Title
Ecocultural Restoration Collaboration: Directing Scatter-Hoarding Dispersal of California Black Oak Acorns for Indigenous Futurity

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Publication Date
2021

Ecocultural Restoration Collaboration:
Directing Scatter-Hoarding Dispersal of California Black Oak Acorns for Indigenous Futurity

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THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

Ecology

in the

OFFICE OF GRADUATE STUDIES

of the

UNIVERSITY OF CALIFORNIA

DAVIS

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2022

II. Acknowledgments

I am eternally grateful to have partnered with the Maidu Summit Consortium and to work in Tásmam Koyóm. So many people from the Summit were instrumental in the creation and execution of this project. In particular, I want to thank Ben Cunningham, Ricky Prows and Reina Rogers, without whom this project quite literally would not have happened. Words cannot do justice to how honored I am to work with such dedicated and wonderful people and to be welcomed to their home.

Thank you to my committee members, Beth Rose Middleton Manning, Dan Potter and Valerie Eviner whose guidance and trust in my work was critical. I also want to thank Mario Pesendorfer who gave me invaluable advice and mentorship. Finally, thank you to my wife, Dr. Clare E.B. Cannon, whose intellectual and emotional support helped me to believe in myself and this project when it seemed impossible.

III. Abstract

Ecosystems dominated by California black oak (*Quercus kelloggii* Newberry) have been disappearing since euromerican colonization of what is now called California. These systems have historically been perpetuated by Indigenous ecological stewardship and are critical for Indigenous food ways and sovereignty. They also have considerable conservation value for non-humans and for landscape-scale climate change resilience. This research aims to contribute to the limited literature on effective mechanisms for establishing California black oak dominant systems where they have been lost. The Maidu Summit Consortium (MSC) and community members partnered in this study to trial a novel restoration method. Feeding platforms were constructed to facilitate and direct Steller's jays' (*Cyanocitta stelleri)* scatter-hoarding in order to overcome black oak seed dispersal limitations in Tásmam Koyóm (Humbug Valley) in the Sierra Nevada mountains of California. While results are limited due to the 2021 Dixie fire's catastrophic destruction of field sites, camera traps at the platforms collected ample evidence that Steller's jays could be successfully recruited to scatter-hoard black oak acorn on sites with no parent trees. All 1,694 acorns supplied to platforms were collected by scatter-hoarders, and photos suggest the majority were collected by Steller's jays. Finally, this research acts as a case study of ecological restoration research in collaboration with Indigenous land-stewards and aims to illustrate the importance and complexities of this multidisciplinary attempt at supporting Indigenous sovereignty.

IV. Introduction

California black oak (*Quercus kelloggii* Newberry) dominant systems are ecologically and culturally significant and have declined from historic levels (Long et al. 2016). Oak savannas and woodlands where California black oak was the primary tree species have shifted to conifer-dominant woodlands and forests due to fire exclusion, criminalization of Indigenous land stewardship, and timber-focused forest management (Fritzke 1997, Fryer 2007, Long et al. 2016). In Tásmam Koyóm (also Tásmam Kojom and T'asmau Kojo')—a montane valley at 1299 meters (1462 ft) in what is now called Plumas County in the northwestern Sierra Nevada mountains of California— the Maidu Summit Consortium (MSC) aims to cultivate California black oak dominant ecosystems for ecocultural functionality. I conducted this research in collaboration with the MSC to trial a novel oak seeding methodology and to establish a population of black oak under Maidu stewardship for Maidu futurity.

According to Maidu oral and written histories, Tásmam Koyóm has been an important location within the traditional homelands of Mountain Maidu since time immemorial (Ogle 1998, MSC 2021). Beverly Ogle (Maidu, Pit River) (1998: 10) explains that the valley has been identified by Maidu elders as "a chosen place by the great spirits" and enumerates the many family networks and important Maidu historical and cultural events that centered around the valley. Archeological sites and oral histories speak to the long legacy of Maidu inhabitance and stewardship of the valley. By the 1800's, euromerican settlers who settled Tásmam Koyóm for cattle ranching were rapidly displacing the Maidu people who lived there. Indian allotments were conveyed in and around the valley around the turn of the 20th century but were quickly canceled or sold without consent in order to develop the land for a damsite and reservoir

(Middleton Manning 2018). The reservoir and dam were never built, but the land remained primarily out of Native ownership, and eventually came under the ownership of Pacific Gas & Electric (PG&E; Middleton Manning 2018).

Currently, the parcels are under conservation easement by the Feather River Land Trust in partnership with the Maidu Summit Consortium (MSC). The MSC was formed in part to attain this easement, when PG&E was made to divest of the land as part of a 2001 bankruptcy settlement with the CA Public Utilities Commission (Middleton Manning 2018, MSC 2021). The MSC easement constitutes 2,325 acres, 1,302 of which are meadow containing Yellow Creek at an elevation of 1299 meters. The surrounding acres rise in elevation to 1470 m of yellow pine forest (*Pinus jefferyi, Pinus ponderosa*), mixed conifer forest and shrubland. Surrounding the MSC lands is Plumas and Lassen National Forests and private ranching and timber companies' properties. The MSC is a nonprofit Native land trust formed in 2003 as a collaboration of nine Maidu organizations (Middleton Manning 2018). According to the MSC purpose statement:

> The Maidu Summit Consortium envisions re-acquired ancestral lands as a vast and unique park system dedicated to the purposes of education, healing, protection, and ecosystem management based upon the Maidu cultural and philosophic perspectives, as expressed through traditional ecology (MSC 2021).

The lands of Tásmam Koyóm were transferred to the MSC on September 20, 2019, and the organization has been stewarding it since for ecocultural resilience. This research project is part of a larger effort by the MSC to care for the lands of Tásmam Koyóm for Tribal resilience in perpetuity. All research was done with the permission and directive of the MSC board and community (further enumerated in the discussion section). Together we identified the current paltry presence of California black oaks in Tásmam Koyóm as a pressing ecocultural concern.

California black oak has great cultural significance to Maidu people and the very few individuals on the property have been severely encroached on by conifers due to a lack of management. Because mature fruiting trees were not found within a seed dispersal range, seed dispersal limitation was identified as the first barrier to overcome to establish an oak grove. Inspired by ongoing research by Motta, Sillet, and Pesendorfer (2020) on Steller's jays caching behavior of acorns provided on feeding platforms, we designed and implemented an experiment to direct the functional role Steller's jays and other scatter-hoarders serve as acorn dispersers for the cultivation of an oak grove where no seed source currently occurs.

To elucidate the contribution of this research to the field of community-engaged ecological restoration, I will review literature on three topics: (1) considerations for partnership with Indigenous communities in research and ecological restoration (2) California black oak ecology and cultural importance, (3) black oak restoration methodologies, particularly the use of feeding platforms for scatter-hoarders. In the methods sections, I will explain how the MSC and I identified the goals of the research and came to design and implement it. I will elaborate on the methodology and results of the experiment, co-created with the MSC, to trial feeding platforms as mechanisms to establish black oak seedlings. Finally, I will discuss the principles I used to guide this collaboration as well as the successes and lessons learned from the process and experiment.

V. Chapter I

Literature Review

Indigenous sovereignty and collaboration

Ecologists, conservation scientists, and restoration practitioners have a growing interest in collaborating with Indigenous peoples in whose lands they work. Many Tribes have Indigenous scientists and conservation experts, however, when researchers, like me, are exogenous and non-Indigenous, a host of ethical considerations are of paramount concern. Literature in the social sciences concerning these questions, past failures and concomitant paradoxes is abundant (see Menzies 2001, Tuck and Yang 2018, Smith 2021). Non-Indigenous restoration ecologists and conservation scientists would be well served by understanding the inherent complexities of research done in collaboration with Indigenous peoples. Of note, are both the success stories and cautionary tales shared by Indigenous scholars who are members of both communities (see McGregor 2004, Kimmerer 2011, Lake and Long 2013). These experts are sometimes overlooked in studies about Indigenous land caretaking (Leonard et al. 2020). Moreover, these examples give insight into the perils and opportunities that research, as a method of knowledge production, affords Indigenous peoples.

