

SCIENCE • TECHNOLOGY • MEDICINE

Just recently scientists have begun to recognize that Washington and Oregon are wrestling with the fate of a unique ecosystem: the ancient



old-growth forests. Modern tree farms are far different from nature's original design; whether this matters is a divisive issue.

## OLD-GROWTH MOSAIC

by Bill Dietrich  
Times staff reporter

**I**t has been suggested that familiarity breeds contempt. So perhaps it was the once-endless, dark blanket of Northwest old-growth forest that led some residents to take such trees for granted and some foresters to disparage the dank, choked stands as "decadent."

Certainly the old-growth timber issue can baffle the public. Woods are woods, aren't they? Clear-cuts are regrown. What's so special about "ancient forests?"

Only recently have scientists begun to recognize that Washington and Oregon are now wrestling with the future of a unique ecosystem.

"This is the richest coniferous forest in the world," said Chris Maser, an Oregon forestry consultant and outspoken critic of present-day forestry practices. "The trees live longer here and grow larger than in anyplace else on the planet."

In his new book, "Fragile Majesty," author Keith Ervin estimates that the biomass of Northwest old-growth forests — the total volume of standing and downed wood — is greater than any other place on Earth, triple that of tropical rain forests.

Elliott Norse of the Wilderness Society has called such conifers "the whales of the forests."

A single Douglas fir, for example, can grow as high as a 30-story building, fatten to 10 feet in

diameter, and bear so many needles that their surface area equals an acre. The tree can stand 750 years — some in Mount Rainier National Park are more than 1,000 years old — and even after falling persist as a decaying log for 300 years more, serving as a home to different species

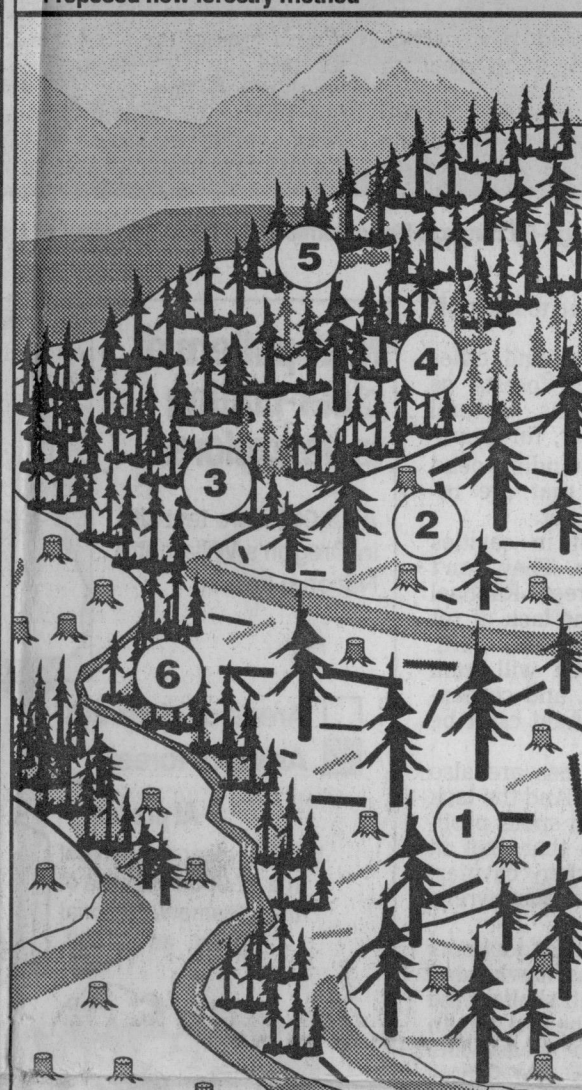
**...The biomass of Northwest old-growth forests ... is greater than any other place**

### The logging controversy on National Forest lands

#### Present logging practices



#### Proposed new forestry method



## Musical works are challenge to the ears

■ Works by Bolcom, Bernstein, Chihara and Copland in the American Music Series, the Seattle Symphony conducted by Gerard Schwarz, Saturday night at the Moore Theater.

by Karen Mathieson  
Special to The Times

**T**he term "theatrical" covers many stages in the expression of human self-awareness — from the ancient forms of dance and acting before a live audience to our century's fascination with flickering shadows on a screen.

Just about every context of the theatrical could apply to the music Gerard Schwarz programmed on the Seattle Symphony's first American Music concert of the season. Yet, despite the trappings of such titles as "Commedia for (almost) 18th-Century Orchestra" and "Music for the Theatre," the composers had planned the action entirely for the ears.

