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Indigenous stewardship of coastal resources in native California

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Indigenous people have profoundly influenced terrestrial and marine ecosystems by modifying coastal habitats to increase the productivity of target species and altering local biotas through their harvesting practices. In some cases, these actions led to local resource depression, while in other instances, Indigenous people engaged with terrestrial and marine resources in sustainable ways, increasing the resilience of ecosystems. In this paper, we interrogate human-environmental relationships that span the last ~7,000 years of Indigenous engagement with coastal resources on the central California coast. Through a historical ecological framework, we assess how Indigenous peoples interacted with terrestrial and marine ecosystems differently across space and through time. In the Middle Holocene, the region's archaeology is typified by mobile populations using diverse terrestrial and marine resources. By the Late Holocene, Indigenous peoples intensified their economies towards a limited number of marine and terrestrial species. During this time, Indigenous people initiated sustained fire management practices that created habitat mosaics still reflected in the contemporary landscape. In the Late Holocene, people also developed resource harvesting strategies for California mussels and forage fishes geared towards long-term productivity.

KEYWORDS
Indigenous archaeology, historical ecology, eco-archaeology, zooarchaeology, paleoethnobotany, selective harvesting, habitat modification

1 Introduction

Indigenous people in California have maintained long-term relationships with terrestrial and marine resources that have persisted since time immemorial. Coastal landscapes and marine resources feature prominently in Native Californian cultural lifeways, serving dietary, symbolic, and ritual purposes (Luby and Gruber, 1999; Gamble, 2017; Lightfoot et al., 2017). Archaeological evidence from the California coast provides a record of ~12,000 years of human relationships with fauna, flora, algae, and a variety of abiotic resources (Jones and Hildebrandt, 1990; Jones, 1991; Erlandson, 2007; Hildebrandt et al., 2009; Tushingham, 2009; Jones and Perry, 2012; Erlandson et al., 2015; Gill, 2015; Tushingham et al., 2016; Ainis et al., 2019; Gill et al., 2021; Lightfoot et al., 2021; Rick et al., 2022). Given the time depth of Indigenous peoples' engagement with coastal resources, the cultural diversity of Native California, and differences in the socio-political organization, researchers encounter significant variation in human-environmental relationships with coastal resources across space and through time. These differences also reflect the diversity of ecosystems and habitats that Indigenous peoples encountered and altered across the state. Indigenous connections to coastal landscapes persisted during three successive waves of European

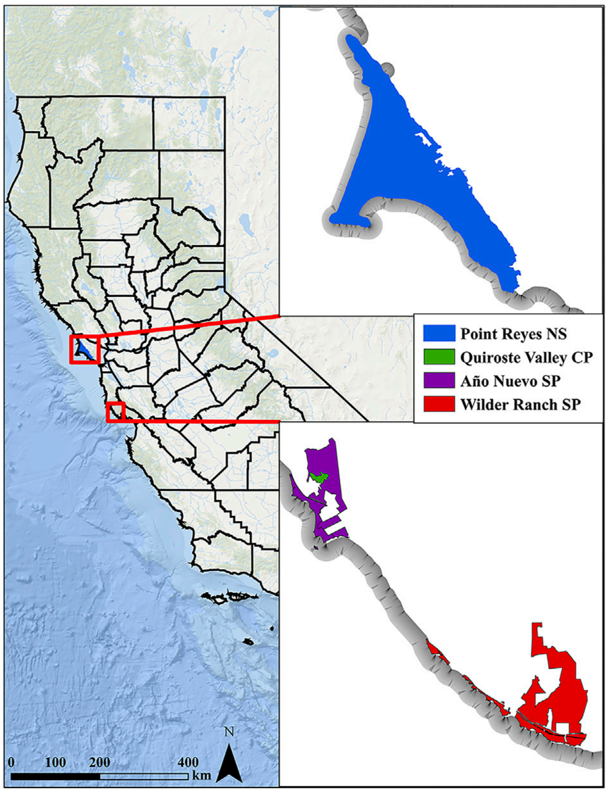

FIGURE 1
Overview of the central California coast with study areas discussed. Specific locations of the archaeological sites have been omitted to protect these sensitive cultural resources.

and Euro-American colonialism and continue in the present (Schneider, 2015; Schneider and Panich, 2019; Sigona et al., 2021).

Native Californian groups ranged from highly mobile populations to sedentary communities with inherited status and complex social organization (Lightfoot, 1993; Ames, 1994; Arnold, 1996; Rick et al., 2005; Lightfoot and Parrish, 2009; Arnold et al., 2016). Archaeological sites along the California coast also include complex mounded landscapes, such as those found on the Channel Islands and the San Francisco Bay Area (Lightfoot and Luby, 2012; Gamble, 2017). These archaeological sites provide evidence for a range of human-environmental interactions that suggest instances of local resource depression, while in others, evidence suggests that Indigenous people engaged with terrestrial and marine resources in sustainable ways, possibly increasing the resilience of coastal ecosystems (Broughton, 1994; Whitaker, 2009; Cuthrell et al., 2012; Cuthrell, 2013a; Broughton et al., 2015; Sanchez et al., 2018; Grone, 2020).

In this paper, we interrogate human-coastal relationships that span the last ~7,000 years of Indigenous engagement with coastal resources on the central California coast, from Point Reyes National Seashore to Monterey Bay, through a historical ecological framework to assess how Indigenous peoples interacted with terrestrial and marine resources differently across space and time (Figure 1). In the Middle Holocene, the region's archaeology is typified by mobile populations using diverse terrestrial and marine resources. Our findings suggest that by the Late Holocene, Indigenous peoples intensified their economies towards a limited number of marine and terrestrial species (See Bettinger et al., 2015 for this perspective broadly in California). By the Late Holocene, people developed resource harvesting strategies for California mussels and forage fishes geared towards long-term productivity through size-selective harvesting practices (Sanchez et al., 2018; Grone, 2020; Sanchez, 2020). In addition, during this time period, Native Californian tribes used fire to alter the successional stages of vegetation communities, with particular evidence of enhancement of coastal prairies (Lightfoot et al., 2021; Lightfoot et al., 2013; Cuthrell, 2013a). There is increasing evidence that Indigenous burning practices created habitat mosaics still reflected in the contemporary landscape (Kelly et al., 2020; Lake and Christianson, 2020; Lightfoot et al., 2021). However, Indigenous engagement with particular resources may have contributed to population declines and local extirpation in other instances. These examples highlight the complexity of human-environmental relationships across space and through time in Native California.

Along the Pacific Coast of North America, variation in human-environmental relationships have been documented in the archaeological record, both regionally and diachronically. This variation has contributed to ongoing debates regarding Indigenous engagement with coastal ecosystems. On a broad scale, these differences suggest various outcomes of Indigenous relationships with coastal resources, including, but not limited to, stewardship, management, epiphenomenal non-conservation, unsustainable harvesting, overharvesting or the tragedy of the commons, resource depression, and local extirpation and variation in topography, environment, among others (Broughton, 1999; Cannon and Burchell, 2009; Cuthrell, 2013a; Augustine and Dearden, 2014; Groesbeck et al., 2014; Jones and Codding, 2019; Grone, 2020; Sanchez, 2020; Lightfoot et al., 2021). Below we outline the theoretical and methodological implications that have contributed to these debates and offer possibilities for future strategies to contribute to this area of research.

1.1 California archaeology, evolutionary ecology, and human behavioral ecology

The field of California archaeology, especially the archaeology of ancient and pre-contact populations, is heavily influenced by evolutionary ecology (EE), human behavioral ecology (HBE), and the application of a diversity of optimization models linking human behaviors to expected material outcomes (Basgall, 1987; Beaton, 1991; Broughton, 1994; O'Connell, 1995; Wohlgemuth, 1996; Hildebrandt et al., 2009; Tushingham and Bettinger, 2013; Bettinger, 2015; Bettinger et al., 2015; Codding and Bird, 2015). Archaeologists working through these theoretical frameworks have significantly contributed to our understanding of California archaeology.

Drawing from evolutionary biology, behavior in EE is considered adaptive when it tracks environmental variability in ways that enhance an individual's inclusive fitness—or the propensity to survive and reproduce (Bird and O'Connell, 2006). In archaeology, EE and HBE are often associated with optimal foraging theory (OFT) and OFT models (Smith et al., 1983; Cronk, 1991; Winterhalder and Smith, 2000; Bird and O'Connell, 2006). These models attempt to predict behaviors in a range of hunter-gatherer societies. According to the theoretical assumptions of these models, maximizing behavior occurs under certain conditions because of Darwinian selection for strategies that maximize individual fitness (Smith et al., 1983).

