Conceptualizing Indigenous Cultural Ecosystem Services (ICES) and Benefits under Changing Climate Conditions in the Klamath River Basin and Their Implications for Land Management and Governance

Authors: Mucioki, Megan, Sowerwine, Jennifer, Sarna-Wojcicki, Daniel, Lake, Frank K., and Bourque, Shawn

Source: Journal of Ethnobiology, 41(3) : 313-330

Published By: Society of Ethnobiology

URL: https://doi.org/10.2993/0278-0771-41.3.313

Journal of Ethnobiology

2021 41(3): 313–330

Conceptualizing Indigenous Cultural Ecosystem Services (ICES) and Benefits under Changing Climate Conditions in the Klamath River Basin and Their Implications for Land Management and Governance

Megan Mucioki[1,2*], Jennifer Sowerwine[1], Daniel Sarna-Wojcicki[1], Frank K. Lake[3], and Shawn Bourque[4]

Abstract. In the Klamath River Basin (KRB) of northern California and southern Oregon, climate-related changes, such as more intense droughts, varied and concentrated precipitation, earlier spring and later fall conditions, extreme temperatures, and decreased snowpack have contributed to increasingly unpredictable plant reproduction and harvest cycles. In this study, we explore contemporary relationships between plants and Indigenous People in the KRB, identifying benefits of cultural ecosystem services (CES) derived from Indigenous stewarding and gathering of culturally significant plants, and discuss how these services may change based on climate change observations and experiences. This study contributes to the conceptualization of Indigenous Cultural Ecosystem Services (ICES), providing a framework for the incorporation of Indigenous concepts, approaches, and perspectives into assessments of ecosystem services (ES) and, particularly, CES. It highlights the value of Indigenous perspectives and observations of climate change effects on plant reproduction and productivity, as well as their contribution to cultural ecosystem resilience and adaptation under changing climate conditions. We propose that incorporating Indigenous concepts and approaches to assessing CES and ES could lead to more holistic management decisions and better-informed climate adaptation initiatives with greater ES for all.

Keywords: climate change, culturally significant food plants, ecosystem services, Indigenous Peoples, Klamath River Basin

Introduction

Over the past decade, California and Oregon have experienced increasing frequency of extreme weather events, including catastrophic wildfires, with the 2020 fire season being the most extensive and destructive in recorded history (Ho 2020; Karuk Tribe 2019). Unreliable rainfall and snowpack and increased summertime highs, coupled with a legacy of fire exclusion, has made Klamath River Basin (KRB) forests and communities vulnerable to large and destructive wildfires (Barr 2010; Karuk Tribe 2019). Historically, Indigenous Peoples in the region stewarded their landscapes with low-intensity burns, minimizing the risk of high-intensity fire (Lake 2018; Tripp 2020); however, these practices were outlawed in the early twentieth century in favor of timber production regulated through newly established federal forests. Indigenous burning, tending, and harvesting practices support both forest and human health and resilience by minimizing ground fuels, pests, and pathogens, reducing tree density, and enhancing production and accessibility of cultural foods, fibers, and medicines (Karuk Tribe 2019; Lake

[1] University of California at Berkeley, Department of Environmental Science, Policy and Management, 130 Mulford Hall, Berkeley, California 94720 USA.
[2] The Pennsylvania State University, Social Science Research Institute, University Park, Pennsylvania.
[3] USDA Forest Service, Pacific Southwest Research Station, Fire and Fuels Program, Arcata, California.
[4] Karuk Department of Natural Resources, Orleans, California.
[*] Corresponding author (mem7005@psu.edu)

2013). Beginning in the 1800s, American settler colonization and extractive fur, gold, agriculture, and timber industries resulted in a massive disruption of Indigenous food systems and resource management (Dunbar-Oritz 2014). Today, climate change impacts, compounded by cumulative impacts of colonial forest management regimes, continue to negatively impact environmental and human health in the region (Karuk Tribe 2019).

In spite of these challenges, and often risking incarceration, the Karuk, Yurok, and Klamath Tribes in the KRB of California and Oregon have remained active stewards of their ancestral territories, through the gathering and management of native plant and fungi foods, fibers/materials, and medicines (Lake 2013) (Figure 1). While often falsely categorized as hunter-gatherers (Kroeber 1976), Tribes in this region are meticulous architects of their landscape, actively and intentionally tending the forest and component layers of fungi, herbs, shrubs, and trees with fire, tilling, weeding, pruning, transplanting, and irrigation to maximize production of gathered botanicals (Anderson and Lake 2013; Lake et al. 2017; Marks-Block et al. 2019). There is substantial evidence that human-induced climate change is negatively impacting ecosystems (Millennium Ecosystem Assessment 2005) with significant disruptions to cultural practices, such as gathering, hunting, or fishing and their derived benefits to human-wellbeing (Díaz et al. 2019; Thorne et al. 2016). For example, in a recent study in the area, 93% of all households reported not having enough culturally significant foods and 66.8% of Tribal household respondents identified climate change as a barrier to having enough culturally significant foods, with over 20% of respondents classifying it as a strong barrier (Sowerwine et al. 2019b).

In this article we (a) examine how climate change is impacting the utilization, availability, and management of culturally significant plants gathered by Indigenous Peoples in the Klamath River Basin and (b) conceptualize climate change impacts to culturally significant plants and Indigenous People by adapting and expanding existing ecosystem services (ES) frameworks to consider important factors—such as Tribal sovereignty, governance, historical trauma, mental health, Indigenous Knowledge systems, and cultural values—important to Indigenous people and the ecosystems they steward. In doing so, this study contributes to the fields of ethnobiology and ethnobotany by offering rich data on Native American experiences, knowledges, and observations of phenological and biodiversity change in response to climate change and climate impact on Native landscape use and management in the Pacific Northwest region of North America. While non-Indigenous resource-dependent communities have made significant contributions to ES scholarship (see Gould et al. 2014; Michaelis et al. 2020), we deliberately focus on Indigenous people in this paper, as the history of long-term land stewardship and subsequent land dispossession and mismanagement under colonialism has shaped both the impacts of and responses to climate change in Indigenous communities and landscapes in unique and specific ways. Indigenous communities are currently at the front lines of climate change, not only in terms of ecological and social vulnerability, but also through their leadership in climate change research and responses (Grantham 2018; Karuk Tribe 2019).

We situate our analysis within the conceptual frameworks of ES and particularly cultural ecosystem services (CES) to illuminate how Indigenous relationships with ecosystems provide services and benefits to ecosystems and Indigenous people themselves and how climate-induced changes both threaten and can be mitigated by those services and benefits. We use our Indigenous Cultural Ecosystem Services (ICES) framework, presented below, as a tool to

Figure 1. Karuk women harvesting culturally significant foods and fibers for consumption and weaving, including (from top left to right) beargrass (*Xerophyllum tenax*), a type of Indian potato (*Dichelostemma capitatum*), Sandbar willow sticks (*Salix exigua*), and wild grape roots (*Vitis californica*).

organize, illustrate, and discuss climate change impacts on Indigenous gathering of culturally significant plants in the KRB within the integrated social, cultural, environmental, and political domains.

