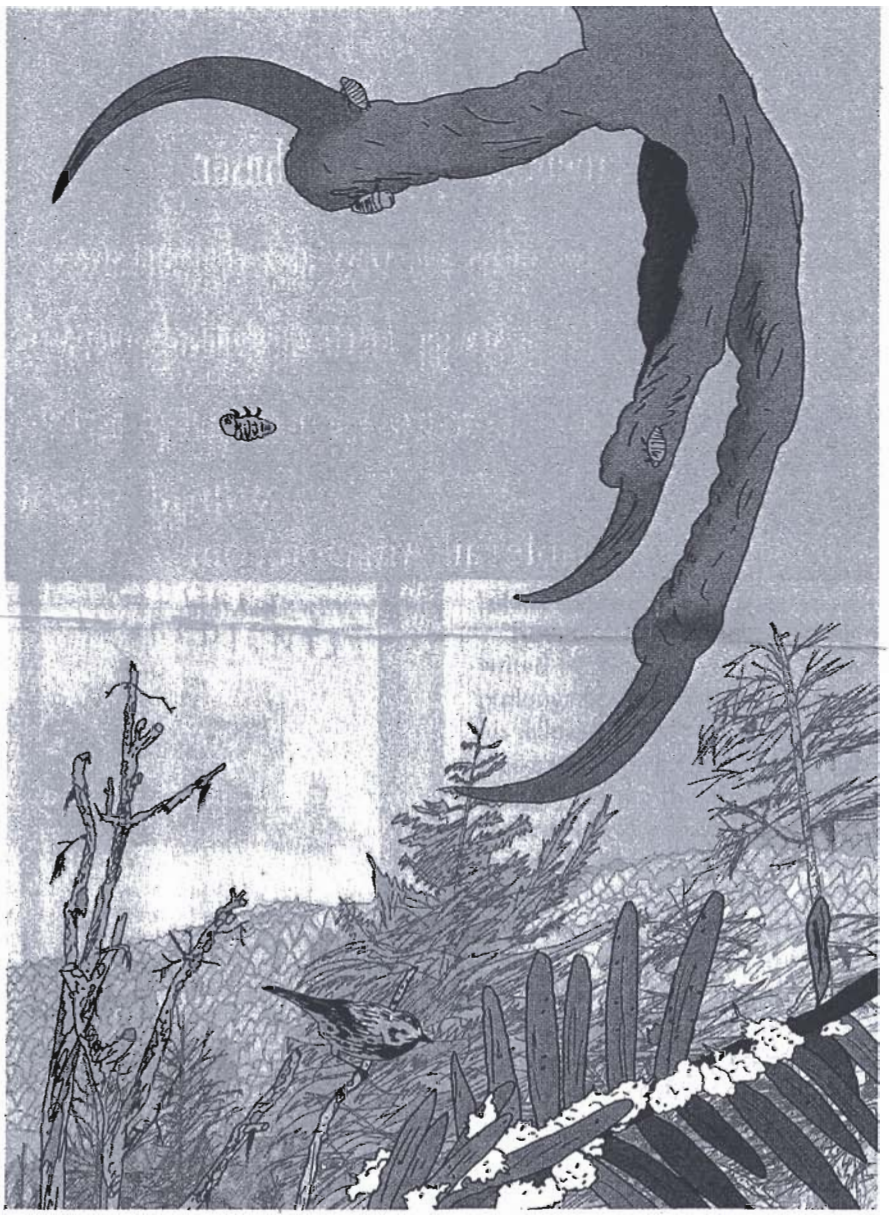
LETTER FROM NORTH CAROLINA

A DEATH IN THE FOREST

Can the trees of the Great Smoky Mountains be saved?

BY RICHARD PRESTON



Foresters knew that the adelgids would spread, but they were surprised at how fast.

