

The Historical Ecology and Ancient Fisheries of the Central California Coast: Insights from  
Point Reyes National Seashore and the Santa Cruz Coast

By

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## Abstract

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The study of ancient and historic fisheries is essential for understanding past indigenous economies and ways of life that have relevance for modern fisheries management, restoration ecology, and conservation biology. Archaeological sites represent long-term biological repositories; they contain relevant information that provides historical baseline data and ecological reference points for contemporary conservation biology, restoration ecology, and fisheries management. Contemporary impacts, historical overfishing, and ecological extinctions threaten coastal ecosystems, as reduced fish populations no longer interact significantly with other species in the community. The time-depth of the archaeological record can provide vital information for scientists, resource managers, policy makers, and sovereign Native American nations to prioritize resources for conservation and restoration.

As a result of collaborative eco-archaeology with the Amah Mutsun Tribal Band, the Federated Indians of Graton Rancheria, the National Park Service, and California State Parks, this dissertation outlines the ancient fisheries of central California from the Middle Holocene to the historic era spanning the last 7,000 years. Through the investigation of fourteen archaeological sites from Point Reyes National Shore to Santa Cruz County, this dissertation offers three case studies that highlight the value of historical ecology and eco-archaeology of ancient and historic fisheries. These data contribute information for tribes and federal and state agencies, to inform the co-management of fisheries by defining the range of organisms used in ancient and historic times, organism biogeography, and indigenous fishing techniques and technologies.

## **Dedication**

This work is dedicated to my wife Janae, whose support, encouragement, and friendship made the research possible; to my parents Miguel and Elizabeth, to the Sanchez, Barrales, Chavez, Fuentes, Ruiz, and Sierra families, and the memory of my grandmother Martina Fuentes Zúñiga.

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## Chapter 1

### **Fire Ecology Meets Ancient Fisheries Studies: Collaborative and Applied Historical Ecology on the Central California Coast**

#### **Introduction**

Eco-archaeological analyses of ancient and historic sites contribute to the management of terrestrial and aquatic ecosystems by providing evidence of the historical range of variability thereby generating historical baselines or examples of ecological resilience and degradation (Gunderson and Holling 2002; Morgan et al. 1994; Pauly et al. 1998). A growing body of literature highlights the critical role of the archaeological record in producing relevant information for resource managers, sovereign indigenous nations, conservation groups, and state and federal agencies that can inform the management of terrestrial and aquatic ecosystems (Braje et al. 2017; Gobalet 2012; Lauwerier and Plug 2004; Lyman 1996; Butler and Delacorte 2004; Rodrigues et al. 2018; Wolverton and Lyman 2012; Wolverton et al. 2016). In other instances, the archaeological record provides evidence of human impacts on ecosystems, anthropogenic management and stewardship of organisms and landscapes, and sustainable harvesting practices by indigenous communities, which enlighten contemporary resource management practices (Alves and Souto 2015; Braje 2007; Braje and Rick 2011; Cuthrell et al. 2012; Cuthrell 2013a; Denevan 1992; Grayson 2001; Lightfoot, Cuthrell, Striplen, et al. 2013; Lightfoot, Cuthrell, Boone, et al. 2013; McKechnie 2007; Sanchez et al. 2018; Smith 2001, 2007; Turner 2005). Often, such studies are conducted under the theoretical framework and research program of historical ecology or environmental archaeology (Balée 2018; Crumley 2017).

Within the fields of global conservation science, archaeology, and ecology there is a growing recognition of the role that indigenous peoples play in shaping and influencing their environments (Berkes 2018; Denevan 1992; Gunderson and Holling 2002; Smith 2001, 2007; Turner 2005). However, debate abounds among archaeologists, ecologists, and indigenous scholars regarding the form, scale, and timing of small-scale societies modification, stewardship, and management of their environment (Denevan 1992; Frazier 2007; Kimmerer and Lake 2001; Lightfoot et al. 2013; Vale 1998, 2000). It is exceedingly important to understand the role that past anthropogenic disturbance and management informs contemporary land-use legacies (Foster et al. 2003; Frazier 2007; Rhemtulla and Mladenoff 2007; Turner 2005). On the other hand, scholars have argued against the involvement of indigenous communities in conservation practice based on perceived human impacts on specific organisms (Broughton 1997:859, 2004:15–16).

While some scholars posit that indigenous communities were the ultimate eco-engineers, actively managing animal and plant communities (Smith 2001, 2007), others have noted significant impacts to ecosystems, animals, and plants through archaeological, paleoecological, and paleontological research (Braje and Erlandson 2013; Boivin et al. 2016; Broughton 1994, 1997, 2004; Butler and Campbell 2004; Erickson 2008; Grayson 2001; Lepofsky and Lertzman 2008; Lepofsky et al. 2003; Martin and Klein 1984; Milberg and Tyrberg 1993; Moss 2012; Steadman 1989, 1995; Weiser and Lepofsky 2009). As a result, it is vital to understand the scope of ancient human impacts, management, and harvesting practices to provide long-term reference points which can inform the management, conservation, and restoration of ecosystems and organisms.

In this chapter, I outline the critical role of collaborative eco-archaeology and historical ecology to inform the co-management of resources between state and federal authorities, the Amah Mutsun Tribal Band, and the Federated Indians of Graton Rancheria. Also, I consider the role of collaborative research in the recovery and continuation of indigenous traditional ecological knowledge (TEK). TEK is the cumulative body of knowledge, practice, and beliefs evolving among indigenous people by adaptive processes and handed down over generations by cultural transmission. TEK transmits information about the relationship of living beings with one another and their environment (Berkes 2018; Berkes and Folke 2002). I consider the value of archaeology in the remembrance and continuation of traditional resource and environmental management (TREM). TREM denotes the beliefs and practices that are intended to maintain or enhance the abundance, diversity, and the availability of culturally significant plants, animals, and ecosystems (Fowler and Lepofsky 2011; Lepofsky and Armstrong 2018).

Second, I summarize over a decade of collaborative and interdisciplinary research on the central California coast between the Amah Mutsun Tribal Band, California State Parks, and the University of California that documents indigenous modification of terrestrial landscapes to expand the extent of coastal prairies (Cuthrell et al. 2012; Cuthrell 2013; Gifford-Gonzalez et al. 2013; Lightfoot et al. 2013). These data shift the discussion of anthropogenic management in California from historical written datasets alone to information derived from multiple independent lines of scientific evidence.

Third, I review the most recent iteration of this project that investigates the time-depth of pyrodiversity practices and the potential for indigenous management or stewardship of near-shore marine ecosystems. Investigation of these practices contributes to the scientific study of sustainable harvesting practices among small-scale economies and the adaptive co-management of resources. The most recent phase of eco-archaeology research was initiated in the summer of 2015 at Point Reyes National Seashore, between the University of California, the National Park Service, and the Federated Indians of Graton Rancheria. In the summers of 2016-17 research was conducted along the Santa Cruz coast with the Amah Mutsun Tribal Band and California State Parks, outlined further below.

Lastly, I outline the dissertation research that focuses explicitly on the use of fish remains from ancient and historic archaeological sites to elucidate ancient fishing practices. These data have the potential to inform contemporary fisheries management by providing historical baseline data and ecological reference points defining the biogeography, size, and relative abundance of fishes (Gobalet 2012; Lyman 1996; Maschner et al. 2008; Wolverton and Lyman 2012; Wolverton et al. 2016). The ultimate goal of the three case studies reported is to define human-fish relationships along the central California coast, to determine the fishes used by the Native peoples, and to employ knowledge of past fisheries in current conservation efforts.

## **Background**

### *Historical Ecology and the Study of Human-Environmental Relationships*

Historical ecology is a theoretical framework that traces the relationship between humans and the biosphere—or socio-ecological interactions—through multiple temporal and spatial scales; these relationships are made manifest in the landscape (Balée 1992, 1998a, 2006, 2018; Beller et al. 2017; Crumley 1994, 2007, 2017). The concept of landscape is central to historical ecology (Balée 2018; Crumley 1994, 2017). The historical landscape is a multidimensional physical entity that has spatial and temporal characteristics and are culturally-impacted arrangements of land, water, and biota (Balée 2018). The landscape is a manifestation of human

activities, intentions, and actions, which represent long-term human-environmental relationships (Balée and Erickson 2006; Crumley 1994). Therefore, historical ecology is landscape and seascape history—the study of ancient ecosystems through the examination of changes in the land and sea over time and across multiple scales—spatial, temporal, economic, social, and political (Crumley 1994, 2017).

Historical ecology includes four main postulates outlined by Balée (2006, 2018). First, humans have impacted almost all of Earth’s environments in physical or material ways. Second, different societies impact environments in distinctive ways due to differences in their internal ordering and structures. Third, human nature is indifferent to species diversity. Fourth, human nature is not programmed genetically or otherwise to lessen or augment species diversity and other environmental parameters.

In contrast to earlier accounts of human-environmental relationships as adaptive, historical ecology views people as creating their local environments through human action, technology, engineering, and cultural practices (Balée 1992; Erickson 2003, 2008). The framework contrasts with previous ahistorical and reductionist ecological approaches in archaeology that exclude human agency and intentionality in human-environmental relationships. Historical ecologists recognize that human action and intention shape past and contemporary landscapes (Balée 1992, 1998b, 2018; Balée and Erickson 2006; Kidder 2013; Thompson 2013). Historical ecologists view human-environmental relationships as knowledge-based due to long-term human engagement with local environments and human modification to landscapes and resources. Understanding these practices provides information that can guide sustainability in the future and identify the extent of human-environmental modifications and impacts through time (Fowler and Lepofsky 2011). As synthesized by Bürgi and Gimmi (2007) the three objectives of historical ecology can be summarized as: the preservation of cultural heritage in ecosystems and landscapes; understanding historical trajectories of pattern and processes in ecosystems and landscapes; and informing ecosystem and landscape management.

As described above, Balée (2006, 2018) proposes that humans have affected nearly all environments on Earth. Furthermore, historical ecologists posit that human nature is not predetermined to lessen or augment species diversity or other environmental parameters (Balée 1992, 1998a, 1998b). Thus, historical ecologists do not assume that people ‘live in harmony with nature’ nor do they presume that people are inherently predisposed to overharvesting of resources and driving environmental degradation (Krech 1999; Nadasdy 2005; Redford 1991). Graham (1998) shares these sentiments as she highlights that the term history, in historical ecology, emphasizes human decision-making and action, not adaptability and fitness outcomes. As noted by Thompson (2013), historical ecology differs from other theoretical frameworks in ecological anthropology by its emphasis on humans as primary drivers of ecological change, its focus on multiple temporal and spatial scales, and landscapes.

Pennings (2013) builds on these ideas by demonstrating three ways historical ecology contributes to the natural sciences and contemporary conservation efforts. First, historical ecology can teach scientists how the past may be affecting the present. Second, it can provide critical historical baselines, restoration targets, and reference conditions for understanding and managing contemporary ecosystems. Third, ecologists are increasingly interested in studying humans as part of ‘natural’ systems, whereas historical ecology seeks to historicize the study of ecology through the inclusion of human culture and human-environmental relationships (Beller et al. 2017).

In conclusion, historical ecology challenges scholars to recognize the often-subtle effects of human engagement with the environment (Balée 1992). Scholarship demonstrates that pristine ecosystems do not exist, rather novel ecosystems with long-term land-use legacies—those transformed by human agency—are what we encounter (Foster et al. 2003; Boivin et al. 2016; Kidder 2013). Recognizing that humans have altered ecosystems in diverse ways through intentional cultural practices and unintended consequences provides a foundation to explore the knowledge systems of these practices. Historical ecology interrogates the long-term relationship between humans and their local environments; thus, these studies provide insights into the mutual protection of natural and cultural diversity (Balée 2018; Crumley 2017), outlined below.

### *Adaptive Co-Management, Traditional Ecological Knowledge, and Traditional Resource and Environmental Management*

As noted above, historical ecology is an interdisciplinary field that seeks to understand human-environmental relationships in a long-term diachronic framework. Consequently, historical ecology is unavoidably involved in the investigation of the material traces of TEK or indigenous knowledge—which is the foundation for TREM (Berkes 2018; Fowler and Lepofsky 2011). As Fowler and Lepofsky (2011) note, TREM consist of the mundane activities of daily life with these practices shifting based on specific organisms of interest and the frequency, timing, and intensity of their use and temporal and spatial characteristics.

Given that indigenous people, local groups, and natural resource users have long-term place-based knowledge; these systems are often compatible with the goals of resource managers and local conservation groups. As a result, the concept of co-operative management or co-management of natural resources offers an opportunity to include the participation of diverse resource users in decision making, thereby, creating connections between users and managers (Berkes 2007). Adaptive management is a concept that guides resource management through learning-by-doing in a science-based way to deal with uncertainty (Berkes 2007).

Adaptive co-management may take many forms, but the importance of user involvement is highly relevant for indigenous groups, especially those disenfranchised from their aboriginal lands, as discussed further in chapter 4 (Taiepa et al. 1997). Co-management arrangements are on a spectrum from consultation to equitable decision-making power (Taiepa et al. 1997). Therefore, the co-management of resources offers an opportunity for community-based development. It is a route for decentralizing decision-making to address problems effectively, and it serves as a mechanism for reducing conflict through participatory democracy (Pinkerton 1989). Besides, co-management systems offer the opportunity for significant community involvement that can be supported by the government through legislation, enforcement, and other assistance (Pomeroy and Berkes 1997).

Adaptive co-management of natural resources is far from a new concept (Berkes 2009; Folke et al. 2002; Holling 1978). One of the earliest treatments of co-operative or adaptive co-management of natural resources is derived from interests in informal, negotiated, and legal agreements between various stakeholders and fisheries managers in the United States and Canada (Pinkerton 1989). As outlined by Pinkerton (1989) through shared decision-making of fisheries by government authorities, individual fishers, and fishing groups, co-management systems allow for greater cooperation. Co-management offers the opportunity to plan for the long-term through equity, efficiency, and appropriate management. Co-management systems pose numerous benefits for resource users, managers, and society through an equitable sharing of decision making and defining policy.

Based on these previous studies, researchers have derived examples of indigenous and local management of resources as an alternative to conventional resource management. These approaches differ from solely a Western science-based approach that is used as the basis for most kinds of resource management on federal and state lands (Agrawal 1995; Berkes and Folke 2002). While the integration of indigenous, local, and state and federal objectives may be difficult, the concept of adaptive co-management offers an opportunity to combine diverse perspectives with learning, experience, experiment, to manage natural resources (Armitage et al. 2009).

In the 1980s, scientific inquiry into TEK and the application of indigenous knowledge in natural resource management and conservation were explored (Berkes 2018). Berkes (2018) suggests that two interdisciplinary areas were open to the inclusion of TEK; these include the study of the commons and environmental history, as discussed below. Interest in traditional social organization and collective property rights systems seek to document practices that are capable of avoiding the dilemma of the “tragedy of the commons,” or the overexploitation of common pool resources and degradation of natural resources, offering insights into sustainable resource use (Berkes 2018; Hardin 1968; Ostrom 1999). Common pool resources are goods—natural or humanmade—that are sufficiently large, which makes it too costly and difficult to exclude or limit users. Also, one person’s consumption of the resource makes it unavailable to others (Araral 2014; Laerhoven and Ostrom 2007; Ostrom 2002). It is believed that these characteristics make common pool resources susceptible to overharvesting and destruction, when associated with non-cooperation, increasing human populations, or high-population densities, otherwise known as the tragedy of the commons (Hardin 1968).

We experience common pool resources daily in our lives such as the ocean, streams and lakes, fishing grounds, and forests (Laerhoven and Ostrom 2007). Common pool resources exist at a variety of social scales from resources held by agreements between individuals or families to resources maintained by nation-states (Eerkens 1999). Thus, the study of ancient and historical common pool resources and the socio-ecological systems that guided their use provides examples that can inform the contemporary use of these resources (Berkes and Folke 2002).

The study of environmental history or landscape history developed interests not only in ancient landscapes but also in understanding past peoples and their resource practices that resulted in these landscapes (Berkes 2018). These practices span a continuum from limited ecosystem impacts to an ecosystem state change, or crossing ecosystem ‘tipping points’ (Gunderson and Holling 2002). It is important to note that the primary difference between environmental history and historical ecology is related to their sources. Environmental history primarily focuses on documentary sources while historical ecology is not limited to any specific dataset, drawing instead from a multitude of sources (Crumley 2017).

While many scholars recognize the value of TEK and TREM and the prevalence of novel ecosystems, issues still exist in elucidating the scale and form of ancient and historical human ecosystem impacts and how these data may be used or should be used in contemporary resource management (FitzGibbon 1998; Hunn et al. 2003; Krech 1999; Nadasdy 1999). Several critiques of TEK and TREM and their relevance to contemporary resource management have been detailed. For example, some posit that local ecosystems have become fundamentally interconnected with global markets. These environments that once supported harvests solely for local subsistence practices were transformed by commercial exploitation, resulting in changing scales between ancient and contemporary use (FitzGibbon 1998; Thornton et al. 2010; Thornton 2015; Thornton and Kitka 2015). Subsequently, existing resources are predominantly harvested

and managed with modern technologies to support large-scale exploitation. Therefore, some argue that the scale of human involvement in these ecosystems is not equivalent to those in ancient and historical times limiting the utility of ancient and historic reference conditions and baselines (Hunn et al. 2003; Morrow and Hensel 1992; Redford 1991). Others posit that indigenous communities are inclined to overharvest resources and degrade ecosystems in both ancient and historical times and that they should not be involved in making decisions about how we manage resources today (Broughton 1997, 2004; Krech 1999; Meilleur 2000). Also, landscape-level transformations have occurred as a result of colonialism that caused changes in landscape use and the introduction of exotic organisms (Lopez 2013). Thus, modern landscape-level changes have been too extreme to return these ecosystems to ancient and historic baselines. Furthermore, centuries of colonialism complicate local, regional, and international geopolitics, potentially challenging the use of TEK and TREM in contemporary society (Morrow and Hensel 1992; Nadasdy 1999; Nassauer 1995).

In contrast to these perspectives, I will attempt to demonstrate the value of coalescing indigenous knowledge with the goals and regulatory challenges of today's society. I outline examples of indigenous stewardship and resource use through three case studies. These data are part of a collaborative eco-archaeology program involving the Amah Mutsun Tribal Band, the Federated Indians of Graton Rancheria, California State Parks, the National Park Service, and various academic institutions. As discussed in this dissertation, these organizations have begun to implement landscape restoration through the integration of TEK and TREM, and eco-archaeological research.

### **Collaborative Eco-archaeology: Working Together with the Amah Mutsun Tribal Band, California State Parks, the Federated Indians of Graton Rancheria, the National Park Service, and the University of California**

#### *Brief History of the Amah Mutsun Tribal Band*

The Amah Mutsun Tribal Band are the descendants of the indigenous groups removed to Mission San Juan Bautista and Mission Santa Cruz. Since time immemorial, the ancestors of the Amah Mutsun Tribal Band have accumulated knowledge of human-environmental relationships in central California (Lopez 2013). The ancestors of the Amah Mustun are defined as one of the Costanoan speaking groups, based on linguistics. Costanoan speaking peoples once inhabited a territory that extended from San Francisco south to Big Sur and from the Pacific Coast inland to the Diablo Range foothills (Bocek 1984; Levy 1978). However, because of Spanish missionization from 1769 to 1821, which worked to suppress indigenous cultural practices and erode tribal culture, tribal knowledge was altered, and other aspects lost. Furthering these changes were the seven missions established within Costanoan territory between 1770-97 and Spanish laws prohibiting indigenous burning practices (Levy 1978; Lopez 2013).

During the Mexican Period (1821-48), the secularization of the missions in 1834-36 by the Mexican government resulted in indigenous people leaving the missions to work as manual laborers on the ranchos established in lands previously held by the missions and now under control of Mexico (Levy 1978; Lightfoot 2005). With the onset of the American Period (1850-present) state and federal officials sanctioned and facilitated a coordinated genocide of California's indigenous peoples between 1848 and 1900 (Cook 1943; Heizer 1974; Jacknis 1993; Lindsay 2012; Madley 2016a; Rawls 1984). Furthermore, as noted by Madley (2016b) disease, dislocation and starvation increased the number of deaths. However, abduction, forced labor, high mortality rates on reservations, unrelenting murders, and battles and atrocious massacres

with state militias and federal troops also took countless lives (Madley 2016b). Therefore, throughout these three periods of colonialism, the main concern for the Amah Mutsun and other indigenous people was survival (Lopez 2013). Most California tribes, including the Amah Mutsun, were unable to continue the tradition of passing on some of their indigenous knowledge regarding TREM practices and other cultural traditions (Lopez 2013). These indigenous practices had become dormant in later historical times.

Consequently, by the time ethnologists began field research with tribal members in the late 19<sup>th</sup> and early 20<sup>th</sup> centuries, significant changes to indigenous lifeways had already occurred. As a result of the successive waves of colonialism, by the early 1900s, fewer than a dozen native elders remembered any of the eight Costanoan languages (Bocek 1984). Also, the ‘memory culture’ methodology employed by these ethnographers, which involved interviews with a few tribal elders in recounting Indian life in their childhood, underestimated the effects of colonialism on indigenous lifeways (Lightfoot 2005; Lightfoot and Parrish 2009). Nonetheless, in the 1920s and 1930s, John P. Harrington of the Bureau of American Ethnology studied the Costanoan language and cultural practices, focusing primarily on the Rumsen and Mutsun language groups (Bocek 1984; Callaghan 1991). Harrington worked with Isabelle Meadows and Ascensión Solórsano, his primary Rumsen consultants to re-elicite older word lists and the Mutsun grammar and phrasebook of Franciscan missionary Arroyo de la Cuesta (1861-62) (Callaghan 1991). Also, Harrington collected more than 500 plant specimens that he then highlighted in discussions with tribal members to understand their uses (Bocek 1984).

