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THE WORLD OF SCIENCE

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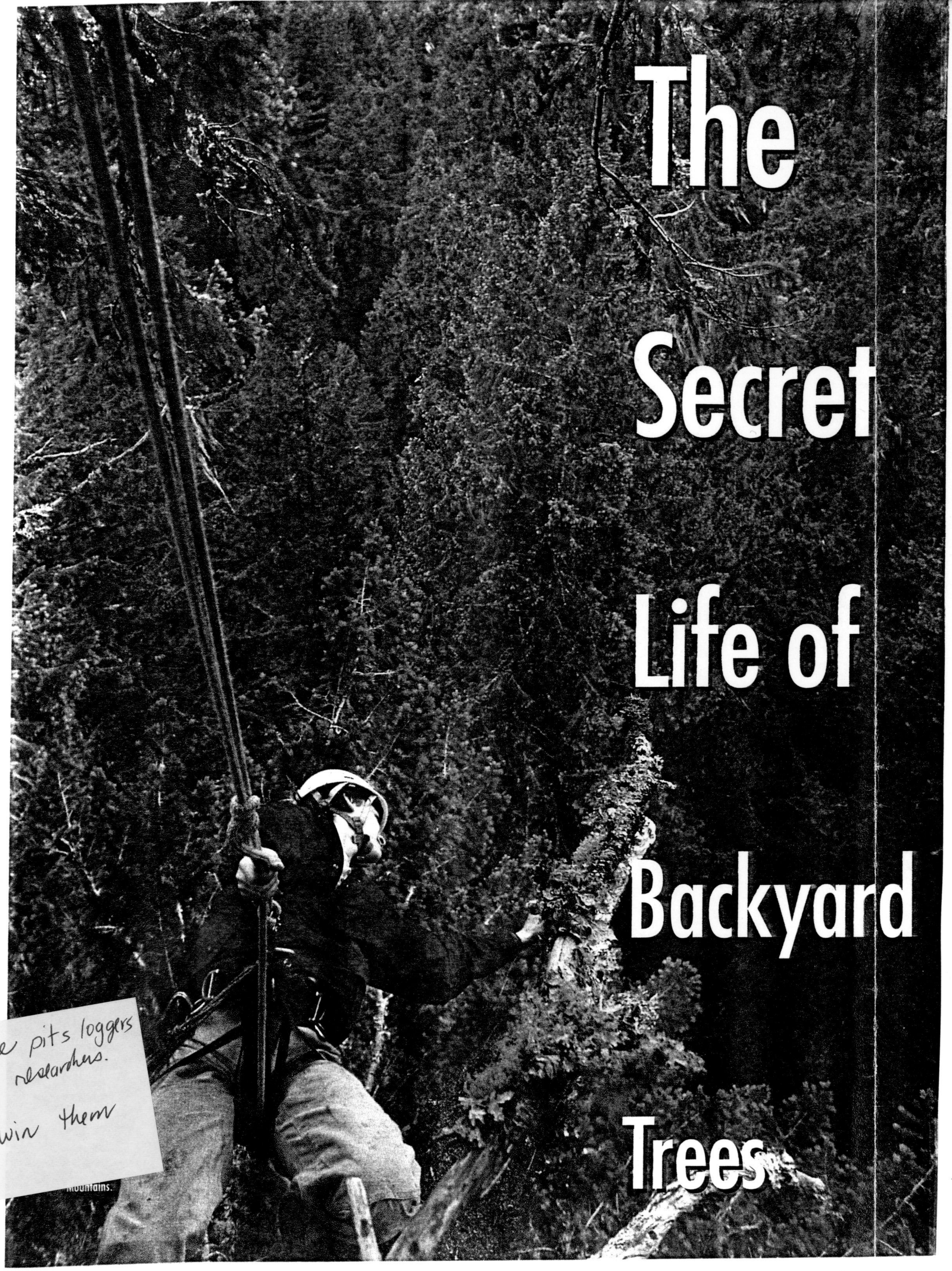


Mountains.

This one pits loggers against researchers. Can't win them all.

The Secret Life of Backyard Trees

A decade ago ecologists climbed into the canopy of tropical rain forests and found a new world of undescribed species and ecosystems. Now they're in the treetops from Florida to Canada—and guess what they've found.

In the fall of 1990, along a forest stream on Canada's west coast, entomologist Neville Winchester was lying on his back, drinking a beer. Gazing up through the foliage of ancient 200-foot Sitka spruces, he could barely make out insect swarms far above—just ghosts of movements flitting across filtered sunbeams. "I wonder what's up there," he thought. A little library research brought his answer: no one knew. He decided to find out. The next summer Winchester—a novice climber, petrified of heights—was 100 feet in the air, clinging to a rope next to a massive tree trunk. "What am I doing here?" he thought as his knuckles whitened and his heart brushed his tongue.

Until recently Winchester's curiosity wasn't widely shared. Except for a burst of little-known but seminal research in the 1970s, northern canopies have held all the scientific allure of a two-by-four. The trees were as familiar as your front lawn, and all you needed to know was in *Peterson's Forest Guide*. The true romance of canopy science, everyone assumed, was in the tropics, where rope-swinging scientists have been finding airborne ecosystems holding, according to some estimates, as much as half the world's biodiversity—weird aerial plants, unknown insects, and if you believe the movies, a cure for cancer.

Now Winchester and others are clambering up backyard oaks and familiar northern conifers . . . and finding airborne ecosystems with weird aerial plants, unknown insects, and possible sources for life-saving drugs, not to mention the power to affect global cycles of water and climate. With researchers suddenly awakened to the lives of North American trees, arboreal platforms, ropes, and towers are sprouting from Florida to the edge of the Canadian tundra.

