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Monitoring of black oak (*xánthiip*) to center indigenous ecocultural revitalization

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Abstract

Indigenous Knowledge, Practice, and Belief Systems (IKPBS) are an ecological and cultural framework with which Indigenous communities have (and continue to) adaptively manage their land since time immemorial. In the current context of climate change and colonial forest and fire management in the western US, Indigenously-led ecological research and cultural revitalization offers a path forward where tribal sovereignty of land stewardship is maintained and the resiliency of natural systems are reestablished. We describe our process of developing an Indigenous-Directed Research (IDR) partnership to study *xánthiip* (Karuk for black oak, *Quercus kelloggii*), a Karuk cultural focal species, in the context of Karuk-led forest restoration. We first outline our process of IDR by describing how this partnership was established, research questions and methodologies were co-developed, IKPBS were centered, and utility to tribal forest restoration processes were prioritized. The primary product of this partnership was a culturally responsive black oak monitoring protocol to assess black oak tree quality over time. We describe how this protocol was developed including conducting semi-structured qualitative interviews with Karuk cultural practitioners, translating qualitative interviews to field protocol metrics, consulting with research partners, testing for field feasibility, and

Kathy McCovey and Colleen Rossier shared co-lead authors.

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sharing back to the local community through field training and youth curriculum development. Second, we analyzed plot data collected from the implementation of the black oak protocol using a two-eyed seeing approach that ensured our ecological findings had cultural relevance for future Karuk-led forest stewardship. Through this analysis we described the dominant black oak tree typologies based on their traits of importance as identified by Karuk cultural practitioners and research collaborators. All natural resources research takes place on Indigenous land. By outlining the steps of this transdisciplinary IDR partnership, we provide a framework for centering IKPBS, respecting Indigenous land sovereignty, and centering Indigenous leadership in ecological research and knowledge co-development.

KEYWORDS
black oak, indigenous stewardship, Indigenous-Directed Research, Klamath Mountains, knowledge co-production, long-term monitoring

INTRODUCTION

Indigenous communities are at the forefront of climate change adaptation and science (Eisenberg et al., 2019; Karuk Tribe, 2019; Kimmerer, 2000). Despite colonial genocide and displacement of Indigenous peoples from their aboriginal land throughout the last 150 years (Miller, 2011), Tribal Nations of the present-day United States (US) retain the right to maintain stewardship across usual and accustomed ranges if not ceded through treaty. All rights, when not explicitly extinguished by a treaty or termination statute, are considered to be 'reserved' to the Tribe, even when a Tribe has been officially terminated or when treaties were never ratified (*United States v. Winans*, 198 U.S. 371, 381, 1905). Tribal rights to maintain land stewardship are reflected in numerous places across US federal land management policy including the Tribal Forest Protection Act of 2004, Indian Self-Determination and Educational Assistance Act of 1975, and the Pacific Southwest Region Traditional Gathering Policy (Diver, 2016; Norgaard, 2014; Yazzie, 2007). These rights are also mirrored in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) that outlines the rights of Indigenous peoples internationally. However, despite these rights, access to land and stewardship has been largely diminished or denied over the last century in the northwestern US as timber industry priorities, shifting US land claims (i.e., Forest Reserves becoming National Forests), policies of fire suppression, and fear of fires have dominated the land management paradigm, and a narrow interpretation (and often ignorance) of 'reserve rights' has been employed by the US federal government (Bower, 1978; Marks-Block & Tripp, 2021). In the context of climate change and increasing size and severity of wildfires, there is growing recognition of the critical importance of Indigenous Knowledge, Practice, and Belief Systems (IKPBS) to guide disaster risk reduction and land stewardship (Hessburg et al., 2021). This has led to rising interest by the US federal government to partner with Tribal Nations to accomplish natural resource management objectives. This interest has been met with efforts within Indigenous communities (and in collaboration with academic, agency, and nongovernmental partners) to ensure that those relationships are not extractive and are in alignment with Indigenous land management goals (Harling & Tripp, 2014; Lake, 2021). These efforts include requiring explicit data sharing and storage/security agreements between Tribes and their research partners (Marks-Block & Tripp, 2021), ensuring that research engagement is tribally-led, and making sure that cultural and tribal well-being goals are represented in forest management decision making.

In landscapes stewarded by Indigenous communities, ecological restoration is most successful and meaningful when coupled with Indigenous cultural revitalization (Mucioki et al., 2021; Norgaard & Tribe, 2019; Tripp et al., 2017). The two are inextricably connected. An Indigenous community's robust relationship to the land, inherently supports the local ecology and vice versa. The term ecocultural revitalization refers to the process of fostering a positive feedback loop between cultural practices and landscape restoration (Kimmerer, 2000). Centering Indigenous cultural well-being in ecological restoration projects supports a paradigm where restoration of relationship to land is given equal weight to the restoration of ecosystem function in evaluating the success of a project (Norgaard & The Karuk Tribe, 2019; Rossier, 2019).

Ecocultural revitalization can only be accomplished sustainably if Indigenous communities themselves have the power to make land management decisions and guide cultural and ecological landscape restoration objectives. Indigenous-Directed Research (IDR) refers to research partnerships in which Indigenous people are both guiding research questions and goals, as well as directing the management and stewardship goals that the research supports (Karuk-UC Berkeley Collaborative, 2015; Rossier, 2019; Steen-Adams et al., 2023). In these partnerships, the Indigenous community of place takes the lead on defining management objectives, framing the research questions, and applying the research findings within ongoing restoration and other work, and then contributes in a meaningful way (to the degree capacity allows) in research design, analysis, and public dissemination of results (Rossier, 2019). In these ways, IDR is a form of Participatory Action Research (PAR), but has the power to address research and management gaps that may be hidden from view by those operating strictly within a Western science context and situates the Indigenous community clearly in the leadership role (Rossier, 2019).

One theoretical technique that has been used to frame research relationships involving both Indigenous knowledge systems and Western research approaches is the concept of two-eyed seeing (Reid et al., 2021). Two-eyed seeing, conceptualized by Mi'kmaw Elder Albert Marshall from present-day eastern Canada, refers to the practice of seeing from one eye with the wisdom and strength of Indigenous knowledges and worldviews, and from the other eye with the strengths of Western knowledges and ways of knowing (Reid et al., 2021). The intention being that you are able to see the world more clearly when looking with both eyes. This framework is particularly relevant in the context of climate change as multiple ways of knowing may be needed to come to novel and adaptive solutions (Hessburg et al., 2021).

Two-eyed seeing, however, is more complicated than simply synthesizing different ways of knowing (Broadhead & Howard, 2021). The ways that ndigenous and Western epistemologies intersect is deeply specific to people and place and there are not uniform best-practices for how to employ two-eyed seeing. This intersection of worldviews can be complicated further if partnering researchers have differing levels of knowledge or training in each way of knowing (i.e., if a research partner trained in Western science methodology does not understand the cultural context of the system of study) (Steen-Adams et al., 2023). While recognizing these qualifiers, we have done our best to use the guiding principle of two-eyed seeing to inform how we built our partnership and co-developed research. This research project is grounded by a desire to see with these two eyes while fundamentally in service of Indigenous research objectives and ecocultural revitalization—that is, IDR with a two-eyed seeing approach.