Resulting from the work of Harrington are ~80,000 pages of field notes that are held within the Costanoan collection currently curated by the National Anthropological Archives, Smithsonian Institution. In 2015, under the direction of the Amah Mutsun Tribal Band and Dr. Rob Cuthrell, students at the University of California, Berkeley began translating the Harrington notes. Since 2017 these data have facilitated the publication of *Mutsun Ways*, a newsletter, which shares information from the Harrington notes with Amah Mutsun tribal members. The information includes Mutsun language, ethnobiology, and tribal histories. Therefore, the wealth of information contained within the Harrington notes is aiding in the revitalization of Amah Mustun traditional knowledge. Below I outline how archaeological studies of ancient and historical era sites are being investigated to complement Native oral traditions, along with the information contained within the Harrington notes and other historical sources, to investigate human-environmental interactions in coastal central California.

### *Quiroste Valley Cultural Preserve and Pyrodiversity Research*

The Quiroste Valley in Año Nuevo State Park is named after the indigenous people who inhabited the area from Point Año Nuevo, northward to Pescadero Marsh, and inland into the Santa Cruz Mountains before Spanish colonization (Hylkema and Cuthrell 2013). Initial archaeological surveys in the Quiroste Valley during the 1980s resulted in the recording of over a dozen ancient and historic sites. Research in 2004-06 by Cabrillo Community College led to test excavations and radiocarbon dating assays, which suggested the presence of a contact era site within the valley, potentially Casa Grande, a Quiroste village visited by the Portola expedition in 1769 (Hylkema and Cuthrell 2013). A collaborative project involving California State Parks, the Amah Mutsun Tribal Band, and UC-Berkeley was initially facilitated by Chuck Striplen, an Amah Mustun tribal member and Ph.D. student in the Department of Environmental Science and Policy Management who was pursuing dissertation research on fire ecology and the historical ecology of California’s forests. A collaborative enterprise unfolded that was designed

to study anthropogenic burning and indigenous landscape management practices in Quiroste Valley (Cuthrell 2013b; Lopez 2013). The Amah Mutsun approved the inclusion of archaeological research through an agreement made with archaeologists to minimize impacts to any sites investigated and avoid the unnecessary disturbance of sensitive cultural materials—such as human remains—through the use of low-impact archaeological methods including geophysics. The collaborative program emphasized the inclusion of tribal members in all phases of research (Lopez 2013). As a result of these agreements the Amah Mustun Tribal Band, researchers from the Department of Anthropology, UC-Berkeley, and California State Parks initiated field research in the Quiroste Valley in 2007.

By 2009 California State Parks had created the 220-acre Quiroste Valley Cultural Preserve, which would be co-managed with the Amah Mutsun. The cultural preserve was established to protect cultural resources, to restore native vegetation, and to re-implement TREM practices. In 2012 the Amah Mustun Native Stewardship Corps was formed to involve young adult tribal members in the conservation and research of the tribe and the Amah Mutsun Land Trust (AMLT)—a nonprofit organization directed toward conservation, restoration, stewardship, and research on aboriginal lands. The AMLT, the Stewardship Corps, and the active conservation and research by the Amah Mustun are all a result of a 2005 decision by the Amah Mutsun Tribal Council that the community should work to re-engage in the stewardship of their traditional territories. Therefore, after years of living in isolation, the Amah Mutsun are now working to restore the indigenous knowledge that was lost (Lopez 2013). Given that they do not possess their tribal lands, their stewardship of traditional territories has been facilitated through the creation of partnerships with public and private landowners.

#### *Previous Pyrodiversity Research in the Quiroste Valley*

In a special issue of *California Archaeology*, Lightfoot and Lopez (2013) summarize a series of empirical investigations designed to evaluate the possibility that anthropogenic fires modified the vegetation history in and around the Quiroste Valley Cultural Preserve at the archaeological site CA-SMA-113. The interdisciplinary research team merged multiple independent lines of evidence (i.e., historical records, landscape geomorphology, paleoethnobotany, palynology, plant population genetics, faunal analysis, and dendroecology) to reconstruct past fire histories, faunal and floral resources, vegetation conversions, and indigenous cultural practices. The findings of these investigations involving tribal scholars, California State Park researchers, and academics from UC-Berkeley and UC-Santa Cruz indicate that indigenous people implemented sustained landscape burning practices that created and maintained productive coastal prairie habitats from ~cal AD 1000 to the time of Spanish colonization (Cowart and Byrne 2013; Cuthrell 2013a; Cuthrell et al. 2013; Evett and Cuthrell 2013; Fine et al. 2013; Gifford-Gonzalez et al. 2013; Lightfoot and Lopez 2013; Lightfoot, Cuthrell, Boone, et al. 2013; Lopez 2013).

In summarizing the research program in the Quiroste Valley and CA-SMA-113, Lightfoot et al. (2013) highlight what each of the diverse datasets has allowed the eco-archaeological project to elucidate regarding the five primary research questions. First, is there empirical evidence for anthropogenic burning in the diverse regions of the state? Second, when did people first initiate sustained anthropogenic burning? Third, what were the characteristics of the anthropogenic fire regimes and what potential impacts did they have on local ecosystems (e.g., what is the evidence for transformation in the structure of local habitats and enhanced biodiversity)? Fourth, how extensive were the areas burned by Native Californians? Fifth, they

addressed whether anthropogenic burning activities were incidental to other foraging behaviors, such as game hunting, or more systematically managed by individuals, family groups or broader communities to produce intended landscape-scale outcomes?

The multiple independent lines of evidence provide answers to the research questions outlined above. First, the findings of the first phase of research support anthropogenic burning in the Quiroste Valley circa ~cal AD 1000-1300 to the historic period, which directly structured local flora and fauna. Second, the earliest evidence for anthropogenic burning in the Quiroste Valley dates to ~cal AD 1000. Third, fire regimes were frequent and of low-intensity and directly shaped the local environment in the Quiroste Valley by maintaining coastal prairie habitat and open forest environments. Fourth, as of now, there is limited information about ancient burning practices throughout the state based on archaeological evidence. Fifth, they found that disentangling human agency and intended consequences whether immediate, long-term, or a combination of factors is complex. The authors suggest that CA-SMA-113 in the Quiroste Valley may have served as the primary village in the local region and was embedded within a logistically organized collector settlement.

*Collaborative Eco-archaeology: Working Together with the Federated Indians of Graton Rancheria, the National Park Service, and the University of California*

#### *Brief History of the Coast Miwok*

Before European colonization, the aboriginal homelands of the Coast Miwok stretched from southern Sonoma County, southward to the Marin Headlands, and eastward to Napa County (Colley 1970; Kelly 1978; Ortiz 1993). Coast Miwok is a language within the broader California Penutian language stock, with two dialectic groups, Bodega and Southern Coast Miwok (Kelly 1978). The Coast Miwok first encountered Europeans during two 16<sup>th</sup> century voyages. The first occurred in 1579 while Francis Drake explored the California coast. The second in 1595 occurred when Sebastian Rodriguez Cermeño entered Coast Miwok territory while sailing from the Philippines (Kelly 1978; Ortiz 1993).

During the 19<sup>th</sup> century, the homeland of the Coast Miwok was a borderland situated between the colonial powers of the Spanish (and later Mexican) missions and the Russians (1812–1841), who had established their mercantile operations through the Russian-American Company based at Fort Ross (Lightfoot 2005; Schneider and Panich 2019). In 1776 with the founding of the Mission of San Francisco de Asís, on the San Francisco peninsula, the Marin peninsula to the north served as an outreach area for the Franciscan padres over the next ~40 years (Schneider and Panich 2019). In 1817 Mission San Rafael was established on the Marin Peninsula resulting in high recruitment of Coast Miwok peoples to the missions after this time. Coast Miwok tribal members primarily went to the two previously mentioned missions as well as Mission San Jose and much smaller numbers to Mission San Francisco Solano (Milliken 2009).

Later, in the late 1840s with the onset of the American Period, Tomales Bay and adjacent lands saw the establishment of farmlands, ranches, and mills in the area (Schneider and Panich 2019). Many Coast Miwok and Southern Pomo peoples worked as laborers in and around their ancestral lands during the American period. This labor regime offered an option for indigenous people to remain within or near their homeland (Schneider and Panich 2019).

In 2000, the Graton Rancheria Restoration Act restored federal recognition to the Federated Indians of Graton Rancheria (Sokolove et al. 2002). Today the Federated Indians of Graton Rancheria and their tribal members are working with state and federal agencies to

steward and restore their ancestral lands that were lost through successive waves of European colonialism (Nelson 2017). Through studies of historical sources, archaeology, and ecology these analyses contribute data that can help guide restoration efforts.

### *Current Research*

In the summers of 2015-17, the second phase of field research was initiated between the Amah Mutsun, the Federated Indians of Graton Rancheria, the National Park Service, California State Parks, and the University of California campuses at Berkeley and Santa Cruz. The project was directed toward the investigation of the time-depth of anthropogenic fires in California and the possibility that indigenous stewardship practices were not confined to terrestrial ecosystems but included aquatic resources.

Research at Point Reyes National Seashore in the summer of 2015 was the result of a collaborative eco-archaeology project made possible through discussions between the Federated Indians of Graton Rancheria, the National Park Service, and the University of California. The goals of the project were to investigate a series of sites within Point Reyes National Seashore in an attempt to document anthropogenic stewardship practices such as pyrodiversity and the management of marine, estuarine, and freshwater organisms. Small-scale and low-impact field research within the National Park was terminated after the 2015 field season. However, the results of vertebrate analysis and fisheries studies are outlined in two case studies. One entitled, *The Historical Ecology of Central California Coast Fishing: Perspectives from Point Reyes National Seashore* (Chapter 2) and the other *Indigenous Stewardship of Marine and Estuarine Fisheries: Reconstructing the Ancient Size of Pacific Herring Through Linear Regression Models* (Chapter 3).

Another component of the second phase of field research involved new archaeological studies along the Santa Cruz coast. After consultation with Mark Hylkema and Amah Mutsun Tribal Band, five archaeological sites in Santa Cruz County were selected for study. These sites lie south of the Quiroste Valley but were chosen in an attempt to document anthropogenic management practices in the broader central California coast. Previous research suggested these sites spanned from the Middle Holocene to the post-Mission era. The results of the research are presented in one case study entitled, *Middle and Late Holocene Fisheries of the Santa Cruz County Coast* (Chapter 4).

### **The Historical Ecology of Ancient Fisheries**

The current research project is directed towards understanding ancient fishing practices along the central California coast to investigate human-fish relationships from the Middle Holocene to the historic era. The study of ancient fisheries is essential for understanding past indigenous economies and ways of life and is pertinent to modern fisheries management, restoration ecology, and conservation biology. The majority of modern ecological research on fisheries are based on studies and data that often only span a decade or longer or on historic catch records with shallow time-depth (Erlandson and Rick 2008; Pauly et al. 1998; Pauly and Palomares 2005; Reitz 2004).

The potential of the archaeological record to expand the time-depth of these studies, to account for transformations in biogeography, ancient human impacts, changes in harvesting practices, and historic era dynamics, and how these data inform contemporary fisheries management is being increasingly recognized (Amorosi et al. 1996; Erlandson and Rick 2008; Gobalet 2012; Reitz 2004). As Erlandson and Rick (2008, 2010) outline there are six possibilities

that historical ecology can offer to the study of ancient fisheries, these include: instances of human-driven resource depression and depletion; changes in size or age profiles of organisms; shifting relative abundances of organisms; shifting biogeography or reductions and expansions of organism geographic range; evidence of trophic cascades; and evidence for fishing down or up ancient food webs. However, issues still exist in communicating archaeological analyses and data sets into practical forms of concepts and methods for use in fisheries management (Reitz 2004; Reitz et al. 2009).

Research into ancient fisheries by zooarchaeologists is far from a new endeavor (Amorosi et al. 1996; Barrett 1997; Casteel 1974; Fitch 1969; Follett 1957, 1964; Gobalet 1989; Olsen 1968). Such research has demonstrated significant differences between the population structure of modern fisheries and the size of fish caught by ancient fisher people (Maschner et al. 2008). In addition, these data offer insights into alterations in the biogeography of organisms, changing environmental and habitat conditions affecting the presence or relative abundance of organisms, shifts in the trophic level of fisheries, and alterations in the diversity of organisms captured through time (Amorosi et al. 1996; Butler and Delacorte 2004; Gobalet 1993; Reitz 2004; Reitz et al. 2009; Quitmyer and Reitz 2006).

Through the investigation of fourteen archaeological sites along the central California coast, this dissertation outlines three case studies that demonstrate the value of historical ecology and eco-archaeology research to contribute to the adaptive co-management of fisheries. I accomplish these goals by defining the range of organisms used, indigenous fishing techniques and technologies, and organism biogeography.

In chapter 2, I outline the evidence for resource depression as an explanation for increased fishing practices during the Late Holocene in central California. In that study, I outline how data derived from ancient fish remains can elucidate fishing techniques and technologies including the mass-capture and storage of Pacific herring (*Clupea pallasii*) and Pacific sardine (*Sardinops sagax*) for local consumption and trade.

In chapter 3, I analyze the Pacific herring and Pacific sardine data through the reconstruction of the size of Pacific herring harvested over a 1,000-year record. I accomplish this through the creation of linear regression models and formulae. These data provide insights into the potential for selective fish harvesting techniques and stewardship of ancient and historic Pacific herring stocks within Point Reyes National Seashore.

In chapter 4, I explore changes in the relative abundances of fishes from the Middle Holocene to the historic era along the Santa Cruz coast to better understand fishing techniques and technologies from this area. I highlight the significant recovery and sampling biases from Santa Cruz County and how these have affected the representation of fishes archaeologically. These biases affect the ability of archaeological data to contribute to tribal revitalization efforts.

Lastly, chapter 5 concludes by placing the three case studies in comparative perspective. In it, I suggest future directions so that the study of ancient and historic fisheries can provide the best available science to inform the stewardship and restoration of ecosystems and single and multi-species management.

## Chapter 2

### **The Historical Ecology of Central California Coast Fishing: Perspectives from Point Reyes National Seashore**

#### **Introduction**

The study of ancient fisheries is essential for understanding past indigenous economies and ways of life, as well as relevance for modern fisheries management, restoration ecology, and conservation biology (Egan and Howell 2005; Lyman 1996; Maschner et al. 2008; Rick and Lockwood 2013; Wolverton and Lyman 2012). Contemporary impacts, historical overfishing, and ecological extinctions threaten coastal ecosystems, as reduced fish populations no longer interact significantly with other species in the community (Jackson et al. 2001; Jackson 2008; Pauly et al. 1998; Pauly and Palomares 2005). Historical ecology provides long-term data regarding human-environmental relationships, applicable to situations where defining historical baselines and the historical range of ecosystem variability is imperative (Rick and Lockwood 2013). Through the integration of historical information, modern datasets, and tribal histories, ecological and environmentally focused archaeological research can contribute relevant information regarding human-environmental relationships in a dynamic framework. Archaeological sites represent repositories of biological and ecological data. These data provide indispensable information for scientists, resource managers, policy makers, and sovereign Native American nations to prioritize resources for conservation and restoration.

In North American archaeology, the study of small-scale societies has witnessed an increase in research concerning pre-contact indigenous resource use and management, and the application of these data in contemporary management decision making (Armitage et al. 2007; Caldwell et al. 2012; Lepofsky 2009; Lightfoot et al. 2013a; Lightfoot et al. 2013b). Similarly, archaeological evidence of Native American fishing practices has the potential to inform contemporary fisheries management by providing historical baseline data through defining the biogeography, size, and relative abundance of fishes (Gobalet 2012; Lyman 1996; Maschner et al. 2008; Wolverton and Lyman 2012; Wolverton et al. 2016).

In this chapter, I examine the Coast Miwok fishery of Point Reyes National Seashore in Marin County, California in relation to what is known about the ancient Native American fishery of the central California coast and portions of northwestern California. I compare my findings to studies of the Native American fisheries north of Point Conception, California. The current distribution of fishes and the archaeological evidence suggest that Point Conception serves as a biogeographic barrier for marine fishes and that this pattern has persisted throughout the Holocene (Gobalet 2000). Previous studies of the ancient Point Reyes fishery have been very limited, qualitative, and based on materials recovered using coarse-grained methods (Follett 1957, 1964; Henn 1970), limiting our understanding of the variety of fishes, fishing techniques, and technologies represented. In contrast, the present study results from small-scale excavations with fine-grained recovery methods (>1 mm sieves), working at the landscape level through the theoretical framework of historical ecology (Balée 1992, 1998a, 1998b, 2006, 2010). The ultimate goal of the study is to define human-fish relationships in Point Reyes National Seashore, to determine the fishes used by the Native peoples, and to employ knowledge of past fisheries in modern conservation efforts.

#### **Background**

### *The Archaeology of Point Reyes National Seashore*

Point Reyes National Seashore includes the coastal area beginning just north of Bolinas, California to Tomales Point, and east to the coastal mountains, an area of approximately 287.5 sq km (Fig. 2.1). Before 2001, only one radiocarbon assay was reported from Point Reyes, with the bulk of chronological work completed through diagnostic artifact cross-dating (Stewart and Praetzellis 2003), limiting our understanding of Point Reyes history. The archaeological study of Point Reyes National Seashore began with an initial survey of the region's cultural resources by Nelson (1909). Later, excavations occurred under the auspices of Nelson (1909) and Gifford (1916).

The Department of Anthropology, University of California, Berkeley, led by Heizer, conducted systematic excavations in Point Reyes from 1940 to 1941. The research project searched for evidence of 16th-century European contact in Drakes Bay and sought to define the cultural sequences of the region (Beardsley 1948, 1954; Heizer 1941). Beardsley (1948, 1954) and Heizer (1941) reported on their systematic excavations, and later Treganza and Schenk (1970) found further evidence of European presence.

The earliest archaeological evidence from Point Reyes, home of the Coast Miwok people, is reported at the McClure Site, a large shell midden deposit located on the western boundary of Tomales Bay. The McClure site is a possible village or residential area, based on the spatial extent of the deposits and the density and diversity of cultural materials recovered (Stewart and Praetzellis 2003). Based on diagnostic artifacts, its occupation may span back 3,000 years (Newland 2013; Schneider 2008; Stewart and Praetzellis 2003). However, no radiocarbon dates are available to support these proposals. Meyer (2003) has recently hypothesized that archaeological deposits older than 3,000 years in Point Reyes National Seashore may be buried by alluvial deposits, while others are threatened by tidal action, subsidence resulting from tectonic activity, erosion, and sea level rise accelerated by climate change (Meyer 2003; Newland 2013).



Figure 2.1. Overview of the California Coast. Inset map includes Point Reyes National Seashore and sites examined for the current analysis.

### *Ethnographic Data of Coast Miwok Fishing*

Kelly (1991) interviewed two Coast Miwok elders, Tom Smith and Maria Copa Frias, to collect ethnographic information regarding the Coast Miwok in 1931 and 1932. Tom Smith, fluent in the Bodega (Western) Miwok dialect, provided a wealth of information on indigenous practices, particularly from the Bodega Bay and northern and western Coast Miwok territory. Maria Copa, who hailed from the indigenous community of Nicasio, spoke the Marin (Southern) Miwok dialect and was particularly knowledgeable about indigenous lifeways in southern and eastern Coast Miwok territory. Both of them discussed Coast Miwok fishing techniques and technologies with Kelly, that included the use of dip nets, spears, fish hooks, watercraft, seine nets, and poisons.

Smith and Copa identify dip nets for taking smelt from shore and salmon from streams (Kelly 1991), while salmon harvesting also included the use of spears (Kelly 1991). Seine nets are mentioned for bay fishing and appear to have been used in the pursuit of herring and surfperches, but could have been used in the pursuit of a diverse range of fishes (Kelly 1991).

According to the ethnographic notes, seine fishing was a boat-based activity, although seines could have been used near shore without boats (Kelly 1991). Hook and line fishing is also described, which suggests the use of baits, bipointed gorges, and bent iron fish hooks (Kelly 1991). Lastly, poisons made from California manroot (*Marah fabaceus*) were used to capture fish in tide pools (Kelly 1991).

Smith and Copa also describe fish preservation in the ethnographic notes (Kelly 1991). These data indicate fish preservation by smoking and salting surf fish and salmon (Kelly 1991). Immediate consumption of fish is recorded, with fish cooked over a fire (Kelly 1991). Together, the ethnographic information suggests the use of watercraft, fishing nets, hook and line, spears, and poisons in the pursuit of fish by the Coast Miwok in the early 20th century.

#### *Archaeological Recovery Methods and Inferences of Fishing Techniques and Technologies*

The use of fine-grained recovery methods is important in archaeological practice, especially for understanding ancient fisheries (Casteel 1972, 1976; Colley 1990; Fitch 1969; Gobalet 1989; Rick and Erlandson 2000; Wheeler and Jones 1989). Archaeological research conducted with coarse-grained methods will typically recover a reduced range of species, over-representing large-bodied fishes and underrepresenting small and medium-bodied fishes (Casteel 1976, 1976; Colley 1990; Ross and Duffy 2000; Shaffer 1992; Thomas 1969; Tushingham and Bencze 2013; Wheeler and Jones 1989). Fisheries research conducted with fine-grained recovery methods is essential for identifying the full suite of fish species harvested and for understanding capture techniques and technologies, such as mass-harvesting and net fishing. As research has highlighted an increase in fishing during the Late Holocene in coastal California archaeology (Broughton 1997, 1999; ; Simons 2016; Tushingham et al. 2016), consideration of recovery methods and archaeological measures of resource intensification is relevant.