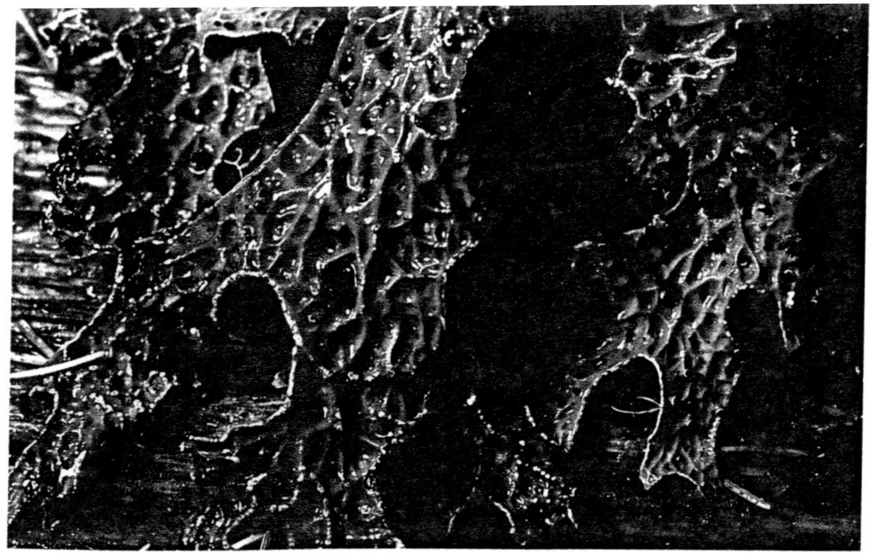
It all sounds as lovely as a tree, but those researchers have quickly become tangled in violent environmental politics. The canopies of ancient forests are particularly rich ecologically, and if they are logged, their newly discovered riches will disappear with them. The United States and Canada have therefore declared millions of acres of North America's few remaining old-growth forests off-limits. Spotted owls—as well as humbler yet no less significant canopy organisms such as lichens—now have a better shot at survival, but the same can't be said for out-of-work loggers, many of whom now view researchers like Winchester as the enemy. His research site was demolished with sledgehammers, chain saws, and hunting knives. A giant research crane erected in Washington has been subjected to threats of similar mayhem. "Canopies, especially old ones, are distinct places with regard to hydrology, nutrient retention, and wildlife," says Jerry Forest (his real middle name) Franklin, the mastermind of the crane. "For that discovery, people either love you or hate you."

The recent discoveries in northern canopies, while remarkable, are also a little embarrassing. How could we have missed so much happening in our backyard? In 1991 ecologist Meg Lowman, who had studied tropical trees and their insects for a decade, built a research walkway 70 feet up between two big oaks near Williams College in western Massachusetts. It was the country's first. She had an undergraduate set traps for small mammals and caught 23 southern flying squirrels—about 22 more than she expected. Researchers had once thought that the squirrels were rare in New England, perhaps because most had tried catching them just five feet off the ground. The squirrels turned out to be devouring tree-stripping gypsy moths, whose devastating outbreaks ecologists have been unable to stop for decades. The deans of defoliation had never noticed. "We forgot to look up," says Lowman. "It's such a basic and obvious oversight."

Such an oversight is even more embarrassing in light of the fact that canopy research really got its start 25 years ago on the far taller trees of the Northwest. There some of the biggest, oldest trees on Earth live—Douglas firs, giant sequoias, and redwoods, some 1,000 years old and 350 feet tall. In the early 1970s, Franklin, then the U.S. Forest Service's chief plant ecologist at the Pacific North-

BY KEVIN KRAJICK

PHOTOGRAPHS BY GARY BRAASCH



CANOPY LICHENS

like *Lobaria* (left), researchers were surprised to learn, supply an old-growth forest with much of its nitrogen. They were also surprised to find that flying squirrels in the treetops (right) may eat a substantial number of gypsy moths (below).

west Research Station, put together a team to build a model of old-growth forests. One member, Bill Denison, a botanist then at Oregon State University, decided to make the treetops his object of study. The canopies of these giants were completely unexplored, and for good reason: How do you climb a tree whose branches don't even start for 100 feet?

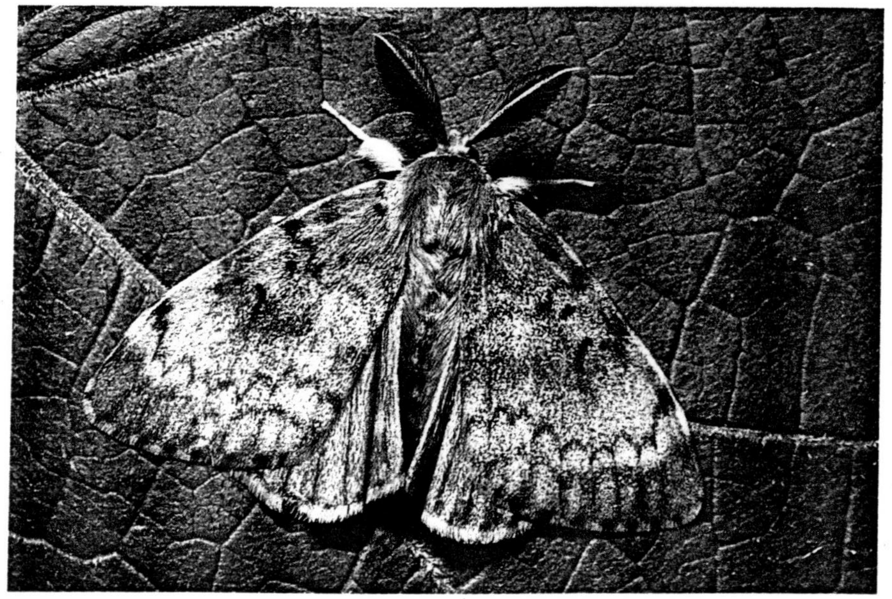
Denison was particularly intrigued by the fertility of old forests. How did they get enough nutrients to grow so big? Nitrogen, for example—there is plenty of it in the air, but in a form that most plants can't absorb. A few fungi and bacteria do the chemistry for them, "fixing" the nitrogen as usable compounds. One day in the woods Denison picked up a leathery, lettucelike thing. It was *Lobaria oregana*, a local tree-dwelling lichen, that had fallen from some high branch. (A lichen is a combination of a fungus and an alga coexisting as a single organism.) Denison had heard European reports of weird lichens that fixed nitrogen, so he tested the fixing ability of the *Lobaria*. It turned out to be highly efficient at the task. Was it actually helping the trees become giants? "The only way to find out was to take a look upstairs," he says.