**The program began** with a concert overture revealing the sly wit of William Bolcom, a Seattle native long resident in Michigan. Antiphonally placed horns were a clue to the music's nature even before Schwarz gave the downbeat: Bolcom's "Commedia" is a study in contrasts.

Offstage strings interject a soothing melody into a scurry of motifs among the body of the small orchestra. Waits from an oboe reed and short upward runs reminiscent of Papageno's flute take turns with the slow alternating appearance of the widely separated horns. The orchestra handled these and other juxtapositions with the aplomb of quick-change artists.

**The mood was more sustained**, and full of expressiveness, in the "Serenade" (after Plato's "Symposium") by Leonard Bernstein. The five-movement work features a solo violin throughout, a part taken on Saturday night by Jun Liang Du, who is among the youngest of the symphony's players.

Following the discourses of Phaedrus, Aristophanes and others, the "Serenade" explores aspects of love from the purely physical to the spiritual. Du provided a sensitive narrative voice from the beginning, and picked up strength in his delivery as the piece expanded. A duet passage with cellist Susan Williams in the fourth movement, an Adagio, had depth and warmth.

Bernstein's 1954 score for strings with percussion — everything from glockenspiel to



## any other place on Earth, triple that of tropical rain forests.

years more, serving as a home to different species in all phases of its existence.

The timber industry has cut this millennial life span to a rotation of 50 years. Trees are clear-cut, then cut, burned, replant-

ed with seedlings of the same age, sprayed, fertilized, thinned, pruned and harvested.

The result is an efficient producer of wood, but a forest far different biologically than the original ecosystem.

Whether this matters is an issue splitting younger foresters from older traditionalists, and public-lands foresters from their private-industry counterparts.

At a recent scientific conference in Newport, Ore., there seemed almost to be a generational divide. Baby-boomers with wildlife degrees, many of them women, have flooded a profession once dominated by male engineers and logging specialists.

When Jerry Franklin of the University of Washington told the crowd, "Thank God we haven't been able to do all that we thought we wanted to do with managed forests" by wiping out more species with the creation of tree farms, a majority applauded.

But others defiantly clapped when Keith Munson of International Paper Co. derided the new research. He called it "popular science, a lot of speculation based on very little fact."

1. Clear-cuts tend to be small, 60-80 acres, but frequent.
2. Wood waste is burned, either by yarding logs and branches into piles or burning entire clear-cut.
3. Roads extend through most of the forest to allow clear-cuts to be spaced out
4. With new trees planted at the same time, each stand is a single species of the same age.
5. The remaining forest is divided into small clumps, fragmenting the ecosystem.
6. Industrial forestry uses air-sprayed herbicides and fertilizers to encourage growth.

Timber traditionalists with the Bureau of Land Management referred to the spotted owl threatened by logging as "the S-word."

And Jim Rochelle, wildlife manager for the Weyerhaeuser Co., argued that it is too early in the research to embrace Franklin's call for a new forestry that preserves old-growth characteristics to save plants and wildlife. "Let's make sure we have conclusive information," he argued.

To many professional foresters, old-growth trees are decadent. Their growth rate falls off sharply after the first two or three centuries, and

1. Clear-cuts are clustered, some trees are left at the rate of 6-12 to the acre, and dead snags remain as habitat.
2. Woody debris is left to rot into the ground and serve as habitat.
3. With logging concentrated in certain drainages, other valleys remain roadless.
4. As the forest regrows, it is a mix of different age trees and includes hardwoods.
5. Large blocks of uncut forest remain, providing habitat for species needing a lot of room.
6. Some hardwoods remain to naturally add nitrogen fertilizer to the ground.

Ed Walker / Seattle Times

eventually they rot from within faster than they grow without.

For decades now, these foresters have believed we can improve on nature with younger, more vigorous trees.

"I regard the Northwest forest as one that can produce all objectives and still be harvested," said

Please see **FOREST** on C 2  
■ Discovery Digest, C 3

Please see **MUSIC** on C 5

## PNB 'Firebird' is beautiful but empty in choreography

by Alexandra Tomalonis  
The Washington Post

**W**ASHINGTON — Once upon a time there was a wonderful ballet called "The Firebird." It was choreographed by Michel Fokine and was one of the hits of the Diaghilev Ballets Russes' second Paris season in 1910. Its story is an ersatz Russian fairy tale — a blend of the highlights, as it were, of real Russian fairy tales — and it exemplified the color and exoticism that were a revelation to audiences of the day. It was also a near-perfect example of how to tell a story in ballet.

