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Traditional Ecological Knowledge: A Model for Modern Fire Management?

For many thousands of years, aboriginal peoples worldwide used fire to manage landscapes. In North America, the frequency and extent of fire (both human caused and natural) were much reduced after European colonization. Fire exclusion became the policy in the United States for most of the 20th century as the country became more settled and industrialized. Past fire exclusion has helped produce landscapes that are highly susceptible to uncharacteristically severe wildfire. An urgent challenge for land managers today is to reduce fire risk through several means, including prescribed burning, without harm to culturally significant resources or human communities. The Joint Fire Science Program (JFSP) is supporting the development of methods and tools aimed at incorporating the traditional ecological knowledge of indigenous peoples into standard science-based fire management. JFSP-supported researchers are also developing tools that provide a framework for organizing and sharing tribal knowledge with nontribal scientists and managers. Because indigenous knowledge and Western science come from such different cultural traditions, blending them is not a straightforward process. Even so, current partnerships among tribal leaders, agency and tribal land managers, and other stakeholders promise to move some landscapes closer to a resilient condition.

A Survival Skill

The Karuk people have been living in the rugged hillsides and bottomlands near the Klamath and Salmon Rivers of northern California for 9,000 years. For most of that time, the forests of their home region, dominated by oak woodlands and pine and mixed-conifer forests, were sparse and relatively brush-free, with grassy avenues between widely spaced trees.

The land was not "naturally" that way. The Karuk people kept it that way by periodic, deliberate burning, conducted according to ancient protocols. Specially designated members of the tribe would set fire to certain patches of the land at particular times of the year to achieve specific objectives: renew the browse for elk and deer, clear the underbrush from groves of oak and tanoak to make it easier to collect acorns, discourage insect pests, and promote straight branches of hazel and willow for the best baskets.

"Indigenous people used fire to modify the environment for their own survival," wrote Robin Kimmerer and Frank Lake in a seminal 2001 Journal of Forestry article titled "The Role of Indigenous Burning in Land Management." Their objective was "the intentional creation of a mosaic of habitat patches that promoted food security by ensuring a diverse and productive landscape." Over the long term, these burns also kept fuels down and reduced the risk of destructive wildfires.

For the Karuk and many other indigenous peoples, knowledge of how, when, where, and why to burn their landscape was a critical survival skill, a precious oral repository of cultural knowledge that was passed down through many generations. Then, abruptly in the early 20th century, fire suppression came to dominate forest policy, and the long oral tradition was nearly silenced.

Now, a hundred years later, many land managers are reckoning with the ecological and economic consequences of trying to keep fire out of landscapes that have been shaped and pruned by human managed fire for many millennia. And the oral tradition of the Karuk and hundreds of other indigenous peoples is starting to be spoken again.

A Conversation

How to cope with increasingly large and severe wildfires—that is a question that keeps land managers awake at night. Around the world, forests and grasslands have built up dangerous quantities of dry fuel. Drought and a warming climate are triggering larger, hotter burns, putting ecosystems, homes, and lives at risk.

In North America, the fire situation has sparked a conversation among managers, researchers, and tribes about putting fire back into the landscape, Indian style. The talk is not just about reintroducing fire—that is not a new idea. Many studies in many ecosystems

Sculpting the Landscape

Indigenous peoples throughout the world sculpted their environment through distinctive burning patterns, developed in response to their material and spiritual needs and the ecosystem they lived in. Many indigenous North American peoples burned woodlands and grasslands in the spring to bring on a lush fall crop of grass that would attract deer and elk. They also used fire to herd and hunt the animals.

Burning killed tree seedlings that sprouted on the prairies, keeping them from reverting to woods and making it easier to gather acorns and hazelnuts. It promoted the growth of other food plants like huckleberries and camas root, as well as medicinal plants of all kinds. Carefully timed spring and fall burns encouraged the growth of basketry materials such as hazel, willow, beargrass, and sedge. Smoke from the fires kept weevils and moths from infesting acorns and drove away flies and mosquitos. Burning also kept travel corridors open, created firebreaks around villages, and reduced the potential damage from major wildfires.

In general, indigenous fires tended to be small, occurring sometimes yearly or twice a year. The fires complicated and enriched the landscape effects of the less frequent, more severe lightning-sparked fires. The result, in many places, was a small-scale, heterogeneous patchwork that promoted food security for the tribe by providing a variety of resources within easy walking distance.