Land management context and black oak ecology

The ancestral territory of the Karuk Tribe is approximately 420,063 ha in the Western Klamath Mountains along the Mid-Klamath River of present-day northern California and southern Oregon (Karuk Tribe & Rocha, 2015). This land has been stewarded by the Karuk Tribe since time immemorial to promote a mosaic of habitats that support diverse cultural resources (Long et al., 2021). This stewardship includes frequent, and strategic low severity-controlled burning to promote fire-enhanced ecocultural resources including acorns, berries, basketry materials, and wildlife (Anderson, 2007; Karuk Tribe, 2019; Marks-Block et al., 2019; Rossier, 2019). These human ignitions along trail systems and near village sites work in consort with upland lightning ignitions to create a mosaic of fire effects across the landscape (Greenler et al., 2024). In part because of this synergy of human and lightning fire ignitions, forests in this region are considered some of the most biodiverse temperate forest systems in the world (Metlen et al., 2018).

Concerted Euro-American colonization of the Klamath Mountains was initiated largely by the goldrush in the mid-1800s (Reed et al., 2016). This process of colonization included the killing or removal of Karuk people from their ancestral territory. Cultural burning was criminalized, large swaths of Karuk ancestral land were seized and incorporated into the US federal forest reserves and, in 1911, fire suppression was codified into law across the western United States (Marks-Block & Tripp, 2021). This led to dramatically increased fire return intervals and a shift to ecosystems dominated by mesic, nonfire adaptive species and fire-prone stand structure (Cocking et al., 2014; Taylor & Skinner, 2003). Heterogenous stands with high spatial complexity filled-in with conifers, creating a matrix of dense forests with increasingly smaller openings (Skinner et al., 2006). Although Karuk communities continued to practice cultural burning, even at the risk of criminalization throughout this time (Clark et al., 2021), this contemporary fire regime setting was dominated by fire suppression resulting in high fuel loading, spatial homogeneity, and infrequent fire return intervals (Reed et al., 2016).

In addition to increased conifer dominance because of fire suppression, conifer trees have been given preferential treatment over hardwoods in colonial land management practices more broadly for the past 100 years. The timber industry's preference for softwood plantations, the intentional removal of hardwoods (including black oak trees), and the current paradigm of replanting conifers post-wildfire, have also greatly contributed to the increasing dominance of fire-intolerant stand structure in the Western Klamath Mountains.

Through our IDR partnership, Oregon State University research partners were asked to support the restoration of stewardship of *xánthiip* (Karuk name for black oak, *Quercus kelloggii*) by co-developing a long-term ecocultural black oak monitoring protocol (Appendix S1: Document S2) in collaboration with the Karuk DNR. Black oak is one of the cultural and ecological keystone species in the oak woodlands and mixed-conifer forests of the Klamath-Siskiyou Ecoregion of northwestern California and southwestern Oregon (Long et al., 2017; Skinner et al., 2006).

Black oak is considered a cultural indicator species for the Karuk for many reasons, including its cultivation around village sites in the low to mid-elevations along the mid-Klamath river corridor, its cultural significance as an acorn food source, its function as wildlife denning and nesting structure, its association with culturally significant understory plant assemblages, the timing of cultural burning associated with black oak woodlands, and its ecological adaptation to frequent, low to moderate-severity fire (Anderson, 2007; Fryer, 2007; Karuk Tribe, 2019; Long et al., 2016, 2017; Tripp et al., 2017; Zielinski et al., 2004).

Ecosystems where black oak is an important vegetative component are fire-dependent and historically experienced short return-interval surface fires or mixed-severity fires (Fryer, 2007). These disturbance conditions have selected for—and in turn been facilitated by—a suite of black oak fire regime adaptive traits. Black oak has thick, insulating bark that protects the cambium from girdling by low intensity surface fires (McDonald et al., 1990). Without frequent fire (e.g., less than 10-year fire return interval), in part because of its suite of fire regime adaptive traits, black oak cannot maintain dominance in most sites and will typically be successionally replaced by conifers such as Douglas-fir (itháriip, *Pseudotsuga menziesii*) and white fir (mahitháriip, *Abies concolor*) (Beckmann et al., 2021; Bright & Gehr, 2005; Cocking et al., 2012, 2014; McDonald et al., 1990). These more shade-tolerant conifer species, although easily killed by fire when young, grow quickly in the absence of fire, develop thicker, fire-resistant bark, and eventually outcompete preexisting oak assemblages by piercing through oak crowns and overtopping canopies (Cocking et al., 2012). These firs compete for nutrients, soil, and light, and structurally function as ladder fuels that can carry benign surface fires into the crown of fire regime adaptive hardwoods leading to further hardwood mortality (Beckmann et al., 2021; Cocking et al., 2012).

Although black oak is often able to survive high-severity fire, legacy and culturally desired growth characteristics (e.g., full open crowns and lower live limbs) are not always retained. If high-severity fire (or other disturbance) manages to top-kill a black oak, the individual has several mechanisms for regeneration. These strategies include suckering/sprouting from the root crown and epicormically from buds along the oak bole and branches (Figure 1), as well as germinating from fallen acorns after their second year of maturation (Cocking et al., 2012; Fryer, 2007; McDonald et al., 1990). However, legacy black oak tree structure facilitates a disproportionate amount of Indigenous cultural ecosystem services, such as providing habitat for culturally important wildlife and understory plant species, as compared with younger or resprouted oaks (Long et al., 2016; Marks-Block et al., 2021; Mucioki et al., 2021; O'Gorman et al., 2022). Legacy trees are considered the 'functional backbone of many forest landscapes' providing wildlife habitat, seed source, and structural complexity in the context of disturbance (Larson et al., 2022, p. 3). Because of distinctive characteristics, such as cavities, extensive branching, and complex canopy structure, legacy trees fulfill many ecological roles that cannot be replicated by oaks of other age classes (Benner et al., 2019; Lake, 2022; Lindenmayer et al., 2014; Long et al., 2016).

Long-term monitoring is an important component of adaptive forest management (Hood, 2010), in the context of restoration. Without this temporal documentation it is difficult to understand the relationship between forest restoration treatments and their effects, which can inform future adaptive management (Hood, 2010). Long-term monitoring is of particular importance when considering restoration treatment impacts to old, large trees because it may take years to realize the implications of management (Hood, 2010). However, the choice of which ecological and/or cultural variables to monitor and how to interpret those findings is value-laden and reflects the priorities of those who develop the monitoring protocols, conduct the analysis, and make management decisions based on the results. Using a two-eyed seeing approach to build a monitoring protocol allows us to use the strengths of a Western science framework as the scaffolding of the protocol development, while directly addressing Karuk cultural values and objectives through the choice of specific monitoring metrics. Based on this underlying approach our partnership objectives included: (1) The development of the black oak monitoring protocol (i.e., interviewing Karuk cultural practitioners, consulting with research partners, writing up field protocol,

FIGURE 1 Examples of several black oak characteristics. Top left image shows a burned black oak sucker resprouting from the root collar; bottom left image shows scarring on a black oak bole from 'hack and squirt' herbicide treatment applied by the USFS likely in the mid-1900s; right image shows a black oak epicormically sprouting from the bole, overtopped by an even aged stand of Douglas-firs. Photos by Jessie Thoreson.

and testing for field feasibility); and (2) the analysis of field data collected from protocol implementation and interpretation using a two-eyed seeing perspective.

