Written in the Rings

Tree rings reveal the climate of the past — and help foretell the future. Their message? Get ready for hot, dry times.

Feature story - From the January 24, 2005 issue of High Country News by Michelle Nijhuis

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The very distant past has an address, and it is Gate 16 of the University of Arizona football stadium in Tucson. Climb two short flights of stairs, travel a dim, echoing hallway, and pass a couple of shuttered snack bars advertising popcorn and Polish sausages. Unlock a heavy, windowless door, step over the threshold, and you're inside the archive of the Laboratory of Tree-Ring Research, surrounded by thousands of years of natural history.

"We have a long-standing relationship with university athletics," jokes Rex Adams, a senior research specialist at the lab, as he weaves through the two main archive rooms. "The first lab was in the old baseball stadium. Then it was in the basketball arena. Then it moved here — to what was supposed to be temporary quarters. That was in 1937."

The archive gives off a whiff of dust and old furniture. Metal and plywood shelving squeezes beneath the sloping underside of the stadium bleachers, each shelf stuffed with rows of cardboard boxes. "That's bristlecone pine," says Adams, opening one worn box and taking a quick, appreciative sniff of the contents. "It usually has a really sweet smell."

Every box is crammed with bits of wood. There are meaty slabs and soda-straw-sized cores from bristlecones, giant sequoias, ponderosa pines and other species. The wood, some of it more than 8,000 years old, comes from as far away as Tasmania and Siberia and as nearby as the Santa Catalina Mountains, the fir-studded range that borders this desert city to the north. Together, the samples represent more than seven decades of research and some three dozen careers. "Nothing is discarded," says Adams. "We've got material that no longer exists anywhere else in the world, because the forest it came from has either been cut or burned."

For anyone fluent in the arcane language of tree rings, this archive has countless stories to tell. The samples stored here yield intricate maps of ancient droughts, fires, cold snaps, and heat waves. They help show, with sobering certainty, that the earth is heating up as never before. They also reveal that the current drought in the West is part of a long and brutal tradition of dry spells, a tradition we can expect to continue — and possibly worsen — in the future.

But is anybody really listening?

Dendrochronology — the study of tree rings — is perhaps the only scientific discipline born and raised in the Interior West. Humans have long noticed that the number of rings inside a tree's trunk corresponds to its age, but ring-counting became a bona fide science thanks to Andrew Ellicott Douglass, a gifted young astronomer who ran northern Arizona's Lowell Observatory in the 1890s.

Douglass had a lonely job, and worse, a troublesome boss. Percival Lowell, the benefactor of the Flagstaff observatory, suffered from nervous exhaustion and championed the increasingly embarrassing theory that Mars was full of engineered canals.

But Lowell lived far away, in Boston, so Douglass was able to develop his own favorite theories. One of them was that the earth's weather responded to variations in sunspots, powerful magnetic fields on the surface of the sun. In the early 1900s, after a nasty and permanent break with Lowell, Douglass hit on the idea of inspecting annual growth rings in trees for evidence of solar influences. Though Douglass never cemented the connection between sunspots and weather patterns, tree rings still brought him a flash of fame.

In the forests around Flagstaff, where moisture tends to be scarce, rainfall is the most powerful environmental driver of tree growth. By inspecting ponderosa pine logs and stumps, Douglass realized that wet and dry years created distinctive patterns of wide and narrow rings. These patterns, he found, could be "crossdated," or compared among trees: Once he identified a pattern in the inner rings of living trees, he could hunt for that pattern in the outer rings of old logs. The old logs then provided links to even older ones, allowing Douglass to create a long, continuous record of precisely dated rings.

Crossdating is a painstaking process, but Douglass was nothing if not patient, as his biographer, George Ernest Webb, recounts in *Tree Rings and Telescopes.* He collected samples from sites around Flagstaff, then struck out for the sequoia forests of California. There, working in the wake of logging crews, he built a chronology stretching back more than 3,000 years.

In the 1920s, as a professor at the University of Arizona, he joined a National Geographic Society research project in northern New Mexico's Chaco Canyon. He found that the roofbeams in the ruins — even wood burned to charcoal — could be dated using his techniques. He eventually deduced the precise dates of 75 ruins at Chaco and elsewhere, remaking the fundamental assumptions of Southwestern archaeology and gaining worldwide attention. The breakthrough also established the reputation of his fledgling tree-ring lab at the university, helping it grow from a one-man operation into a substantial institutional force.