In 1911, a woman named Sallie Dooley established a Japanese garden at Maymont, her estate in Richmond, Virginia. She planted bamboo, built a gazebo and a waterfall, and, according to her husband, James Dooley, a financier, "purchased the most costly evergreens from all parts of the world." She died in 1925, and Maymont was left to the city of Richmond. It became a park, and the Japanese garden went untended. In 1951, an entomologist with the Virginia Department of Agriculture discovered a species of Asian insect known as the hemlock woolly adelgid infesting an eastern hemlock—a tree native to North America—on property near Maymont Park. The hemlock woolly adelgid is a tiny brown bug similar to an aphid; the body of an adult is covered with a protective white fluff that makes it look like a fleck of cotton. It is a parasite, and it feeds on several species of hemlock and spruce trees in Asia. This was its first known appearance in eastern North America. The suspicion was that it had come with Sallie Dooley's imported evergreens, though no one could be sure. Experts considered it a curiosity.

After hatching from an egg, the woolly adelgid goes through a crawler stage, when it moves around. The crawler is almost invisible to the naked eye. It can drift in the air from tree to tree, and it can cling to the legs and feathers of migrating birds. The insect eventually settles down among the needles of a host tree. It inserts a bundle of mouthparts at the base of a needle, and spends the rest of its life—a few months—sucking nutrients out of the tree. The woolly adelgid goes through two generations a year, and each female lays between a hundred and three hundred eggs. A female can lay eggs without being fertilized by a male. The offspring are clones of their mother—genetically identical to her. As it has turned out, the population of woolly adelgids in North America seems to consist entirely of female clones. Males still hatch occasionally, but they breed and live in spruce trees, and American spruces lack nutrients that they need, so they die—a further indication that the adelgids are transplants. It hardly matters: a single female clone can generate as many as ninety thousand copies of herself in a year.

In Asia, the host trees have developed resistance to the woolly adelgid; in eastern North America, though, the hemlocks have virtually no resistance, and the insects have no natural predators. When millions of woolly adelgids cover the branches of an eastern hemlock, it turns a dirty whitish color, as if it had been flocked with artificial snow. Many of its needles fall off. The tree puts out a new crop of needles the following spring, but the crawlers attach themselves to the new needles, the tree goes into shock, and the needles fall off again. The cycle of shock and defoliation continues until the tree dies, usually in two to six years.

There weren't many eastern hemlocks in Richmond; the few that were there

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were planted in people's yards, scattered through the city. Many of them eventually died, but gardeners found that if they sprayed an infested hemlock once a year with pesticides or an oil spray the adelgids would be suppressed. Tim Tigner, an entomologist who worked at the Virginia Department of Forestry, told me recently that, for most of the nineteen-eighties, "we advised people not to worry about them. They didn't seem to be doing anything."

In the late eighties, Tigner learned that the insect had got into a stand of old hemlocks on the York River, forty miles east of the city, and he went to have a look. He got a shock: ninety per cent of the hemlocks were dead. The woolly adelgids had turned the grove into a sun-bleached ruin.

Botanists sometimes refer to the eastern hemlock—its species name is *Tsuga canadensis*—as the redwood of the East. It is a tall, long-lived conifer with soft, flat needles and feathery foliage, and occurs naturally in the Appalachian Mountains from Georgia to New Brunswick, with a range that runs westward through Michigan into Wisconsin. The tallest existing eastern hemlocks are somewhat more than a hundred and seventy feet high, and the largest (measured by volume of wood) can be more than six feet in diameter. The oldest living specimens may be more than six hundred years old.

Hemlocks do especially well in the temperate rain forest found in the southern Appalachian Mountains, where they grow on mountain slopes and form dense stands in upland valleys called coves. Hemlocks create deep shade and cover the ground with beds of needles, altering the temperature, moisture, and chemistry of the soil around them, and creating a distinctive habitat for certain animals and plants. Some ecologists believe that those coves contain—or, until recently, contained—the last examples of primeval rain forest in eastern North America. Only small fragments of old-growth forests remain in the East. Many of them are in Great Smoky Mountains National Park, which, straddling Tennessee and North Carolina, covers half a million acres; about a fifth of the park has apparently never been logged. Loggers haven't bothered to go into many coves to cut hemlocks, because the tree is practically worthless for lumber: the wood is full of knots, and often fractures when the tree falls.