Fokine's version to the beautiful Stravinsky score was very, very popular and still exists but, for reasons best understood by contemporary choreographers, is hardly ever staged. Instead, the great, near-great and not-so-great have had a go at the "Firebird," with very small success. Even Balanchine's three attempts have been stored away. But every ballet company seems to need a "Firebird," and Kent Stowell, co-artistic director of the Pacific Northwest Ballet, has choreographed a version, which received its world premiere last night at the Kennedy Center Opera House.

It's a very pretty "Firebird." Ming Cho Lee's delicate, pastel sets, with a spare, silver tree and a tiny white castle with blue onion domes, have a picture-book quality, as do the pretty pastel costumes of Theoni Aldredge. The stage is always aswirl with pink and baby blue and white, even when the monsters dance, and the wedding clothes in the finale are gloriously rich — white upon white, layers of dresses and petticoats and embroidered detail. It's a safe storybook, the kind that wouldn't scare the youngest child for a minute.

But even the prettiest sets and costumes, and the best efforts of a splendid cast, can't deflect attention from the fact that there's nothing much going on choreographically. More importantly, the sets and costumes remain illustrations for a story that never unfolds. It's not clear that Prince Ivan has captured the Firebird (he keeps jumping over her leg during their duet). The Firebird's feather is stolen, snatched from her turban by Ivan, not given by her in exchange for her freedom. Instead of the Firebird's lulling the monsters to sleep, she wakes up the dreaming

Please see **PNB** on C 5

### INSIDE

Auctions turn to river cruising and Poncho kicks off its season with a glitzy party, in Seattle Scene.

C 3



## Scientists find old Denny Hill — at bottom of Puget Sound

by Hill Williams  
Times science reporter

**D**ISCOVERY Denny Hill, one of Seattle's original seven hills, has been gone for more than half a century, leveled to make way for expansion of the downtown business district.

But the old hill, a part of Seattle's history, apparently lives on. Geologists studying the bottom of Puget Sound have found a massive shoal off the central waterfront that they believe is what's left of Denny Hill.

Discovery of the shoal was an offshoot of a U.S. Geological Survey study of the possibility of underwater slides that could endanger structures along the shoreline.

Denny Hill, which once loomed north of Pine Street, was sluiced and dug away in a series of projects ending in 1931, leaving the area known as the Denny Regrade, which includes today's Seattle Center.

Much of the material was loaded on barges, dumped in Elliott Bay and forgotten. But Mark Holmes, a member of the Geological Survey stationed at the University of Washington, is convinced the survey has turned up the final resting place of the legendary Denny Hill.

Holmes said the underwater ridge lies about 500 feet off Piers 65 through 69, is about 4,000 feet long and 1,500 feet wide and rises 120 feet from the bottom to



Seattle Times file

In 1931, dirt sluiced off Denny Hill to form the Regrade is loaded onto barges for dumping into Puget Sound.

Please see **DENNY** on C 2



# OLD-GROWTH MOSAIC

## Current forestry methods under review

### FOREST

continued from C 1

Mike Newton, a forestry professor at Oregon State. "Almost any habitat can be improved."

Besides, "We can't afford to grow 450-year-old trees," pointed out Tom Terry, manager of Western forestry research for Weyerhaeuser. "We can't make a return on our investment."

Franklin agrees more research needs to be done, but says if there is to be a delay to complete it, it should be a delay in cutting down the centuries-old trees, not a delay in modifying logging. "Public forests are becoming the court of last resort to solve all the (log supply) problems caused by private lands being overcut," he complained.

Maser, the consultant, charges that current forestry is gambling with the Northwest's future ecological health, running the risk of soil exhaustion and genetic vulnerability.

"Forests run on rotting wood," said Maser. Tree farms, he argued, don't leave much. "If we're going to reinvest, we have to leave some of the dead wood out there."

Experience in Europe and China, he contended, shows that intensive forestry can't be sustained.

"The magic number of repeated rotations around the world for some reason seems to be three. You won't see the result of a forest that has deteriorated for a century, and then when it collapses it will be too late to do anything about it."

Other old-growth champions, such as Franklin, don't believe Northwest forest soil will be exhausted after just three crops, but they do agree the potential of soil depletion deserves more study than it has gotten.

