



Climate resilience through ecocultural stewardship

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The climate crisis has exacerbated many ecological and cultural problems including wildfire and drought vulnerability, biodiversity declines, and social justice and equity. While there are many concepts of social and ecological resilience, the exemplar practices of Indigenous stewardship are recognized in having sustained Indigenous peoples and their countries for millennia and past climate change events. California has been at the crossroads of many of these issues, and the historic and current contributions of Indigenous peoples to addressing these provide an excellent study of ecocultural stewardship and leadership by Indigenous peoples to achieve climate resilience.

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Consequences of the climate crisis are evident in the effects of devastating wildfires, severe droughts, extensive floods, rising seas, and biodiversity decline among other issues, but they are largely not new problems, and the knowledge to live with and through such change is imperative to social and ecological resilience. It is clear that immediate action is necessary to curb and reverse anthropogenic drivers of warming and avoid dire consequences for the planet and its inhabitants. Globally, Indigenous people's contributions to climate resilience and biodiversity conservation have gained momentum (1–6). From a community perspective, climate resilience and biodiversity conservation represent a narrowed scope of benefits derived from integrated ecocultural relationships encompassing much broader and holistic understandings within Indigenous knowledges (IK). The breakdown of ecocultural systems is globally significant and motivating considering the poor treatment of Indigenous peoples. Currently, Indigenous peoples comprise less than 6% of the global population and steward approximately 80% of the world's biodiversity (7) on about 24% of the earth's terrestrial environments (8). This is a product of factors including injustice, inequality, and erasure through colonial subjugation, degradation of natural areas due to a decrease in connections to nature in the broader society, and general reciprocal relationships with country maintained by Indigenous peoples. Here “country,” a term increasingly used by Indigenous peoples to describe connections to place, is a singular term encompassing lands and waters and more broadly the storscape connecting peoples and kinship (e.g., biota) from broad regions.

Indigenous peoples maintain a unique relationship to country (9, 10), and Indigenous cultures (e.g., languages, objects, knowledges, stewardship practices, and lifeways) generally reflect the environment where they originate. However, there are often nearly universal stewardship practices and approaches such as the use of fire (11) shared among peoples. Stewardship is an intergenerational lifeway

responsibility with the current generation upholding obligations to past and future ancestors. Stewardship of country replicates and complements other natural keystone processes and is guided by holistic systems understanding.

California poses a unique focal point of consideration at the interface of climate, fire, water, and ecocultural processes. Similar to other areas of the world, California has experienced increased impacts and vulnerability from wildfires and area burned in recent decades—particularly high fire severity in forests (12, 13) resulting from comingled influences of fuel loading, extreme and prolonged drought, insect and disease outbreaks in vegetation, and shifting climate conditions including warmer temperatures and greater vapor pressure deficits. Among key impacts from these wildfires are their contributions to further biodiversity decline and degraded ecosystem function in terrestrial and aquatic systems, which threaten the combined socio-ecological health of ecosystems and communities, economic impacts, and increased emissions (Fig. 1). Land use and land use change are also important regulators of climate, fire, water, and biodiversity. While biodiversity declines in California primarily stem from land use change (i.e., habitat loss due to conversion to agriculture and urbanization), climate-driven influences are causing ecological shifts from rapid environmental change events resulting in habitat type conversion and declining general suitability and range shifts (13). Biodiversity is an important metric of environmental health and stewardship.

California is recognized as both a global biodiversity (14, 15) and Indigenous cultural diversity (16) hotspot. Over millennia, Indigenous people's stewardship of country within California's cultural regions exemplifies adaptation to changing environmental conditions to meet diverse ecocultural objectives including influences on fire, water, and biodiversity (17–19) and ensure social and ecological resilience. Indigenous fire stewardship (e.g., cultural burning) is perhaps the most significant keystone process due to its extensive use within the landscape, while water stewardship tends to be more

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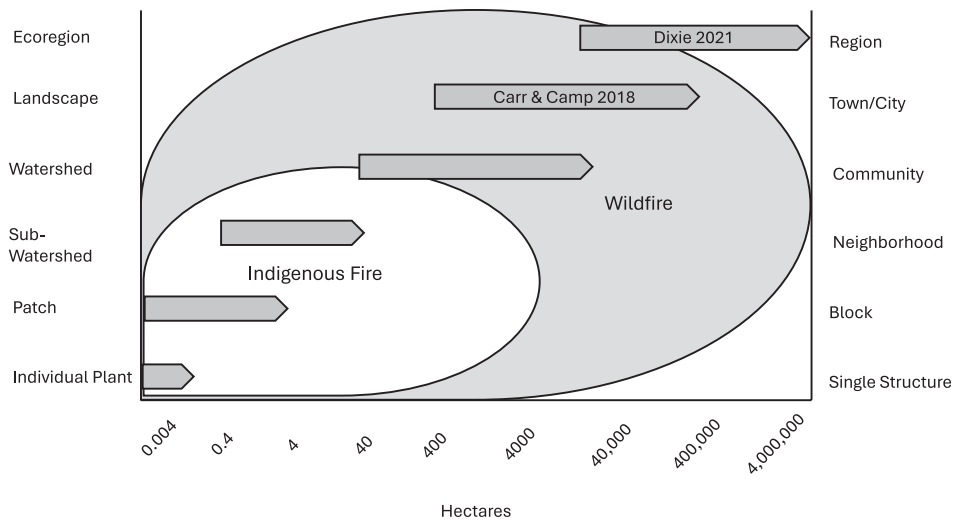


