

fire & fuels management

Returning Fire to the Land: Celebrating Traditional Knowledge and Fire

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Indigenous peoples' detailed traditional knowledge about fire, although superficially referenced in various writings, has not for the most part been analyzed in detail or simulated by resource managers, wildlife biologists, and ecologists.... Instead, scientists have developed the principles and theories of fire ecology, fire behavior and effects models, and concepts of conservation, wildlife management and ecosystem management largely independent of native examples.

(Lewis and Anderson 2002, p. 4)

North American tribes have traditional knowledge about fire effects on ecosystems, habitats, and resources. For millennia, tribes have used fire to promote valued resources. Sharing our collective understanding of fire, derived from traditional and western knowledge systems, can benefit landscapes and people. We organized two workshops to investigate how traditional and western knowledge can be used to enhance wildland fire and fuels management and research. We engaged tribal members, managers, and researchers to formulate solutions regarding the main topics identified as important to tribal and other land managers: cross-jurisdictional work, fuels reduction strategies, and wildland fire management and research involving traditional knowledge. A key conclusion from the workshops is that successful management of wildland fire and fuels requires collaborative partnerships that share traditional and western fire knowledge through culturally sensitive consultation, coordination, and communication for building trust. We present a framework for developing these partnerships based on workshop discussions.

Keywords: wildland fire, fuels reduction, American Indians, cross-jurisdiction, communication

Fire is a key ecological process influencing the distribution, structure, and function of many biomes worldwide (Bond and Keely 2005, Bowman et al. 2009). In North America, landscape fire effects are critical to many tribal cultures. Most tribes have traditional knowledge (TK) about how fire affects ecosystems, habitats, and resources (Lewis 1993, Bowman et al. 2009, 2011, Trosper et al. 2012, Welch 2012, Huffman 2013). Many tribes used fire to improve the quantity, quality, and functionality of valued resources and

habitats, but the extent of fire use varied across North America (Stewart 2002). Some tribes used fire extensively and purposively, as American Indian men and women carefully planned and conducted burns (prescribed) for different reasons, at different locations, in different seasons, and at different frequencies (Stewart 2002, Williams 2002, Eriksen and Hankins 2014). Tribes used fire associated with hunting, crop improvement, pest control, habitat diversity, range management, fireproofing, fuelwood, travel route maintenance, riparian area clearing,

growth of basket materials, communication, and ceremonies (Stewart 2002, Williams 2002, Trauernicht et al. 2015). Huffman (2013) found that TK included fire effects on fungi, plants, and animals; timing of fire relative to plant phenology and season; fuel moisture; time since previous fire (and severity); and control of fire behavior and spread.

To promote desired resources, tribes influenced fire regimes by affecting when, where, and how fires burned. These cultural fire regimes (Bonnicksen et al. 1999, Lewis and Anderson 2002) reflected the composition, structure, fuel loading, and characteristics of habitats and cultural resources (Timmons et al. 2012, Welch 2012). Cultural fire regimes, associated with human ignitions and management of fuels, often differed from natural fire regimes in (1) seasonality of burning, (2) frequency of fire, (3) fire intensity and effects, (4) sites burned or protected, and (5) strategic application of ignitions given conditions that promoted desired fire behavior and effects (Bonnicksen et al. 1999, Lake 2007). Whereas many tribal communities desire to apply TK and cultural burning with contemporary wildland fire and resource management, a number of factors limit application of this knowledge today (Rasmussen et al. 2007, Eriksen and Hankins 2014, Norgaard 2014). We summarize themes that emerged during two workshops within the context of published

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literature to highlight challenges and solutions for using TK and western knowledge (WK) approaches to wildland fire, fuels, and natural and cultural resource management. We conclude with a framework for applying TK to fire management and research.

Methods

Understanding Challenges to the Use of TK with Fire Management and Research

We held two workshops to engage a diverse community of tribal and nontribal managers, scientists, and students. The first workshop, held in Polson, Montana in 2012, was organized with the Confederated Salish and Kootenai Tribes Forestry Department following the recommendations by Mason et al. (2012, p. 192), to “bring keepers of TK together with representatives of management entities, practitioners, and academic and research institutions.” Tribal elders welcomed and spoke to workshop participants during a field trip. Sixty-three people participated in workshop activities. During breakout sessions, participants discussed challenges to using TK regarding key topics: (1) cross-jurisdictional management, (2) fuels reduction strategies, (3) wildfire management, and (4) research (Figure 1). We organized a second workshop, in conjunction with the Large Wildland Fires conference in Missoula, Montana in 2014, to validate and deepen our understanding of workshop themes. The co-leaders of the second workshop, a subset of the first workshop’s leaders, organized discussion topics and questions around themes documented during the first workshop into the following topics: communication, understanding, and trust; fuels reduction and prescribed fire; and wildfire. Thirty people affiliated with tribes, universities, agencies, and forestry or fire-associated organizations from around the world participated, about 10 of whom had participated in the first workshop. Although there was some overlap in participants, the second workshop had a greater diversity of participants as part of an international conference. Each topic session in both workshops was facilitated by one or two leaders, and key points were captured with flip charts and hand-written and computer-typed notes. Although we did not conduct a formal analysis, we report on recurring and salient (Buetow 2010) discussion topics raised across workshops and across discussion groups within each work-



Figure 1. Celebrating Traditional Knowledge and Fire Workshop 2012. Small groups of tribal elders, community members, tribal forest managers, and agency managers discuss challenges and solutions to cross-jurisdictional management of cultural and ecological resources. (Courtesy of Vita Wright, USDA Forest Service.)

shop. Workshop details and related resources are available.¹ Unless otherwise noted, we report results for the two workshops combined as the first workshop informed the second. In reporting these themes, we also draw on findings from the literature broadly and use examples from the Northern Rockies and Pacific West regions of the United States.