Burning did not cease immediately after the first Europeans arrived. Early settlers quickly grasped fire's usefulness as a cheap, easy way to clear land for agriculture. But as America became more settled and urbanized, widespread burning became a threat to towns, homesteads, farm crops, and timber.

After the U.S. Forest Service adopted its zero-tolerance policy for wildfire in the early 20th century, the practice known as "light burning" quickly fell out of favor. By this time, most of the Indian people were no longer permitted to burn, and the knowledge of how to do it began to fade.

currently support some combination of thinning and prescribed fire to reduce fuels and lower the risk of damage from major wildfires. Rather, the conversation is about how these state-of-the-art management strategies might benefit from an infusion of ancient indigenous wisdom. This reveals a growing consensus that today's landscapes were shaped far more by early humans than most experts believed even a short time ago.

The trouble is that today's management paradigm hasn't caught up, says Canadian ecologist Cliff White. Fire management practice is still rooted in a "biophysical paradigm," in which managers "tend to conceptualize that lightning ignitions have long burned the majority of the area...and for various reasons do not believe that human ignitions could have substantially contributed to historic fire regimes."

In a 2011 paper titled "Burning at the Edge," White, who works for Parks Canada in Banff, Alberta, and his colleagues argue that effective management starts with an accurate understanding of how the landscape evolved to its current state—how its ecology was shaped by cultural as well as natural fire. Thus, managers should focus less on the biophysical influences of fire (lightning strike patterns, vegetation succession, recurring wet and dry spells, temperature extremes) and more on the burning practices of the earliest humans.

The northern and western regions of Australia, where aboriginal peoples still burn in the traditional ways, provide a model for integrating traditional fire knowledge into modern management, says Don Hankins, a geographer specializing in fire who teaches at California State University, Chico. Hankins, who traces his lineage from the Miwok people of the Sacramento-San Joaquin Delta, says, "There's been a tremendous amount of work done in Australia with respect to indigenous burning and how those fires can mitigate devastating wildfires." In the wake of the deadly Australian fires of recent years (which have struck mostly areas where fire has been excluded for a long time), fire managers there have reached out to traditional owners themselves, drawing on their traditional knowledge, to start creating burning prescriptions that are ecologically robust and culturally sensitive.

In the U.S., such integration is mostly still in the conversation stage. But a growing number of natural resource academics and practitioners are hopeful that the knowledge and experience of America's first people can be combined with Western scientific practice to make America's landscapes more resilient, both ecologically and socially.

"That momentum is very interesting to those of us who practice forest science," says Larry Mason, a retired University of Washington natural resources scientist and member of the third Indian Forest Management Assessment Team (IFMAT), which issued a comprehensive—and largely favorable—report on Indian forest management last year. Mason says conventional land management is not coping very well with long-term challenges like climate change, instability of carbon stores, vanishing habitat, degraded water quality, and the decline of rural ecosystems and economies. "We," he says—referring to mainstream land management professionals—"have developed very sophisticated understandings of discrete sciences such as genetics and regeneration, but we've never had an integrated approach to forestry problem solving. We do not have an institutional arrangement for long-term commitment. We're searching for direction, for stewardship, for sustainability."

These, he says, are precisely the qualities that Native Americans have developed over thousands of

Nikki Michail

Don Hankins, California State University professor, confers with a member of the Chuulangun Aboriginal Corporation in the Kaanju Ngaachi Wenlock and Pascoe Rivers Indigenous Protected Area in Queensland, Australia. Hankins has engaged in fire research involving indigenous California and Aboriginal Australian communities.

Elizabeth Hankins

Don Hankins conducting research in the Kaanju Ngaachi Wenlock and Pascoe Rivers Indigenous Protected Area in Queensland, Australia.

years of strategic land management. "Native cultures had to develop that kind of understanding of their environment, or they wouldn't have survived. Their management is underpinned with very important spiritual attributes, but the realistic fact is, these cultures existed for thousands of years before European arrival. That would seem to reflect an understanding of how to interact with environments in a successful way."

Representing the IFMAT team, Mason made this point to the House Committee on Natural Resources in April 2014. "There appears a growing acceptance of an Indian worldview that 'all things are connected,'" he told committee members, "accompanied by recognition that environmental challenges cannot be contained within political boundaries. Tribal knowledge and stewardship are now uniquely positioned to help sustain forests beyond reservation boundaries."