Fig. 1. The spatial extent and effects of Indigenous fire and wildfire influence ecological and social units in different ways. The social ecological scaling of fire here illustrates the localized nature of Indigenous fires and their influence on finer-grained attributes, whereas wildfires may influence coarser-grained impacts to socioecological systems.

localized with exception to landscape scale interactions between fire and water. Ecosystem productivity and heterogeneity were historically enhanced at scale by Indigenous stewardship (IS) (20). Colonization largely disrupted these processes. Early European visitors and colonists frequently noted astounding abundance of fish and wildlife resultant of intentional stewardship actions of Indigenous peoples but often failed to connect the contributions of Indigenous peoples to this richness. This oversight came at the cost of Indigenous peoples and the entirety of country.

Ultimately, each fire, flood, and drought-stressed landscape exists within Indigenous people's country (see refs. 18, 19, and 21). The laws of settler colonial governments are not founded in the same recognition of nature as traditional law (i.e., natural law) does for Indigenous peoples. This difference creates conflicts between the ability to live symbiotically with nature (see ref. 22) by following traditional law. The deep time perspective and benefit of Indigenous knowledge provides unique lessons and opportunities to address these factors through ecocultural frameworks to further nature-based solutions to become more resilient.

Settler Colonial Roots of the Climate Crisis

Population declines, forced movement, and pressure from colonial presence across North America changed Indigenous people's relationships with their country. Indigenous communities often recognize colonization as the beginning of the climate crisis (e.g., ref. 23). The combined effects of mass Indigenous depopulation of an estimated 55 million people and subsequent vegetation regeneration in the Americas following 1492 contributed to the Medieval Cooling (24). California's precontact population was among the highest in North America north of Mexico and estimated to be between 310,000 (25) and 1 million. While initial depopulation may have occurred during the early conquest of the continent, most certainly, California's depopulation followed events from early exploration in 1542 to mission establishment in 1769, malaria and smallpox epidemics in the 1830s, and statehood in 1850, when California's first governor Peter

Burnett and legislature proclaimed a war of extermination on the state's Indigenous peoples lasting into the early 1900s. By the early 20th century, various censuses estimated Indigenous populations to be around 16,000 (26).

In the elapsed time, new species were introduced (27–29). Spanish, Mexican, and American governments enacted policies enabling private ownership of land and forbidding Indigenous peoples from setting fires—often with extreme penalties (i.e., death). Fire regimes began to deviate due to the decline in IS, livestock grazing, logging, fire suppression policies, and other factors. The decoupling of ecocultural systems in California is particularly discernable in fire histories (30) and other evidence. The combination of population decline, policy, and changes in land use and tenure ultimately degraded and removed ecosystems and curtailed IS of country resulting in species decline and precarious states of social ecological systems.

Framing Ecocultural Health

Approximately 24% of California's land area and 16% of coastal waters are conserved (31). However, these areas are disproportionately located in inland and mountainous areas whereas some of the rarest, most impacted, and historically most biologically rich ecosystems occur in coastal and lowland areas. Examples of greatly reduced ecosystems include native grasslands (<2%), valley oak woodlands (<2%), Central Valley riparian forests (<2%), and wetlands (<5%) (numbers indicating what remains). Clearly these ecosystems need conservation, restoration, and stewardship.

Healthy country supports healthy communities and reflects Indigenous relationships to place (see refs. 32 and 33). Healthy country is evident in the diversity and abundance within the country to support material culture production including baskets, regalia, and ceremonial objects of Indigenous California. These material culture objects and ceremonies they are produced for often reflect relationships with multiple species and ecosystems. Virtually every ecosystem has culturally significant species, which serve as indicators of that country's health and cultural inerties (see also ref. 34). For instance, the feather belts of Central California are velvet-like textiles made

from milkweed fibers with individual feathers of culturally significant bird species woven into geometric patterns. The healthy country conditions needed to produce such items are scant in today's landscapes but were abundant in precolonial times (35).

Stewardship of country including wetlands, grasslands, shrublands, woodlands, and forests is place and time specific according to natural cycles tied to cultural understanding (see refs. 34 and 36). Prior to American settlement, extensive areas of California were burned annually with Indigenous burning and lightning working in tandem resulted in an estimated 1.8 to 4.8 million hectares burned annually (37, see also ref. 20)—trading “fires of chance for fires of choice” (38). The patterns and frequencies of Indigenous burning ensured that wildfires were mostly self-limiting. It is difficult to recognize the need for burning without understanding the cultural context for burn objectives (see ref. 36). Fire stewardship objectives are diverse and include fuel reduction and food and fiber production (17, 39–43). While most Indigenous fires are characterized as low to moderate intensity, there is also recognition of times when hotter more severe burns are necessary for specific purposes such as generating an ecological reset or type conversion. Experienced cultural fire practitioners have knowledge to burn in different ecosystems within country. This knowledge includes species autecology, seasonal and site-specific conditions, and species tolerances to fire types, which inform burning for desired outcomes as culturally determined. Landscape aesthetic is often a key purpose of burning to reduce vegetation densities, such as when vegetation is too thick or unproductive or too much litter has accumulated. Late dry season “clean-up” burns traditionally set prior to or upon arrival of wetting precipitation maintain the aesthetic. However, stewardship in different seasons maintains habitat patches in various seral states, ensuring suitable conditions to support a diversity of plants and animals and their age cohorts. Fire is also an important part of protecting community and sacred sites from wildfire, maintaining travel corridors, water stewardship, and many other purposes. These purposes and outcomes become apparent when one engages in burning for these cultural purposes (see refs. 18 and 43–46).