In California archaeology, intensification of indigenous hunter-gatherer-fisher economies is often attributed to increasing human population densities (*sensu* Boserup 1965), as well as climatic events, territorial circumscription, decreased mobility, and potential decreases in resource availability or food production (Basgall 1987; Beaton 1991; Bouey 1987; Broughton et al. 2015). I recognize that other factors may also be involved, including changes in regional exchange networks, social organizations, and taste/cuisine. Resource intensification is often identified based on changes in the paleoethnobotanical record (Basgall 1987; Bettinger 2015; Bouey 1987; Wohlgemuth 1996) or in the use of animal resources, which result in increased labor and energy investment accompanied by decreased energetic returns (Broughton 1994, 1997, 1999). Recent discussion of the intensification of ancient fishing practices suggest that there was a shift from generalized and broad-spectrum fishing to the development of specialized fishing technologies with an emphasis on a limited range of species, often mass-captured small to medium-bodied prey (Simons, 2016; Tushingham and Bencze, 2013; Tushingham et al. 2016). These changes are often explained in relation to the development of sedentary or semi-sedentary villages, environmental change and degradation, resource overexploitation, or increasing human populations (Boone 2012; Simons 2016; Tushingham and Christiansen 2015; Tushingham et al. 2016; Whitaker 2012).

Resource intensification practices may also be correlated with the development of food production among small-scale societies and associated changes in settlement-subsistence patterns, the institutionalization of social inequalities, specialization, and the creation of surplus,

storage, and exchange networks (Morgan 2015; Morrison 1994, 2007). Consequently, knowledge of the antiquity and focus of pre-contact fishing practices is relevant for understanding California history and the formation of contemporary seascapes.

Evidence of fishing techniques, technologies, and resource intensification in fishing may be signaled through quantitative measures of zooarchaeological data and the presence of technological artifacts (Bettinger et al. 2006; Pletka 2012; Ugan et al. 2003). Specialization in the production and use of fishing technologies may include added labor, material, and time investment to produce and maintain a diverse range of fishing-related paraphernalia including watercraft, woven traps or nets, harpoons, fishhooks, and other specialized aquatic technologies such as poisons (Bertrando and McKenzie 2012; Erlandson et al. 2014). The increased use of nets requires substantial labor, material, and time investment to produce and maintain, and may indicate fishing specialization (Ugan et al. 2003; Whitaker 2012).

Recent archaeological research is providing crucial information about the fishing gear employed in the capture of different kinds of fish (Bertrando and McKenzie 2012; Rick and Erlandson 2000; Voorhies et al. 1991). This body of work indicates that fishing nets may capture a diverse range of fishes of varying body sizes, while hook and line and spearfishing should generally be correlated with the capture of large-bodied prey (Bertrando and McKenzie 2012; Boone 2012; Pletka 2012; Whitaker 2012). Morphometric analysis of archaeological fish remains provides evidence of fishing techniques in the absence of artifactual evidence (Bertrando and McKenzie 2012; Casteel 1974; Rick and Erlandson 2000; Voorhies et al. 1991). Bertrando and McKenzie (2012) quantify variation in fishing techniques between hook and line fishing and netting for rockfish (*Sebastes* sp.) and surfperches through metric studies of pre-caudal vertebrae. Given rockfish ecology, hook and line fishing is considered the primary mode of acquisition. In contrast, surfperches may be captured through hook and line fishing and netting. Bertrando and McKenzie's (2012) findings suggest surfperch with pre-caudal vertebrae diameters less than 2.8 mm are not large enough to be caught with hook and line. Therefore, zooarchaeological assemblages dominated by small-bodied fishes indicate net fishing, while assemblages in which small-bodied fish are rare or absent indicate other fishing techniques (Bertrando and McKenzie 2012; Rick and Erlandson 2000; Voorhies et al. 1991). Certain fishes such as embiotocids, atherinopsids, Pacific mackerel (*Scomber japonicus*) and Pacific jack mackerel (*Trachurus symmetricus*) may be captured with both techniques (Bertrando and McKenzie, 2012). Conversely, engraulids and clupeids likely represent capture through nets rather than hook and line (Bertrando and McKenzie 2012).

## **Methods and Materials**

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 (NPS), and the Federated Indians of Graton Rancheria with participation by Sacred Sites Committee Members. 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. 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; see Fig. 2.1). The nine sites were selected from a sample of 88 documented archaeological sites.

The sites were surveyed using low-impact and minimally invasive archaeological methodologies outlined in Lightfoot (2008). The field methodology was explicitly designed to avoid disturbing burials, and we followed NPS protocols in consultation with members of the Sacred Sites Committee in respecting the remains of Coast Miwok ancestors. We conducted near-surface sampling of artifacts by applying the ‘dogleash’ method (Binford 1964) along with ‘catch and release’ analysis. Surface survey units were spaced 5m apart in perpendicular survey transects. The ‘dog-leash’ technique serves as an expedient survey tool. When combined with in-field documentation of artifacts that are returned near their original context, this approach employed by University of California, Berkeley archaeologists has been called the ‘catch and release’ method (Gonzalez 2016; Gonzalez et al. 2006).

Survey also included limited geophysical testing, auger sampling, and opportunistic column sampling. The results of the catch and release and geophysical survey guided the placement of auger and column samples. Previous research by Cannon (2000) suggests flotation samples derived from auger sampling serve as an accurate and efficient method for accessing the focus and intensity of site-specific and regional fisheries. Subsequently, one auger sample (10 cm diameter) per site and, in one case, an opportunistic column sample (50 cm × 50 cm) for CA-MRN-224 were taken in 20 cm intervals, screened on site (to ensure no sensitive materials such as human remains or sacred objects were removed), and bagged *en toto*.

Auger bulk sediment samples and associated artifactual materials were separated from matrix through water flotation at Point Reyes National Seashore, dividing materials into light and heavy fraction samples. Sixty-four flotation samples totaling 186 liters in volume were analyzed in this study (Table 2.1). Samples were processed using a modified SMAP-type tank (Pearsall 2000) with 1 mm heavy fraction mesh and ca. 0.2 mm light fraction mesh. After drying the heavy fraction materials, samples were sieved at the California Archaeology Laboratory, University of California, Berkeley, into the following size fractions through nested geologic sieves: >4 mm, 2–4 mm, and 1–2 mm. Heavy fraction materials were separated into artifact classes, and all archaeofaunal remains were sorted based on size classes. Archaeofaunas were further sorted if they could be identified as fishes, mammals, or birds in the >4 mm and 2–4 mm size fractions. In order to assess whether the use of >4 mm and 2–4 mm size fractions biased fish recovery, I conducted a 12.5% sub-sample of the 1-2 mm portion of 20 radiocarbon dated heavy fraction samples. I concentrated on the identification of vertebrae within the 1–2 mm size class, as I was concerned that small-bodied fishes were underrepresented in larger mesh sizes.

Table 2.1. Sample type, quantity, and volume of flotation samples from Point Reyes archaeological sites.

| Site         | Sampling Method | Heavy Fraction Samples | Volume-Liters |
|--------------|-----------------|------------------------|---------------|
| CA-MRN-287   | Auger           | 4                      | 11.4          |
| CA-MRN-277   | Auger           | 7                      | 23            |
| CA-MRN-224   | Auger           | 10                     | 32.5          |
| CA-MRN-224   | Column          | 7                      | 10.1          |
| CA-MRN-222   | Auger           | 8                      | 26            |
| CA-MRN-AL1   | Auger           | 7                      | 23            |
| CA-MRN-258   | Auger           | 4                      | 12            |
| CA-MRN-659   | Auger           | 5                      | 16.5          |
| CA-MRN-379   | Auger           | 7                      | 17.5          |
| CA-MRN-249   | Auger           | 5                      | 14            |
| <b>Total</b> |                 | <b>64</b>              | <b>186</b>    |

The recovered fish remains were identified using comparative skeletons from the Gobalet osteological collection (Department of Ichthyology, California Academy of Sciences, San Francisco), supplemented by additional materials from the California Academy of Sciences, and the Museum of Paleontology, University of California, Berkeley. The 1–2 mm sub-samples were analyzed using Sanchez's osteological fish collection housed at the California Archaeology Laboratory, University of California, Berkeley. Laboratory protocols and faunal identifications were conservative in examining cranial and post-cranial elements (Driver 2011; Gobalet 2001). Sanchez and Gobalet completed the faunal analysis, and Gobalet confirmed or revised Sanchez's identifications. A dissecting stereomicroscope was used to discern diagnostic features that allowed designation to the most exclusive taxon, usually a family. Identification protocols for clupeid vertebrae follow Gobalet et al. (2004:807). I follow Page et al.'s. (2013) use of scientific and common names. Osteological and provenience data were recorded for each skeletal specimen, with the results cataloged and quantified in Microsoft Excel, using the measure of number of identified specimens (NISP) (Grayson 1984; Lyman 2008). With the minor exception of some elasmobranch remains, non-diagnostic specimens were identified as Actinopterygii and excluded from the analysis.

I follow Cannon (2000) and McKechnie (2007) in estimating abundances for column and auger samples through three calculations. These include the relative abundance of identified skeletal specimens of a taxon in relation to the total number of identified specimens (%NISP); the percentage of archaeological contexts in which a certain taxon is found (ubiquity); and number of identified specimens per liter (NISP/liter) to measure density. As McKechnie (2007) notes, these measures may be subject to diverse taphonomic and quantitative biases. However, their combined use provides evidence for documenting changing trends in the relative abundance of organisms.

To infer fishing techniques and technologies used in harvesting the fishes, I measured the maximum width of complete pre-caudal vertebrae from a 20% sample (1,814 NISP) of the assemblage. The samples included materials derived from the >2 mm size fractions. Samples were judgementally selected to represent a range of sites spanning multiple habitats and temporal scales (i.e., CA-MRN-249, Tomales Bay; CA-MRN-258, Drakes Bay; CA-MRN-277, inland near the Point Reyes headlands; CA-MRN-287, open coast; CA-MRN-379, rocky reef; and CAMRN-659, inland with proximity to a freshwater stream). Maximum vertebral width

measurements have been applied by a variety of researchers to infer fish size, fishing techniques, and technologies (Casteel 1974; Bertrando and McKenzie 2012; Rick and Erlandson 2000; Voorhies et al. 1991). I measured the landmarks of pre-caudal vertebrae following Casteel (1974). Specimens were measured using a calibrated Mitutoyo CD-6" ASX digital calipers (accurate to 0.01 mm), and data were compiled and analyzed in Microsoft Excel.

Rob Cuthrell identified terrestrial paleoethnobotanical remains for radiocarbon dating. Rhytidome and parenchymous tissue of terrestrial vegetation were selected, to avoid biases or the 'old wood' effect (Ashmore 1999; Schiffer 1986; Stuiver et al. 1986). One basal and one upper deposit radiocarbon sample were selected from each of the nine archaeological sites. Specimens for radiocarbon dating were selected from light fraction materials >1 mm in size. Radiocarbon samples were processed and analyzed by the Keck Carbon Cycle AMS Facility, Earth System Science Department, University of California, Irvine. Radiocarbon dates were calibrated using the program CALIB 7.0 and the IntCal13 calibration curve (Reimer et al. 2013; Stuiver and Reimer 1993).

## Results

The results of the radiocarbon dating demonstrate that the sites sampled were occupied between 800 and 770 cal BC to cal AD ~1,800 (Appendix A, Fig. 2.2). Site CA-MRN-287 provides the earliest date recorded in the assemblage, with an occupation history spanning the time from ~800 cal BC to 300 cal BC. Radiocarbon dates from site CA-MRN-277 suggest occupation from 90 cal BC to cal AD 770. The remainder of the sites clusters from cal AD ~770 to the historical era.

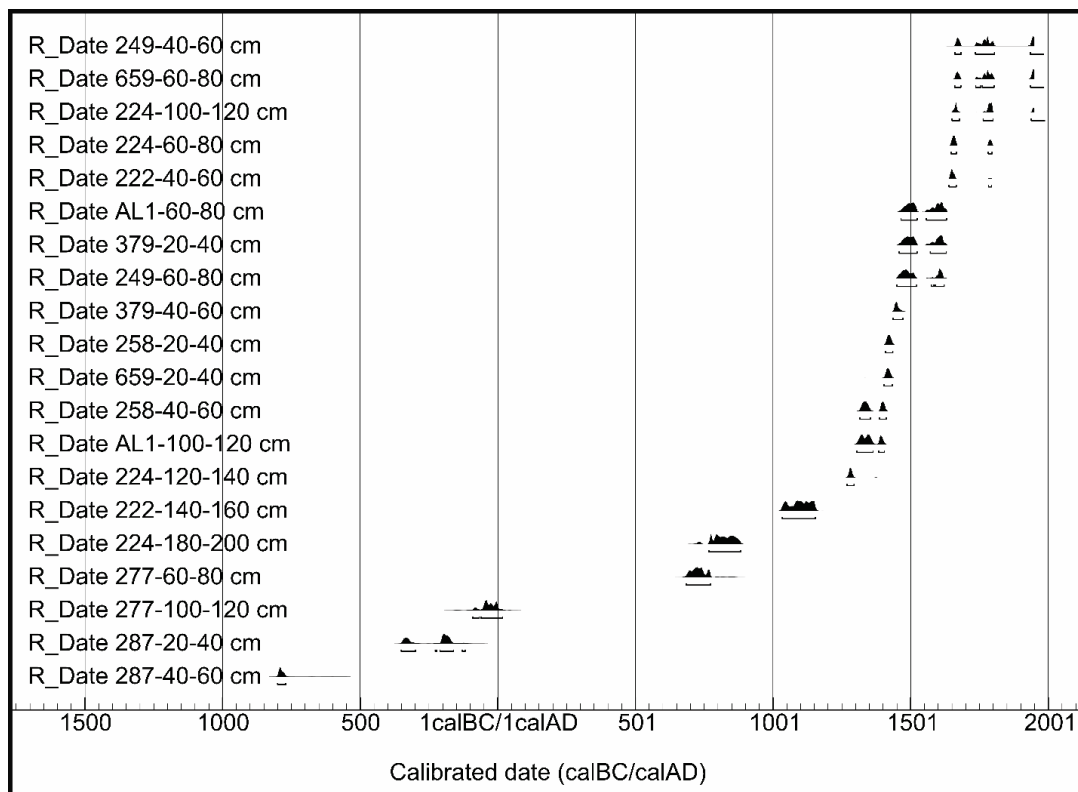


Figure 2.2. Calibrated 2-sigma radiocarbon dates reported in this study presented by site and depth below surface.

The faunal analysis resulted in the identification of 9,071 fish specimens from the >4 mm and 2–4 mm size classes (Table 2.2). At least 33 species are represented within 19 families among these remains. Fishes from the family Clupeidae represent the bulk of the assemblage, accounting for 8,005 of the total NISP or 88.2% of the assemblage. Clupeids include *Clupea pallasii* (Pacific herring, n=466), *Sardinops sagax* (Pacific sardine, n=108), and 7,431 elements identified to the family level. At least eight species of embiotocids are represented, and these include 562 specimens or 6.2% of the assemblage. Embiotocids identified include *Brachyistius frenatus* (kelp perch), *Cymatogaster aggregata* (shiner perch), *Damalichthys vacca* (pile perch), *Embiotoca* sp. [*E. jacksoni* (black perch) or *E. lateralis* (striped seaperch)], *Hyperprosopon* sp. [*H. anale* (spotfin surfperch), *H. argenteum* (walleye surfperch), or *H. ellipticum* (silver surfperch)], *Phanerodon atripes* (sharpnose seaperch) and *Phanerodon furcatus* (white seaperch), and *Rhacochilus toxotes* (rubberlip seaperch). Members of the family Atherinopsidae comprise 294 specimens of the assemblage NISP (3.2%) and include *Atherinops affinis* (topsmelt) and *Atherinopsis californiensis* (jacksmelt). Lastly, *Engraulis mordax* (Northern anchovy) includes 102 specimens (1.12%). Together the clupeids, embiotocids, atherinopsids, and engraulids account for 98.72% of the total assemblage.

The 1–2 mm sub-sampling of 20 radiocarbon dated heavy fraction samples resulted in the identification of 378 specimens (Table 2.3). These include 175 Northern anchovies, 132 clupeids, 26 embiotocids, 25 atherinopsids, and 17 specimens from the family Osmeridae. Therefore, the >4 mm and 2–4 mm samples may underrepresent the use of engraulids, clupeids, embiotocids, and osmerids within the assemblage, especially those fishes likely caught using nets. However, the results suggest the >4 mm and 2–4 mm size classes are sufficient for identifying the broader trends in fishing practices at Point Reyes, which appear directed toward the acquisition of mass-captured clupeids. The results of the 1-2 mm subsamples are excluded from the counts reported in Table 2.2, and I omit them from the discussion of the results of the >2 mm sampling below.

Table 2.2. Faunal analysis results with NISP and relative abundance (RA) by site. Includes ubiquity and taxon totals across all sites.

| Taxon                              | CA-MRN-224 (Auger) | CA-MRN-224 (Auger): RA | CA-MRN-224 (Column) | CA-MRN-224 (Column): RA | MRN-222 | MRN-222: RA | CA-MRN-249 | CA-MRN-249: RA | CA-MRN-ALI | CA-MRN-ALI : RA | CA-MRN-277 | CA-MRN-277: RA | CA-MRN-258 | CA-MRN-258: RA | CA-MRN-659 | CA-MRN-659: RA | CA-MRN-379 | CA-MRN-379: RA | CA-MRN-287 | CA-MRN-287: RA | Ubiquity | Taxon Total |     |
|------------------------------------|--------------------|------------------------|---------------------|-------------------------|---------|-------------|------------|----------------|------------|-----------------|------------|----------------|------------|----------------|------------|----------------|------------|----------------|------------|----------------|----------|-------------|-----|
| <b>Salt Water Fishes</b>           |                    |                        |                     |                         |         |             |            |                |            |                 |            |                |            |                |            |                |            |                |            |                |          |             |     |
| Elasmobranchiomorphi               |                    |                        |                     |                         |         |             | 1          | 0.0            | 1          | 0.0             |            |                |            |                |            |                |            |                |            |                |          | 22.2        | 2   |
| <i>Myliobatis californica</i>      |                    |                        |                     |                         |         |             |            |                | 1          | 0.0             |            |                |            |                |            |                |            |                |            |                |          | 11.1        | 1   |
| <b>Engraulidae</b>                 |                    |                        |                     |                         |         |             |            |                |            |                 |            |                |            |                |            |                |            |                |            |                |          |             |     |
| <i>Engraulis mordax</i>            | 61                 | 0.0                    | 6                   | 0.0                     | 11      | 0.0         | 12         | 0.0            | 8          | 0.0             | 1          | 0.0            | 3          | 0.0            |            |                |            |                |            |                |          | 66.7        | 102 |
| <b>Clupeidae</b>                   | 3165               | 0.8                    | 817                 | 0.8                     | 2011    | 0.9         | 587        | 0.8            | 554        | 0.8             | 22         | 0.5            | 173        | 0.4            | 89         | 0.8            |            |                | 13         | 0.5            | 88.9     | 7431        |     |
| <i>Clupea pallasii</i>             | 195                | 0.1                    | 58                  | 0.1                     | 114     | 0.1         | 62         | 0.1            | 24         | 0.0             | 1          | 0.0            | 8          | 0.0            | 3          | 0.0            |            |                | 1          | 0.0            | 88.9     | 466         |     |
| <i>Sardinops sagax</i>             | 56                 | 0.0                    | 15                  | 0.0                     | 11      | 0.0         | 10         | 0.0            | 11         | 0.0             |            |                | 3          | 0.0            | 2          | 0.0            |            |                |            |                | 66.7     | 108         |     |
| <b>Osmeridae</b>                   | 1                  | 0.0                    |                     |                         |         |             |            |                |            |                 |            |                |            |                |            |                |            |                |            |                | 11.1     | 1           |     |
| <b>Batrachoididae</b>              |                    |                        |                     |                         |         |             |            |                |            |                 |            |                |            |                |            |                |            |                |            |                |          |             |     |
| <i>Porichthys notatus</i>          |                    |                        |                     |                         | 1       | 0.0         | 1          | 0.0            | 8          | 0.0             |            |                |            |                |            |                |            |                |            |                |          | 33.3        | 10  |
| <b>Atherinopsidae</b>              | 83                 | 0.0                    | 14                  | 0.0                     | 27      | 0.0         | 10         | 0.0            | 25         | 0.0             | 3          | 0.1            | 103        | 0.2            | 3          | 0.0            |            |                | 10         | 0.4            | 88.9     | 278         |     |
| <i>Atherinops affinis</i>          | 2                  | 0.0                    | 1                   | 0.0                     | 5       | 0.0         | 1          | 0.0            | 2          | 0.0             |            |                | 1          | 0.0            |            |                |            |                |            |                | 55.6     | 12          |     |
| <i>Atherinopsis californiensis</i> | 1                  | 0.0                    |                     |                         |         |             | 3          | 0.0            |            |                 |            |                |            |                |            |                |            |                |            |                | 22.2     | 4           |     |
| <i>Engraulis mordax</i>            |                    |                        |                     |                         |         |             |            |                |            |                 |            |                |            |                |            |                |            |                |            |                |          |             |     |
| <b>Clupeidae</b>                   | 3                  | 0.0                    |                     |                         |         |             |            |                |            |                 |            |                |            |                |            |                | 3          | 0.1            |            |                | 22.2     | 6           |     |
| <i>Clupea pallasii</i>             | 2                  | 0.0                    |                     |                         |         |             |            |                |            |                 |            |                |            |                |            |                |            |                |            |                | 11.1     | 2           |     |
| <i>Sardinops sagax</i>             |                    |                        | 2                   | 0.0                     |         |             |            |                |            |                 | 3          | 0.1            |            |                |            |                | 4          | 0.1            |            |                | 33.3     | 9           |     |
| <b>Osmeridae</b>                   | 3                  | 0.0                    |                     |                         |         |             | 2          | 0.0            |            |                 |            |                |            |                |            |                |            |                | 1          | 0.0            | 33.3     | 6           |     |
| <b>Scorpaenidae</b>                |                    |                        | 1                   | 0.0                     |         |             |            |                |            |                 |            |                |            |                |            |                | 1          | 0.0            |            |                | 22.2     | 2           |     |
| <i>Sebastes</i> sp.                |                    |                        |                     |                         | 1       | 0.0         |            |                |            |                 |            |                |            |                |            |                |            |                |            |                | 11.1     | 1           |     |
| <b>Hexagrammidae</b>               | 2                  | 0.0                    |                     |                         | 1       | 0.0         |            |                | 1          | 0.0             | 1          | 0.0            | 1          | 0.0            |            |                | 1          | 0.0            |            |                | 66.7     | 7           |     |
| <i>Hexagrammos</i> sp.             | 1                  | 0.0                    |                     |                         | 1       | 0.0         |            |                |            |                 |            |                |            |                |            |                |            |                |            |                | 22.2     | 2           |     |
| <b>Cottidae</b>                    |                    |                        |                     |                         | 1       | 0.0         |            |                |            |                 |            |                |            |                |            |                |            |                |            |                | 11.1     | 1           |     |
| <i>Artedius</i> sp.                |                    |                        |                     |                         |         |             |            |                |            |                 |            |                |            |                |            |                |            |                |            |                |          |             |     |
| <i>Enophrys bison</i>              |                    |                        |                     |                         |         |             |            |                |            |                 |            |                | 1          | 0.0            |            |                |            |                |            |                | 11.1     | 1           |     |