METHODS

Developing an IDR partnership

In this work, we describe the process of an IDR partnership between the Karuk Tribe DNR in the mid-Klamath region of present-day northwestern California, and an Oregon State University Master's graduate student (Jessie Thoreson) and her committee (see Appendix S1: Document S3, for first author positionality statement). The first step of this research process involved discovering mutual interest in a research partnership. Conversations began informally when Jessie attended several in-person community events in the Mid-Klamath region in the fall of 2021. Jessie's graduate research funding (USDA NIFA National Needs Graduate and Postgraduate Fellowship [NNF] Grants Program and Oregon State University) was built to be flexible and responsive to research interests of community partners. Informal conversations with Karuk DNR employees and community members provided the groundwork to develop a research program that directly addressed Karuk DNR research interests while providing Jessie with the research experience needed to complete her graduate program. During these initial relationship-building conversations, Karuk DNR employees within the *Pikyav* Field Institute expressed interest in research regarding the ecocultural revitalization of *xánthiip* (Karuk for black oak, *Q. kelloggii*) groves that was grounded in the framework of Karuk IKPBS. This work would expand and build upon similar black oak tribal research done elsewhere in California (Long et al., 2016). The Karuk Tribe's *Pikyav* Field Institute is the community/youth engagement and intergenerational knowledge-sharing integrated program area within the Karuk DNR. Among other things, they oversee the *Practicing Pikyav Process for Collaborative Research* with external researchers, particularly those who will be working with IKPBS (Karuk-UC Berkeley Collaborative, 2015). Once we decided that a research partnership could be mutually beneficial, and would work within the existing timing and funding constraints, we collaboratively developed research questions and established methodologies to address this topic.

A *Pikyav* Review Committee (Karuk-UC Berkeley Collaborative, 2015, Revised by Karuk DNR 2022) within the Karuk DNR was established in the winter of 2022 to co-develop and support this research endeavor. *Pikyav* means 'to repair' or 'to fix' in Karuk (Bright & Gehr, 2005). Karuk people are often described by tribal members and descendants as, 'fix-the-world-people' meaning that the Karuk Tribe holds a responsibility to repair and restore the complex social, cultural, and ecological systems of the world. Practicing *Pikyav* Research Agreements between researchers and the Karuk Tribe are built out of this fundamental responsibility, and endeavors to ensure that collaborative projects with the Tribe always support Karuk philosophies and practices of *Pikyav* (Karuk-UC Berkeley Collaborative, 2015, Revised by Karuk DNR 2022). The *Pikyav* Review Committee for this project included a local community liaison and Karuk cultural practitioner, Kathy McCovey, a Karuk DNR employee, Colleen Rossier, and two experienced researchers, Meg Krawchuk and Arielle Halpern. In an effort to ensure *Pikyav* oversight of the OSU process, and ensure OSU inclusion in the *Pikyav* process, two committee members served on both committees: Meg Krawchuk (OSU), and Colleen Rossier (K-DNR). This *Pikyav* Review Committee and agreement provided shared understanding and contractual assurance that tribal knowledge sovereignty would be maintained throughout the research process. See Appendix S1: Document S4, for full Practicing *Pikyav* Research Agreement and Data Management Plan.

Project area and forest management context

The climate context supporting the culture and ecology of the project area in the Klamath Mountains of present-day northern California can largely be defined as Mediterranean with summers that are dry and warm and winters that are cool and wet (Skinner et al., 2006). Average precipitation near the coast ranges from 3861 to 8077 mm per year, whereas, precipitation on the east side of the Klamath Mountains is typically 965 to 1600 mm per year.

Black oak in this region are typically found within the Low Elevation Karuk Cultural Management Zone (Karuk Tribe, 2019). This zone is found along the mid-Klamath river corridor on high solar insolation south or southwest facing slopes (Karuk Tribe, 2019). Typical tree species associations with black oak in this region, followed by both their Karuk and Latin names, include ponderosa pine (ishvirip, *Pinus ponderosa*), tanoak (xunyêep, *Notholithocarpus densiflorus*), Douglas-fir (itháriip, *Pseudotsuga menziesii*), Pacific madrone (kusrípan, *Arbutus menziesii*), and Oregon white oak (axvêep, *Quercus garryana*). Understory shrub associates include California hazel (surip/aththip, *Corylus cornuta* ssp. *californica*), greenleaf manzanita (pahaav, *Arctostaphylos patula*), ocean spray (piytírih, *Holodiscus discolor*), and poison-oak (kusvêep, *Toxicodendron diversilobum*) (Bright & Gehr, 2005; McDonald et al., 1990).

Since time immemorial, cultural and ceremonial fires have been set on *Ikxariyátuuyship* ('Spirit Mountain') also called Offield Mountain, near the confluence of the Klamath and Salmon rivers in present-day northern California, every August as a part of the Karuk World Renewal Ceremony (Karuk Tribe, 2019). In 1905 the US federal government asserted ownership over this land through the establishment of the Klamath National Forest and the next century was defined by fire exclusion, cultural genocide, and removal of Karuk people from their land (Bower, 1978; Diver, 2016). According to Mamie Offield (Karuk woman) as recorded in Schenck and Gifford (1952), 'before the forest service came in, there was no dense underbrush and therefore, when a forest fire occurred, it burned only the annuals, grasses, and so forth, and did not harm the forest trees. She says that these yearly fires prevented disease from attacking the first trees. The people used to set fires every year'. Karuk people have continued to exercise their rights and inherent responsibility to place since time immemorial, despite the challenges and barriers to doing so. They are continuing to revitalize Indigenous fire stewardship to this culturally significant place and assert their rights to steward and manage their aboriginal landscape (Diver, 2016; Harling & Tripp, 2014; Lake, 2021). The Western Klamath Restoration Partnership (WKRP) is a collaborative landscape restoration partnership between the Karuk Tribe, the Six Rivers National Forest, Klamath National Forest, and local nongovernmental organizations (NGOs) including the Mid Klamath Watershed Council and the Salmon River Restoration Council. WKRP was founded in 2013 with the goal of restoring fire resiliency at a landscape scale (Harling & Tripp, 2014; Long & Lake, 2018). One of the current landscape restoration projects for WKRP is on *Ikxariyátuuyship* with the central goal of restoring cultural fire regimes on the mountain. This will be accomplished through targeted forest treatments that aim to restore historical stand structure and composition that is both conducive to restored cultural burning, and is also more resilient to wildfire (Karuk Tribe, 2019).

The project area contains Unique Prescription Areas (UPAs). UPAs are smaller areas within the larger project planning area where the enhancement of specific Karuk cultural indicator species clearly guide restoration, as opposed to other management objectives. This novel technique was conceptualized by Karuk tribal member, Chook-Chook Hillman, as a way to fit cultural resource management objectives into federal processes including NEPA (the National Environmental Policy Act). These UPAs are purposefully small (<2 km^2), relative to the full restoration project area, so that they can be easily and adaptively managed in novel ways. The intention of these UPAs is to set a precedent of success for future landscape-scale cultural resource revitalization (Hillman, 2022). Black oak is one such cultural indicator species that has been chosen to guide restoration objectives. Within the Black Oak UPA, the Karuk DNR and other WKRP partners will develop and implement unique prescriptions to restore robust black oak grove structure and prepare this landscape to receive prescribed fire with cultural objectives (i.e., US Forest Service and Karuk Tribe cooperative or Klamath River TREX burns), and cultural fire once again.