At the time, this was much easier said than done. To find out what was happening at the top of a tree, you essentially had only two approaches: you could either pick up stuff that had fallen from above or you could cut the tree down—akin to killing a person and performing an autopsy when all you wanted to do was feel his pulse. One of Denison's students was a rock climber, and she suggested adapting rope techniques for trees. That worked well. Someone else suggested shooting arrows attached to fishing line over high limbs, then hauling up climbing ropes, and inching up on ascenders. That worked even better. Finally, with access to high branches, researchers were able to start asking basic questions. For example, how many needles are on a tree? (Answer: On a big Douglas fir, about 60 million.)

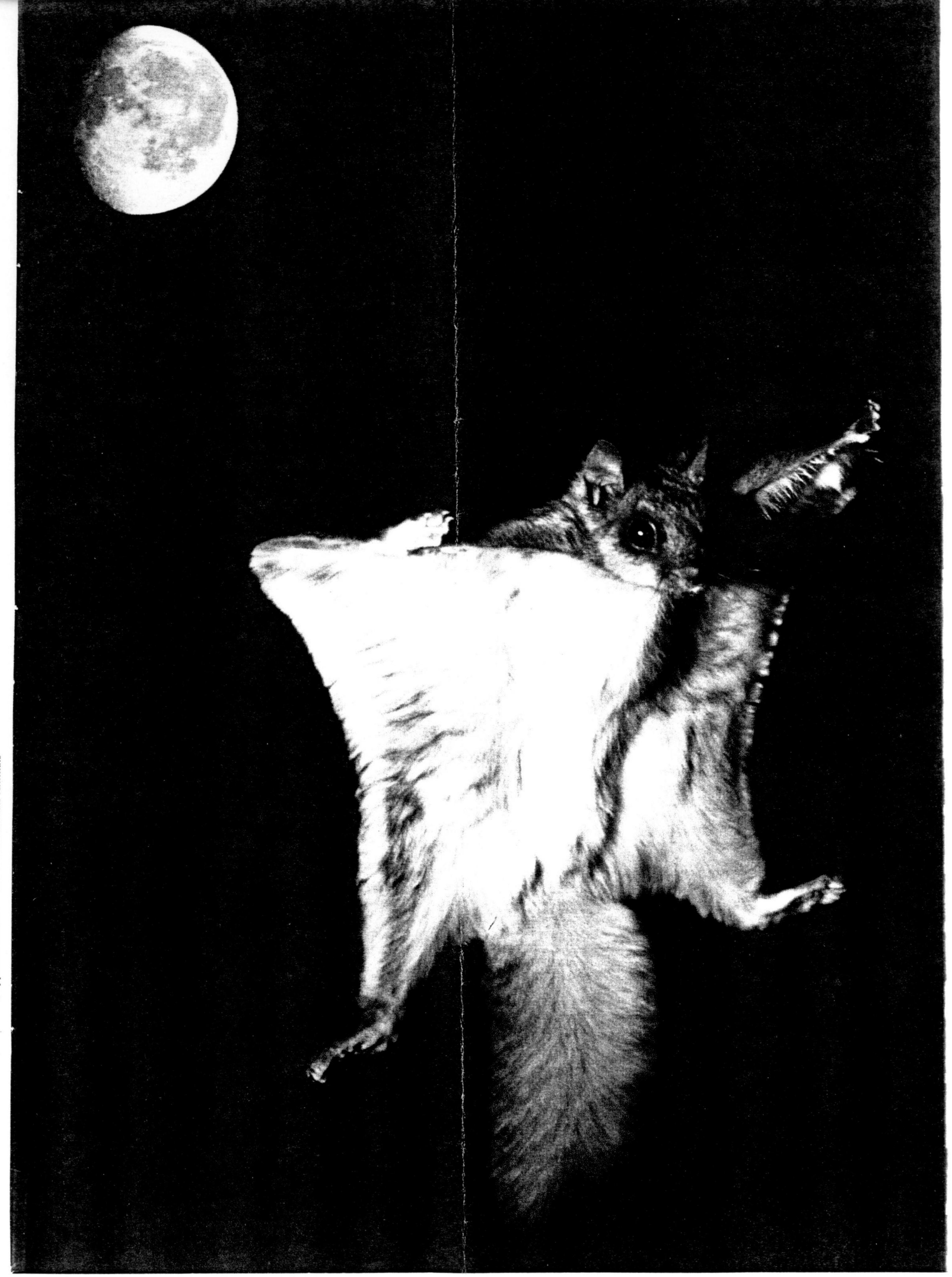
Those needles, they found, perform some unanticipated functions, with wide-ranging effects. For instance, the needles regulate how much water reaches the ground. In winter they support heavy globs of snow, which, spread over the great volume of foliage, melt or evaporate gradually. This softens the blow of the spring thaw of ground snow, thus protecting soil from erosion and streams from silting. During summer the foliage *increases* stream flow by intercepting fog and moist air; it also shades streams, keeping water temperatures down and helping salmon and other fish survive. Felling too many trees can wipe out fish. Salmon in some logged Oregon runs have dropped 90 percent in recent years.

