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Fostering Socio-Ecological Resilience to Wildfire by Interconnecting Knowledge Systems at Cal Poly Humboldt

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Abstract

The wildfire-related challenges of Northern California and many other regions in the western United States are daunting in scope and magnitude. Ecologically and culturally salient solutions that limit the negative impacts of wildfire and promote resilience of human and ecological systems will require newer approaches. Through Cal Poly Humboldt and the Fire Resilience Institute, there is greater emphasis on the interconnection of knowledge systems across education, training, research, and management. Here we highlight several on-going efforts that seek to enhance the fire resilience workforce, promote socio-ecological resilience through interdisciplinary projects, and inform management through monitoring and research projects that intentionally incorporate multiple knowledge systems. Shifting to a more inclusive process has many potential benefits but will also pose challenges and require modification of approaches. Here we emphasize some on-going efforts at Cal Poly Humboldt to intentionally bridge knowledge systems to make advances on wildfire-related challenges. Socio-ecological resilience and coexistence with fire can be fostered but the long-term effectiveness will greatly benefit from approaches that are inclusive, equitable, and interconnected across the many stakeholders affected and disciplines involved.

Keywords: co-production, fuels management, interdisciplinary, knowledge exchange, prescribed fire, wildfire

Fire is an ecological and cultural process that has long contributed to the biodiversity of California (van Wagtendonk et al. 2018). Over the last several decades, the drying of fuels induced by rising temperature has been one of the main causes of the increased frequency, size, and severity of fires in the western US (Abatzoglou and Williams 2016; Westerling 2016; Parks and Abatzaglou 2020). The other major contributor to these trends is forest densification that resulted from past state and federal land management policies (fire suppression and intensive logging), and the removal of Indigenous burning practices. California now faces burgeoning costs and wide-scale adverse impacts to human communities and ecosystems (Steel et al. 2015, Syphard et al. 2017, Mann et al. 2016, Hoover 2020).

Much of the forestland in the Western United States is managed by federal agencies. Until recently, fire suppression has remained the de facto national management approach despite a growing body of knowledge emphasizing the ecological and social harm of attempting to stop all fire (Quigley et al. 1996; Stephens and Ruth 2005). Butler and Goldstein (2010) claim that

land management institutions like the USDA Forest Service are "caught in the rigidity trap" of fire suppression, which is reinforced through "incentive structures, agency budgets, and professional practice" (1), as well as by the encouragement of many rural citizens. The ongoing crises of large-scale wildfires can reinforce financial and/or political support for the status quo as people implement previous strategies on which they have been trained (Yaffee 1996; Stephens and Ruth 2005; McCaffrey 2015). Despite evidence of maladaptation, including a reduction of productivity in ecosystems and damage to property and lives, rigidity traps are persistent because of risk aversion and learned behavior among stakeholders (Gunderson and Holling 2002; Butler and Goldstein 2010; Nair and Howlett 2016; Cumming 2018). In a rigidity trap, new information or circumstances may not result in changed behavior, as "there is no explicit need to learn, because the bureaucracy already knows what should be done" (Lebel et al. 2011: 50).

At the federal level, there is evidence of a culture shift in land management agencies such as the Departments of Agriculture and the Interior. They have created innovative policies to address threats to human communities and residences from changed wildfire patterns. These policies call for large-scale, cross-ownership boundary fire and fuels management projects that proactively address wildfire risk and re-incorporate fire as a beneficial ecological and cultural process (USDA Forest Service 2012; North, Collins, and Stephens 2012; Steelman 2016; Bixler et al. 2016). Policies include the 2014 National Cohesive Wildland Fire Management Strategy[1] to create resilient landscapes and protect homes and communities, and funding initiatives that incentivize large-scale and multi-landowner fuels treatments, including the Collaborative Forest Landscape Restoration Program, and USDA and USDOI Joint Chiefs funding (Butler and Schultz 2019, Schultz, McCaffrey, and Huber-Stearns 2019; Kelly, Charnley, and Pixley 2019). At non-federal levels experimentation and strong local leadership (often among municipal or county governments, Tribes, or non-governmental organizations) have helped to re-introduce a fire culture built on resilience rather than reaction. Much of this work is grounded in the efforts of Tribal land managers. Long and Lake (2018) trace the displacement of Tribes in the Western U.S. as a major part of the wildfire suppression rigidity trap and note Tribal re-engagement in landscape management as a solution.