A Scholarly Bridge

A Joint Fire Science Program (JFSP)-supported symposium that Mason helped to convene in 2010 on the Flathead Indian Reservation brought tribal elders, Indian students, and representatives of the Intertribal Timber Council together with academics and agency researchers and managers. In a frank and freewheeling discussion, the group explored the promises and challenges of managing fire across jurisdictional boundaries and cultural divides. They published their findings in a 2012 Journal of Forestry article coauthored by all 27 participants, and titled "Listening and Learning from Traditional Knowledge and Western Science: A Dialogue on Contemporary Challenges of Forest Health and Wildfire." (Please see "For Further Learning" for information on this and other sources consulted for this digest.)

The JFSP has continued this conversation through additional sponsored workshops. In November 2012, the Northern Rockies Fire Science Network hosted a gathering called "Returning Fire to the Land" at Salish Kootenai College in Pablo, Montana. A highlight of the symposium was the joint keynote presentation by Frank Lake of the U.S. Forest Service (USFS) and Bill Tripp, ecocultural restoration specialist for the Karuk Tribe of northern California. The men, both of Karuk descent, described the burning traditions of their ancestors and explained the relevance of these traditions to the study and practice of land management in the 21st century. Their talk is recorded in a video called "The Creator's Gift of Fire: Traditional Knowledge, Responsibility, and World Renewal."

Lake, a USFS research ecologist with the Pacific Southwest Research Station, has spent his career building a scholarly bridge between traditional knowledge and Western science. He did his doctoral research on how traditional Karuk burning practices affected the growth of willow and hazel shoots used by tribal basket weavers. Lake has continued to look deeply into traditional ecological knowledge through the lens of his training as an ecologist. His research partnerships with tribal elders, community organizations, and nontribal scientists and managers are enriching both traditional indigenous knowledge and Western science and demonstrating how each can inform and cross-fertilize the other.

A key factor in successful integration, Lake told the workshop participants, is to ensure that whatever is being studied, measured, and managed has meaning in both cultures. Traditional knowledge and Western science have typically held different assumptions about what matters in ecosystem processes; they have historically differed on what is worth measuring and why.

Even so, Lake said, a fruitful blending is possible. For example, in talking extensively with Karuk tribal basket weavers for his doctoral research, he learned that long, straight, slender hazel shoots are the most desirable for the best quality baskets. Baskets are essential in the traditional Karuk way of life, for all kinds of everyday use and also for ceremonial purposes. Traditional Karuk burners developed complicated burning protocols to encourage the plants to produce the best basket weaving shoots.

Fire causes hazel to produce shoots—that much is known in both traditions. "But a standard ecological measure [of the effects of fire on sprouting shrubs] might focus on crown size or density of the hazel plant," Lake said, and not necessarily on the straightness of the shoots. So a nontribal researcher interested in the effects of fire on understory shrubs could simply go ahead and study how fire affects hazel sprouting or clumping or groundcover or whatever. Or he or she could make it a richer investigation by designing additional measures into the study that focus on cultural resources relevant to tribal people—such as which fires, at what times of the year, produce the straightest shoots?

Lake asked that question, and his doctoral work confirmed that the carefully timed fall burns of the Karuk people do indeed produce the straightest, best hazel shoots. From examining this ancient cultural

practice through the lens of modern science, he said, he appreciates his ancestors' wisdom all the more. "I now understand how that shrub, burned in October and harvested two Mays later, would yield enough of this particular size of basket stick. And I now understand how many acres have to be burned in that very specific way to produce enough shoots of the same size to serve all those cultural purposes."

A Web of Relationships

The essence of traditional ecological knowledge is the intuition that all things, living and nonliving, are connected and that humans are part of this web of relationships. This idea is rooted in the spirituality of the Karuk people, said Tripp. He told the people gathered at the "Returning Fire to the Land" symposium:

"In the beginning, it was a dark place up until the great transformation. Then spirit people transformed into all things on earth. Humans were also part of this transformation. So all things are relations. All of us are linked together. We were given hands to take care of nature, to take only what we need and leave enough for all of our relations to thrive."