During the years that followed, researchers at the lab collected samples throughout the Western states, usually using a tool called a Swedish increment borer to extract chopstick-thin cores without harming the trees. In the 1950s, they were especially delighted to discover that some living bristlecone pines in the Great Basin were well over 4,000 years old. One area in the White Mountains of eastern California, known as the "Methuselah Walk," still supplies remarkably long ring records to tree-ring lab researchers.

"The living trees look like Martians — they're gnarled beyond belief — and there's dead wood lying around that's up to 10,000 years old," says current lab director and fire ecologist Tom Swetnam. "It's like a religious place for us."

In the 1960s, dendrochronologists again made international headlines, as Michael Cohen, visiting professor at the University of Nevada, Reno, relates in his book *A Garden of Bristlecones.* Tree-ring records showed that the popular technique of radiocarbon dating — which pinpoints the age of a piece of wood or bone by measuring the concentration of an unstable form of carbon within it — suffered from a systematic error. Some prehistoric ruins in Europe turned out to be more than a thousand years older than radiocarbon dating had suggested, a find that seriously rattled the archaeological establishment.

Tree-ring scientists, it seemed, were making a habit of springing surprises on their colleagues. And they weren't finished yet.

The next revelation sprouted from the work of Hal Fritts, a sweet-natured botanist who joined the Arizona tree-ring lab in 1960. He retired from the lab more than a decade ago, and now spends at least as much time photographing wildflowers in the Swiss Alps as he does analyzing data, but he still grins when asked about his work under Wildcat Stadium. "I guess I just have a good rapport with trees," he says.

When Fritts arrived in Tucson from the Midwest, tree-ring researchers had already "calibrated" their ring records with climate data from modern weather stations. They'd observed, as Douglass had in Flagstaff, that narrow rings in trees from arid areas usually indicated drought. Narrow rings from high elevations, meanwhile, hinted at unusually cold temperatures.

To Fritts, the first trained botanist at the lab, these theories sounded a bit simplistic. He and other botanists knew that trees were not machines, and that countless factors affected tree-ring growth. So he developed a type of dendrograph, a device that measures the daily growth of trees, to untangle the real connections between tree rings and climate. The relationships were complex, just as he'd suspected. But with the right field sites and statistical methods, he found, it was possible to draw a few distinct, reasonably accurate climate "signals" out of the chaos of influences on tree rings. Then, he says, "I became an evangelist," spreading the good word about tree rings to his fellow researchers — and almost single-handedly establishing the new subdiscipline of dendroclimatology.

Fritts and his colleagues found tree rings to be gloriously useful tools. They began to use ring chronologies to look at past droughts and temperature variations, and they reconstructed ancient streamflows by sampling trees throughout particular watersheds. Inspired by such work, scientists around the world took up the new science, and international collaborations became commonplace. But for the most part, these researchers worked in peaceful anonymity, unknown to the general public.

That soon began to change. By the late 1970s, many climate scientists had documented a rise in atmospheric temperatures, and more than a few blamed the thickening blanket of carbon dioxide and other greenhouse gases produced by human activities.But many other researchers argued that the recent warming was simply a normal variation in the climate, like countless others in the distant past. Records from weather stations were far too short to resolve the debate, so the puzzle fell to a few tree-ring scientists.

One of them was Malcolm Hughes, an English-born researcher with an interest in ancient temperatures.Trained as a general ecologist, Hughes had been inspired early in his career by the work of Hal Fritts, and he'd undertaken tree-ring research in his home country. But in the British Isles, old trees are scarce: Instead of hiking through high-elevation bristlecone forests, he says, "you have to crawl around in the roofs of pubs and churches and so on to get your material." An offer of the directorship of the tree-ring lab drew him to Tucson in 1986, and he happily embarked on research among what he calls "real trees," the giant sequoias of California.

In the 1990s, Hughes was one of many researchers who adopted the so-called multiproxy approach. (" 'Multiproxy' sounds too much like a Chicago election," he grouses, in his still-strong English accent. "I'm not too fond of that word.") The technique uses several types of climate "proxies," natural recorders of past climates such as tree rings, corals, layers in glaciers and ice sheets, and lake- and sea-bottom sediments. Since each proxy has different strengths and weaknesses — trees, for instance, are found in many more places than ice sheets, but ice cores can probe much more deeply into the past than tree rings — the theory is that multiple proxies lead to a fuller and more accurate picture of ancient climates.