|                                   |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     |       |      |
|-----------------------------------|------|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|-----|----|-----|-------|------|
| <i>Scorpaenichthys marmoratus</i> | 145  | 0.0 | 42  | 0.0 | 69   | 0.0 | 34  | 0.0 | 49  | 0.1 | 6   | 0.1 | 115 | 0.3 | 3   | 0.0 | 8  | 0.3 | 2  | 0.1 | 100.0 | 473  |
| <i>Clinocottus</i> sp.            |      |     | 1   | 0.0 |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     | 11.1  | 1    |
| <i>Oligocottus</i> sp.            | 17   | 0.0 | 8   | 0.0 | 10   | 0.0 | 3   | 0.0 | 7   | 0.0 |     |     | 5   | 0.0 | 1   | 0.0 | 1  | 0.0 |    |     | 77.8  | 52   |
| <b>Carangidae</b>                 | 5    | 0.0 | 5   | 0.0 | 2    | 0.0 | 1   | 0.0 | 1   | 0.0 | 2   | 0.0 | 1   | 0.0 |     |     |    |     |    |     | 66.7  | 17   |
| <i>Trachurus symmetricus</i>      |      |     | 2   | 0.0 | 2    | 0.0 |     |     | 1   | 0.0 |     |     | 1   | 0.0 |     |     |    |     |    |     | 44.4  | 6    |
| <b>Embiotocidae</b>               |      |     |     |     | 1    | 0.0 |     |     |     |     |     |     |     |     |     |     |    |     |    |     | 11.1  | 1    |
| <i>Brachyistius frenatus</i>      |      |     |     |     | 1    | 0.0 |     |     |     |     |     |     |     |     |     |     |    |     |    |     | 11.1  | 1    |
| <i>Damalichthys vacca</i>         |      |     |     |     | 2    | 0.0 |     |     |     |     |     |     |     |     |     |     |    |     |    |     | 11.1  | 2    |
| <i>Embiotoca</i> sp.              | 1    | 0.0 |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     | 11.1  | 1    |
| <i>Rhacochilus toxotes</i>        |      |     |     |     |      |     |     |     |     | 2   | 0.0 |     |     |     |     |     | 1  | 0.0 |    |     | 22.2  | 3    |
| <i>Hyperprosopon</i> sp.          |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     | 5  | 0.2 |    |     | 11.1  | 5    |
| <i>Phanerodon</i> sp.             |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     | 7  | 0.2 |    |     | 11.1  | 7    |
| <i>Phanerodon atripes</i>         |      |     | 5   | 0.0 |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     | 11.1  | 5    |
| <i>Phanerodon furcatus</i>        |      |     | 1   | 0.0 |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     | 11.1  | 1    |
| <b>Stichaeidae</b>                | 2    | 0.0 |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     | 11.1  | 2    |
| <i>Cebidichthys violaceus</i>     |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     |       |      |
| <i>Xiphister</i> sp.              |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     | 1  | 0.0 |    |     | 11.1  | 1    |
| <b>Clinidae</b>                   | 1    | 0.0 |     |     | 1    | 0.0 |     |     |     |     |     |     |     |     |     |     |    |     |    |     | 22.2  | 2    |
| <i>Gibbonsia</i> sp.              |      |     |     |     | 1    | 0.0 | 1   | 0.0 |     |     |     |     |     |     |     |     |    |     |    |     | 22.2  | 2    |
| <i>Heterostictus rostratus</i>    |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     |       |      |
| <b>Gobiesocidae</b>               |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     |       |      |
| <i>Gobiesox meandricus</i>        |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     |       |      |
| <b>Pleuronectiformes</b>          |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     |       |      |
|                                   |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     | 9  | 0.1 |    |     | 33.3  | 9    |
| <b>Fresh or Salt Water Fishes</b> |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     |       |      |
| <b>Salmonidae</b>                 | 3    | 0.0 | 1   | 0.0 | 1    | 0.0 |     |     | 2   | 0.0 |     |     |     |     |     |     |    |     |    |     | 33.3  | 7    |
| <i>Oncorhynchus</i> sp.           |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     |       |      |
| <b>Gasterosteidae</b>             | 4    | 0.0 | 2   | 0.0 | 1    | 0.0 |     |     | 6   | 0.0 |     |     |     |     |     |     |    |     |    |     | 33.3  | 13   |
| <i>Gasterosteus aculeatus</i>     |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     |       |      |
| <b>Cottidae</b>                   | 1    | 0.0 |     |     | 5    | 0.0 |     |     | 2   | 0.0 |     |     |     |     |     |     |    |     |    |     | 33.3  | 8    |
| <i>Leptocottus armatus</i>        |      |     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |    |     |    |     |       |      |
| <b>Embiotocidae</b>               |      |     |     |     |      |     | 1   | 0.0 | 1   | 0.0 |     |     |     |     |     |     |    |     |    |     | 22.2  | 2    |
| <i>Cymatogaster aggregata</i>     |      |     |     |     |      |     |     |     | 1   | 0.0 |     |     |     |     |     |     |    |     |    |     | 11.1  | 1    |
| <b>Total</b>                      | 3754 |     | 981 |     | 2280 |     | 728 |     | 703 |     | 41  |     | 415 |     | 110 |     | 32 |     | 27 |     |       | 9071 |

Table 2.3. Results of 1-2 mm sub-sampling with NISP by site and taxon total across all sites.

| Taxon                    | NISP       |
|--------------------------|------------|
| <b>Salt Water Fishes</b> |            |
| Elasmobranchiomorphi     | 1          |
| <b>Engraulidae</b>       |            |
| <i>Engraulis mordax</i>  | 175        |
| <b>Clupeidae</b>         | 116        |
| <i>Clupea pallasii</i>   | 13         |
| <i>Sardinops sagax</i>   | 3          |
| <b>Osmeridae</b>         | 17         |
| <b>Atherinopsidae</b>    | 25         |
| <b>Scorpaenidae</b>      |            |
| <i>Sebastes</i> sp.      | 1          |
| <b>Embiotocidae</b>      | 26         |
| <b>Pleuronectiformes</b> | 1          |
| <b>Total</b>             | <b>378</b> |

The density of fishes recovered varies by site and through time at Point Reyes (Table 2.4). The earliest site, CA-MRN-287 has a total fish density of 2.4 (NISP/l) recovered and identified to a useful taxon. In contrast, the auger and column samples taken from CA-MRN-224 have a density of specimens per liter of 115.5 and 97.1 respectively. These findings suggest that fishes comprised a minor constituent of the shell middens early in the occupational history of Point Reyes (see CA-MRN-287 and CA-MRN-277 in Table 2.2). However, by ~cal AD 700 (as evidenced by radiocarbon dates and faunal remains at CA-MRN-224) people inhabiting Point Reyes were harvesting fishes in greater numbers in and around estuaries, based on the high densities of clupeids within the assemblage. The variation between sites may also reflect task-specific locales for resource collecting. Sites in and around bays may reflect sedentary populations supported by specialized fishing stations. Given the small scale of the excavations and the small sample of artifactual materials recovered with the low-impact methodology, limits my ability to address the reasons for these differences in detail.

To address the possibility that the variation in fish density may result from taphonomic differences between sites, I conducted taphonomic evaluation of 20 radiocarbon dated flotation samples representing 3,279 NISP or 36.1% of the total assemblage. In this study, I assume that the taphonomic condition of the flotation samples is representative of the total site assemblage. I assessed the specimens individually under magnification (10×) using a stereomicroscope identifying burned elements, vertebral centra deformation, acid modification including pitting and rounding, cut marks, and carnivore modifications (Butler 1996; Butler and Schroeder 1998; Fisher 1995; Wheeler and Jones 1989; Willis and Boehm 2014; Willis et al. 2008). The findings suggest that fish bone preservation is good across all sites, with no major differences noted between the 20 flotation samples. I found no evidence that the faunal remains were damaged due to weathering or transport from aeolian or hydrologic processes. The incidence of burning (146 NISP, 4.5%), deformed (i.e., crushed or compressed) vertebral centra (110 NISP, 3.4%), acid modification in the form of pitting (2 NISP, 0.1%), and carnivore modification (2 NISP, 0.1%) are low throughout the assemblage.

Table 2.4. Density of fish remains per liter from flotation samples by site, organized chronologically.

| Site       | Sampling Method | Heavy Fraction Samples | Volume Liters | NISP | Density Per Liter | Calibrated C14 Dates       |
|------------|-----------------|------------------------|---------------|------|-------------------|----------------------------|
| CA-MRN-287 | Auger           | 4                      | 11.4          | 27   | 2.4               | 805 cal BC-115 cal BC      |
| CA-MRN-277 | Auger           | 7                      | 23            | 41   | 1.8               | 95 cal BC- cal AD 775      |
| CA-MRN-224 | Auger           | 10                     | 32.5          | 3754 | 115.5             | cal AD 765- cal AD 1,800   |
| CA-MRN-224 | Column          | 7                      | 10.1          | 981  | 97.1              | cal AD 1,265- cal AD 1,800 |
| CA-MRN-222 | Auger           | 8                      | 26            | 2280 | 87.7              | cal AD 1,030- cal AD 1,795 |
| CA-MRN-AL1 | Auger           | 7                      | 23            | 703  | 30.6              | cal AD 1,305- cal AD 1,635 |
| CA-MRN-258 | Auger           | 4                      | 12            | 415  | 34.6              | cal AD 1,315- cal AD 1,440 |
| CA-MRN-659 | Auger           | 5                      | 16.5          | 110  | 6.7               | cal AD 1,400- cal AD 1,800 |
| CA-MRN-379 | Auger           | 7                      | 17.5          | 32   | 1.8               | cal AD 1,435- cal AD 1,630 |
| CA-MRN-249 | Auger           | 5                      | 14            | 728  | 52.0              | cal AD 1,450- cal AD 1,800 |

Fish elements may have been burned intentionally, either in association with cooking or through discard of materials into a fire, but burning could also have occurred incidentally following deposition in the site or after site abandonment as a result of landscape fire. Deformation of vertebral centra may result from mastication and digestion by humans or carnivores (Butler and Schroeder 1998; Wheeler and Jones 1989), but may also represent post-depositional crushing due to trampling, sediment compression, or other processes. Pitting was recorded on two elements, both clupeid maxillae, suggesting these elements passed through the gut of a human or animal. Carnivore modification is represented by tooth punctures in a cabezon (*Scorpaenichthys marmoratus*) post-temporal and a clupeid vertebra. These findings suggest that carnivores had access to fish remains from Point Reyes and may be affecting the representation and preservation of specimens. The lack of cut marks in the assemblage is not surprising, as Willis and Boehm (2014) and Willis et al. (2008) suggest cut mark representation on diagnostic fish bone elements are generally low. However, I did not assess cut mark presence on non-diagnostic fish elements, or those identified as Actinopterygii, where cut marks may typically be found, such as vertebral neural and haemal spines, vertebral transverse processes, ribs, and pterygiophores (Willis et al. 2008).

The results of the fish ubiquity analysis demonstrate that embiotocids are recovered across all sites evaluated. These findings are not surprising, as 18 species of embiotocids are found in California marine waters in a variety of habitats (Love 2011). Clupeids and atherinopsids are found in 88.9% of the sites sampled, but not at CA-MRN-379 near Duxbury

Reef, a locality without the beaches amenable to the utilization of seines or other fish nets. At CA-MRN-379, the fishes harvested are primarily comprised of non-schooling fishes that inhabit rocky shallow waters, likely taken with hook and line or spears (Table 2.2).

The results of the fish vertebral diameter morphometric analysis are presented in Fig. 2.3. Given the expectations of primary capture of rockfish and surfperch proposed by Bertrando and McKenzie (2012), I apply 2.8 mm as the minimum threshold of fish pre-caudal vertebral diameter required for the use of fishhooks common in California Coast archaeological assemblages. If these trends in vertebral size are transferable to other species with pre-caudal vertebrae <2.8 mm diameter, then 77.3% of the fish assemblage from Point Reyes National Seashore was acquired by netting rather than hook and line fishing. When the morphometric data are evaluated by family, it appears the majority of the fishes represented archaeologically were captured with nets, including clupeids, engraulids, and atherinopsids (Fig. 2.4). Embiotocids were probably captured with nets or using hook and line depending on the size of the individual fish.

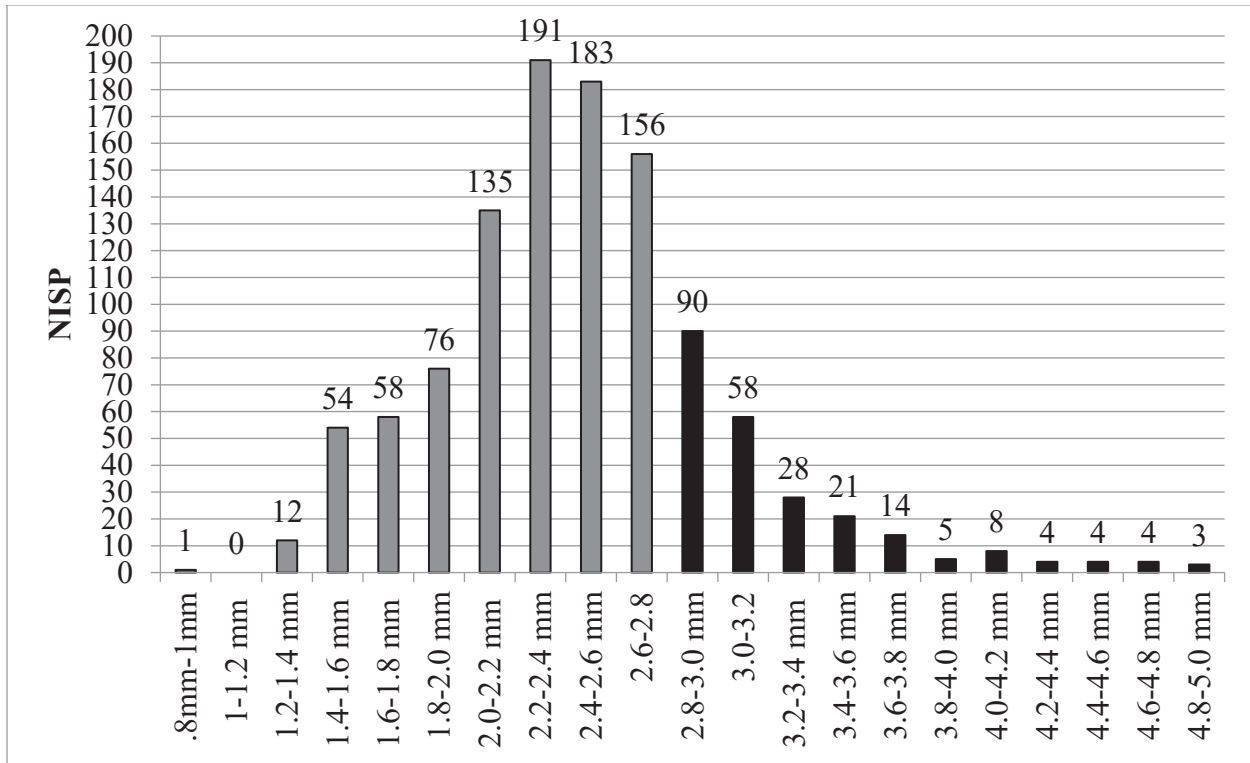


Figure 2.3. Fish vertebral diameter representing a 20% sub-sample of assemblage or 1,119 pre-caudal vertebrae NISP. The figure excludes 14 specimens ranging from 5.1 mm to 8.8 mm.

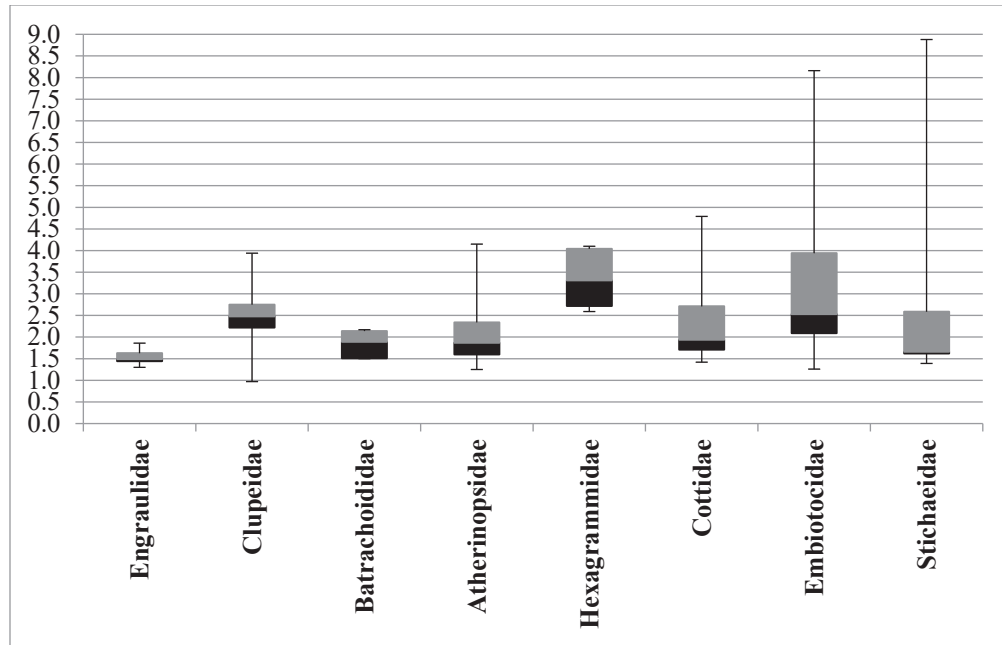


Figure 2.4. Fish pre-caudal vertebral diameter in millimeters by family.

## Discussion

The analysis of fish remains excavated from eight of the nine archaeological sites located in Point Reyes National Seashore suggest Native Americans inhabiting the area harvested small- to medium-sized fishes from ~800 cal BC to the historical era, primarily through net fishing. The outlier, CA-MRN-379, reflects a fishery focused on rocky intertidal species primarily acquired through hook and line fishing, spearfishing, or trapping. Clupeids were paramount at eight sites, accounting for ~48% of fish encountered in the earliest site CA-MRN-287, and by ~cal AD 700 these increased to ~80–85% across most sites, including CA-MRN-222, CA-MRN-224, CA-MRN-249, CA-MRN-AL1, and CA-MRN-659. These findings are supported by fish density estimates from CA-MRN-287 suggesting 2.4 NISP/l in the earliest assemblage with fish density increasing to 34–115.5 NISP/l in later assemblages, around cal AD ~700. While CA-MRN-277, CA-MRN-379, and CA-MRN-659 did not demonstrate these trends in fish densities, it appears people inhabiting sites near bays and estuaries (CA-MRN-222, CA-MRN-224, CA-MRN-249, and CA-MRN-258) with access to small- and medium-sized schooling fishes, emphasized mass-capture of fishes. Only one site, CA-MRN-659, provided evidence of salmonids, and their use in limited numbers. These are likely Coho salmon (*Oncorhynchus kisutch*) or steelhead rainbow trout (*O. mykiss*). The salmonids were likely captured in Olema Creek or Lagunitas Creek, which both drain into Tomales Bay. These data thus document the ancient presence of a salmonid in these streams.

While ethnographic and ethnohistoric data primarily associate Native Californian fishing practices with the acquisition and storage of salmonids (Heizer and Elsasser 1980; Kroeber 1925; Kroeber and Barrett 1960; Swezey and Heizer 1977), the findings highlight the important role that mass-harvesting and possibly storage of Pacific herring and Pacific sardine played in central California. I hypothesize that some sites situated near estuaries may represent permanent or semi-permanent villages or fishing camps where bulk storage of fishes helped facilitate year-round or seasonal occupation, but this interpretation is tentative at this time given the small-scale and limited excavations.

In other instances, mass-harvested fishes were transported to inland locations. For example, mass-harvested estuarine fishes recovered from site CA-MRN-659 would have been transported nearly 13 km from the closest possible site of acquisition, Tomales Bay. Clupeids represent ~85% of the fish at CA-MRN-659, with salmonids contributing ~8%. At CA-MRN-277, located inland, clupeids represent 55% of the relative abundance. The Pacific Coast is ~1.5–2 km away from CA-MRN-277, Drakes Bay is ~8 km, and Tomales Bay ~20 km, all potential sources of the clupeids found at the site. CA-MRN-AL1 situated within Abbots Lagoon may represent another site where clupeids were transported ~2 km from the Pacific Ocean, ~7–8 km from Tomales Bay, or ~4 km from Drakes Bay. Archaeological fisheries studies highlight similar transport patterns of small schooling forage fishes to inland locations throughout the central California coast, discussed further below (Boone 2012; Gobalet 1992; Gobalet and Jones 1995; Jones et al. 2016; Langenwalter and Bowser 1992).