In 1988, around the time Tigner saw the woolly adelgid by the York River, it was discovered in Shenandoah National Park, in northern Virginia. It seems to have got there when crawlers clung to the legs and feathers of migrating birds that visit or nest in hemlock trees—the black-throated green warbler, the solitary vireo. In Shenandoah, the insect multiplied with explosive speed. By 1992, most of the hemlocks in the park were infested, and three years later the majority of them were dead. Today, stands of eastern hemlock have essentially disappeared from Shenandoah National Park.

The crawlers spread rapidly northward. They were moving southward only slowly, though, possibly because there were few crawlers around in the autumn when birds flew south. By 1998, many of the hemlock groves in the Delaware Water Gap National Recreation Area, which lies between Pennsylvania and New Jersey, were infested and had begun to die. From eastern Pennsylvania to Connecticut, hemlocks were being turned into skeletons. The insect got to Massachusetts. Stands of old hemlock there were defoliated. However, a spell of intensely cold weather during the winter of 1996, when temperatures in parts of the Northeast fell to as low as twenty degrees below zero, seemed to kill many adelgids. "The hemlocks looked O.K. after that cold winter," James Åkerson, an ecologist with Shenandoah National Park, said. "It may have given us a false sense of hope."

Invasive species of microbes, plants, and animals are changing ecosystems in a biological upheaval that may affect almost everything that lives. The cause of the upheaval is the human species. Life on the planet is being homogenized by the expanding human population and the frequent and rapid movement of people and goods, which carry invasive organisms with them. These invasives often flourish in their new ecosystems because, like the woolly adelgid, they have escaped their predators. A fungal disease called chestnut

blight, which colonizes chestnut trees in Asia, first appeared in North America in 1904. Spread by wind, rain, and birds, it killed almost every American chestnut tree. Chestnuts had once saturated vast stretches of forest in the Appalachians. Since the nineteen-thirties, the American elm has virtually disappeared, pushed into oblivion by an invasive Asian fungus spread by an invading beetle from Europe. A fungal disease of unknown origin has killed off the vast majority of the wild flowering dogwoods in North America. Another disease, sudden oak death, has killed hundreds of thousands of oaks in California and may get into Eastern oaks. A European insect, carrying a European fungus, has lately caused a mass dying of the American beech tree. An Asian beetle called the emerald ash borer arrived in Michigan in 2001 in packing wood from China. It is devastating to a number of species of American ash trees. Despite strong efforts to control it, the emerald ash borer keeps appearing in different places, and it seems capable of not only wiping out the ash but threatening the classic major-league baseball bat (which is commonly made of ash). Another invader, the Asian long-horned beetle, had its North American début in Brooklyn, where it showed up in a park near warehouses that held large amounts of packing wood from China. The Asian long-horned beetle has infested tens of thousands of trees in New Jersey and Long Island, and it has showed up in Sacramento. It could take out the sugar maple.

When a parasite moves to a new habitat, it can find new hosts, through a process called the trans-species jump. Often, the new host has no resistance; it and the parasite haven't had time to adjust to each other through natural selection (it is frequently not in the best interest of a parasite to kill its host quickly). One example is the human immunodeficiency virus. H.I.V. appears to have once lived in chimpanzees, though it didn't make them sick. In Africa, it made trans-species jumps, and amplified itself in its new hosts.

Global climate change has become entangled with the problem of invasive species. A warmer climate could allow some invaders to spread farther, while causing native organisms to go extinct in their traditional habitats, and making room for invaders. The earth's biosphere could be thought of as a sort of palace. The continents are rooms in the palace; islands are smaller rooms. Each room has its own décor and unique inhabitants; many of the rooms have been sealed off for millions of years. The doors in the palace have been flung open, and the walls are coming down.