Applications of TK and WK in Fire Management

TK is differentiated from traditional ecological knowledge (Mason et al. 2012, Huffman 2013) in that it is more inclusive

of tribal beliefs, philosophies, and practices that integrate metaphysical and biophysical ways of knowing (Eriksen and Hankins 2014, Norgaard 2014). TK is the cumulative collective understanding derived from individuals and communities about ecological processes, natural resources, and socio-cultural adaptive responses to the environment. As local and place-based knowledge, TK guides the holistic approach of tribal people when burning and performing subsequent subsistence or stewardship practices (Anderson 2006). TK informs purposeful application of fire for specific reasons by

Management and Policy Implications

Many tribes across North America used fire as a tool to perpetuate habitats and resources that sustained their cultures, economies, traditions, and livelihoods. Tribal uses and knowledge of wildland fire have decreased as a result of fire suppression policy and management decisions that have limited the use of fire to manage landscapes. The federal government has a trust responsibility to American Indian tribes. This trust responsibility extends to federal agency and tribal governance for management of natural and cultural resources. Many tribes seek to use traditional burning in a modern context to achieve multiple resource objectives including reducing hazardous fuels and reintroducing fire into fire-adapted ecosystems to protect life, property, and valued resources. Scientists and managers can learn about fire ecology and effects from tribal Traditional Knowledge. We provide a framework for improving fire management and research based on traditional and Western Knowledge systems. This includes strategies for hazardous fuel reduction and the reintroduction of fire in the context of tribal community values, cultural revitalization, and collaborative landscape restoration efforts. The objectives of this framework are to strengthen communication, developing trust and partnerships among managers, scientists, and tribal members.

tribes (Lewis and Anderson 2002). Knowledge of fire behavior and effects on valued habitats and natural and cultural resources is often acquired during subsistence activities, stewardship practices, and religious functions. There is increasing academic interest in TK related to fire ecology and effects (Boyd 1999, Anderson 2006, Mason et al. 2012, Huffman 2013).

In contrast, WK is collective understanding and documentation of natural phenomena that result from observation, experimental manipulations, or modeling. WK strives to be objective, to discriminate among or between variables, to test hypotheses, to minimize assumptions, to identify causal factors, and to consider fire as a physical phenomenon affecting biological and socioeconomic relationships (Conedera et al. 2009). TK and WK perspectives on fire regimes and fire effects on resources are often congruent and complementary on a broad scale (Stewart 2002), but when applied locally can lead to different objectives and sometimes conflicting approaches to managing fire (Conedera et al. 2009, Whitlock et al. 2010, Lake 2013, Crawford et al. 2015). TK and WK of fire regimes and effects are learned, experienced, understood, and transmitted with different methods, institutions, and educational systems (Mason et al. 2012, Trosper et al. 2012, Huffman 2013, Bussey et al. 2016). Tribal communities are pursuing complementary applications of both TK and WK into their wildland fire and landscape restoration management and research efforts (Charnley et al. 2007, Ray et al. 2012, Gordon et al. 2013, Tripp 2015, Bussey et al. 2016).

TK and WK are two different yet complementary ways of knowing (Mason et al. 2012, Bussey et al. 2016). Using TK with WK can more fully inform fire management to reduce fire risk and hazard, reintroduce fire, and maintain cultural landscapes (Mason et al. 2012, Huffman 2013). Resource managers and local communities are currently grappling with how to successfully implement hazardous fuel treatments to lessen the degree to which large wildfires threaten life, property, and valued resources (Watson et al. 2009, Collins et al. 2010, McCaffrey et al. 2013, Hessburg et al. 2015). Emphasis has been on the wildland-urban interface (WUI), but culturally valued resources beyond the WUI are also affected by fires, particularly those where vegetation composition and structure have greatly changed because of the altered fire regimes

and other land uses (Timmons et al. 2012). Whereas vegetation biomass is fuel for fires, plants are also food, medicine, material, and habitat for animals and people. Many prescribed burning and fuels reduction assessments do not account for the cultural role of plants. For example, the Fire Effects Information System (FEIS)² synthesizes WK about how plants respond to fire. TK about use of fire to promote or inhibit plants is still predominantly in the minds of tribal elders; however, efforts to capture this knowledge are growing. For example, the Fire on the Land fire history project documents elder knowledge about the use of fire as a land management tool.³