Climate variability over short and long time periods has influenced fire activity, species distributions, and other physiographic factors. Wetter years typically reduce the extent of area burned but produce more fuel for future fires, and drier years can increase the extent of area burned (47) (see also ref. 48 regarding the spatial extent of analogous Indigenous burning in Western Australia). Climate variability through millennia has caused fluid movement of species across the landscape along with increases and decreases in fire activity. Through these times, Indigenous fire stewardship synergistically enabled associations of species to respond to these cultural and physical drivers. Considering ecocultural species (i.e., culturally significant species), their presence and health is often dependent on factors including the season and types of fires they evolved with. Fire size, fire behavior, and effects inclusive of emissions and carbon sequestration can be moderated through stewardship actions. Indigenous burning is recognized to produce less emissions than wildfires (49, 50) and aid in carbon sequestration (51).

Indigenous knowledge recognizes the relationship between fire and weather locally, such as the production of smoke under inversion to cool stream temperatures (52), and regionally through particulate production as condensation nuclei to enhance precipitation. At a landscape scale, burning is also essential to water stewardship (see ref. 53) to enhance infiltration, storage, and regulate stream flow resulting from shifts in vegetation composition (18, 54). These stewardship actions enhance water availability and could be coupled with site-specific activities to pool, slow, and spread water (55, 56) onto the land, creating infiltration areas or saturated areas, even in arid desert ecosystems. The relationship between fire and water is foundational for Indigenous knowledge and stewardship and essential to resilience through past climate variability. However, the abrupt transition away from Indigenous ecocultural processes within the past 250 y of settler colonial influence has created unhealthy landscape conditions ranging from increased fire risk due to forest density and homogeneity to less reliable water supplies.

There are many parallels between the atrocities to Indigenous peoples, to their relations (i.e., species), and to country. The war of extermination was not limited to Indigenous peoples but extended to country as exemplified by the draining of wetlands (57), uplands plowed for agriculture and turned to urban sprawl (58–60), and species lost to overexploitation and incompatible management. Multispecies kinship between plants, animals, and country is foundational to the web of life recognized by Indigenous peoples; it is rooted in creation stories to establish roles and responsibilities and accountability and ethics (see ref. 32). The interrelated and interdependent relationship of species inclusive of people has been thoroughly recognized and respected. In consideration of the breadth and depths of the web of life, there are many ecocultural species, but a vast majority of those of particular significance due to their role in creation have also suffered considerably. Among those most broadly recognized across many Indigenous groups include California condor (*Gymnogyps californianus*), grizzly (*Ursus arctos californicus*), wolf (*Canis lupus*), spring run Chinook salmon (*Oncorhynchus tshawytscha*), California red-legged frog (*Rana draytonii*), beaver (*Castor canadensis*), milkweed (*Asclepias* sp.), whales (e.g., *Eschrichtius robustus*), abalone (*Haliotis* sp.), and some ecosystems including valley oak woodlands, riparian forests, and other wetlands. These kinship species and ecosystems upon which they depend have been maintained through ancestral obligation to stewardship. These species may be significant as food, fiber, and/or medicine, some are considered sacred, and others may be valued as messengers or teachers, but they are also indicators of environmental health—cultural keystone species.

Careful stewardship maintained these relations in abundance within country for millennia. However, under the current state of country, many species have already succumbed to the stressors of change. Ross (61) conveys a nearly universal assessment of loss while reflecting on the human and climate driven decline of abalone: “In our tribal stories, Abalone Woman has different colors and shapes and habits, gracing our waters since time immemorial. It is almost beyond thought to consider saying goodbye to her.” Many Indigenous peoples have faced extinction themselves, and extinct and declining species are inherently tied through kinship to

people (32). Ultimately, the loss of species is further reflected in the loss of cultural practice and heterogeneity (17).

The concomitant loss of people, species, and country created intergenerational trauma still damaging Indigenous communities. While ecological health has deteriorated, so have Indigenous cultures through the loss of ceremony, language, access to country due to land tenure shifts, and other deleterious impacts. Since Indigenous cultures are derived from country, removal and exclusion from country has been detrimental to maintaining cultures and has further manifested into physical and mental health issues for some individuals (62). Where these impacts persist, they are often compounded (63).