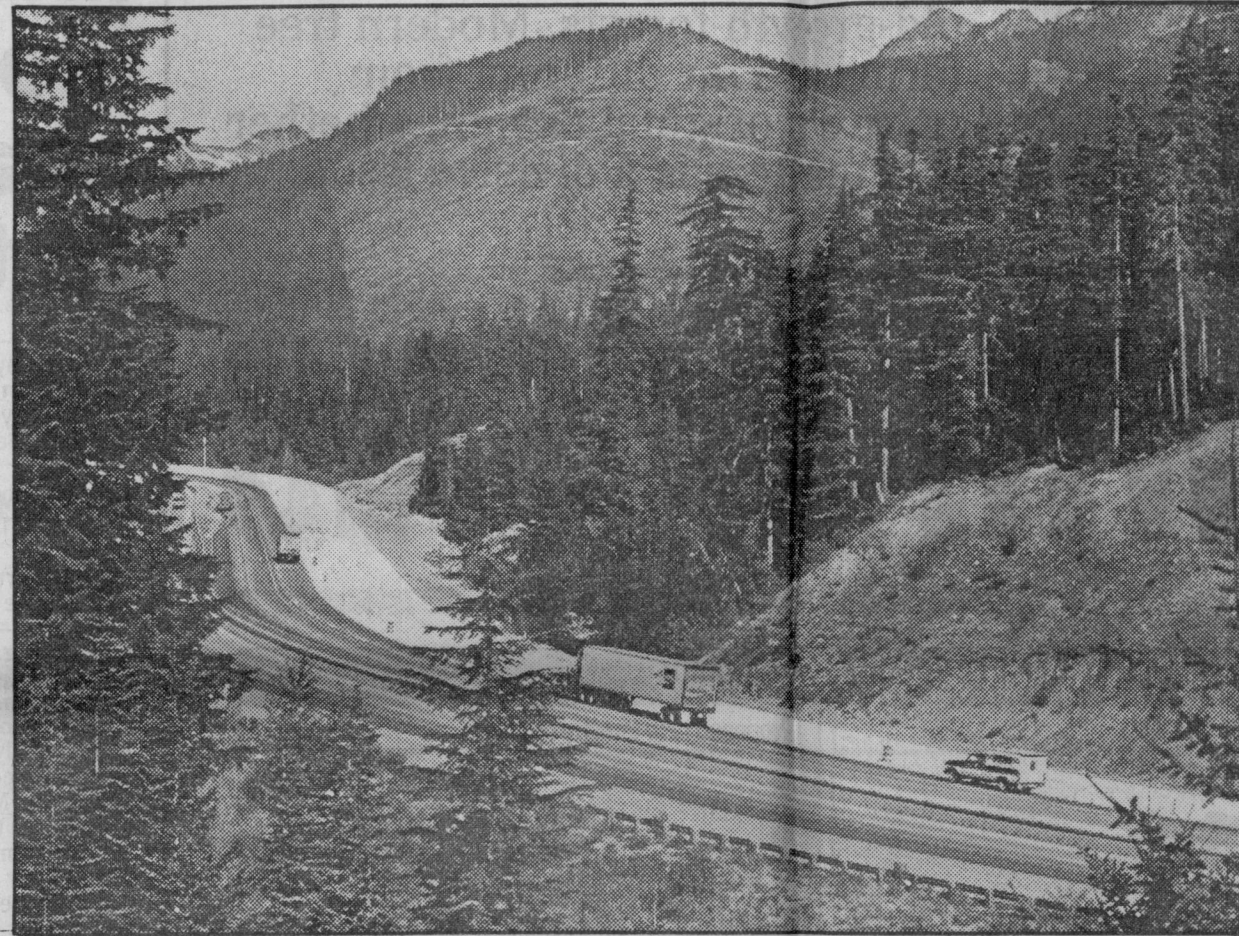
And they take issue with the assumption that all Northwest forests should be converted to managed stands to maximize timber production.

"There's no question the amount of old growth is getting to a critical minimum," said Marty Raphael, director of the Forest Service research lab near Tumwater.

"As a biologist, I have a sense of crisis," said Franklin.

### ONLY A REMNANT

Old growth on private and state



Motorists traveling along I-90 through Snoqualmie Pass have this view of a squared-off clear-cut.

Greg Gilbert / Seattle Times

makes us think we have to back off our philosophy."

Researchers have found other values in old-growth forests as opposed to tree farms. Several species of woodpecker, for example, depend on the standing dead trees, called snags, that are removed during a clear-cut.

