TRIBAL STEWARDSHIP FOR RESILIENT FOREST SOCIO-ECOSYSTEMS

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INTRODUCTION

The Yurok Tribe, along with other Tribal communities in northwest California, non-profit organizations, universities, and governmental agencies are working to restore forests and woodlands to be more resilient to wildfires, drought, pests, and diseases. Our current work within Ancestral Yurok territory is designing and evaluating effects of forest treatments including hazardous fuels reduction, tree harvesting, and intentional burning based upon Indigenous traditional knowledge and associated Tribal stewardship practices. Central to these evaluations are the potential availability, quantity, and quality of desired cultural resources used for food, basketry, medicine, ceremony, tools, and building materials, as well as habitat quality for the plants, fungi, and animals that are an integral part of the Yurok homeland and culture.

Our study area in northwest California encompasses the Tribe's aboriginal territory within Yurok Reservation, 34,000 acres of Tribally acquired private and allotment lands, and portions of the Six Rivers National Forest (Fig. 1). Located at the convergence between the Cascade, Sierra Nevada, and Coast Range Mountains, this western Klamath mountain ecoregion represents some of the most ecologically diverse assemblages of forest habitats in northern California and the southern Pacific Northwest. However, these forests are some of the most threatened by current and projected climate disturbance events and processes (Olson et al. 2012, DellaSala et al. 2015), and from a legacy of colonial-settler land management, in particular fire exclusion (Halofsky et al. 2016, Tepley et al. 2017). Yurok People have lived with and created

Figure 1, above: Plot-site evaluation with Yurok cultural practitioner, and Cultural Fire Management Council representative, Elizabeth Azzuz (left), and Forest Service researcher Frank Lake (right). Photo: Chas Jones, DOI-USGS Northwest Climate Adaptation Science Center/Affiliated Tribes of Northwest Indians

Figure 2: Map of Yurok Ancestral Territor. Map: Yurok Tribe 2019

the landscape through generations of careful practice and accumulated generations of knowledge about their environments.

A key element of the restoration approach is to utilize fuels, forestry, and fire treatments to promote and maintain prairie, and open forest and woodland habitats that support cultural keystone species for a range of Tribal interests and practices (Sloan and Hostler 2014). Yurok Elders have decried the loss of meadow or prairie habitat. Over 5,500 acres of prairie from the 1940s have been encroached upon by conifers, hardwoods, brush and invasive species (i.e., Himalayan blackberry (*Rubus armeniacus)*, Scotch or French broom (*Cytisus scoparius*, and *Genista monspessulana)*, and annual non-native grasses). Many individual prairies have suffered up to a 99% area loss as a result of the removal of Tribal stewardship and fire use coupled with fire suppression actions, and exclusion policies. Areas that were historically dominated by oaks (*Quercus* spp. and *Notholithocarpus densiflorus*) are now more vulnerable to drought, wildfire, and pests or disease because cessation of Indigenous fire stewardship has encouraged encroachment of Douglas fir (*Pseudotsuga menziesii*) and other vegetation that is less adapted to drought and frequent fire (Engber 2010, Schriver et al. 2018, Mucioki et al. 2021).

CONTINUING RESEARCH TO BRIDGE INDIGENOUS KNOWLEDGE AND WESTERN SCIENCE

We are examining the current condition of different forest types and how they are likely to respond in the future given climate change, how restoration prescriptions can advance diverse Tribal values, and reflect the guidance of Indigenous knowledge. We are planning to work in five habitat types of Tribal and regional conservation importance ranging from the coast to the interior and across elevation gradients (Table 1). We are building upon previous efforts to relate Tribal practitioners' knowledge to standard quantitative forest data collected by Western science institutions, including examples that target beargrass (*Xerophyllum tenax*) (Hummel and Lake 2015), California hazel (*Corylus cornuta* subsp. *californica*) (Marks-Block et al. 2019) and evergreen huckleberry (*Vaccinium ovatum*) (Rossier 2019).

We are compiling existing data from forest and woodland plots gathered by the Yurok Tribe, USDA Forest Service, and University of CA Cooperative Extension, plus collecting new data (i.e., establishing additional plots within the different forest types). In coordination with the Yurok Tribe and Tribal community organizations, Tribal practitioners conduct site evaluations at recently measured and existing plot locations representative of the forest types. Based upon previous work and collaborative discussions with practitioners, we are identifying desirable conditions (Fig. 1) and relevant metrics, as well as evaluating and relating the effects of climate and forestry management at these sites.