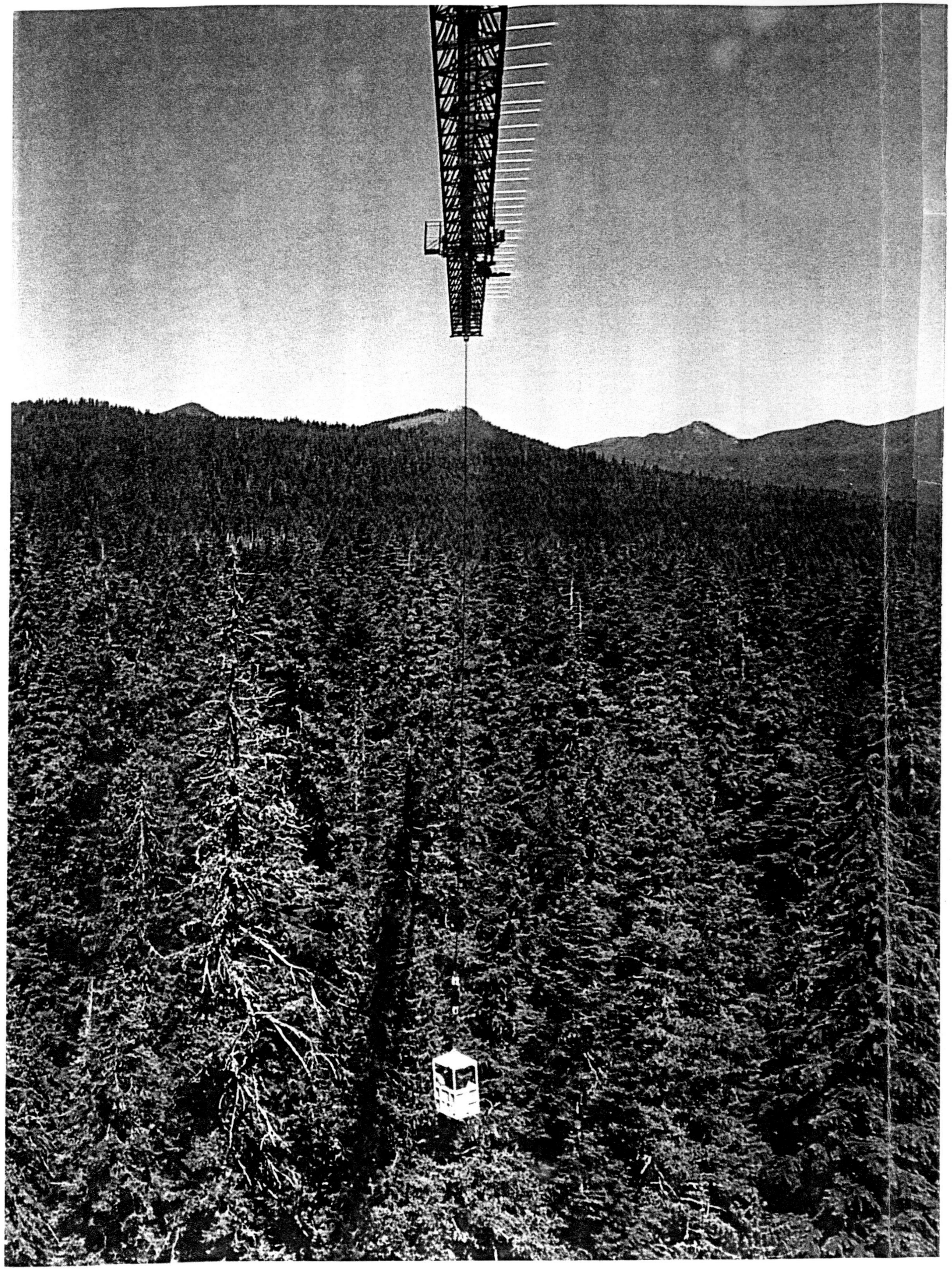
Living within the needles and branches, the researchers discovered, were a staggering variety of microscopic organisms, some harmful and some beneficial. University of Oregon microbiologist George Carroll found that one old-growth tree might carry 1,000 strains of a single species of fungus. This is in stark contrast to young timber-plantation trees, which have a paltry diversity of these organisms. As it happens, these younger trees are also eaten by bugs a lot more, and Carroll has found a possible connection: some strains of fungus defend their homes by producing compounds that kill tree-eating insects. Drug companies are interested in these natural chemical factories; Merck, for instance, is looking at a newly discovered antibiotic from a fungus that grows on New Jersey white cedars.

Forest canopies are also home to plants and lichens known as epiphytes, which, like Denison's *Lobaria*, live on rather than within the trees. They were long thought to be minor oddities. "No one had any idea how much was growing



Bottom: David C. Rentz/Bruce Coleman; opposite: Richard Allen Wood/Animals Animals





AT 260 FEET UP,

a new research crane in Washington State (left) is giving researchers an unprecedented look at the canopy of a North American forest. The marbled murrelet (right) hunts fish in the Pacific but needs inland canopies for its nests (below).

there until we climbed up," says Denison. When they got up there, they found that the trees were like aerial coral reefs full of weird, colorful life-forms. The more they climbed, the more they found: recent surveys show as much as 1.16 tons of epiphytes per acre—four times the weight of some trees' foliage. In Northwest forests, Denison now knows of about 130 lichen species alone; hundreds of microscopic epiphytes are probably still hidden there.

In the late 1970s other ecologists adapted Denison's methods to tropical forests, where they soon discovered some of the most complex ecosystems on Earth. Funding flowed south, drying up research in the north for years. In the last few years, however, a new generation of ecologists have begun looking seriously again at northern canopies. Steve Sillett, a student of Denison's, is one of them. He has been climbing since 1988. "It's my passion," he says. One recent day he drove his pickup along a boulder-strewn dirt road in Oregon's Cascade Mountains, through miles of steep slopes turned to dust by clear-cutting. Erosion was so bad that someone had poured concrete down a onetime streambed to keep the mountain in place. Sillett drove over a pass, and suddenly deep waves of green surrounded by cloud-ringed rocky peaks unfolded. Here was the Middle Santiam Wilderness, not leveled since the ice ages and saved from the saw by massive protests in the 1980s. Stumbling with 80 pounds of gear through underbrush and fallen trunks, Sillett arrived at the base of a 230-foot Douglas fir.