The problems associated with wildfire in California are multifaceted and complex with impacts that are increasingly affecting a greater number of human communities and ecosystems. Socio-ecological resilience involves the capacity of systems to endure, adapt, and influence change in the presence of disruptions and to innovate and transform into new, more desirable configurations in response to disturbance (Folke 2006). This perspective highlights the need to think of human communities and ecosystems as coupled systems whose interconnections are essential for fostering resilience (Moritz et al. 2014). Enhancing socio-ecological resilience to wildfires will benefit from new formulations of concepts and approaches in how communities produce, exchange, and use knowledge. Some existing knowledge systems related to fire management include traditional ecological knowledge (also referred to as Indigenous knowledge), western scientific knowledge, and local empirical knowledge (managers and community members). In many cases, knowledge of fire is often underutilized, and fire management decision-making may not integrate relevant skills and approaches across multiple sources (Hunter 2016, Adams et al. 2017). While advances have been made in creating better connectivity among knowledge systems through greater emphasis on management-relevant research and monitoring (LeQuire 2011, Shuman et al. 2022), co-production of knowledge (Norström et al. 2020), and knowledge exchange (e.g., Fire Science Exchanges, Maletsky et al. 2018), barriers and opportunities persist (Kocher et al. 2012, Hunter, Collavito, and Wright 2020, Glenn et al. 2022).

Sound approaches to socio-ecological resilience with respect to fire-related challenges will require better involvement of Indigenous communities to lead and share in decision-making processes. It is particularly

1. The National Cohesive Wildland Fire Management Strategy and updates are available at https://www.forestsandrangelands.gov/strategy/.

vital to respect and elevate knowledge of Indigenous communities in fire research and teaching. There are historical and current reasons that partnerships between non-Indigenous and Indigenous groups have been problematic because of misalignment of knowledge systems, governance, and institutions. As an example, Indigenous firefighters in California and Australia reported barriers and resistance to Indigenous concerns in implementing firefighting measures (Eriksen and Hankins 2014), even though Indigenous people in both locations have long-standing knowledge of the impacts and importance of fire in their landscapes. But institutional inertia and biases restrict the incorporation of indigeneity into fire management. Similarly, incorporating Indigenous knowledge and questions into research requires that we be willing to make significant changes to how we conduct our work—including sustained engagement with Tribes over the long term, receptiveness to new knowledge, and a willingness to be adaptive. These are attributes that are not always supported in typical grant-funded research, which comes with strict deadlines and deliverables.

In Northern California, the transition of Humboldt State University to California State Polytechnic University, Humboldt and the creation of the new Fire Resilience Institute create a foundation to address wildfire-related challenges. By expanding engagement in interdisciplinary programs and projects, these changes more holistically combine socio-ecological perspectives and foster greater interconnection of knowledge systems including Indigenous knowledge. In 2021, an interdisciplinary group of Northwestern California researchers and regional partners engaged with fire research, education, training, and management to form the Fire Resilience Institute. The overarching purpose of the Fire Resilience Institute is to serve as a center of expertise in fire science, ecology, and management that cultivates partnerships and fosters interdisciplinary research, education, training, and outreach to promote effective solutions to wildfire-related challenges while incorporating the need for, and importance of, fire as an ecological and cultural process. Starting in 2022, Cal Poly Humboldt became the third polytechnic university in California. Leveraging existing strengths in science, technology, engineering, and mathematics, including the largest forestry and fire management program in the state, and with an infusion of financial support from the state, the university is developing new programs that seek solutions to these 21st century challenges.

The 2023 launch of a Cal Poly Humboldt Bachelor of Science in Applied Fire Science and Management provides students with an interdisciplinary education focused on developing practical knowledge and skills to become fire science or fire management professionals. The wildfire-related challenges of Northern California and beyond are daunting in scope and magnitude. However, this set of challenges provides a unique opportunity following the transition to Cal Poly Humboldt and the creation of the new Fire Resilience Institute to facilitate the production and exchange of knowledge, employ new approaches to enhance engagement across stakeholder communities, and implement ecologically and culturally sound solutions to promote coexistence between people and fire.