Traumatic events are correlated with increases in domestic violence, substance abuse, and suicide (64). Numerous studies following wildfires and floods have demonstrated these health implications from recent disasters within Indigenous and non-Indigenous communities. Aside from abuse patterns, there is also a growing recognition of solastalgia (65), including in Indigenous communities (66, 67). For Indigenous peoples, narratives and knowledge of precontact country may contribute to added grief of loss through intergenerational experience (18, 19). Reflecting on intergenerational experiences of Indigenous communities historical and contemporary traumas, there is obviously a need to prioritize this issue, but also recognize the perpetuation of a growing list of disasters is also problematic to society at large.

Concepts to Advance Ecocultural Resilience

ʔelelte. IS is rooted in a holistic understanding of environmental and cultural interactions. For instance, assessing the stewardship needs of a fire-prone ecosystem by “reading the landscape” for fire (36). In Miwkoʔ (Plains Miwok) language, the word ʔelelte- (unconjugated) refers to reading. With exception to traditional patterns and figures in cultural items, Miwkoʔ is an oral language until a textual system was created in the last century. The concept of ʔelelte- does not reference text but is sensory. The ability to “read” comes from the integration of sight, smell, sound, touch, taste, and the sixth sense of spirit or intuition of life force. While fields of psychology and neuroscience explore the concept of a sixth sense, Indigenous perspectives recognize it as a vital component to the way of knowing and being (e.g., refs. 68–70) beyond the mind. The sense of spirit is not necessarily based in a belief system (such as religious beliefs), but an inherent connection to all interactions, and therefore the interrelated and interdependence within creation. Spirit creates accountability and moral relationships and illustrates how a holistic understanding of ecological interdependence of creation is often lacking in Western science (71). Spirit sense is also affiliated with traditional law. In recognizing relationships of all things and interpreting the needs of country, traditional law becomes intuitive (72). To do so requires being receptive to this process and sensory approach. However, this awareness is not necessarily something understood in non-Indigenous knowledge systems such as Western science. Reading the environment is a multifaceted process of assessment feedback, and the ability to read country is critical to meeting stewardship needs. While there are many good tools for assessing and modeling environmental conditions, none can replace being present and interacting with the landscape

itself. In modern times, new tools such as remotely sensed data and environmental models can be helpful in planning or scheduling activities in the field and can provide another element of consideration in decision-making and forecasting in conjunction with ʔelelte-. ʔelelte- can also provide a framework for cross-cultural or interdisciplinary work, such as bidirectional learning (73), but such learning need not be a mandate.

Reading country for stewardship needs by assessing ecosystem health and cultural objectives requires an understanding of basic questions of where, when, what, why, and who about the location, but also species-level autecology, phenology, and seasonal variations among other factors. In many cases, stewardship actions are limited to times when the species or system is “at rest” (e.g., not during the growing season of plants or during the reproductive period for animals). Synergistically, the entirety of an ecosystem or elements within it may be synchronously at rest, making it suitable for landscape scale action. In the case of fire, burning activities during bird nesting or molting season (34) or the flowering period of native herbs or other cultural plant species are often culturally unacceptable.

Indicators. Reading country is also a matter of identifying indicators. While there are many indicators that could be referenced in reading the landscape, species presence and relative abundance is commonly used to assess the health of country. Balanced abundance is an indicator of successful stewardship, such as when greater densities of predators are sustained within country. The material cultural wealth of California is exemplar indicator of a healthy ecocultural system. North Fork Mono leader Ron Goode asks “can you live there” as a means of determining the success of stewardship actions. Consider any plot of wildland within the state in relation to some areas with the highest precontact Indigenous populations exceeding ten people per 259 ha coinhabiting with species such as grizzlies, who also existed in high densities. A thriving ecocultural system is a product of abundance across country. Could any 259 ha in the state’s wildlands support such a balanced abundance today? Similarly, rightful numbers is another way to frame and reflect the abundance of a species, particularly rare ecocultural species to exist in sufficient numbers to enable sustained collection of the species without decline. The example of the feathered belt previously described demonstrates this in relation to bird species used in making ceremonial regalia. Regalia across Indigenous California is strongly rooted in what the environment provides. Bird feathers and parts are a key component of many ceremonial and gift items (e.g., ref. 34). Reading and stewarding for healthy country ensures populations are in balance and representing the existence of seral states required to support those species within country.

Rarity is commonly used as a criterion of contemporary conservation stewardship. Recognizing many rare species are also culturally significant, applying IS for those species is often curtailed by regulatory concerns (e.g., Endangered Species Act). While conservation of these species is of great importance, the single species approach to conservation may come at a cost to other species and ecosystems. To this point, the concept of multispecies justice (74) or ecocultural equality (18) reframes conservation to ensure functional ecosystems and cultural needs are met to recover and sustain species

and create healthy country. Part of the reframing includes recognizing the ecocultural ethnography of species within country. Recognizing the cultural relationships with stewardship needs of those species is foundational to appropriate stewardship.