Global climate change may be helping the adelgids spread both north and south. Winters in the north are becoming steadily warmer, and the insects are not being hit as often with deep cold. Summers in the southern Appalachians have lately become drier and hotter, and drought stress makes infested hemlocks

far more susceptible to dying. Climate change may also mean that the adelgids are more active when birds fly south. Recently, the woolly adelgid has turned up in Ohio, Michigan, Vermont, New Hampshire, and Maine—approaching the northern limits of the hemlock range. Wherever it goes, it seems to get into every hemlock. It kills saplings before they can produce seeds, and so it keeps the species from reproducing. Many experts have concluded that the insect could kill nearly all the eastern hemlocks, and the species could essentially disappear from the wild. The term that biologists use for this is "functional extinction."

On December 3, 2001, an arborist named Will Blozan discovered woolly adelgids on the branches of a wild hemlock in the Ellicott Rock Wilderness, on the Blue Ridge in South Carolina, near the extreme southern end of the hemlock range. No one had expected to see the insect this far south, so soon. "It was a spear through the heart," Blozan told me. He phoned Rusty Rhea, an entomologist and the forest-health specialist for the Forest Service in Asheville, North Carolina. Rhea was surprised. He sent out a bulletin to all rangers in the area warning them to look for adelgids. Within two weeks, Rhea was getting reports. The woolly adelgid had gone all over the mountains.

Will Blozan is the co-owner of a tree-care company called Appalachian Arborists, based in Asheville. He is also the president of the Eastern Native Tree Society, a small organization dedicated to discovering giant trees in the East. Since 1993, he had been spending his spare time exploring patches of old-growth forest in the Appalachians from New Hampshire to Georgia. In the Great Smokies in summer, the heat can be Amazonian; the land can slope sixty degrees, and in many places the undergrowth consists of a mesh of rhododendrons. "'Rhodo wrestling' may be the appropriate term for movement in the Smokies," Blozan said. When he found a big tree, he would get an estimate of its height using a laser device. Later, he would climb to the top and send a measuring tape down along the trunk—this is the only way to get the height of a tree to the nearest inch.

Blozan discovered that the upland coves of the Cataloochee Valley, a rumpled drainage that lies at the southeastern tip of Great Smoky Mountains National Park, have the highest average tree height—more than a hundred and sixty feet—of any watershed in eastern North America. The valley contains more than eighty per cent of the world's tallest eastern hemlocks. It also contains the world's largest yellow poplar and four of the world's tallest white pines. In effect, the Cataloochee Valley is the Notre Dame cathedral of the eastern forests.

By the summer of 2002, the woolly adelgid had been found in the Cataloochee. Kristine Johnson, the park's forester, is a slender woman in her fifties, with a calm manner. "We currently have about a thousand sites in the park where exotic plants have got in, and we're dealing with ninety different species of invading organisms," she said to me recently—everything from Japanese stiltgrass to princess tree and fire ants. "We knew that sooner or later we would have the woolly adelgid. We were still surprised by how quickly it got here."