The main objectives of this article are to describe the ways that Cal Poly Humboldt and the Fire Resilience Institute are directly addressing some of the grand wildfire-related challenges, with specific emphasis on: 1) enhancing the fire resilience workforce; 2) promoting socio-ecological resilience to wildfire; and 3) interconnecting fire knowledge systems to foster resilience under a new fire future. While these approaches have the capacity to make substantive contributions, it will require continued reflection and adaptation to promote and maintain advances.

Enhancing the Fire Resilience Workforce

The current wildfire crisis in California has prompted the USDA Forest Service (USFS) and the State of California to set an ambitious commitment to collectively treat 1,000,000 acres per year by 2025 (USDA Forest Service and State of California 2020). While these targets are laudable, attainment requires the rapid expansion of the fire and fuels management workforce in the state. The existing pool of trained and experienced professionals are already over-extended in many regions. Thus, there is a strong need to rapidly educate and train new pro-

fessionals who can quickly contribute to fuel reduction efforts across many different ownership types. However, successful implementation of fuel reduction treatments also requires practitioners have a balance of education, training, and experience to increase the pace and scale of effective treatments that are ecologically and culturally sound.

Efforts to reincorporate fire as a management tool have expanded across the Western US. The call to increase prescribed fire to a "landscape scale" has become commonplace in the recent scientific literature (Noss et al. 2006; North et al. 2015) and in policy (Wurtzebach and Schultz 2016). However, efforts to scale up prescribed fire face many challenges, including legal and policy barriers, institutional inertia, and negative public perception (Quinn-Davidson and Varner 2012; Ryan, Knapp, and Varner 2013; Melvin 2018). Though legal impediments are frequently cited as constraints, recent research indicates that the most notable barriers may be related to capacity, including availability of qualified people, and the incentives to conduct burning (Schultz, McCaffrey, and Huber-Stearns 2019). This perspective suggests the need to not only train people in prescribed burning, but to also nurture a culture of burning, forest restoration treatments, and to build upon partnerships in which these activities can be done.

Increasing workforce capacity for prescribed fire and other fuels management treatments requires a multi-pronged approach. At Cal Poly Humboldt, the BS in Applied Fire Science and Management was created to assist in this effort. Development of this program resulted from a partnership between the Forestry, Fire, and Rangeland Management, and the Native American Studies departments with extensive consultation from local and regional practitioners across federal, state, private, Tribal, and non-profit sectors. These productive conversations were essential in creating one of the most comprehensive and novel fire education programs in the country. This degree program will provide students with an interdisciplinary education focused on developing practical knowledge and skills to become fire science or fire management professionals. The primary aim of the program is to create a better-educated workforce that recognizes the importance of fire as an ecological and cultural process. This program will teach students how to manage wildfires more effectively, to plan and implement fire and other fuels management treatments, and to mitigate the undesired impacts of wildfires.

A key component of the Applied Fire Science and Management program is the inclusion of Native American courses centered on Indigenous history, policy, and cultural practices. Cal Poly Humboldt resides on the unceded territory of the Wiyot Tribe; the broader region represents the highest Indigenous population density within California including the Hupa, Karuk, Tolowa, Wiyot, Yurok, and other Tribes. Each of these Tribes has extensive knowledge and history of cultural burning for a wide range of land stewardship goals in the region (e.g., Marks-Block et al. 2019; Halpern et al. 2022; Knight et al. 2022a). The knowledge and skills of cultural burning still exist and are the cornerstones of cultural revitalization (Kimmerer and Lake 2001; Long and Lake 2018; Marks-Block and Tripp 2021).

At Cal Poly Humboldt, we have a strong tradition of supporting Tribal students in the natural resources through programs such as the Indian Natural Resources, Science, and Engineering Program. Our students also have multiple means of engaging with Tribal communities and practices through the fire program. For instance, students participate in field trips where they meet cultural fire leaders, tour recent prescribed fire sites, and learn about Tribal burning objectives and practices. Students are also provided opportunities to participate in prescribed fire training exchanges that are co-led by local Tribes. However, much work remains in such areas as curricular development, recruiting more Indigenous students and students from other minoritized groups, and enhancing connections with Tribal communities.

Efforts to infuse the program with greater experiential learning and training opportunities for students include expanding existing partnerships with local groups and developing new partnerships. As of 2023, we have on-going or developing partnerships with Six Rivers National Forest, Mid-Klamath Restoration Council, Karuk Department of Natural Resources, Watershed Training and Research Center, Cultural Fire Management Council, California State Parks, Redwood National Park, CalFire, and the Bureau of Land Management,

Arcata Office. Given the inherent multidimensionality of the fire science and management field, the program allows greater flexibility for students to supplement the strong focus on fire science and management with individualized course selection in areas such as Botany, Geospatial Sciences, Native American Studies, Archeology, Rangeland Resources, and Wildlife Management.