This interconnectedness can also be understood in terms of secular ecology. For example, said Lake, "the elders remind us of how fire is related to water." In conversation with a traditional subsistence fisherman after the 2008 fire season, he learned that smoke from the fire somehow resulted in easier migration for the fall chinook salmon, and he looked at the science behind it.

Lake traced the cascade of effects from the smoke: it reflected more of the sun's rays back and cooled the air on hot summer afternoons; its particulate matter plugged the stomata of trees under the inversion and inhibited their photosynthesis; the trees then took up slightly less water because of reduced evapotranspiration, which resulted in slightly more water being delivered to the stream; the increased waterflow and cooling of the air combined to make the stream slightly cooler, which made it easier for the fish to move between cold-water refugia at seeps and creek mouths.

As a Western-trained ecologist, Lake said he might describe this process as the alteration of a thermal barrier to salmon migration (namely, too-warm river water) through a smoke-induced change in stream conditions. "These are concepts that were taught by my grandfather and others about linking the Creator's gift of fire to the trees to the water, the streams, and the fish," Lake says. "But it took the science for me to put that story together."

Catching Fire

The Karuk Tribe has been working with the local fire safe council to restore fire to the forests and meadows of northern California's Klamath country. The tribe, which does not have a reservation of its own, regards the whole Klamath-Salmon watershed as its ancestral homeland. And today's Karuk people have not forgotten the burning practices of their grandparents. "The importance of fire can't be overstated as a management tool," said Leaf Hillman, Karuk Tribe Department of Natural Resources Director, in a video produced by Klamath-Salmon Media called "Catching Fire: Prescribed Burning in Northern California." Hillman added, "The fires were very frequent in these forests—they came back again and again."

Along with their nontribal neighbors, the modern-day Karuk people have watched with alarm as the forests of their homeland have become more fuel choked and the fire behavior more severe. The tribe cannot legally conduct prescribed burns. But in 2000, after a landmark fire season, the National Fire Plan spelled out a policy for managing fire risk, which included programs to help communities reduce hazardous fuels.

In 2001, Karuk tribal members worked with others in the community to form the Orleans/Somes Bar Fire Safe Council. "We decided to formalize ourselves with a mission statement and strategic plan…to protect communities from the threat of wildfire," said council coordinator Will Harling. "But also wrapped up in our mission statement was the understanding that [the council's mission] is tied to restoring historic fire regimes."

The council developed a burn plan for areas of the Six Rivers and Klamath National Forests, as well as 8,000 acres of private land along the middle section of the Klamath River. The burn plan draws heavily on the ancestral knowledge of Karuk tribal members, said Harling. "Ever since our formation, we've worked closely with the tribe to identify not just the areas that needed to be treated, but what types of treatments were specific to that vegetation type, that slope, that aspect."

Prescribed burns (the first was done in 2005) have been carefully planned to promote growth of important plants like hazel and tanoak, as well as to reduce fuels. The most recent burn took place in 2012 on USFS land within the Happy Camp/Oak Knoll Ranger

District. Tribal and contractor fire crews staffed the burn around the clock to keep the fire from escaping. "We are working together at the community scale to reinitiate fire," said Tripp. "It has to be done by people who are going to be here a long time. In order to learn from what you're doing, it has to become an intergenerational process."

The council's prescribed burn program has passed the wildfire test for 2 years in a row. Last summer—a bad one for wildfire in Siskiyou County—the lightning sparked Whites Fire, part of the big July Fire Complex, threatened a historic mining site near the community of Sawyers Bar. "But (prior) fuels reduction followed by prescribed fire allowed firefighters to successfully defend Rainbow Mine near Sawyers, (which) was completely surrounded by the Whites Fire," said Harling. The previous summer, when the Butler Fire, part of the Orleans Complex, threatened Butler Flat in Siskiyou County, "the prescribed burns…allowed firefighters to successfully defend the seven homes there," Harling said.

Fire is Medicine

Don Hankins is another scientist with tribal roots who is researching traditional burning patterns through a scientific lens. He did his doctoral work on fire effects from a tribal burn in a riparian ecosystem. Part of his job at Chico State is managing the university's 4,000-acre Big Chico Creek Ecological Reserve, formed from land purchased from private ranchers in the late 1990s and now part of the university's research foundation.