After getting a rope into the tree limbs, Sillett hoisted himself up, pointing out the progression of epiphyte environments along the way. You first see an array of mosses and other bryophytes clinging to the trunk. Not until you reach 120 feet do you encounter limbs, and they're as thick as telephone poles. In these lower reaches, falling needles, bark,

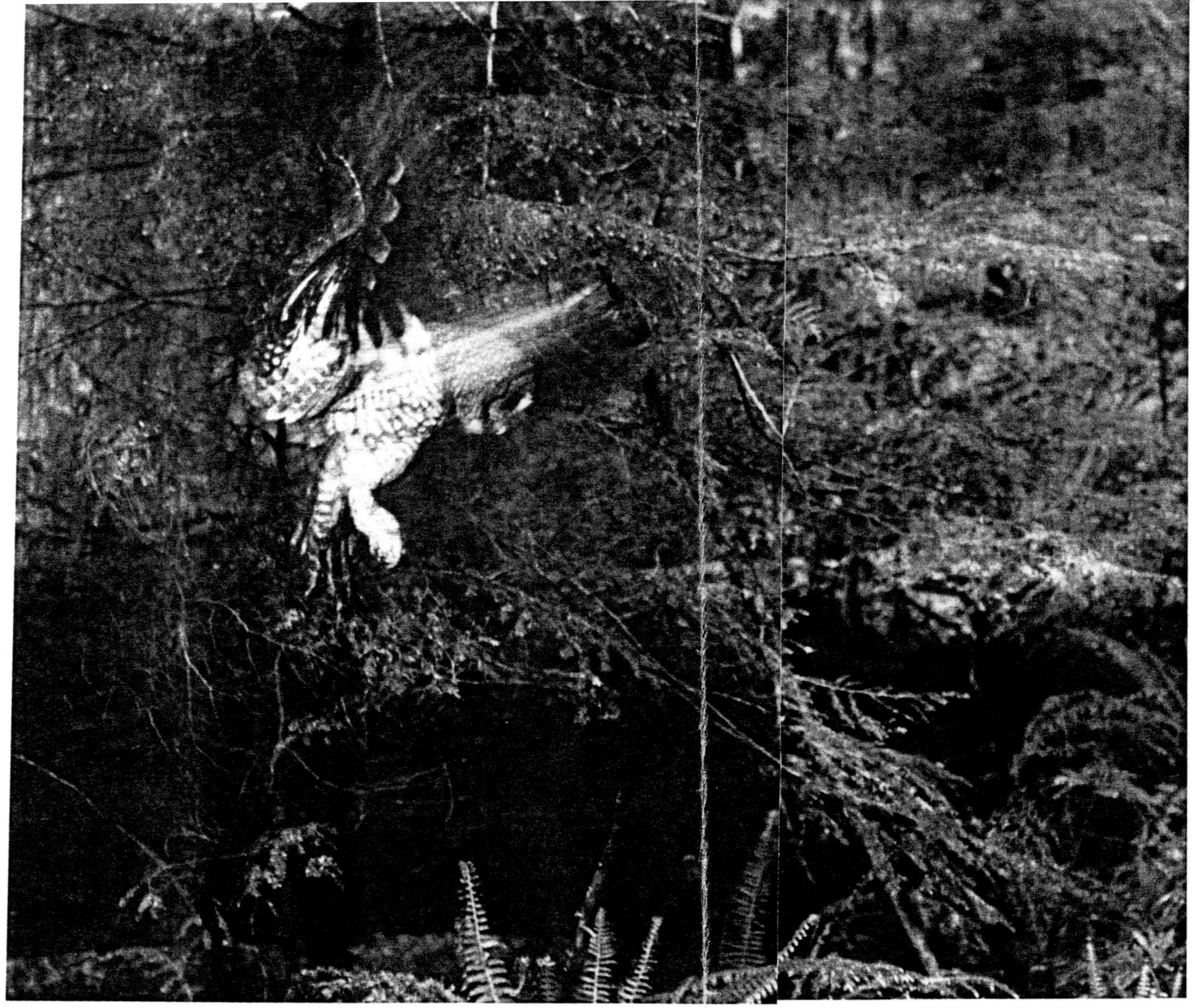
and dead insects collect in crotches and knotholes, creating patches of aerial soil. Elbow-deep mats of *Antitrichia curtipendula* moss, perched like great Cheshire cats, grow in these cradles, and as they decompose they too add to the soil. Insects, rodents, and even salamanders may nest inside these ancient tufts.

"Wow! Biggest *Sticta weigelii* I ever saw!" Sillett cried, pointing to a coral-like growth 12 feet out from the tree. Roped to the trunk, he was dangling upside down under a limb, swinging around in midair and chatting with the relaxed gaiety of a dinner host pouring coffee. "That is cool! Such a little garden!"

Farther up in the midcanopy there was plenty of *Lobaria* hanging off branches. Sillett pointed out luxuriant beards of hairy brownish *Bryoria* lichens draped over outer twigs like Christmas tinsel run amok. Squirrels use them for nesting and food; during winter, elk and deer subsist on the lichens that fall to the forest floor. Finally, at the very tops of the trees, come what Sillett calls the true pioneers—hardy growths like *Hypogymnia* that can survive high wind, aridity, and unfiltered sun.

As Denison had suspected, these epiphytes nourish the forest by sucking nutrients from fog, rainfall, and dry floating particles in the air. The vast filigree of epiphytes picks up and stores many nutrients that would otherwise float by on wind or wash away in runoff. Nalini Nadkarni, an ecologist at Evergreen State College in Washington, estimates that epiphytes in some forests hold nutrients equivalent to half of that in the trees' foliage. In the Northwest, *Lobaria* seems key; Denison estimates that it fixes up to 75 percent of the minimum level of nitrogen an old forest needs to survive. Rain leaches out some of these nutrients; they fertilize lower epiphytes and eventually reach the ground, where they are consumed by roots. When the epiphytes die and fall to the soil, they are eaten or decompose. Sometimes the trees are less patient. According to Nadkarni, common northern trees like big-leaf maples send out roots from their branches that seek out canopy moss and lichen mats and suck nourishment from them.

This fantastic world is a vulnerable one. Many lichens are killed by modest levels of pollution; nitrogen fixers are long gone from most of Europe and the eastern United States. Now they are disappearing from woodlands downwind of fast-growing Portland. Many epiphytes live only in ancient forests—some don't even appear for the first 150 years. Researchers suspect that the epiphytes disperse slowly to new trees and must often wait for specific conditions provided only by the eccentric topography of old trees, such as huge, deeply shaded bottom limbs and desertlike dead tops. "You might not see the full range in abundance until a forest is 400 years old," says Sillett. Once they do appear, they live in slow motion. A *Lobaria* takes half a century to grow to the size of a head of lettuce. As a result, Denison thinks, many repeatedly harvested forests may be in trouble in the long term. The nitrogen that epiphytes fix is like a forest's income, he says. Once that source is gone, the forest has to turn to its capital—the nitrogen in its soil—to survive. "You're heading for the poorhouse," says Denison.