In order to demonstrate the trends in the Point Reyes fish data, I evaluated the probable primary fishing technologies and techniques used by Native peoples. To do so, I analyzed the relative abundance of fishes within the 20 radiocarbon dated heavy fraction flotation samples (Appendix A, Fig. 2.2). Given the results of the morphometric analysis, I reasoned that nets primarily captured clupeids, engraulids, and atherinopsids. In contrast, I assume that larger embiotocids, cottids, hexagrammids, salmonids, and other fishes not commonly associated with net fishing are representative of hook and line, trap, or spearfishing. These assumptions are conservative and likely underrepresent the use of nets within each flotation sample, as small-sized fishes not commonly associated with net fishing may represent bycatch, captured with nets rather than hook and line, traps, or spearfishing.

The results suggest that net fishing practices occurred within Point Reyes during all times of occupation (Fig. 2.5). CA-MRN-379 is the only site where netted fish are not present, (in the >2 mm assemblage), presumably a result of its proximity to Duxbury Reef and lack of human transport of fish caught with nets to the site. Overall, the fish record of Point Reyes implies that the fishery was directed toward the acquisition of forage fish from lower and intermediary trophic levels through all times of occupation. However, towards the end of the Middle Period (600 cal BC to cal AD 1,000), the Middle/Late transition (cal AD 1,000–1,250), and continuing through the Late Period (cal AD to 1,250–1,750) (Jones et al. 2007), Native people inhabiting Point Reyes appear to have harvested forage fishes in greater numbers and transported these fishes to inland locations. Site CA-MRN-379 provides limited evidence of larger prey species, especially rockfish and pricklebacks (Stichaeidae) associated with Duxbury Reef, and CA-MRN-659 includes limited numbers of salmonids.

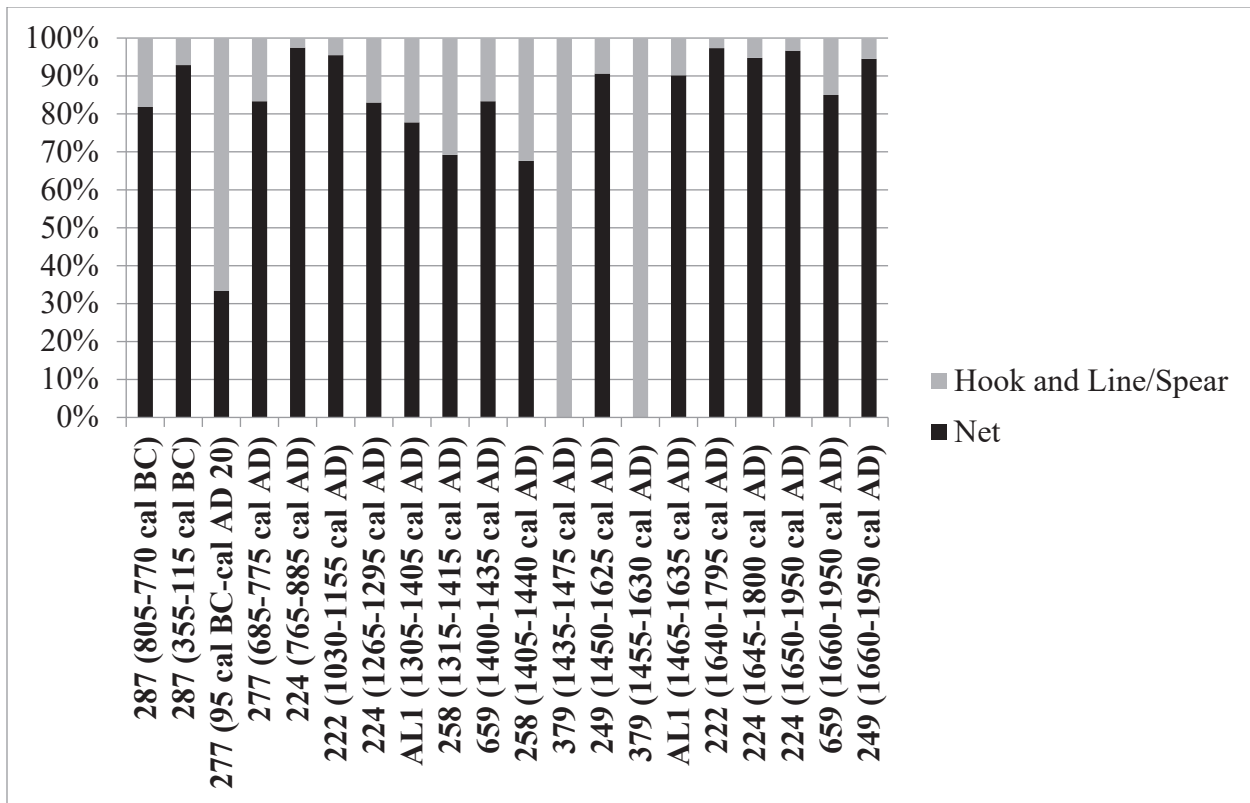


Figure 2.5. Relative abundance of fishes by primary mode of capture, presented chronologically in radiocarbon dated components.

### *Ancient Fisheries of the California Coast*

In order to contextualize the findings from Point Reyes, I highlight case studies of ancient fisheries on the California Coast. As previously mentioned, I compare my findings to studies of Native American fisheries north of Point Conception, California. Tushingham et al. (2016) applied similar sampling and recovery methods and found that the majority of their fish assemblage at CA-HUM-321 is dominated (~81%) by forage fishes such as small schooling osmerids—similar to my finding within Point Reyes. Identifications in Tushingham et al. (2016) designated only as Clupeiformes undoubtedly represent clupeids and/or engraulids (Gobalet 2017; Tushingham and Hopt 2017). The quantity and ubiquity of smelt bone at CA-HUM-321 supports the argument that a mass-capture smelt fishery was in place by the early part of the Late Period or from cal AD ~435–1,070 (Tushingham and Bencze 2013; Tushingham and Christiansen 2015; Tushingham et al. 2013, 2016).

Jones et al. (2016) analyzed a large central California coast fish database from Monterey County to San Luis Obispo County that included 86 excavated sites. Jones et al. (2016) identified 57 sites, which included 79 temporal components that were well delineated and radiocarbon dated. The 57 sites yielded 75,532 NISP processed through dry (42 components) and wet screening (37 components). The record spans from ~8,000 cal BC to the Late Period. Six fish groups dominate the large assemblage of wet and dry screened samples: clupeids (NISP=30,195; 39.9%), embiotocids (NISP=11,376; 15.1%), atherinopsids (NISP=8,773; 11.6%), rockfishes (NISP=7,018; 9.3%), cabezon (NISP=1,751; 2.3%), and pricklebacks (NISP=907; 1.2%). I reanalyzed the density trends for clupeids recovered through wet screening using 3.2 mm mesh sieves reported by Jones et al. (2016) to produce clupeid densities by temporal phase (Fig. 2.6).

These data suggest an increase in clupeid use regionally during the Late Period. The increase in clupeid NISP during the Late Period is primarily associated with two inland sites located 16 km from the coast, CA-MNT-1485/H and CA-MNT-1486/H (Gobalet and Jones 1995; Langenwalter and Bowser 1992). The sites date from cal AD 890–1,760 (CA-MNT-1485/H) and cal AD 1,000–1,790 (CA-MNT-1486/H). The original investigators interpret the occupation as a Late Period site (Langenwalter and Bowser 1992). Together CA-MNT-1485/H and CA-MNT-1486/H account for 21,012 NISP or 84.6% of the total clupeid assemblage wet screened using 3.2 mm sieves reported by Jones et al. (2016). The sites represent 99.2% of the wet screened Late Period clupeid assemblage.

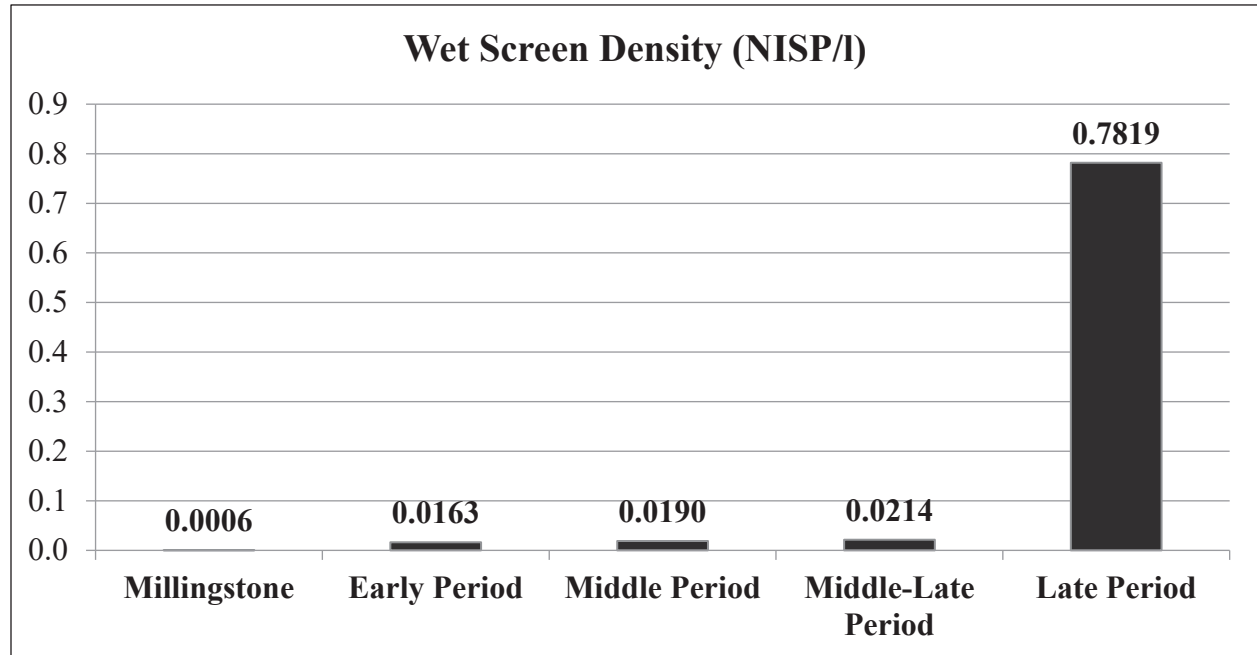


Figure 2.6. Wet screened clupeid densities reported by Jones et al. (2016) represented temporally.

Similarly, Boone (2012) analyzed 18,168 fish specimens from 13 sites spanning the coastlines of Monterey Bay and Carmel Bay, Monterey County. The trans-Holocene assemblage dates from 5,950–5,200 cal BC to cal AD 1,550–1,700. Boone's research demonstrates changes in the emphasis of the fisheries through time. Estuarine and marine forage fishes, likely Pacific sardine, which Boone interprets as requiring boat-based mass-capture fishing techniques, have the highest representation in the Millingstone Period, decline in the Early and Middle Periods, and increase in the Middle-Late Transition/Late Period. Interestingly, one site, CA-MNT-1701, a large village associated with the Rancho San Carlos complex, which includes sites CA-MNT-1485/H and CA-MNT-1486/H, contains predominantly Pacific sardine and Pacific herring remains. The site dates to cal AD 800–1,450, suggesting the increasing use of mass-capture fishes and transport to inland locations during the Middle-Late Transition and the Late Period.

Similar results are reported by Simons (2016) at CA-CCO-297 in the San Francisco Bay Area. Radiocarbon dates suggest an occupation spanning from cal AD 1,325–1,950, which the author interprets as a single-component Late Period site dating to cal AD 1,350–1,800. In total, 21,130 marine and freshwater fish bones were identified to at least a family. Small schooling fishes (NISP=14,093; 66.7%) dominate the assemblage including clupeids (NISP=11,033;

52.3%) and atherinopsids (NISP=3,040; 14.4%). Moderate numbers of embiotocids (NISP=2,100; 10.0%), and bat ray (*Myliobatis californica*) (NISP=2,787; 13.2%) are present. Simons (2016) suggests the faunal remains indicate that the site represents a village or task site occupied by people focused on harvesting a suite of marine resources using nets and watercraft to provide food for on-site consumption and to produce commodities for interregional trade.

Gobalet (2014) reports findings from six archaeological sites along the drainage of the Cayuma River in San Luis Obispo and Santa Barbara Counties (CA-SLO-95, CA-SBA-380, CA-SBA-574, CA-SBA-575, CA-SBA-585, and CA-SBA-3931). Gobalet identified a variety of marine and freshwater fish species, with 490 NISP reported. Of these, 370 NISP or 75.5% of the fishes represent engraulids, clupeids, (including Pacific sardine), and osmerids. These fishes are ~50 km from their nearest source, the Pacific Ocean. Most of the assemblage, or 401 NISP, are derived from one site, CA-SLO-95. CA-SLO-95 accounts for 321 engraulid, clupeid, and osmerid NISP, or 65.5% of the total assemblage. Radiocarbon dates, temporally diagnostic projectile points, and historic artifacts indicate a Late Period (cal AD ~1,350) and historic era occupation (Mikkelsen et al. 2014).

These examples demonstrate that Native Californian fishing practices have a long history reaching back at least to the Early Holocene (Rick and Erlandson 2000), with indigenous people fishing throughout the marine food web and trophic levels. These fishing practices contrast with modern commercial fishing practices that fish down marine food webs (Erlandson et al. 2009; Pauly et al. 1998; Pauly and Palomares 2005). Given the wide distribution of forage fishes such as clupeids and their presence in many assemblages recovered through fine-grained recovery methods, their use by Native Californians is likely underestimated in archaeological studies that do not employ fine-grained methods to recover faunal remains down to at least 2 mm in size or smaller. My findings suggest that California archaeology would benefit from further fine-grained archaeological research when studying food production and subsistence practices, particularly ancient fisheries. Similar observations have been made often (Casteel 1972, 1976; Fitch 1969; Gobalet 1989; Moss et al. 2017; Rick and Erlandson 2000). In addition, my findings provide relevant information for fisheries management, especially of important forage species such as Pacific herring, Pacific sardine, and Northern anchovy that contribute significantly to the diets of larger organisms (California Department of Fish and Wildlife 2008; Enticknap et al. 2011; Love 2011; Pikitch et al. 2012).

### *Implications for Contemporary Fisheries*

One goal of historical ecology is to use historical datasets to understand the development and functioning of contemporary ecosystems and to apply these data to ecosystem management (Swetnam et al. 1999). This historical dataset provides insights into ancient fisheries that have relevance in contemporary management, especially of forage species. Pacific herring represent a critical forage species. They are used as forage at each stage of their life history, from egg to adults, feeding large numbers of invertebrates, fishes, birds, and mammals, including humans (Enticknap et al. 2011). Pacific herring within California waters are commercially fished for their roe, as bait, and for food. California state managers have set harvest limits between 0 and 15% of the spawning biomass. However, the actual commercial exploitation rate was closer to ~20% in the 1990s (Enticknap et al. 2011). The largest Pacific herring spawning aggregations in California occur in San Francisco Bay and Tomales Bay (California Department of Fish and Wildlife 2008). The San Francisco Bay population collapsed in 2007, harvest rate decreased, and the fishery subsequently closed in 2009. The population shows signs of recovery but remains

skewed, with few older Pacific herring present (Enticknap et al. 2011). Similarly, Pacific sardine is a major forage species in the California Current. Feeding primarily on plankton, they play a vital role in transferring energy from low to higher trophic levels (Enticknap et al. 2011; Pikitch et al. 2012). The Pacific sardine fishery is the largest forage fishery by weight of landings in the California Current (Pikitch et al. 2012).

Historically, Tomales Bay supported a local Pacific herring fishery, but since 2007 these commercial fisheries have declined due to perceived reductions in the Tomales Bay Pacific herring population. For example, during the 2006-07 fishing season in Tomales Bay, Pacific herring landings totaled 1.2 tons, far less than the 350-ton season quota (Bartling 2007; California Department of Fish and Wildlife 2008). Today the San Francisco Bay supports the largest Pacific herring fishery in the state (Watters and Mello 2001). Pacific herring spawning biomass estimates were conducted in Tomales Bay from 1972-73 to 2005. The estimates suggest that Pacific herring biomass has declined significantly, with an estimated biomass of 22,163 tons in 1978, 345 tons in 1990, and 586 tons in 1998. According to the California Department of Fish and Wildlife (2008), the spawn estimate for the 2005–2006 seasons recorded 2,000 tons of herring. Due to the low exploitation rate from commercial fishing operations, levels of harvest do not seem to be the only factor in the biomass decline for Tomales Bay (California Department of Fish and Wildlife 2008). Contemporary data regarding Pacific sardine abundances around Tomales Bay is lacking due to the separation of state (Pacific herring) and federal management (Pacific sardine).

The archaeological data suggest that within Point Reyes National Seashore, people harvested clupeids during the last ~2,700 years. However, historical impacts, including potential overfishing, punctuated by warm and cold-phase El Niño-Southern Oscillation events, and a reduction in clupeid spawning habitat (i.e., *Zostera marina*, eel grass) (Enticknap et al. 2011; Huntington and Boyer 2008; Orth et al. 2006; Pikitch et al. 2012), indicates the necessity for further clupeid conservation within Point Reyes. Clupeids are biological and cultural keystone, indicator, and umbrella species (Thornton and Kitka 2015) that play a crucial role in marine food webs. Clupeids support large populations of people, fish, mammals, and seabirds that feed on the fishes and their roe (Kelly and Tappen 1998). The results of the archaeological work, in combination with the ethnographic descriptions of herring and surf fish harvests (e.g., Kelly, 1991:142–143), highlight the importance that this fishery has played in Coast Miwok history. Therefore, sustaining clupeids and their spawning habitat is relevant to maintaining functional estuarine ecosystems within Point Reyes, coastal California, and the California Current Ecosystem (Hughes et al. 2013). In addition, the persistence of clupeid populations is crucial for the continuation of Coast Miwok cultural practices. While the clupeid population is extant in Tomales Bay, the reduction in clupeid biomass suggests the population may be in decline and warrants further attention by resource managers.

## **Conclusion**

My findings highlight the important role that Pacific herring and Pacific sardine played in the foodways of the Coast Miwok people who inhabited Point Reyes National Seashore. These findings are consistent with previous studies that point to an increase in the use of small schooling forage fishes during either the Middle Period, Middle/Late transition, or the Late Period. It appears the Point Reyes fishery represents specialized food production among small-scale societies with economies directed toward the mass-capture of forage fish. This fishery was in place by the end of the Middle Period. While high-ranked or large-bodied fishes such as

salmon, cabezon, rockfish, and flatfishes (Pleuronectiformes) were recovered in the Point Reyes assemblage, their numbers and densities were far lower than those of mass-harvested fishes, especially by cal AD ~700. The question of whether the change in the relative proportions of larger-sized fishes in California coast archaeological assemblages is a result of human-induced resource depression, that resulted in resource intensification, remains unanswered.

Further research is needed to understand the transition from a broad-based fishery to one primarily geared toward the mass-capture, processing, and probable storage of forage fish. Further research is also needed to understand how this transition was influenced by increasing human population densities, climatic anomalies, increasing territoriality and interpersonal violence, resource availability, and anthropogenic landscape modifications. However, the increased investment in the production and use of nets, a labor-intensive and materially expensive technology (Bettinger et al. 2006; Pletka 2012; Ugan et al. 2003), is consistent with resource intensification models derived from ancient fisheries studies (Boone 2012; Broughton 1997; Simons 2016; Tushingham and Christiansen 2015; Tushingham et al. 2016; Whitaker 2012), paleoethnobotanical evidence (Basgall 1987; Bettinger 2015; Bouey 1987; Wohlgemuth 1996), and zooarchaeological analyses of mammals and birds (Broughton 1994, 1999; Broughton et al. 2007).

Although clupeids were harvested throughout all times sampled, their numbers and densities increased by cal AD ~700, as evidenced at sites around Tomales and Drakes Bay. These sites likely represent semisedentary villages and fishing stations. Both Pacific herring and Pacific sardine are represented in the site assemblages where species identifications were possible. Given that small schooling fish such as Pacific herring, Pacific sardine, and Northern anchovy are primarily harvested using nets, while embiotocids and atherinopsids may be taken through both hook and line or netting, the Coast Miwok people of Point Reyes invested significant time and material resources towards the production of fish nets. In addition, net fishing seems to have contributed the overwhelming majority of the fish analyzed, suggesting significant investment in net fishing over other fish acquisition strategies.

In a broader context, the Native American fishery of California was diverse, and emphasis on site-specific and regional contexts is vital for studying California's ancient fisheries. Where long-term records are available (Boone 2012; Jones et al. 2016), these data suggests that Native people employed a diverse range of technologies and fishing techniques (Boone 2012; Braje et al. 2012; Rick and Erlandson 2000; Rick et al. 2001; Simons 2016; Tushingham et al. 2013, 2016). The California archaeological records suggest a general increase in fishing and continuity in diverse resource use throughout the Holocene. However, specific sites such as CA-MRN-659, CA-MNT-1701 (Boone 2012), CA-MNT-1485/H and CA-MNT-1486/H (Gobalet and Jones 1995; Langenwaller and Bowser 1992) and the Cayuma Valley assemblage, particularly CA-SLO-95 (Gobalet 2014; Mikkelsen et al. 2014) indicate an increase in mass-harvested fish species and transport to inland site locations on the central California coast during the Middle Period, Middle/Late transition, or the Late Period. Lastly, the archaeological findings contrast with contemporary ecological data regarding the status of forage fishes in the California Current Ecosystem, especially Pacific herring. What appears to have once been a sustainable fishery for over 3000 years is now in such decline as to be uneconomical. In developing future protocols for the management of these waters and resources, I believe scientists, tribal nations, and resource managers can gain clearer insights from the historical analysis of the Coast Miwok and from collaboration and discussion with Coast Miwok people, whose cultural practices involved the extensive and continued harvesting of forage fish over many centuries.