The picture that emerged was more dramatic than anyone expected. In 1998, Hughes and two other researchers published a paper in the journal Nature that mapped the past 600 years of atmospheric temperatures in the Northern Hemisphere. The average of those temperatures, when plotted over time, rose and fell relatively gently until the early 1900s. Then, the average curved sharply upward toward the present day. In search of a cause for the abrupt warming, the authors inspected trends in solar radiation, volcanic activity, and carbon dioxide in the atmosphere. They concluded that the dominant culprit was most likely greenhouse gases.

The blame for a warming world, it appeared, lay largely with humanity. The next year, Hughes and his co-authors — Michael Mann, now at the University of Virginia, and Raymond Bradley of the University of

Massachusetts at Amherst — published a second paper, extending the timeline to 1,000 years. The longer view only accentuated the modern temperature spike, showing that the 1990s were the warmest decade of the past 1,000 years in the Northern Hemisphere.

The two papers were the first hemisphere-wide view of temperature changes over the past millennium, and they became the scientific equivalent of runaway bestsellers. "Mann, Bradley and Hughes just revolutionized the way paleoclimate data are used to put this century into perspective," says Jonathan Overpeck, a paleoclimatologist — a specialist in ancient climates — who published a reconstruction of Arctic temperatures shortly before the Hughes studies.

The 1,000-year-long graph was included in a summary for policy-makers of the 2001 Intergovernmental Panel on Climate Change report, an international compilation of current science on global warming. (For climate scientists, this is a little like getting chosen for Oprah's Book Club.) Dubbed the "hockey stick" for its long, more or less flat beginning and upward-shooting endpoint, it became an icon in the scientific and political debate over global warming. It flashed on screens at scientific conferences and congressional hearings, and for many it delivered a simple message: Get worried. Now.

The hockey stick gained global prominence in January 2001, just a few weeks before President George W. Bush announced his administration's opposition to the Kyoto Protocol — the international agreement limiting greenhouse gas emissions that had been signed by the Clinton administration in 1998. In criticizing the protocol, Bush stressed the scientific uncertainty about global warming, and argued that mandatory controls on greenhouse gas emissions were unnecessary.

During the popular and political debates over the protocol, Mann, Bradley and Hughes suffered personal attacks and, perhaps inevitably, saw their science distorted. The uncertainties inherent in the data were often swept aside, or used to dismiss the work altogether.

"I'm always reminded of the Gary Larson cartoon of the bird's-eye view of the world, where everyone has targets on their heads," says Hughes. "By being early in the game, we obviously became one of the targets."

Even the scientific discussion, usually polite to a fault, got so nasty that it reached the pages of *The New York Times* and *Scientific American*. In 2003, Willie Soon and Sallie Baliunas, a pair of researchers at the Harvard-Smithsonian Center for Astrophysics, published a reanalysis of paleoclimate data that showed that the so-called Medieval Warm Period from about 800 to 1300 A.D. was just as warm or warmer than the 20th century.

Soon and Baliunas' methods were roundly criticized by veteran paleoclimatologists, and the publication of one of their papers in the journal Climate Research began a controversy that led three members of the editorial board to resign in protest in the summer of 2003. Yet the study acquired political legs. According to documents obtained by the National Wildlife Federation, the Bush administration pushed to include a reference to the study in the Environmental Protection Agency's 2003 Report on the Environment. Rather than endorse the maligned study — and accept other controversial edits proposed by the administration — EPA staffers excised the section on climate change from the report.

The hockey stick also inspired a more traditional, and much more mannerly, debate in the scientific literature. Though other paleoclimatologists have arrived at somewhat different results than Mann, Bradley, and Hughes, they generally agree that the 20th century warming is unprecedented. Outside critics "were focusing their attacks on one study, or series of studies, when all these other studies were coming out using other methods, other data, and coming up with the same answer," says Overpeck, now the director of the University of Arizona's interdisciplinary Institute for the Study of Planet Earth.

"It is possible that we might find some period that's warmer than the last three decades," Hughes acknowledges now. "If it were impossible, it wouldn't be worth looking. The whole business in science is that

you've got to be ready to be wrong.

"But in the context of the last few hundred years," he adds, "it's a very, very robust result. There's even reason to believe that in the context of recent millennia. Very old ice is melting on tropical mountains at high elevations, and that points to recent decades being very unusual."

Overpeck says paleoclimatologists around the world are working to "create a new icon," one based on more tree rings and other proxies. Still, he expects the principal findings of the hockey stick to endure. "The real truth won't look exactly like the hockey stick, but the hockey stick got us so close," he says. "It brought us so much further towards reality than any other study."