THE SPOTTED OWL (left), thanks to recent lawsuits, is the most famous resident of old-growth forests, but it is not alone. Canopies offer food and shelter for predatory mammals such as marten and bats (below).

ONCE NEVILLE WINCHESTER HAD AT least partially conquered his fear of climbing, he and Richard Ring, an entomologist at the University of Victoria, set up traps in four old-growth trees in Carmanah Valley on Vancouver Island. The Western Canada Wilderness Committee helped them by installing ropes and platforms; the organization hoped, not so secretly, that the researchers would find new biodiversity and thus justification to protect the area from logging. It wasn't disappointed: from that site alone Winchester and Ring have collected an estimated 150 new species of mites, springtails, flies, wasps, and other creatures unique to the canopy.

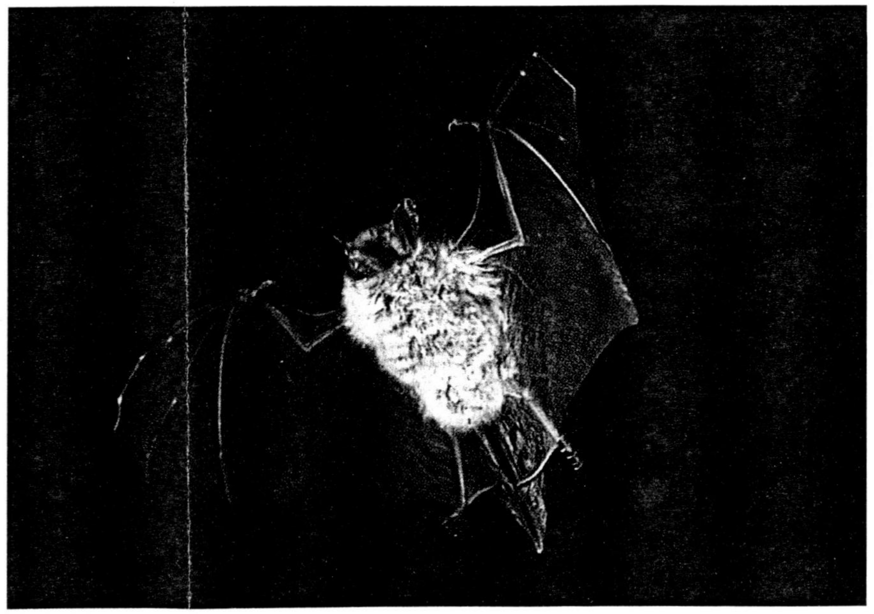
Like some epiphytes, many arthropods too apparently exist only in forests at least 250 years old. Some take up residence in centuries-old aerial moss mats, which are worlds unto themselves. Winchester has drilled into the mats and found communities of beetles and mites that probably never leave these shelters during their entire lifetime. By weight some 40 percent of all the canopy arthropods are predators—a bafflingly high proportion. Winchester and Ring suspect that they supplement their diet of vast numbers of tree-eating insects with ground-dwelling insects that visit the canopy for reasons unknown. Stone flies, for example, live most of their lives in shady forest streams, but during the summer they ascend in gigantic pulses to the high canopy to mate. "I have no idea why they go there," says Ring. "It just seems to set the stage for romance."

Bats, themselves voracious insect eaters, also take advantage of the buggy treetops. Populations of some species, like the *Myotis* and silver-haired bats, are three to ten times greater in old-growth forests than elsewhere. The old-growth canopy provides them with not only food but lodging. Researchers suspect that many Northwest bats roost and reproduce in crevices and under chunks of decaying bark high in old trees. In the first comprehensive study of where forest bats roost, published just last year, Arizona biologists radio-tagged lappet-brow bats and tracked them to previously unknown colonies in high cavities of old, dead ponderosa pines; they had been thought to roost only in caves and mines.

Bats' predilection for dead wood is served well by old forests—it often makes up a fifth of the forests' standing mass. This includes as much as half of the limbs and twigs of living trees and their rotted trunk interiors, as well as up to 30 dead standing trees (known as snags) per acre. Dead wood, almost absent from young forests, is central to the old-growth ecosystem: arboreal wood-boring insects, yeasts, fungi, and decomposing bacteria inhabit it, and evidence suggests that at least 100 Northwest wildlife species depend on it. Snags are vital for woodpeckers, which leave behind holes for wrens and other cavity-nesting birds.

Mammals such as flying squirrels often nest in rotted-out knotholes, crevices, and hollow trunks in living trees, where foliage and epiphytes provide food, cover, and nest material. Aside from bats, the most arboreal Northwest mammals are red tree voles, little rodents that eat conifer needles and get their water from fog-soaked lichens and mosses. They may not come down for generations. Assorted other mammals live upstairs part-time, ranging from raccoons to marten—predators that will eat almost any other mammal or bird in a tree. Many details of arboreal mammals' lives are hidden, though, for most of these mammals are nocturnal and difficult to track.