## Chapter 3

### Indigenous Stewardship of Marine and Estuarine Fisheries: Reconstructing the Ancient Size of Pacific Herring Through Linear Regression Models

#### Introduction

This chapter is an outgrowth of the recent eco-archaeological study reported in chapter 2, conducted in collaboration with the Federated Indians of Graton Rancheria, which outlined the ancient and historic fisheries of Point Reyes National Seashore, (Fig. 3.1). The study suggests significant differences between ancient clupeid abundances, specifically Pacific herring (*Clupea pallasii*) and Pacific sardine (*Sardinops sagax*) when compared to the contemporary Pacific herring fishery in Point Reyes. The findings suggest a sustainable Coast Miwok Pacific herring fishery may have persisted for nearly 2,500 years. If so, the ancient fishery contrasts significantly with the current state of clupeids within Point Reyes, where evidence suggests the Pacific herring fishery collapsed in 2007 and has not fully recovered (California Department of Fish and Wildlife 2008; Enticknap et al. 2011). The San Francisco Bay Pacific herring population also collapsed during this time frame but is showing signs of recovery. However, the age structure is still highly skewed, with few older herring, while the Tomales Bay population is no longer monitored (California Department of Fish and Wildlife 2008; Enticknap et al. 2011).

As a compliment to these findings, this study is directed toward the creation of regression formulae to establish the ancient size of Pacific herring from the Point Reyes assemblages. I compare the archaeological datasets with Pacific herring fishery data collected by the California Department of Fish and Wildlife within Tomales Bay from 1972-80 (Spratt 1981). These data have relevancy toward understanding the long-term population structure and history of Pacific herring along the Pacific Coast of North America, the documentation of indigenous fishing practices, and the identification of changing technologies used in fishing efforts (Greenspan 1998; Maschner et al. 2008; Orchard 2003). The results of this study also have the potential to highlight selective harvesting of fishes or the identification of ancient and historic human impacts on fauna (Braje et al. 2017; Broughton 1997; Smith 2009, 2011). Through a reconstruction of Pacific herring size, this project can provide reference points relevant for the management of Pacific herring within the California Current and provide critical data to tribal nations concerned with maintaining cultural keystone species in perpetuity.

#### Background

##### *Previous Research on Point Reyes Clupeids*

The archaeology of fisheries of Point Reyes National Seashore was outlined in chapter 2. The study applied low-impact archaeological field methods including the catch and release surface survey, geophysical survey, and the collection of bulk sediment samples through auger and column sampling. Fish remains and other artifactual materials were recovered through flotation. In total, nine sites and 186 liters of sediment were sampled as part of the study. Radiocarbon assays demonstrate that the sites were occupied between 800 and 770 cal BC to cal AD ~1,800.



Figure 3.1. Point Reyes National Seashore and sites examined in the current analysis. Inset map includes an overview of the central California coast.

The faunal analysis of the Point Reyes assemblage resulted in the identification of 9,071 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 8,005 of the total NISP or ~88%. Subsampling of the 1-2 mm mesh size class suggests that the 1-2 mm assemblage includes elasmobranchs, clupeids, atherinopsids, Northern anchovies, osmerids, embiotocids, flatfishes (*Pleuronectiformes*), and rockfishes (*Sebastes* sp.).

I interpreted the fish remains from these sites as indicative of people directing their fishing efforts within bays and estuaries at sites CA-MRN-222, CA-MRN-224, CA-MRN-249, and CA-MRN-258, (Fig. 3.1), where they could access small- and medium-sized schooling fishes. Native people at these sites emphasized mass-capture of forage fishes, which play a crucial role in nutrient transfer in marine ecosystems, (Fig. 3.2). By cal AD ~700, fishing efforts focused almost entirely on Pacific herring, Pacific sardine, atherinopsids, and Northern

anchovies with these fishes being transported at least 13 km inland to site CA-MRN-659. The fish remains recovered from the study offer an exceptional opportunity to establish the size of ancient Pacific herring captured along the shorelines of Point Reyes through regression analyses of diagnostic skeletal elements.

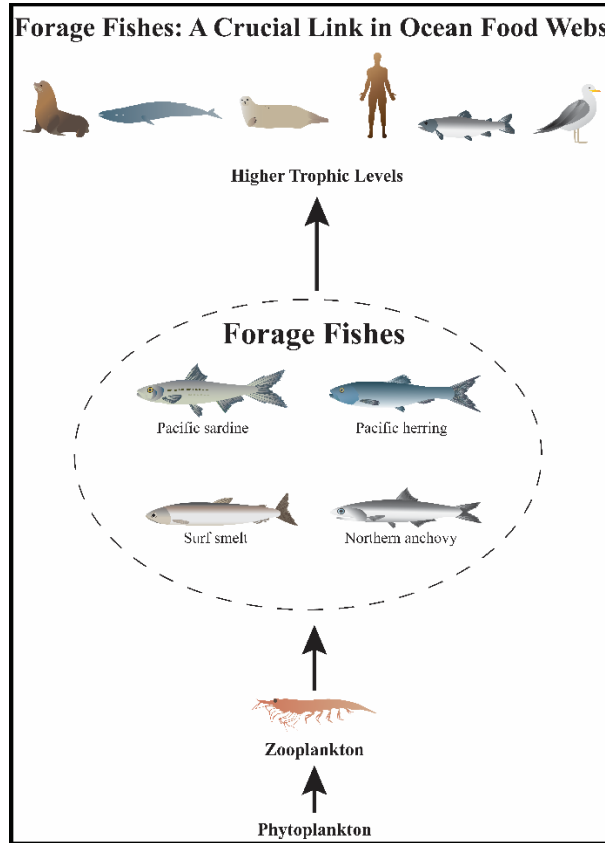


Figure 3.2. Forage fish provide critical ecosystem services by transferring energy from primary and secondary producers to higher trophic levels.

### *Morphometrics, Linear Regression, and Allometric Formulae*

The application of regression analysis has been used widely to characterize the relationship between the size of bone elements and the live size and weight of mammals, birds, fishes, and shellfish (Campbell 2015; Campbell and Braje 2015; Casteel 1974, 1976; McKechnie et al. 2015; Nims and Butler 2019; Orchard 2003; Reitz et al. 1987; Singh and McKechnie 2015; Wolverson 2008; Wolverson et al. 2007). The use of regression analysis in zooarchaeological case studies is possible given proportional changes in skeletal elements of an organism as the size of that organism increases, known as allometric scaling (Reitz et al. 1987).

As noted by Reitz et al. (1987), the creation and use of allometric formulae to reconstruct the size of specimens recovered in archaeological assemblages places size, weight, and dietary reconstruction studies on a firmer biological foundation. In addition, these studies offer the potential to reconstruct the size range of organisms more accurately. The creation and application of allometric formulae allow analysts to use the estimated body size of animals to reconstruct the location, technology, and season of capture of prey (Reitz et al. 1987). To reconstruct the ancient and historic size of fauna, researchers create linear regression formulae through statistical measures correlating a relationship between specific measurements taken from modern skeletal

elements to the length or weight of the organism (Casteel 1974; Morales and Rosenlund 1979, Anon 2011). Through the creation of these formulae, researchers may predict the length or weight of archaeological specimens.

This project uses linear regression analyses to create formulae for specific clupeid vertebrae. These elements include the atlas and axis. As shown by Gobalet et al. (2004) the atlas, axis, and third vertebrae of Pacific herring and Pacific sardine are diagnostic; therefore, differentiating these organisms by these elements is possible. In contrast, the abdominal vertebrae encountered archaeologically are identifiable only to the family, Clupeidae with no diagnostic landmarks available to differentiate Pacific herring from Pacific sardine. Consequently, I exclude Pacific herring abdominal vertebrae and the formulae derived from them in this study.

### *Forage Fishes and Aquatic Ecosystems*

Forage fishes such as Pacific herring and Pacific sardine are critical components of aquatic ecosystems and food webs (Hill et al. 2017; Takahashi and Checkley 2008; Watters and Mello 2001). They are used as forage at each stage of their life history, from egg to adults, feeding large numbers of invertebrates, fishes, birds, mammals, and humans (Enticknap et al. 2011; Pikitch et al. 2012). A large body of literature highlights the role that forage fish play in maintaining functioning marine and estuarine ecosystems (Enticknap et al. 2011; Froehlich et al. 2018; McClatchie et al. 2018; Pikitch et al. 2012; Szuwalski et al. 2019). Forage fish provide critical ecosystem services by transferring energy from primary or secondary producers—plankton and zooplankton—to higher trophic levels. Therefore, reductions in the abundances of forage fishes beyond historical variations—which archaeology may help define—risk modifying and adversely affecting aquatic food webs (Moss et al. 2016, 2017; Thornton et al. 2010; Thornton 2015).

Beyond the value of forage fishes for ecosystem functions, these fishes are critical components of local, regional, and global economies. Archaeological evidence across the Pacific Coast of North America highlight the critical role forage fishes play in indigenous economies and foodways (Cannon 2000; McKechnie et al. 2014; Moss 2016; Moss et al. 2017; Sanchez et al. 2018; Tushingham et al. 2013, 2016). Today, these fishes are processed into fish meal and oil used in aquaculture, agriculture, and for human consumption (Enticknap et al. 2011; Pikitch et al. 2012). Given the ecological, nutritional, and economic benefits of forage fishes, maintaining sustainable forage fish populations is vital to supporting functioning aquatic ecosystems, local and global economies, and indigenous subsistence fishing.

### *The History of Pacific Herring Use in California*

The Pacific herring ranges from Baja California to Alaska and across the North Pacific to Korea and Japan (Love 2011; Spratt 1981; Watters and Mello 2001). Prior to the contact era, Pacific herring were an important part of the economies and diets of Native Californians (Love 2011; Sanchez et al. 2018). Following European contact but before 1972, the commercial Pacific herring fishery in California was insignificant in its economic impact, especially when compared to the Pacific sardine fishery (Spratt 1981, 1992). In 1965 a California fishery focused on Pacific herring roe deposited on seaweed commenced. The roe on seaweed fishery supported the Japanese market demand for this product following the collapse of the Japanese Pacific herring fishery (Spratt 1981, 1992). The Japanese Pacific herring fishery persisted from 1447 to the 1950s when the stock declined significantly and was no longer able to support the Japanese

fishing industry (Love 2011; Morita 1985; Nagasawa 2001; Spratt 1981; Sugaya et al. 2008; Watters and Mello 2001).

In 1972-73 the California Department of Fish and Wildlife (CDFW) commenced an annual sampling program to evaluate the herring resource to assess the landings for age, size, sex, and maturity data (Spratt 1981). The commencement of the California Pacific herring sac roe fishery is tied to a decision by the Japanese government to begin importing Pacific herring roe in addition to the roe on seaweed imports (Love 2011; Spratt 1981, 1992; Watters and Mello 2001). Thus, historically and today the California Pacific herring fishery is primarily driven by Japanese markets.

### *A Historical Perspective on Pacific Herring Fishing Technologies*

Historical data of Native American fishing practices are available in Kelly (1991) through her interviews with two Coast Miwok elders, Tom Smith and Maria Copa Frias, in 1931 and 1932. Both Smith and Frias discussed Coast Miwok fishing techniques and technologies with Kelly, that include the use of dip nets, spears, fish hooks, watercraft, seine nets, and poisons.

According to Smith and Frias, dip nets were used in taking ‘smelt’ from shore (Kelly 1991). Seine nets are mentioned for bay fishing and appear to have been used in the pursuit of herring and surfperches, but could have been used in the pursuit of a diverse range of fishes (Kelly 1991). According to the ethnographic notes, seine fishing was a boat-based activity, although seines could have been used near the shore without boats (Kelly 1991).

Spratt (1981) outlines the gear used in the pursuit of Pacific herring within California and Tomales Bay by modern fishers. According to Spratt (1981), lamparas were introduced in Tomales Bay in 1972. The lampara is a round haul net that is set in a circle around a school of fish, which are forced into a bag by retrieving both ends of the net.

The year 1974 marked the introduction of purse seines to the Pacific herring fishery (Spratt 1981). Gill nets and beach seines were used throughout the years, but gill nets became an important gear type in the 1975–76 season once they were legally permitted (Spratt 1981). Following the approval to use gill nets the Pacific herring sac roe fishery shifted from a round haul net dominated fishery to a gill net fishery (Spratt 1981). In the 1977–78 season round haul nets were prohibited in all areas except San Francisco Bay (Spratt 1981). The shift was driven by buyer’s preference for larger fish and a higher percentage of females taken offering the potential to harvest more roe. These changes in fishing technologies offered the prospect of higher roe returns given the older age classes and larger size of fishes caught (Spratt 1981).

### *Fishing Gear Selectivity*

Research regarding the efficiency and selectivity of different fishing technologies and gear types offer insights into how different technologies structure fish catch (An et al. 2013; Colley 1987; Greenspan 1998; Ingólfsson et al. 2017; Poulsen et al. 2000). The selectivity of fishing gear is an important research topic as fishing with selective gear types is commonly used as a management protocol to promote sustainable commercial fisheries (O’Neill et al. 2019; McClanahan and Mangi 2004). In this discussion, I consider gill nets, seine nets, and hook and line fishing.

Gill nets are considered one of the most selective fishing gear types affecting fish size since they catch fish by entangling them at the gills as fish try to swim through the net mesh (Colley 1987; Greenspan 1998). Fish larger in size than the gill net mesh are not caught. Fish smaller than the mesh can swim through without being entangled. Given the selectivity of gill

nets, a net of a specific mesh size will tend to be most efficient at catching fish within a particular size range (Poulsen et al. 2000). Therefore, a gill net constructed with a uniform gauge mesh will capture fish in a reasonably limited size range.

While fishing nets do not commonly preserve in coastal California archaeological sites, bone net mesh gauges occasionally do (Beardsley 1954; Rick and Erlandson 2000; Rick et al. 2001). Thus, it may be possible to understand past fish net mesh size in instances where the physical remains of nets are not recovered, but net mesh gauges are (Walker 2000). Net mesh gauges vary by length but have a specified width, which is used to maintain a consistent size of the net mesh (Walker 2000). The width of the net mesh gauge correlates to the length of one side of the mesh. This measurement doubled equals the net mesh opening, which relates to the size of the fish captured (Walker 2000). Given this correlation between net mesh gauge width and net mesh size, these gauges provide a critical dataset for exploring ancient selective fishing practices. Walker (2000) highlights this relationship through her research of coastal Florida fishers: in measuring the widths of artifactual net mesh gauges, she shows that this information can provide an indirect but accurate indication of netting technology and net-fishing strategies.

In contrast to gill nets, seine and dip nets are less selective regarding fish size. When fish are captured in seines those smaller than the mesh size can swim out while fish larger than the mesh are retained (Colley 1987; Greenspan 1998). Research has shown that seine nets will tend to catch fishes of smaller body sizes than gill nets (McClanahan and Mangi 2004). Seines will also catch the highest number of species or bycatch depending on where the fishing effort is occurring (McClanahan and Mangi 2004).

Hook and line fishing is not as size selective as gill nets, but more selective than seines as the fish captured depend on multiple variables such as size of the hook, shape, and size of bait, feeding behavior of fishes, and other factors (Colley 1987; Greenspan 1998; Ingólfsson et al. 2017). Taking all these issues into consideration hook and line fishing may result in the attraction and selection of a low diversity of high trophic level predators (McClanahan and Mangi 2004).

### *Pacific Herring Age and Size Data*

Pacific herring are aged in contemporary fisheries survey studies through the use of scales and otoliths. California herring may live to be nine or 10 years old and reach a standard length (SL) of about 280 mm (Spratt 1981, 1992). However, individuals older than seven are rare (Watters and Mello 2001). Research by Spratt (1981) sampled and analyzed Pacific herring for age and size determinations from the Tomales Bay and San Francisco Bay spawning grounds and the summer herring fishery of Monterey Bay. Spratt (1981) sampled herring and recorded their SL—measured from the tip of the snout to the end of the body near the caudal peduncle—in mm with age determinations derived from herring otoliths. At the time Spratt (1981) published his findings he classified the SL fish size measurement as body length instead of using the now standardized classification. However, I report SL in this study to be consistent with modern fisheries reporting.

Pacific herring reach sexual maturity at age two when they are roughly 177 mm SL while all are sexually mature at age three (Spratt 1981; Watters and Mello 2001). Pacific herring within California spawn in a relatively short season. Although spawning may occur from November to April, the bulk of the spawn takes place from December through March, but peaks in January and February (Spratt 1981, 1992; Watters and Mello 2001).

According to the research by Spratt (1981) during January and February spawns, two-year-old herring average 162 mm SL. During the same period immature or one-year-old herring

in Monterey Bay average 113 mm in SL (Spratt 1981). These young-of-the-year herring first appear mixed with Northern anchovy catches when they are ~90 mm SL (Spratt 1981). Capture by the round haul or lampara fishery begins when the individuals are age two and is complete by age three (Spratt 1981). In 1977-78 Pacific herring fishing in Tomales Bay was restricted to the use of gill nets. The selection of herring by the gill net fishery begins at age four and is complete at age five or six, depending on the size of the individuals (Spratt 1981), (Fig. 3.3). In the late 1970s and 1980s, five to seven-year-old herring dominated the gill net catch (Spratt 1981). The change in age composition and size of individuals after the 1976–77 season is indicative that the gill net fishery is size selective and not representative of the total Pacific herring population age structure (Spratt 1981), (Fig. 3.3).

Historically, the size of individual fish within the Tomales Bay round haul catch ranged from 140 to 248 mm SL (Spratt 1981). The average SL of Pacific herring taken by gear types has fluctuated from season to season, but generally, Tomales Bay Pacific herring individuals are larger than those of San Francisco Bay. Researchers have suggested genetic differences may be responsible for the large size of Tomales Bay herring, but these hypotheses have yet to be confirmed (Spratt 1981, 1992). The gill net catch increased in the 1976–77 season, and data collected from the gill net fishery during the 1976–77 to 1979–80 seasons indicate herring typically ranged in size from 194 to 248 mm SL, (Fig. 3.3). It is clear from the data presented by Spratt (1981) that gill nets were selective toward large individual herring.

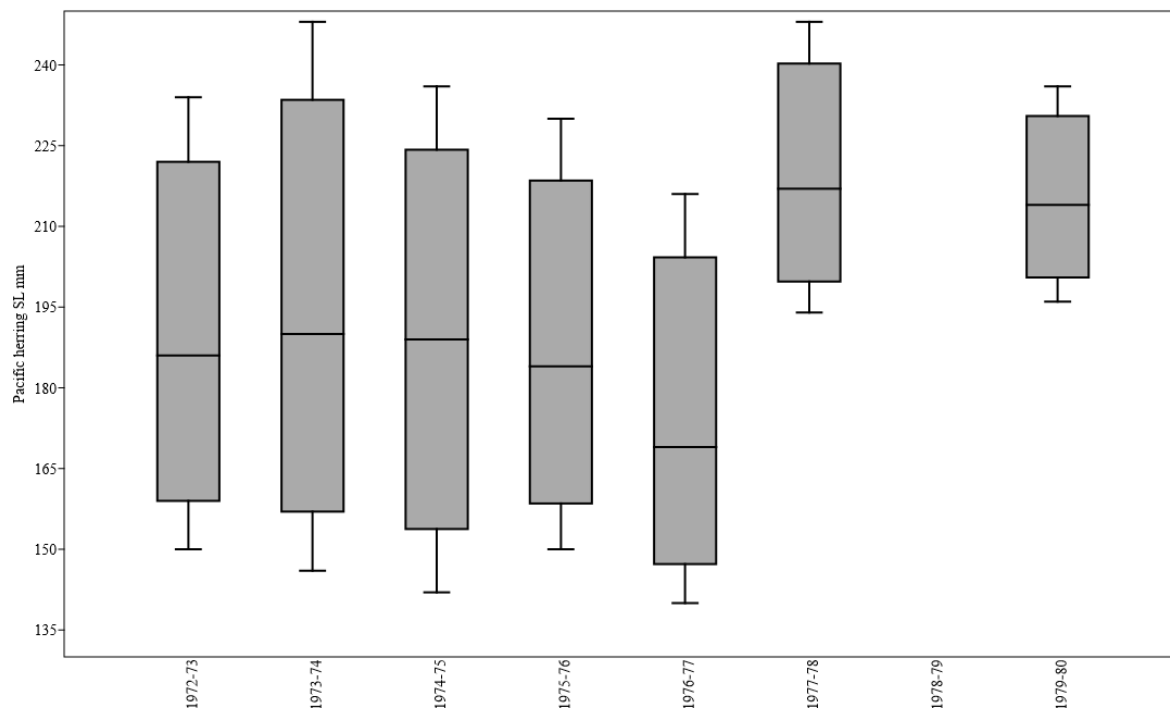


Figure 3.3. California Department of Fish and Wildlife Pacific herring fishery data from Tomales Bay 1972-80, adapted from Spratt (1981).

#### *Anthropological Theories Regarding Human-Environmental Relationships*

The archaeological record offers an opportunity to investigate long-term human-environmental and human-fish relationships in a diachronic framework. Ecological approaches

in anthropology are uniquely situated to investigate human-environmental relationships, especially historical ecology and human behavioral ecology. Historical ecology posits four expectations regarding human-environmental relationships: 1) humans have impacted Earth's habitable environments in physical ways; 2) societies impact environments in distinctive ways; 3) human nature is indifferent to species diversity; 4) human activity does not necessarily lead to environmental degradation nor does it inevitably increase biodiversity or species abundance (Balée 1998, 2018). In addition, the theoretical framework of historical ecology emphasizes that the environments with which humans interact are continually changing and that the maintenance of diversity—both natural and cultural—should be promoted through activist research programs of resource and landscape conservation, maintenance, and enhancement (Balée 2018).