There are many reasons why land managers may want to work with tribal governments and communities to document historical landscape changes resulting from fire suppression and/or the removal of indigenous land use and occupancy (Kimmerer and Lake 2001, Anderson and Barbour 2003, Lake 2013). Many areas today, often viewed by the public as natural or unmanaged, including designated protected areas, were historically burned or used by tribal peoples (Moon-Stumpff 2000, Ratner and Holen 2007, Watson et al. 2011). Land within and beyond current tribal reservation boundaries is still used for tribal subsistence activities and possesses other cultural values. A better understanding of cultural fire regimes and TK associated with specific plant communities is advised for landscape-level fire management (Ray et al. 2012, Huffman 2013, Lake and Long 2014, Long et al. 2015). Restoring heterogeneity and fostering resilience across landscapes can support ecocultural revitalization (Hessburg et al. 2015, Trauernicht et al. 2015, Tripp 2015) as well as reduce fire hazard, reintroduce fire for ecological benefits, and achieve sociocultural objectives (McCaffrey et al. 2013). Increased value in resources (e.g., timber, recreation, rural residences, and wildlife habitat) may also warrant the exclusion of fire or managing for longer fire frequencies in locations formally burned frequently by tribes (Rasmussen et al. 2007, Watson et al. 2009, Abt et al. 2015, Long et al. 2015).

Results and Discussion

Our workshops provided opportunities for cross-cultural dialogue on the challenges of and potential solutions for using TK and WK. Challenges are not limited to the Northern Rockies and Pacific West regions of the United States (Bowman et al. 2009,

Trosper et al. 2012, Huffman 2013, McCaffrey et al. 2013). However, TK of fire was historically strong here, and there is momentum for applying it to modern wildland fire and resource management (Gilles 2017, Rasmussen et al. 2007). Through self-determination and interactions with government fire managers, tribes in these regions are actively engaged in natural resource management on reservations and adjacent lands (Gordon et al. 2013). This tribal involvement is being scaled up to landscape collaborative restoration projects in several regions of the western United States (Donoghue et al. 2010, Goldstein et al. 2010, Tripp 2015). Use of TK within existing landscape restoration programs and projects is needed. We describe the main topics around which workshops were organized and highlight cross-cutting themes evident across discussion topics and workshops.

Cross-Jurisdictional Work and Cultural Resources

Cross-jurisdictional work is defined here as fuels reduction and wildland fire planning and implementation across multiple land ownerships in a culturally sensitive manner that achieves cultural and ecological objectives at meaningful scales. Cross-jurisdictional planning is essential to the protection of both living and nonliving cultural resources during fuels reduction and wildland fire activities (Timmons et al. 2012, Welch 2012). Jurisdictions may include tribal, federal, state, and local management entities with various missions and responsibilities. Jurisdiction within organizations is often allotted across departments (e.g., forestry, fire, natural resources, heritage, and culture). In addition to coordination by managers within and across agencies, planning efforts benefit from input from tribal communities both on and off reservations (Jurney et al. 2017). Workshop participants focused on cultural resources as a main component of cross-jurisdictional work.

Cultural resources are legally protected by a suite of treaties, laws, executive orders, and regulations (Welch 2012). However, the resources culturally important to many tribes often include living resources: habitats, plants, animals, and fungi. These living cultural resources can be inadvertently disturbed by field personnel, fire crews, and recreationists. Workshop participants discussed the benefits and drawbacks of disclosing the location of cultural resources to protect them.

Table 1. Framework for applying TK and WK in wildland fire and fuels management and research.

Key elements	Wildland fire and fuels	
	Management	Research
1. <i>Sources of TK</i> Literature based or communication with tribes and tribal organizations.	Publications and presentations of fire effects on cultural resources, traditional fire knowledge, and practices.	Conduct literature review. Ethnographic materials at universities, agencies, or tribal archives.
2. <i>Tribal outreach</i> Request of tribal government, cultural committee, or members for incorporation of applicable TK.	Contact tribes about planning and management strategies, short- and long-term project objectives.	Contact tribes and tribal organizations for researchable questions of interest and science support needs.
3. <i>Tribal consultation</i> Government-to-government—identify management or research issues and actions of interest.	Consult with tribal government, departments, or committees for proposed actions (emergency or NEPA).	Request input from tribal councils, departments, and committees to develop preliminary research questions and methods.
4. <i>Building trust</i> Tribal identification, transfer, and authorization of TK use.	Develop or renew agency-tribe fire management agreement. Identify designated tribal representatives and heritage advisors.	Obtain formal agreements, permission or authorization of TK use: IRB, OMB, and tribal approval.
5. <i>Active learning for TK and WK</i> Cross-cultural appreciation of TK used with management actions and research methods.	Workforce education of management effects on heritage/cultural resources and tribal values. TK informs NEPA and WFDSS planning.	Researcher and student education on tribal TK, fire use, and fire effects through academic courses, workshops and field trips.
6. <i>Tribal oversight</i> Coordination and communication with tribes on planning and implementation of projects.	Tribes review proposed management treatments or incident objectives and identify missing values or issues.	Tribes approve research methods, metrics used, and analysis planned, identifying specific values or addressing issues of concern.
7. <i>Active listening and sharing</i> TK informs workforce, treatment implementation, mitigation activities or research practices.	Interdisciplinary or Incident Command Team works with tribal staff to identify values at risk and develop mitigation actions.	Tribal members/youth assist researchers. Collect data with tribal members. Conduct new interviews if needed.
8. <i>Applying TK with WK</i> Tribal participation and stewardship activities.	Tribal partnerships using TK to guide fuels treatments, fire operations and mitigation strategies.	TK collaboratively guides experimental methods, study sites, treatments, indicators, or variables of research interest developed.
9. <i>Tribal review</i> Tribal approval and oversight of project implementation and results.	Tribes review project implementation or fire management and modify actions for adaptive management.	Tribes review analysis results, discussion, and recommendations for management or additional research. Clarify TK and data ownership.
10. <i>Reporting</i> Share and celebrate accomplishments and lessons learned from TK and WK.	Identify postfire actions: BAER practices, share/reflect on lessons learned from After Action Review.	Best available science is developed. Publications and presentations co-authored with tribes and tribal organizations.