In standard models of ES (defined as ecosystem conditions, processes, or goods that support human life) there are four broad categories of services: cultural, provisioning, regulating, and supporting (Millennium Ecosystem Assessment 2003). CES are defined as "nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including: cultural diversity, spiritual, and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, and recreation and ecotourism" (Millennium Ecosystem Assessment 2003). While CES are often identified as "intangible services" (Millennium Ecosystem Assessment 2003) and, thus, hard to consider in policy and management, cultural significance of ecosystems can make *tangible* contributions to human well-being that are observed in identities, experiences, and capabilities (Fish et al. 2016). In this study, we challenge the linear flow of benefits and resituate people as active stewards of ecosystems rather than passive beneficiaries (see also Chan et al. 2012; Díaz et al. 2018), presenting a mutu-

alistic relationship between ecosystems and Indigenous people largely absent from ES models. To this end, there is a small, emergent scholarship centering Indigenous perspectives within some ES frameworks (see Comberti et al. 2015; Fish et al. 2016; Sangha et al. 2015, 2018; Winthrop 2014). One such study, by Sangha et al. (2015), states that deriving benefits from nature as represented by the stock flow model, often used to explain ES, excludes the worldview of Indigenous Peoples who assume responsibility as caretakers and stewards of their land and cultural resources (not just consumers), which in turn provides food, medicine, materials, tools, and more. Our research affirms the importance of stewardship and mutualism in ES when applied in the Indigenous context.

Conceptualizing Indigenous Cultural Ecosystem Services and Benefits to Human and Ecosystem Wellbeing

In this study, we modify Fish et al.'s (2016) CES framework to conceptualize an *Indigenous* Cultural Ecosystem Services (ICES) framework (Figure 2) and the myriad of services and benefits derived therefrom. We use the ICES model to illustrate how climate change is influencing ICES and associated benefits related to the cultural practice of gathering and managing culturally significant plants, and how ICES, in turn, have the potential to mitigate climate change impacts and support overall social-ecological resilience in gathering areas.

ICES, as we conceptualize them (see Figure 2), both shape and are shaped by environmental spaces, cultural practices, and climate change impacts, as well as the biophysical and policy and governance domains. ICES also give rise to both tangible and intangible benefits to both the environment and people. Cultural values influence all components of the ICES model and have the ability to support or diminish ICES and social-ecological resilience, depending on whose cultural values are prioritized and applied. In the Indigenous context, cultural values that both inform and are informed by ICES and associated benefits are exemplified by the caretaker responsibility, a moral code of providing for all living things that is not voluntary but rather imperative for current and future Tribal generations (Lertzman 2009).

A limitation of CES models that we also seek to address is the ability to assess the role that policy and governance play in both managing climate change and enabling or prohibiting CES. In the case of the KRB, it draws attention to the enduring effects of Euro-American settler colonization on CES and associated benefits and provides space to acknowledge the historical dispossession of ancestral lands by the federal government and ongoing restrictions and challenges Indigenous communities have in maintaining the continuity of their cultural practices and benefits derived therefrom (Schultz et al. 2019; Tripp 2020). From a management perspective, it draws attention to the challenges of subsistence and cultural survival under changing climate conditions, as well as the possibilities for new governance models that are inclusive of Indigenous cultural values, paying attention to CES and associated benefits from an Indigenous perspective.

Below, we identify and define the components of our ICES model, which includes elements from Fish et al.'s (2016) model, and specific additions or modifications in relation to our case study. Our additions are listed in italics.

- Cultural values: Norms and expectations influencing and influenced by services, benefits, and their biophysical context.
- *Social-ecological resilience: The ability to maintain function under stress by adapting, mitigating, or transforming.*
- Biophysical domain: the biotic and abiotic environment (e.g., animals,

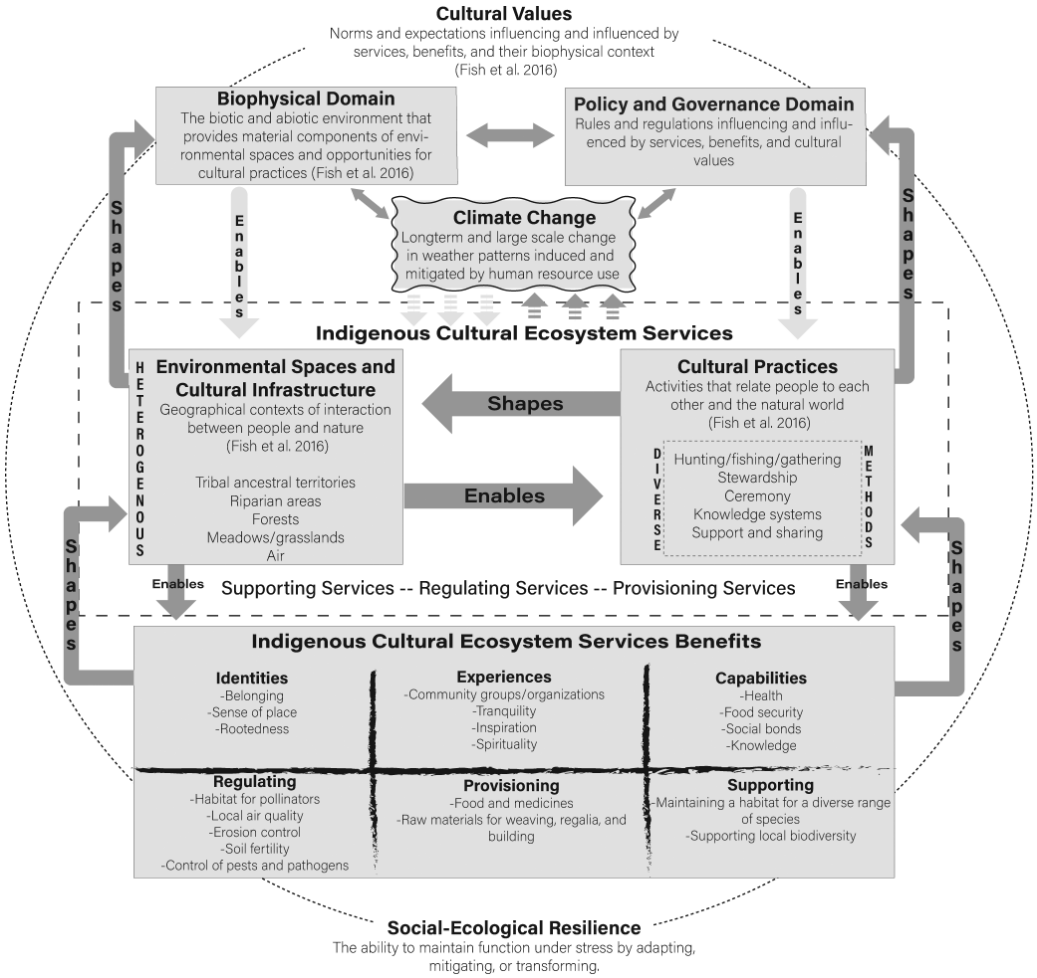

Figure 2. The Indigenous Cultural Ecosystem Services and Benefits model based on our case study with Tribes in the Klamath River Basin.

fungi, plants, soils, rocks, climate) that provides the material components of environmental spaces and opportunities for cultural practices.