Collaborations between non-Indigenous researchers and Indigenous community members may encounter several obstacles. For instance, such collaborations face issues of differing epistemologies and power imbalances. Academic knowledge production structures have both minimized and appropriated other forms of knowledge in order to reify and privilege scientific research (Nadasdy 1999, Tuck and Yang 2018). As Linda Tuhiwai Smith (Ngāti Awa, Ngāti Porou, Tūhourangi) states in *Decolonizing Methodologies* “Knowledge and the power to define what counts as real knowledge lie at the epistemic core of colonialism" (Smith 2021). Non-Indigenous researchers often bring to collaborations the assumptions of the universality of scientific knowledge and a reductive understanding of traditional ecological knowledge (TEK) as simply "the knowledge Native people have about their environment" (McGregor 2004: 395). Indigenous forms of knowledge are epistemologically and ontologically different. Robin Wall Kimmerer explains that TEK has not just "biological knowledge" but includes a praxis and "worldview of respect, reciprocity, and responsibility" (Kimmerer 2011: 259). The assumption of universality and supremacy of research-based knowledge can lead to errors in findings and cause harm to Indigenous communities. The ahistorical erasure of the ecological impact of centuries of Indigenous land management in what is now called North America is a good example of the ways cultural tropes – in this case Indigenous erasure – distort scientific thinking (Leonard et al. 2020). Recognition of the subjectivity and limits of scientific knowledge is a foundational understanding needed to create a successful collaboration. For instance, Tengo et al.'s (2014) *Multiple-Evidence Base Approach* describes how knowledge evaluation should happen *within* epistemologies. Communication and compromise *across* these epistemological differences, is fundamentally challenging and necessary for true partnership. Non-Indigenous contributors need to internalize that equitable collaboration requires that different knowledge systems are valued equally and used synergistically, not hierarchically (Tengö et al. 2014).

The most troubling failure of collaborations between non-Indigenous researchers and conservation practitioners is the perpetuation of concentration of power away from the local people who contribute valuable knowledge toward centralized bureaucracies (Nadasdy 1999, Diver 2016). This can happen when TEK is treated merely as data contribution to research questions exogenously designed. By filtering TEK into scientific preconceptions of relevant information for conservation decision-makers, scientists can make careers out of extracting what is useful for their preconceived objectives (McGregor 2004). This mirrors a history of knowledge and other forms of extraction from Indigenous peoples by settler colonialist structures (Tuck and Yang 2018). To guard against this, Indigenous collaborators must have ownership of the knowledge produced as well as power to make conservation management decisions, in a word, sovereignty. Structures where all stakeholders have equal decision-making power and input is, not coincidentally, a foundational strategy of successful collaboration as outlined by McGinnis and Ostrom (2008).

Academic institutions are implicated in a long and ongoing history of settler colonialism and Indigenous dispossession (see Lee and Ahtone 2020, de Paul 2020). A storied record of proclivity toward knowledge extraction and environmental colonialism makes researchers from academic, governmental, and environmental organizations historically untrustworthy partners (Karuk-UC Berkeley Collaborative 2011, Tuck and Yang 2018, Smith 2021). Consultations with Tribes by natural resource agencies have often been treated as a box to check, while the labor, knowledge and recommendations Tribes give go ignored (Baldy 2013). Conservation and restoration efforts have at times both overlooked and conflicted with Tribal priorities in both methodology and purpose (Long et al. 2020). Ecological dominance is an integral part of settler colonialist systems (Whyte 2018). Conservation efforts are not exempt from this systemic violence just because they have self-proclaimed noble aims. Conservation as a construct has been used as a tool in the colonial project, for example to displace and dispossess Indigenous peoples to “preserve wilderness” and convert Indigenous homelands into National Parks

(Kantor 2007). Ecological restoration without inclusion of Indigenous leadership is complicit in this system of control. Conservation and natural resource management often operate in an ahistorical public good framework, but this belies the lived and historical realities of the land (Middleton Manning 2018). More work is needed to establish a foundational awareness of these failures in conservation sciences, and to establish methodologies that are inclusive of Indigenous peoples and not harmful.

Conservation and restoration efforts also benefit from empowerment of Indigenous caretakers for several reasons. As outlined by the Society for Ecological Restoration, the revitalization of ecosystems requires the recovery of cultural resources “including support for the cultural survival of indigenous peoples and their languages as living libraries of traditional ecological knowledge” (SER 2004). Local buy in, whether Indigenous or not, is recognized as contributing to restoration and conservation projects’ success (Higgs 2005). Community engagement in conservation and restoration can engender care and investment by the people directly surrounding and most impacted by an environmental system. These efforts can create political and economic incentive to support policies and contribute to execution (Kimmerer 2011). Economic interdependence between communities and their environmental can be further woven together for increased resiliency of both (Kimmerer 2011). Indigenous peoples are obvious stakeholders who already often “depend on the integrity and productivity of their immediate environment”(Senos et al. 2006:393) and TEK practitioners aim to promote the wellbeing of all members of the ecosystem, human and non-human (Long et al. 2020). The knowledge and ethos of TEK practitioners speaks to a culture of responsibility and caretaking that is desperately needed in long-term management to attain goals of restoration and conservation strategies (Senos et al. 2006). Furthermore, prioritizing Indigenous goals and leadership helps prevent “shifting baseline syndrome” that is perpetuated by ahistorical assessments of rapidly changing ecosystems (Long et al. 2020). Although Indigenous land stewardship has shaped ecosystems for millennia, there is not a strong foundation of knowledge concerning this history in most ecology/natural resources academic learning environments (Leonard et al. 2020). Additionally, much of the knowledge held within Indigenous communities is proprietary and not to be shared with researchers or practitioners (Tuck and Yang 2018). Because of these factors, in order to have a comprehensive understanding of historical reference sites, hyper-local conditions, and methods for holistic ecosystem recovery, restoration projects should include Indigenous experts, TEK practitioners and community members. Most importantly, it is an ethical imperative to prioritize the people whose homeland the research is predicated on. Restoration and conservation projects are inherently political and cannot ignore historical and political realities.

To prevent these past harms from being continually replicated, several research consortiums have been working to create guidelines for research by non-Indigenous scholars that impacts and engages with Indigenous groups (see Karuk-UC Berkeley Collaborative 2011, CLEAR Lab 2016). Shared goals of these guidelines are to create collaborations that are non-exploitative, have informed consent, prioritize Indigenous expertise and community-defined goals and protect sovereignty and property (knowledge, cultural, food or otherwise). It remains to be seen whether these types of efforts can be widely adopted to prevent the type of knowledge extraction and power consolidation that has marked the history of research engaging with Indigenous peoples. This approach is iterative, not generalizable and centers

Indigenous sovereignty throughout the pursuit of scientific knowledge. Doing so necessitates a re-thinking of the ways we do scientific research, navigate potential conflicts, and advance ecological insights collaboratively. Successful collaboration in ecological restoration projects should be measured by the both the biological and cultural outcomes. Further exploration of these considerations as they relate to this research process will be explored in the discussion section.

Cultural importance of California black oak

Oaks (*Quercus* spp.) are significant to the Indigenous peoples of what is now called California for food, cultural resources, and as habitat for wildlife. Acorns have been and continue to be a critical food source for people and for game species (Anderson 2009). Records show that Native peoples historically gathered, processed, and stored thousands of pounds of acorns per family per year (Long et al. 2016). California black oak (*Quercus kelloggii* Newberry) supplies an important food source for Native peoples both within its range and beyond, providing the favored acorn among many Tribes (Long et al. 2016). There is evidence that along with salt, black oak acorn was the most widely traded item in California pre-contact (Anderson 2005). As stated by Danny Manning (Maidu) in “Restoring California black oak ecosystems to promote tribal values and wildlife” by Long et al. (2016; 17), “Black oaks are significant to the Maidu because they were/are one of our primary food sources” as well as providing materials for the construction of important items uses like cradleboards. Black oak acorns have a large nut, high oil content and store well because of high tannin levels; these tannins also enhance texture and flavor and have dietary benefits (Long et al. 2016). Numerous sites in Tásmam Koyóm hold hundreds of acorn grinding stones, where acorns were processed for generations.

In addition to providing a staple food for numerous Tribes, materials from black oak trees are used in basketry and construction, dyes, and medicine (Anderson and Roberts 2003). Important items such as cradleboards, digging sticks and hand game drums are examples of the many items built from black oak materials (Ogle 1998, Anderson 2005). Black oak plays an important role in social, spiritual, and ceremonial activities around tending and harvesting (Long et al. 2016). This type of comprehensive resource supply, cultural significance, and trade value has led some to consider California black oak a ‘cultural keystone’ species (Long et al. 2016). Cistancho and Vining (2004: 155) describe a culturally defined keystone species as one “whose existence and symbolic value are essential to the stability of a culture over time.” This type of universalizing terms, though reductive, can help in articulating conservation value in, for example, Cultural Impact Assessments. The continuation and preservation of California black oak ecosystems is central to Maidu biocultural and food sovereignty; Beverly Ogle (Maidu) (1998) describes black oak acorn bread and mush as central to the Maidu diet. Food sovereignty is a broad term used in many contexts (Grey and Patel 2014, Whyte 2017); I use it here to describe the right of Maidu peoples to continue their traditional food ways and have self-determination over the cultivation of their food. Biocultural sovereignty is described by Cutcha Risling Baldy (Hupa, Yurok, Karuk) (2013:5) as a “means of resistance and revitalization” through relationship with the land by “continuing biological and cultural knowledge of gathering in northern California.” These terms also serve as a reminder that this right is inextricable with the larger fight for political and cultural sovereignty. The ongoing settler colonial project of land dispossession and forced assimilation attempts to separate Indigenous peoples from their traditional food ways(Matties 2016). Access to land and the ability to perform ceremonial, environmental, cultural stewardship of food ways in Indigenous homelands have been systematically decimated by settlers, resulting in monumental shifts in diet, health, and cultural resilience (Norgaard et al. 2011). Resistance to this genocidal strategy is abundant throughout Indian country (see Daigle 2017, Mihesuah and Hoover 2019, Wires and LaRose 2019) and the Maidu project of land rematriation and black oak acorn cultivation are once example of this movement.