Interviewing Karuk cultural practitioners

Building a monitoring protocol using a two-eyed seeing framework, for a non-Indigenous researcher, requires first endeavoring to understand how Karuk cultural practitioners see their relationship to black oak groves and identifying their priorities for ecocultural revitalization. Foundational work by Jonathan Long (USFS Pacific Southwest Research Station), and Kat Anderson (UC Davis) alongside cultural practitioners from the Mono, Maidu, Karuk, and Takelma Tribes among others has been done to conceptualize black oak cultural qualities on a California-wide scale (Anderson, 2007; Long et al., 2016, 2017). The intention of our research was to ground these conversations in the Western Klamath Mountains as it pertains specifically to Karuk people and current black oak restoration efforts within their aboriginal territory. We developed an interview guide (Thoreson et al., 2023), in consultation with the *Pikyav* Review Committee, that was informed by a Western science literature review of oak ecology, but grounded in two-eyed seeing (Reid et al., 2021), decolonizing methodologies (Smith, 1999), materials produced by the Karuk Tribe (Harling & Tripp, 2014; Karuk Tribe, 2019; Tripp et al., 2017), and other sources that articulate conceptions of cultural stewardship and cultural value (Lake, 2019; Rossier, 2019). The question guiding this research was: *How do Karuk cultural practitioners describe good black oak grove and tree quality?* We answered this question through conducting qualitative semi-structured interviews with Karuk members and descendants who hold knowledge about Karuk Indigenous cultural management and who are involved with Karuk DNR work (Thoreson et al., 2023). The selection of participants was based on recommendations by the *Pikyav* Review Committee and constrained by both the limited project timeline and the desire by the Karuk DNR to implement the resulting protocol in Summer 2022. Below, is a list of the interviewees. Their names and titles are listed in the way preferred by each individual.

> **Chook-Chook Hillman**, Karuk Indian, ithivthaneen aachip va'arar ('center of the world person' in Karuk).
>
> **Frank K. Lake**, Karuk Descendant, USDA Forest Service Research Ecologist, PhD.
>
> **Kathy McCovey**, Karuk Tribal Member, Cultural Practitioner, Archaeologist, and Anthropologist.
>
> **Analisa Tripp**, Karuk Woman, Karuk Tribe DNR Collaborative Stewardship Program Manager.
>
> **Bill Tripp**, Karuk Tribal Member, Director of Natural Resources and Environmental.
> Policy, Karuk Tribe.

The intention of these interviews was to conceptualize what a subset of Karuk cultural practitioners see as the most important attributes of ecocultural revitalization as it pertains to black oak.

After the interview guide was developed, it was reviewed and approved by the Karuk *Pikyav* Review Committee (following the *Practicing Pikyav Policy and Protocol for Collaborative Research*), the Oregon State University (OSU) Internal Review Board (IRB) Human Resources Protection Program, and Karuk Tribal Council. Free, prior, and informed consent was obtained by all participants prior to each interview. Per the *Practicing Pikyav Protocol* and *Pikyav* Field Institute guidance, this consent agreement also included choices regarding participant preferences for confidentiality, both in the storage of raw interview data, and in public dissemination of findings. All five participants chose to have their identity associated with their interview transcript, allowed for interview transcript storage within Karuk DNR, and chose to be cited directly when direct quotes are used publicly. It should be noted that while participant confidentiality is considered standard for many social science protocols, best research practices with Indigenous communities include the choice of whether to identify interviewees and give credit, particularly where IKPBS are concerned (Kari Norgaard & The Karuk Tribe, 2019; Rossier, 2019; Smith, 1999). Additionally, the Karuk Tribe asserts intellectual property over their members' and affiliated descendants' knowledge as they pertain to heritage and cultural resources (Karuk-UC Berkeley Collaborative, 2015).

Interviews were conducted in the summer of 2022 in Orleans and Happy Camp, CA. Follow-up conversations took place in fall 2022 over Zoom to discuss preliminary results and to ask practitioners to elaborate on topics discussed in the summer. Audio recordings of interviews were transcribed verbatim, and transcripts were uploaded to NVivo qualitative data software (QSR International Pty Ltd. Version 12, 2018) for analysis. Each transcript was coded using a combination of a priori codes that came from the interview guide and emergent codes that were uncovered during the analysis process. These interview data were used to build a broad, qualitative framework for thinking about social and ecological restoration of black oak which is discussed in Thoreson et al. (2023).

For the purposes of constructing a black oak monitoring protocol, we analyzed interviews with the goal of synthesizing how practitioners defined attributes of black oak quality. We broke down these attributes into 'poor' and 'good' cultural quality (Long et al., 2017; Rossier, 2019). We then refined these attributes into key metrics that could be quantifiable within a replicable field monitoring protocol.

Developing a culturally responsive black oak monitoring protocol

The synthesis of research from the black oak literature, practitioner-defined metrics, discussions with research partners, and field testing collectively informed a suite of ecological indicators which were captured in the final monitoring protocol. This synthesis provided a robust framework for understanding both ecological and cultural indicators to track throughout implementation of treatments within the *Ikxariyátuuyship* Black Oak UPA. Metric development began by reviewing relevant black oak mensuration literature (Cocking et al., 2014; Long et al., 2016, 2017; O'Gorman et al., 2022). This knowledge then informed an interview guide to understand Karuk cultural practitioner descriptions of black oak grove quality in the context of their own lives and knowledge. Practitioner articulations of the positive or negative value of these various traits informed how each one was interpreted in plot data analysis. In some cases, practitioners provided specific recommendations for how to capture these metrics in the field. These metrics and mensuration choices were then evaluated by other research partners to ensure that they were appropriately replicable and would work in the context of the Black

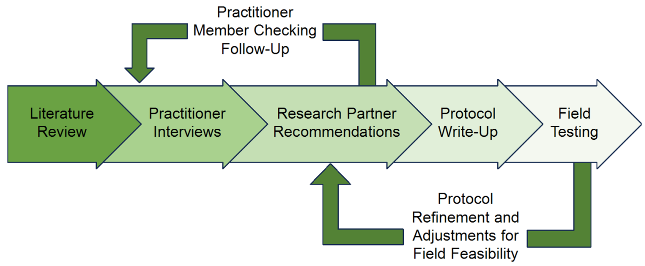

FIGURE 2 Protocol development. Flowchart of the protocol development process and refinement. Backward facing arrows show where and when member-checking occurred.

Oak UPA. This included conversations with Karuk DNR forestry crew members Cody Conrad and Forrest Davis as well as other Karuk DNR research partners and *Pikyav* Review Committee members including Dr. Arielle Halpern (Sealaska Heritage Institute), Dr. Colleen Rossier (Karuk DNR), Dr. Jeff Kane (Cal Poly Humboldt), Heather Rickard (Karuk DNR), Dr. Ashley Hawkins (US Forest Service) and Dr. Lucy Kerhoulas (Cal Poly Humboldt). This process of member-checking with those in the community ensured cultural relevance, field feasibility, and community buy-in for continued long-term monitoring. This member-checking process also ensured that the metrics captured could effectively inform restoration treatments and future research goals. Figure 2 shows this protocol development process from start to finish and demonstrates where member checking refinements occurred.