Through an ecocultural lens, each ecosystem contains a suite of culturally significant species that can be utilized as indicators. Identifying ecocultural species can be useful for many purposes including monitoring and planning. An ecocultural species list can be focused on a specific group of species as umbrella species (see ref. 75), a taxonomic grouping arranged through either Western Science and/or Indigenous understanding (e.g., ref. 34), ecocultural species recognized across broad regions such as California condor and grizzly, or a comprehensive list of ecosystem associates. Ecocultural species accounts developed similar to species accounts utilized to track species level impacts under the Endangered Species Act can be a bridge between Indigenous knowledge in communication with agencies and other entities in regulatory and planning processes (19). Multiple lines of evidence including Indigenous story and language might provide geographically specific knowledge of where species should be found in country (18), and their presence or absence from those places might be telling of stewardship needs. Overall, ecocultural species are indicators of healthy country, such as identifying ecocultural indicators for Indigenous fire stewardship.

Burning produces a vegetation mosaic (e.g., age classes generated in time since fire) within the landscape matrix. By reading country, stewards can identify the needs of species within the given ecosystems based on the condition, presence, or absence of the species. Conceptually, successful landscape stewardship ensures indicators of early through late successional species are present in appropriate distributions and abundances within the immediate landscape. A species-specific example is sourberry (*Rhus trilobata*) used for basketry materials and for food in many areas of California and beyond. The sticks used in basketry are collected from regenerating sprouts available within the first to second years following fire. For food, berry production typically occurs on more established shrubs a few years after fire but often decreases in time since fire. To ensure the availability of sticks and berries, a mix of fire regenerating patches is needed, and is part of the reason fine grain mosaics historically existed in shrub communities to ensure availability of suitable materials for cultural practitioners.

Ecocultural Conservation Planning. Biodiversity conservation frequently comes at the cost of Indigenous peoples, who have often been removed from their country and their ability to steward. There are many examples of conserved areas where this has happened, including Yosemite National Park, where the affiliated tribes including the Southern Sierra Miwuk were excluded following park establishment. Land managers globally have ignored the contributions and rights of Indigenous peoples as ecosystem stewards (76). The recognition of the rights of Indigenous peoples to access, steward, and otherwise sustainably use their country is noted in multiple international agreements developed in recent decades, such as the United Nations Convention on Biological Diversity and Declaration on the Rights of Indigenous Peoples, and the International Union

for the Conservation of Nature's protected areas designations. While many opportunities for IS occur on lands and in partnership with other organizations such as parks, there are also different models for conservation acquisitions by and for Indigenous peoples including land trusts (77–79). Growing interest in land acknowledgments has brought awareness of Indigenous peoples to the broader population, and in some cases, this has opened dialog toward conservation acquisitions or transfer through title exchange, easements, and other mechanisms. Similarly, “landback” (80) and “waterback” (81) movements have opened conversations and enabled access and ownership to country, but necessarily should recognize the complex history and relationships Indigenous peoples have with their country and each other, and avoid further inequities.

The historic absence of Indigenous peoples in conservation planning is evident from an ecocultural conservation perspective. For example, Indigenous people's planning horizons and prioritization of conservation areas may differ from strictly ecological prioritizations. Indigenous planning is intergenerational and typically considers timeframes of three to seven generations including past, present, and future. Conservation actions should be mindful of these timeframes to develop an understanding of what a system has been and what its potential is in the future. A guiding principle in this planning is to leave country in a condition that is as good or better than the current generation inherited. As a result, Indigenous prioritizations based on this approach would likely look and function quite different from contemporary conservation prioritization in terms of conservation values, mechanisms, and longevity (for contrast, see refs. 82 and 83). Considering the deep time of inheritance from the time of creation, prioritization of sacred geography is a good starting point, as those areas connect the responsibilities of all generations. The relationship between ecological and cultural diversity is not coincidental. Many global biodiversity hotspots are also cultural diversity hotspots (84, 85). The storyscapes (i.e., sacred geography) of Indigenous peoples as narrated in story and recognized by traditional law are not only centers of origin for culture but for species too. Sometimes there is a coincidental alignment of conservation to protect such places of significance. For example, many conserved areas including national and state parks are situated within the storyscapes of Indigenous peoples, but their values were not considered in the act of conservation, and for the most part neither has their stewardship. Taking Yosemite National Park again as an example, the park is situated within the storyscapes of multiple Indigenous groups. Its natural beauty along with iconic species including Giant Sequoia (*Sequoiadendron giganteum*) has also resonated spiritually with conservationists including Muir and Roosevelt, yet the climate crisis including wildfires poses significant risk to those values due to the removal of IS. Recent partnerships with Indigenous groups and the park signify interest and action in revitalizing cultural stewardship.

Conservation planning tools and processes developed by or inclusive of Indigenous peoples are an emerging area of conservation biology. While conventional conservation planning approaches have been used by Indigenous peoples to establish conservation areas, indigenizing conservation planning through Indigenous-centered approaches represents a comprehensive

means to achieving ecocultural conservation priorities. Commonly used conservation methodologies such as the Five-S Framework (86) and Conservation Open Standards (87) have been applied to some Indigenous initiatives and ultimately evolved into Healthy Country Planning (88, see also ref. 89). Separately, the Mauri-o-meter was developed as a heuristic model by Indigenous scientists in Aotearoa (New Zealand) as an environmental impact assessment tool (90, 91). The Mauri-o-meter evaluates impacts to the environment, cultural well-being (inclusive of metaphysical aspects), social well-being, and economic well-being based on responses to prompts filtered through the model. This model has been useful to Indigenous peoples in planning, response to environmental impacts, and illustrating the ability for projects to achieve ecocultural objectives. The integration of these tools into conservation planning brings fresh perspective and needed voice of Indigenous peoples to address deficiencies in historic conservation planning efforts. Indigenous perspectives in conservation planning can provide valuable approaches not represented within other planning systems (see refs. 76 and 92).