Another key component of the Applied Fire Science and Management program will be the expansion of experiential learning and training opportunities in prescribed fire. In 2008, the Prescribed Fire Training Exchange (TREX)[2], a partnership between The Nature Conservancy's Fire Learning Network and the Departments of Agriculture and Interior, was created to address capacity issues related to prescribed fire implementation (Spencer, Schultz, and Hoffmann 2015). Since 2013, Cal Poly Humboldt faculty and students have regularly participated in these events to gain crucial experience and training with a diverse group of land managers, agencies, Tribes, and landowners. Beginning in 2017, a local group of private landowners and community members formed the Humboldt County Prescribed Burn Association[3]. Modeled after similar programs in the Great Plains region, this was the first of its kind in the Western U.S. In the short time since forming, it has inspired numerous other county prescribed burn associations throughout California, Oregon and Washington. This and other prescribed burn associations focus on sharing resources and people to safely implement prescribed fire projects on private lands. Humboldt County Prescribed Burn Association has also provided an excellent opportunity for Cal Poly Humboldt students to gain prescribed fire experience with a diverse set of local practitioners.

Cal Poly Humboldt can assist in increasing capacity in fire and fuels management professionals outside of traditional academic pathways by leveraging our existing educational strengths and our multifaceted connections with federal, state, Tribal, private, and non-profit partners. Through a 2022 Cal Fire grant, the Fire Resilience Institute will initiate the "Integrated Fire Education, Training, and Experience Program" by leveraging existing resources, knowledge, and capacity at Cal Poly Humboldt and through numerous well-established partnerships. This program will develop and expand our offerings related to fire and fuels education, training, and outreach in Northwestern California. Our project aims to achieve the following goals: 1) create and deploy a 24-unit fire and fuels management certificate program through Cal Poly Humboldt Extended Education Program; 2) coordinate offering 5-6 fire and fuels training courses, available to students, professionals, and community members; and 3) develop a community fire outreach and extension program. We estimate that a minimum of 100 students, professionals, and community members will participate in our integrated fire education and training program over the next four years. Through expanding the number of qualified candidates for fire and fuels management positions, the proposed program will directly facilitate many of California's Wildfire and Forest Resilience Action Plan[4] goals.

Promoting Socio-Ecological Resilience to Wildfire

Promoting resilient landscapes and communities requires adaptation to living with fire. While fire suppression will remain an important tool for mitigating impacts to communities and ecosystems, it can no longer be the primary tactic to promote longer-term landscape-level resilience (North et al. 2015). Fuel reduction treatments within the wildland-urban interface, revitalization of cultural burning practices, and strategic restoration of forests and fire to ecosystems are essential to limiting costs and the impacts of future wildfires

2. Information about the Prescribed Fire Training Exchanges and key resources are available at http://www.conservationgateway.org/ConservationPractices/FireLandscapes/HabitatProtectionandRestoration/Training/TrainingExchanges/Pages/fire-training-exchanges.aspx.

3. The Humboldt County Prescribed Burn Association website has updates and information available at https://humcopba.net/.

4. The California Wildfire and Forest Resilience Task Force website maintains updates and information, available at https://www.fire.ca.gov/media/ps4p2vck/californiawildfireandforestresilienceactionplan.pdf.

(North et al. 2021). These practices will require greater coupling of both social and ecological aspects to promote fire resilience.

Social-ecological resilience is based on the complex, non-linear dynamics of social and ecological systems (Folke 2006). Achieving this goal will have profound implications for planning and governance as we build *adaptive* capacity (Wilkinson 2012). Resilience for communities includes strategies to "cope with, adapt to, and shape change" (Imperiale and Vanclay 2016: 206). Communities are more than just resilient individuals; people work together to problem-solve, and thus community leadership and strategic action are important components to resilience (Magis 2010; Kulig and Botey 2016). Much of the existing disaster recovery literature involves case studies of communities that have experienced non-fire disasters such as hurricanes, earthquakes, and tornadoes and focuses on social and physical infrastructure (e.g., Sadri et al. 2018, Yabe et al. 2020). However, wildfire-impacted communities are uniquely able to create resilience because of the importance of human management in mitigating fire behavior and the feedbacks between social and ecological variables (Schumann et al. 2020). As identified by Berkes and Ross (2013), we envision fire-adapted community resilience as a combination of both social and ecological resilience.