California back oak is also a critical species for wildlife (Fryer 2007), which has cultural importance for supporting game animals for consumption but also corresponds with a cultural responsibility to steward the land as home for non-human relations (LaDuke 1994, Kimmerer 2011, Long et al. 2020). Indigenous languages, spiritualities and social relationships are often deeply intertwined with the plants, animals, and landscapes in their ecosystems; reciprocal relationships with these beings are described by Robin Wall Kimmerer (Potawatomi) as a responsibility to kin where each takes care of the other and in the "interconnectedness of land and people, all flourishing is mutual" (Kimmerer 2011: 271). Farrell Cunningham [*yatam*][1](Mountain Maidu) (2005) ties the perpetuation of Maidu culture to traditional ecology and the daily acts of taking care of the land (Cunningham 2005). This work can reforge human relationships to the environment disrupted by settler colonialism and strengthen Tribal resilience and self-determination (Whyte 2018). Restoration of black oak ecosystems and

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[1] Maidu respective term for the departed.

revitalization of stewardship opportunities presents an avenue to nurture ecocultural resilience and Indigenous futurity.

California black oak ecology and historical changes

Quercus kelloggii is one of the most widely distributed oaks in California and its ecological history is bound up with Indigenous land stewardship (Long et al. 2016). It currently ranges throughout California into southern Oregon, with an isolated population in Baja California, Mexico (Long et al. 2016). Its elevation ranges from 61m to 1438m based on precipitation rates and latitude (McDonald 1990). In Northern California - the region of the field sites for this research - California black oak occurs on west and south facing slopes above 1067m, on all aspects between 762 and 915m and only on north slopes below 300m (McDonald 1990). It is abundant in woodland, ponderosa, and mixed-conifer forests along the western Sierra Nevada and the lower slopes of the Klamath and Cascade mountains (Fryer 2007). Waddell and Barret (2005) estimated that California black oak occurs on 2.9 million ha, or 7% of California land, and is evenly distributed on private land and national forest. Because timber inventories often ignored hardwood species in California, it can be difficult to quantitatively compare black oak populations of today to pre-colonization forests (Long et al. 2016). However, there is evidence that California black oak dominant ecosystems were more widespread pre-euromerican settlement and that stand structure has altered to more conifer-dominated forests (Fryer 2007, Cocking et al. 2012, Schriver et al. 2018). Further evidence of this is supported by oral traditions that have documented a significant change in the quality and structure of acorn collections sites (Anderson 2009). In a survey from 1990, California black oak was the predominant tree in less than one fifth of where it occurs, meaning where it occurs it is most often highly encroached upon by conifer species (Waddell and Barrett 2005).

Fire suppression and criminalization of cultural burns as well as forced displacement and dispossession have prevented Indigenous caretaking and land stewardship since contact (Kimmerer and Lake 2001). Because of fire exclusion starting in the 19th century, black oak dominant stands have declined and stand structure has shifted toward conifer predominance (Fritzke 1997, Fryer 2007, Cocking et al. 2012). Long et al. (2016) argue that fire regimes could have shifted as early as the late 1700s because as Indigenous peoples' populations decreased due to disease and extermination policies, land stewardship footprints would have diminished. Furthermore, black oaks were systemically removed to increase conifer lumber production in the 20th century (Long et al. 2016). Frequent low-intensity surface fires are necessary for California black oak to be dominant, without which they tend to be replaced by shade-tolerant conifers (Parsons and DeBenedetti 1979, Fryer 2007). California black oak is shade-intolerant throughout its life cycle; saplings develop low caliper until reaching full sunlight and at any age if they are overtopped, eventually succumb (McDonald 1990). When open-grown, black oaks grow in trunk diameter and become multi-branched and broad (McDonald 1990). Competition for light by conifer encroachment leads to higher structural branches, thinner crowns, and less acorn production (McDonald 1990). California black oak often associates with fire-prone species and survives by resistance to stem mortality in low intensity fires (Cocking et al. 2012).

Lower intensity fires were historically and are currently used by Indigenous peoples to prevent encroachment by shade tolerant species like *Calocedrus decurrens* and *Abies concolor*, which can grow to overtop black oaks (Fritzke 1997, Anderson 2005, Long et al. 2016).

Reduction in competition allows trees the sunlight and space necessary to develop large, broad, and low branches with high acorn production (Lake and Long 2013). Many acorn harvesters prefer to knock acorns out of trees or climb into trees to harvest to avoid diseased acorns (Anderson 2005). Shaded California black oaks develop branches 6-12m above ground, making harvesting inaccessible, compared to open-grown trees, which can have lower branching, at times nearly touching the ground (Fryer 2007). In addition to developing preferable branching structure, fire technology is also used under California black oaks by Indigenous peoples for disease prevention, to increase herbaceous and fungal harvesting resources underneath, and to prevent high-intensity, crown-burning fires (Anderson and Roberts 2003, Lake and Long 2014). California black oak is deciduous and when open grown allows increased sunlight for high levels of biodiversity, particularly of herbaceous plants for basketry, medicine, and other resources under its canopy (Long et al. 2016). Fire is used to reduce competition for desirable plants as well as to stimulate growth of morels (Long et al. 2016). California black oak have the most flammable litter of California oaks as well as low fuel accumulation; this aids in the cultivation of frequent low intensity fires (Skinner et al. 2006, Long et al. 2016). However, California Indians have notoriously inadequate land ownership and limited opportunities to cultivate ecocultural resources (Middleton Manning 2018, Long et al. 2020). The history of California black oak distribution and stand structure is highly altered by current modified fire regimes lacking in Indigenous management. Without this frequent low intensity disturbance, acorn collection sites are less abundant, acorns are lower quality, and this specific ecosystem and its associated ecocultural resources is in decline.

California black oak seed dispersal

California black oak seed is dispersed by gravity (rolling downhill) and by seed-caching animals (Fryer 2007). Unretrieved cached seed is dispersed farther and is more likely to germinate (McDonald 1990). The distance that animals will disperse seeds is context- and species-dependent. Borchert and Tyler (2010) studied the spatial distribution of California black oak seed dispersed by birds and mammals after a stand-replacing fire. They searched in a 25m radius around a source plot of acorns (implanted with magnets) provided and found the average cache was 5.27m but presumed most of the seed was transported by rodents (Borchert and Tyler 2010). Long et al.'s (2016) report on California black oak shared that the longest distance a black oak seedling reported was 50m away from the nearest potential parent tree. Animal-mediated transport is critical to the dispersal of California black oak seed, particularly up-hill and over long distances.

In the ecosystems of Tásmam Koyóm, Steller's jays (*Cyanocitta stelleri)* are the most important California black oak acorn dispersers. Steller's jays are corvids associated with patches and edges of forests in western North America at elevations of 900-3,000 m (Gabriel and Black 2010). They are socially monogamous, and pairs defend territory close to their nests, but have overlapping ranges with neighboring conspecifics (Gabriel and Black 2010). Steller's jays are one of the many corvid species that buries seed in distributed locations (synzoochory) for later consumption (Pesendorfer et al. 2016a). They cache food throughout the year for short-term (days) and long-term (months) storage periods (Rockwell et al. 2013a). This behavior is termed "scatter-hoarding" and is fundamental to the dispersal and population dynamics of large-seeded trees (Rockwell et al. 2013b). Scatter-hoarding behavior is socially and ecologically complex (Kalinowski et al. 2015) and is difficult to predict in part because it has not been widely studied in wild, unmanipulated corvids (Pesendorfer et al. 2016b). Fuchs et al. (1999) measured Steller's jays dispersal distances from *Quercus garryana* parent trees that ranged from 3cm-600m from parent trees in British Columbia, Canada. They did not share the average or most frequent distance acorns were transported, but they did anecdotally observe some individuals transporting what appeared beyond 1km (Fuchs et al. 1999). Kalinowski et al. (2015) measured Steller's jays caching locations of peanuts from a feeding platform to compare transport distances in different social contexts. They found that the location of the cached peanuts ranged from 2-120 m from feeders and was dependent on the presence of and relationship to other Steller's jays. Solitary Steller's jay's mean caching distance was 12m, when a mate was present 23m, and with a conspecific neighbor present 33m. One study of Steller's in Nevada measured average transport distance of *Pinus lambertiana* seeds at much farther distances (203.7m), however these seeds are significantly smaller and lighter than black oak (*Quercus kelloggii)* acorns (Thayer and Vander Wall 2005).