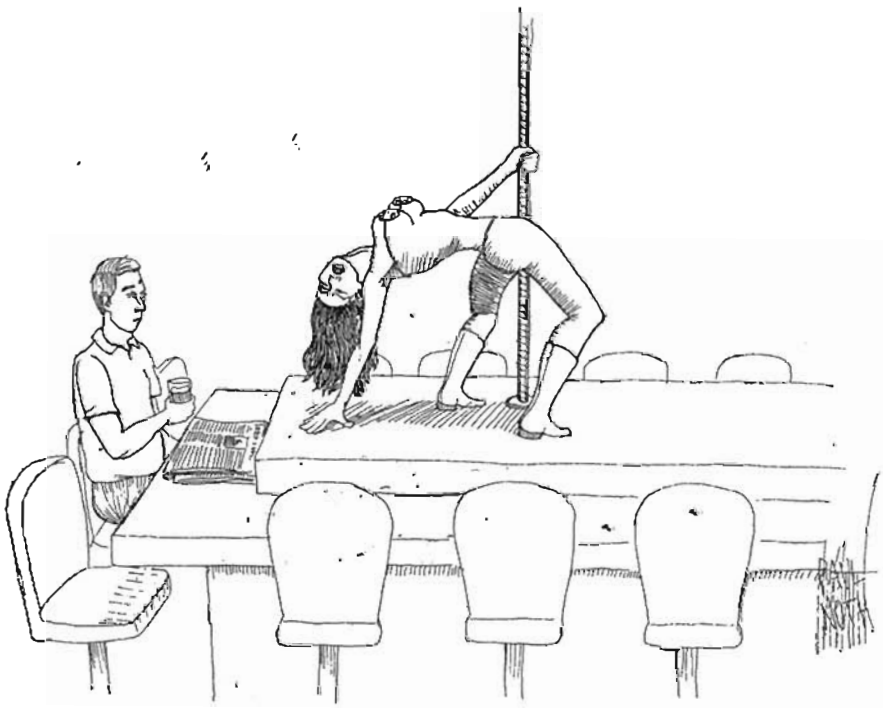
Oil spray—the treatment that had helped smaller trees in urban yards—wouldn't work in wilderness areas, where hundreds of thousands of large hemlocks would need to be drenched every year. There were two other promising options, though. Scientists at the University of Tennessee—funded in part by a private group, Friends of the Smokies—started a small lab for breeding a kind of lady beetle native to Japan that eats woolly adelgids. It was hoped that the beetles, released into the wild, would eventually cut down on the insects. Rusty Rhea, of the Forest Service, pushed the beetle strategy forward, and researchers began releasing the beetles. The bugs initially cost about two and a half dollars each; a handful cost hundreds of dollars. When they were released at test sites, they had no measurable effect. Lately, though, a test in Banner Elk, North Carolina, in which different species of adelgid-eating beetles were released over several years, has had promising results—one type of beetle, from the Pacific Northwest, has got established at the site and is eating adelgids, and the hemlocks there are looking better. Questions remain about whether and how quickly such results can be

achieved on a larger scale—if enough beetles can be bred and released and can multiply fast enough to save the hemlock forests that are dying or under immediate threat. The beetles may work in the long run, but by then it may be too late for most hemlocks.

There is also an insecticide treatment, a chemical called Imidacloprid, which is made by Bayer. Imidacloprid normally is mixed with water and injected into the soil around the root system of a hemlock. The chemical slowly moves into the foliage. When the adelgids suck it into their bodies, they die. Imidacloprid is an artificial kind of nicotine. (Tobacco plants produce nicotine as a natural insecticide.) The injections are labor-intensive, but at the moment there is no good alternative: if Imidacloprid was sprayed from the air, it would wipe out beneficial insects and wouldn't kill many adelgids—the insect's woolly coat sheds water. Imidacloprid has some advantages: it doesn't migrate much through soil, and it degrades in sunlight quickly. However, it is a toxic compound that could kill many grubs in the soil near the tree and insects feeding on it. It does not seem to affect vertebrates—frogs, salamanders, birds. "I wouldn't want to see chemical treatment be the only way to save hemlocks, but nothing else is ready right now," Blozan said. "Either you get some invertebrate kill around the treatment site or you get an ecosystem collapse—that's the choice."

As soon as adelgids were found in the park, the Forest Service and Bayer began seeking Environmental Protection Agency permission to use the chemical in wild forests (it was approved for ornamental and landscape settings). The park treated ten old-growth hemlocks, as a test. Will Blozan's company, Appalachian Arborists, was hired to climb the trees and take samples of the foliage, to see how the chemical was moving in the tree. It can take a year or two for the benefits to become noticeable; some trees die anyway. "After treatment, the hemlock can look completely dead, but sometimes it will come back, and in three years it'll be vigorous," Blozan said. The ones that live need to be re-treated every few years. The hemlocks would be like AIDS patients: they would never be free of the disease, though some could survive indefinitely on drugs. "What you get is a forest on life support," Blozan said. "But at least it can be kept alive while we hope for a cure."