As part of the Fire Resilience Institute, a newly funded project entitled "*Recovery of human communities after wildfire: building social-ecological resilience*" will begin in 2023. Principal investigators and members of the Fire Resilience Institute seek to answer the following questions: what does recovery look like in diverse communities impacted by destructive wildfires, and how are communities working towards recovery and building social-ecological resilience? We have received a Joint Fire Science Program (USDA and USDOI) grant to conduct this research in several selected case study locations in Northern California and southern Oregon. Alongside Cal Poly Humboldt graduate students, we are working with community partners (Firebrand Collective, Southern Oregon University, Slater Fire Long-term Recovery Group, Mid-Klamath Watershed Council, and Watershed Training and Research Center) engaged with wildfire recovery and resilience efforts in these locations.

As part of the new project, we plan to incorporate a participatory action research (PAR) approach. PAR is an umbrella term for a process that "begins with a research topic of importance to the community with the aim of combining knowledge and action for social change to improve community health and eliminate disparities" (Minkler et al. 2003). This approach offers a range of methods for bridging community and academic methods to knowledge generation by anchoring research more centrally within communities, sharpening the focus of project objectives, increasing the relevancy of research to partner sites, and maximizing the overall impact of the research (Chevalier and Buckles 2019). PAR complements traditional research through its unique approach in involving the community under study in guiding the research process (Wadsworth 1998), and dissemination of research findings to community stakeholders. The use of PAR has helped communities recover and adapt from floods (Meyer et al. 2018) and other natural disasters, as well as develop climate change resiliency plans (Douglas et al. 2018). In alignment with federal principles of "centering equity and environmental justice" (e.g. U.S Department of Interior 2021), incorporating community-based components is our fire resilience research in our region is especially important, as many communities most impacted by fire tend to have higher rates of poverty and are often underserved by multiple levels of government (Adams and Charnley 2020; Masri, Jin, and Wu 2022). Previous fire-related research in Northern California has also successfully engaged communities using a PAR approach to address questions about traditional ecological knowledge (Lake 2007), barriers to prescribed burning (Quinn-Davidson and Varner 2012), and food sovereignty (Sowerwine et al. 2019).

The use of a participatory action research framework to address socio-ecological resilience is important and can be effective, but this approach has its own set of challenges (Long et al. 2016). For instance, PAR requires sustained community engagement in developing and implementing research. One implication is that PAR cannot be implemented solely through student projects

because of the short-term tenure of student engagement. In working to implement PAR in our fire projects, we are building on a long history of community engagement between the university and communities in our region to build institution-level connections. In conjunction with the transition to Cal Poly Humboldt, the administration recently hired a special assistant to the president who will specifically focuses on Tribal relations and community engagement. We are hopeful that this position will help bolster and improve interconnections with Tribal communities in the region. With fire, this is notably taking place with the Fire Resilience Institute, which is hiring a community fire outreach coordinator to help improve community connections. Through the institute we are also engaging and consulting with the managers and practitioners of surrounding communities to align our activities with community values and needs.

The Fire Resilience Institute-led project has the advantage of looking more cohesively at both social and ecological perspectives for communities at an intermediate stage of recovery from wildfire. Previous research on post-fire recovery has emphasized the biophysical impacts of wildfires and other climate change-related disturbances on ecological resilience (Allen 2007, Millar and Stephenson 2015). Wildfire social science has often focused on fire preparedness and mitigation (Jakes and Sturtevant 2013, McCaffrey 2015) and human community responses during and soon after wildfires (Paveglio et al. 2015, Paveglio and Edgeley 2017). There has been less attention on the longer-term recovery of communities from wildfires, especially with an emphasis on what recovery looks like for communities and how recovery after a wildfire can lead to long-term social-ecological resilience within the context of climate change. As Shumann et al. (2020) argue, wildfire recovery represents an opportunity to build transformative resilience on the landscape, moving from tactical fire recovery to responsive fire-adapted communities (see also McWethy et al. 2019).