Despite the international reach of tree-ring science, the Western United States remains its home territory. Dendroclimatologists have studied the West longer, and in more detail, than anywhere else in the world. So it's no surprise that some of the most sophisticated tree-ring research hits us very close to home.

Dendroclimatologists discovered decades ago that the Colorado River was at an unusually high point during the 1920s, when its waters were divvied up among the states that share its watershed. The Colorado River Compact of 1922, which divided rights to use of the river between the upper and lower basin states, optimistically assumed that about 18 million acre-feet of water flowed across the Utah-Arizona border each year. But tree-ring researchers point out that a half-dozen serious dry spells have racked the upper Colorado River Basin over the past 500 years. Drought, it seems, is a habit hard to break.

For years, many water managers and policymakers did their best to ignore this grim news. "There's been a willful neglect of tree-ring research," says Ben Harding of the Boulder, Colo., office of Hydrosphere Resource Consultants, a company that works with public agencies and private companies on water management issues. Many in the Colorado River Basin, says Harding, "have just not wanted to embrace the message" that much of the past century was not normal, but unusually wet.

Connie Woodhouse, who obtained her Ph.D. at the Arizona tree-ring lab and now works as a researcher for the National Oceanic and Atmospheric Administration Climatic Data Center in Boulder, remembers telling a group of Colorado water managers about the abundant evidence of past droughts in the tree-ring record. One official said her results were interesting, but that he already had his hands full with arguments over water rights. "I don't have time to look at the past," he said.

Tree rings recently got a publicity boost from nature, however. During the summer of 2002, the region faced the deepest and most widespread drought in at least 50 years, and outsized wildfires erupted in Montana, Arizona, and nearly everywhere in between. Crop failures bankrupted farmers throughout the region — closing some operations that dated back to the homesteading era — and more than 800 Westerners lost their homes to forest fires. The Denver water utility began a tongue-in-cheek campaign advising urbanites to shower in groups. And water managers started spending a lot more time with tree-ring scientists.

"Before 2002, people would say, 'Climate is nice, but weather is what really drives our decision-making,'" says Gregg Garfin, a climatologist who earned his Ph.D. from the tree-ring lab. Garfin manages the CLIMAS project, a federally funded University of Arizona effort to translate climate research into user-friendly doses of information. He says many of his clients are now eager to understand past climates, hoping knowledge of long-term patterns will help them make better guesses about the future. One of the most outspoken experts on past Western climates is Julio Betancourt, a U.S. Geological Survey researcher in Tucson and a longtime associate of the tree-ring lab.

Using both tree-ring data and weather station records, Betancourt and his collaborators have developed an elaborate theory about the combined influences of Atlantic and Pacific ocean temperatures on Western drought. Their work has its skeptics, but its implications are nevertheless disturbing: Tree-ring records indicate that warm and cold phases in the northern Atlantic Ocean last for an average of 23 years. If a warm

North Atlantic is in fact at work in the current dry spell, says Betancourt, that very rough measure suggests that "we're only half done with this drought."

Though wet El Niño years such as this one can temporarily reverse long droughts, the relief is all too brief. "A little rain can spoil our resolve," says Betancourt, and distract us from drought-planning efforts.

Betancourt, who moved from his native Cuba to Texas as a child, has a deep voice with the remnants of a Texas twang. He's used his pipes to present his and his colleagues' work to the public more than 30 times during the past year and a half. He's talked to small-town mayors, watershed associations, Senate staffers, state officials of various political stripes, and then-Assistant Interior Secretary for Water and Science Bennett Raley. "I could have used the time to write more papers," he says, "but those papers weren't going to have the impact I was having by giving a detailed talk that showed how all this has worked for the last 1,000 years."

His audiences, already all too familiar with the realities of drought, were hungry for the heavy-duty information Betancourt had to offer. "It was almost like a revival meeting nearly everywhere I went," he says, and he's already given a couple of encore performances.

Betancourt "raised the specter of really long-term droughts," says the director of the governor's drought task force in New Mexico, Anne Watkins, who heard the scientist speak at the 2003 New Mexico drought summit. "He increased the awareness that we need to start emphasizing preparedness."

Drought preparedness — as opposed to simple crisis management — has acquired a new cachet since the summer of 2002. "From a policy and decision-making perspective, we're at a crossroads," says Don Wilhite, director of the National Drought Mitigation Center at the University of Nebraska at Lincoln. The triple threat of ongoing drought, a regional population explosion, and the mounting evidence of global warming "has instilled a sense of urgency into a lot of people," he says, and inspired them to take drought planning seriously.