The metrics and mensuration strategies evolved throughout this process. Figure 3 illustrates where specific cultural and ecological inputs and recommendations came from and how these recommendations were translated into protocol language. It was important that protocol metrics were not only replicable and feasible to implement in the field, but also reflected the priorities of those in the community and of those conducting future black oak research. Many of the metrics used are typical forestry measurements and do not require detailed refinement. These include diameter at breast height (DBH), tree height, stand density, etc. However, because of the unique structure of these black oak trees in the context of fire suppression and the need to understand cultural values, other metrics required more refinement before data collection could begin. Figure 3 shows an example of more nuanced metrics and how they were developed, from interview excerpts, to mensuration refinement, to finalized protocol language.

There are many other researchers working in partnership with the Karuk DNR assisting in the investigation of research questions regarding restoration of cultural and ecological resources, including acorn quality, understory

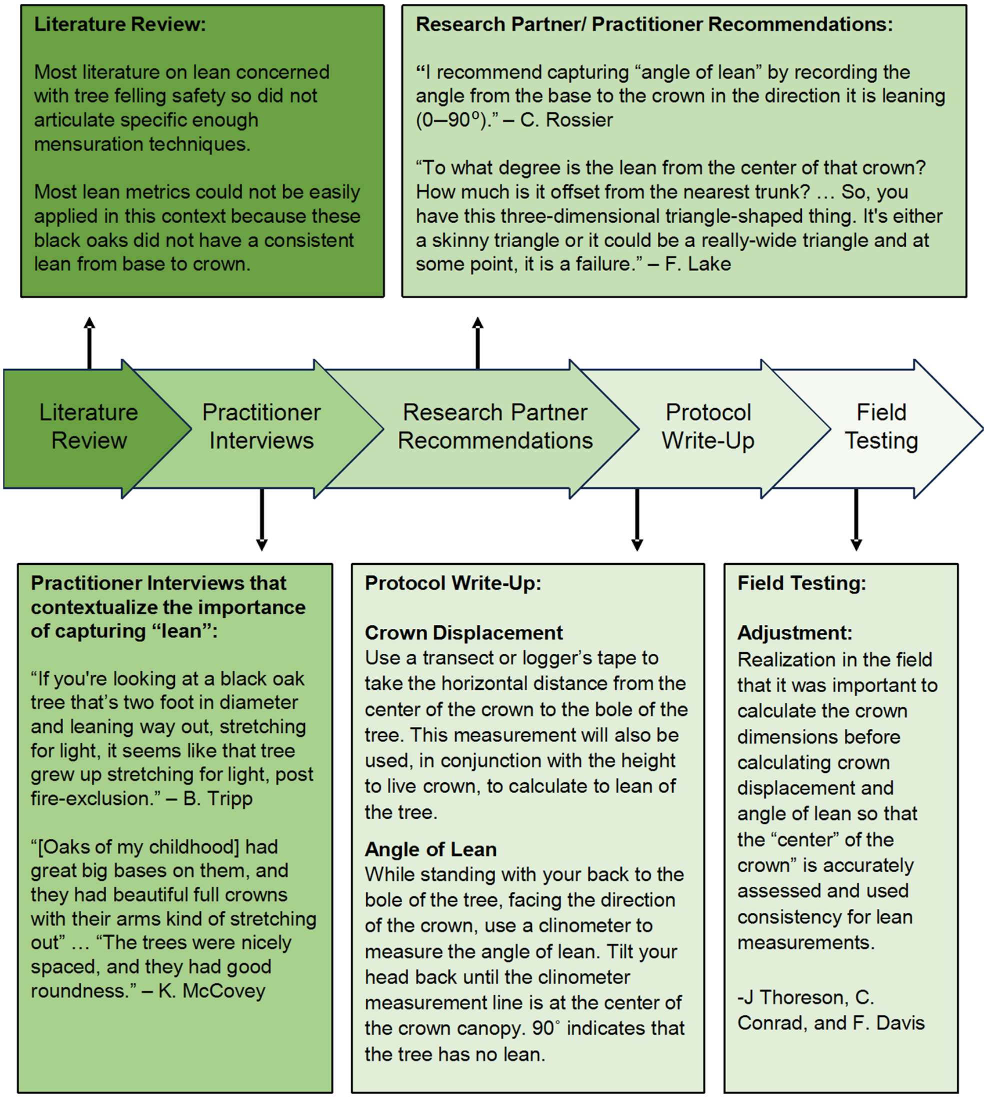

FIGURE 3 Metric development. Description of how the metrics capturing focal oak 'lean' were developed in the black oak monitoring protocol.

assemblages, and fuel loading. For the purposes of this study, we focus on focal black oak tree structure and overstory structure and composition. See Appendix S1: Table S1 for a comprehensive list of metrics that we included in the protocol as well as justification for their inclusion.

Implementing the black oak monitoring protocol

Plot data for 30 trees were collected in summer 2022 within the *Ikxariyátuuyship* Black Oak UPA. Plot size was of 10 m radius centered on individual focal oak trees, following methods in Cocking et al. (2012) and O'Gorman et al. (2022). Plots were located in three distinct oak groves (grove A, grove B, and grove C), and 10 trees were sampled per grove. Placement of these plots was informed by discussions with interview participants about the location of specific black oak groves of interest, review of previous legacy black oak mapping done in the valley by the Karuk DNR cultural resources program, as well as field scouting efforts. Plots were established at least 25 m apart to avoid overlap between adjacent plots. Fieldwork was carried out by OSU Master's student, Jessie Thoreson, and two Karuk DNR forestry crew members, Cody Conrad and Forrest Davis.

ANALYSIS OF OAK GROVE PLOT DATA

The black oak monitoring protocol was co-developed in a way that allows it to resource many different analytical techniques and answer many different longitudinal research questions as research priorities may shift over time. The following analyses demonstrate one way to utilize this dataset to answer questions directly related to the Karuk cultural context of these trees. In the words of *Pikyav* Committee member, Colleen Rossier, these results demonstrate a 'culturally responsive statistical analysis'. Understanding the current state of these oak trees from a structural and cultural perspective was an important first step, identified by Karuk DNR and WKRP, to establish baseline conditions preceding experimental restoration treatments. Our objective in this plot data analysis was to describe current black oak groves within the *Ikxariyátuuyship* Black Oak UPA based on focal oak tree attributes. Results from Karuk cultural practitioner interviews informed the characterization of cultural value associated with each tree attribute. This choice of framing allowed us to interpret the results of this ecological plot data in a culturally responsive way. Using these interpretations, we identified groups (clusters) of focal oak trees based on their suite of measured, structural traits. We aim for these descriptions and groupings to inform restoration treatment decisions and experimental design for adaptive management. This pretreatment dataset will set the stage for future research to monitor and assess implications of restoration treatments.

We use three research questions to understand these baseline ecological and cultural data: (1) What are the relationships between black oak tree traits? (2) How is cultural value related to these tree traits? (3) How are focal black oak trees clustered in trait space based on their similarities?