There is evidence that seed-caching dispersal distances can also vary based on habitat and seed availability, which is particularly relevant to California black oak as a masting species (Fryer 2007, Pesendorfer et al. 2016a). However, the effect of seed availability on caching distances has not been studied in wild, unmanipulated Steller's jays (Pesendorfer et al. 2016b). Pesendorfer et al. (2016b) investigated this effect on wild, unmanipulated population of island scrub jay (*Aphelecoma insularis*) endemic to Santa Cruz Island, California and a closely related species to Steller's jays. The mean distance scrub jays dispersed acorns of *Quercus agrifolia* and *Quercus pacifica* was 38.5m with a maximum distance of 400m, and caching rates and distances increased with higher acorn availability. Additionally, caching rates were negatively correlated with conspecific territorial aggression, but dispersal distance was unaffected. Kollman and Shill (1996) showed that European jays, *Garrulus glandularius*, show preferential caching in disturbed and mown habitats (Kollmann and Schill 1996). Steller's jays in one study preferentially cached acorns in habitats with sparse herb vegetation and dense shrub or tree cover (Fuchs et al. 1999). Several studies have shown that jays preferentially cache adjacent to or under small shrubs, which also have the potential to facilitate seedling germination and recruitment (Kollmann and Schill 1996, Wenny 2001). These studies illustrate that caching behavior and spatial patterns of transport are species-, habitat- and context-dependent and not entirely understood. One common finding is that dispersal distances have a long-tailed distribution, with farther caching locations becoming less frequent.

There is no localized or species-specific research to be able to accurately predict the distance or spatial pattern of California black oak acorn dispersal by Steller's jays in the Sierra Nevada. It can be reasonably assumed, due to the lack of California black oak seedlings in Tásmam Koyóm, and the most relevant observations of dispersal distances in the literature being under 1km, that dispersal limitation is an obstacle to overcome in establishing an oak population at the field site. The 2,325 acres of Tásmam Koyóm has very few observed California black oaks on the land. Two trees were observed over 1km away, produced few acorns and were estimated to be under the 80 years of age when black oaks start reliably producing large crops of acorns (Long et al. 2016).

Seed dispersal direction in restoration

Within the growing body of literature about the importance and mechanisms of scatter-hoarding corvids in tree population dynamics, are implications for how this mutualism can be leveraged for restoration purposes (Pesendorfer et al. 2018). There is recognition of the 'ecosystem services' seed-caching corvids can provide for habitat restoration and conservation (Whelan et al. 2008, Pesendorfer et al. 2016a). Some studies have measured the effectiveness of leaving seed-source trees for Eurasian jays or creating habitat structures that suit nutcracker caching preference for pine seeds (Pesendorfer et al. 2016a). Other research has studied frugivore seed dispersers in tropical forests and zoochory (seed ingestion and defecation) enhancement by building artificial perches (Wenny 2001, Pesendorfer et al. 2016a). Very little research has explored the potential for targeting or augmenting scatter-hoarding by corvids for directed seed dispersal. Scatter-hoarders continue to cache seeds after satiated, so large seed availability should lead to higher numbers of unretrieved seed and higher recruitment (Pesendorfer et al. 2016a). Current research is underway to test the effectiveness of providing feeding platforms with acorns to facilitate and enhance oak restoration in a multi-year study on Santa Cruz Island, California. In it, Motta et al. (2020) aim to answer whether acorn caching by scrub island jays can be enhanced on post-fire landscapes to facilitate oak regeneration. They placed 10 acorns at a time on platforms along with peanuts for baiting. Researchers vocalized in order to attract jays to platforms and caching distances were observed and measured. So far, in unpublished results shared by Mario Pesendorfer 67.5% of the 1,020 *Q. pacific*a acorns put on platforms were ignored, 14.3% were dropped or eaten and 18.1% were cached. Feeding platforms were mounted 25-40 m from the transition of intact habitat into a fire scar and acorns were cached between 3.6m to 306.6m from seed platforms. Of the cached acorns, 80% were buried within fire scar compared to intact habitat and most jays traveled in the direction towards intact habitat. Mean dispersal distance was 65.8m ±3.1m (± standard error), where transport over long distances was observed at a much lower frequency than shorter flights. Mean dispersal distances differed between the 6 platforms, ranging between 35 m to 124 m. The highest frequency distances of all cached acorns were between 40 and 50m and dropped precipitously after 70m. The authors were not able to find seedlings in the preliminary results but planned to return for more extensive searches.

Oak restoration plantings

There is not an abundance of California black oak restoration installation examples in the literature. Of the research that exists, one study near Idyllwild, California at 1400 m elevation showed a 75% survival rate in the first year of California black oak seedlings planted in chaparral (Smith and Roberts 1982). This study measured no effect from stratification on seed germination or watering on seedling survivorship. It did show that fall-planted trees had higher survival and growth rates (Smith and Roberts 1982). In an eight-year study in Yosemite Valley, seedlings treated with fertilizer showed no significant difference in survival, growth, and vigor (Fritzke 1997). However, tree shelters, both open plastic mesh or solid plastic, improved survival, growth, and vigor (Fritzke 1997). Overall, 172 of 500 transplants in this study survived over 8 years. Other studies have also shown that recruitment is hindered by deer browse (Long et al. 2016). Several studies have shown that seedling recruitment is usually high, but sapling and pole size classes drastically lose survivorship (Fryer 2007).

California black oak seedling emergence was observed in one study at 1,130m elevation from April 8-July 8 (Fryer 2007) and has been observed from May through August in the areas around Tásmam Koyóm. Black oak seedlings can grow 5-10 cm in height in the first 30 days after emerging and up to 20cm in the first year (McDonald and Tappeiner 2002). Post-fire sites are beneficial for oak seedling establishment as California black oaks prefer open mineral soils or light duff for establishment (Fryer 2007). California black oaks do not thrive in heavy clay, but otherwise do not have a strict soil texture requirement (Fryer 2007).

Methods

Project history and identification

This conception and design of this research project resulted were created in partnership with the Maidu Summit Consortium (MSC). In my role at the UC Davis Arboretum and Public Garden, from 2017-2019, in partnership with the Intertribal Agricultural Council, I propagated and grew out culturally important native plants for restoration plantings in Tásmam Koyóm. The plants were identified by MSC board members and volunteers, seed was collected, then shared with me and propagated at the arboretum nursery facilities. We then planted the propagules in various sites throughout Tásmam Koyóm. Over time as these relationships developed, I was invited by the previous MSC Executive Director, Alisha Wilson, to help facilitate the 2020 MSC Field Camp, an annual community gathering and workday in Tásmam Koyóm. After co-leading seed gathering and starting workshops and elderberry plantings with Reina Rogers, we held a community discussion about oaks —their cultural uses and significance, ecology, and cultivation. The MSC traditional ecological knowledge (TEK) advisory board, Maidu community members and other volunteers and scientists all sat together to discuss the future of oaks in Tásmam Koyóm. The TEK advisory board shared ecological knowledge and cultural significance of California black oak and I shared what I know about its cultivation and ecology. In this discussion, the lack of California black oak in Tásmam Koyóm was identified as an important issue to address. As elder and MSC Board Member Lorena Gorbet (Maidu) stated, “You look around and the most important thing you don’t see, oak.” Gorbet identified west facing slopes of shrubland along the entrance to Tásmam Koyóm as potential planting sites. This area is the location of 2013 back burn fire of approximately 50 acres in Tásmam Koyóm. The conifer trees in the area were then salvage harvested by PG&E without permission from the MSC. She described her vision of the site transformed from this painful event to an oak savanna.

I posed several questions to the group, including: (1) Where would the TEK advisory board recommend black oaks be planted for biocultural use? (2) Where should seed for plantings be sourced from? (3) Are there culturally significant specimens that could serve as seed source? (4) What TEK/cultural practices should be implemented in their cultivation? (5) Are there related questions that need answering? I presented several ideas for the types of questions that could be answered with a potential experiment such as: (1) What seed provenance would be most adapted for projected climate changes in Tásmam Koyóm? (2) Can scatter-hoarders be cultivated as collaborators to disperse acorns? Question (2) pertaining to Steller’s jays received enthusiastic interest from those present. Several people suggested including camera traps as part of the research design to help identify the animals present in the valley. This discussion and the feedback and answers to these questions completely guided the goals and methods of this experiment. After the discussion, Ben Cunningham, Chairperson of the MSC Board, took us to several locations to identify seed sources and collect acorns.

Research questions and experimental design

Two goals emerged from these discussions with MSC and TEK advisory committee members: (1) to establish oak trees in a salutary stand structure for future acorn collection; (2) to develop and answer the following research questions:

1. Will Steller's jays and other scatter-hoarders cache acorns supplied at feeding platforms?
2. Will jays disperse within a 50 m radius, enabling targeting of specific areas? What would seedling density within 50 m be?
3. Will unretrieved cached seed germinate? What percentage of seeds supplied to platform will germinate?
4. How many unretrieved cached seedlings will survive their first summer? How will this compare to survival rate of planted seedlings grown in a nursery setting collected from the same seed source and planted in similar habitat?
5. How does the cost and labor investment differ between seeding platforms and seedlings plantings?