Woodpeckers nest in cavities they peck into trees. They can't use young healthy trees, Raphael explained, because the lack of rot makes the excavation too hard. Sap on a young tree will gum woodpecker feathers, and carpenter ants and similar food can't be found in them.

Most plantation trees are also too small in diameter. And the lack of woodpecker habitat spells problems for other birds that nest in abandoned woodpecker cavities, species ranging from house wrens to bluebirds.

Snags provide hunting lookouts for predators such as hawks and owls. The canopy itself shelters the squirrels, which are the owl's main food. Similarly, two weasel-like predators — martens and fishers

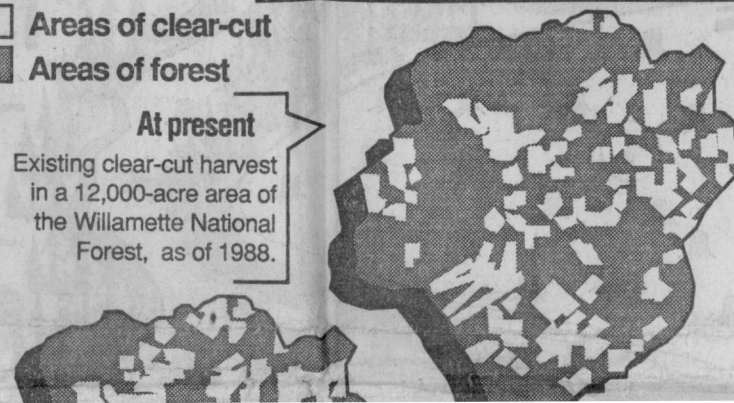
### New pattern of clear-cutting to be explored

A 12,000-acre test site in Oregon's Willamette National Forest

Areas of clear-cut  
Areas of forest

#### At present

Existing clear-cut harvest in a 12,000-acre area of the Willamette National Forest, as of 1988.



just a choice between logs and trees. He believes existing logging patterns can be modified to satisfy both concerns.

Simply setting aside more old growth as a de facto wilderness area is not enough, Franklin argued. "It's not something we can do simply by drawing lines on a map and leaving areas alone," he said. "It is a hell of a lot more complicated."

### CHANGING THE PATTERN

Proposed at the Newport conference was preservation of some old growth. But with it came proposals to change the pattern of clear-cuts in the rest to reduce fragmenting, and modifying Northwest logging methods to give second-growth forests old-growth characteristics.

This "new forestry" would change the look of the national forests. At present, clear-cuts are scattered like a shotgun blast through a wide swath of forest, supposedly to lessen their cumulative impact by separating them with standing blocks of trees. The result is the patchwork pattern so visible from an airplane.

Now the Forest Service is considering clustering clear-cuts in one drainage and leaving an adjacent drainage alone. The agency would connect larger blocks of surviving old growth with corridors of uncut trees, like hallways between rooms. This would enable animals to move and give them enough contiguous acreage to thrive.

Other advantages, scientists theorize, is that there would be more usable forest available for recreation. And concentrating clear-cuts in one part of the forest would reduce the need for logging roads, saving money. The mileage of logging roads in the national forests of Washington and Oregon alone, scientists were told in Newport, is double that of the interstate highway system.

The new forestry would also reduce the amount of old growth exposed on its edges to wind, drought, heat and cold. In one experimental 12,000-acre block in Oregon, estimated Miles Hemstrom of Willamette National Forest, simply clustering clear-cuts could reduce the amount of edge from 135 miles to 95 miles.

Clear-cuts themselves would change under the new forestry. Douglas fir, the preferred timber species, grows best in full sunlight and, accordingly, the forest is

## Scientists uncover old Denny Hill in sound

### DENNY

continued from C 1

within 50 feet of the water's surface.

In the last phase of the regrading, conveyor belts took material along Battery Street to the waterfront, where it was loaded onto barges. But records are unclear as to where in the bay the material was dumped.

"The material was piled so high that ships started running aground in 1931 and they had to dredge the top off the ridge," Holmes reported at the recent Oceans '89 conference here.

Bottom profiles show the summit of the ridge is flat, indicating where the dredging scooped off the top, he said.

Holmes and other investigators calculated the ridge contains about 6 million cubic yards of material, only about two-thirds of the total removed in the Denny regrading. They speculated that some of the missing material may have slid into deeper water.

"The slopes of the ridge are so steep they verge on instability," Holmes said. "They apparently are the scene of earthquake-triggered slumps" into deeper water.