As Douglas Bird and O'Connell (2006) note, the models are never tested. Instead, situation-specific assumptions or hypotheses are formulated to be tested against predictions. As Lee Cronk (1991) highlights, one advantage of working with simple models is that it is easy to see when people's behavior does not fit the theory or its expectations. These instances have received significant attention in archaeology as examples of social and symbolic behavior, such as feasting, that cannot be explained as serving solely dietary requirements (Hildebrandt et al., 2009). As Bruce Winterhalder and Smith (2000) note, EE models and predictions seek to capture essential features of an adaptive problem and neglect "ancillary variables" of concern in the more particularistic tradition of anthropology (see Gremillion et al., 2014).

Given the theoretical underpinnings and assumptions inherent in EE and HBE, researchers applying these models often consider immediate gains (i.e., immediate return economies) rather than long-term perspectives (i.e., delayed return economies) when considering human-environmental relationships, although exceptions exist (see Bettinger, 2006; Codding and Bird, 2015; Winterhalder and Kennett, 2009; Woodburn, 1980). Recent discussions of delayed return economies have focused almost exclusively on the transition from hunting-gathering economies to agriculture. While archaeologists applying HBE to agricultural societies offer some possibilities for economies and human agency that would provide long-term (i.e., agriculture) rather than immediate-return (i.e., foraging) decision-making, the same possibilities have not generally been extended to hunting, gathering, and fishing societies like those found in California.

In those instances where Indigenous cultivation of wild foods in California has been documented, the catalyst to these relationships may be "thought to result from intensified subsistence economies required by population pressure or a decline in the abundances of high-ranked prey taxa" (Whitaker, 2008, see also Anderson and Wohlgemuth, 2012 regarding the development of protoagriculture in California). Indigenous stewardship and/or management would suggest that Indigenous peoples engage with resources with long-term harvesting regimes rather than to meet immediate or short-term goals. These actions likely do not result from population pressure or resource depression alone. From a cursory review of the California archaeological literature, when possible sustainable human-environmental relationships are identified, these cases are often explained as epiphenomenal non-conservation, epiphenomenal conservation, epiphenomenal sustainable hunting, incipient aquaculture, pseudo-aquaculture, pseudo-cultivation, among others (Whitaker, 2008; Jones and Codding, 2019). Although archaeologists applying EE and HBE theories in California have represented a prominent approach in evaluating the diachronic interactions Native people had with ecosystems, there are other notable ecological and economic approaches outlined below.

1.2 Common-pool resources and the tragedy of the commons

As outlined by ecologist Garrett Hardin (1968), the tragedy of the commons is a theoretical perspective that suggests the inevitable outcome of shared common-pool resources, increasing human population, and individual maximization assumptions culminate in the eventual overexploitation of resources. The application of the tragedy of the commons in California archaeology has often occurred by proponents of EE and HBE, likely given the shared emphasis on rational and parsimonious behavior, individual maximization assumptions, and the primacy of population (Jones and Hildebrandt, 1995; Porcasi et al., 2000; Jones and Codding, 2019).

As economist Elinor Ostrom (2008) outlines, common-pool resources occur on such a scale that it is difficult, but not impossible, to define recognized users and exclude other users altogether. According to Ostrom (1990, 2008), common-pool resources can be managed by a diversity of institutions such as governments, privately, and by communities, or comanaged among these institutions. However, open-access or common-pool resources accessible for entry or harvest by anyone are likely to be overharvested and potentially destroyed (Ostrom, 2008).

Jones and Codding (2019) highlight that resource locales for California Indians were common-pool resources or finite, and when an individual extracts from this pool, this inevitably takes resources from another individual. For Jones and Codding (2019), this situation of the commons allows three trends to emerge from the archaeological record. The first is evidence of harvesting having a negligible or limited impact on the wild resource base and no clear indication of resource depression. The second is resources mediated by cultural, ceremonial, and practical reasoning about how and when to harvest (Butler, 1993; Butler and O'Connor, 2004; Thornton et al., 2015; Royle et al., 2018). The third example of common-pool harvesting trends is extinction and local extirpation (Morejohn, 1976; Jones et al., 2021; 2008; Grayson, 2008; Rick et al., 2012).

1.3 Indigenous archaeology, eco-archaeology, and Indigenous stewardship

In California archaeology, there has been a growing interest in Indigenous archaeology, collaborative archaeology, community-based participatory research, and community-engaged research protocols working in collaboration with Native Californian Tribes (Gonzalez et al., 2006; Lightfoot, 2008; Gonzalez, 2016; Sanchez et al., 2021). One outcome of the development and growth of Indigenous and collaborative archaeology in California is the advancement of eco-archaeological approaches.

Lightfoot et al. (2021) define eco-archaeology as a research approach that integrates multiple ecological and archaeological datasets to construct robust perspectives about human-environmental interactions. In contrast to the perspectives outlined in the sections above, Indigenous and collaborative archaeologists working through an eco-archaeological framework often conduct their research following the tenets of historical ecology. Historical ecology is an interdisciplinary field that traces

TABLE 1 Expectations and archaeological correlates of human-environmental relationships in Evolutionary Ecology, the Tragedy of the Commons, Historical Ecology, and Indigenous Stewardship.

Framework	Expectations	Archaeological correlates
Evolutionary Ecology/Human Behavioral Ecology/Optimal Foraging Theory (OFT) Models	• Models human foraging in terms of prey abundance, energy gained per item, and energy and time expended	• Changing relative abundances of taxa
	• High-return (high-caloric) resources will be selected for over lower return or low-ranked items	• Changes in the age/sex of fauna represented
	• High-ranked resources generally correlate with body size	• Shift in high-ranked to low-ranked taxa
		• Reduction in size of high value prey species through time
Tragedy of the Commons	• Shared common-pool resources, increasing human population, and individual maximization assumptions culminate in the eventual overexploitation of resources	• Evidence of overexploitation of resources
		• Shift in high-ranked to low-ranked taxa
		• Changes in the size of taxa such as shellfish
		• Reduction in vertebrate species size or relative abundance of plants and animals
Historical Ecology	• Societies impact environments in distinctive ways	
	• Human nature is indifferent to species diversity	
	• Human activity does not necessarily lead to environmental degradation or increasing biodiversity	
Indigenous Stewardship	• Resources can be sustainably stewarded through habitat enhancement and selective harvesting practices	• Evidence of habitat enhancement *via* ecosystem engineering (i.e., fire management practices)
	• Size selective harvesting practice geared towards maintaining demographic stability	• Shifts in the relative abundance of taxa
		• Alterations to the size or age of targeted species
		• Size classes of prey species represented in the archaeological record reflective of limited impact to population demography of targeted species
		• Evidence of economic intensification of specific taxa

the relationship between our species and the planet through multiple temporal and spatial scales—these relationships and human agency manifest in the landscape (Crumley, 1994; Balée, 1998; Balée, 2006; Crumley, 2007).

Historical ecology is uniquely positioned to interrogate Indigenous stewardship, given that its postulates do not assume that human activity inevitably increases nor degrades species abundance and diversity but instead posits that these issues must be interrogated using multiple independent datasets from a diversity of scientific approaches (Balée, 1998). Building from Fowler and Lepofsky's (2011) conceptualization of traditional resource and environmental management, we follow Lightfoot et al. (2021) in defining Indigenous stewardship "as the application of traditional ecological knowledge to maintain or enhance the abundance, diversity and/or availability of natural resources or ecosystems." Therefore, Indigenous stewardship is more closely reminiscent of discussions regarding resource management, but we use the term stewardship to reflect local Indigenous perspectives of these practices.

Building from the nuanced perspective of the spectrum of Native Californian engagement with diverse resources, we synthesize the current literature on Indigenous resource stewardship. Below we outline the theoretical and archaeological evidence for Indigenous stewardship of coastal prairies through fire management strategies and size-selective harvesting techniques applied to Pacific herring (*Clupea pallasii*) and California mussels (*Mytilus californianus*) spanning the last ~1,300 years.