Relationships between black oak traits of focal trees

To understand the relationships between black oak trees in trait space we used principal components analysis (PCA) with Euclidian distance to ordinate focal oak trees in trait space (McCune & Grace, 2002). PCA was chosen because the scatterplot matrix of the focal oak traits demonstrated bivariate normality suggesting linear methods could be used to explain most relationships between oak trait variables within this dataset.

All analysis was done within the program PC-ORD (version 7.0), an ordination software that performs multivariate analysis of ecological data (McCune & Mefford, 2016). In preparation for PCA analysis we compiled the data into two matrices, a main matrix, and an environmental matrix. The main matrix contained all trait data associated with the focal oak tree (DBH, height to live crown, canopy position, crown volume, lean angle, etc.). The environmental matrix contained both abiotic environmental conditions (slope, aspect, elevation, etc.) as well as biotic stand conditions and characteristics (wildlife presence, overstory tree density, black oak seedling counts, etc.). See Appendix S1: Table S2 for definitions of variables and their units, and how they were scored or measured. A series of adjustments were made to both the main matrix and the environmental matrix before analysis. We converted three environmental variables: aspect, slope, and latitude into heat load using the heat load conversion from McCune and Keon (2002). This adjustment allowed us to more accurately represent the impact that aspect and slope have on environmental conditions compared with their raw values. There was one categorical variable in the environmental matrix ('landform' with categories: flat, side slope, bench, ridge). We assigned each landform category its own binary column to allow quantitative analysis. We then assessed all main matrix and environmental matrix variables for skewness to determine if any transformations were needed to normalize the data. We log-transformed all variables with a skewness of >2.0. Based on these criteria, the following variables were transformed: crown volume, crown displacement, basal cavity, dead branches, black oak seedling count, conifer seedling count, ridge landform, and bench landform. The skewness was reduced for all quantitative variables, and stayed the same for all binary variables, once this log-transformation was complete (McCune & Grace, 2002).

We relativized both the main matrix and the environmental matrix by standard deviation, meaning that all variables were transformed to means equaling 0 and variances equaling 1. We then performed an outlier test using Euclidian distance among focal oak trees in trait space. Although two focal oaks were identified as outliers, their standard deviations were low and their lack of impact on point cloud shape was minimal, so we determined that neither outlier needed to be removed from the dataset prior to analysis (McCune & Grace, 2002).

Initial assessment of data indicated that evaluating the PCA ordination with two axes was most appropriate. This assessment was based on the Rnd-Lambda recommendation, a stopping rule that is relatively robust to non-normal data, as well as randomization *p*-values ($p < 0.02$).

Black oak trait cultural value

To understand how cultural value is related to oak traits, we created a synthetic vector that signifies the value that Karuk cultural practitioners place on each particular black oak trait. Based on the suite of traits for each individual oak, we assigned each oak tree a cumulative cultural value. Then we (in consultation with B. McCune) augmented the PCA environmental matrix with this new vector representing cultural value and overlaid it on the ordination of focal oak trees in traits space to identify where sampled oak trees were located in relationship to high cultural value.

The assessments of cultural value were derived from the semi-structured interviews with Karuk cultural practitioners. Cultural value was assigned to traits based on whether they were considered to represent poor (−1), neutral (0), or good (1) high cultural value. For example, large DBH was considered a good cultural attribute and was therefore assigned a 1 in the cultural value vector. High lean angle was considered a poor cultural attribute and was therefore assigned a −1 in the cultural traits vector. The main matrix quantifying focal oak traits was then multiplied by the transpose of the cultural value vector to calculate the cultural value attribute for each focal oak plot (sample unit). The environmental matrix was then augmented with the cultural value vector. Each element of the cultural value attribute thus represents the sum of the desirability of its traits; these values ranged from poorest quality (−10.66) to best quality (8.27).

Black oak trait clusters

To answer our third research question about how focal oak trees are clustered based on their traits, we performed an agglomerative hierarchical cluster analysis of the focal oak-centered plots (sample units) to assess their associations in traits space. We used Euclidian distance with Ward's linkage method, a space-conserving strategy, to establish these clusters. We described clusters by assessing trait means within each cluster. We then use a convex hull overlay within the PCA ordination to visualize clusters within traits space (McCune & Grace, 2002).

Plot data: Results and discussion

Relationships between black oak traits of focal trees

Locations of focal oaks in trait space are illustrated by the PCA ordination in Figure 4. We rotated the ordination 100° and flipped vertically so that axes 1 and 2 would best represent traits gradients. The resulting axis 1 describes 30% of variance and axis 2 describes 31.2% of variance, for a total of 61.2% variance explained. A joint-plot of focal oak traits on the ordination shows that high values on axis 1 are associated with high crown volume, large DBH, dominant canopy position, and high number of dead branches. In general, this demonstrates that focal oak tree dominance increases in relation to axis 1. High trait values on axis 2 are associated with high canopy closure, high lean angle, and high crown displacement. Low trait values on axis 2 are associated with high height to live crown, and high density of epicormic sprouting. In general, this demonstrates that focal oak tree lean and light stress increases in relation to axis 2.

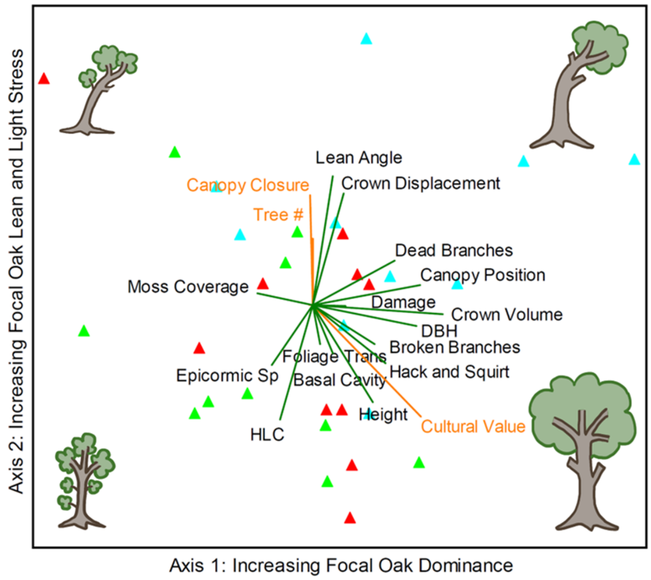

FIGURE 4 Principal components analysis (PCA) ordination of focal oaks (sample units) in trait space. Triangles indicate focal oak location in the ordination and triangle color represents the grove associated with each oak (red—grove A; green—grove B; blue—grove C). Radiating green lines and black text indicate the focal oak traits used to ordinate the sample units in this space. Radiating orange lines and orange text show linear relationships with the environmental attributes with strongest associations to the ordination. Illustrations show representative tree structure in each corner of the PCA ordination. See Appendix S1: Table S2 for variable definitions.

A cluster of traits closely aligned with axis 1 but slightly oblique (pointing down and to the right in Figure 4) includes basal cavities, foliage transparency, 'hack-and-squirt' herbicide treatment, broken branches, and other damage. This third cluster of traits can largely be described as having high damage or 'structural character'.