- *Policy and governance domain: Rules and regulations influencing and influenced by services, benefits, and cultural values over time.*
- *Climate change: Long-term and large-scale change in weather patterns induced and mitigated by anthropogenic causes.*
- Environmental spaces: places/landscapes *(e.g., ancestral territory forests, rivers, gardens, meadows, ceremonial, or sacred areas)* where people interact with each other and the biophysical domain. *Coordination among Tribal families living in a similar area (region/watershed) using different gathering places and patches increases ecological heterogeneity and resilience at different scales.*
- *Cultural infrastructure: Places, sites, and ecological structures (i.e., fishing sites, hunting camps, trails, culturally modified trees, arranged*

rocks formations, etc.) created by cultural practices to increase functionality and/or acquisition of resources that facilitate subsistence, ceremonial/ritual, and economic security. Cultural infrastructure is integrated with natural systems that provide services to humans and the environment (see Jones and Steen-Adams 2020).

- Cultural practices: activities that relate humans to each other and to the natural environment. *In our case, cultural practices include stewardship, gathering, hunting, and fishing culturally significant foods, fibers, and medicines, intergenerational knowledge systems, social and familial systems, and ceremonies. Diversity in ways of doing supports resilience in cultural continuity through a range of methods that can adapt to change.*
- *Indigenous cultural ecosystem benefits:* Contributions to human and non-human wellbeing derived from CES, including identities, experiences, and capabilities (e.g., knowledge, a sense of belonging, health, security, sense of place) *as well as regulating services (e.g., habitat for pollinators, erosion control, soil fertility), provisioning services (cultural foods and medicines, raw materials for weaving, regalia, building), and supporting services (e.g., biodiversity, diversified habitat quality to support diverse species), all of which are benefits derived from CES.*
- Provisioning services: material outputs of ecosystems *(e.g., sticks and fibers for basketry or tanoak acorns for acorn soup)* (Millennium Ecosystem Assessment 2003).
- Regulating services: maintenance or regulation of ecosystem processes *(e.g., regulation of plant pests and pathogens using low-intensity fire)* (Halpern 2016; Millennium Ecosystem Assessment 2003).
- Supporting services: services necessary for the production of other ES (*e.g., soil formation and nutrient release following low-intensity burns)* (Millennium Ecosystem Assessment 2003; Santin and Doerr 2016).

Methods

This research was part of a collaborative Tribal-university-agency research, education, and extension project, spanning seven years (2014–present), and focused on enhancing Tribal health, food security, and agroecosystem resilience through sustainable food systems in the KRB. Research was conducted in partnership with the Karuk Tribe and Yurok Tribe of northern California and the Klamath Tribes of southern Oregon (see Sowerwine et al. 2019a). Using community-based participatory research methods (Fals Borda 1984), we worked closely with Tribal collaborators and other research partners to identify research questions, co-design and implement methods, interpret data, and develop recommendations and publications. An ethical research protocol was followed, with all research components and publications approved by Tribal councils and Tribal and university research ethics boards prior to commencement of research or submission for publication.

The data used for this study were collected in focus group discussions (21 total, 128 participants) and key informant interviews (179 total) conducted in 2015-2016 and 2019-2020. All interviews and focus groups were audio recorded and transcribed with participant consent. Focus groups (7 participants average) took place in nine towns in the KRB with Tribal members and descendants. Participant ages ranged from 14 to 62 years with an average age of 44, and included both men and women. One focus group (2019) included

a phenological calendaring exercise of culturally significant plants. Interviews were conducted with Tribal members and descendants. Sixty-four of the interviews took place in Karuk gathering areas (2019-2020) with five cultural practitioners (25–65 years old). Interview and focus group questions focused on the following content areas:

- Barriers to culturally significant food acquisition and consumption.
- Use and management of cultural ecosystems and resources.
- Timing of phenophases and harvest of culturally significant plants.
- Availability, quality, and abundance of culturally significant plant resources.
- Climate impacts on culturally significant plants and habitat condition within traditional gathering areas.
- Recommendations for mitigating and improving identified stressors and barriers.

Analysis of Interview and Focus Group Data

Interview and focus group data were coded using content analysis and flexible coding (Schreier 2014). A codebook was developed from all qualitative data, using inductive and deductive coding (Fereday and Muir-Cochrane 2006) by developing our initial coding themes as a team and based on interview/focus group guides. We then identified 15 codes relevant to this analysis and organized them by four ICES model components: Climate change (change in weather or climate, drought, impact on cultural resources, pests or pathogens, wildfire); ICES (cultural practices, cultural fire, land and ecosystems management/stewardship, gathering); ICES benefits (sharing and trading, knowledge systems, food security, culture); and Policy and governance (legacy of colonialism, policy barriers; see Supplementary Table 1 for code definitions). We analyzed overlaps between climate change and ICES, policy and governance, and ICES benefits to understand climate impacts on each. All analysis was conducted in NVivo (Version 11.4.3).

Results

Participants identified changes in climate and weather patterns over the last half-century, including significant changes in snowpack, less volume and duration of precipitation, drier and warmer summer months, and an earlier onset of spring-like temperatures. These observations align with regional climate studies in the area (Barr et al. 2010; Grantham 2018; Halofsky et al. 2020) and the general trajectory of climate change impacts on culturally significant foods (Karuk Tribe 2019; Lynn et al. 2013). In the sections below, we detail Indigenous observations of how climate change is altering ICES in the KRB.

Climate Change Impacts on ICES

Respondents described climate change impacts on their ability to access and harvest culturally important foods (a practice that often involves social bonding, intergenerational knowledge sharing, stewardship practices, and food sharing) in their ancestral territory. They reported that climate change has made it challenging to consistently predict the timing of harvest for different food, fiber, and medicinal species, which proves particularly challenging for scheduling harvest visits with family. Reduced or unreliable harvest timing has implications for the application of IK systems, including the timing of ceremonies and culturally significant foods served at ceremonies, the ability to support family and community, and continuity of place-based knowledge and cultural practices.

Respondents reported that the seasonal timing for harvesting culturally significant foods, fibers, and medicines is different from their childhood (20–50 years ago). As one person explained, people are experiencing "the speeding up of seasons and seasonal harvests," making it difficult to predict when to begin harvesting. One

elder respondent in the upper basin shared that wocus (*Nuphar polysepala*), which she used to harvest in August or September, was nowadays ready to harvest and almost spoiled by mid-July, the same time she was harvesting cattails (*Typha latifolia*) and tule roots (*Schoenoplectus* spp.). In the middle basin, evergreen huckleberries (*Vaccinium ovatum*), which previously were first harvested in September (October in the early 1900s [see Warburton and Endert 1966]), are now often ready in July.