Presstige Pictures/Oxford Scientific Films/Animals Animals

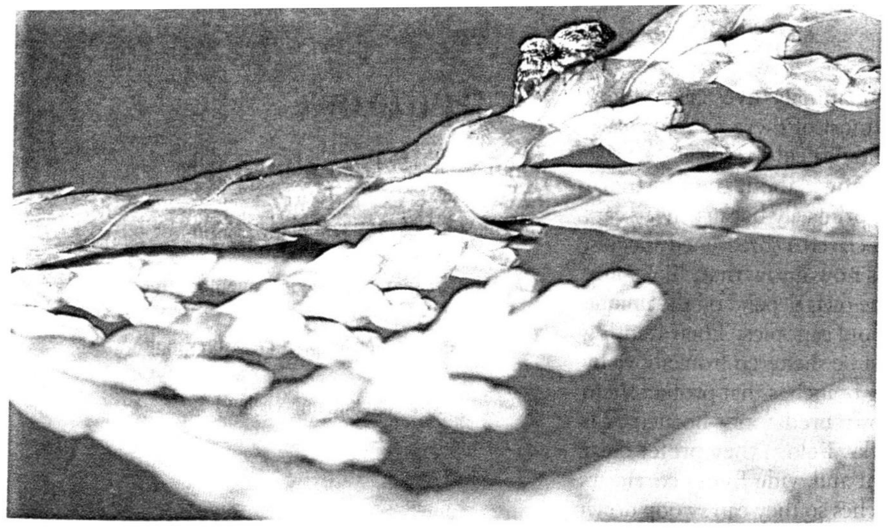


More is known about the Northern spotted owl, primarily because five years ago it was declared a threatened species. Researchers now know that, like some epiphytes, the owls depend on the unique structure of old canopies. Their hunting perches must be sheltered from above by overhanging branches that protect them from their own predators—horned owls and goshawks. Below, they prefer clear lines of sight and wide flying corridors free of branches so they can swoop down on prey such as flying squirrels. The owls also move throughout the canopy to handle changes in the weather—going up to warm, sunny areas when it's cold, and descending to shady, humid interiors when it's hot. Such landscapes don't exist in dense young forests—only in old growth.

The other imperiled bird of the high canopy is actually a seabird: the marbled murrelet. Until 1974 it was the only North American bird whose nesting place was unknown. That year a climber trimming limbs in a big Douglas fir five miles inland came on a strange web-footed chick in a high moss mat. Marbled murrelets, researchers now realize, depend on fish in coastal waters but nest high in old trees as far as 50 miles inland. The trees must offer high limbs big enough for wide moss beds, which in turn must be camouflaged by branches to protect the chicks from predators like jays. The birds' numbers at sea suggest that the population is declining, and in 1992 they were declared threatened. Their biggest threat is logging.

Learning more about the murrelets' lives in the trees has been difficult. "They depend on secrecy for their existence," says murrelet researcher Kim Nelson of Oregon State University. The birds return from the ocean with fish for their young in the hour before dawn, and from the ground all you can see are dark figures shooting over the trees at 60 miles an hour. This summer Nelson tried to get a better look by hiring five climbers to inspect likely trees for nests. (Nelson herself supervised from the ground. "Oh no, I don't like heights," she says. "I'm not going up there. No.") In the previous 20 years, only 65 nests had ever been spotted; in a few weeks Nelson found 13 new ones in Oregon alone.

These data could help establish which trees should be protected and put more forests out of reach of a logging industry already hit hard by research. Although 85



THE INSECT WORLD of the treetops is a puzzle. Predators like spiders (left) make up a disproportionately large 40 percent of the arthropod population, while unidentified insect species teem in the canopy. The mystery bug below lives 200 feet up in an Oregon forest. Right: A crane researcher examines the growing tip of a tree.

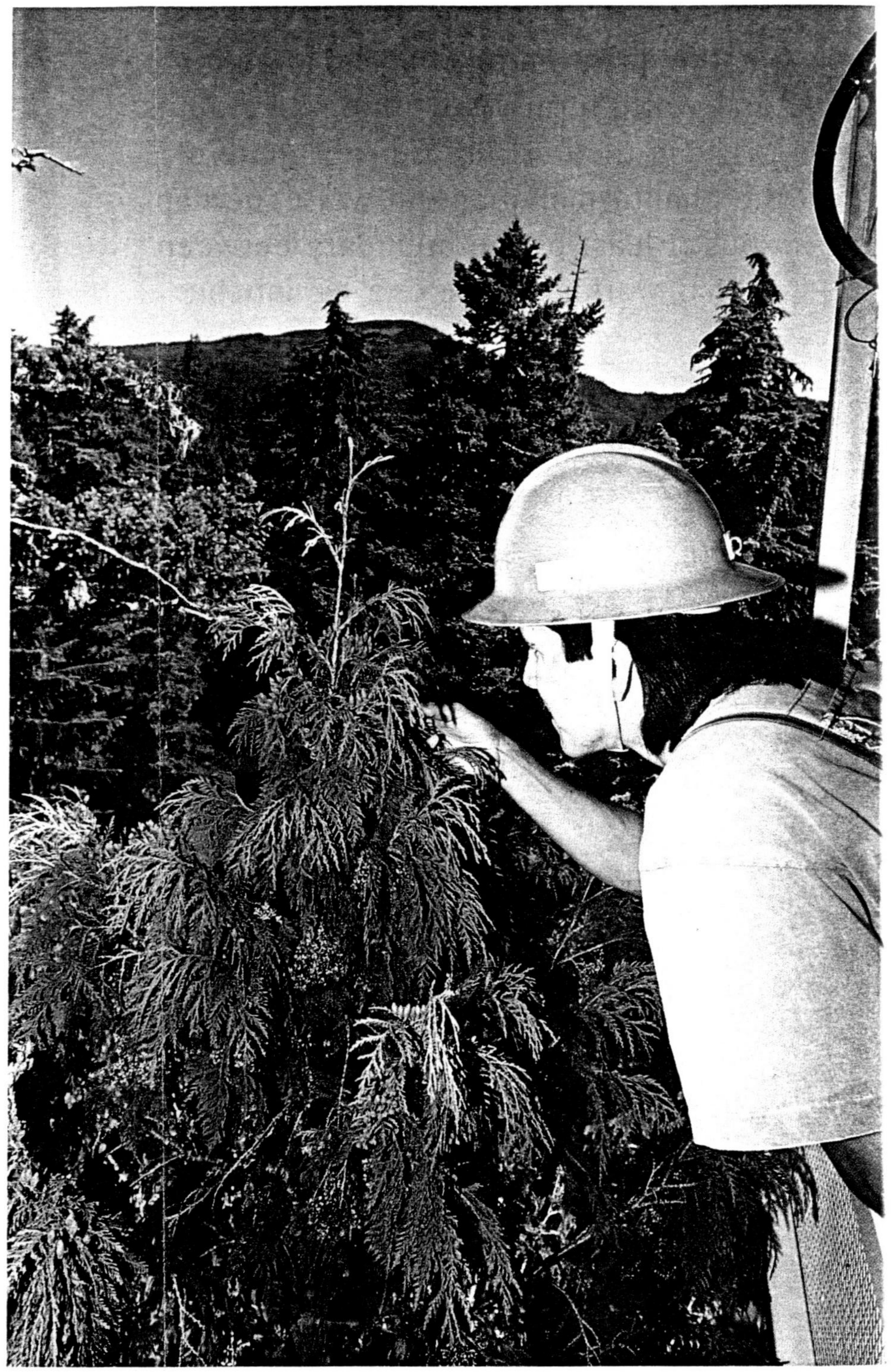
percent of the U.S. Northwest's old trees were already gone by 1990, 4.6 billion board feet were still flowing every year out of the region's federal land, where most old-growth remnants survive. In 1991 the courts froze much of the cutting in spotted owl territory, and one judge chastised the government for having no plan for preserving the trees the owls depend on. Economic havoc and bitter protest ensued in logging communities, and in April 1993, President Clinton charged a team of nearly 100 scientists to come up with a plan to solve the crisis. The team was headed by Forest Service biologist Jack Ward Thomas (since appointed the head of the agency) and included Jerry Franklin.