A few years ago, Hankins started a burning program on the reserve's oak savanna landscape in cooperation with Mechoopda and Konkow tribal members, whose ancestral lands include the reserve. "It is a personal goal of mine," he says, "to facilitate the appropriate people from various tribes to become reconnected with fire in their traditional landscapes, not as observers but as participants."

Such a project had been a dream ever since Hankins' undergraduate days, when he became aware that many of California's natural areas were overrun with yellow star-thistle (*Centaurea solstitialis*), annual grasses, and other nonnative plants and that these were crowding out culturally important natives like yarrow (*Achillea millefolium*), Ithuriel's spear (*Triteleia laxa*), and blue wildrye (*Elymus glaucus*). "I kept thinking about those traditional stories about the Miwok people," he says, "about how they understood that certain species required periodic burning."

In his experimental burns, Hankins tries to follow the methods of a traditional burner as much as possible: choosing the most favorable time of year and time of day, paying attention to phenology, carefully monitoring fuel moisture, taking advantage of natural firebreaks, eschewing heavy machinery. "We don't put much protective equipment out there," he says, adding that this makes university authorities decidedly nervous. "But we want to demonstrate that we know how to read the landscape, that we know how to put fire in."

So far his burns have gone off beautifully. The postburn data suggest that the invasive plants are knocked back the first year after the burn, and the second year brings a three- to fourfold increase in the native species: "the nonnatives are still there, but the native perennials start to dominate."

It doesn't require traditional ecological knowledge to arrive at this conclusion, but this knowledge has nuances of reasons and methods that give it power to extend and enrich the ecological data. "The researcher Henry Lewis, back in the 1970s, described at least 73 reasons why indigenous peoples in California used fire," Hankins says. "Some are quite specific to given outcomes. When we think about standard prescribed burning, it's typically for a very small subset of those reasons: fuel reduction, fire hazard reduction, maybe some landscape restoration. From an ecological perspective, if I have many different reasons to burn, then maybe the timing of each burn is going to be slightly different because of those reasons. And maybe the outcomes are going to change because of that different timing."

In short, traditional ecological knowledge can produce many ecological outcomes on a given landscape, not just a few. "It's the complexity of traditional fire knowledge," says Lake, "that guided what should be prescribed in different circumstances." He adds, "Fire is medicine—not enough can make the land sick, too much can hurt it."

Of course, the landscapes Hankins and Lake are burning are not the same as the ones their ancestors burned. That is the challenge facing anyone trying to apply traditional ecological knowledge in the modern age. Fuels have built up; landscapes are full of exotic weeds that love a good fire; the artifacts of human habitation are denser and more permanent.

"Just because burning was done in the past doesn't mean it's appropriate everywhere now," says Brent Johnson, a botanist with Pinnacles National Park in west-central California. Johnson has collaborated with the Amah Mutsun people to conduct traditional

prescribed burns there and in Yosemite National Park (see more about his work in the sidebar "Small Burn, Big Promise"). "Today, we have infrastructure that was not here 500 years ago—homes, roads, schools. The low-elevation grasslands have been transformed; they're dominated by Mediterranean annual species now, which may behave differently in a fire than the species they've displaced. One of our research questions is, 'How do TEK management practices function in a novel system?'" Traditional-style burning should certainly be on the table, he says, "but, as with everything else, we should proceed with caution and an understanding of the consequences."

Restoring Boreal Meadow for the Bison

In Liard River, British Columbia, the Cree and Dene people of the Fort Nelson First Nation started a burning program to restore habitat for the threatened wood bison, which roamed across the landscape of their ancestors. The animals had been gone from northern BC since the last century. Twenty years ago, two small herds originating in the Northwest Territories were released into the region in the hope that they would repopulate their old range. But after many years of fire exclusion, the formerly lush boreal meadows were choked with shrubs and small trees. There was not enough grass for the bison to eat, so the animals strayed into the cleared patches alongside the Alaska Highway, and more and more of them were killed by cars. "The Nordquist wood bison herd spends 72 percent of its time within 100 meters of the Alaska Highway," because they need the grass for food, says Sonja Leverkus, a consulting ecologist and research scientist working with the Fort Nelson First Nation.