Weather extremes and fluctuations cause uneven ripening of fruits and erratic physiological and reproductive cycles. Respondents reported that extreme heat during the summer speeds up the ripening and senescence of fruit; this has been observed in the harvest of trailing blackberries (*Rubus ursinus*), black cap raspberries (*Rubus leucodermis*), and evergreen huckleberries, where the berries ripen and soon thereafter shrivel up and spoil. Plants like gooseberry (*Ribes* spp.), redbud (*Cercis occidentalis*), willow (*Salix exigua*), California beaked hazel (*Corylus cornuta* var. *californica*), and huckleberry are observed budding and flowering months ahead of time. Early budding interrupts the rhythm of hazel stick harvest, creating a shorter window when sticks can be harvested before the buds leaf out too much. Also, periods of warming and freezing temperatures in the spring are thought to contribute to unpredictable and abnormal stripping of the outer bark on willow and hazel sticks used for basket weaving. The sap runs a lot earlier and faster in trees, as observed in the harvest of alder bark (*Alnus* spp.). Some bulbs, such as camas (*Camassia quamash* var. *breviflora*), in the upper basin, shrivel up, shrink in size, or do not even propagate in low moisture conditions. Unpredictable showers of rain and hot and cold spells cause abnormal flowering and ripening patterns, disrupting pollination and aborting flowers and fruits during freezing periods, as observed in madrone berries (*Arbutus menziesii*) and huckleberries.

Increased incidence, spread, and duration of wildfire due to hot and dry summer conditions causes months of heavy smoke inversion layers. This influences plant growth and, in some cases, has sped up senescence. One respondent observed *yerba buena* (*Clinopodium douglasii*) turning purple and dying in August during an intense wildfire season, something this person had never seen before. Other people noticed *yerba buena* migrating to places it did not grow previously and having a shorter period of dormancy attributed to warmer winters and earlier springs.

Years with less precipitation result in lower productivity of some culturally significant plants. For example, respondents attributed multiple years of limited tanoak (*Notolithocarpus densiflorus*)/black oak (*Quercus kelloggii*) acorn and tanoak mushroom (*Tricholoma murrillianum*) production to low rainfall (soil moisture availability). It is currently a struggle to harvest and provide enough acorns at ceremonies, which often requires one family to provide 60 or more people acorns for ten consecutive days. Not being able to provide enough acorns for ceremonies leads to stress and worry.

> I know last year it had a big impact on us. When we're having to say, "How many acorns do you have?" "I only have this many." We're worried about it, having enough for the dance, let alone…I can't make acorns because this is all I have and I got to save it for dance time. (Interview #25, 10/29/2015)

For several species (chinquapin [*Chrysolepis chrysophylla*], peppernut [*Umbellularia californica*], sugar pine [*Pinus lambertiana*], and madrone), there have been years of mass production followed by little reproduction and coupled with extreme weather and signs of deprivation. Cultural practitioners suspect heavy production is a stress-induced response to safeguard genetic continuance when an individual is in physiological decline. Decreased precipitation has resulted in

significantly lower river flow and near elimination of flooding events (compounded by dam regulation of high flows) which hampers the quality and health of willow roots and sticks for basketry, a material that requires periodic scouring from high flows to break off old growth, spur new growth, and decrease saw fly (*Euura exiguae*) populations (species of saw fly identified in Lake 2007).

ICES and Climate Mitigation

The cultural practice of managing plants with fire contributes to climate mitigation in two ways: it enhances the health and productivity of culturally significant plants and reduces fuel loading, which minimizes the risk of high intensity forest fires. This practice safeguards both cultural resources and communities. Fire suppression policies implemented in the 1900s have led to overstocked forests littered with fuels that are prime for high intensity fires in changing climate conditions. Cultural burning, used by Indigenous communities in the region since time immemorial, is now being adapted by federal agencies to manage against catastrophic fire. However, the cultural values of burning are important to consider, as the practice and end goals can be strikingly different (e.g., managing for culturally significant foods versus timber and fuel reduction). One respondent said:

> The Forest Service and other agencies want to do the burning themselves yet they don't have the objective of why they're burning that Native people do. It would look like a totally different forest if the Native people were managing it versus the Forest Service. (Interview #61, 12/01/2015)

This respondent emphasizes the need for Indigenous-led burning practices, with a focus on native plant management, highlighting the importance of cultural values in our ICES model.

Transplanting, seeding, watering, and thinning culturally significant plants are cultural practices, which, in the contemporary context of climate change, are emerging as important mitigation strategies for water and heat stress and the decline of native species in some habitats. Respondents reported transplanting culturally significant plants closer to their homes or re-planting gathering areas in decline or after a disturbance. One respondent said:

> My ones [evergreen huckleberry] in my yard are doing really good, but they're irrigated. They're fertilized. They're pruned. They're sung and talked to when the bumblebees are planting the flower, and they're watched in the summer when they're growing. I have a few places like that up on the hill too, on National Forest lands that I go visit. Generally speaking, I think those ones you steward and care for the most are going to produce well. (Interview #62, 12/02/2015)

Native people in the KRB play an important role in the long-term survival and health of native plant species and resilient ecosystems in the face of climate change; however, they must have sovereignty over these practices, as demonstrated in the next section.

Policy, Governance, and the Legacy of Colonialism

Today, large portions of Tribal ancestral territories in the KRB are federal lands, and the harvest and management of culturally important plants are governed by public policies restricting Tribal sovereignty over ICES. The harvest of non-timber forest products (e.g., fungi, willow, beargrass, and hazel) on public lands is governed by the US Forest Service Traditional Gathering Policy, which allows certain culturally important plants to be gathered without a permit and management to be conducted collaboratively (USDA Forest Service Region 5 2021). This policy excludes timber products and hunting and fishing. At times, public policies limit cultural practices, for example, harvesting seaweed on the coast in Yurok

Ancestral territory is limited to ten pounds of seaweed (see California Department of Fish and Wildlife 2021), the equivalent of about ten patties of seaweed, which is not enough for a substantial contribution to any cultural event or even a household (Focus group #11, 6/22/2015). In many cases, gathering and harvesting any type of culturally important resource requires a permit from a public agency, which is in violation of Indigenous sovereignty. Asking for and granting of permission to use ancestral landscapes and cultural resources that have been inhabited, used, and managed by Native people since time immemorial is recognized as disrespectful and offensive by Tribal people. Many prefer to risk fines and even jail than to take on the emotional and mental angst associated with submitting to permitting requirements.