Where needed, we establish new plots with input from these practitioners (Fig. 3).

They provide associated cultural resources and values, given current conditions and potential restorative treatment interventions (types of treatments and stewardship practices). These include the reduction of hazardous fuels such as brush and small trees, pile burning of slash, felling of trees, prescribed fire, and cultural burning (Fig. 4) as intermediary steps of aligned treatments.

One tool we are using to evaluate vulnerability and resilience is the Forest Vegetation Simulator (FVS) software (Dixon 2002). Federal agencies (e.g., USDA Forest Service) widely use this tool, which allows simulation of treatments and fire in treed habitats, to evaluate how forests or woodlands will change over time. Further, the Climate-FVS extension (Crookston 2014) employs climate models and emissions scenarios, and it

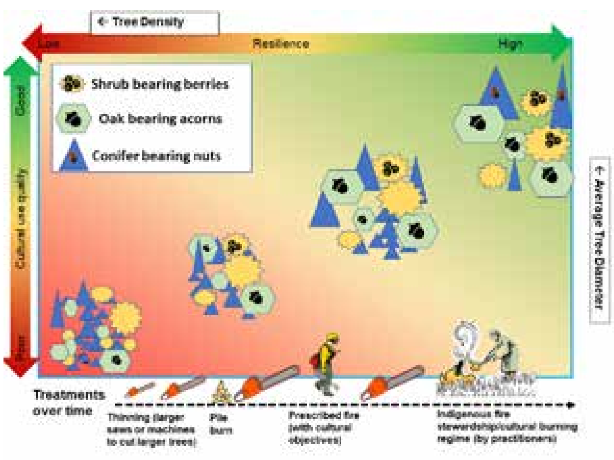

Figure 3, above: This area received Yurok Cultural Fire Management Council manual understory thinning and cultural burning treatments. Margo Robbins, cultural practitioner and CFMC representative in a representative "Good" forest type selected as study plot location. Photo: Chas Jones, Change to: DOI-USGS Northwest Climate Adaptation Science Center/Affiliated Tribes of Northwest Indians

Figure 4, left: Diagram relating cultural use quality, tree species, density/size distributions, and a process of treatment steps—treatments over time, such as thinning, prescribed fire, and Indigenous Fire Stewardship with Cultural Burning—to move toward better cultural use quality and higher socio-ecological resilience (rightward in diagram). For example, the tan symbol with berries as madrone (*Arbutus menziesii*), and the aqua symbol with acorns as an oak, and the blue triangle symbol as a conifer being sugar pine (*Pinus lambertiana*) or Douglas fir.

modifies predicted growth and mortality of trees based on current relationships between climate and species.

DESIGNING TREATMENTS

Managing cultural resources based upon Indigenous knowledge may contribute to prescriptions that can differ vastly from those widely implemented for commercial timber production. Non-Tribal forest managers in the region have long viewed hardwood trees as competitors with more commercially valued conifers. But for Tribes, hardwood fruits such as oak acorns are a critical resource.

Tribally desired conditions include having a low density of large oaks with wide-spreading crowns (i.e., open limb structure), potentially intermixed with larger conifer trees, but occurring with fewer small understory trees and brush that may hinder collecting of desired resources and affect hazardous fuel levels during fire use (Fig. 3 and 5). In the case of tanoak, long-used "orchard" stands in Yurok territory are often dominated by large—e.g., 24" diameter at breast height (DBH) tanoak trees, this also applies to California black oak (*Quercus kelloggii*), a secondary acorn use species (Fig. 6a: pre-, Fig.6b: during Yurok Cultural Fire Management fire treatment in research plot showing the trunks of madrone (*Arbutus menziesii*) on left and California black oak on right early June 2022. (See also Figure 6c.)