Black oak trait cultural value

The cultural value metric has the strongest association within the trait space ordination as illustrated in Figure 4 by overlaying environmental attributes in the trait space and evaluating the strength of those linear relationships. Cultural value falls between focal oak traits that signal stand dominance (such as high DBH, height, and crown volume) and focal oak traits that signal high damage or 'structural character' (such as basal cavity presence and broken branches). This position is consistent with descriptions by cultural practitioners who describe culturally stewarded oak trees as being both large, vigorous, and dominant, as well as maintaining character, showing age, sustaining damage, and providing wildlife forage and habitat.

The term 'hack and squirt' refers to herbicide treatments used by the USFS in the mid-1900s to systemically remove oak trees from these forests in favor of higher-value timber trees such as Douglas-fir. These treatments typically left significant scarring on the trees that survived herbicide application (Figure 1). In the ordination (Figure 4), 'hack-and-squirt' damage appears to score highly in cultural value. Although these scars indeed represent structural character, it is not the 'hack-and-squirt' treatment itself that is high in cultural value; in fact, it could more accurately be described as the exact opposite; a colonial action of hardwood eradication. However, trees that have lived long enough (>75 years) to have experienced this herbicide treatment typically have higher cultural value because of other attributes that they present as old, legacy, black oak trees. This caveat demonstrates the importance of historical context and cultural interpretation when assessing and assigning value to tree structural attributes.

Black oak trait clusters

The cluster analysis produced a dendrogram that we used to evaluate group identity for each focal oak tree based on trait association. We determined that seven groups would retain the appropriate percentage of information (approximately 50%) explained in the dendrogram. This grouping cut-off choice allowed for large enough clusters to assign qualitative titles to each group based on within-group averages but retained enough clusters to make comparisons between groups. We used this new grouping variable—Clustr Group—to visualize the clusters within the PCA ordination (Figure 5). Although there was some overlap between clusters toward the center of the ordination, more disparate groupings highlighted where specific suites of traits were unique to particular clusters of trees. These clusters, as compared to the grove groupings, demonstrate that the trait-assigned clusters are different from the grove groups, indicating that grove association is not the most significant determiner of focal oak traits.

To describe the seven unique clusters, we summarized cluster attributes using the within-group means of each focal oak trait. We then assigned each mean a value of very low (<-1), low ($-0.9 < -0.5$), average ($-0.5 < 0.5$), high ($0.5 < 0.9$), or very high (>1) based on the within-group mean distance from the grand mean of 0. Using these values, we assigned a short, descriptive title to each cluster. Appendix S1: Table S3 describes justification for cluster titles, or typologies. The resulting descriptors, when overlaid on the PCA ordination, clarify what each cluster of trees represents in traits space (Figure 5).

Plot data: In summary

The restoration of culturally robust black oak structure within groves, requires understanding the values and priorities of Indigenous cultural practitioners. Monitoring movement overtime toward robust cultural character requires information on the current condition of these historically stewarded trees. By evaluating current characteristics (or traits) of trees based on practitioner-defined attributes, restoration can be tailored to fit directly into stewardship revitalization goals. This study identified tree traits correlated with each other and how those trait clusters are arranged in relation to cultural value. These trait clusters are important to conceptualize because restoration treatments, at the scale of the UPA, will be tree-specific, meaning that specific traits may dictate restoration decision making. Further, describing oak tree types based on their traits allows for further research to be more targeted at specific trees of interest. The intention of black oak restoration in the Western Klamath Mountains is to return groves to a state that is ecoculturally vigorous, productive, and robust. Presently, there are not many oak trees that score high in the attribute of cultural value and this makes sense given the history of 100+ years of colonization and suppressed Indigenous stewardship (Cocking et al., 2014; Long et al., 2016). The outcomes from this trait analysis can help inform restoration techniques to move trees into a more culturally desirable and robust state. For example, 'Leaning Trees' may benefit from topping or coppicing to correct lean and increase crown volume. Similarly, 'Smallest Trees' that experience light stress may benefit from decreased canopy closure, through techniques such as thinning. The data and findings reported here represent a starting point for long-term monitoring of these oak groves, both to inform tribally directed treatment decisions and to assess restoration outcomes once treatments have occurred. This analysis will help inform the tailoring of tree-specific restoration meant to push individual tree trait composition in the direction of high 'cultural value' with the end goal of restoring Indigenous stewardship to these groves. It is important to recognize how IDR methods inform restoration treatments that foster and facilitate the reintroduction of intentional fire

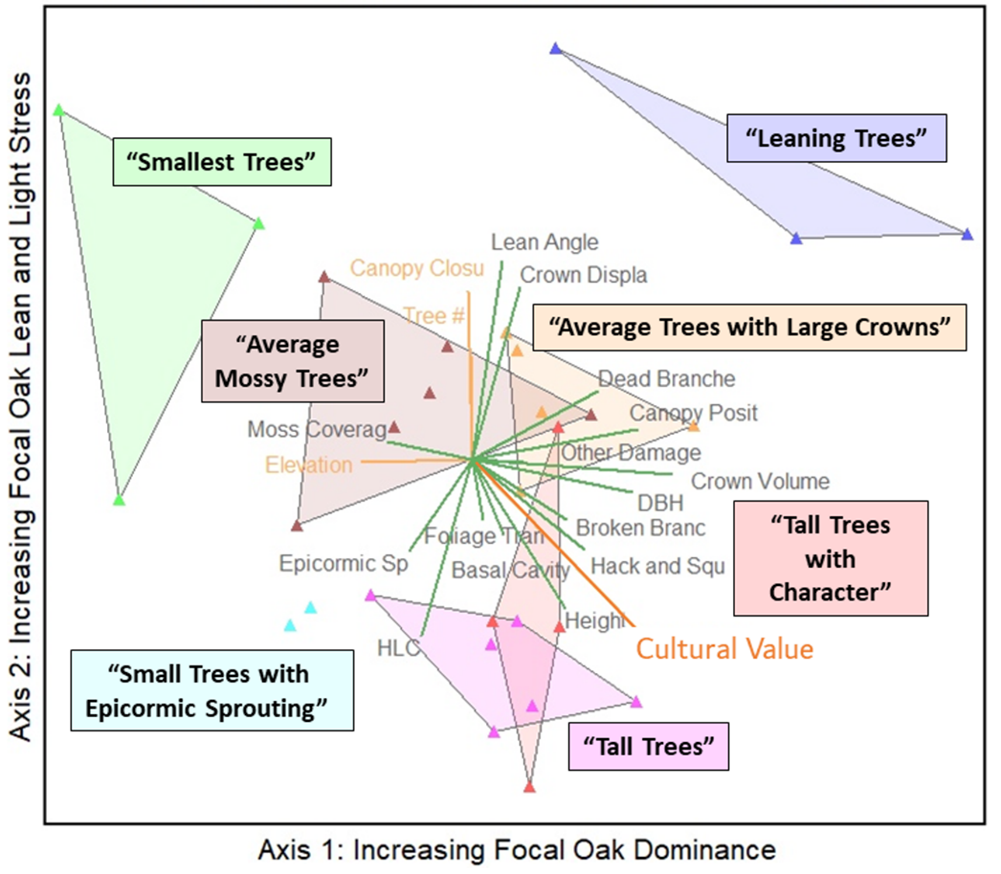

FIGURE 5 Principal components analysis ordination of focal oaks (sample units) in trait space, including typologies for groups of trees determined using a clustering algorithm. Triangles indicate focal oak location in the ordination. Triangle color, as well as colored polygons, represent the clusters assigned to each oak based on the agglomerative hierarchical cluster analysis or 'Clustr Group'. Radiating blue lines and black text indicate the focal oak traits used to ordinate the sample units in this space. Text in quotations represents descriptive titles assigned to each cluster based on trait means in Appendix S1: Table S3.

use. This research paradigm helps to guide restoration that specifically values cultural practices.