Climate change has made it more difficult to manage culturally important plants with prescribed or cultural fires, as permitted burn windows are now shorter and less frequent and the permitting process for public lands is challenging. Nevertheless, without fire, many culturally significant plants in this area are not viable for use. In recent years, federal and state administrative or emergency declaration policies have closed National Forests to public and Tribal access due to fire danger or wildfire suppression, prohibiting cultural practices in these spaces. To regulate smoke emission, burn permits from air quality districts are required. Any prescribed/cultural burning project on federal lands also requires environmental and social analysis by the Environmental Protection Agency and, when the time is scheduled, an approved burn plan for conducting the burn with adequate fire personnel and resources. Recent climate-induced drought and weather events make vegetation burning risky, making it harder to find days which are permissible for cultural burning. Furthermore, when the KRB is in ideal condition for cultural burning practices, longer and more intense fire seasons fatigue or occupy essential fire personnel needed for permit approval. One respondent reflects on the importance of cultural fire management and the challenges in doing so today:

> Controlled burns would help a lot. I almost lost my house to a fire years ago because there's a lack of burns. To be able to control a burn when you want to, this one they had the TRX people, that was really cool, but they weren't really able to follow complete traditional way after it rains. It seems like when I was younger, people were able to do that more on their own properties, didn't have to ask permission to do it or get a permit, during a time of year when they'd be necessarily—I know that for regalia you have to get a permit and you have 10 days to use it. What if it rains in those 10 days and you don't want to have a bunch of firefighters on standby, you just want to do it yourself. That's how my uncle used to do it, my great uncle didn't have a team of firefighters access all the time, he just waited until it rained and did it, and it never got away because it was able to do what they wanted to, versus when you're able to get it when it's the time. (Interview #21, 10/27/2015)

Given contemporary regulations surrounding cultural/prescribed fire management and the influence of climate change, we demonstrate how the policy and governance dimension limits Tribal land stewardship, a critical ICES, thereby impacting the quality and abundance of culturally significant plants and the myriad benefits derived therefrom.

ICES Benefits

ICES benefits are directly and indirectly influenced by climate change. Misguided land management policies compounded by climate change impacts on biophysical landscapes affect ICES and associated benefits. We detail examples of ICES benefits associated with identity, experiences,

and capabilities, including spirituality, food security, health, family, and more to highlight the potential risk for Indigenous communities in the KRB due to the consequences of climate change.

Respondents identified "identity" benefits related to ICES, including spiritual/religious connection to ecosystems and childhood memories, which engender a sense of belonging to place and people and responsibility to care for the land and component resources.

> It [gathering] makes you more connected to the land that you're from. It makes you have that connection that your people have always done. I think people that gather and hunt traditional foods in their area care more about their area and are more interested in being advocates for their land and the animals that are there. (Interview #31, 11/3/2015)

ICES "experiences" generated from formal or informal community groups related to gathering and stewardship strengthen social and familial bonds, critical to mental health, and continuity of culture and cultural ES. Basket weaving groups in the area are an important cultural activity deepening intergenerational relationships and knowledge systems, which further sustain CES. One respondent illustrates the social and cultural health benefits of CES:

> These guys [the basket weaving group] were like my family, even though being a kid and teenager or whatever, going through all that crap, it was like no matter what mood I was in, no matter what dumb stuff I was doing or whatever, they always were there for me, like family. They would just build you up, make you feel good. That's what they do to this day. We all do that to each other or even pick on each other, like, "What in the hell are you making?" or "Your sticks are too big, you're making a bird basket, that's not a tray." It's love. This is my family. (Interview #67, 12/8/2015)

Lastly, ICES provide benefits related to an array of "capabilities," including physical and mental health, food security, social systems and bonds, and Indigenous Knowledge systems, that support the human condition and "know-how" to continue carrying out cultural practices. As this quote demonstrates, gathering provides much more than food.

> Just yesterday, my sister and I and two of my daughters and their kids all went out gathering acorns with a family friend on her property. It was funny because my daughter, she was down there with me too and she said her husband asked her, "Why do you got to go clear up Hoopa to get acorns? We got acorns right here." She said, "Because it's just not the same gathering by yourself." It's a family thing, which is really nice. (Interview #13, 10/5/2015)

Discussion

Climate change has negatively impacted ICES (environmental spaces and cultural practices) in the KRB, diminishing plant and animal health, shifting plant reproduction cycles, influencing water quality, temperature, and availability, and altering the timing of hunting, gathering, and burning. These changes ultimately affect ICES benefits by a) changing Indigenous people's ability to carry out cultural stewardship practices and b) changing the timing, location, availability, and health of cultural resources (or the ability to utilize them at all). Our data reflect not only the challenges posed by climate change but also by the laws, policies, and values in the region that negatively impact forest structure and health, and the potential for ICES to mitigate the impacts of those challenges. The added policy and governance dimension to our ICES framework shows how management decisions in the KRB have historically privileged Euro-American settler colonial

values, emphasizing more extractive "provisioning" ES (logging, mining, fire suppression) and Euro-centric conceptualizations of CES (aesthetic, recreation, hiking) (see Hurwitz 2014; Sarna-Wojcicki et al. 2019) over Indigenous values that center stewardship, responsibility, and reciprocity. As climate change intensifies catastrophic wildfire in the KRB, existing laws and policies continue to exclude Native people from applying low-intensity cultural fires in their territories. Indeed, such management techniques reduce the risk of high-intensity fire and enhance the productivity and health of ecosystems and people (Lake et al. 2017). Exclusion of cultural fire management has reduced ICES benefits, including the health and productivity of cultural use species (Marks-Block et al. 2019). For example, weaving materials, like beargrass (*Xerophyllum tenax*), hazel, and willow, require frequent management with fire to generate quality material for weaving (Hart-Fredeluces et al. 2020; Lake 2007; Marks-Block et al. 2019). Weaving supports community well-being and helps maintain Tribal identity, with baskets used for a wide range of cultural activities (Smith 2016). Losing access to quality materials as a "provisioning" service would negatively impact many ICES benefits, including, but not limited to, a sense of belonging, cultural knowledge, social bonds, and cultural health.

Tribes of the KRB have adapted and responded to the effects of climate for millennia (Karuk Tribe 2019), clearly possessing an unequivocal connection to place and temporal knowledge of environmental change that is unparalleled in academic studies. Indigenous Knowledge and, in particular, Indigenous phenological knowledge, can inform climate mitigation and adaptive management strategies (Armatas et al. 2016). Authors have observed the resilient and adaptive capacity of diverse familial gathering and stewardship practices that ensure the continuity of household and ceremonial consumption of acorn soup, roasted fish or game, and berries. This heterogeneity of cultural landscape practice and consumption of culturally significant foods promotes a plethora of ICES benefits and community resilience. More formalized applications of IK in landscape management and climate mitigation have formed in collaborations among Tribal, federal, and non-profit agencies; for example, the Western Klamath Restoration Partnership in the KRB (Lake et al. 2018; Lynn et al. 2013). The recent success of cultural fire stewardship programs in Australia demonstrate how ICES can garner much-needed financial and political support for Indigenous-led fire programs to conduct traditional burning across large-scale landscapes (~90 million acres) (Firesticks Alliance Indigenous Corporation 2020). Calls for similar programs in the KRB and western United States are gaining momentum in climate adaption plans, and such programs are strongly desired by Tribes. As the Karuk Department of Natural Resources director, Bill Tripp, stated in September 2020, "We know the solution is to burn like our Indigenous ancestors have done for millennia."