To answer these five questions, we designed the following experiment. Two feeding platforms were built and mounted to attract Steller's jays at two distinct sites within the preferred area expressed by the TEK advisory committee. Platforms were supplied with acorns collected from black oaks under 5km away at similar elevation to experiment plots. Camera traps were mounted to identify who visited the platforms and because community members were interested to see wildlife involved in research. Fifty-meter radii around the platforms were flagged and surveyed for black oak seedlings emerging from unretrieved cached acorns. Two additional plots were planted with nursery-grown black oak seedlings from the same seed source. These plots were planted with standard restoration installation of seedlings in corresponding 30 m circle plots near the platform plots with the purpose of comparing survivorship with cached acorn seedlings. Planting seedlings also increased the likelihood that some trees ultimately would establish in Tásmam Koyóm, thus accomplishing community-defined goals. Further details of the methods of this experiment follows.

Platform and planting site selection

The four sites were chosen for cultural and ecological reasons. Within the area identified by the TEK advisory committee, 4 sites were found to be ecologically compatible with black oak soil, aspect, elevation, and drainage requirements. California black oak occurs on west and south facing slopes above 1067m, is shade intolerant and benefits from the mineral soils, light duff and lack of heavy clay soil found at these sites (McDonald 1990, Fryer 2007). Fifty-meter radii around the platforms are west facing and have exposed mineral soil and duff for Steller's to cache seeds. Both platform and planting sites are in the elevation rise that surrounds the meadows of Tásmam Koyóm (Humbug Valley) in Plumas County, California. Sites were also selected that are close to the Yellow Creek campground road and have primarily gentle inclines for future acorn collection accessibility. Areas around sites were assessed to find any other California black oaks within 1km to preclude caching from alternate seed source. The sites are within fire scars from a 2013 controlled back burn and post-fire salvage harvest that left very few scattered conifers over an approximately 50-acre site. Sites have mosaic of varying levels of shrub cover, open mineral soils, slash, and forbs. Mario Pesendorfer advised that some functional vegetative structure could be attractive to Steller's jays (personal correspondence, 2020). Several studies have shown that jays preferentially cache adjacent to or under small shrubs, which also have the potential to facilitate seedling germination (Kollmann and Schill 1996, Wenny 2001). The sites have patches of heavy shrub cover as well as open areas with sparse vegetative cover. Each site had at least 2 mature conifers within the plots as well as conifer seedlings under 10 years old. The conifer and shrub cover are patchy and assessed to not present too dense a cover to prevent seedling establishment; however, the management plan being co-created by the author and the TEK advisory committee will address the long-term problems of conifer encroachment and shrub competition to oak recruitment. Mechanical removal as well as controlled burns will be used to reduce competition. Planting sites were situated close to platform sites to match conditions; however, this increased the risk of acorns being cached within planting sites. Planted seedlings were flagged with pink tags and were protected with tubes to prevent misidentification.

Platform 1 (40.141819, -121.242923) was mounted at 1344-meter elevation and the 50m radius around it includes 3 mature conifers, patches of shrub dominated by *Ceanothus cuneatus,* patches of open soil, herbaceous annuals and perennials, and minimal downed trees and slash. The acorn platform was erected 4m east of a solitary mature pine which was used to post a camera trap 1. Planting site 1 was situated with the center of the 30m radius plot being

100m southwest of platform 1. Planting site 1 and platform site 1 were similar in shrub cover and elevation change.

Platform 2 was erected approximately 475 meters away from platform 1, at 1329 m elevation with a camera trap mounted 2m south on a 2m wood post. The 50m radius around platform 2 encompassed the Yellow Creek Campground Road flanked by a stand of a dozen dense, mature conifers, patches of *Ceanothus cuneatus* dominant scrub, an area of slash with minimal vegetation, and open mosaics of bare mineral soil, herbaceous annuals, and perennials. Planting site 2 was situated with the center of the 30m radius plot approximately 200m south of platform 2 and had similar vegetative and soil conditions.

Figure 1. Planting site 1 – volunteers planting seedlings

Figure 2. Planting site 2 – Ricky Prows (MSC board), Ben Cunningham (Chairperson of MSC board), Reina Rogers (MSC volunteer), Abbey Hart (author) planting seedlings

Figure 3. Platform site 1 after Dixie fire, October 2021

Figure 4. Platform site 2, the author after mounting the platform and camera trap

Acorn collection

With MSC volunteers, 2,059 acorns were collected on September 26, 2020, and October 10, 2020, at 5 locations identified by Ben Cunningham, Chairperson of the MSC board. The five collection sites, each with between one and five trees, were approximately 4 km west from platform and planting sites and ranged from 1307m elevation to 1380m. Acorns were collected by hand from the ground with MSC volunteers and sorted to remove insect damaged seed. Seed was kept in loosely closed plastic bags 5 degrees Celsius refrigeration until planted or put on platforms. Seed was divided with 18% of the seeds from each collection site being set aside for nursery propagation and the remainder mixed together to be split evenly between the two platforms. Collection and sorting took approximately three hours with travel time for the authors and three volunteers; two of the sites had heavy acorn production and three had minimal.

Feeding platform experiment

Acorn feeding platforms were designed as a mechanism to overcome seed dispersal limitation by providing acorns to Steller's jays within the range of the selected site. Acorns were collected by three MSC volunteers and me for three hours near Tásmam Koyóm. Platforms were modeled after Motta et al.'s (2020) study and methods for attracting jays were shared in personal correspondence with Mario Pesendorfer in November 2020. On October 23, 2020, MSC volunteers helped build and erect 2 platforms on 4"x4'x8' wood posts. Platforms were built with 1 & 1/8-inch plywood into 12"x12" with 2" rim and drilled into posts. Posts were erected into 18" holes dug into the ground.

Each platform was initially filled with 330 acorns and camera traps were set to high sensitivity. The camera trap at platform 1 was originally set to 1 photo per trigger, then changed on November 30, 2020, to 3 photos per trigger. Camera trap at platform 2 was set to 3 photos per trigger for duration of experiment. On November 11, 2020, several holes were drilled in the bottom of each platform so precipitation could drain, and 10 oz of unsalted raw peanuts in the shell were added to each platform on top of acorns. Jays were called with "*pshp shpsh*" vocalizations and peanuts were tossed in the direction of any observed birds and toward the platforms from 10 m away for 1.5 hours at each site. Nineteen days later when platforms were empty of seed, 400 acorns and 10 oz of the same peanuts were added to each platform. The remaining 234 acorns were then placed in moist 9:2:2 perlite: peat: vermiculture mixture in plastic bag in refrigerator at 5 degrees Celsius. On May 9, 2021, when sites were again accessible, 117 acorns and 10 oz of peanuts were added to each platform. In total, 1,694 acorns and 60 oz of peanuts were split evenly between 2 platforms over a period of 7 months. Feeding platform seeding reported in Table I.

Table I.

Platform	**Year**	**Month**	**Day**	**Time**	**Acorns added**	**Peanuts added**
1	2020	10	23	14:20	330	
2	2020	10	23	15:45	330	
1	2020	11	11	14:30		10 oz
2	2020	11	11	12:15		10 oz
1	2020	11	30	13:45	400	10 oz
2	2020	11	30	14:20	400	10 oz
1	2021	5	9	15:00	117	10 oz
2	2021	5	9	15:15	117	10 oz
				Total:	1694	

Plots were marked at 30m and 50m radius circles around each platform. Seedlings were searched for with help from MSC volunteer, Reina Rogers, by walking in concentric circles every 5m. Particular attention was paid between 30-50m because observation in several studies indicate caching sites drop precipitously before and after (Borchert and Tyler 2010, Rockwell et al. 2013a)(Mario Pesendorfer, personal correspondence). Black oak seedlings emerge May through August in Tásmam Koyóm, and were searched for on May 9, 21, and June 11, 2021. The Dixie Fire made site visitations impossible again until October 2021.

Planting experiment

Planting plots were incorporated into the experiment to compare survival between cached acorns and planted trees. The plots were also planted to ensure that the goal of establishing California black oak savanna, as articulated by the community, was accomplished. Between December 27-30, 2020, 365 acorns were started in 4” Anderson tree bands and grown in the UC Davis Arboretum nursery in a cage with hardware cloth to exclude predators. Irrigation was kept light for the overwintering period. All trees were grown using *Phytophthora* prevention best management practices (BMPs) and were tested for *Phytophthora* contamination using the testing procedures developed by Swiecki and Bernhardt (Swiecki and Bernhardt 2019). On May 22, 2021, the best specimens were selected for planting to mimic common practices in restoration plantings. MSC volunteers were trained by the author and assisted with installation of seedlings. Thirty-two trees were planted at each planting site, 9 m apart on center with a bamboo stake zip-tied inside to hold up 2 ft Tubex tree tube (4ft tree tubes cut in half). Trees were checked by the author to ensure the planting depth of the soil was no higher than the root collar. Trees were hand watered with 24 gallons split between 64 trees after planting. Subsequently, seedlings were hand watered twice weekly by MSC volunteers, with 8-10 gallons being split between 32 trees at each site until the Dixie fire prevented all access to Tásmam Koyóm in July 2021. Neither hand watering, nor irrigation were part of original experimental design due to lack of nearby water and to compare to seedlings more accurately from cached acorns. However, MSC volunteers were motivated to hand water the planting plots, so I asked that they keep the watering consistent between planting site 1 and 2 and record how often sites were watered.