In fact, the researchers found places where mud flows from the shoal had eroded canyons 20 to 40 feet deep in the bottom of Elliott Bay.

The discovery of Denny Hill's

**'That's an incredible ditch out there.'**

Mark Holmes

final resting place was part of a Geological Survey study of the sediment accumulations in Puget Sound since the last ice age. The study is showing that nature's work can make the earth-moving efforts of humans seem puny.

"People think of Puget Sound (a little deeper than 600 feet off Seattle) as a glacial scour feature," Holmes said. "But the actual scour contours (of the most recent ice advance) are as much as 1,700 feet below the bottom of the sound



Old growth on private and state land is for all practical purposes gone, except for a remnant of 50,000 acres of state land on the Olympic Peninsula.

Weyerhaeuser, for example, has cut at least 95 percent of the old-growth timber on its lands. Two-thirds of its tree harvest last year were trees less than 60 years old. Plum Creek Timber, a late starter that is harvesting former Burlington Northern railroad lands, has cut more than half its old growth since the early 1980s and hopes to remove the rest within a decade.

Of the six big national forests in western Washington and western Oregon, the Forest Service initially estimated there were 2.5 million acres of old growth left. But a more detailed analysis by the Wilderness Society, an environmental group, showed only 1.1 million acres.

Worse, the organization's study showed the forest has been so fragmented by existing clear-cuts that 439,000 acres of that were in patches fewer than 80 acres or near roads. And even that overstates the survival of the "green cathedrals." The Wilderness Society found only 340,000 acres in Washington and Oregon that had the classic big trees more than 300 years old.

Forest Service biologists now believe the Wilderness Society figures are the most reliable available, but the agency has launched a crash satellite-mapping program of its own to try to get even better numbers by next spring.

## THE ROLE OF VOLES

**S**o? What good is old growth? Consider mouse droppings. Research into old-growth forests has turned up a never suspected plant-animal cycle in which tree voles — mice that spend most of their lives in the tree canopy — play a key part.

It seems that tree roots here rely on a fungus called mycorrhizae, which live on the root hairs, to help extract nutrients from the soil. Mycorrhizal fungus colonies eventually form truffles. The voles descend to dig and eat the truffles. As the mice scurry on they excrete, and their scattering of deposits contain undigested mycorrhizal spores.

Thus the mice distribute a fungus essential to conifer growth.

Now the kicker: Many of the voles, scientists have learned, seem to thrive only in old-growth forests. "It may be the elimination of old growth and the removal of small animals will affect the dispersal of mycorrhizal fungi," said the Forest Service's Raphael, "and if you don't have fungi, the trees won't grow."

Nonsense, said Weyerhaeuser's Terry. Tree nurseries using fumigated, sterilized soil are swiftly recolonized with mycorrhizae with no help from endangered mice, he said. "Most spores are spread by the wind. Nothing we've seen

predators — martens and fishers — bound from tree to tree in

In fact, much of the life of an old-growth forest plays out far over the heads of human hikers, little seen or suspected.

search of prey in an old-growth area equal to or greater than that required by owls.

In fact, much of the life of an old-growth forest plays out far over the heads of human hikers, little seen or suspected.

The very rot that drives industrial foresters crazy is heaven not only to cavity-nesting birds and bats, but to dozens of other species. Insects thrive in the decay, and the wet downed logs are home to secretive salamanders. The lizard-shaped amphibians are far less famous than spotted owls, but some people get quite excited about them: Amherst, Mass., has constructed salamander tunnels under a road to help them migrate from hibernation burrows to ponds.