While the frequent use of fire helps oak woodlands to persist (Mensing 2015), more intensive mechanical tree removals may be required to initiate and maintain

Figure 5: A depiction of mixed oak/prairie forest habitat-type with culturally important species being used as resources is seasonally shown in this image of California black oak (*Quercus kelloggii*), Oregon white oak (*Q. garryana*), and California hazel, as well as the other wildlife applicable to the Yurok Tribe of northwestern California. This illustration depicts a desired condition that reflects a "Good" cultural use quality, and habitat attributes that support Indigenous Fire Stewardship and other cultural practices. Artist: Kirsten Vinyeta

Figure 6a (left) and 6b (right): A research plot where treatments included removal of small trees and brush followed by burning by Yurok Cultural Fire Management Council cultural practitioners. 6a: pre-treatments. 6b: recently burned. Photo: Joe Hostler, Yurok Tribe. Yurok CASC plot June 2022

recovery in hardwood stands compromised by decades of fire suppression and exclusion (Devine and Harrington 2013). Because low-intensity fire is not hot enough to injure and kill larger conifers, mechanical thinning is a type of treatment used to release suppressed oaks, and other valued hardwoods, from competition and increase tree vigor where oak canopies have been pierced and overtopped by conifers (Devine and Harrington 2006, 2013; Hilberg et al. 2019 a,d). Prescriptions for treatment are heavily dependent on the current forest state and how far departed it is from a historical and/or desired state (Fig. 4).

Tribal practitioners have emphasized the importance of revitalizing Tribal stewardship practices for restoration treatments and for increasing adaptative capacity in response to climate change stressors (i.e., drought and wildfire). Decisions on the ground about which trees should be cut may benefit from a cultural/Tribal practitioner's judgment. In the case of oaks, for instance, a practitioner uses their Indigenous knowledge and experience to translate the goals of better acorn collecting, and pests reduction into treatments that reduce shading and enhance tree radial growth. They also consider site factors that foster fruits such as huckleberries, hazelnuts, understory forbs, and other herbs by creating the appropriate amount of available sunlight and for canopy shading and implications for desired wildlife habitat (Fig. 5).

An example using stands with mature tanoak illustrates how a treatment can be geared toward better cultural use quality. At two sites with established forest research plots, a cultural practitioner decided which individual trees should be cut and suggested removal of a proportion of brush (Fig. 1). This type of treatment often cannot be captured by commonly used prescriptions that specify thinning a given proportion of certain species within a specified diameter range. The practitioner's approach here results in the majority of cut/harvested-tree volume being in Douglas fir trees between 25" and 35" diameter at breast height. Tribes may be able to derive revenue from the thinned and removed merchantable "timber" conifers as a restoration byproduct.

We are attempting to model treatments in FVS based on practitioner prescriptions informed by their Indigenous knowledge and cultural values, for example, tree cutting in 2025, followed by pile-burning slash and the smaller existing surface fuels, then two prescribed fires in 2027 and 2037, and finally a regular regime of cultural burning (Fig. 4). As a contrast, we also simulated wildfire under relatively extreme fuel moisture and weather conditions in a future year.

It is difficult to represent the subtlety and nuance of Tribal or Indigenous fire stewardship in these simulations, especially since they would necessarily respond to space-and-time specific conditions. The goals of agency or other non-Tribal entity's prescribed fire are often more narrowly focused on hazardous fuel reduction, reducing the risk of high-severity fire, and retention of timber conifer trees. Cultural burning often has more

Above: Three generations of Yurok Indians gathering California hazelnut basketry stems at a cultural burn site near Weitchpec, California (left to right): Phillis Donahue (mother), Chris Peters (son), and Nicki Peters (granddaughter). Cultural fires generate significant resources to sustain Karuk and Yurok basketweaving. Photo: F.K. Lake

nuanced goals that maintain a variety of interrelated habitat qualities and specific resources from the understory to the canopy trees. Analytical modeling of fire effects is less useful at quantifying effects of cultural burning that are intrinsic to indigenous knowledge. Thus, software tools like FVS are perhaps most useful in assessing initial treatments that remove younger trees and reduce fuel accumulation resulting from legacies of fire suppression and exclusion. Then, Indigenous fire stewardship can be re-established on more frequent intervals as a means to maintain conditions through time, and bolstering Tribal adaptive capacity and stewardship opportunities into future generations. This can be more responsive to observed fluctuations in establishment and growth of conifer seedlings, brush, and other understory plants.

Table 1: Five culturally important habitat/forest types targeted for research, and some of the main tree/plant species used. Species that have a particular importance for given materials from the corresponding type are emboldened. Superscript letters correspond to Landfire GAP/NatureServ Id habitat descriptions below. Superscript numbers refer to Latin binomial species names in Table 2.