BAER, burned area emergency response; IRB, institutional review board; NEPA, National Environmental Protection Act; OMB, Office of Management and Budget; TK, traditional knowledge; WFDSS, Wildland Fire Decision Support System; WK, western knowledge.

During our workshops, participants discussed the tradeoffs of informing fire personnel of cultural resource locations. Sacred sites, gathering areas, rock art, scarred trees, traditional travel routes, and other cultural resources can be damaged by wildland fire and fuels activities (Welch 2012). Such damage is often irreparable, making it imperative that potential impacts are assessed before fire or fuels treatments. Workshop participants recommended involving tribes in the development of collaborative management plans (Watson et al. 2009). For example, participatory geographic information systems (GIS) can be used to facilitate collaboration without disclosing resource locations (McBride et al. 2017). Participants noted that both interdepartmental cooperation and interagency cooperation are critical to protecting cultural resources in working across jurisdictions to assess and avoid, minimize, or mitigate impacts. Partnerships can promote synergy, and more work can be

completed by combining financial and intellectual resources.

For all topics, workshop participants concluded that building and improving communication and relationships between tribes and federal agencies, between disciplines within agencies, and between tribal land managers and tribal members are critical issues that need to be addressed for successful cross-jurisdictional fire and fuels management (Journey et al. 2017). Experiences of tribal and fire managers highlight that effective communication depends on active listening, transparency, accountability, and trust and requires an understanding of the culture and goals of those affected by management decisions and actions (White and McDowell 2009, Abt et al. 2015) (Table 1). Workshop participants emphasized that consulting with tribal elders and other key community members during planning and implementation of land management activities and fire use is essential to effective

cross-jurisdictional management (Mason et al. 2012, Journey et al. 2017). Managers can increase their effectiveness in identifying and understanding cultural resources and tribal values relevant to shared goals (Welch 2012, Lake and Long 2014). Likewise, tribal members can increase understanding by communicating their needs and desires to tribal and agency managers. Improved communication in consultation and project planning can lead to strategies for minimizing or mitigating impacts on tribally valued resources before fuel treatments and wildfires occur (Rasmussen et al. 2007, Lake 2011, Timmons et al. 2012, Welch 2012, Norgaard 2014).

Fuels Reduction Strategies

Fuel treatments can facilitate prescribed fire and future management of wildfires for resource benefits (Resource Innovations 2006, Watson et al. 2009, Collins et al. 2010, Timmons et al. 2012, Welch 2012,

Tripp 2015). Fuel treatments are often focused around residential areas (WUI), ignoring the important ecological role that fires have in promoting culturally important plants, habitats, and tribal traditions across the broader landscape (Stewart 2002, Eriksen and Hankins 2014, Lake and Long 2014). Workshop participants emphasized that it is important to think beyond hazardous fuels reduction and expand use of such treatments to meet ecological and cultural objectives (Lake and Long 2014, McCaffrey et al. 2013). Workshop participants concluded that it is important to clarify how fuels reduction strategies can be used to promote cultural resources while also meeting goals for reducing the undesirable impacts of large, intense wildfires.

Wildland Fire Management (Planned and Unplanned Ignitions)

Prescribed fire plays an important role in maintaining traditional lifeways (Lake and Long 2014, Tripp 2015), while increasing landscape resilience and heterogeneity (Yapp et al. 2010, Moritz et al. 2011, Hessburg et al. 2015). Prescribed fire is defined as “any fire intentionally ignited by management actions in accordance with applicable laws, policies, and regulations to meet specific objectives” (National Wildfire Coordination Group [NWCG] 2015). Workshop participants and session facilitators noted that many prescribed fires are designed without addressing the need to maintain culturally important species, habitats, places, and traditions, even when these outcomes could be complementary with other resource objectives. Workshop participants, reiterating findings in the literature, identified obstacles to the use of prescribed fire to meet cultural and land management goals. These include lack of funding to support prescribed fire for purposes other than fuels management, administrative and jurisdictional challenges to using prescribed fire across landscapes with mixed land management (e.g., WUI; federal, state, private, and tribal lands; and federal and tribal wilderness), conflict with policies (e.g., Clean Air Act, Endangered Species Act, and fire restrictions and burn bans), loss of knowledge regarding traditional uses of fire, concerns related to tribal intellectual property rights and compensation (CTWK 2014), and the use of fire to address climate change (Armatas et al. 2016, Gilles 2017).

