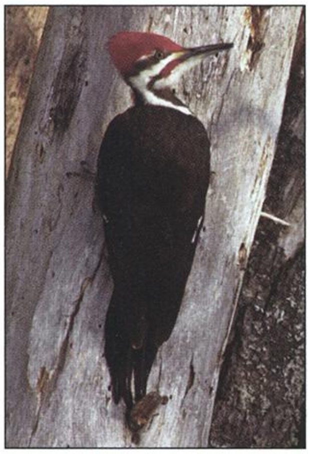
ECOLOGY

Defending Deadwood

Decaying trees turn out to play crucial roles on both land and sea, starting chains of biotic interactions and providing oases of nutrients in the ocean's barren abyssal plains; removal of dead trees may threaten ecosystems

Out in the deeps of the southern Atlantic and Pacific oceans, tuna captains have started to follow floating logs washed from faraway continents. Off the California coast, other fishing captains use sonar to look for piles of sunken wood. They are after more than the lumber: It turns out that the nutrients and housing provided by deadwood can fuel whole ecosystems of bacteria, worms, and bivalves, on up to commercial-size fish. People who fish—top predators on this weirdly dislocated food chain—are not the only ones on the trail of deadwood: Scientists on land and sea are coming to appreciate the central roles that dead and decaying trees play in forests, streams, estuaries, and the oceans. New studies show that forest animals like bats rely on them much more than anyone had realized and that even stream organisms like salmon depend on logs to help shape their environment.



Hole story. Nesting holes drilled by the pileated woodpecker shelter many birds.

Recognizing the value in this once-overlooked habitat, scientists have stepped up their scrutiny, sponsoring deadwood conferences and Internet sites.* The Wood in World Rivers conference, held last year in Corvallis, Oregon, drew more than 100 papers from 14 countries strictly on deadwood in water. "The message is, if you want live things, you need dead trees," says Torolf "Torgy" Torgerson, an entomologist at the U.S. Forest Service Pacific Northwest Research Station (PNWRS) in La Grande, Oregon. Humans, however, are putting the sting back into tree death: By taking too many dead or destined-to-be-dead ones for their own uses, they threaten many ecosystems.

* See www.egroups.com/group/dead_wood and riverwood.orst.edu

If a tree falls ...

Left unlogged, forests can be breathing necropolises, with decay providing all sorts of biological niches. As far back as the 1920s, researchers realized that dead trees provided nesting hollows for some forest animals, but no one knew how much more they offered. Major research started only in the 1980s, when loggers were wiping out the remnants of many old-growth forests and it became clear that creatures such as salmon and spotted owls were in trouble.

Recent Forest Service studies show that in virgin tracts, fully dead standing trees, or "snags," may number 75 or 100 per hectare and stand 40 years or more. When they fall to become logs, big ones may last 300 years: A study coauthored by Torgerson found 400-some linear meters per hectare in old conifer stands.

The first to feast on sick trees are fungi, the main decomposers, followed by bacteria, yeasts, mites, and nematodes. Then the biotic chain lengthens further. In long-term Forest Service studies, PNWRS research biologists Catherine Parks, Evelyn Bull, and others have found that 80-some animals in the Pacific Northwest alone need deadwood, starting with the powerful pileated woodpecker. The holes it drills in ailing but still-standing trees shelter not only the bird itself but also a cycle of "secondary cavity nesters," which need tree holes but cannot dig themselves. This makes the pileated woodpecker a keystone species, with dependents including nuthatches, chickadees, bluebirds, and swifts. As more space opens, mammals come: squirrels, fishers, martens, woodrats, then black bears. A study by Bull in the Winter 2000 issue of *Northwestern Naturalist* shows that nearly half of black bears have their cubs or rest in rotted-out tree cavities.

Not just any rotting tree will do: Most creatures need big, old ones with plenty of room for rot, says Parks. A mycologist, she studies fungal heart rot, which eats large living trees from the inside out and provides the protected temperature and humidity-regulated spaces many animals need. One obligate heart-rot dweller is the endangered red-cockaded woodpecker, which nests only in longleaf pines in the southeastern United States.