Results

Feeding platforms

Feeding platforms were almost entirely untouched for the first two weeks. Nineteen days after the first 330 acorns were left, all remained on the platform. The camera trap at platform 2 captured the only photos of animals, 5 photos of chipmunks in one day. Three acorns at each platform were cut open to assess damage to embryos and all appeared normal. After baiting platforms and using vocalizations and tossing peanuts to attract Steller's, acorns were quickly taken. On November 11, 2020, while first baiting the platforms, two Steller's jays were observed in the 1.5 hours spent at platform 2 approximately 40 m west from platform in conifers along the road, perhaps attracted to the vocalizations and peanuts tossed in their direction. No Steller's were observed at platform 1 in 1.5 hours "*pshp shpsh*ing" and tossing peanuts toward the platform.

The first photo captured of a Steller's at platform 1 was five days after baiting it with peanuts. Forty-one photos were captured of Steller's visiting the platform over the next 19 days and none of any other animals (except human).

The first photo of any animal after baiting the platforms with peanuts was captured the day after of a chipmunk at platform 2. Three hundred and fifty-nine photos were captured of chipmunks visiting the platform and transporting caches for the following four days. It is unclear how many acorns this accounts for since animals can carry more than one seed at a time, and it is possible that the camera traps did not always go off when an animal was present. However, many of the photos show chipmunks with visible peanuts or with unidentified stashes in their cheek pouches. The second night after baiting platforms, 19 photos of a nocturnal mouse were captured. The first Steller's jay photo at platform 2 was captured 15 days after baiting platform and 643 photos of jays were captured over the subsequent 4 days when platforms were baited again. Ample photos showed jays with acorns in their beaks either at the platform or flying away. All mammal photos stopped once Steller's photos began.

Within 24 hours of refilling each platform with 400 acorns and 10oz of peanuts on November 30, 2020, camera traps caught photos of Steller's visiting the platforms. Photos of Steller's continued until the first week of January 2021 at platform 1 with 311 captured photos. Photos of Steller's continued until May 5 at platform 2, with a total of 1,481 photos of Steller's. All acorns were once again gone once field sites were accessible again on May 9, 2021.

Other animals captured during this time include 2 photos of black bears (*Ursus americanus*) at each platform and deer (*Odocoileus hemionus*) (55 photos at platform 1 site, 2 at platform 2). Platform 2 saw 43 photos of other bird species, but none were caching species and they seemed to be using the platform as a perch. Two Steller's jays at a time were captured in photos at both platforms and five photos of 3 jays were captured at platform 2. quantity of photos and animal visitors are reported in Table II.

Table II. Quantity of photos captured with animals in the frame

Platform	1 jay	2 or 3 jays	mouse	chipmunk	other birds	bear	squirrel	deer	none	Total
1	344	8	0	0	0	3	3	2	25,737	26,098
2	2124	131	23	360	43	2	0	55	745	3,483

Camera traps were taken down before the last supply of acorns and peanuts put on platforms on May 9, but all 234 acorns and 20oz of peanuts (split evenly between 2 platforms) were gone by field visit 12 days later.

In total at platform 1, 97.8% of photos of animals captured were of Steller's Jays visiting the platform. At platform 2, 82.4% of photos of animals captured were of Steller's Jays, 14.0% were of scatter-hoarding mammals, and 4.2% were of non-caching animal species who were not interacting with the acorns. The photos of Steller's on both platforms were abundant and many clearly showed them flying away with acorns. Several photos even show Steller's flying to the ground (potentially caching acorns) within the frame at both sites. Platform 2 showed some initial small mammal visitation on the camera traps, but these almost completely stopped once jays started visiting.

Figure 5. Two Steller's Jays (*Cyanocitta stelleri)* at platform 1, one with cache in beak flying away from platform.

Figure 6. Two Steller's jays at platform 1; one on the ground next to the platform

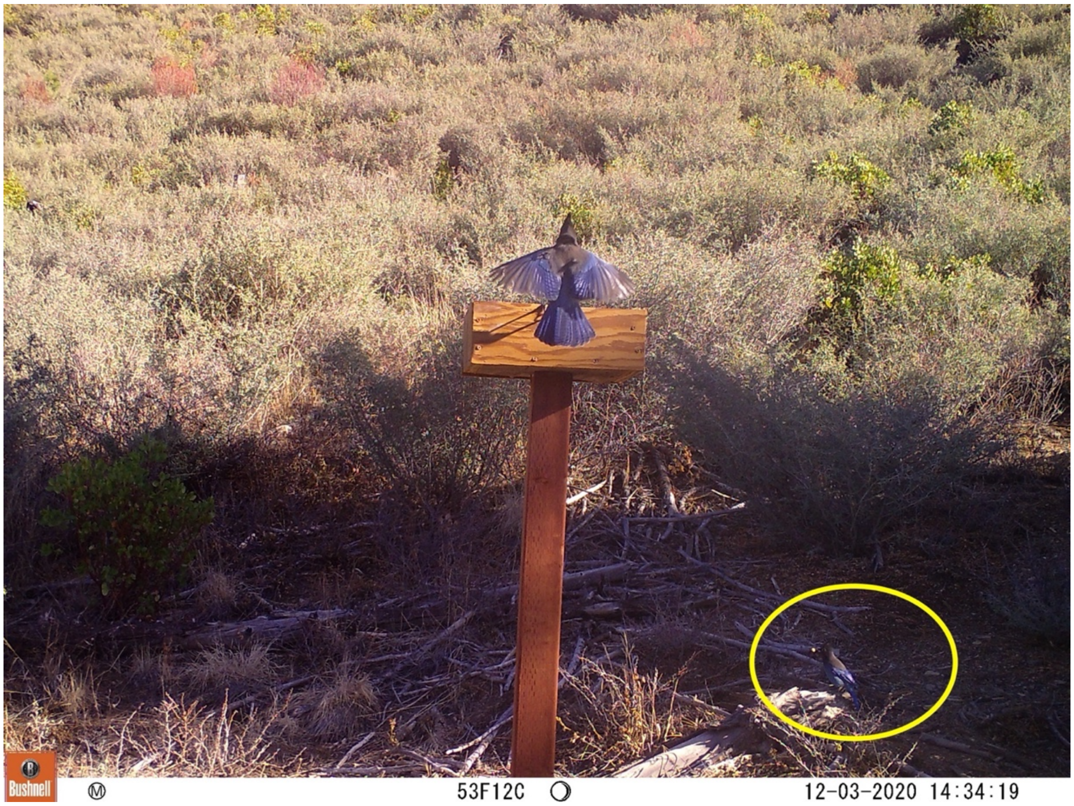

Figure 7. Two Steller's Jays at Platform 2, one with acorn in beak flying away from platform

Figure 8. One Steller's jay with acorn on platform 1

Figure 9. Black bear (*Ursus americanus*) at platform 1

Figure 10. Deer (*Odocoileus hemionus*) browsing around platform 1

Figure 11. Three Steller's jays at platform 2

Figure 12. One Steller's jay flying away from platform 2 with acorn in beak

Figure 13. Two Steller's jays at platform 2, one with acorn in beak

Figure 14. Steller's at platform 2 with acorn in beak

Figure 15. Steller's flying away from platform 2 on Dec 2, 2020 at 10:59:16

Figure 16. Photo taken in sequence after figure 11 at same time stamp showing 2 Steller's, one leaning into platform 2, the other flying to the ground near platform 2

Figure 17. Steller's jay with acorn in beak at platform 2

Figure 18. Chipmunk at platform 2 with peanut

Figure 19. Mouse at platform 2

Nursery seedlings

Nursery-grown seedlings showed no evidence of *Phytophthora* contamination using the testing procedures developed by Swiecki and Bernhardt (Swiecki and Bernhardt 2019). Over 70% of acorns germinated by May 22, 2021, had more than 2 leaves and were between 7-12cm. By June 11, 2021, 4 seedlings planted at planting site 1 and three seedlings installed at planting site 2 had succumbed, likely due to desiccation. All seedlings at planting site 1 were burned in Dixie fire in August 2021. Twenty-three of thirty-two of planted seedlings were burned at site 2.