1.4 Archaeological expectations

Based on the human behavioral ecology literature, if Native people were acting optimally to maximize net gains in their subsistence practices, we could expect that people would be focusing on the highest net return gain for their efforts (Table 1). These decisions might involve the prioritization of high-ranked plant and animal resources such as storable seed and other plant foods and large-bodied animals with the highest return rates. We recognize that scholars conducting research through this framework have also identified social factors in resource use such as prestige hunting (McGuire and Hildebrandt, 2005).

Expectations from the tragedy of the commons literature evaluate the relationship between shared common pool resources, population growth, and individual maximization assumptions. While models recognize that social structures may limit some harvesting of resources, especially those considered private, the tragedy of the commons literature does suggest that those resources that are common pool will inevitably become overexploited. Archaeological correlates for these models tend to suggest patterns of overexploitation of resources and economic intensification often similar to human behavioral ecology explanations of changing or widening diet breath (Broughton, 1997; Porcasi et al., 2000).

Indigenous stewardship and traditional resource and environmental management literature suggest human practices to maintain or enhance the abundance, diversity and/or availability of natural resources or ecosystems can be recognized archaeologically through material correlates. These approaches have emphasized four aspects of Indigenous peoples that would contribute to these practices such as harvesting methods, enhancement strategies, tenure systems, and worldviews and social relations (Anderson, 2005; Lepofsky and Caldwell, 2013). We could expect Indigenous stewardship practices to result in evidence of habitat enhancement such as fire management strategies, size-selective harvesting practices of plants and animals, shift in the relative abundance of taxa as economic intensification occurs with stewarded resources, and changes in the age and/or size of targeted species. For example, if Native people were stewarding or managing a resource, such as Pacific herring, we could expect to see the limited take of the largest adult-sized individuals and juveniles to allow the fish population to reproduce and mature. However, if Native American fishing practices were selecting the largest sized fishes within the fishery, which would be correlated with the oldest fishes, we could expect to see a reduction in the size of fishes through time, consistent with other archaeological fisheries studies (Broughton, 1997; Broughton et al., 2015). This idea has also been discussed in the context of plant resources as well, such as selective harevesting of large cormlets, and the return or replanting of small cormlets to maintain the abundances of geophytes (Anderson, 2005).

2 Methods

Along the central California coast, four primary research areas have been testing grounds for Indigenous stewardship practices that have informed our current understanding of the time depth and development of these practices. From north to south, these include Point Reyes National Seashore, Año Nuevo State Park, Quiroste Valley Cultural Preserve, and Wilder Ranch State Park (Figure 1). The research has been completed collaboratively with several Native Californian tribes, including the Amah Mutsun Tribal Band at Año Nuevo State Park, Quiroste Valley Cultural Preserve, and Wilder Ranch State Park. In addition, research was conducted with the Federated Indians of Graton Rancheria at Point Reyes National Seashore. These projects span nearly 2 decades of research with, for, and by Native Californian tribal communities with research goals and priorities towards supporting Indigenous leadership in the world of natural resource conservation and cultural revitalization.

2.1 Amah Mutsun Tribal Band

Most of the data presented in this paper are derived from collaborative research with the Amah Mutsun Tribal Band, the California Department of Parks and Recreation, the University of California, Berkeley, and several other institutions. The Amah Mutsun Tribal Band became engaged in archaeological research in 2007. Working with Professor Kent Lightfoot and Dr. Rob Cuthrell, University of California, Berkeley and the California Department of Parks and Recreation, the Amah Mutsun Tribal Band initiated an eco-archaeological study of Indigenous fire use at Quiroste Valley in Año Nuevo State Park (Cuthrell, 2013a; Gifford-Gonzalez et al., 2013; Hylkema and Cuthrell, 2013; Lightfoot et al., 2013; Lightfoot et al., 2021). Later research was conducted at Wilder Ranch State Park during the summers of 2016-17 (Sanchez, 2019; Grone, 2020; Lightfoot et al., 2021).

The foundation of the research protocols in working with the Amah Mutsun Tribal Band was an agreement that all research would work to minimize adverse impacts on the archaeological site(s) studied. Tribal members were included in all field research to build capacity within the tribe, so their members could gain training and increase their ability to advocate for their own archaeological resources in the future (see Sigona et al., 2021 regarding how the tribes' experience with archaeologists has evolved into applied management programs). The research team agreed to integrate low-impact field methodologies, such as geophysics, to identify discrete deposits which might contain high-densities of cultural materials and artifacts related to Indigenous foodways and other activities of particular interest to the tribe (Cuthrell, 2013a; Lightfoot and Lopez, 2013; Grone, 2020; Lightfoot et al., 2021; Sanchez et al., 2021).

2.2 Archaeological field methodologies

Through the two primary field projects with the Amah Mutsun Tribal Band, diverse research and sampling strategies have been developed, modified, and refined. The initial field project developed in 2007 at the Quiroste Valley Cultural Preserve centered around CA-SMA-113, otherwise known as Quiroste Village. The Quiroste termed the coastal village *Mitine* (Hylkema and Cuthrell, 2013) (Figure 2). The field research at *Mitine* from 2007-09 was guided by geophysical survey techniques, including gradient magnetometer survey, soil resistivity, and ground penetrating radar (Cuthrell, 2013a). Based on the findings of these surveys, 22 1 m^2 excavation units were excavated at 10 cm arbitrary levels unless cultural or natural stratigraphy was encountered. In addition, five to 10-L samples were collected for flotation. Further in-depth discussion of field methodologies and sampling can be found in Cuthrell (2013).

During the 2016-17 field research, the research team focused on a series of archaeological sites south of *Mitine* along the Santa Cruz coastline. Four archaeological sites were excavated during these field seasons, including CA-SCR-7, CA-SCR-10, CA-SCR-14, and CA-SCR-15 (Figure 2). While each site had site-specific sampling strategies, the field methodologies followed similar protocols as those applied at *Mitine*. However, by the 2016 field season, the sampling strategies had changed. Specifically, the quantity and size of excavation units had been reduced. Therefore, in later iterations of field research, excavations utilized 1 m^2 and 0.5 m^2 units but a reduced number of units per site. See Grone (2020) and Sanchez (2019) for further information.

The collaborative research team studied multiple independent lines of evidence supporting this research throughout the years.

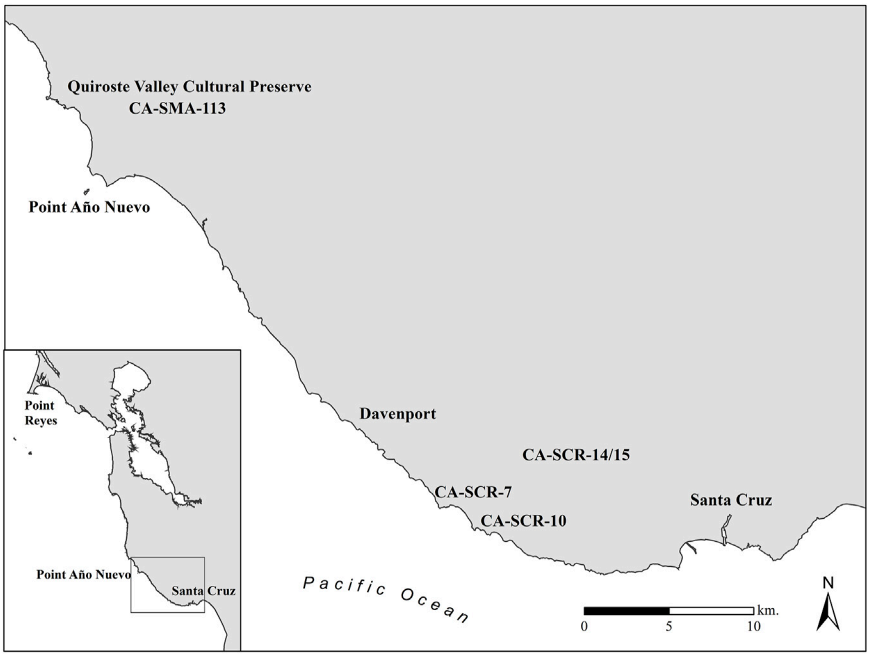

FIGURE 2
The Quiroste Valley and Santa Cruz Coast Study Areas from the 2007–09 and 2016–17 field seasons. Specific locations of the archaeological sites have been omitted to protect these sensitive cultural resources.