Ecocultural Restoration and Stewardship. Many conserved areas in California are in a current state of vulnerability as the climate crisis unfolds. Regardless of the country being conserved, the conserved attributes therein (i.e., habitat conditions) are likely to deteriorate without active stewardship. The need for stewardship is apparent in looking at many conserved lands across California—from overstocked and monotypic conifer forests, and many ecosystems impacted by invasive species, to erosional rills on hillslopes. Vulnerabilities are widespread and are exacerbated by the exclusion of Indigenous peoples in addressing stewardship and restoration needs within country. The development and implementation of conservation, planning, and stewardship actions throughout the state's history have mostly occurred with the exclusion of Indigenous peoples unless through more recent government-to-government consultation policy requirements (18, 19). Even where consultation exists, these efforts rarely include up-front engagement with Indigenous peoples to develop or codevelop planning or project implementation.

Ecocultural restoration differs from ecological restoration in several ways centered on the relationship of Indigenous peoples and country as an ecocultural system. The integrity of an ecocultural system is rooted in multispecies kinship relations (93–95). The process of ecocultural restoration revitalizes relationships with country (96) to also support cultural practices and knowledge transfer. Ecocultural restoration revitalizes appropriate structures, compositions, functions, and processes by integrating Indigenous knowledge (97) to create healthy country. Healthy ecocultural systems within country are characterized by structural diversity, functions, and resilience across ecological and social components (98).

At the core, ecocultural restoration and stewardship embodies Indigenous sovereignty. Federal and state policies recognize the sovereign rights of Indigenous peoples but have been less nimble in actuating it. Stewardship as a sovereign right is not simply a matter of collective governance of nations, rather it is inclusive of individual rights of traditional cultural practitioners as knowledge holders maintaining rights to uphold their responsibilities and relationships to country. In

some cases, this relationship might be site-specific, where the stewardship rights to a place are maintained by an individual or family. As lands are restored through ecocultural frameworks, stewardship responsibilities can also be revitalized as appropriate for the traditional cultural practitioner or peoples involved. Moving from a period where Indigenous peoples have often been an afterthought, excluded, or consulted only as required by governmental policy in many conservation efforts, engagement of Indigenous peoples is essential to achieving ecoculturally just and equitable solutions, revitalizing nations (71), but also achieving socio-ecological resilience. The conditions of restoring or revitalizing healthy country are supportive of sustainable livelihoods (99) and in turn ensure an ongoing commitment to stewardship (97).

Ecocultural Resilience in Action

Indigenous people's commitment to country has not wavered. In many places, stewardship responsibilities are largely maintained by individual cultural practitioners and families. Throughout California, Indigenous peoples and partners are engaging in actions to revitalize ecocultural relationships and resilience. These actions include work that is Indigenous-led, -guided, codeveloped, comanged, and costewarded. Utilizing the holistic understanding provided by reading country, recognizing indicators, planning, restoring, and stewarding is timely and critical to addressing the climate crisis and general connections to country. There are many diverse ways Indigenous peoples and partners are bringing about meaningful change for ecocultural systems. Below are examples to illustrate some of those efforts recognized through published materials or other public information. While this is a limited representation, it should be noted there are efforts statewide to support and advance IS.

Ross et al. (100) describe the formation of the Cache Creek Nature Preserve's Tending and Gathering Garden in Woodland, California. Since its inception, the garden has served as a place for cross-cultural exchange and educational purposes regarding IS of basketry plants including fire (43, 44). It has continued to support these activities including workshops on Indigenous fire stewardship (101), which more recently have garnered support from CalFire. Similar cultural tending sites have emerged in other locations for basketry plants and to promote food sovereignty, while also serving as public areas to demonstrate stewardship.

Protection of country by Indigenous peoples takes various forms in California. These range from informal agreements for access to land acquisitions supported by diverse funding mechanisms including private foundations and government grants, and in some cases revenue from tribal businesses. Various Indigenous land trusts exist to fulfill conservation needs of specific Indigenous groups such as the Amah Mutsun Land Trust (102), Sogorea Te' Land Trust (103), and partnerships among multiple Indigenous groups such as the Kumeyaay Digueño Land Conservancy and Mountain Maidu Summit Consortium revitalize connections to country. These efforts are particularly powerful when considering several of these efforts are being carried out by Indigenous peoples regardless of federal or state recognition status. This exemplifies the strong bonds Indigenous peoples have to country.