Habitat-Forest Type	**Tribal resources-use species:**	**Uses of species:**
[a]Mixed [Evergreen] conifer/ hardwood forest types	Douglas-fir[1]; Ponderosa pine[2]; Incense cedar[3]; Jeffrey pine[4]; **Sugar pine**[5]; Canyon live oak[6]; **CA black oak**[7]; Pacific madrone[8]; **Tanoak**[9]; Oceanspray[10]; OR grape (short[11] and tall[12]); CA bay laurel/pepperwood[13]; Chinquapin[14]; **Port Orford cedar**[15]; **CA hazelnut**[16]; **Evergreen huckleberry**[17]; Salal[18]; Sadler oak[19]; Pacific bigleaf maple[20]	• Food (nuts, acorns, berries) • Materials (craft-tools, lumber, ceremonial/housing, dyes) • Medicinal plants • Wildlife (regalia/hunting)
[b]Mixed oak/prairie	OR white oak[21]; **CA black oak**; Pac. Madrone; Douglas- fir; Canyon live oak; CA bay laurel/pepperwood; **CA hazelnut**; Strawberry[22]; (CA) Trailing blackberry[23]; **Geophytes-Indian potatoes/lilies**[24]; Native Grasses/Forbes (Tarweed[25]; **Yerba Buena**[26])	• Materials (tools, basketry) • Food (acorns, bulbs, seeds, nuts, berries); • Medicinal (teas); • Wildlife (regalia/hunting);
[c]Serpentine mixed conifer/ hardwood	Douglas Fir; Gray/foothill pine[27]; **Sugar pine**; Jeffery pine; Incense cedar; Port Orford cedar; shrubby tanoak; Huckleberry oak[28]; Sadler oak; **Manzanita**[29]; Coffeeberry[30]; Silk tassel[31]	• Materials: (lumber-regalia, ceremonial) • Food (berries/acorns) • Medicinal plants • Wildlife (regalia/hunting)
[d]Higher-elevation montane conifer/hardwood	White fir[32]; Incense cedar; **Sugar pine**; Jeffrey pine; Ponderosa pine; Douglas-fir; Pac. bigleaf maple; Dogwood[33]; Chinquapin; **Sadler oak**; Huckleberry oak; *Ceanothus* spp.[34]; Gooseberries/currants[35]; **CA hazelnut**; **Beargrass**[36]; Ocean-spray; Tall OR grape	• Food (nuts, berries); • Materials (basketry-crafts/ regalia, lumber, tools-implements) • Medicinal plants
[e]Coastal redwood	**Redwood**[37]; Douglas-fir; **Sitka spruce**[38]; Western hemlock[39]; **Tanoak**; Pac. bigleaf maple; **Port Orford cedar**; **Salmonberry**[40]; Thimbleberry[41]; CA spikenard[42]; Tall OR grape; Salal; Red huckleberry[43]; **Evergreen huckleberry**	• Food (nuts, acorns, berries) • Materials (basketry-crafts/ regalia, lumber, tools-implements) • Medicinal plants

a) 2027: Mediterranean California Dry-Mesic Mixed Conifer/CES206.916; 3043 Med. Ca. Mixed Evergreen Forest/CES206.919; **b)** 3008: North Pacific Oak Woodland/CES204.852; 3029 Med. Ca. Mixed Oak woodland- Cal. Broadleaf Forest and Woodland/CES206.909; 3260: Mediterranean California Lower Montane Black Oak Forest and Woodland/CES 206.923; **c)** 3021: Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland/CES206.917; 3022: Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Woodland/CES206.914; 3170: Klamath-Siskiyou Xeromorphic Serpentine Savanna and Chaparral/CES206.150; **d)** 3028: Mediterranean California Mesic Mixed Conifer Forest and Woodland/CES206.915; 3200: Coastal Douglas-fir Woodland/A3674; **e)** Coastal redwood: 3015: Ca. Coast Redwood Forest/CES 206.921

CHANGING CLIMATE AND SYSTEM RESILIENCE

This research effort builds upon and helps actualize the Yurok Tribe's Climate Change Adaptation Plan (Cozzetto et al. 2018-), which emphasizes restoring forestlands for ecosystem health, species conservation, water quality improvements, carbon sequestration, and improved cultural resources. Recent climate change assessments for areas pertaining to Yurok ancestral lands point to combinations of more extreme summer temperatures, reduced snowpack, earlier snowmelt leading to lower summer moisture availability for plants, and more frequent and larger wildfires (Butz and Safford 2010, Cozzetto et al. 2018). Such climate-related water deficits are expected to induce greater tree mortality from pests (van Mantgem and Stephenson 2007), and problems with seedling establishment related to moisture stress for many important habitats in Yurok territory. Previous assessments of habitat types (Hilberg et al. 2019a-d; Hilberg and Kershner 2021) suggest that these plant communities are mostly moderately vulnerable to predicted changes in climate.