While resilience and adaptive capacity are long-term goals, community recovery after any disaster occurs in phases from an emergency period (of rescue and relocation) to rehabilitation (when essential infrastructure is re-built) to reconstruction (when long-term physical and social needs of residents are addressed and the community attempts to rebuild in a way that increases its resilience; Colten et al. 2008). This last phase may also be termed long-term recovery, and occurs 2-3 years after a disaster, as community capacity is re-built and long-term plans are put in place (Blackman et al. 2017). Post-wildfire recovery is multifaceted, and includes rebuilding physical infrastructure; resuming municipal, social, and economic activities; and promoting psychological healing and recovery as residents struggle with "losses and prolonged distress" (Lalani et al. 2021: 2). Our research project is gathering data from three diverse sites in Northern California and Southern Oregon three to four years after they were devastated by wildfires. This work will allow us to assess both immediate post-disaster community responses and more long-term community recovery efforts in three communities that vary in size, cultural composition, and interagency organizational capacity. Rather than focusing narrowly on the "aftershock" social and economic factors (Imperiale and Vanclay 2016), we will consider the direction of recovery with several years' worth of lessons learned.

The timeline of post-disaster recovery is important: soon after disaster there may be a sense of community cohesion and working together toward a common cause (Paveglio and Edgeley 2017), a period described as a "honeymoon" phase (McGee et al. 2020). This perspective suggests that recovery efforts may lag or run into community conflicts after some time. Conversely, new actors and leaders within communities may emerge to facilitate recovery efforts and contribute to renewed social cohesion and community agency (Blackman et al. 2017). Lidskog (2018) found that nine months after a fire in Sweden, there was still increased social cohesion and people described their community as "stronger" after the fire. In one of the few studies to assess community recovery several years after the fire, Carroll et al. (2011) found that five years after the Rodeo-Chediski Fire, nearby communities had both maintained a "coming together" spirit that spurred community action, *and* had developed post-fire conflict, distrust, and disagreements. Our project will add to the existing knowledge regarding post-wildfire recovery and assess the prospects of fostering longer-term social-ecological resilience to

wildfire within communities, as well as implications for other communities in the region that will experience future wildfires.

Of the limited research related to post-wildfire recovery available, Tribal perspectives are often not represented (Carroll et al. 2011) in part because of the many challenges in conducting research with Indigenous partners. To enable the inclusion of Indigenous perspectives, we will limit these barriers through incorporating lessons learned from previous projects (Long et al. 2016, Sowerwine et al. 2019), utilize guidelines when available or work with partners to assist in their development, train students, faculty, and staff in best practices, and engage with communities early to make sure expectations are clear and appropriate. These efforts will aid in better serving the project and community, while also working to establish trust and greater engagement.

Interconnecting Knowledge Systems to Foster Coexistence with Fire

Knowledge systems are the ways in which we understand and represent the world. Rather than primarily focusing on the entities involved in the process of generating and using knowledge, there is increased recognition for the need to interconnect entities across the components of knowledge systems and thus to better foster knowledge equity (Glazer 1998) or "knowledge democracy" (Veld 2010). Here we highlight one general perspective of a knowledge system with an emphasis on four components: 1) knowledge identification, 2) knowledge acquisition, 3) knowledge translation, and 4) knowledge application. Knowledge identification refers to the process of identifying gaps in knowledge or areas of uncertainty in existing knowledge. Knowledge acquisition refers to the generation of understanding through observation, experience, practice, inquiry, and other methods. There are many forms of knowledge acquisition and ways to gain important information that clarifies understanding the world and informs decision making. Knowledge translation is the dissemination and sharing of knowledge with an emphasis on providing needed information to those engaged with knowledge application, or the use of knowledge to aid decision making for management and policymaking.

An interconnected knowledge system accepts that there are multiple existing systems of knowledge and recognizes the importance of engaging across knowledge systems to find solutions while also maintaining knowledge integrity and appropriate attribution. Below, we highlight a project where we are actively using an interconnected knowledge system approach to collaboratively design and direct a monitoring and research study that aims to reintroduce fire and restore a culturally important species and landscape.