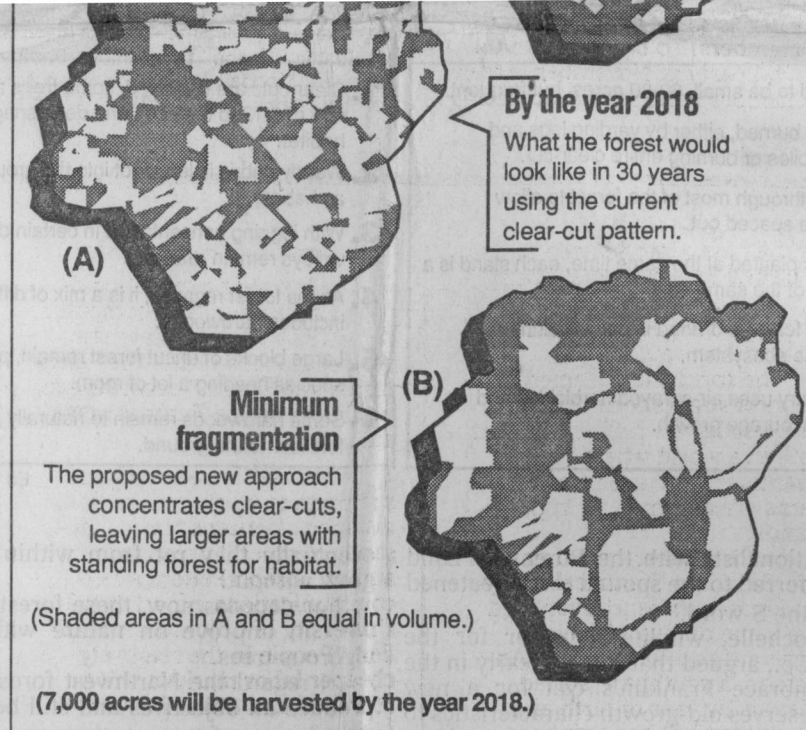
Jeff Peterson, a forester at Oregon State, has concluded that leaving snags in a tree stand will increase bird numbers by 30 percent. He said 70 percent of Northwest amphibians and 85 percent of Northwest reptiles need downed logs — largely absent from tree farms — to survive.

## A COMPLEX SYSTEM

**A** lot of what drives old-growth ecosystems is only dimly understood. "The NASA space program is simpler than a single acre of old-growth forest," asserted Maser. "We've got to maintain enough of its blueprint to learn. If we don't have a few healthy patients (groves of natural trees) how can we diagnose diseased ones?" such as tree plantations.

Nalini Nadkarni, a UW graduate student, used mountain-climbing gear to get up into the canopy of the Olympic rain forest. What she found was a unique you-scratch-my-back ecological system: Deciduous trees in old-growth forests support huge mats of mosses far off the forest floor that have the ability to take nitrogen from the atmosphere and store it. The maples, in turn, sink roots into the moss for this natural fertilizer.

Franklin has found that old growth creates a beneficial microclimate important to scores of species that tree plantations can't match. The dense forest cover tends to be cooler in summer and warmer in winter. Critters ranging from elk to insects take advantage of the differential.



Ed Walker / Seattle Times

## VALUABLE GENE POOL

**W**ith deforestation in the tropics wiping out an estimated 100 species per day, scientists are concerned about similar possibilities here.

"It is now becoming increasingly clear that loss of biological diversity will undermine society's ability to achieve full technological ability," argued Larry Irwin, a member of the pulp and paper industry's National Council for Air and Stream Improvements.

As examples of the benefits of species preservation, Irwin cited a Central American corn strain that saved U.S. agriculture \$1 billion by proving effective against a corn disease. And the trailing feathers of owl wings have been studied by engineers for tips on how to abate aircraft noise.

A classic case cited by environmentalists is that of Jay Hair, director of the National Wildlife Federation. Hair said that in the fall of 1984 his 5-year-old daughter, Whitney, was diagnosed with having a rare and fatal case of cancer called T-cell lymphoma. She was treated with an experimental drug taken from the rosy periwinkle, a flower in Madagascar. Today, Whitney is cured. And the plant that led to the drug is now extinct, lost in logging that has consumed 80 percent of Madagascar's tropical forests.

Closer to home, the bark of the Northwest's Pacific yew tree, which thrives in the shade of old-growth forests, is being studied by the National Institutes of Health as a treatment for slow-growing cancerous tumors.

Hair said 40 percent of the drugs we use originally came from native plants. "Just at the time we are learning so much about genetic diversity," he said, "we are destroying entire gene pools."

Franklin adds that the old

growth preserved in high-elevation parks and wilderness areas is an insufficient substitute for the lower-elevation, more species-productive forests being cut. "Our wilderness system has done an abominable job of protecting old-growth forests," he said.

Industry remains skeptical of scientists' tentative conclusions. Weyerhaeuser's Terry cites the case of logs in streams. Initially, timber companies were told to clear debris out of streams because biologists feared that fish passages would be blocked. Now they are told to leave organic debris, because it creates pools, shade, and breaks up the current and erosive power of steep creeks.

He also disagrees with the need to leave a lot of rotting wood. "Look at a clear-cut," he said. "There's a tremendous amount of debris out there, tons and tons. Pre-commercial thinning (in which some trees in a stand are felled to give their companions more room to grow) leaves even more. It's an argument used by people who want to protect old growth and aren't looking at managed stands."