The Fort Nelson First Nation partnered with a hunting outfitter, Chris Schippmann of Liard River Adventures, to conduct prescribed burns on a small fraction of their ancestral lands. The partners applied to the BC provincial government to burn in the Liard River Corridor of the Muskwa-Kechika Management Area, in a location that had experienced only a few burns since the bison were reintroduced.

After some delay, permission was granted to burn a limited area near the bison's calving grounds. The approval was slow in coming, said Lana Lowe, Fort Nelson's Lands Department Director. "There is a perspective out there that all of this shouldn't be touched by fire, that it should stay in a pristine state," she told a Canadian Broadcasting Corporation reporter in a 2013 video. Such a view, she added, fails to acknowledge that these lands owe their "pristine" appearance to centuries of native management by fire. Lowe said her grandfather burned every spring to keep the brush down and bring on a lush crop of grass for the game. "He did it because the land needs to be taken care of. And that's part of taking care of the land." Tribal elder Rose Loe added, "Fire, used properly, is a friend, not an enemy."

The burn was conducted in May of 2013, while there was still snow on north facing slopes. To avoid hazards of having people on the ground, remote patches were set on fire by incendiary balls dropped from a helicopter. Rose Loe watched through binoculars as the smoke and flames rose above the brushy trees. "It's overwhelming—the power of it, the strength of it, the spirit of the fire," she said. "It's healing the land. It's setting things as it should be."

The First Nation plans to continue its burning program, but they still have to seek permission from BC's natural resources authorities for each burn. Official policy is to encourage burning wherever it's ecologically appropriate, but, in practice, the agency—like many—is cautious. Additionally, the permitting process can be long and slow. "It's discouraging not only to First Nation," Leverkus says, "but also to others with an interest in conserving biodiversity through ecological processes such as fire."

What's more, having to ask permission bothers many tribes, who say the right of indigenous peoples to hunt, fish, gather, and manage on their ancestral lands preexists any state or provincial laws. "The only rights you have are the ones you assert," says Lake. "To ask permission is to relinquish sovereignty."

Chris Schippmann

Lana Lowe, Fort Nelson Lands Department Director, makes her opinion on prescribed burns clear.

Small Burn, Big Promise

At California's Pinnacles National Park, a patch of deergrass was ceremonially burned in the traditional way of the Amah Mutsun people. The fire was touched off by a flint spark, to the accompaniment of singing and drumming.

The prescribed burn in McCabe Canyon was part of a many faceted study of fire regimes and Native American burning practices in the coastal mountains surrounding Monterey Bay. "This area was probably one of the most densely populated in North America before Europeans arrived," says Brent Johnson, botanist and lead researcher for the JFSP-funded study (JFSP Project No. 10-1-09-3). "It's an ideal setting for examining the landscape-level effects of anthropogenic fire, because there are very few lightning ignitions but a lot of evidence of frequent fire prior to European settlement." Johnson worked with ecologists, archaeologists, environmental historians, land managers, and members of the Amah Mutsun Tribal Band to probe the relationship between presettlement human societies and landscape fire at several sites.

To reconstruct fire history, team members analyzed tree rings for scars and other evidence of past fires. They also looked at phytoliths—persistent assemblages of silica in the cells of plants whose distinctive cell-like patterns remain in the soil after the plants die. (They concluded that phytolith analysis is a promising but not yet reliable method for reconstructing fire history in grasslands and other areas with insufficient tree-ring evidence.) The researchers walked their sites looking for cultural artifacts, researched archives to learn about the postsettlement history of the area, and assembled layers of mapped data.

A key study site was McCabe Canyon, an area rich in culturally valuable plants including deergrass (*Muhlenbergia rigens*) and Santa Barbara sedge (*Carex barbarae*), which the indigenous people prized for basket weaving. The canyon's savanna/chaparral plant community also has valley oak (*Quercus lobata*), coastal live oak (*Quercus agrifolia*), and gray pine (*Pinus sabiniana*), which served as food sources.

While the archaeological evidence does not point to large settlements in the canyon, Johnson says, it's likely that the people walked there from nearby villages to gather food and basket materials. So it's reasonable to assume they burned it frequently—maybe once or twice within a decade—to keep those resources productive. "A subdecadal fire interval would have been ideal to maintain the oak woodland and grassland habitats that existed in the canyon lands over at least three centuries," he says. The fires likely extended the grasslands up the canyon sides and pushed the chaparral vegetation farther up on the ridges. Today, the chaparral grows nearly to the bottomlands.