Indigenous Concepts in ES Models

Indigenous People are active stewards, not peripheral components, of ecosystems, giving, enhancing, and reciprocally receiving ES. The ICES model presented and applied in this study illuminates Indigenous cultural resource use and stewardship in the context of climate change that comparable studies have failed to capture. While Comberti et al. (2015), Fish et al. (2016), Winthrop (2014), and Sangha et al. (2015) laid the foundation to realize mutual social-ecological relations in ES models, we extend these baseline concepts to account for the influence of climate change impacts and policy and governance on ES and the mitigation potential of cultural practices. Our model uniquely illustrates how CES not only benefit humans but broadly influence ES and ecosystem functioning. Indigenous Knowledge systems and stewardship of

ancestral territories through cultural burning, for example, reduces the likelihood of pest infestations (regulating service) (Halpern 2016), and enhances the health and productivity of culturally important foods, fibers, and medicines (provisioning service) (Marks-Block et al. 2019). It also promotes new vegetative growth that serves as forage for game (supporting service) (Long et al. 2008), and reduces the likelihood of catastrophic fires (regulating service) (Lake 2013). Enabling these practices through appropriate laws and policies would enhance the regulating, provisioning, and supporting services for both human and nonhuman elements of the natural world, ultimately strengthening the socio-ecological resilience of the KRB. Our ICES model advances conceptualizations and application of ES models beyond Euro-centric framings, and also deepens our understanding of how climate change and policy and governance influences human-biological relationships. We envision our model being used by communities and researchers alike to understand how ICES and ICES benefits can sustainably be supported.

CES are Tangible and Measurable

Contrary to the common definition of CES (e.g., *non-material* benefits obtained from ecosystems [Millennium Ecosystem Assessment 2003]), our results suggest that many CES are also tangible and easily identified by those that benefit from and depend on those services. Participants in our study identified CES benefits they observed in their life, family, and community, including improved mental and physical health, enhanced food security, quality medicines and basketry materials, and healthy habitats that support diversity of plant and animal species. As in Fish et al. (2016), these benefits are broadly recognized as *capabilities*, which we describe as continuing cultural practices and connection with environmental spaces and others through social bonding, *identity* as Indigenous people within a specific place-based community guided by a set of cultural values and responsibilities, and *experiences* of inspiration or interconnectivity on the landscape and in organized community groups engaged in gathering, stewardship, or weaving (Figure 2). Sowerwine et al. (2019b) demonstrated that benefits derived from CES, including close family ties, intergenerational knowledge sharing, and reciprocity within families or communities, positively influenced household food security and well-being in Native households in the KRB, highlighting tangible contributions CES make to human wellbeing. Ecological studies conducted with Tribal partners demonstrate regulating and supporting benefits from cultural management practices (Marks-Block et al. 2021). Such measurable indicators can be used to evaluate the benefits (sustained or deteriorated in changing climates) of CES to people and ecosystems.

Gathering as a Cultural Ecosystem Service

Within the field of ES, the acquisition of food from the environment is considered a utilitarian provisioning ES, in which the former provides the raw materials and cultural goods for consumption and utilization. In our model, provisioning services are ICES, inclusive of the cultural meaning and significance of goods and related cultural practices, and the culturally relevant ways in which they are sourced and utilized. Kawamura (2004) similarly found that the practice of gathering culturally important food plants today for the Nez Perce Tribe in Idaho often holds more social and cultural significance than the physical product itself. A more holistic view of ecosystems and the services derived from and benefiting them includes the whole suite of both tangible and intangible values and cultural services associated with gathering plants.

Because culturally important foods obtained through gathering are not solely important for their nutritional benefit, rather than being considered a "cultural good" (as in Fish et al. 2016), they should

be considered as "*cultural ecosystem benefits*." Considering them as "cultural goods" implies potential for commodification or monetization but, under our framework, burning, gathering, hunting, and fishing are considered CES, and the foods derived from those practices are "*cultural ecosystem benefits*" rather than "goods." Culturally important foods contribute not only to enhanced food security and nutritional health, but also toward strengthening cultural identity, a sense of belonging, connection to place, and stronger social and familiar relations (Lake 2018).

Conclusion

This paper developed and tested a novel ES conceptual model to demonstrate the relevance and importance of *Indigenous* CES to both general ES theory and practice, as well as to specific applications in climate change monitoring, mitigation, and adaptation in Indigenous territories. Among Karuk, Yurok, and Klamath Tribal communities in the KRB, a rich body of IK about culturally important foods, fibers, and medicines illustrates how ICES, in the context of gathering, are being affected by climate change. ICES benefits make vital contributions to Tribal wellbeing, which rely on Indigenous cultural practices on the landscape (CES), including hunting, gathering, fishing, stewardship and management, knowledge systems, and reciprocity, all of which contribute to human and ecosystem health. Given the high rates of food insecurity, poverty, and diet-related disease in Indigenous communities, cultural ES that contribute in very tangible ways to health, wellbeing, and nutrition are important to consider in food systems and forest management policy and programing given the Federal Government's Trust responsibilities for health, education, and resource protection for Native people (Baer 1987; Warne and Frizzell 2014; Wood 2003). As each Indigenous community and landscape will have unique histories, legal and regulatory structures, people-plant relationships, cultural values, knowledge practices, and traditions related to the management of their cultural plant species and habitats, we recommend community-engaged participatory approaches to both identify and assess threats to ICES, as well as to operationalize ICES through management, policy, and practice to improve social-ecological resilience and wellbeing. ICES frameworks will likely be more successful if designed by and for Indigenous communities and implemented through Indigenous-led initiatives that affirm Tribal sovereignty. Inclusion of community-defined ICES in climate adaptation and cultural ecosystem restoration initiatives in Indigenous lands can support Tribal sovereignty in management, planning, and decision-making processes by establishing oversight protocols to ensure that ICES frameworks appropriately reflect IK and cultural values and protect any sensitive cultural information (Karuk Tribe 2019). Authentic engagement with Indigenous communities is needed to ensure full consideration of the place-based knowledges and cultural ecosystem practices and range of potential services and benefits that can result in more informed, inclusive, and effective governance and climate adaptation initiatives within Indigenous ancestral homelands.

Acknowledgments

The authors would like to recognize the invaluable contributions of community members from the Karuk, Yurok, and Klamath Tribes who participated in our research, and the cultural practitioners from whom we have learned so much, namely Lisa Hillman, Leaf Hillman, Ron Reed, Kathy McCovey, and Vikki Preston. This work was carried out with funding from the USDA National Institute of Food and Agriculture: Agriculture and Food Research Initiative Food Security Grant # 2012-68004-20018, Agriculture and Food Research Initiative Resilient Agroecosystems in a Changing Climate Challenge Area Grant # 2018-68002-27916, and the USDA Forest Service and DOI-USGS Northwest Climate Adapta-

tion Science center. All opinions, findings, and conclusions or recommendations expressed here are those of the authors and do not necessarily reflect the views of the University of California-Berkeley or Tribes, and should not be construed to represent any official USDA or U.S. Government determination or policy.