Research into all these questions is still underfunded, said George Brown, associate dean for forestry research at Oregon State. "There are lots of interesting bits and pieces of information about how systems perform," he said, "but we haven't been able to put them together. We're under-invested in the research we're called on to do, far, far less well funded than, for example, the agriculture industry."

One 1985 study by the National Science Foundation showed that while American industry as a whole invested 3.8 percent of its net sales in research, forestry devoted only 0.7 percent.

Franklin said the political split between the timber industry and environmentalists is unfortunate because the old-growth issue is not

species, grows best in full sunlight and, accordingly, the forest is typically cut bare. Clear-cuts are often subsequently burned to reduce litter and make it easier to plant new trees. Herbicides are used to keep weedy species down until the young Douglas firs gain the necessary height to compete, and fertilizers speed growth.

The reformers would change that. Instead of cutting every tree, they would leave six to a dozen live trees per acre to give wildlife different-aged trees to choose among as the forest regrows. They would leave some standing dead trees to provide homes for insects and birds. They might leave some deciduous trees to help infuse the soil with nitrogen. They would leave all the woody debris, burning none of it. They would reduce or eliminate the use of herbicides and fertilizers.

There are doubts. Can Douglas fir be regrown successfully on such a half-shaded cut? Won't the uncut trees, left unprotected, be blown down anyway? And are such drastic steps needed to ensure forest diversity? So many competing species invade tree plantations anyway, contended Terry, that, "We (Weyerhaeuser) couldn't get a pure Douglas fir stand if we tried."

Leaving snags is another dumb idea, he said. "People get killed that way. The classic way to get killed in the woods is by a falling snag."

Other ideas have surfaced. One is to devote part of the national forests to high-yield, intensive forestry such as practiced on industrial tree farms in order to leave other parts alone. Another is to add to the national forests private lands, now poorly managed, which could be devoted to wood production. Still another is to seed and close some logging roads.

## PUSHING THE DEBATE

**S**ome change is already under way. A Timber, Fish, Wildlife agreement between environmentalists and timber companies is encouraging the leaving of strips of trees along streams or patches on the crowns of hills around tree farms. Under way are a series of studies to see if these methods are working.

But scientists are pushing the debate beyond that, to the value of an ecosystem with global political significance.

William Reilly, the administrator of the Environmental Protection Agency, remarked recently that a Brazilian foreign minister said Americans had no right to criticize Brazil's deforestation of the Amazon given the old-growth logging they were allowing in the Pacific Northwest.

"It is a magnificent ecosystem," said Dr. Charles Meslow of Oregon State University. "It is somewhat presumptuous of us as humans to lay waste to something that was here 200 years before we were a nation."

"We are practicing the politics of extinction," said Maser.

advance) are as much as 1,700 feet below the bottom of the sound.

"That's an incredible ditch out there."

The researchers used low-frequency sound signals to probe beneath the sound's bottom to reconstruct events since the retreat about 13,000 years ago of the lobe of ice that scooped out Puget Sound.

The bottom layer, about 450 feet thick, is composed of boulder-studded debris that accumulated at the foot of the ice sheet. On top of that is a 600-foot-thick layer of fine sediment, deposited by a huge lake that formed in front of the retreating glacier.

The upper deposit, a 600-foot-thick layer that forms today's floor of the sound, represents sediment that has been dropped since the ice retreated far enough to the north to permit ocean water to reoccupy Puget Sound after an absence of many thousands of years.

**And that's not** the whole Puget Sound story. Beneath the ditch scooped out by the last ice lobe lies another 1,350 feet of sediment left by a previous glacial advance.

That means Puget Sound, the "incredible ditch," measures more than 3,600 feet from water surface to bedrock.

The last glacial advance left steep slopes beneath Puget Sound, just as it did on some of Seattle's hills. The possible hazard posed by huge slides down those underwater slopes, perhaps triggered by earthquakes, is one focus of the Geological Survey study.

"One of the mechanisms we've discovered for transporting large volumes of material from shallow to deeper water are these large slumps which have occurred frequently in the past and apparently can still occur today," Holmes said.

A big one could cause damaging waves or, if it began near shore, undercut structures along the shoreline.

Working with Holmes on the study of the Denny Regrade material were Richard Sylwester, a Seattle engineer, and Robert Loeffler of Santa Ana, Calif.

## Denny Regrade revisited