Although it started with the owl, the timber plan mushroomed into a public examination of all life in old forests. The canopy research was a crucial element. "Until we started looking in the treetops, all we knew was that old forests were pretty and like cathedrals," says Franklin, who is now at the University of Washington. "This gave us a real reason for saving them." The team synthesized the work that had been done on epiphytes, mammals, and insects that lived in the big trees, as well as work on the relationship between foliage and declining fish stocks. "It all showed that you can't replace forests with tree farms without any harm to water, soil, or wildlife," says Franklin. Last December a court approved a plan to set aside most federal trees, and when cutting resumed this year, it was 20 percent of its former level. Loggers are fighting back on all fronts. Sympathetic members of Congress got a law passed in July that waters down the plan. Environmentalists have responded with a lawsuit.

The plan doesn't directly affect private land, but here the Endangered Species Act holds sway. As a result, in February a judge forbade Pacific Lumber Company from cutting 137 acres of ancient California redwoods and Douglas firs it owns because murrelets live there. The judge accused the company of twisting the work of its own scientists, who had surveyed for birds. (He noted a staff party where a picture of a murrelet was used as a dartboard.) Nelson—whose testimony on nesting was key in the case—recently requested access to a private road from an executive of another timber company. According to Nelson, he fixed her with his eyes and said: "If you threaten my livelihood, I will kill you."

In Canada the fight has just begun. Each year 120,000 acres of British Columbia old growth is still being cut. The province is polarized over it: almost 1,000 protesters from both sides were arrested last year. "The cutting is probably wiping out species we don't even know exist," says Richard Ring.

Franklin wants to find out more. Congress recently gave him $1 million to build a 260-foot crane to swing scientists over six acres of forest—North America's first such facility and the world's largest. (Two others are in Panama and Venezuela.) He and his coworkers made the mistake of planning to build it near Forks, Washington, where families have logged for generations. In anonymous phone calls, people threatened to drop a tree onto the crane, shoot it, or torch the forest it was intended to study. "Look at what so-called science has done to us," says Larry Mason, a bankrupted Forks sawmill owner, now a college student. "They're going to climb up in that crane and find more species to ruin our lives." Franklin's crane, he says, "would be like having a feudal landlord rape your wife, then letting him build a mansion in your lower acreage." Unable to guarantee the crane's safety, the local Forest Service nixed it. "We got our asses kicked and went with our tails between our legs," admits site director David Shaw.



Shaw later found a patch of old growth 300 miles away, and the crane, bought secondhand from a skyscraper-building firm, went up this April. It is now lowering scientists in a gondola to any point over 1,200 trees. While no more sophisticated than a bulldozer, it will greatly expand our knowledge of northern forests, simply because it enables researchers to study things they otherwise can't without risking their lives, such as snags and the very tops of trees.

The crane provides a close-up view of canopy topography rarely seen by humans. From the ground, forests may look like cathedrals, but from above they look like the surface of a fantastic, rugged green planet. Trees throw out branches and foliage in whorls, fans, and lacy patterns shaped like ice crystals or a cascading rocky stream. Between the trees are deep canyons where parachuting seeds float on air currents and birds navigate at *Star Wars* speed. Ancient snags jut into space like Gothic spires. Most startling—and strangely moving—is the way you can reach out and stroke the single growing finger that tops each mighty fir: a green tassel with a stem sometimes no thicker than twine, and needles as tender as a baby's hair. It is all alone, exposed to winds, blasting sun, and thunderstorms. If it were a person, you might think: what courage. You realize that trees are merely attached to the ground by roots; they are really residents of the sky.

This landscape is the next frontier of canopy research. "Trees are Earth's main point of contact with the air," says Franklin. "This is our opportunity to look into the dialogue between them and the atmosphere." In the dense forest surrounding the crane, the collective surface of the leaves can be ten times bigger than the ground they shade. All together, leaves are as expansive as the face of the entire planet. Vast amounts of sunlight, atmospheric gases, and water pass in and out of them, affecting everything from the local groundwater to the global climate, but in many ways we don't understand.

For instance, no one is sure where all the extra carbon dioxide produced by the razing of forests and burning of fossil fuels goes. A quarter is absorbed by oceans, and as much as half ends up in the atmosphere, possibly causing worldwide warming. Where is the rest going? Scientists now think northern trees are taking up much of it through photosynthesis. If that's true, how we manage them could affect the course of world climate.

This summer the BOREAS Project, an international consortium of NASA and other scientific agencies, erected forest towers and fielded a fleet of low-flying aircraft across northern Canada to measure the gulps and sighs of gases there. New instruments can take air samples several times a second, creating a transcript of the dialogue between canopy and air. Similar surveys are under way from South Carolina to Washington.

Twenty-five years after he helped start the canopy revolution, Bill Denison is still looking to the air. He is still fascinated by lichens, but at 67 he now needs an hour to get up a rope to where they are. Young people are so much faster. Now he sometimes thinks about hot-air balloons. "I talked to a guy locally who knows all about it," he says. "He knows where I can get one. I think this might actually work." D