Figure 20. Seedlings grown in nursery during *Phytophthora* testing

Cost

An enduring question in ecological restoration is cost and labor inputs compared to success. Expended costs for this project were minimal due to the partnership with the nursery at the UC Davis Arboretum and Public Garden and finding alternate sources for many supplies. Costs are estimated in Table III to compare the two treatments. Estimates include for in-house propagation of oaks, wholesale purchase of oak seedlings and for building platforms. None of the estimates include cost of seed or transport of supplies to the site. Collecting the acorns took approximately 3 hours for 4 people including travel time; estimating the “cost” of acorns would be highly variable based desired parentage and yearly masting differences. Because black oaks are fairly abundant and the seed is easy to collect from the ground, it was not considered a major limitation for this project. An exact labor comparison between building platforms and planting seedlings is difficult because of variation in volunteer capacity and support. Overall, mounting the two platforms took approximately half of the time that installing 64 seedlings took with similar volunteer numbers.

Prices	**Price per item**	**QTY**	**Total**
In house propagation estimate			
Tubex treeshelters	6.25	64	400
Stakes	0.35	64	22.4
Zip ties	0.03	64	1.92
Anderson tree bands	0.39	64	24.96
TRAY5	3.25	2	6.5
Soil	2	2	4
		Total:	459.78
93.75		$/tree	7.18
Wholesale purchase estimate			
Tubex treeshelters	6.25	64	400
Zip ties	0.03	64	1.92
Stakes	0.35	64	22.4
Oaks* Based on January 2021 price of *Quercus lobata in* T4 from Putah Creek Council	7	64	448
		Total:	872.32
		$/tree	13.63
Platform			
4x4x8 lumber	2	15	30
Plywood	1	35	35
		Total:	65
		$/platform	32.5

Discussion

Feeding platforms

Overall, the answer to our first question— will Steller's jays and scatter-hoarding mammals disperse acorns provided on feeding platform — is yes. The platforms combined with vocalization and peanut baiting were extremely effective, with 100% removal of seed by scatter-hoarders. This finding was surprising given previous research only had 32% seed removal (Motta et al. 2020). Between the two platforms, an average of 90.1% of the photos captured of animals by the camera traps were of Steller's jays visiting the platforms. The many photos of Steller's flying away from the platforms with acorns in their beaks as well as the literature about their typical behavior supports the inference that some of the acorns supplied at the platforms were cached by Steller's jays. Scatter-hoarding small mammals also visited platform 2 but their visitations were limited to the first week acorns were supplied. Further additions of acorns saw only 1 additional photo of small mammal visitations to the platform. Platform 1 had no photos of chipmunks or mice, but this could be because of a difference in proximity or angle of the camera. The camera trap at platform 2 was two meters closer to the platform than at platform 1. At platform 1, the three photos of a squirrel were on the ground and seemed to be long after the platforms had been emptied of acorns. However, the photos of squirrel indicate that the camera at platform 1 could have captured photos of chipmunk or mice if there had been frequent visitation. Counting how many acorns were taken by whom, was outside the scope of this study. Future research should consider mounting cameras closer to feeding platform at an angle to measure the reduction in acorns from the platforms.

The complete removal of acorns from the platforms is particularly notable, when compared to the high rate of acorns ignored by jays in the Motta et al. (2020) research the experiment is modeled on. There are several possible explanations for this finding. It may be due to there being little to no acorns within a 1km range of the platforms in Tásmam Koyóm compared with “local acorn abundance” in Motta et. al’s field site. Acorns were also supplied to the platforms differently in the two experiments. Motta et al. left small amounts of acorns frequently and observed the platforms to record caching locations. In Tásmam Koyóm, we left several hundred acorns at a time, then the sites had little to no human traffic for weeks, or months. Finally, the differences in jay behavior could also reflect species or population differences.

Significantly, the difference in Steller’s jay’s visitation to the platforms before vocalization and baiting with peanuts versus after, indicates this could be a critical step to the success of feeding platforms. No Steller’s jays visited the platform in the first 19 days and all acorns remained on the platforms before baiting and vocalization was added to each site. On day 19, I did vocalizations (*“psh-pshing”*), tossed peanuts toward Steller’s sited and toward platforms for 1.5 hours at each site, as well as added 10 oz shelled unsalted peanuts to the platforms. The abundant visitation of Steller’s afterwards was more immediate at platform 1 (5 days) compared to platform 2 (15 days) after these interventions. Further research could trial the addition of vocalizations and baiting methods compared to a platform with no peanuts or vocalizations to see if they are in fact necessary to attract the jays. Further research could also isolate the addition of peanuts to the platforms from the vocalizations and tossing of peanuts to assess their respective effects, the latter being more time intensive.

Seedling emergence

Questions two through four, measuring seed dispersal and survival were unanswerable due to the complete burn of the field sites in the Dixie fire. Despite 100% removal of seed from platforms by seed-caching animals, no emerging seedlings were found within a 50m radius of either platforms before the Dixie fire. Reasons for not finding seedlings could include: (1) Jays show a range of caching distance maximums and averages in the literature. There is no documentation specific to Steller's jays and California black oak acorns, let alone specific to this population or habitat. Steller's visiting these platforms could average longer transport distances or have preferential habitat caching locations. The research design was based on results from the most relevant literature, but differences in behavior could lead to seed caches being located outside of the scope of this research design. (2) Seed predation by mammals of cached acorns has been documented to highly reduce recruitment (Fuchs et al. 1999). Several (non-experiment-related) oak seedlings planted in Tásmam Koyóm have been eaten, likely by pocket gophers. (3) Predation from deer is a huge obstacle to oak recruitment (Ted Swiecki, private correspondence). We had planned to put tree tubes around any cached seedlings found, but deer and other mammals could have found them first. The abundant photos of deer captured at platform 1 indicate this as a relevant concern. (4) The Sierra Nevada region in 2020-21 has seen moderate to severe drought conditions (NOAA 2021) which could lead seedlings to die-back from desiccation. (5) The quality of habitat the acorns are cached in could facilitate or detract from recruitment. Fuchs et al. (1999) suggest that differences in caching vegetation cover and habitat portends acorn germination and seedling survival. Steller's in Tásmam Koyóm could have preferred to cache in open areas prone to desiccation. (6) California black oak seed can lose viability from extended heat or solar exposure (Fryer 2007). This means that, likely some of the acorns, like those on the top of the pile that were initially placed on the platform that were not cached for 2 weeks, were possibly non-viable. (7) Seedling emergence searches were halted by the Dixie fire before the full germination period. Some seedlings could have been destroyed by fire which burned at medium to high severity throughout both plots.

Cost comparison

Question five, comparing the costs of the platforms and a typical restoration planting, has incomplete answers. Survival rate comparisons between the cached seedling and the planted seedling are necessary to truly compare costs, and these are not available due to catastrophic losses from the Dixie fire. However, we can extrapolate based on the estimated cost of materials in each method. Without including labor for installation, the estimated materials cost per tree planted ranges from $7.00 to $14.00, if grown in-house or purchased, respectively (see Table III). The cost of each platform material is estimated at $32.50. In order to start a baseline comparison, I will make three assumptions, the first two based on prior research (Motta et al., 2020), and the third, as a device for comparison. I will discuss the issues with these assumptions after. (1) the caching rate is 18% of acorns supplied; (2) 10% of cached seeds germinate; and (3) the annual survival rate between the seedlings that are planted and the un-retrieved cached seed that germinate are equal. Each platform had 847 acorns supplied; 18% of those acorns cached is 152.46. If 10% germinate that is 15 seedlings. With the projected materials cost, if between 3-5 seedlings survive from the platform installation, it is cheaper than 3-5 planted trees. With these assumptions, a reasonable amount of acorns could be supplied to the platform to accomplish greater returns at less cost than the materials necessary for a typical seedling planting. Additionally, the labor invested in the platforms in mounting the platforms was about half, reducing the labor input.

However, the assumptions this calculation is based on are far from certain. First, the caching rate in this study is unknown. Though our platforms saw complete removal of acorns, compared to Motta et al.'s (2020) 32% removal, we do not know the rate of caching, versus eating or dropping. In Motta et al.'s (2020) results, less acorns were eaten/dropped than cached, but it is unknown whether that would be replicated. Secondly, I was not able to find data that predicts the 10% germination assumed by Motta et al. (2020), or any other data that would predict a cached seed germination rate, so that remains unsupported. Finally, equal survivorship of unretrieved cached seedlings and planted seedlings is unknown, considering the compounding factors of predation, caching site preferences and irrigation. It is possible unretrieved cached seeds would have lower survivability after germination than planted seedlings because plantings sites can be chosen to optimize for seedling survival. This is further complicated by the need for protection from predation. Tree tubes are typically used and widely considered critical for restoration planting success of oaks. Adding tree tubes to this calculation augments the labor investment and cost needed in the platform design. It is difficult to estimate how much additional labor because searching for seedlings varies with the terrain and vegetation, but the additional cost of materials, for example, of 15 seedlings (from the hypothetical scenario above) is $99.45. Without seedling protection, very high rates of acorn caching and seed germination would be needed to overcome inevitable predation.