A possible solution where populations may be maladapted to a changing climate is to plant seeds of the same species from lower elevation/hotter-climate sources; this solution could mitigate for tanoak loss at low to mid elevation, and it may be recommended for other oak species in California as well (Sork and Wright 2021). Unfortunately, little development of oak and other hardwood seed sources to match specific areas and elevation bands has been undertaken.

Another way to retain functions of a species where it is vulnerable on the whole to climate change is to plant a different, less vulnerable species that provides a similar resource(s). For example, California black oak could be an alternative to tanoak, as another producer of Tribally preferred acorns that already exists in a mosaic of woodlands among tanoak habitats. Our modeling may help inform conversations among land managers and Tribal cultural practitioners regarding how to adapt to more extreme shifts of species within culturally valued forest types. This approach is hoped to increase socio-ecological resilience, the Tribal community's adaptive capacity, as well as the forest habitats and culturally valued resources they depend upon.

Our efforts to combine Tribal values and Indigenous knowledge with quantitative field measurements and modeling can inform restoration strategies, site level approaches, advance Indigenous stewardship,

Table 2: Latin binomials for species in Table 1.

1	*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*	23	*Rubus ursinus* Cham. & Schltdl.
2	*Pinus ponderosa* Lawson & C. Lawson var. *ponderosa*	24	*Dichelostemma* spp.; *Brodiaea* spp.
3	*Calocedrus decurrens* (Torr.) Florin	25	*Madia* spp.
4	*Pinus jeffreyi* Grev. & Balf.	26	*Clinopodium douglasii* (Benth.) Kuntze
5	*Pinus lambertiana* Douglas	27	*Pinus sabiniana* Douglas
6	*Quercus chrysolepis* Liebm.	28	*Quercus vacciniifolia* Hittell
7	*Quercus kelloggii* Newb.	29	*Arctostaphylos* spp.
8	*Arbutus menziesii* Pursh	30	*Frangula californica* (Eschsch.) A. Gray
9	*Notholithocarpus densiflorus* (Hook. & Arn.) Manos, C.H. Cannon & S. Oh var. *densiflorus*	31	*Garrya fremontii* Torr.
10	*Holodiscus discolor* (Pursh) Maxim.	32	*Abies concolor* (Gordon & Glend.) Lindl. ex Hildebr.
11	*Berberis nervosa* Pursh	33	*Cornus nuttallii* Audubon
12	*Berberis aquifolium* Pursh	34	*Ceanothus* spp.
13	*Umbellularia californica* (Hook. & Arn.) Nutt.	35	*Ribes* spp.
14	*Chrysolepis chrysophylla* (Hook.) Hjelmq. var. *chrysophylla*	36	*Xerophyllum tenax* (Pursh) Nutt.
15	*Chamaecyparis lawsoniana* (A. Murray bis) Parl.	37	*Sequoia sempervirens* (D. Don) Endl.
16	*Corylus cornuta* Marshall subsp. *californica* (A. DC.) E. Murray	38	*Picea sitchensis* (Bong.) Carrière
17	*Vaccinium ovatum* Pursh	39	*Tsuga heterophylla* (Raf.) Sarg.
18	*Gaultheria shallon* Pursh	40	*Rubus spectabilis* Pursh
19	*Quercus sadleriana* R. Br. ter	41	*Rubus parviflorus* Nutt.
20	*Acer macrophyllum* Pursh	42	*Aralia californica* S. Watson
21	*Quercus garryana* Hook. var. *garryana*	43	*Vaccinium parvifolium* Sm.
22	*Fragaria vesca* L.; *Fragaria virginiana* Mill.		

and develop frameworks to monitor success and test modeling predictions. This approach can support a more inclusive and active adaptive management that supports Tribal community interests and builds greater capacity to respond successfully to the challenges that climate change is bringing to the Yurok Tribe, and other Indigenous communities in this and other regions. This research builds upon other study areas and regional climate adaptation, hazardous fuels reduction and wildfire risk reduction, and forest landscape restoration efforts, but specifically advances approaches for the integration of indigenous knowledge that represents Tribal interests, and the values of the Yurok Tribe.

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