References Cited

Anderson, K. M., and F. K. Lake. 2013. California Indian Ethnomycology and Associated Forest Management. *Journal of Ethnobiology* 33:33–85.

Armatas, C. A., T. J. Venn, B. B. McBride, A. E. Watson, and S. J. Carver. 2016. Opportunities to Utilize Traditional Phenological Knowledge to Support Adaptive Management of Social-Ecological Systems Vulnerable to Changes in Climate and Fire Regimes. *Ecology and Society* 21:16.

Baer, S. D. 1987. The Public Trust Doctrine–A Tool to Make Federal Administrative Agencies Increase Protection of Public Land and its Resources. *Boston College Environmental Affairs Law Review* 15:385.

Barr, B. R., M. E. Koopman, C. D. Williams, S. J. Vynne, R. Hamilton, and B. Doppelt. 2010. Preparing for Climate Change in the Klamath Basin. National Center for Conservation Science and Policy and The Climate Leadership Initiative, Eugene. Available at: https://www.climatewise.org/images/projects/klamath-report-final.pdf. Accessed on February 25, 2021.

California Department of Fish and Wildlife. 2021. Recreational Harvest of Kelp and Other Marine Algae. Available at: https://wildlife.ca.gov/Conservation/Marine/Kelp/Recreational-Harvest. Accessed on February 24, 2021.

Chan, K. M. A, T. Satterfield, and J. Goldstein. 2012. Rethinking Ecosystem Services to Better Address and Navigate Cultural Values. *Ecological Economics* 74:8–18.

Comberti, C., T. F. Thornton, V. Wyllie de Echeverria, and T. Patterson. 2015. Ecosystem Services or Services to Ecosystems? Valuing Cultivation and Reciprocal Relationships Between Humans and Ecosystems. *Global Environmental Change* 34:247–262.

Díaz, S., U. Pascual, M. Stenseke, B. Martín-López, R. T. Watson, Z. Molnár, R. Hill, et al. 2018. Assessing Nature's Contributions to People. *Science* 359:270–272.

Díaz, S., J. Settele, E. S. Brondízio, H. T. Ngo, J. Agard, A. Arneth, P. Balvanera, et al. 2019. Pervasive Human-Driven Decline of Life on Earth Points to the Need for Transformative Change. *Science* 366:eaax3100. DOI:10.1126/science.aax3100.

Dunbar-Oritz, R. 2014. *An Indigenous Peoples' History of the United States*. Beacon Press, Boston, Massachusetts.

Fals Borda, O. 1984. Participatory Action Research. *Development: Seeds of Change* 2:18–20.

Fereday, J., and E. Muir-Cochrane. 2006. Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods* 5:1–11.

Firesticks Alliance Indigenous Corporation. 2020. Firesticks. Cultural Burning: Healthy Communities, Healthy Landscape [web page]. URL: https://www.firesticks.org.au. Accessed on July 31, 2020.

Fish, R., A. Church, and M. Winter. 2016. Conceptualizing Cultural Ecosystem Services: A Novel Framework for Research and Critical Engagement. *Ecosystem Services* 21:208–217.

Gould, R. K., N. M. Ardoin, U. Woodside, T. Satterfield, N. Hannahs, and G. C. Daily. 2014. The Forest Has a Story: Cultural Ecosystem Services in Kona, Hawai'i. *Ecology and Society* 19:55.

Grantham, T. 2018. North Coast Summary Report. California's Fourth Climate Change Assessment. University of California, Berkeley. Publication number: SUM-CCC4A-2018-001. Available at: https://www.energy.ca.gov/sites/default/files/2019-11/Reg_Report-SUM-CCCA4-2018-001_NorthCoast_ADA.pdf. Accessed on February 25, 2021.

Halofsky, J. E., D. L. Peterson, and B. J. Harvey. 2020. Changing Wildfire, Changing Forests: The Effects of Climate Change on Fire Regimes and Vegetation in the Pacific Northwest, USA. *Fire Ecology* 16:1–26.

Halpern, A. A. 2016. Prescribed Fire and Tanoak (*Notholithocarpus densiflorus*) Associated Cultural Plant Resources of the Karuk and Yurok Peoples of California. Doctoral Dissertation, Department of Integrative Biology, University of California at Berkeley, Berkeley, CA. Available at: https://escholarship.org/uc/item/02r7x8r6. Accessed on June 1, 2021.

Hart-Fredeluces, G. M., T. Ticktin, and F. K. Lake. 2020. Simulated Indigenous Fire Stewardship Increases the Population Growth Rate of an Understory Herb. *Journal of Ecology* 109:1133–1147.

Ho, V. 2020. Fire Tore Through the Karuk Tribe's Homeland. Many Won't Be Able to Rebuild. *The Guardian*. October 23, 2020. https://www.theguardian.com/us-news/2020/oct/23/karuk-tribe-california-slater-fire-insurance. Accessed on February 21, 2021.

Hurwitz, L. 2014. Got Land? Thank an Indian: Settler Colonialism and the White Settler in the Karuk Ancestral Territory. *Humboldt Journal of Social Relations* 36:59–76.

Jones, C., and M. Steen-Adams. 2020. Appendix B: American Indian Communities in the Contiguous United States: Unmet Infrastructure Needs and the Recommended Pathway to Address a Fundamental Threat to Lives, Livelihoods, and Cultures. Bureau of Indian Affairs. Washington, D. C.

Karuk Tribe. 2019. *Karuk Climate Adaptation Plan*. Karuk Tribe Department of Natural Resources, Orleans, California. Available at: https://karuktribeclimatechangeprojects.files.wordpress.com/2019/10/reduced-size_final-karuk-climate-adaptation-plan.pdf. Accessed on February 26, 2021.

Kawamura, H. 2004. Symbolic and Political Ecology Among Contemporary Nez Perce Indians in Idaho, USA: Functions and Meanings of Hunting, Fishing, and Gathering Practices. *Agriculture and Human Values* 21:157–169.

Kroeber, A. L. 1976. *Handbook of the Indians of California*. Dover Publication, Inc., New York.

Lake, F. K. 2007. Traditional Ecological Knowledge to Develop and Maintain Fire Regimes in Northwestern California, Klamath-Siskiyou Bioregion: Management and Restoration of Culturally Significant Habitats. Unpublished Doctoral Dissertation, Department of Environmental Sciences, Oregon State University, Corvallis, Oregon. Available at: https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/1z40kw515. Accessed on February 26, 2021.

Lake, F. K. 2013. Historical and Cultural Fires, Tribal Management and Research Issue in Northern California: Trails, Fires and Tribulations. *Occasion: Interdisciplinary Studies in the Humanities* 5:1–22.

Lake, F. K. 2018. Fire as Medicine: Fire Dependent Cultures and Re-Empowering American Indian Tribes. Fire Adapted Communities Learning Network [web page]. URL: https://fireadaptednetwork.org/fire-as-medicine-fire-dependent-cultures/. Accessed on August 25, 2020.