Ultimately, tribal communities, managers, and scientists must learn from each

other to move forward collaboratively to better apply prescribed fires in ways that meet multiple objectives (Gilles 2017). Tribal practitioners and fire managers can explore why, when, how, where, and which ignition strategies to use (Huffman 2013) to accomplish fire use objectives given socio-cultural values and resource conditions (Timmons et al. 2012, Lake and Long 2014). Thoughtful consideration of how traditional fire use can be employed on the landscape promises to provide new strategies for meeting both specific cultural and broad land-use goals (Watson et al. 2009, Tripp 2015). With proper use, prescribed fires can promote culturally important species, habitats, and traditions and enhance ecosystem function while also reducing wildland fire risk and hazard (Huffman 2013, Lake and Long 2014, Gilles 2017).

Many tribes desire burning for cultural purposes, but workshop participants explained that this is often restricted because of land tenure, competing internal and external societal values (e.g., fear of wildfire, air quality, and urbanization), and capacity. Some tribal members, like the general public, may also have an aversion to wildland fires. Younger generations have been influenced by societal fear of fire, leading to a culture of fire suppression and unease about using fire (Carroll et al. 2010, Norgaard 2014, Abt et al. 2015). However, some public and tribal land managers have a renewed interest in using prescribed fire to reduce hazardous fuels and mitigate the impact of climate change and longer fire seasons (Westerling et al. 2006, Littell et al. 2009, Stavros et al. 2014, Gilles 2017). WK and TK can be integrated during planning to address climate change and other challenges. For example, in the Pacific Northwest and California, many tribes place higher value on culturally significant trees (e.g., pines and oaks) that are fire-adapted and drought-tolerant, promoting these species in landscape restoration strategies (see Voggesser et al. 2013). Fire and fuels management decisions that favor fire-adapted species can increase the resilience of valued habitats and associated resources to fires.

Wildfire is defined as “an unplanned, unwanted wildland fire including unauthorized human-caused fires, escaped wildland fire use events, escaped prescribed fire projects and all other wildland fires where the objective is to put the fire out” (NWCG 2015). This is in contrast to “management by objectives,” which includes intentionally

identifying multiple objectives for unplanned fires and selecting appropriate strategies and tactics to achieve objectives (NWCG 2015). On American Indian reservations and in the ancestral territories of tribes, the objectives and desired management strategies of a wildfire may be to manage for resources or other cultural benefits while using point protection strategies to protect areas of concern rather than aggressively suppressing wildfire (Abt et al. 2015).

Workshop participants identified their key topics regarding wildfires and fires managed to meet objectives on tribal lands: communication, planning, education, and funding to support wildland fire management. An overarching workshop theme was that the main challenges regarding wildfires on tribal lands stem from the lack of communication or miscommunication between managers and local communities, between agencies, and between agencies and tribes (White and McDowell 2009, Ray et al. 2012, Bussey et al. 2016). Participants noted that using technical jargon when discussing wildfire suppression tactics with tribal community members can often lead to misunderstanding and a shutdown in communication. Communities may view the value of a wildfire versus risk trade-off differently from the managers on teams charged with managing fires. Participants suggested developing strategies and approaches that improve lines of communication between wildfire incident managers, agency decisionmakers, and tribes (White and McDowell 2009).

Misunderstanding can arise during management of fires when the cultural importance of a particular value or threatened at-risk resource is conveyed (White and McDowell 2009, Watson et al. 2009). This may be best addressed in advance through the government-to-government consultation processes and identification of site-specific sensitive data pertaining to the fire. Tribes may not want to share all the information about the importance of an area threatened by wildfire. Efforts are needed to prevent or mitigate adverse impacts to tribal cultural resources, such as sacred sites, where fire suppression tactics may have undesirable impacts (Welch 2012). Allowing wildfire to burn through these areas or assigning local tribal staff to work on point protection or mitigation treatments are options to consider (Lake 2011). Further, allowing lightning-caused fires to spread within tribal ancestral territorial or within reservation boundaries, even if other agencies are engag-

ing in fire suppression tactics, may be desirable and should be considered by decision-makers (Watson et al. 2009, White and McDowell 2009).

Planning efforts such as formal consultation with tribes on projects are an opportunity to convey managers' intent and to avoid undesirable outcomes from wildland fire management. In addition, participants recommended conducting workshops with fire managers and tribes before each fire season to clarify issues that may arise when fires occur. Workshops could include information used in the Wildland Fire Decision Support System (WFDSS) (Noonan-Wright et al. 2011) for formulating strategic objectives and identification of values at risk for different geographical areas, based on landowner jurisdiction. Participants and session facilitators of both workshops emphasized that identifying values at risk and management objectives, preseason planning, and contingency management actions are better than emergency consultation and rushed communication during fires. Finalizing agency-tribal-organization fire management agreements before the beginning of each fire season could prevent negative impacts on tribally valued resources and relationships during a wildfire event.