Numerous fire stewardship efforts are underway around the state (6). In 2015, the Indigenous Peoples Burning Network (IPBN) (see ref. 104) was founded among diverse partners along the Klamath River including Yurok, Karuk, and Hupa traditional cultural practitioners, bringing people together around a shared goal of restoring fire to country. Collectively, Indigenous representatives developed the Yurok-Hupa-Karuk Healthy Country Plan. Core leadership from the IPBN has founded additional organizations including the Cultural Fire Management Council and Indigenous Stewardship Network to support fire stewardship and capacity building among Indigenous and non-Indigenous partners, and groups like Tribal Ecocultural Restoration Alliance have emerged through collective interest of regional tribes. Education and research opportunities have provided a foundation to support Indigenous fire stewardship around the state and in diverse ecosystems (see refs. 43, 45, and 105).

Indigenous engagement with water is equally vigorous with significant interest in wetlands restoration and fisheries. Many water infrastructure projects including dams, levees, and other conveyance elements within the state have been detrimental to ecocultural systems, and as they age and deteriorate they are providing the opportunity to address longstanding environmental impacts through their removal and remediation. Through strong efforts of the Karuk, Yurok, Klamath Tribes and allies, the process of dam removal is underway to reduce impacts of harmful algal blooms and barriers to fish passage by restoring habitat and access for ecocultural keystone species including Chinook salmon (see ref. 106). Multiple components of California's water infrastructure converge in the Sacramento-San Joaquin Delta and have had long-term impacts on ecocultural systems (18). Current planning and restoration efforts within the Delta as identified in the Delta Islands Adaptations project include ecocultural restoration frameworks (codeveloped by author) which seek to achieve diverse conservation objectives including ecocultural species, subsidence reversal, and carbon sequestration (107). Such frameworks are currently being incorporated into additional planning and restoration within the region.

Recovery of ecocultural species to achieve equality and justice is a critical part of restoring and revitalizing country. Some Indigenous peoples have actively engaged in monitoring, captive rearing, and reintroduction of ecocultural species. The Big Valley Band of Pomo has actively engaged in water quality and monitoring for Clear Lake hitch (*Lavinia exilicauda chi*) (82)—with “chi” referencing the Pomo name for the fish. After many years of planning, the Yurok Tribe released California condors onto their country (108). The return of ecocultural species to California's lands, waters, and skies represents some examples of success in upholding responsibilities to these species for future generations and as indicators of ecosystem health.

Communication between Indigenous peoples and partners across broad and diverse regions is one way to ensure successful adaptation into the future. Likely, these sorts of communication historically occurred through trade and ceremonial networks spanning North America. To safeguard ecocultural relationships and identify new challenges, the Climate Science Alliance—Tribal Working Group was established to convene 18 tribes within San Diego County (109).

Members within the working group collaborate on a range of issues affecting their country including invasive species and Indigenous fire stewardship.

Achieving climate resilience through Indigenous ecocultural stewardship is happening through many grassroots efforts that are sometimes informal, but many have developed into formalized organizations and networks. At the grassroots level, traditional cultural practitioners are engaged in stewarding their country and futures planning through activities linked to tending and harvesting foods, medicines, and fibers. These types of activities are carried out primarily by individuals and families, but also organizations and governments. However, due to historic impacts of colonization on Indigenous peoples, there are some knowledges that have not been as recently practiced, or there is a need for support to scale the stewardship. In these cases, reconnecting with knowledges and supportive actions through informal and formal mentorship or training and establishing networks of practitioners are revitalizing ecocultural stewardship and communities. One such approach may be the formation of stewardship training centers to support various learning needs not only for Indigenous peoples, but also serving others from private and public sectors where appropriate, or through scaffolded learning modules. For instance, cultural fire stewardship scaffolded with other types of fire learning which other entities might provide or utilize bidirectionally.

The synergy of these efforts is beneficial to Indigenous peoples and country and provides broader benefits overall. In recent years, the State of California and federal government have sought opportunities to engage with Indigenous peoples in environmental planning and climate action. This comes in sharp contrast to the state's historic treatment of tribal entities and ultimately the ecological state. The urgent need for action and growing recognition of the essential role for IS in actions to address wildfires (110), droughts and flooding, and biodiversity declines (31) in favor of climate resilience (111) has led to policy initiatives, investment, and other support for Indigenous peoples. Such efforts have catalyzed opportunities across the state, albeit some may need refinement as new issues arise. Indigenous peoples in the state are significantly underrepresented as a population. In recognizing this, actuating necessary changes will require broader engagement through partnerships with federal, state, private organizations, other Indigenous entities, and allies. Similarly, further policy alignment necessitates access to policy makers, associated institutional knowledge, and ability to engage in visionary reform inclusive of all aspects of Indigenous knowledge, governance, and sovereignty regardless of political status or body.