Discoveries about such secret chambers keep turning up. Until the mid-1990s, for example, most bats were assumed to live in mines and caves, but recent studies have shown that many actually roost and nest in abandoned woodpecker holes or on the undersides of loose bark on aged trees. Biologist Michael Rabe of the Arizona Game and Fish Department in Phoenix reported in the Fall 1998 *Journal of Wildlife Management* that he had radio-tracked eight bat species to bark crevices on 150- to 300-year-old ponderosa pine snags in Coconino National Forest. In one tree, he counted 984 Arizona occult bats. Mammalogist Carol Chambers of Northern Arizona University in Flagstaff recently discovered the first known nesting colonies of the tiny *Myotis auriculus* bat, in rot pockets in gambel oaks; these oaks were considered useless "junk" trees, notes Chambers.

Beach tree. Dead trees and driftwood serve as a perch for shore birds; underwater, such wood serves as a home for wood-gnawing shipworms (*inset*).

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Once a snag falls, a new phase begins. Rodents use logs for shelter and protected travel; owls often lurk near the ends. PNWRS biologist Keith Aubry says that many amphibians need humid, woody debris for feeding, reproduction, and hiding. "In forests where [people] take [the debris] away, some species may wink out eventually," he says. Logs also support huge colonies of carpenter ants—which supply a full 97% of the all-important pileated woodpecker's diet and are black bears' second most important food source (after plants), according to another study by Bull, in press at *Northwest Science*.

Gifts from the forest. Logging operations created this giant logjam on the St. Croix River between Minnesota and Wisconsin in 1884, but many creatures once depended on huge natural logjams to help shape their habitat.

Conventional wisdom holds that woody debris also recycles nutrition to the forest floor to grow new trees—but new studies show that things don't necessarily work as supposed. Seedlings of many species do sprout almost exclusively on "nurse logs," crumbly masses in the last stages of decay. However, Cindy Prescott, a professor of forestry at the University of British Columbia in Vancouver, has measured nutrient flows in Rocky Mountain forests and found that logs release mostly unusable carbon; 95% of key ingredients like nitrogen and phosphorus come from leaves and needles. The hidden reason for nurse logs, she says, is that pathogenic fungi in the soil wipe out almost all seedlings, but the fungi cannot survive in deadwood. "The logs are vital, but not for the reason we thought," says Prescott, whose study appeared in the October 1999 *Canadian Journal of Forest Research*.

Dead in the water

Land managers once thought that deadwood clogging streams and rivers was a hindrance not only to human navigation but also to the life cycles of fish; now they are finding exactly the opposite, at least for the fish. "Deadwood shapes almost everything in a stream," says James Sedell, national water coordinator for the Forest Service in Washington, D.C., and co-author of *From the Forest to the Sea*, a seminal 1994 book on the subject.

Many papers at the Wood in World Rivers meeting showed that vast amounts of wood enter streams via windthrow, bank erosion, landslides, and logging. And once in streams, the wood may stay a long time. In the February issue of *Bioscience*, aquatic scientist Robert Naiman of the University of Washington, Seattle, documented a Sitka spruce stuck in Washington's Queets River for 1500 years; river logs in Tasmania have been dated to 4000 years. Furthermore, Naiman says his ongoing studies in South Africa suggest that riparian forests would literally not exist without streamside tangles of dead trees, which collect sediment and provide protection from floods so that plants can start again in washed-out sections.

In-stream wood, along with the leaves, needles, and sediment it traps, also provides substrate and food for aquatic fungi, algae, and invertebrates. That starts a food chain that biologists now believe may provide up to half the food for fish in some streams. (Few invertebrates eat the wood itself—they don't have the enzymes—but they graze on slimes covering it.) What's more, studies from the Northwest show that small dams and waterfalls made by trees provide up to 80% of the deep pools in small- to medium-sized streams, features needed by salmon to rest, hide, and forage in.