That may explain why water managers and lawmakers in Arizona, long reluctant to even utter the word "drought" for fear of scaring off Sun Belt retirees, are beginning to speak a new language. At the behest of Gov. Janet Napolitano, D, the state released a draft of its first-ever comprehensive drought plan this fall. Though the plan has been dismissed by at least one environmentalist as "gentle nudging," it does include mandatory water-conservation measures for state agencies and universities during dry times, and acknowledges the reality of recurring drought in the region.

Several other Western states have created or revised drought plans in the past five years. And in Colorado, Connie Woodhouse now routinely shares her work on past streamflows with water managers and other officials. She still encounters a few who don't want to look at the past — "It's too scary for some," she says — but many are intensely interested in tree-ring research.

The deepest lesson of tree rings, however, is one that most politicians will only acknowledge in private. When Western cities expanded during the wet decades of the last century, they gambled that the climate would continue to underwrite human development. They gambled that our reservoirs would always brim with snowmelt; that our growing cities would never go thirsty; that our population would never outstrip our natural resources. Decades of tree-ring research show we're likely to lose those bets. Dealing with the consequences will take an unusual sort of political heroism.

And greenhouse gases are likely to tip us further into unexplored territory. If, as predicted, global warming causes snow to melt earlier, reservoirs to evaporate faster, and soils to dry out more quickly, past droughts may begin to look mild in comparison. "We can learn a lot about the past" from tree rings, says Arizona lab director Swetnam, and changes in ancient ecosystems during exceptionally warm periods may provide partial lessons for the future. "But if we're in a no-analogue situation — an entirely new ballgame — because

of what humans have done, what can we learn from the past that will be instructive? I don't know."

Ironically, the droughts and fires foretold by tree rings may eventually destroy the raw data itself. Researchers at the tree-ring lab got a taste of this last summer, when a fire in the Santa Catalina Mountains destroyed study sites and several trees dating back to the 1400s and earlier. "If we get these kinds of disturbances that are subcontinental in scale," warns Betancourt, "we're going to lose a lot of information that's critical to making predictions about the future." Before long, he says, researchers may be practicing a brand of salvage science.

Until that happens, however, tree-ring researchers have a lot of work to do. There are always more trees to sample, always places on the planet where the tree-ring record could be extended further into the past, and always new problems and old questions that could be answered with more confidence. Researchers are now collecting samples in the Himalayas — where tree-ring records are sparse — and Michael Evans, an assistant professor at the tree-ring lab, is working on new methods of reading tree rings in the tropics, where relatively stable climate conditions make tree-ring research notoriously difficult.

The Arizona tree-ring lab itself, after more than seven decades in so-called temporary quarters, will soon get more gracious digs. Maybe. The lab is scheduled to move into a newly constructed nearby building in the next two to three years, but tree-ring researchers, familiar with university construction delays and unfulfilled promises, aren't holding their collective breath. "Knock on hairy wood," says senior research specialist Rex Adams, tapping his head and chuckling.

Though there's more room for faculty and students in the new building, there won't be space for the venerable archive. The tree-ring samples collected by A.E. Douglass and his intellectual descendants will, for the foreseeable future, stay where they are — piled in their cardboard boxes, wedged under the Arizona stadium bleachers, and, on fall weekends, largely ignored by as many as 58,000 football fans.

Michelle Nijhuis is contributing editor of *High Country News*.

This story is funded in part by a grant from the Engel Fund of the San Diego Foundation.

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Michael Mann and Raymond Bradley — two of the developers of the "hockey stick" — have, along with several other well-known climate scientists, established www.realclimate.org. This brand-new blog seeks "to provide a quick response to developing stories and provide the context sometimes missing in mainstream commentary."

Add Comment

Editor, High Country News:

The piece on dendrochronology is well put together and I learned all kinds of news things. The article points out nicely that dendro might have to follow in the footspteps of poor old archeology (my home boys), and realize that we are all flying by the seats of our pants. This makes it no less science, in fact probably more so. We do the best we can with the available data.

Our fair country was built by three things: land speculation, watered stock, and snake oil. All three are clearly abundant still. The common human assumption about the future is homeostasis. The planet is much more erratic. Scientists talk to other scientists and when any useful ideas propagate, they are grabbed as sound bytes to make fodder for the general press, or any politico with ambition.

Dennis DeSart, Denver

Reply