These data include fire ecology modeling, analysis of historical photos for the reconstruction of vegetation histories, ethnohistorical and ethnographic documents, paleoethnobotanical data including phytoliths, zooarchaeological remains, the study of sediment cores for palynological and charcoal accumulation rates, dendrochronology, and fire scar histories to reconstruct fire return intervals, and ancient DNA analyses of plant and animal remains. For in-depth details of sampling strategies, excavation techniques, and sample processing, please refer to the following sources (Cuthrell, 2013a; Lightfoot and Lopez, 2013; Sanchez, 2019; Grone, 2020).

2.3 The Federated Indians of Graton Rancheria

During the summer of 2015, fieldwork was conducted at Point Reyes National Seashore as part of a collaborative eco-archaeological project involving the University of California, Berkeley, the National Park Service, and the Federated Indians of Graton Rancheria with participation by Sacred Sites Committee Members (Figure 3). The project was designed to assess the temporal and material record of sites threatened by sea level rise and coastal erosion, as well as to contribute to ongoing landscape and seascape management research (Sanchez, 2019). As part of this project, crew members surveyed, recorded, and tested nine archaeological sites from Point Reyes National Seashore, sampling from all major habitats within the park (i.e., bay, open coast, inland localities, and reef sites). The nine sites were selected from a sample of 88 documented archaeological sites.

All Point Reyes National Seashore sites were surveyed using low-impact and minimally invasive field methodologies following Lightfoot (2008). These include surface survey applying the "dog-leash" method (Binford, 1964), catch and release surface survey sampling (Gonzalez, 2016), subsurface geophysical survey, auger sampling (10 cm diameter auger sampled in 20 cm arbitrary levels), and one opportunistic column sample (50 cm × 50 cm) at CA-MRN-224. For in depth details of sampling strategies, excavation techniques, and sample processing please refer to Sanchez et al. (2018), Sanchez (2019), Grone (2020), Sanchez (2020).

3 Results

3.1 Santa Cruz and San Mateo coast: Middle Holocene trends in plant and animal use

Of the four study areas only Wilder Ranch includes evidence of Middle Holocene occupations at CA-SCR-7. CA-SCR-7 is an imposing shell mound that lies adjacent to Laguna Creek and extends along the coastal bluff and uplifted marine terrace. The site is a remnant of a large dune complex with intermingled cultural deposits. Radiocarbon dates from CA-SCR-7 suggest an occupation from 6,740-6,660 cal BP (CA-SCR-7 Component A in Figure 4, see below) to 4,240-4,090 cal BP (CA-SCR-7 Component B in Figure 4, see below) (Sanchez, 2019; Grone, 2020; Lightfoot et al., 2021). Paleoethnobotanical data from CA-SCR-7 and other coastal and inland sites from the study are is summarized by Cuthrell (in review). Cuthrell (in review) analyzed paleoethnobotanical

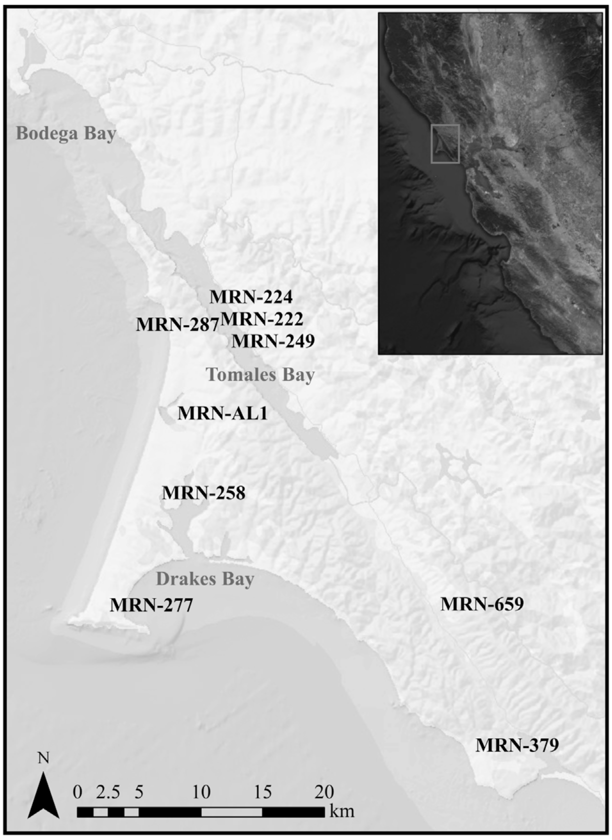

FIGURE 3
The Point Reyes National Seashore Study Areas from the 2015 field season. Specific locations of the archaeological sites have been omitted to protect these sensitive cultural resources.

remains, anthracological samples, and phytoliths from the Año Nuevo, Quiroste Valley, and Wilder Ranch study areas.

Phytolith content from CA-SCR-7 suggest relatively weak evidence for long-term grasslands near the site, especially when compared to Late Holocene occupations across the study areas. As Cuthrell (in review) notes, these results are unsurprising, as CA-SCR-7 and the surrounding area was once an active dune field that would be expected to support more ephemeral grasslands than locations with stable soils. According to Cuthrell (in review) at CA-SCR-7 driftwood represents the main source of wood fuel. The primary wood fuel recovered and identified was redwood (*Sequoia sempervirens*) and alder (*Alnus* sp.). Cuthrell (in review) suggests it is unlikely that redwood or alder could have grown in proximity to the site (active sand dune habitat), even in the mid-Holocene and likely represent the use of driftwood for fuel.

Following trends for coastal sites in the Año Nuevo and Wilder Ranch study areas, especially when compared to inland locales, CA-SCR-7 is marked by relatively low densities of edible plant remains, such as nuts and edible seeds (Figure 4). These trends are generally consistent across the Middle and Late Holocene coastal bluff sites, where evidence of plant processing is minimal when compared to inland sites, see discussion below. However, CA-SCR-7 Component A contained a relatively high percentage of edible nut remains, at 20.3%, while CA-SCR-7 Component B had 36.4% edible nut remains (quantified by count). Other coastal sites displayed edible nut percentages from 4.6%–13.9%, and inland sites had values ranging from 3.8%–21.1%. Chi-square comparisons of edible nut count vs. other identified macrobotanical specimen count between CA-SCR-7 Component B and all other coastal sites/components returned statistically significant differences in all cases ($p < 0.05$) (Cuthrell, in review). In sum, the archaeobotanical analysis of 176 flotation samples indicates a shift to focusing on inland sites to process plant foods, while coastal sites indicate a primary emphasis on marine resource use.

At CA-SCR-7, the primary zooarchaeological data recovered is related to ancient vertebrate and invertebrate fisheries. While mammal and bird remains have been recovered, their abundances are best representative of the presence and absence of species rather than relative abundance, given the small-scale and fine-grained excavations strategies that improve the recovery of minute remains (Grayson, 1984). In terms of vertebrate fisheries at SCR-7, the >2 mm samples are principally surfperches (Embiotocidae), which comprise ~28% of the assemblage. Surfperches include pile perch (*Damalichthys vacca*), shiner perch (*Cymatogaster aggregata*), and barred, calico, or redtail surfperch (*Amphistichus* sp.). Greenlings comprise 21% of the assemblage by relative abundance and include lingcod (*Ophiodon elongatus*), kelp, rock, or masked greenling (*Hexagrammos* sp.). Skates (Rajidae) make up 15% of the assemblage. Rockfishes (*Sebastes* sp.) make up another 10%. Together surfperches, greenlings, rockfishes, and skates make up 74% of the assemblage, with 18 genera making up the remaining 26%. The density of fish remains recovered and identified within the assemblage to at least the taxon Actinopterygii is 3.5 NISP/l. The Shannon Index for the assemblage, calculated at the genera level, is 2.4, suggesting more significant heterogeneity, with evenness or equitability measured at 0.85, signifying an assemblage closer to equal distribution. Analysis of this fishery suggests Indigenous peoples had a broad-based economy with a diversity of genera (n = 25) targeted. These trends of highly mobile populations with broad-based economies typify the region's archaeology during the Middle Holocene (Hylkema, 2002), (Hylkema, 1991).