CONCLUSION

IDR reflection

The ultimate goal of this partnership was to utilize an Indigenous-Directed Research (IDR) approach to co-produce a replicable black oak monitoring protocol for long-term use by the Karuk DNR. In the production of this protocol, we attempted to balance cultural relevance, thoroughness, simplicity, and field feasibility. This protocol, baseline data collected, initial analysis, and a plan for sustained monitoring is now owned by the Karuk DNR to continue the monitoring into the future. This process formally embeds long-term legacy black oak monitoring within the Karuk DNR in support of tribal sovereignty, self-governance, and self-determination.

There are several critical components of this IDR partnership that made it successful. First, flexible, open-ended funding allowed for timelines, research questions, and methodologies to be responsive to priorities of the Karuk DNR. Second, Karuk DNR oversight in OSU processes (i.e., a Karuk DNR employee serving as a MS committee member for Jessie Thoreson) allowed for more trust to build between institutions and helped to avoid siloed thinking. Third, the *Pikyav* process for Collaborative Research provided critical oversight and facilitation for engaging with culturally sensitive issues and building relationships within the community. Fourth, as part of our *Pikyav* research agreement, we co-developed K-8 curriculum for the local elementary schools based on our research and implemented the resulting lesson plan in three classrooms in the spring of 2023. Engaging with local youth was an incredibly rewarding way to build community relationships and a critical component of this reciprocal research partnership (See Appendix S1: Document S5). Fifth, member checking throughout the process insured that our choices in protocol development and implementation were best reflecting cultural priorities of Karuk practitioners and best informing future Indigenous-directed forest management and research. Without this expectation of member checking, the buy-in from the community and the Karuk DNR for continued adaptive monitoring would not have been robust.

Black oak data reflections and limitation

As Linda Tuhiwai Smith states in her book Decolonizing Methodologies (1999), research is never innocent. The truth that is exposed by research findings is fundamentally shaped by researcher worldview and interpretation (Smith, 1999). Acknowledging and accepting that research is never innocent gives us the freedom to be transparent about the motivations driving our research questions and results interpretation. In this case, based on Indigenous-directed priorities identified through the partnership, we chose to cater the interpretation of our research findings through a cultural lens explicitly defined by Karuk cultural practitioners. We accomplished this work to the best of our ability, with the recognition that any Western-trained non-Indigenous scientist partner was limited in their ability to fully adopt a cultural lens, especially within our research timescale.

Although this study focused on describing cultural value of legacy black oak trees, cultural value is inherently qualitative and extends beyond that particular class of old, stewarded individuals. For example, in the context of black oak grove restoration, many types of black oak trees are necessary to restore a robust black oak system including recruitment of younger oak that have the potential to become legacy individuals. As Karuk cultural practitioner, C. Hillman, articulated,

> You want a good mix of young ones that don't have a huge canopy, but then you have some of those older ones in there that do, for seed. I like black oaks a lot of different ways. I don't mind a nice black oak where the top fell out and the birds and squirrels and other animals are using it for different things. I want a nice mixture of the different types of black oaks.

Similarly, there are important intangible and relational attributes of black oak that cannot be captured and quantified through an ecological protocol. These include other cultural benefits of a thriving ecocultural oak grove system including increased food security, cultural health and well-being, intergenerational learning opportunities, belonging, sense of place, and spirituality among others (Mucioki et al., 2021; Thoreson et al., 2023). That does not make these relational qualities any less important or worthy of consideration when making management decisions. This protocol is an attempt to best acknowledge factors of cultural value while still creating replicable standards that can be measured through time in an ecological protocol. The intention of this protocol is not to holistically capture what makes a black oak tree culturally valuable, but instead provide a starting point, and set of culturally responsive data, to inform Indigenous-directed adaptive management moving forward, including management choices that directly address those relational priorities.

Data and knowledge sovereignty

The final step of this partnership was to ensure that all data relating to this research were transferred into Karuk Tribal ownership. These included spatial data, field protocols and field data, interview audio recordings, interview transcripts, and field notes. Ensuring tribal sovereignty over these data was agreed to via our *Pikyav* Research Agreement and a critical component of making this research partnership successful (Karuk-UC Berkeley Collaborative, 2015). Climate change and the failure of fire suppression strategies (and resulting wildfire crisis) have increasingly led non-Indigenous land managers to turn to IKPBS to find climate adaptations and solutions (Norgaard, 2014). However, Indigenous knowledge is a fundamental cultural practice and should not be exploited. Nor can it be 'used' or 'integrated into management' in the absence of its people, or displaced from its land (Norgaard, 2014). In contrast, one of the primary motivations of Western science is often to discover broadly applicable theories, models, or patterns that can be shared and applied universally (Kimmerer, 2000). These fundamental epistemological differences in the treatment of knowledge, and expectations around knowledge use and access, point to the importance of clear expectations around knowledge sovereignty and data sharing (Norgaard, 2014). These differences do not mean that IKPBS and Western science cannot be complimentary (Rossier, 2019), and, in fact, the fruits of partnership between these ways of knowing can lead to the most creative, inclusive, and novel solutions (Lake, 2021). However, epistemological differences reinforce the importance of memoranda of understanding (MOUs) such as our *Pikyav* Research Agreement and Protocol with Agreements that contractually obligate tribal ownership of Indigenous knowledge.

The future of land management in the Western United States is predicated on the legacy—and continuation—of Indigenous land stewardship. This partnership demonstrates how IDR with a two-eyed seeing approach can effectively utilize Western science within an Indigenous science framework to inform land management decision making from a cultural and ecological perspective.

AUTHOR CONTRIBUTIONS

Jessie Thoreson: Conceptualization; data curation; formal analysis; investigation; methodology; visualization; writing – original draft. **Kathy McCovey:** Conceptualization; methodology; supervision; validation. **Colleen Rossier:** Conceptualization; project administration; resources; supervision; writing – review and editing. **Frank K. Lake:** Methodology; validation; writing – review and editing. **Reem Hajjar:** Conceptualization; funding acquisition; methodology; supervision; writing – review and editing. **Chook-Chook Hillman:** Conceptualization; methodology; validation. **Arielle Halpern:** Conceptualization; supervision; writing – review and editing. **Bill Tripp:** Methodology; validation. **Meg Krawchuk:** Conceptualization; funding acquisition; methodology; project administration; supervision; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data processing documentation can be found in the supplementary information associated with this manuscript (Appendix S1: Document S1). Data collected for this research are not publicly available due to ownership by the Karuk Tribe Department of Natural Resources (DNR). Access to these data may be available through the Karuk DNR via a Practicing *Pikyav* Research agreement or a nondisclosure agreement (NDA). Contact Karuk DNR by mail at: PO Box 282, Orleans, CA 95556 or by phone at: (530) 627-3446.

ETHICS STATEMENT

The author has read, agrees to, and abided by the ESA's code of ethics.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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