Education and training can improve understanding of how TK and WK can inform fire management (Mason et al. 2012, Bussey et al. 2016). Workshop participants highlighted the need for targeted education to reduce common misconceptions and improve cultural awareness across all agencies, organizations, and contractors that work on wildfires within culturally sensitive areas. They brainstormed ways for elders to share TK with tribal youths and to nurture these youths into professional natural resources positions (Mason et al. 2012, Bussey et al. 2016). Infusing TK into workforce training and education as "Active learning for TK and WK" (Table 1) could increase community and tribal capacity for wildland fire management and use (Gilles 2017). This approach is an aspect of fire adapted communities, within The National Strategy (2014), fostering cultural and ecological resilience to fire. Education can promote fire as an important management tool, enhancing cultural practices and traditions as well as functioning ecosystems (Timmons et al. 2012, Welch 2012, Abt et al. 2015, Bussey et al. 2016).

Education for a variety of culturally appropriate fire suppression tactics and discus-

sions on strategically placed fuel reduction treatments that facilitate the use of wildland fire around culturally sensitive areas or communities (Taber et al. 2013) could foster communication among agencies with adjacent jurisdictions. This could improve communication effectiveness when fire managers are on a wildfire within American Indian lands or within a tribe's ancestral territory (White and McDowell 2009).

Funding was identified as a fire management limitation. Workshop participants concluded that more funding is needed to support culturally prescribed fire for traditional purposes or cultural resources enhancement. Currently, funding for hazardous fuels and prescribed fire for tribally important lands (via Department of Interior Bureau of Indian Affairs [DOI-BIA]) primarily is associated with congressional allocations to federal agency budgets. Furthermore, federal fire policies influence the appropriation of funding to specific hazardous fuels reduction, geographic regions, and particular goals (e.g., National Fire Plan 2000, Healthy Forest Restoration Act 2005 for Wildland-Urban Interface, and The National Strategy 2014) for landscapes, communities, and wildfire response. The cost of wildfire suppression and management has increased, requiring more expenditures from federal budgets (e.g., Federal Land Assistance, Management, and Enhancement Act 2009, amended 2012). Recently, federal agencies have pursued ways to fund integrated fuels, wildland fire, and landscape restoration efforts (Title IV of the Omnibus Public Land Management Act of 2009). Federal funding to tribal programs, such as the DOI-BIA's Reserved Treaty Rights Lands Program, are intended to support tribal engagement for wildland fire management in ancestral lands across all jurisdictions.⁴ However, strategies are needed to help tribes apply for funding and encourage fire management entities to invest in prescribed fire for tribal cultural resources.

Use of TK and WK in Research

Exploring and exchanging information from TK and WK can be challenging, but when achieved, extremely rewarding. Workshop participants and session facilitators identified several issues that pose difficulties for successful exchange and sharing of TK and WK to occur. First are communication challenges between researchers and the tribes, including sharing of TK from tribal elders with managers and researchers while

protecting sensitive information and formulating data sharing and ownership agreements (White and McDowell 2009, Beatty and Leighton 2012). Where incorporation of TK and WK is a shared goal, the synergy can be effective (Huffman 2013), but, as workshop participants explained, only if there is mutual trust and respect built on open communication (Kimmerer and Lake 2001, Mason et al. 2012, Bussey et al. 2016). Second, best practices for investigating and sharing TK are clearly needed (Charnley et al. 2007). Inclusion of all relevant stakeholders and disclosure on the potential implications of the research and data ownership and access can facilitate more respectful and appropriate methods. Third, research inquisitiveness can harm relationships if researchers inadvertently offend tribal members with their questions and assumptions. Addressing these and other concerns will require effective communication, including shared and open discussion about the mutual goals and concerns (Beatty and Leighton 2012).

Despite challenges, fostering use of both TK and WK in fire research is critically important (Wells 2014). Workshop participants recommended that funding for fire research be focused on addressing challenges in the application of TK outlined above (Charnley et al. 2007, McCaffrey et al. 2013). For such efforts to be effective, questions of importance to the tribes can be discussed in ways that are relevant while also being respectful and sensitive to TK and tribal cultures. These efforts will foster knowledge sharing, collaborative research, and the production of science useful to all partners (Beatty and Leighton 2012, Bussey et al. 2016).

One of the greatest challenges to drawing research conclusions is that knowledge is local, holding it is a responsibility, and it must reflect the history and sustainability of place and culture (Ratner and Holen 2007). Learning sessions for managers have been most successful when tribal members leading the sessions have established working relationships and some level of trust with the participants (Mason et al. 2012). Many tribal elders are eager to share their TK, especially to mentor future tribal generations, but this requires some commitment of the recipients to respect this information (Bussey et al. 2016). Likewise, researchers are often motivated to share knowledge through publications and presentations to support management and inform policy de-

velopment. Workshop participants recommended that researchers should be aware of tribal intellectual property rights, and data sharing and ownership agreements for the use of TK are needed (Climate and Traditional Knowledges Workgroup 2014). Agencies, organizations, and academic institutions working with tribes could develop and formalize data ownership agreements for use and protection of TK and place-based sensitive data (Environmental Protection Agency–Tribal Science Council 2011).

Trust and Understanding Leads to Effective Management and Research

As noted formerly in the literature and by workshop participants, it is imperative that managers and researchers understand and use formal and culturally sensitive approaches for contacting tribal government and community members. Strong working relationships are built around common understanding and forming trust among individuals who represent or work in tribal, agency, academic, organization, and other professional and community roles (Donoghue et al. 2010). Participants described the importance of accountability after meetings. Session facilitators and participants emphasized that it is important for managers and researchers to understand broad versus specific tribal fire-related issues and values and that prescriptions and treatment should reflect local and general public values for projects and programs. Hence, managers and researchers should aim to understand the traditional reasons for fire use to achieve multiple objectives in a modern context (Rasmussen et al. 2007, Tripp 2015).