3.2 Santa Cruz and San Mateo coast: Humans and coastal prairies

Research by Cuthrell (2013a, 2013b) interrogates Indigenous fire management strategies with particular emphasis on the Quiroste Valley. Later research by Cuthrell and others focus on the Santa Cruz coast sites south of *Mitine* in the Wilder Ranch study area (Lightfoot et al., 2021). The collaborative research team has studied multiple independent lines of evidence supporting this research. These data included fire ecology modeling, analysis of historical photos to reconstruct vegetation histories, ethnohistorical and ethnographic documents, paleoethnobotanical data including macro and micro remains, zooarchaeological samples, the study of sediment cores for palynological and charcoal accumulation rates, dendrochronology and fire scar histories to reconstruct fire return intervals, and ancient DNA analyses of plant remains (Cuthrell, 2013a; Cuthrell, 2013b; Cowart and Byrne, 2013; Evett and Cuthrell, 2013; Fine et al., 2013;

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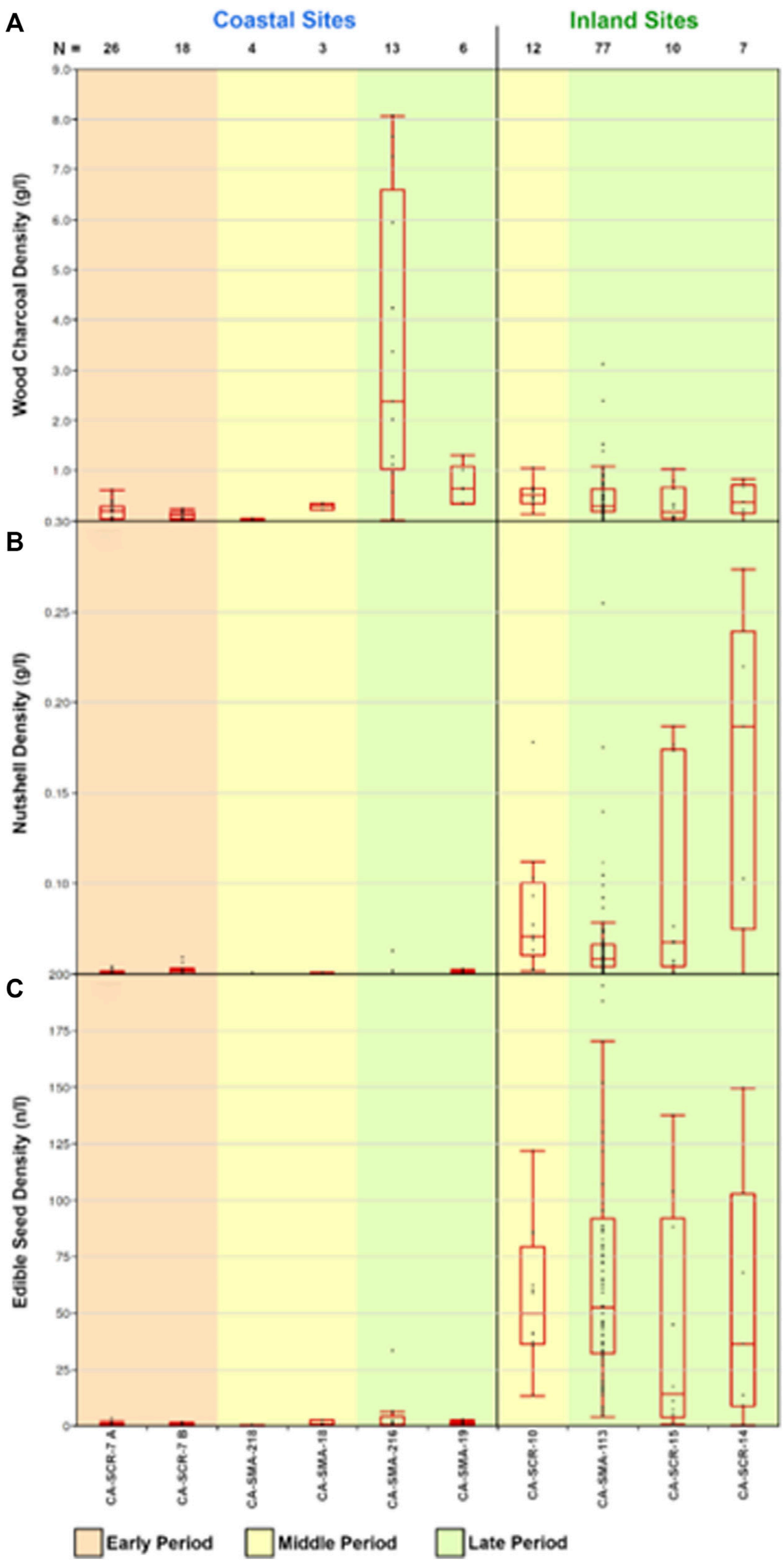

FIGURE 4
Box plot inter-site comparison of: **(A)** wood charcoal density (g/L); **(B)** edible nutshell density (g/L); and **(C)** edible seed density (n/l). Each data point represents a flotation sample (Cuthrell, in review).

TABLE 2 Point Reyes National Seashore sites, calibrated radiocarbon dates, clupeid NISP, Pacific herring NISP, and mean Pacific herring SL.

Site	(95.4% CI)	Clupeid NISP	Pacific herring NISP	Mean P. herring SL
CA-MRN-287	810–110 cal BCE	13	1	---
CA-MRN-277	100 cal BCE to cal CE 780	22	1	---
CA-MRN-224 (Auger)	cal CE 760–1800	3165	195	177 mm
CA-MRN-222	cal CE 1030–1800	2011	114	178 mm
CA-MRN-224 (Column)	cal CE 1260–1800	817	58	177 mm
CA-MRN-AL1	cal CE 1300–1640	554	24	175 mm
CA-MRN-258	cal CE 1310–1430	173	8	---
CA-MRN-659	cal CE 1400–1800	89	3	---
CA-MRN-379	cal CE 1430–1630	0	0	---
CA-MRN-249	cal CE 1450–1800	587	62	176 mm
Total		7431	466	

Gifford-Gonzalez et al., 2013; Hylkema and Cuthrell, 2013; Lightfoot et al., 2013; Lightfoot and Lopez, 2013; Lopez, 2013; Striplen, 2014). The Research by Cuthrell (2013a, 2013b) is particularly relevant as it directly interrogates the issue of natural and anthropogenic fire regimes and fire return intervals, setting important expectations for vegetation communities with and without disturbance. Below we synthesize data from Cuthrell (2013a, 2013b) that highlight key points from the broader research program.

In his seminal research interrogating Indigenous fire use in the Late Holocene, Dr. Rob Cuthrell (2013) combined fire ecology models, historical records, and archaeobotanical methods to investigate anthropogenic fires to understand how burning practices may have structured local biotic communities. Cuthrell (2013) set observable baseline expectations regarding vegetation and forest successional stages in natural fire conditions based partly on lightning strike densities along the central California coast.

Based on the low incidence of lightning fires within the Quiroste Valley and evidence of historical vegetation change, he suggests anthropogenic burning would have been required to maintain the availability and abundance of plant food resources that are reflected in the archaeological record. Macrobotanical and anthracological evidence suggests the assemblages are compatible with models of anthropogenic burning through the abundance of fire-adapted plant communities in the past, which are rare today in the modern population structure. The archaeological research at CA-SMA-113 also indicates that during the Late Holocene (ca. cal AD 1,000–1,300), site inhabitants relied heavily on grassland seed foods and nut species that are culturally or ecologically fire-associated. The findings from this project suggest that the ancestors of the Amah Mutsun Tribal Band conducted cultural burning from at least cal AD 1000 to the time of Spanish colonization (Cuthrell, 2013b; Lightfoot et al., 2013; Lightfoot and Lopez, 2013).

Comparing trends in plant use across coastal and inland sites from the Middle to Late Holocene, Cuthrell (in review) identified significant differences in the paleoethnobotanical assemblages across space and time. For example, Cuthrell (in review) found that the densities of edible nuts differed between coastal and inland sites, with all coastal sites containing median edible nut density <0.8 mg/L (<0.6 n/l) and all inland sites displaying median edible nut density >8.2 mg/L (>2.0 n/l). In addition, Cuthrell (in review) observed higher densities of edible seeds were consistently observed among inland sites in comparison to coastal sites. Median edible seed density at inland sites ranged from 14.1-52.5 n/l, but only 0.3–1.4 n/l at coastal sites (Figure 4). Among inland sites, the edible seed assemblages of the three sites in Santa Cruz County were dominated by seeds of grasses, which comprised 66.0%–87.5% of edible seeds and 39.6%–71.8% of identified macrobotanical specimens. This archaeobotanical study by Cuthrell (in review) also provides detailed discussion on grass silica phytolith abundances over time, which also support interpretations of active stewardship of coastal prairie ecostyems during the Late Holocene through the use of fire within the study area. While marine resource management is the focus of our paper, we elect to highlight coastal archaeobotanical research as an example of Indigenous coastal stewardship because we believe it provides evidence that supports the discussion of Indigenous stewardship as a broader phenomena.