Additionally, the labor/cost of collecting acorns would depend greatly on accessibility of collecting sites and abundance of acorns which varies yearly due to the masting nature of oaks. For this research, collection sites were accessible and acorn production was low at three sites and high at two. With acorn production lower than this, any relative advantage to the platform compared to planting diminishes. In lower seed production years where seed collection is a limiting factor, direct-seeding or planting seedlings could be more cost-effective. The cost of seed was not factored into any of these calculations, because it varies with a given project and for us there was free, readily available seed. Limited seed supply would likely render the platform design infeasible, considering the presumably low level of germination from cached seed compared to nursery grown seedlings.

This study indicates the need for more research to fully answer such questions. This research shows that directing dispersal is possible; further research is needed to show if the germination and survival rates of cached seed would make this methodology feasible for black oak restoration.

Lessons learned and further questions

To address the problem of sun exposure on seed, future studies should increase the rim on the south and west sides of the platform to decrease solar exposure on acorns. Future studies should also plant seeds close to platform to observe localized germination and growth rate to aid in search for cached seedlings.

A previous attempt at direct seeding a limited number of acorns in other areas in Tásmam Koyóm had not been successful, so there was little community interest in attempting this method again. The previous direct seeding attempt was inconsistent and with very few seeds (< 30) and cannot be used as a basis for scientific trial from which to draw conclusions about the suitability of the site to support seeding black oak. There are many advantages to direct seeding acorns compared to planting seedlings, namely, *Phytophthora* prevention and reduction in costs. In retrospect, I could have promoted direct seeding as part of the experimental design for these reasons. I could have also argued that with the added protection of tree tubes in better prepared sites it would have had better outcomes, but I was eager to ensure that the project had community support. Future studies should consider direct seeding instead of planting seedlings.

Platforms were mounted on 4”x4”x8’ post but instead could be mounted on t-posts which would reduce the cost and labor for mounting. However, we did capture photos of bears interacting with the posts, so the posts were useful for structural integrity given the wildlife of our region.

Further experiments should consider what the optimal number of acorns to supply on platforms would be to maximize the cost and labor of platform inputs before diminishing returns. This would particularly help indicate when acorn supplies are low if this is an advantageous methodology. This of course, brings up the potential concern of feeding and manipulating wild populations of birds, particularly on a larger scale, which should be considered.

Conclusions

The loss of oak savannas and woodlands and their associated wildlife, biodiversity and cultural resources is an ecocultural conservation concern throughout California (Long et al. 2016, Valachovic et al. 2016). In addition to being a critical food and habitat source for people, birds, arthropods and mammals, California black oak is disproportionally used (compared to conifers) by several protected species such as California spotted owls, and fishers (Fryer 2007) and their deep root systems have been shown to protect watershed quality (McDonald 1990). Finally, California black oak's contribution to cultural and food resilience are important to the long-term sovereignty of Indigenous peoples.

In addition to its cultural and ecological importance, California black oak dominant patches present additional advantages to ecological resilience in a changing climate. The loss of oak woodlands and shift to conifer dominance has contributed to vegetative homogeneity on a larger scale (Schriver et al. 2018). This loss of horizontal heterogeneity in forest types could be a factor in the widely documented increases in fire severity and size (Miller and Safford 2012). Mature California black oaks are resistant to low intensity fires (Anderson and Roberts 2003) and are highly drought tolerant (Fryer 2007). Black oaks have low-density crowns, which makes them less likely spread crown fires than conifers (Long et al. 2016). Increasing the patches of oak savanna and woodland could contribute to overall resilience to increasing drought and catastrophic fire due to climate change (Long et al. 2016).

There is a growing body of work studying how shifting fire regimes have changed and will affect the future of California black oak ecosystems (Valachovic et al. 2016, Schriver et al. 2018). My research aims to contribute to the less abundant information on effective mechanisms for establishing California black oak dominant systems where they have been lost. Post fire landscapes could present generative opportunities for establishing oak woodland and savanna if seed dispersal limitations are overcome. Typical restoration plantings can be labor and resource intensive. Seed platforms could be a tool for oak regeneration at larger scales. Furthermore, these sites could be used as opportunities for community member involvement, as the approach is engaging, and the expertise needed minimal. Seeding platforms also present opportunities for research on corvid scatter-hoarding behavior. Oak habitats are being degraded throughout the Northern Hemisphere, and enhanced seed dispersal could be an important tool for oak restoration particularly in response to shifting ranges due to climate change (Pesendorfer et al. 2016a).

Seed dispersal limitation and deer browsing are the main obstacles to overcome for establishing California black oak seedlings (Fritzke 1997, Long et al. 2016). Longer term, however, the prevention of conifer encroachment is critical to restoring California black oak dominated ecosystems. There is increasing evidence that the persistence of black oak woodlands and savannas require some level of management (Schriver et al. 2018). Because oak dominant systems need frequent disturbance but are sensitive to high severity fires, they are vulnerable to both fire exclusion and increasing fires from climate change (Nemens et al. 2018). Tásmam Koyóm is a model example of the type of active stewardship of the land in perpetuity that can maintain the conditions necessary for California black oak dominant ecosystem. California black oak regeneration projects should prioritize partnerships with Indigenous land stewards for the greatest possible ecocultural benefits. Oak savannas could be maintained in special cultural management areas within national forests, for example (Long et al. 2020).

Acorn feeding platforms represent one possible strategy for engaging caretakers, community members and existing dispersal mechanisms – Steller's jays, in this case – in this ongoing work. Because of the circumstances of this experiment, we cannot answer at what rate cached seed may germinate and survive. Future research could answer this question by assessing at what germination and survival rate this methodology would be cost-effective given acorn supply and accessibility.

On collaboration

Many Tribal organization do not have protocols like the Karuk *Practicing Pikyav* (Karuk-UC Berkeley Collaborative 2011), and the diversity of Tribes and types of Tribal organizations means there is not a one size fits all approach to research collaboration. The Maidu Summit Consortium does not currently have specific protocols but does have a history of successful collaborations with many researchers and restoration practitioners. Based on the work cited in the literature review and my own experiences, I have tried to follow the principles below and I have shared these intentions with collaborators.

I. *Free, prior, informed consent* as outlined in the United Nations Declaration on the Rights of Indigenous Peoples (UN 2016): Research ideas and plans were discussed openly and extensively in community gatherings and approved by MSC executive directors, board members, TEK advisory committee and community members.

II. *Community-prioritized goals:* Research goals were defined by the priorities and goals identified and expressed by the community. The priority for this research was establishing an oak stand with salutary attributes for acorn collection as expressed by community members and approved by the MSC Executive Director. The research questions and design were built around this goal and with community input on how best to accomplish it. Additional (non-experimental) oaks have been planted in Tásmam Koyóm and an oak grove long term management plan is being collaborated on to ensure that this long-term goal can be met. Trees that were burned in Dixie fire were replanted in October 2021. Results and findings are to be presented at Board meetings and community gatherings.

III. *Confidentiality*: Publication and public media about the project shall be approved by the MSC. Personal stories and TEK shared with me is considered proprietary and is not shared without consent.

IV. *Humility, respect, and gratitude*: Always in this work, I held onto the recognition that I am a visitor who has limited knowledge compared to the deep time, relational and complex history of Tásmam Koyóm, and its Maidu caretakers. I invested time into gaining historical and contextual information while also accepting that I would not ever gain a full understanding or 'expertise' on this front. Humility in this regard helped me keep the work grounded in immense gratitude for being welcomed to build relationships with the people and the land.

V. *Reciprocity*: Much research done about and with Indigenous peoples produces nothing of value for them (Nadasdy 1999, Smith 2021). I wanted to be sure that the knowledge and time that was shared with me was met with results that benefit the community. To that end, time was contributed to volunteering on other projects, unrelated to research, on community workdays and trainings dedicated to Tribal capacity building. I hope to continue these relationships and support these goals into the future.

VI. *Sovereignty*: all forms of Maidu sovereignty – food, knowledge, political – were considered paramount in all decision-making.

My experience is not meant to serve as a universal example or protocol. This research was developed in a highly relational, iterative process. I, at times, failed to live up to these principles, I am sure. Of particular difficulty for me was assuring I understood the context of what *Practicing Pikyav* identifies as 'situated knowledge' (Karuk-UC Berkeley Collaborative 2011). The authors explain how the diversity of families and individual experiences within a community means that no one person speaks for the whole and researchers need to communicate with a range of community members. I found this particularly important to remember when trying to understand who had the authority to approve projects or make decisions. I came in with cultural conceptions of who would be the leaders and had to adjust over time as I gained a more nuanced understanding. This is well-documented error that has been perpetuated by non-Indigenous people, both well-intentioned and for duplicitous purposes since contact.

Finally, one of the most important resources that must be contributed to partnership is time. Relational trust-building, understanding historical and cultural contexts, as well as establishing agreements and protocols takes significant time and cannot be rushed or an afterthought. Funding agencies should consider this time investment to be a critical part of the work of restoration. Overlooking it will lead to the perpetuation of cycles of harm caused by colonialism.

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