Lake, F. K., J. Parrotta, C. P. Giardina, I. Davidson-Hunt, and Y. Uprety. 2018. Integration of Traditional and Western Knowledge in Forest Landscape Restoration. In *Forest Landscape Restoration: Integrated Approaches to Support Effective Implementation*, edited by S. Mansourian and J. Parrotta, pp. 198–226. Routledge, New York.

Lake, F. K., V. Wright, P. Morgan, M. McFadzen, D. McWethy, and C. Stevens-Rumann. 2017. Returning Fire to the Land: Celebrating Traditional Knowledge and Fire. *Journal of Forestry* 115:343–353.

Lertzman, K. 2009. The Paradigm of Management, Management Systems, and Resource Stewardship. *Journal of Ethnobiology* 29: 339–358.

Long, R. A., J. L. Rachlow, J. G. Kie, and M. Vavra. 2008. Fuels Reduction in a Western Coniferous Forest: Effects on Quantity and Quality of Forage for Elk. *Rangeland Ecology and Management* 61:302–313.

Lynn, K., J. Daigle, J. Hoffman, F. Lake, N. Michelle, D. Ranco, C. Viles, et al. 2013. The Impacts of Climate Change on Tribal Traditional Foods. *Climatic Change* 120: 545–556.

Marks-Block, T., F. K. Lake, and L. M. Curran. 2019. Effects of Understory Fire Management Treatments on California Hazelnut,

an Ecocultural Resource of the Karuk and Yurok Indians in the Pacific Northwest. *Forest Ecology and Management* 450: 117517.

Marks-Block, T., F. K. Lake, R. B. Bird, and L. M. Curran. 2021. Revitalized Karuk and Yurok Cultural Burning to Enhance California Hazelnut for Basketweaving in Northwestern California, USA. *Fire Ecology* 17. https://doi.org/10.1186/s42408-021-00092-6.

Michaelis, A. K., W. C. Walton, D. W. Webster, and L. J. Shaffer. 2020. The Role of Ecosystem Services in the Decision to Grow Oysters: A Maryland Case Study. *Aquaculture* 529:735633. https://doi.org/10.1016/j.aquaculture.2020.735633.

Millennium Ecosystem Assessment. 2003. Ecosystems and Human Well-Being: A Framework for Assessment. Island Press, Washington, D.C. Available at: https://pdf.wri.org/ecosystems_human_wellbeing.pdf. Accessed on February 26, 2021.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-Being: Current State and Trends. Findings of the Condition and Trends Working Group. Island Press, Washington, D.C. Available at: https://www.millenniumassessment.org/documents/document.766.aspx.pdf. Accessed on February 26, 2021.

Sangha, K. K., A. Le Brocque, R. Costanza, and Y. Cadet-James. 2015. Ecosystems and Indigenous Well-Being: An Integrated Framework. *Global Ecology and Conservation* 4:197–206.

Sangha, K. K., L. Preece, J. Villarreal-Rosas, J. J. Kegamba, K. Paudyal, T. Warmenhoven, and P. S. RamaKrishan. 2018. An Ecosystem Services Framework to Evaluate Indigenous and Local Peoples' Connections with Nature. *Ecosystem Services* 31:111–125.

Santin, C., and S. H. Doerr. 2016. Fire Effects on Soils: The Human Dimension. *Philosophical Transactions of the Royal Society B* 371:20150171.

Sarna-Wojcicki, D., J. Sowerwine, L. Hillman, L. Hillman, and B. Tripp. 2019. Decentering Watersheds and Decolonizing Watershed Governance: Towards an Ecocultural Politics of Scale in the Klamath Basin. *Water Alternatives* 12:241–266.

Schreier, M. 2014. Qualitative Content Analysis. In *The SAGE Handbook of Qualitative Data Analysis*, edited by U. Flick, pp. 170–183. SAGE Publication Ltd., Los Angeles, CA.

Schultz, C. A., S. M. McCaffrey, and H. R. Huber-Stearns. 2019. Policy Barriers and Opportunities for Prescribed Fire Application in the Western United States. *International Journal of Wildland Fire* 28:874–844.

Smith, C. 2016. Weaving *pikyav* (to-fix-it): Karuk Basket Weaving in-Relation-with the Everyday World. Unpublished Doctoral Dissertation, Department of Anthropology, University of California at Berkeley, Berkeley. CA. Available at: https://escholarship.org/content/qt8hx01626/qt8hx01626_noSplash_d529381b669bc1bd2a385169b84f9c36.pdf?t=ppfl5c. Accessed on August 20, 2021.

Sowerwine, J., M. Mucioki, E. Friedman, L. Hillman, and D. Sarna-Wojcicki. 2019a. Food Security Assessment of Native American Communities in the Klamath Basin with the Karuk Tribe, Klamath Tribes, Yurok Tribe, and Hoopa Tribe. Karuk-UC Berkeley Collaborative. University of California at Berkeley, Berkeley, CA. Available at: https://nature.berkeley.edu/karuk-collaborative/wp-content/uploads/2019/05/Food-Security-Assessment-Web-5.20.pdf. Accessed on February 26, 2021.

Sowerwine, J., M. Mucioki, D. Sarna-Wojcicki, and L. Hillman. 2019b. Reframing Food Security by and for Native American Communities: A Case Study Among Tribes in the KRB of Oregon and California. *Food Security* 11:579–607.

Thorne, J. H., R. M. Boynton, A. J. Holguin, J. A. E. Stewart, and J. Bjorkman. 2016. A Climate Change Vulnerability Assessment of California's Terrestrial Vegetation. California Department of Fish and Wildlife, Sacramento, CA. Available at: https://lccnetwork.org/sites/default/files/Resources/California%20Climate%20Vulnerability%20Assessment%20of%20Macrogroup%20Vegetation_01.31.2016_FINAL.pdf. Accessed on February 26, 2021.

Tripp, B. 2020. Our Land was Taken. But We Still Hold the Knowledge of How to Stop Mega-

Fires. *The Guardian*. September 16, 2020. https://www.theguardian.com/commentisfree/2020/sep/16/california-wildfires-cultural-burns-indigenous-people. Accessed on February 26, 2021.

USDA Forest Service Region 5. 2021. Traditional Gathering Policy. https://www.fs.usda.gov/detailfull/r5/workingtogether/tribalrelations/?cid=FSEPRD683463&width=full. Accessed on February 24, 2021.

Warburton, A. D., and J. F. Endert. 1966. *Indian Lore of North California Coast*. Pacific Pueblo Press, Santa Clara, California.

Warne, D., and L. B. Frizzell. 2014. American Indian Health Policy: Historical Trends and Contemporary Issues. *American Journal of Public Health* 104:S263–S267.

Winthrop, R. H. 2014. The Strange Case of Cultural Services: Limits of the Ecosystem Services Paradigm. *Ecological Economics* 108:208–214.

Wood, M. C. 2003. Indian Trust Responsibility: Protecting Tribal Lands and Resources through Claims of Injunctive Relief Against Federal Agencies. *Tulsa Law Review* 39:35.