Several federally funded programs are supporting tribal work to apply TK and WK. The Joint Fire Science Program recognizes the need for methods and tools that apply tribal knowledge with fuels and fire management strategies (Wells 2014). The National Science Foundation is expanding research opportunities for tribes. Research with tribes is also supported by the US Department of Agriculture (USDA) Forest Service Research and Development branch (Farley et al. 2015) and by the Department of Interior Landscape Conservation Cooperative Network.

Many tribes are developing research partnerships with federal agencies and academic institutions, including tribal and state colleges and universities. Having researchers that are respectful and sensitive to TK, tribal values, and culture is important because this

allows for successful application and further exchange. Research partnerships that incorporate tribal knowledge and values can foster the development of the best available science to guide management and for the formation of meaningful policy that serves the needs of tribal communities and the public (Trosper et al. 2012, McCaffrey et al. 2013).

Implications and Recommendations

A Framework for Incorporating TK and WK into Management and Research

We present a framework for supporting the application of tribal TK and WK in wildland fire and fuels management and research (Table 1). We incorporate key elements from both workshops and the literature to highlight the barriers and challenges to respectful sharing and use of TK and WK (Mason et al. 2012, Bussey et al. 2016). The framework is informed by “lessons learned” from working with tribes regarding challenges with wildland fires and fuels management and research using TK and WK (Timmons et al. 2012). Frameworks are useful if they facilitate building trust and support effective consultation, coordination, and communication with tribes (Watson et al. 2009, Mason et al. 2012, Timmons et al. 2012, Bussey et al. 2016). We hope this framework can build trust, support communication, and assist with identification of tradeoffs in wildland fire and fuels management and research projects.

TK Informs Effective Fire Management

TK can effectively inform managers, researchers, and the public about how wildland fire affects the tangible and intangible values associated with natural and cultural resources (Kimmerer and Lake 2001, Welch 2012). Both TK and WK can enhance understanding of fire effects and associated cultural practices using fire-influenced landscapes for different ecosystems, habitats, and a range of fungi, plant, and animal species (Kimmerer and Lake 2001, Trosper et al. 2012, Lake and Long 2014). For example, effective fire management can promote traditional foods (Norton 1979, Johnson 2000) and basketry materials (Anderson 1999, Hummel and Lake 2015) and protect landscape heritage and cultural resources (Timmons et al. 2012). When one considers TK, it is important to understand tribal fire

use, both historically and currently as a sociocultural phenomenon (Eriksen and Hanjins 2014). This requires managers and researchers to learn about the traditional roles and responsibilities of tribal community members (Huffman 2013).

Consultation, Coordination, and Communication Promotes Collaboration

Building relationships and trust is required to successfully address fire management challenges across jurisdictional boundaries (Mason et al. 2012). The communication needed to build trust and respect across cultures takes time, dedication, and an attempt to understand challenges from different perspectives (Donoghue et al. 2010). Effective communication may require methods different from those used commonly within and among government agencies, nontribal organizations, and academic institutions (Bussey et al. 2016). Consultation policies and directives for working with federally recognized American Indian tribes are meant to increase effective coordination and meaningful communication while building trust, gaining respect, and fostering collaboration (e.g., Executive Order 13175, Master Cooperative Wildland Fire Management and Stafford Act Response Agreement).

Meaningful communication goes beyond the government-to-government consultation (per Executive Order 13175) required for federally planned and funded projects and with the development or revision of land and resource management plans. In-person communication among organizational leaders, practitioners, and tribal members is needed to build trust and facilitate communication (Bussey et al. 2016). Federal agencies may separate and not view causal linkages between disciplinary specialties, but the tribes often do. Greater communication on this effect is needed. Initiating various methods of communication across cultural and jurisdictional boundaries will improve dissemination of information regarding the use of TK and WK to inform effective fire management and research (Donoghue et al. 2010, Journey et al. 2017). Sharing knowledge on field trips is highly valuable to tribes. One workshop participant noted the value of “walking the land” together. Personal phone calls or in-person visits are better than e-mail for fostering effective communication.

Tribal consultation provides an oppor-



Figure 2. Klamath River TRES 2015 [Oct. 10, 2015]. Karuk and Yurok ignitors prescribe burning in the wildland-urban interface (Lake property, near Orleans, CA) to reinstate traditional burning in a modern context for fuels reductions, acorn research, and tribal food gathering enhancement. (Courtesy of Frank K. Lake, USDA Forest Service and Karuk Tribe.)

tunity for tribes to confidentially express and share sensitive information about cultural uses of valued habitats and resources, sacred sites, and fulfillment by federal agencies of trust responsibilities. Effective federal agency-tribal government consultation improves coordination for cross-jurisdictional management and can lead to collaborative projects (Watson et al. 2009, Donoghue et al. 2010, Butler et al. 2015). Tribes may be reluctant to disclose sensitive information at collaborative meetings where members of the public, other tribes, or agency specialists are present. Facilitation by a neutral third party at collaborative meetings can promote inclusivity of participants and assists in building trust and transparency (Goldstein et al. 2010), as well as clarifying ownership and protection of sensitive information. The goals of collaboration must be clear to all parties involved, including what are member roles and responsibilities, who is contributing what, who retains the final decision authority for the course of action (Donoghue et al. 2010, Butler et al. 2015), and who will steward, own, and protect sensitive information. Communities and tribes can work together to understand who has the final decisionmaking power for the implementation of a project on lands managed by federal agencies, within a tribe's ancestral territory, as well as available means of conflict resolution or mediation.