Getting funding to fight the insect in the Great Smoky Mountains park was a byzantine process. The National Park Service, Kristine Johnson's employer, runs the park, but the Forest Service has responsibility for controlling pests in fed-



"Are you even listening to me?"

eral forests, including the national parks. The Forest Service is in the Department of Agriculture, while the National Park Service is in the Department of the Interior. Funding for insect control competes with other Forest Service needs, such as fighting forest fires. And the Forest Service appears to concentrate its pest-control efforts on trees that have commercial value—it has spent more than a hundred million dollars trying to get the emerald ash borer contained—and hemlocks aren't marketable. In 2003, Kristine Johnson asked for and got about forty thousand dollars from the Forest Service to save the hemlocks in the Great Smoky Mountains park. Since then, the Forest Service has spent about fifteen million dollars on research into ways to control the adelgid, but it has spent far less to deploy the means now available. Direct Forest Service funding for the park to fight the bugs was only two hundred and fifty thousand dollars this year, with private donations increasing the total somewhat. ("The government is so damned slow," Blozan said. "Very little was done in the first two to three years.")

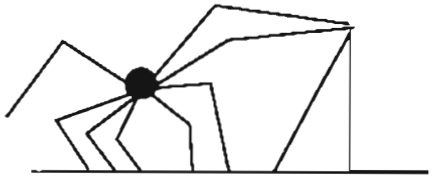
At the same time, Charles Taylor, then a Republican North Carolina congressman, who was the chairman of the appropriations subcommittee for the Department of the Interior, sought about six hundred million dollars to build a highway across Great Smoky Mountains National Park. It would probably have to include three bridges longer than the Brooklyn Bridge. Congress appropriated sixteen million dollars to develop plans for the road. None of the money could be used for controlling the insects.

In 2003 and 2004, Great Smoky Mountains Park employees treated hemlocks near public areas with Imidacloprid—trees in campgrounds and along roads—but not those deeper in the woods. The next year, the chemical was approved by the E.P.A. for use in forests, and Johnson and her colleagues designated special zones, called "hemlock conservation areas," where every hemlock would be treated. Appalachian Arborists won a contract, and put a crew of five to work, while another crew, of eight, went to work under a park forester, Tom Remaley. The conservation areas totalled two square miles; the park covers eight hundred square miles.

The biggest problem was carrying the water needed to mix with the chemical. The crews collected water from creeks in jugs, put the jugs in backpacks, and rhodo-wrestled their way up the mountainsides. A crew could treat between a hundred and four hundred hemlocks a day. At that pace, saving all the hemlocks in the national park was simply not possible. (Recently, Bayer has come up with a sort of pill containing Imidacloprid, which can be tucked among the roots of a hemlock. If it's effective, a crew might be able to treat thousands of trees a day.)

In no other park were officials making this kind of effort. "Many other parks are 'monitoring the decline,' as I would put it, while they're implementing control in high-public-use areas," Johnson said. "I could put a hundred people to work treating hemlocks." The woolly adelgid has not yet arrived in Cook Forest State Park, in northwestern Pennsylvania, which contains some of the richest old-growth eastern-hemlock forest. "These parks should have a plan ready, and at the first sign of adelgids they should execute their plan," James Åkerson, the Shenandoah ecologist, said. A few million dollars could probably save the remaining fragments of old-growth hemlock forests.

While the parks were waiting for Washington, Appalachian Arborists was hired to treat hemlocks on private property using the soil-injection method. The Reverend Billy Graham had thousands of sick hemlocks at his religious training center near Black Mountain, North Carolina; Blozan saved them. ("If you don't treat the tree, it will die, and then you'll have to spend two or three thousand dollars having it removed," he said.) He has also begun treating another species, the Carolina hemlock. It is a rare tree, occupying a narrow range, primarily in North and South Carolina, where it grows on dry, rocky outcrops. The Carolina hemlock looks like something out of a Chinese painting; it's a wind-blasted thing, with a mushroom-shaped top and limbs flowing into space. The State of South Carolina hired Blozan and his partners, and the men treated nearly every specimen in the state, five hundred and twenty in all, often while rappelling down a cliff. Most of the Carolina hemlocks across the border in North Carolina are on national-forest land, however, and haven't been treated.