3.3 Point Reyes National Seashore: Pacific herring fishery

The Pacific herring remains reported in this study were previously reported by Sanchez (2020) and Sanchez et al. (2018). In total, the Point Reyes faunal assemblage resulted in the identification of 9071 fish specimens from the >2 mm mesh size class. At least 33 species were represented within 19 families. Clupeids represent the bulk of the assemblage, accounting for 8005 of the total NISP or ~88% (Table 2). See Sanchez (2020) and Sanchez et al. (2018) for further information. Using modern clupeid atlas and axis elements from Pacific herring specimens of known standard length (SL), Sanchez (2020) created linear regression models that show statistically significant ($p < 0.05$)

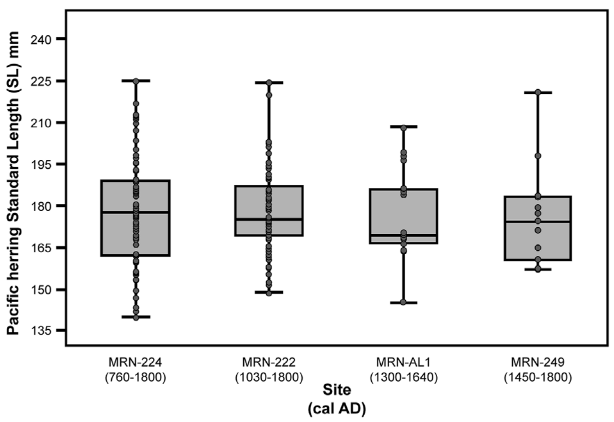

FIGURE 5
Box and whisker plot of Point Reyes Pacific herring standard length based on the atlas and axis vertebral width measurements. Archaeological data presented chronologically with radiocarbon date ranges from Sanchez (2020).

and significant (R^2 values) relationships between SL and maximum vertebral centrum dimensions (Sanchez, 2020).

Applying these formulae to ancient Pacific herring from Point Reyes National Seashore from sites CA-MRN-224, CA-MRN-222, CA-MRN-249, CA-MRN-AL1, the linear regression analyses based on archaeological atlases suggest that the mean size of Pacific herring sampled in the study ranged from ~174 to ~178 mm SL. The size of the Pacific herring based on the axis measurements suggests that the mean size of Pacific herring at the four sites ranged from ~173 to ~185 mm SL. Sanchez (2020) compared the mean SL estimates calculated from the atlas to those of the axis. He conducted a *t*-test in the statistical program PAST comparing the mean SL estimates from atlases and axes (Hammer et al., 2001). The results of the *t*-test revealed no statistical difference between the two samples ($t = 0.48$, $p = 0.64$, critical t value = 2.4). Based on the results of the *t*-test, Sanchez (2020) merged the Pacific herring atlas and axis data. These data illustrate that Coast Miwok peoples were consistently harvesting similar size classes of Pacific herring with insignificant variation at the sampled sites (Figure 5; Table 2). These findings suggest that Pacific herring with a mean SL of 175-178 mm were harvested by Coast Miwok ancestors from cal CE 760 to ~1800. These data demonstrate that the Point Reyes Pacific herring fishery was in place by at least cal CE 760, if not earlier, and that the Coast Miwok Pacific herring fishery persisted until the contact era.

3.4 Santa Cruz and San Mateo coast: California mussel fishery

The California mussel remains reported in this study were previously reported by Grone (2020). In the study, Grone (2020) analyzes data from three sites in Santa Cruz and San Mateo Counties with dates ranging from 4750 cal BCE to cal CE 1920 (Table 3). Taxa from all sites display a heavy reliance on marine resources in the Middle Holocene through to the Late Holocene, evidenced by a broad range of species that span the entirety of the intertidal zone.

Research on mussel assemblages has resulted in the development of multiple regression formulae to broaden the interpretive value of fragmented California mussel remains beyond relative abundance, providing methods for measuring mussel umbones to reconstruct individual size (Campbell and Braje, 2015; Singh and McKechnie, 2015). While there is some debate about the application and interpretation of these formulae (Campbell, 2015; Singh et al., 2015), they appear to be an effective way to estimate mussel size from archaeological materials and make the most out of fragmented shellfish assemblages. These formulae used in Campbell and Braje (2015) were developed by using modern comparative specimens collected in Southern California. Due to the observed biogeographical morphological variation of California mussels north and south of Point Conception (Glassow and Wilcoxon, 1988), Grone (2020) developed an experimental morphometric formula from n = 151 modern specimens collected from Pescadero State Beach by Dr. Rob Cuthrell. After measuring the same elements used by Campbell and Braje (2015) and Singh and McKechnie (2015), Grone (2020) used umbo thickness in his study as it tends to be the most well preserved in archaeological specimens. Therefore, Grone (2020) created linear regression models that show statistically significant ($p < 0.05$) and significant (R^2 values) relationships between California mussel length and umbo thickness.

3.5 Comparison of harvesting patterns

To assess mussel harvesting practices, Grone (2020) applied morphometric data analyses and stable isotope isotope analyses (Apodaca et al., in review)[1] to model mussel harvesting profiles through time. While these data provide a robust perspective regarding California mussel harvesting trends by people that lived in the Quiroste and Cotoni polity areas, a complete review of the study is beyond the scope of this paper. Therefore, Grone (2020) applied the morphometric formulae to n = 2901 umbones from SCR-7, SCR-14, and SMA-216 (spanning 4785 cal BCE to cal CE 1920). The results are outlined below.

As displayed in (Figure 6; Table 4), the average size of mussels is significantly greater at CA-SCR-7 than at CA-SCR-14 or CA-SMA-216. This trend suggests that the mean size of mussels decreased in size over time from Middle Holocene to Late Holocene times, consistent with expectations of resource depression. However, while there is a smaller average size in the two Late Holocene sites compared to the Middle Holocene sites alone, the average size of California mussels increases slightly during the Late Holocene (Figures 7, 8; Tables 5, 6). These data suggest that people may have employed harvesting methods that maintained the stability of the mussel populations over several centuries in Late Holocene times. In addition, there is a greater density of umbones per sample in the two

1 Apodaca, A. J., Brown, J. F., and Grone, M. A. (in review). "Seasonality of Mussel harvesting at three Holocene sites on the Santa Cruz coast: Insights from isotopic variation in marine mollusks," in *The study of indigenous landscape and seascape stewardship on the central California coast: The findings of a collaborative ecosrchaeological investigation*. Editors K. G. Lightfoot, M. A. Grone, and G. M. Sanchez (Berkeley, CA: Contributions of the University of California Archaeological Research Facility).

TABLE 3 Shellfish data from the Año Nuevo and Wilder Ranch study areas outlining most abundant shellfish taxa by weight.

Sites	Site type	(95.4% CI)	Most abundant	Second most abundant	Third most abundant
CA-SCR-7	Coastal Midden	4785–2200 cal BCE	*Mytilus californianus* (70.4%)	*Balanus spp.* (28.7%)	*Pollicipes polymerus* (0.9%)
CA-SMA-216	Coastal Midden	cal CE 1300–1640	*Mytilus californianus (40.9%)*	*Tegula funebralis (37.4%)*	Chitons (8.3%)
CA-SCR-14	Upland Village	cal CE 1160–1920	*Mytilus californianus* (93.2%)	*Balanus* spp. (2.9%)	*Pollicipes polymerus* (1%)

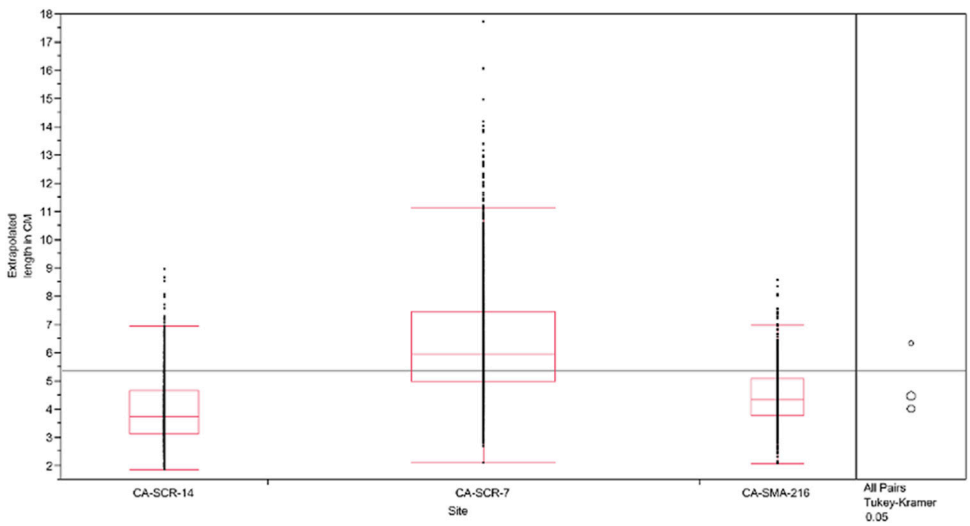

FIGURE 6
Comparison of California mussel umbone data from sites.