Multiple models for such collaboration exist, including the Fire Learning Networks led by The Nature Conservancy (Goldstein and Butler 2010, Goldstein et al. 2010, Huffman 2013) and the federal Collaborative Forest Landscape Restoration Program (Butler et al. 2015). Several opportunities for mutual training for prescribed burning and wildfire management exist (e.g., Prescribed Fire Training Exchanges led by The Nature Conservancy and DOI-BIA Reserved Treaty Rights Lands Program) and are examples for applying tribal TK with traditional burning in a modern context for achieving multiple resource objectives (Figure 2) (Gilles 2017).

Conclusions

Integrating knowledge systems about fire will be especially important in this era of rapid increases in area burned and environmental disturbances (Huffman 2013, Armatas et al. 2016). The active engagement we had in both workshops shows a growing interest in how best to collaborate based on shared TK and WK across jurisdictions and cultures. Although consultation with tribes is required for federal land management, approaches are often inadequate to fully address tribal values, interest, and concerns across jurisdictions. Effective collaboration depends on building mutual respect and trust through personal contact and local ex-

periences (Donoghue et al. 2010, Bussey et al. 2016). Collaboration can support sharing information, improve communication, and facilitate coordination with combining TK with WK about fire and management effects. Such integrated approaches will be important in the face of ongoing environmental change.

The following key findings emerged during the workshops and were reiterated in the literature review:

1. Communication is critical to effective collaboration across tribal and nontribal management and research entities (Bussey et al. 2016).
2. Communication about TK should be done in a culturally sensitive and respectful way that honors tribal traditions, cultures, and the sensitivity for the types of knowledge shared.
3. In addition to identifying culturally sensitive resources and values, TK can inform and guide fuels and fire management so as to perpetuate living and nonliving resources culturally important to tribes.
4. Collaboration will be most effective if time is spent to build relationships, gain trust, share knowledge, and recognize different perspectives on the outcomes and implications of fire and resource management (Journey et al. 2017).
5. To gain support for using fire as a tool for multiple objectives, community awareness, acceptance of fire, and the traditional and ecological roles of fire, including culturally important ecosystem services, should be increased.
6. There is a need to identify and highlight examples of successful cross-jurisdiction collaboration for the research and management of wildland fire conducted with tribes.

Our key recommendations center on increasing tribal participation and knowledge in the protection of valued habitats and resources for wildland fire management and research (linked with key elements of Table 1). Successful planning identifies potential effects to tribal values before the wildfire or projects occur. Agencies, organizations, or tribes could do the following:

1. Host annual tribal government to federal government consultation summits.
2. Incorporate at-risk tribal values as confidentially identified spatial data (e.g., cul-

tural resources, sacred sites) for wildfires if tribes desire to share these with federal partners. The information could be integrated into strategic objectives in the WFDSS. GIS mapping can be used as an analysis tool to identify important areas without divulging specific locations (see McBride et al. 2017). Agency heritage, archaeological, or qualified cultural resource staff can work with tribal advisory councils. This provides another avenue for planning identifiable actions that can be taken to protect and to avoid or mitigate impacts to tribally valued resources, places, sites, or intangible values (Welch 2012).

3. Develop memorandums of understanding (MOU) or other agreements regarding tribal participation and involvement with wildland fire management (Lake 2011, Bussey et al. 2016) and research. This will provide opportunities for tribes to be directly involved during fires and projects having designated tribal representatives and heritage resource consultants who work directly with agencies, incident management teams, organizations, tribes, or researchers.
4. Establish and fund tribal-agency-academic-organization research partnerships to investigate the differences in why, when, how, where, and which management or ignition strategies contribute to desired and actual fire effects.
5. Use post-wildland fire or project “after action review” findings to learn and improve relations in support of adaptive management.
6. Use TK to inform collaborative wildland fire and fuels management and research projects for further understanding of tribal intent and desire for confidentiality and protection of culturally sensitive data. Protection measures may be in the form of management or research plans, data sharing/ownership agreements, or other legally binding agreements in which the signatories (collaboration partners) have made clear how, when, why, or for what circumstances or not tribal knowledge will be used.

Endnotes

1. For more workshop information see nrfirescience.org/event/returning-fire-land-celebrating-traditional-knowledge-and-fire.
2. For more information on FEIS see www.feis-crs.org/feis/.

3. For more information on the Fire on the Land fire history project see www.csktribes.org/natural-resources/tribal-forestry/fire-history-project.
4. For more information on the DOI-BIA Reserved Treaty Rights Lands program see www.bia.gov/cs/groups/xnifc/documents/document/idc1-030969.pdf.

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