The ecological literature provides a source of information that can be used to set expectations for indigenous fishing methods. Fisheries produce selective pressures through elevated mortality and harvests, they can also generate ecosystem-level responses, as overexploitation and stock depletions reduce food availability which can lead to trophic cascades within ecosystems (Heino and God 2002; Jackson et al. 2001; Jackson 2008; Scheffer et al. 2005; Palkovacs 2011). Fishing can be selective with respect to size, shape, behavior, and habitat and removes individuals of both target and nontarget species (Heino and God 2002). Most fishing gears are selective such as hook and line, spear, and gill net fishing while others are considered to be nonselective such as seine nets (Heino and God 2002). Overfishing and depletion of stocks through either method of capture can significantly alter ecosystem functioning and the composition and the genetic structure of stocks (Pauly et al. 1998; Palkovacs 2011). Therefore, in ecosystems with high fishing pressure, a decrease in the proportion of older and larger individuals through time could lead to resource depressions or fish population truncation (Pauly et al. 1998). However, changes in the size of fishes within stocks can also be correlated with changes in environmental factors such as water temperature and food availability (Heino and God 2002; Ware and Thomson 2005).

As noted by Sadovy (2001) short-lived fishes, such as Pacific herring, combine early sexual maturation and high rates of intrinsic population growth, which make them theoretically more resilient to overfishing. Regardless, a reduction in the quantity of fishes can have an impact on the number of viable offspring produced due to the positive relationship between maternal age, relative fecundity and egg viability affecting local and global food webs (Pauly et al. 1998; Pauly and Palomares 2005; Pauly and Zeller 2016; Sadovy 2001; Wright and Trippel 2009).

Another ecological and evolutionary approach to archaeological analyses arises from evolutionary ecology, human behavioral ecology, and optimal foraging theory (OFT) models (Bettinger 1991, 2015; Bird and O'Connell 2006, 2012; Broughton and O'Connell 1999; Cronk 1991; Winterhalder and Smith 2000). OFT maintains that human decisions related to diet, foraging location, foraging time, and other variables are made to maximize the net rate of energy gain (Bettinger 1991, 2015). The OFT approach through the lens of the diet breadth model suggests that human foragers encounter a range of resources that vary with respect to their abundance, energy gained per item, and energy and time expended in acquiring the resource (Bettinger 1991, 2015; Broughton 1994a). In essence, the models attempt to account for the amount of energy gained and spent in foraging to model human decision making through the quantification of return rates.

The general expectation in OFT models and the diet breadth model is that high-return resources will be selected for over lower return or low-ranked items (Bettinger 1991, 2015). Research suggests high-ranked resources generally correlate with body size (Bayham 1979;

Broughton 1994a, 1994b; Broughton et al. 2015). While the models recognize the potential for individual and cultural food preferences and other factors, according to the theory, the resource item is either optimal in terms of net gain, or it is not (Bettinger 1991, 2015). An uncomplicated outlook of these models would infer that the use of a low-ranked resource implies that all high-ranked resources were unavailable, likely due to resource depression or extirpation (Bettinger 1991, 2015).

Two complicating factor within these models noted by Bettinger (1991) and Madsen and Schmitt (1998), and others, are resource items that are seasonally abundant and offer the opportunity for mass collection and changes in technology such as the use of nets in mass collecting (Bettinger et al. 2006; Ugan et al. 2003; Ugan 2005). As highlighted by Madsen and Schmitt (1998) when an abundance of lower-ranked resources increase, such as schools of forage fishes, so does ranking as they become high-ranked prey through mass capture leading to a more efficient, overall return rate (Broughton 1994b). Therefore, an individual small-bodied animal can be considered a low-ranked resource but may become high-ranked when large schools form and when mass capture technologies are available. In addition, consideration of the nutritional gains of forage fish meat, roe, and oil such as those of Pacific herring have shown to be higher than other high-ranked resources like salmon (Moss 2016). Consequently, although Pacific herring are small-sized fish, their nutritional ecology suggests Native people may have targeted large schools due to their abundance, availability, and the opportunity to collect a high-calorie fish.

#### *Eco-archaeological Expectations of Fishing*

Based on the human behavioral ecology literature, if Native people were acting optimally to maximize net gains in their fisheries and subsistence practices, we could expect that people would be focusing on the highest net return gain for their efforts. These decisions might involve the harvest of large-bodied fishes with the highest return rates. Also, net-based fishing efforts may have focused on the indiscriminate harvesting of the full spectrum of the fish population age and size structure or only on the largest sized fishes without concern for long-term goals or the conservation of sustainable fisheries.

Based on the ecological literature if Native people were stewarding a resource, such as Pacific herring, we could expect to see the limited take of adult-sized individuals and juveniles to allow the fish population to reproduce and develop. 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).

### **Methods, Materials, and Results**

#### *Pacific Herring Linear Regression*

In order to reconstruct the SL of Pacific herring through time, I created linear regression models relating SL to the maximum width of the atlas and axis. As previously noted, I use the atlas and axis vertebrae in this study as Gobalet et al. (2004) demonstrate the use of these elements to discriminate between Pacific herring and Pacific sardine, the two clupeids within the project area. While abdominal and individual caudal vertebrae of clupeids are most commonly recovered archaeologically, these elements are only identifiable to the family with no diagnostic landmarks available to differentiate Pacific herring or Pacific sardine, except for the penultimate and antepenultimate vertebrae (Gobalet et al. 2004).

I gathered morphometric data from 32 modern Pacific herring specimens in museum collections housed at the Ichthyology Collection, California Academy of Sciences, San Francisco, California and comparative materials housed in the Department of Anthropology, University of California, Berkeley. The Pacific herring measured in this study were collected from Monterey Bay, California to Hariat Bay, British Columbia. The minimum and maximum SL in the sample range from 94 mm to 188 mm, (Table 3.1). I took three measurements of the atlas of every specimen to understand error rates of measurements through standard deviations (SD) and one measurement of the axis, (Table 3.1).

Table 3.1. Standard length and atlas and axis maximum width measurements of Pacific herring used in linear regression models.

| <b>Catalog #</b> | <b>SL (mm)</b> | <b>Atlas Average mm</b> | <b>Atlas SD mm</b> | <b>Axis mm</b> |
|------------------|----------------|-------------------------|--------------------|----------------|
| CAS: 66535       | 170.00         | 2.77                    | 0.01               | 2.77           |
| CAS: 65987       | 122.00         | 2.01                    | 0.01               | 1.85           |
| KG: 00001        | 188.00         | 3.35                    | 0.03               | 2.96           |
| KG: 00002        | 182.00         | 3.29                    | 0.02               | 3.05           |
| KG: 00005        | 108.00         | 1.79                    | 0.01               | 1.69           |
| KG: 00006        | 103.00         | 1.97                    | 0.01               | 1.81           |
| KG: 00007        | 94.00          | 1.53                    | 0.00               | 1.40           |
| KG: 00008        | 105.00         | 1.78                    | 0.01               | 1.70           |
| AG:00001         | 175.00         | 3.13                    | 0.01               | 0.00           |
| AG:00002         | 170.00         | 2.93                    | 0.03               | 2.77           |
| AG:00003         | 155.00         | 2.37                    | 0.01               | 2.30           |
| AG:00004         | 155.00         | 2.81                    | 0.01               | 2.78           |
| AG:00005         | 164.00         | 2.66                    | 0.04               | 2.60           |
| GS:00005         | 153.75         | 2.68                    | 0.03               | 2.59           |
| GS: 00007        | 175.00         | 3.01                    | 0.01               | 2.88           |
| GS: 00008        | 165.00         | 2.94                    | 0.01               | 2.57           |
| GS: 00009        | 165.00         | 2.79                    | 0.00               | 2.64           |
| GS:00010         | 140.85         | 2.35                    | 0.01               | 2.29           |
| GS:00011         | 141.75         | 2.82                    | 0.01               | 2.59           |
| GS:00012         | 150.20         | 2.72                    | 0.01               | 2.64           |
| GS:00019         | 147.00         | 2.35                    | 0.04               | 2.23           |
| GS:00020         | 149.00         | 2.63                    | 0.03               | 2.35           |
| GS:00021         | 157.00         | 2.49                    | 0.02               | 2.45           |
| GS: 00031        | 185.00         | 2.96                    | 0.03               | 2.82           |
| GS:00032         | 166.00         | 2.66                    | 0.04               | 2.47           |
| GS: 00033        | 184.00         | 3.11                    | 0.01               | 2.79           |

|           |        |      |      |      |
|-----------|--------|------|------|------|
| GS:00034  | 165.00 | 2.65 | 0.01 | 2.42 |
| GS: 00035 | 127.00 | 2.04 | 0.02 | 1.96 |
| GS: 00036 | 167.00 | 2.67 | 0.03 | 2.55 |
| GS: 00037 | 165.00 | 2.71 | 0.01 | 2.71 |
| GS: 00038 | 130.00 | 2.14 | 0.01 | 2.05 |
| GS: 00039 | 127.00 | 2.01 | 0.01 | 1.91 |

Note: CAS = California Academy of Sciences; KG = Kenneth Gobalet Collection; AG = Ariadna Gonzalez Collection; and GS = Gabriel Sanchez Collection.

Following protocols outlined by Casteel (1974), I gathered maximum width measurements from the atlas and axis of Pacific herring. Specimens were measured using calibrated Mitutoyo CD-6" ASX digital calipers (accurate to 0.01 mm), and data were compiled in Microsoft Excel. Linear regression models were created in R version 3.5.0 comparing the SL of Pacific herring to the maximum width of the atlas and axis, (Fig. 3.4 and 3.5). The two models show statistically significant ( $p < 0.05$ ) and significant ( $R^2$  values) relationships between SL and maximum vertebral centrum dimensions, (Table 3.2). The linear regression models resulted in the creation of formulae for Pacific herring atlas and axis, (Table 3.3).

Table 3.2. Summary of linear regression models calculated for Pacific herring standard length estimation.

| Dependent variable | Independent variable | Coefficient | Intercept | df    | F     | p value | $R^2$ |
|--------------------|----------------------|-------------|-----------|-------|-------|---------|-------|
| Standard length    | Atlas Width          | 52.29       | 17.45     | 1, 30 | 240.9 | <0.001  | 0.89  |
| Standard length    | Axis Width           | 57.13       | 13.39     | 1, 29 | 242.9 | <0.001  | 0.89  |

Table 3.3. Formulae for Pacific herring standard length estimation.

| Element | Formulae               |
|---------|------------------------|
| Atlas   | $y = 17.45 + 52.29(x)$ |
| Axis    | $y = 13.39 + 57.13(x)$ |

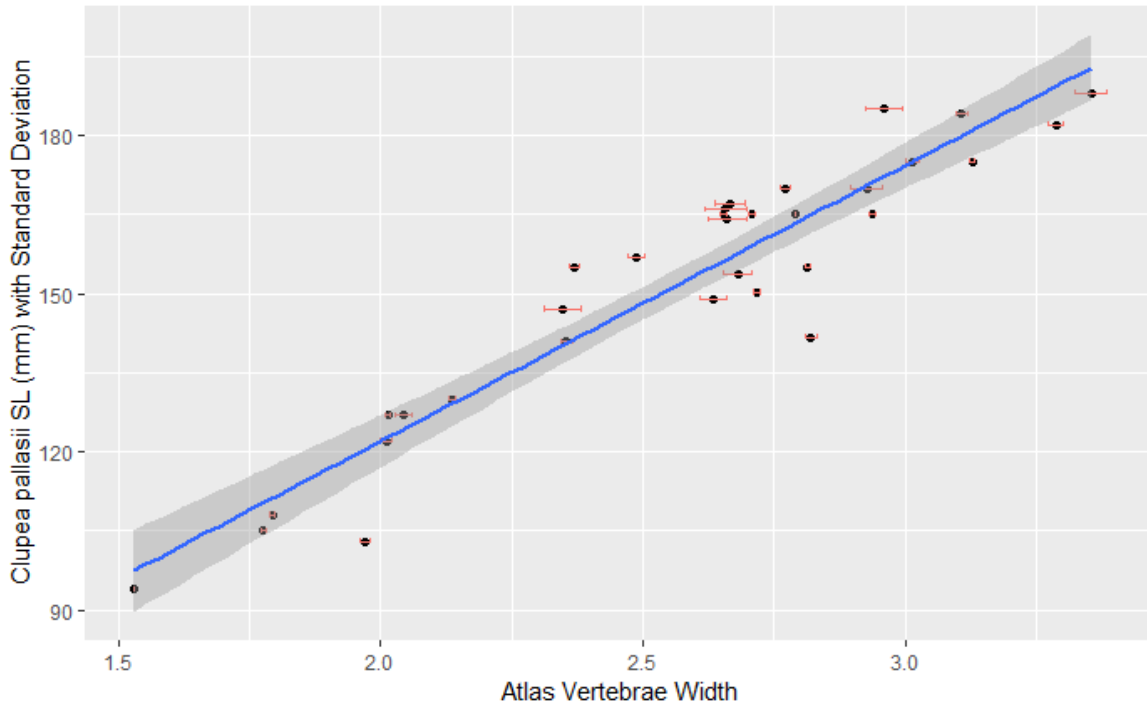


Figure 3.4. Regression plot of Pacific herring atlas vertebral width and standard length, confidence interval of 0.95.

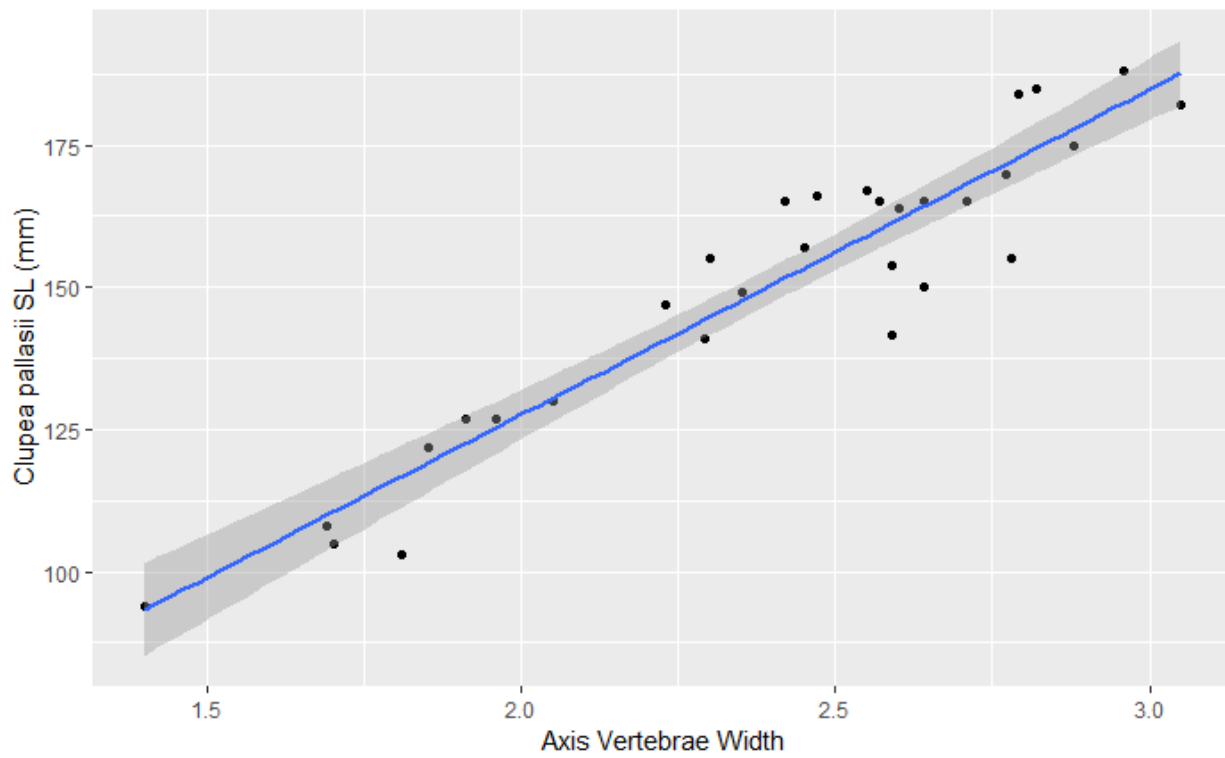


Figure 3.5 Regression plot of Pacific herring axis vertebral width and standard length, confidence interval of 0.95.

*Archaeological Point Reyes Pacific Herring Materials*

The Pacific herring remains used in this study were previously reported in chapter 2. These fish remains were recovered from bulk sediment samples derived from auger samples from nine sites and one opportunistic column sample taken from CA-MRN-224. Sixty-four flotation samples totaling 186 liters in volume were analyzed in this study. Samples were processed using a modified SMAP-type tank (Pearsall 2000) with 1 mm heavy fraction mesh. After drying the heavy fraction materials, samples were sieved at the California Archaeology Laboratory, University of California, Berkeley, into the following size fractions through nested geologic sieves: >4 mm, 2–4 mm, and 1–2 mm. Heavy fraction materials were separated into artifact classes, and all archaeofaunal remains were sorted based on size classes. Archaeofaunas were further sorted if they could be identified as fishes, mammals, or birds in the >4 mm and 2–4 mm size fractions.

The recovered fish remains were identified using comparative skeletons from the Department of Ichthyology, California Academy of Sciences, San Francisco, supplemented by additional materials in the Museum of Paleontology, University of California, Berkeley. Laboratory protocols and faunal identifications were conservative in examining cranial and post-cranial elements (Driver 2011; Gobalet 2001). Sanchez and zoologist Kenneth Gobalet completed the faunal analysis, and Gobalet confirmed or revised Sanchez's identifications. A dissecting stereomicroscope was used to discern diagnostic features that allowed designation to the most exclusive taxon, usually a family. Identification protocols for clupeid atlas and axis vertebrae follow Gobalet et al. (2004), and I follow Page et al. (2013) for scientific and common names.

Following the creation of the linear regression formulae, I measured the atlas and axis of archaeological Pacific herring from four sites within Point Reyes National Seashore—CA-MRN-222, CA-MRN-224, CA-MRN-249, and CA-MRN-AL1—due to the larger sample sizes of Pacific herring at these sites. I exclude CA-MRN-277, CA-MRN-287, CA-MRN-349, and CA-MRN-659 due to the low clupeid counts at each site (<500 NISP), (Table 3.4). The atlas and axis measurements from the archaeological data were input to the formulae and analyzed in Paleontological Statistics (PAST) software version 3.22 (Hammer et al. 2001).

Table 3.4. Point Reyes clupeid NISP and Pacific herring NISP by archaeological site.

| Site                       | Clupeid NISP | Pacific herring NISP |
|----------------------------|--------------|----------------------|
| <i>CA-MRN-224 (Auger)</i>  | 3165         | 195                  |
| <i>CA-MRN-224 (Column)</i> | 817          | 58                   |
| <i>CA-MRN-222</i>          | 2011         | 114                  |
| <i>CA-MRN-249</i>          | 587          | 62                   |
| <i>CA-MRN-AL1</i>          | 554          | 24                   |
| <i>CA-MRN-277</i>          | 22           | 1                    |
| <i>CA-MRN-258</i>          | 173          | 8                    |
| <i>CA-MRN-659</i>          | 89           | 3                    |
| <i>CA-MRN-379</i>          | 0            | 0                    |
| <i>CA-MRN-287</i>          | 13           | 1                    |
| <i>Total</i>               | <b>7,431</b> | <b>466</b>           |

*Results of Linear Regression Analyses*

The results of the linear regression analyses based on the archaeological atlases suggest that the mean size of Pacific herring from the four sites sampled in this study range from ~174 to ~178 mm SL, (Table 3.5 and Fig. 3.6). In total 127 Pacific herring atlases were measured. Fifteen atlases from the sites sampled were either too fragmented or too deformed to take measurements. The minimum SL of the Pacific herring within the samples span from ~140 to ~163 mm. The maximum SL range from ~202 to ~225 mm.

Table 3.5. Point Reyes Pacific herring SL (mm) estimated from archaeological atlas vertebral measurements.

| Site       | Min   | Mean  | Max   | NISP/MNI | Excluded |
|------------|-------|-------|-------|----------|----------|
| CA-MRN-224 | 139.8 | 177.6 | 225   | 59       | 7        |
| CA-MRN-222 | 148.7 | 174.8 | 202   | 45       | 6        |
| CA-MRN-249 | 157.4 | 176   | 220.8 | 13       | 1        |
| CA-MRN-AL1 | 163.3 | 176.2 | 208.3 | 10       | 1        |

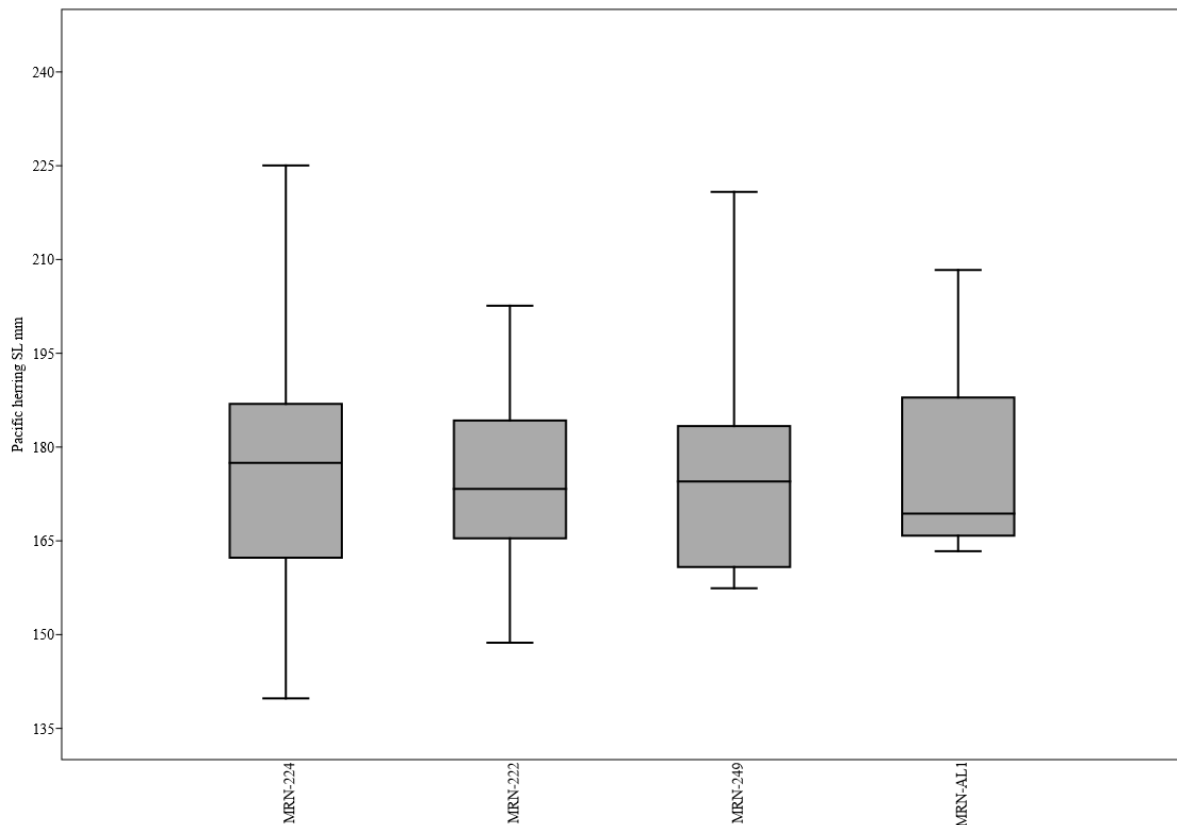


Figure 3.6. Point Reyes Pacific herring SL (mm) based on archaeological atlas vertebral measurements.