TABLE 4 Estimated average sizes of mussels from the Año Nuevo and Wilder Ranch sites.

Site	Age	n=	Average size (cm)	Std. Deviation
CA-SCR-7	4785–2200 cal BCE	1,409	8.0	2.9 cm
CA-SMA-216	cal CE 1300–1640	796	5.0	1.9 cm
CA-SCR-14	cal CE 1160–1920	696	4.7	1.8 cm

Late Holocene sites, suggesting mass harvesting events of greater numbers of individual mussels than at CA-SCR-7.

These harvesting profiles may indicate a stripping method of harvesting, as Whitaker (2008) described, which could account for both the reduced size and greater number of individuals per context. The standard deviation of mussel size is also less for CA-SMA-216 and CA-SCR-14, consistent with expectations of a stripping method of harvest. At CA-SCR-7, there is a higher standard deviation of mussel size, which may indicate plucking larger mussels as well as stripping entire beds.

The isotopic seasonality research by Apodaca et al. (in review)[1] suggests a proportionally greater likelihood that mussel harvesting occurred along a broader seasonal window for the coastal midden sites (CA-SCR-7 and CA-SMA-216). This differs from the readings obtained from isotope samples from the Late Holocene inland village site CA-SCR-14, where the shellfish recovered appear to have been harvested during a much tighter seasonal window consistent with winter months. The studied sites show that mussel harvesting patterns have a stronger relationship with site type and spatial proximity to shoreline rather than as a function of chronological time. The mussel assemblage at the inland site reflected a winter harvesting trend, while the coastal site assemblages suggested a broader harvesting window throughout the year. The interpretations regarding harvesting trends at the three sites should be considered tentative, considering the limited sample size.

4 Discussion

As outlined in this review, Indigenous people have profoundly influenced marine and terrestrial ecosystems by modifying coastal habitats to increase the productivity of target species and shape local biotas through their stewardship and harvesting practices. While these practices span a spectrum of effects and scales on ecosystems, there has been growing evidence that Native Californian communities may have relied on these practices interacting with specific resources, landscapes, and ecosystems with long-term rather

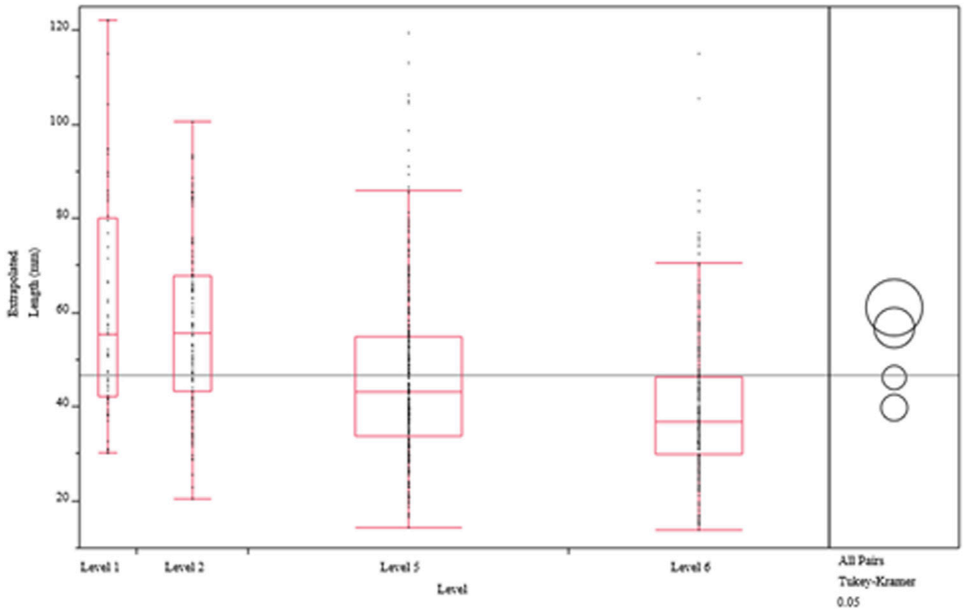

FIGURE 7
Mussel umbone data from CA-SCR-14. Data from Excavation Unit 2 and separated by excavation level. AMS Range 1160 CE- 1920 CE. N = 696.

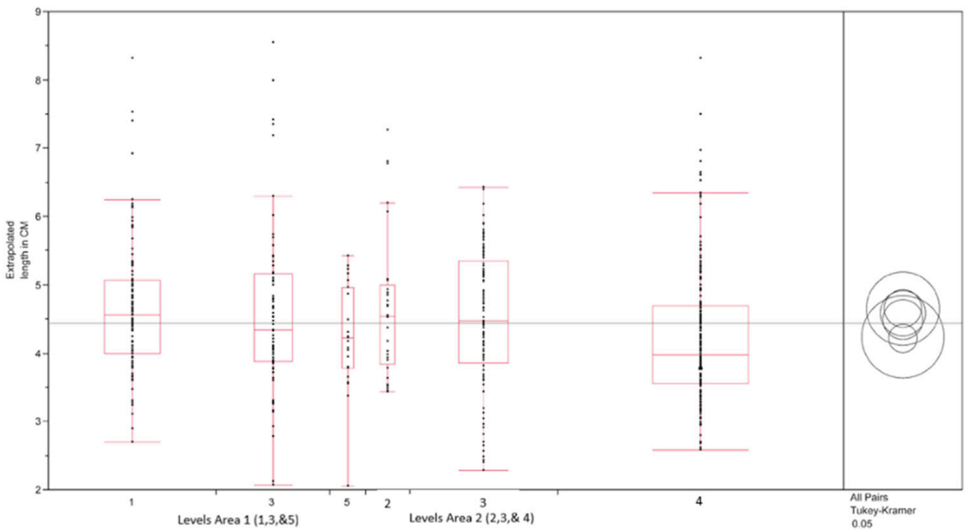

FIGURE 8
Mussel umbone data from CA-SMA-216. Data from Area 1 and 2. AMS Range 1300 CE-1640 CE. N = 796.

than short-term subsistence goals, especially by the Late Holocene. However, while some scholars conducting archaeological research on small-scale societies have recognized these practices, others have tended to overlook the likelihood of long-term perspectives in human-environmental relationships, such as traditional resource and environmental management, traditional ecological knowledge, and Indigenous stewardship practices. For example, Jones and Codding (2019) recognize that evidence supports the conclusion that the Quiroste used fire to meet intermediate goals. However, they suggest that the practice within the Quiroste case study does not meet the *scale* necessary to make the resources fit within the modern concept of the commons, meaning birds, fish, marine and terrestrial mammals that are accessible to “hundreds of unrelated, autonomous communities” (Jones and Codding, 2019).

Although the scale of the cultural practice of controlled burning along the central California coast (Cuthrell, 2013b; Lightfoot et al., 2021) does not meet the criteria of common pool resources available across a large scale, it does provide an example of Indigenous

TABLE 5 Average size of mussel from Excavation Unit 2 at CA-SCR-14.

Level	Age	n=	Average size (cm)	Std. Dev. (cm)
1	NA	55	5.9	2.4
2	1695-1725 CE (0.27); 1815-1840 CE (0.20); 1870-1920 CE (0.49)	113	5.7	1.8
5	1270-1410 CE	321	4.6	1.8
6	1160-1210 CE	262	4.0	1.5

TABLE 6 Average size of mussel from Area 1 and 2 at CA-SMA-216.