Once wood drifts to estuaries, it may strand in marshes to provide perches for kingfishers, eagles, and other avian predators, says Charles Simenstad, an aquatic scientist at the University of Washington, Seattle, who presented work at the conference. And once wood hits salt water, it encounters another new phenomenon: marine invertebrates that, unlike their freshwater cousins, eat wood ferociously. Along with pill bug–like gribbles, there are at least 175 known species of shipworms—actually clams, which sport shells with nasty teeth and bodies that may trail nearly a meter through the tunnels they carve.

Until now there has been plenty for them to eat. Recent dredging off the mouth of Northern California's Eel River by oceanographer Marie de Angelis of Humboldt State University in Arcata, California, shows that many large pieces of submerged driftwood, often the debris of logging, roll along the bottom during winter storms. Farther out, sizes get smaller, but volumes bigger; at 400 meters, she has found "woodpiles" —large depressions loaded with sunken wood fragmented by abrasion and worms; she dredged enough in 10 minutes to fill a small truck.

Still standing. Dead trees may stand for decades, providing homes to birds and mammals such as these Australian flying foxes.

These woodpiles are biological hot spots. Dredging and underwater photography show that wood borers throw out powder and feces used by many other creatures, which in turn attract a halo of predatory limpets, snails, and small fish; and big fish eat little fish.

CREDITS: (TOP TO BOTTOM) MINNESOTA HISTORICAL SOCIETY/CORBIS; K. ATKINSON/ANIMALS ANIMALS

Tuna especially often follow large driftwood, which may float for 5 years and go thousands of kilometers, says Curtis Ebbesmeyer, an expert on floating objects with the Seattle oceanographic firm Evans-Hamilton. "One piece can develop its own movable ecosystem weighing tons, including birds and sharks," says Ebbesmeyer. The proof is in the catch: Some captains have lately taken to putting radio beacons on driftwood or even hauling in their own artificial logs, made of masses of bamboo, if there are no natural ones to attract fish.

A surprising amount of this drift sinks to the deep-sea floor, where specialized communities lurk as far down as 8000 meters, awaiting the blessed rain. First documented in detail in the early 1980s by the late Harvard marine biologist Ruth Turner, these communities include a subfamily of wood-specialized bivalves, *Xylophaginae*. By dropping wood packets off New York's Long Island, Turner showed that by some unknown method these mollusks home in within weeks on the otherwise barren sea floor, boring quarter-sized holes and soon attracting a huge secondary community.

This discovery was regarded as a curiosity until the past few years, when others began suspecting that deep-sea wood acts as a sort of missing link to animals at deep-sea hydrothermal vents and cold seeps. Marine biologist Craig Smith of the University of Hawaii, Honolulu, has begun studying sunken wood and other scattered organic troves like whale skeletons and kelp, and he has found that some denizens there are related to—or the same as—those on vents. "Wood may act like islands for them to hop from one far-flung vent to another," says Smith.

Some wood-associated organisms appear to use the same metabolic pathways as vent organisms, with bacteria breaking down matter to make hydrogen sulfide, which then is used directly or indirectly by a spectacular complex of fungi, protists, snails, tubeworms, and bivalves. DNA studies of the wood-dwelling mussel *Idas washingtonia* suggest that it may be the ancestor of the major vent mussel subfamily, according to work by Smith and his collaborator Daniel Distel of the University of Maine, Orono. In an article published last February in *Nature*, they suggest that wood that washed down continental slopes may in fact have been an evolutionary steppingstone, providing oases that allowed mussels to eventually colonize vents and seeps.

With humans rapidly razing forests, though, the reign of deadwood may be ending. Giant natural rafts that once clogged most rivers—in 1816 Louisiana's Atchafalaya had one 16 kilometers long, with upright 20-meter trees sprouting on it—have long ago been cleared for navigation. In the United States, the old-growth forests that supplied them are 95% gone; salvage harvesting of stumps, logs, and even driftwood is doing away with the debris.