Indigenous peoples, including the Karuk and Yurok, have managed oak woodlands in lower montane regions of the Klamath Mountains since time immemorial with frequent low-intensity fire (Anderson 2005; Lake, Tripp, and Reed 2010; van Wagtendonk et al. 2018). Evidence of frequent burning includes traditional knowledge, the presence of surviving legacy trees, and fire scar and charcoal records (Metlen et al. 2018, Knight et al. 2022b). Xánthiip, or California black oak (*Quercus kelloggii*), along with other hardwoods, are important cultural, ecological, and economic species in the region (Long et al. 2016; 2017). In the long absence of fire, competition from shade-tolerant conifers such as itháriip or Douglas-fir (*Pseudotsuga menziesii*) has dramatically reduced legacy hardwood vigor. After about 100 to 150 years of fire exclusion, conifers begin to overtop black oak, leading to substantial mortality of these shade-intolerant legacy trees (Hunter and Barbour 2001; Cocking et al. 2012; Cocking et al. 2014). Reintroduction of low intensity surface fires, whether through wildfire or prescribed burning, has limited effectiveness in killing mature Douglas-fir, and may have the unfortunate outcome of further weakening or killing of legacy California black oak (Cocking et al. 2012; personal communication, Bill Tripp, Frank Lake), if mitigation measures are not taken to protect vulnerable old trees. Effective restoration of these stands often requires the mechanical removal of Douglas-fir to improve oak vigor (Devine and Harrington 2013; Kane et al. 2019). However, the long absence of fire and dense shade cast by Douglas-fir has promoted growth forms of California black oak with a low diameter-to-height ratio and excessively leaning boles that may be predisposed to windthrow, especially after thinning.

These circumstances require unique solutions to limit negative impacts while retaining California black oak and its important eco-culturally associated species. As a part of this project and others, the Fire Resilience Institute and partners will focus on a co-production model of research and employ an updated version of the Practicing Pikyav[5] guidelines for collaborative projects with the Karuk Tribe. A process that was developed and refined in part through the Karuk and University of California, Berkeley collaborative focused on food sovereignty through a participatory action research approach (Sowerwine et al. 2019).

In collaboration with the Karuk Department of Natural Resources, Mid-Klamath Watershed Council, Salmon River Restoration Council, Oregon State University, USDA Forest Service, and Southern Oregon University, members of the Humboldt Fire Resilience Institute have begun participating in the "*Black oak (xánthiip) monitoring and research project.*" This project will examine the effectiveness and impacts of specialized treatments to improve California black oak vigor and survival and to reintroduce fire and promote restoration as a part of the broader initiative of the Western Klamath Restoration Partnership. The study will take place on Ikxariyatuuyship (Offield Mountain) within the Karuk Aboriginal Territory, at a site once regularly burned in September as part of the World Renewal Ceremony (Lake, Tripp, and Reed 2010; Norgaard 2022). While the specific details of the research questions and approach are still in development, the process has been centered on Tribal cultural values and has been deliberately inclusive of multiple knowledge systems. The aim of this approach is to identify the challenges and to assure the knowledge generated will be responsive to the goals of improving social and ecological resilience in California black oak and its associated species.

Through this project each of the partners are engaged with many of the four knowledge system components. For instance, knowledge identification was initially conducted by local practitioners that identified the scope of the impacts of past management on California black oak and possible methods of improving conditions. These ideas were put forward to the larger group of partners in a series of meetings to flesh out monitoring and research approaches that were responsive to cultural and ecological perspectives. Initial monitoring protocols are being developed with continued input from many partners, with a focus on Indigenous perspectives. Knowledge acquisition will occur through both monitoring and research efforts that will be conducted by multiple partners. Inclusion of all partners early and iteratively in the process will facilitate knowledge translation and application for later stages of this project. Furthermore, this cooperative approach will also facilitate feedback into identifying subsequent knowledge needs or areas of uncertainty.

Closing Remarks

Coexistence with fire that promotes socio-ecological resilience is possible. The scope and magnitude of the wildfire-related challenges in California and other regions are complex, but substantive advances that promote inclusion and interconnection across disciplines and knowledge systems are needed. Through Cal Poly Humboldt and the Fire Resilience Institute, we are intentionally incorporating this approach. Inevitably this process will be iterative with a need to adapt over time, learn from successes, and find ways to improve on shortfalls. Our approach has been informed by many regional partners that are already actively fostering the interconnection of knowledge systems and working across boundaries to address many of the current challenges related to wildfire. We look forward to continuing to build these relationships and develop new relationships in the coming years.

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6. The Practicing Pikyak document and other resources are available at https://sipnuuk.karuk.us/system/files/atoms/file/ATALM17_PracticingPikyav.pdf.

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