One day this past August, I drove into the Cataloochee Valley with Will Blozan, in his Jeep, to see what had happened. We followed a dirt road that switchbacked down into the valley. It was a lush place, lined with meadows at the bottom, rising into ridges and coves blanketed with forest. The forest was streaked with gray areas, as if smoke filled it. We parked in a meadow and hiked into the woods along a creek called Rough Fork, crossing bridges made of single logs.

Big hemlocks, hundreds of years old, appeared. Sunlight seemed to blister its way through them. They were between fifty and eighty per cent defoliated, but the national-park crews had treated them, and many seemed to be alive, for now. "That one's looking better," Blozan said, squinting at a hemlock that looked half dead to me. He had a map of the forest in his mind, with individual trees in it. Around and above us extended ghosts, hemlocks that had been treated too late, and were dead or beyond saving. I couldn't see any adelgids; the parasites had died with their hosts. The air was filled with clouds of gray branches, like giant floating dust bunnies.

We stopped under a tall hemlock that glowed with green, a survivor in the cove. "This may be the healthiest hemlock in the park," Blozan said. It was known as Jim Branch No. 10, and it was a hundred and fifty feet tall. It was one of the ten experimental trees that the park had treated in 2003, and it had been treated again in 2005.

Blozan pulled the end of a climbing rope out of his pack and tied it to a cord he'd left strung in the tree. He put on a helmet and a tree-climbing harness, and began ascending along the rope, using rope ascenders. I followed him up. As you climb, you hang from branches with a system of ropes known as a motion lanyard, placing your feet lightly on the trunk and the stronger branches.

The tree was filled with a spicy tang,

the scent of green hemlock, and it was covered with living things. There were rare dark-brown lichens called cyanolichens, which fix nitrogen straight from the air. They fertilize the canopy of old forests. There were small hummocks of aerial moss, spiderwebs, insects associated with hemlock habitat. There were mites living in patches of moss and soil on the tree, many of which probably had never been classified by biologists. The hemlock forest consists in large part of an aerial region that remains a mystery, even as it is being swept into oblivion.

We stopped and rested at a hundred and thirty feet. Blozan was standing on a small limb. "When these trees die, the nearby streams turn brown," he said. "The water gets full of tannic acid. As long as I've been coming here, these streams were crystal clear. Now they look like they're coming out of a bog." Many insects and fish that live in hemlock streams, such as the stonefly and the brook trout, are threatened by sunlight and heat pouring into stream environments that were once shady and cool.

From the top of Jim Branch No. 10, we could see that the forest canopy was a ruin. The crowns of the dead trees were still encrusted with living material—a hemlock rain-forest canopy without the hemlock. It was a scaffold of lichens and other organisms. The trees that harbored them had died so recently and so suddenly that they were all carrying on, for the moment, as if nothing had happened.

When it became apparent that the eastern hemlock might nearly cease to exist, Blozan and his partners founded the Tsuga Search Project, an effort to identify and measure the world's tallest and largest eastern hemlocks before they were gone. To date, the partners have spent a hundred thousand dollars of their own money on it. Brian Hinshaw, one of the partners, told me, "We just want to try to understand what we once had in these hemlocks." In the Cataloochee Valley, Blozan walked into groves where he found what had been the world's tallest hemlocks. They were already dead, but he climbed the skeletons and measured them anyway. "The data are for someone someday," he said.

Three flagship species of migrating birds make their nests in hemlocks: the Blackburnian warbler, the black-throated green warbler, and the solitary vireo. In spring, they arrive in the Cataloochee before leaves come out on hardwoods; the evergreen hemlocks offer them cover, food, and a place to nest. No one knows what will happen to them next spring. Many other birds feed in hemlocks or nest in them, including the Acadian flycatcher, the Louisiana waterthrush, the winter wren, and the red-breasted nuthatch. The flying squirrel lives in hemlocks, and it feeds on fungi around their roots; recently, the flying squirrel seems to have gone into a decline. When an old hemlock falls, a world passes away. As for the Cataloochee Valley, most of the eastern hemlocks there are dead. ♦