Since deadwood's significance started becoming clear, managers have made some attempts at repair and preservation. Old longleaf pines are now scarce in the Southeast, so Parks of PNWRS is trying to make young ones rot inside, by injecting fungi. States have started requiring loggers to leave a certain number of snags and logs per acre and preserve a narrow, uncut strip along waterways. And after a century of pulling wood from rivers, the U.S. Army Corps of Engineers is anchoring artificial piles of it in select places in the Pacific Northwest, at great expense. Fish and birds have been shown to colonize some of these habitats, but no one is sure how much is needed for recovery. "Given the growing human population, we can probably never put back enough," says the Forest Service's Sedell. "But we ought to try. So much depends on it." —KEVIN KRAJICK

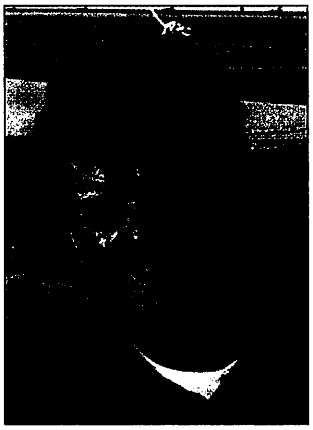
Kevin Krajick is the author of *Barren Lands: An Epic Search for Diamonds in the North American Arctic.*

METEORITICS

A Meteoriticist Speaks Out, His Rocks Remain Mute

After 40 years of searching meteorites for the solar system's origins, John Wood believes that his field faces a dead end—but he offers a way out

The prestigious Harold Masursky Lecture should have been an uplifting look at chondrites, the most common type of meteorite, from one of the field's leading practitioners, John A. Wood of the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Massachusetts. And predictably, Wood began his plenary talk at last year's Lunar and Planetary Science Conference with a review of 19th century studies. They described curious millimeter-sized blobs of rock encased within chondrites and now called chondrules as "drops of a fiery rain" that froze just as the solar system was forming. Wood moved on to what chondrules say about how the solar system formed from a disk of gas and dust 4.6 billion years ago. Then he lowered the boom.



Chondrite pessimist. John Wood despairs that after 2 centuries of dissecting chondrite meteorites, meteoriticists aren't getting any closer to understanding them.

CREDIT: J. A. WOOD

"We still don't understand what the meteorites are trying to tell us," Wood told hundreds of his colleagues assembled in the main gymnasium of NASA's Johnson Space Center south of Houston. "I personally wonder whether we ever will. There's just no convergence."

In the 40-plus years Wood has plied his specialty, geologists and geophysicists have figured out that the continents move, and astronomers have learned how stars are formed, he said. But his field's near-exclusive focus on deciphering chondrites' composition on ever finer scales "has not worked," he declared, "and it won't work." Understanding how the oldest rocks in the solar system formed from the early nebula of dust and gas will require meteoriticists to merge their crabbed analyses of chondrules with a big-picture understanding of how stars form that is being developed by astrophysicists. A grand theory is the only way to make progress, he argued.

"That talk upset a lot of people, especially students," says his first student, Harry McSween of the University of Tennessee, Knoxville, who heard "a senior person saying that what we do is a waste of energy, that this is an unresolvable problem. I thought it was too negative, too." The talk was "an unmitigated disaster," recalls Glenn MacPherson of the National Museum of Natural History in Washington, D.C., who admits to having been discouraged a few years ago, too, but no longer. "We have a way to go, but I think we're making progress."

The birth of blob studies

All would agree that progress in the study of chondrites by chemists and geologists has come in fits and starts. Wood reviewed that history in his talk as well as in a profusely illustrated, self-published version of his presentation that he distributed this spring to 150 colleagues. (The editor of the field's leading publication, *Meteoritics and Planetary Science*, had asked Wood to submit a manuscript, but the two of them could not agree on its format.) Wood