Ecocultural conservation and stewardship may be pivotal to reducing impacts of climate change on ecosystems and communities. It is not solely a matter of the way we think about problems, but also enabling a fluid ability to act within the landscape at scale to address problems at the right time, in the right place, with the right people. Ecocultural stewardship is conducted when seasonally and at frequencies appropriate to achieve the objectives. This includes the awareness of place-specific considerations such as patterning of wind, soil moisture, and species interactions. The right places also means the ability to work where work is needed. Many projects take years to develop and bring to action. What may have been a priority

at one time may be superseded by emerging priorities of greater urgency. This means reconsidering and reframing the role of project-specific funding and actions and encouraging adaptive approaches in places where work needed is within country as a shifting priority. Examples include the ability to maintain landscapes with fire following unplanned ignitions, disease or insect damage outbreaks, and storm damage. This approach also enables scaling stewardship more readily to country. The right people is multifaceted. In an age of land acknowledgments, there is a deeper engagement necessary to bring meaningful change. Recognizing the need to elevate Indigenous leadership in these areas, the right people includes identifying appropriate practitioners and leaders. Specifically, not all tribal individuals or entities are cultural practitioners, nor adhere to or maintain Indigenous knowledge or ecocultural relationships to country and its stewardship needs. The right people also recognizes broader engagement across lands is necessary. Agencies often do not have staffing or funding to take needed action, and private entities including individual private landowners may not either. Ecocultural stewardship has many efficiencies as a nature-based approach and provides additive socio-ecological return on investment (112). Working together across boundaries is one way to act when and where it is needed with diverse partners. Similarly, utilizing opportunities for broader private and public involvement to achieve scalability in some places may be appropriate. The Western Klamath Restoration Partnership illustrates this approach with Indigenous and non-Indigenous partners working across organizational and land tenures in Northwestern California. Engaging locally builds a network among citizens of place, it builds and supports community, and strives toward reconciliation. An ecoculturally literate and intergenerationally invested society brings forth the concept of becoming Indigenous to place (95). To achieve this without appropriating Indigenous identities, implores living within the landscape in a way consistent with stewardship principles and actions the Indigenous ancestors past, present, and future of that place would respect, while also coming to terms with the historic and current factors of disenfranchisement. Moreover, these principles and actions should be rooted in traditional law and the leadership of Indigenous peoples while reconciling relationships through respectful and reciprocal engagement with country and each other.

Healthy Country for a Resilient Future

While there is no certainty what the future will bring, change is constant. Undoubtedly, skepticism about country being too altered by changes brought forth since colonization began would prohibit what has been proposed herein. However, the adaptive nature of IK and IS present time-tested solutions to the current state in a future-facing manner and should be among solutions considered and applied, as they have been unjustly denied to this point. Examples provided above are a glimpse of current and innovative applications that are shaping future outcomes. Despite numerous present obstacles to scaling IS, they are mostly constructs of social and political systems, which are perhaps the most challenging to overcome, but not insurmountable. The decision to steward country provides agency to make change and achieve resilience. In the case of fire, examples of IS abroad (6, 48, 49) have

already demonstrated it is possible, as similarly found with prescribed fire (113, 114).

Indigenous practical knowledge passed down through millennia offers guidance to address some of the greatest environmental challenges of the climate crisis by centering ecocultural practices in Indigenous-led, -guided, codeveloped, or otherwise comanaged efforts. Indigenous-centered efforts provide an opportunity to revision relationships with lands and peoples through ecocultural intent. For Indigenous peoples, the act and outcomes of stewardship or the lack thereof are strongly linked (94), and this brings greater significance to inclusivity of leadership in such efforts. The current lack of IS, and stewardship in general is evident in the vulnerability of many ecosystems to the climate crisis, and it is imperative to act in ecoculturally framed ways to address this crisis (115). In process-driven country including fire-prone landscapes, more effective policies and practices will come from integration of frameworks such as those described herein (116). It is difficult to fathom the complex feedback relationships of IS without a deep ecocultural awareness. The lens of ecocultural stewardship provides a means to connect people to country and with each other to achieve resilience and brings rich ideas and context to address ongoing environmental change.

Ecocultural stewardship clearly provides many possible benefits to ecosystem health and resilience. In a time of decreased connections to nature among the broader public—at least until it is gone—ecocultural stewardship provides many benefits to individual and community health. Solastalgia has become common vernacular in Indigenous communities and communities impacted by natural disasters. Having agency to proactively address vulnerabilities and create resilience within country through stewardship is a way to reduce solastalgia and concomitant impacts of intergenerational trauma (see refs. 67, 117, and 118). Soliphilia (22, 65) is an antonym of solastalgia wherein the love of country is established through place-based relationships and developing social responsibility for a shared future in symbiosis with the environment. The phrase “healthy country supports healthy communities” epitomizes the holistic health benefits of stewardship. Stewardship involves physical, mental, and spiritual engagement. The stewardship activities of Indigenous peoples in Arnhem Land, Northern Territory, Australia, demonstrate some benefits of IS on



Fig. 2. Conceptual feedback model of Indigenous fire compared to severe wildfire.

enhanced health of Indigenous participants (119, see also ref. 6). The ability to connect with nature provides many benefits. For example, the act of stewardship requires higher cognitive function and demands on the body by supporting whole-body thinking (120).

California as collective country covers nearly 42.4 million hectares with extensive stewardship needs to achieve climate resilience goals and healthy country. Through ecocultural frameworks, Indigenous peoples and the remainder of the state's almost 39 million people can take action to revitalize a balanced relationship with fire and water, while striving to conserve the astounding biodiversity it is known for. By working together through intergenerational planning, we can reduce emissions, sequester carbon, and improve water quality and availability through processes including Indigenous

fire practices and other time-tested approaches, so living generations can provide a better world for those unborn across all our kinship. Regardless, the no-action alternative (see ref. 121) is not a viable option (Fig. 2).

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