The burn was small—only 2 acres—but it portends big things, not only for the Amah Mutsun people but for the whole ecological and human community. McCabe Canyon's oaks, grasslands, and riparian bottomlands represent a once widespread but now threatened California ecosystem. Before the 2009 prescribed burn, the unmanaged canyon was overrun with wild pigs and full of exotic weeds. "Native Americans used to burn frequently in there," says Johnson. "And then one day it stopped. We're working with fire now to restore species diversity, but we're also helping to restore the other things that have been lost—the cultural processes of the people."

Brent Johnson

A prescribed burn in McCabe Canyon at Pinnacles National Park in 2011.

Disruptions in Timing

Traditional ecological knowledge can help researchers better understand the fine-level effects of fire exclusion, such as disruptions in ecological patterns in response to climate change. Brooke McBride is nearly finished with a JFSP-funded study on traditional phenological knowledge (JFSP Project No. 12-2-01-18). Her study draws on the complementary science of phenology, which concerns the timing of seasonal biological events—animal migrations, plant reproduction and flowering, insect emergence.

Traditional phenological knowledge, she explains, is an intimate understanding of the seasonal dynamics of plants and animals that were important for survival. "It's a rich knowledge of the biota, landscapes, weather, and seasonal cycles, rooted deeply in a given place," says McBride, an ecologist and a postdoctoral research assistant at the University of Montana and the Aldo Leopold Wilderness Research Institute in Missoula, where she is working with principal investigator Alan Watson and a host of collaborators. "This knowledge was essential to indigenous people for ensuring an ongoing supply of resources, predicting events, and signaling when to pursue

Doug Trent, CBC

Sonja Leverkus, Fort Nelson First Nation ecologist and research scientist, loads an aerial ignition dispenser used to light the prescribed burn at Fort Nelson in May 2013.

different cultural activities."

Phenological cues can also signal a disturbed ecosystem. "With climate change, we're seeing changes in the timing of these indicators," McBride says. "There are critical mismatches in the timing of seasonal events and activities on the landscape. The question we're asking is, how can traditional phenological knowledge be used to inform adaptation to climate change?"

McBride searched the scientific literature to discover relationships between these natural cues and the various cultural activities of indigenous peoples, particularly those related to fire. Then she approached tribal college faculty, natural resource managers, and other tribal leaders and invited them to collaborate on projects exploring traditional phenological knowledge from their particular tribal perspective.

McBride brings to the collaboration a participatory GIS mapping tool called MapMe, which allows tribal people (or indeed anyone) to identify locations on the landscape that have cultural or historical significance. Developed by the Leopold Institute and the University of Leeds, MapMe (its name is short for "mapping meaning") has been used in several collaborations between the Leopold Institute and the Confederated Salish and Kootenai Tribes of western Montana. It is a kind of Rosetta Stone that helps nontribal people grasp the values that native people ascribe to their landscapes. One of MapMe's capabilities is "fuzzy" definition, which allows tribal members to identify areas of cultural meaning without giving away the precise location.

"MapMe has been the primary organizing platform for helping to communicate traditional knowledge, in a format that preserves the knowledge for the tribe but also allows part of it to be communicated with managers," says McBride. "As we approach tribal collaborators, we offer the tool and do demos in workshops." McBride is now collaborating with

Facilitators at a GIS workshop at the Salish Kootenai College, sponsored by the Aldo Leopold Wilderness Research Institute. From left to right: Fernando Sanchez-Trigueros, University of Leeds; Brooke McBride, University of Montana; and Robert Kenning, Salish Kootenai College.

the Santa Clara Pueblo in New Mexico and the Confederated Salish and Kootenai Tribes in Montana to develop case studies on various approaches for incorporating traditional phenological knowledge into land management.

Protecting Artifacts

A better understanding of traditional ecological knowledge also might help to bring fire safely back into a landscape where fuels have built up to dangerous levels. The arid forestlands of the Jemez Mountains of northern New Mexico have been hit by four uncharacteristically severe fires in the past 20 years. The land is rugged and diverse, with an array of low- to high-elevation forests spread over multiple ownerships.