Area/Level	Age	n=	Average size (cm)	Std. Dev. (cm)
1/1	NA	186	5.0	1.5
1/3	1300 CE-1420 CE	105	5.2	1.8
1/5	NA	27	4.8	1.1
2/2	NA	37	4.7	2.1
23	1460 CE-1640 CE	129	4.9	1.8
2/4	NA	312	4.5	1.4

engagement with resources that suggest human-environmental relationships do not inevitably result in the tragedy of the commons or overexploitation. Instead, the case of controlled burning provides an excellent example of Indigenous stewardship, habitat modification, and niche construction. Therefore, these data provide a possibility of understanding Indigenous practices beyond individual maximization assumptions. Furthermore, through the long-term perspective from the Middle to Late Holocene of the sites studied, trends emerge that diverge from expectations from the maximization literature. For example, Middle Holocene populations in the Wilder Ranch study area appear to have been highly mobile and their economies focused on a broad swath of resources, yet few fit the model of high-ranked taxa based on the invertebrate and vertebrate fisheries (Sanchez, 2019; Grone, 2020). However, by the Late Holocene we find evidence in Point Reyes National Seashore, the Quiroste Valley, and Wilder Ranch, that Indigenous economies intensified towards a limited number of species. These findings also conflict with expectations from EE and HBE that suggest shifts in economic focus towards low-ranked taxa represent a widening diet-breadth that is often driven by resource depression and overexploitation, while we suggest this represents a narrowing diet-breadth that emphasized culturally important ecosystems, habitats, and species (Broughton, 1997).

In this review, we have provided an example of probable long-term intentionality of Indigenous engagement with fisheries, a resource that commonly fits the conceptualization of common pool resources (Ostrom, 1990; Ostrom, 2008). In the case of Pacific herring, they represent a fishery that occurs on a large scale, spanning the coast of North America from Alaska to Baja California (Fisheries, 2022). Pacific herring live in depths from the surface to around ~396 m. In California, Pacific herring spawn from October through April in large estuaries like Tomales Bay and San Francisco Bay (California Department of Fish and Wildlife, 2022) (Figure 3). Therefore, Pacific herring fits the criteria of common pool resources as previously described. They occur across a large scale through various habitats, from nearshore environments to offshore depths. During the spawning season, which spans several months, herring are available through mass capture fishing techniques, such as seines and gill nets, feeding humans and a diversity of organisms, serving as an umbrella and keystone species (Sanchez et al., 2018; Sanchez, 2020).

Coast Miwok fishing practices at Point Reyes National Seashore appear to have persisted from cal CE 760 to ~1800, based on the archaeological samples recovered from the 2015 excavations. However, the mean SL of Pacific herring from four archaeological sites does not vary significantly, with sites CA-MRN-224 (177 SL mm), CA-MRN- 222 (178 SL mm), CA-MRN-249 (176 SL mm), and CA-MRN-AL1 (175 SL mm) having nearly identical mean values (Figure 5; Table 2). Therefore, it does not appear that there is a reduction in the size of the Pacific herring caught within Point Reyes through time, based on the mean SL. These data suggest that Coast Miwok people may have been catching and retaining a narrower size range of Pacific herring based on the mean, which could relate to gear selectivity or release of unwanted size classes.

Since fishing nets represent a technology created based on net mesh gauges, these data suggest long-term cultural practices (i.e., traditional ecological knowledge, traditional resource and environmental management, and Indigenous stewardship) and knowledge related to fish net production and herring fishing techniques. As further evidence of this long-term perspective, we must consider that the Pacific herring fishery at these four sites are not contemporaneous. CA-MRN-224 provides the initial radiocarbon dates available for intensive Pacific herring fishing within Point Reyes dating to cal CE 760. CA-MRN-222 is inhabited after CA-MRN-224–300 years later at cal CE 1030. CA-MRN-AL1 follows CA-MRN-222 after another ~300 years dating to cal CE 1300. Lastly, CA-MRN-249 dates ~150 years following the earliest dates available for CA-MRN-AL1, dating to cal CE 1450. Thus, these sites offer an excellent opportunity to trace human-fish relationships diachronically and to identify long-term continuity or declines in the size of Pacific herring through time.

Lastly, in the case of California mussels, their spatial scale is confined, as harvesting practices, much like the case of coastal prairies, are restricted to specific habitats, such as nearshore environments, to ~24 m in depth. However, the harvesting techniques and seasons vary significantly in contrast to coastal grasslands. Researchers have devoted much time to developing methods for assessing the archaeological signatures of different harvesting strategies and the seasonality of harvest of California mussels (Basgall, 1987; Jones and Richman, 1995; Bettinger et al., 1997; Whitaker, 2008; Cuthrell, 2013b; Grone, 2020). Two primary methods of harvesting have been proposed and modeled: plucking individual mussels or stripping entire beds. According to a study by Bettinger et al. (1997), plucking is always a superior method of harvesting based on energy expenditure return rates. However, it has been demonstrated (Bouey and Basgall, 1991) that return rates for California mussel beds are higher when mussels beds have been periodically disturbed by human predation, similar to some plants that become more productive when subject to disturbances, such as fires. Fortunately, these different harvesting strategies result in differences in shellfish assemblages. In the case of the plucking method, we expect to see a decrease in shell size through time with non-seasonally specific harvesting practices. However, in the case of the stripping method, we could expect to see the presence of a wide range of size classes with small to medium average sizes and a seasonally specific range of harvest of mussel beds.

In the case of California mussels studied by Grone (2020), there is a decrease in the size of mussels from the Middle Holocene at CA-SCR-7, with an average size of ~8 cm. By the Late Holocene at CA-SMA-216 and CA-SCR-14, California mussels range from 5.0 cm to 4.7 cm, respectively. While these data could be interpreted as an indication of resource depression based on size differences alone, Grone (2020) suggests that these assemblages represent differences in harvesting strategies at these three sites rather than indicative of resource depression or overexploitation. The stripping method as a harvesting strategy targeting medium sized mussels has been proposed to ensure continued and consistent mussel harvests, as the harvest of larger mussels could impact the larger brooding stock of mussel populations responsible for proliferation of a larger number of gamete, while the harvest of smaller mussels which have yet to reach reproductive viability could similarly disrupt mussel population. There, the harvest of medium size mussels *via* a repetitive stripping method of harvest may be indicative of Indigenous stewardship practices (Whitaker, 2008; Grone, 2020).

5 Conclusion

Indigenous people have profoundly influenced marine and terrestrial ecosystems by modifying coastal habitats to increase the productivity of target species and shaping changes in local biotas through their harvesting practices. In some cases, these actions have led to local resource depression, while in other instances, it appears Indigenous people engaged with marine resources in sustainable ways, increasing the resilience of coastal ecosystems. However, some scholars believe that there is still little evidence that California Indians employed sophisticated stewardship practices as a way to increase the carrying capacities of circumscribed territorial resources [See Jones and Codding, (2019) regarding discussion of Anderson (2005); Lightfoot and Parrish (2009)].

Eco-archaeological research of Indigenous stewardship is still an emerging field in California archaeology, and programs are learning how to best evaluate stewardship practices in the archaeological record (Sanchez, 2019; Grone, 2020; Lightfoot et al., 2021; Sigona et al., 2021; Reeder-Myers et al., 2022). Nevertheless, the approach contributes to alternative ways of thinking about the long-term foodways and stewardship practices of California Indians and how these communities augmented vegetation from the individual (organism) to the landscape (ecosystem) scale during the Late Holocene. Lightfoot et al. (2013) and Lepofsky and Lertzman (2008) indicate the empirical challenges with analyzing archaeological signatures of cultural burning and other Native management strategies in the archaeological record alone. We emphasize that, when possible, eco-archaeological research should maximize its relevance for supporting Tribal cultural and ecological revitalization goals. Today, coastal habitats that are essential for Indigenous cultures are becoming increasingly impacted. One of the reasons is the exclusion of people from their traditional homelands and their connection to cultural burning and other Indigenous stewardship practices, such as resource harvesting, representing long-term rather than solely short-term goals.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

GS, MG, and AA contributed to the conception of the study. GS wrote the first draft of the manuscript. GS, MG, and AA all wrote sections of the manuscript. All authors contributed to the manuscript revisions, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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