The area also is rich with cultural artifacts—dwellings, stone tools, and ceramic pots left by the ancestors of today's Pueblo of Jemez and other tribes. Wildfires have already damaged or obliterated some of these precious resources, and the rest remain at risk, not only from wildfire but also from fire-suppression activities and even from prescribed burns intended to make the landscape more fire-resilient.

Managers are legally required to protect cultural resources, says USFS research scientist Rachel Loehman, but there are additional compelling reasons

to shield them from fire's destruction. "This is a time when we have the strongest need to understand how ancient people used this landscape," she says. "They lived here for a thousand years; they used their environment, weathered many cycles of drought and abundance, and didn't severely compromise the land's structure or function. If we don't do something, fire will remove these artifacts from the landscape just when we need to understand them the most."

Loehman is leading a JFSP-funded project called ArcBurn (JFSP Project No. 12-1-04-5), which aims to quantify the effects of fire, both wild and prescribed, on cultural resources in a variety of ecological settings. She and her team are analyzing fire, both in the laboratory and on the landscape, to determine the threshold of direct heat (in terms of both temperature and duration) that will damage the artifacts. They are also quantifying the indirect effects of wildfire, principally erosion from burned landscapes.

Working with fire managers and cultural resource experts, Loehman will synthesize the findings into practical guidelines for conducting prescribed burns in landscapes with ancient artifacts. "We don't want the presence of these cultural resources to be a barrier to reintroducing fire," she says. "With this project, we hope to be able to flag these areas and use prescribed fire in a way that protects them, so that eventually we can return the whole landscape to a more fire-adapted state."

Respect

Incorporating tribal stewardship into modern land management is not a simple process of technology transfer. Traditional ecological knowledge and Western science are different ways of knowing, rooted in different ways of seeing the world. Tribal leaders and nontribal managers agree that each way of knowing can enrich the other greatly—but only in the context of an equitable, respectful, long-term partnership.

"As a starting point," says Marla Emery, "everybody must set their minds that TEK and Western science are complementary sources of knowledge and that the experts in both TEK and Western science deserve and must be treated with equal respect." Emery, a research geographer with the USFS Northern Research Station, led a collaboration between Anishinaabe tribes of the Great Lakes region and the USFS Forest Inventory and Analysis (FIA) team to document the qualities of birch bark that were important for tribal purposes and then incorporate these characteristics into an FIA inventory protocol. Paper birch (*Betula papyrifera*) is considered a "keystone species" in the Anishinaabe culture, its bark used for canoes, containers, canvases for etchings, and many other purposes.

Equal respect, Emery says, means equal say over the research agenda—the "what is the question?" part. "In our project, the FIA analysts crunched the data. But it was TEK experts who said, 'This is what counts in this piece of birch bark. This is what we're looking for, seeking birch bark for the variety of uses made of it. These are the characteristics that are important to the tribal people.' If you don't know what's important, if you don't know what to measure, then you won't do very good research."

Respect also means not rushing things. "It took us a while to coalesce into an effective partnership," Emery says. "It was an iterative, back-and-forth, give-and-take process. It went something like, 'This is what we know in TEK.' 'Oh. This is what we know in Western science.' 'Ah! This is what we know in TEK …..' In that way, the knowledge is constantly being reexamined and refined. But it's going to take time."

It may also take skillful facilitation to overcome cultural barriers and, sometimes, lingering resentments stemming from memories of past exploitation. "So at times, in some projects, it's likely that there will need to be cultural experts on the research team, people who are adept at bridging between or translating between TEK and Western science," says Emery.

Another key factor is respect for the tribal community's right to steward its own knowledge. "Many tribes consider knowledge to be a responsibility," says Lake. "Intellectual capital held by tribal elders is wisdom, not status entitlement, as some people with Western graduate degrees expect." Tribes reserve the right to set the terms of disclosure and to withhold information that is deemed proprietary or confidential or sacred. Respect also translates into compensation for tribal knowledge holders. "There isn't a Western scientist sitting at the table who isn't collecting a paycheck or drawing grant funds," Emery says. "TEK expertise is not free, and tribal people must not be expected to volunteer it."

At a symposium held at the Flathead Indian Reservation in 2010, Salish-Pend d'Oreille Tribal Elder Pat Pierre gave a simple prescription for cross-cultural progress: "Open communication, education, respect, and friendliness." Today's experiments to braid traditional ecological knowledge with Western science seem to be moving forward under those humane and hopeful principles.

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