The size of Pacific herring based on the axis measurements suggests the mean size of Pacific herring at the four sites ranged from ~173 to ~185 mm SL, (Table 3.6 and Fig. 3.7). In

total 72 Pacific herring axes were measured. Fifteen axes were unmeasurable. The minimum SL of the Pacific herring within the samples span from ~143 to ~158 mm. The maximum SL range from ~196 to ~225 mm.

Table 3.6. Point Reyes Pacific herring SL (mm) estimated from archaeological axis vertebral measurements.

| Site       | Min   | Mean  | Max   | NISP/MNI | Excluded |
|------------|-------|-------|-------|----------|----------|
| CA-MRN-224 | 143.6 | 176.2 | 217.3 | 32       | 6        |
| CA-MRN-222 | 158.2 | 184.7 | 224.2 | 22       | 7        |
| CA-MRN-249 | 157.4 | 176   | 220   | 13       | 1        |
| CA-MRN-AL1 | 145.3 | 172.8 | 196.2 | 5        | 1        |

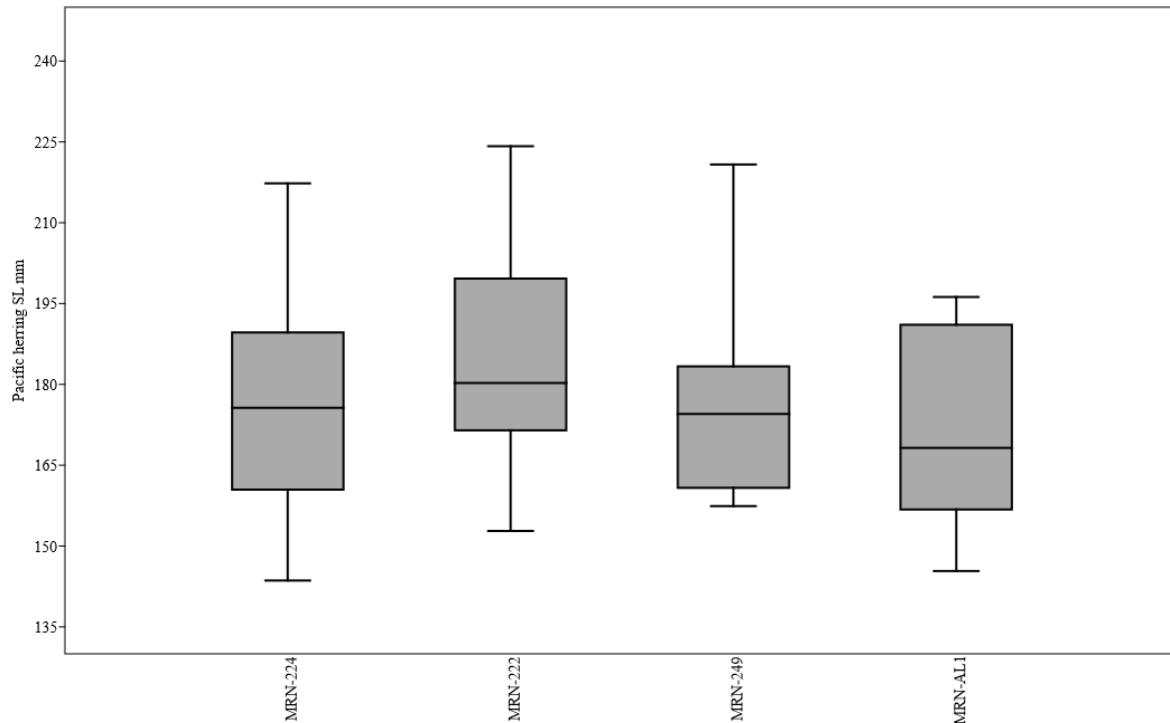


Figure 3.7. Point Reyes Pacific herring SL mm based on archaeological axis vertebral measurements.

As the sample sizes for the Pacific herring atlases and axes vary between sites and due to the potential that atlases and axes may be better preserved or represented at specific sites based on preferential survivorship of elements, I compared the mean SL estimates calculated from the atlas to those of the axis. I 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 I merged the Pacific herring atlas and axis data, (Fig. 3.8). These data illustrate that at the four sites sampled Coast Miwok peoples were consistently harvesting similar size classes of Pacific herring with insignificant variation.

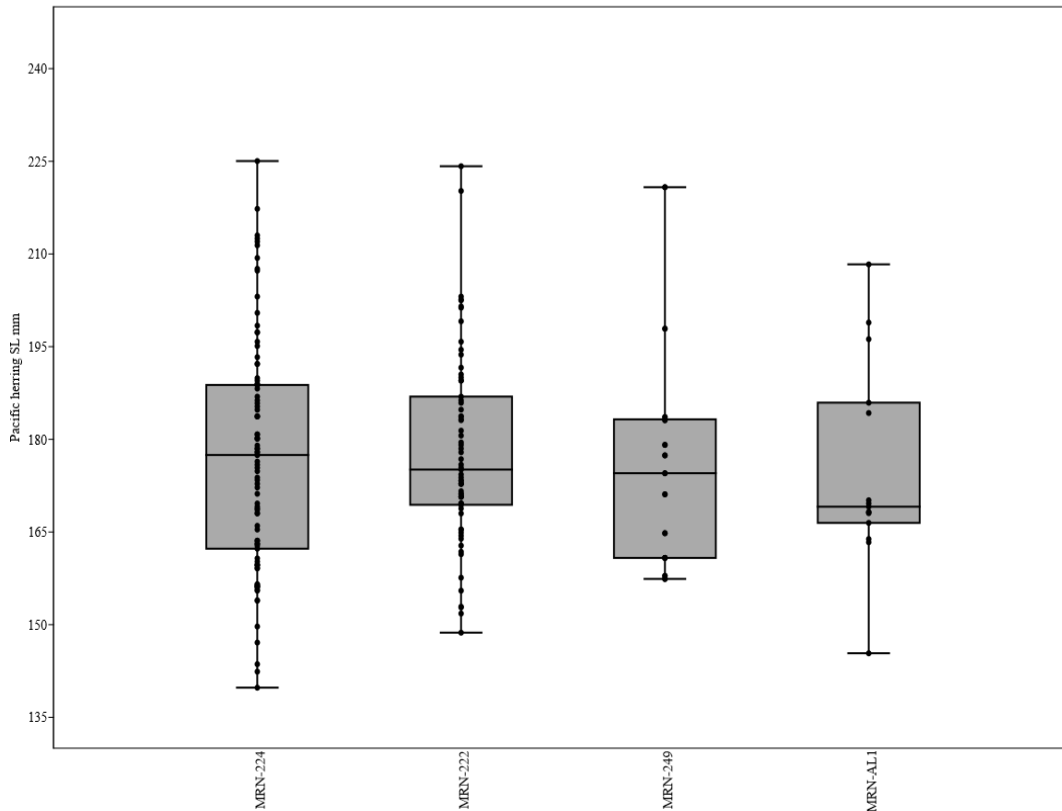


Figure 3.8. Box and jitter plot of Point Reyes Pacific herring SL mm based on the atlas and axis data.

### Discussion and Conclusion

Previously reported radiocarbon assays described in chapter 2, (Appendix A), for the Point Reyes assemblage demonstrate that the sites sampled span from 800 and 770 cal BC to cal AD ~1,800. However, the four sites included in the Pacific herring research reported here are much more constrained and recent, dating from cal AD 760 to ~1,800, (Table 3.7). These data demonstrate the Point Reyes Pacific herring fishery was in place by at least cal AD 760, if not earlier, and that the Coast Miwok Pacific herring fishery persisted until the contact era. However, the Pacific herring fishery for these four sites are not all contemporaneous. CA-MRN-224 provides the initial radiocarbon dates available for intensive Pacific herring fishing within Point Reyes dating to cal AD 760. CA-MRN-222 is inhabited after CA-MRN-224 ~300 years later at cal AD 1,030. CA-MRN-AL1 follows CA-MRN-222 after another ~300 years dating to cal AD 1,300. Lastly, CA-MRN-249 dates ~150 years following the earliest dates available for CA-MRN-AL1 dating to cal AD 1,450. Thus, these sites offer an excellent opportunity to trace human-fish relationships diachronically and to identify a reduction in the size of Pacific herring through time.

Table 3.7. Radiocarbon dates for the Point Reyes sites previously reported by Sanchez et al. (2018).

| Site       | cal AD (95.4% CI) |
|------------|-------------------|
| CA-MRN-224 | 760 to 1,800      |
| CA-MRN-222 | 1,030 to 1,800    |
| CA-MRN-249 | 1,450 to 1,800    |
| CA-MRN-AL1 | 1,300 to 1,640    |

The mean size of Pacific herring from the four Point Reyes 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, (Fig. 3.9). Therefore, it does not appear that there is a reduction in the size of Pacific herring caught within Point Reyes through time. However, the size of the ancient and early historic Pacific herring recovered archaeologically differs when compared to the California Department of Fish and Wildlife data from 1972-80 (Spratt 1981), (Fig. 3.9). These data suggest that Coast Miwok people may have been catching and retaining a narrower size range of Pacific herring, which could relate to gear selectivity or release of unwanted size classes of fishes.

The narrower range of fish sizes found archaeologically could also be driven by differences in modern and ancient ocean conditions such as productivity and temperature (Heino and God 2002; Ware and Thomson 2005), especially since the occupation of these sites span the Medieval Climatic Anomaly (MCA)—cal AD 800-1,350—and the Little Ice Age (LIA)—cal AD 1,400 to 1,700 (Mann et al. 2009; Stine 1994; Malamud-Roam et al. 2006). However, given the time-depth of the archaeological Pacific herring materials, which span over millennia and are derived from multiple independent sites, it is highly unlikely that the uniformity of Pacific herring SL can be explained by oceanic conditions alone. For example, CA-MRN-224 precedes the MCA but appears to span the MCA and LIA. CA-MRN-222 was occupied during the MCA, the LIA, and after. CA-MRN-AL1 and CA-MRN-249 were inhabited during the MCA and the LIA.

The MCA within California is argued to have resulted in abrupt and extreme hydroclimatic shifts from extreme dryness, to excessive wetness, and back to dryness over several hundred years (Stine 1994). The LIA represents a return to cooler and wetter conditions following the MCA (Malamud-Roam et al. 2006; Stine 1994). Jones and Kennett (1999) demonstrate that sea temperatures were slightly cooler (1°C) than present from cal AD 1-1,300 during the MCA. From cal AD 1,300 to 1,500 or during the MCA and LIA sea temperatures were variable. Between cal AD 1,500 to 1,700 during the LIA they were significantly cooler (2-3°C) than the present. However, studies of marine forage fish fisheries by Jones and Kennett (1999) that were recovered archaeologically throughout this time suggest these fisheries remained stable.

The Point Reyes archaeological Pacific herring SL data are within the size range of spawning age fish, not immature fishes or juveniles. Research by Spratt (1981) suggests Pacific herring reach sexual maturity at age two when they are roughly 177 mm SL, within the mean size range of the archaeological assemblage. These data suggest that Pacific herring fishing may have taken place during the spawning season when large aggregations of fishes would facilitate mass capture of herring for their roe and meat and possibly roe on seaweed and seagrass.

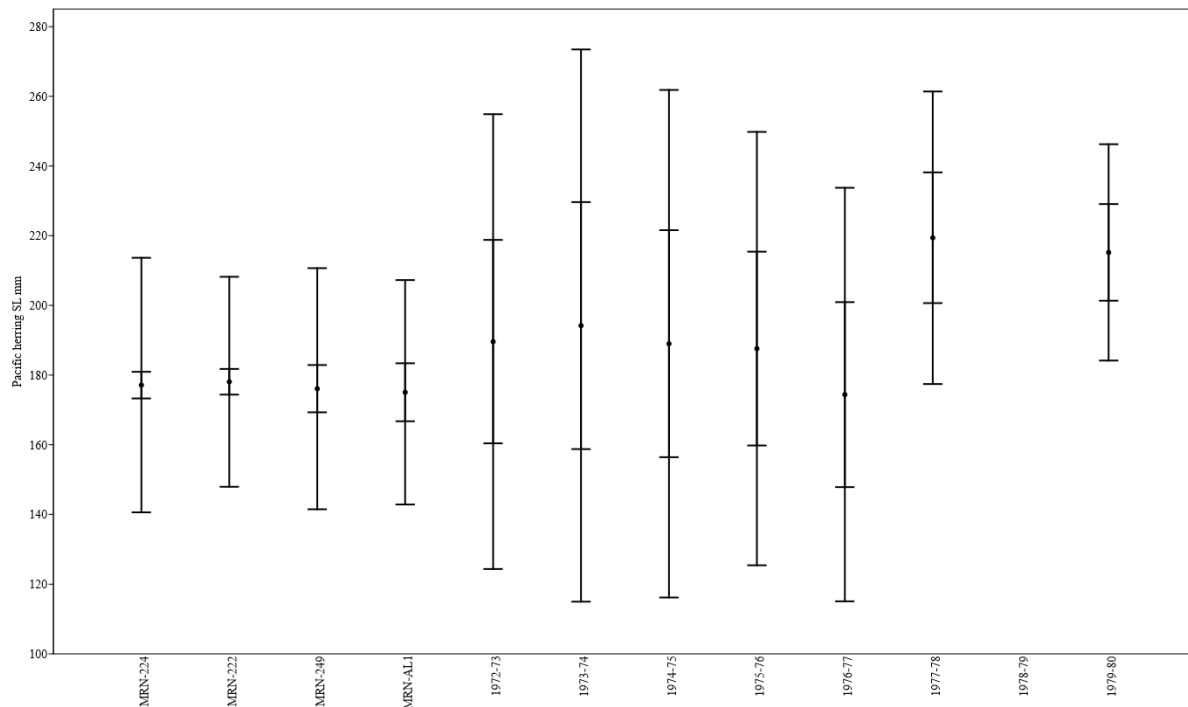


Figure 3.9. Mean and whisker plot of Point Reyes archaeological data and 1972-80 CDFW Tomales Bay data. Standard error and standard deviation included. Confidence interval of 0.95.

Comparing the Pacific herring SL of the archaeological materials to the CDFW record for Tomales Bay, (Fig. 3.9), also reveals potential information regarding the types and sizes of nets that may have been used by the Coast Miwok in the past. Three distinct patterns appear within these data. First, the round haul and lampara nets used in Tomales Bay by commercial fisherman from 1972-77 show that the use of these nets harvested the full range of the spawning Pacific herring population with limited fish size selectivity, consistent with expectations from the fishing technology selectivity literature (An et al. 2013; Colley 1987; Greenspan 1998; Ingólfsson et al. 2017; Poulsen et al. 2000). Second, the shift in 1977-78 to the use of gill nets (2" mesh) exclusively in the Pacific herring fishery demonstrates that gill nets selectively fished for large-sized individual Pacific herring, consistent with expectations from the fishing technology selectivity literature (Spratt 1981, 1992). Third, the archaeological patterns differ from these two datasets suggesting the harvest of a much more constrained size class of Pacific herring. These data appear to represent size selectivity of Pacific herring similar to the 1978-80 Tomales Bay gill net fishery but with selection for smaller and younger mature fishes.

As gill nets are one of the most selective fishing gear types, which affect the size of fishes caught it is plausible that Coast Miwok fishers may have used gill nets in their fishing efforts targeting Pacific herring. Given the relationship between fish net mesh size and the size of fishes captured, a net of a specific mesh size was likely used to capture such a limited size range of fishes (Poulsen et al. 2000). In contrast to gill nets, seine nets are less selective regarding fish size as fishes smaller than the net mesh size can escape while all fishes larger than the mesh are retained (Colley 1987; Greenspan 1998). Thus, unless Coast Miwok fishers were consistently

encountering fishes of equivalent size through time, it appears unlikely that seine nets could correlate with the archaeological Pacific herring SL patterns observed.

Given that gill nets select for a limited size range of Pacific herring the data from Point Reyes suggests that Native people fished for and retained a specific size range of fish and that this range in size persisted for ~1,000 years. Whether the specific size range caught is driven by cultural preferences, cuisine, or selective size selection to steward fish resources is unclear. Nonetheless, the Pacific herring fishery appears to have persisted for millennia without evidence for fish size reductions. Consequently, these data may provide guidance in the minimum and maximum size range of fishes that should be retained in the contemporary fishery.

Lepofsky and Caldwell (2013) outline four aspects of indigenous coastal management including harvesting methods, enhancement strategies, tenure, and worldview. Fish size selection through standardized net mesh size encompasses various indigenous management or stewardship strategies considered by Lepofsky and Caldwell (2013). While the material evidence of Coast Miwok fish nets is not preserved in the archaeological record, indigenous peoples agency and intentionality in net production and the selective harvesting strategies that resulted from the use of these nets can be inferred through the analysis of fish remains. These data suggest the possibility that the Coast Miwok helped steward the Pacific herring fishery in Tomales Bay for nearly 1,000 years. In contrast to these findings, the modern Tomales Bay Pacific herring fishery collapsed in 2007 and appears to have not recovered (California Department of Fish and Wildlife 2008). The reduction of the Pacific herring population through overfishing and climatic events is having a devastating effect on contemporary Coast Miwok subsistence fishing practices within their aboriginal lands and aquatic environments (Pauly and Zeller 2016).

In conclusion, the analysis of Pacific herring atlas and axis vertebrae through linear regression models and formulae to reconstruct the ancient and historic size of these fishes within Point Reyes suggests that Coast Miwok fishers selected for and retained a specific size class of herring likely during the spawning season. In this study, I examined 8,005 clupeid remains and identified 199 Pacific herring atlases and axes from four sites dating from cal AD 760 to ~1,800, which encompasses over 1,000 years of indigenous fishing. The findings suggest Coast Miwok fishers likely used gill nets with a standardized net mesh size to harvest Pacific herring of a specific size throughout this time. These data contrast significantly from the CDFW data derived through the exclusive use of gill nets in the harvesting of Pacific herring, which removed the largest and oldest fishes from the ecosystem (Spratt 1981, 1992). My data indicate the possibility of indigenous stewardship and management of the Point Reyes Pacific herring fishery for over 1,000 years.

The structure of the archaeological Pacific herring fisheries closely resembles expectations from the ecological and fisheries ecology literature regarding resource stewardship with a limited take of adult-sized individuals and juveniles which would allow the fish population to reproduce and develop. These data are contrary to expectations of fishing practices derived from evolutionary ecology, human behavioral ecology, and OFT models (Bettinger 1991, 2015; Broughton 1994a, 1997; Broughton et al. 2015; Cronk 1991; Winterhalder and Smith 2000). According to these frameworks, if Native people were acting optimally in their fishing practices, we could expect that people would be focusing on the highest net return gain for their efforts including the harvest of large-bodied fishes with the highest return rates. If Native American fishing practices were selecting the largest sized Pacific herring 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). My findings correlate closely with expectations of sustainable fishing practices derived from the ecological and fisheries literature with no evidence for the harvest of large-sized Pacific herring or a reduction in the size of fishes through time (Pauly et al. 1998; Pauly and Palomares 2005; Pauly and Zeller 2016; Sadovy 2001; Wright and Trippel 2009). Based on these findings recommendations of minimum and maximum size of take derived from the ancient and historic Coast Miwok fishery could help maintain the Pacific herring population in perpetuity (Pauly et al. 2002; Roberts et al. 2005).

## Chapter 4

### Middle and Late Holocene Fisheries of the Santa Cruz County Coast

#### Introduction

Archaeological investigations of the Santa Cruz County coast, which lies between Monterey Bay and San Francisco offer an exceptional opportunity to understand human habitation of the coastline and coast ranges from the Terminal Pleistocene and throughout the Holocene (Cartier 1989; Hylkema 1991, 2002; Jones et al. 2007; Sanchez et al. 2017). In this chapter, I present the results of a study directed toward a better understanding of ancient and historic fishing practices along the Santa Cruz coast. I sampled five archaeological sites that span from the Middle Holocene to the Contact Period to investigate long-term human-fish relationships through low-impact excavations and fine-grained analyses (i.e.,  $\geq 2$  mm).

Previous studies of the ancient and historic fisheries of Santa Cruz County have been limited and based on materials recovered using coarse-grained recovery methods (Hylkema 1991; Jones and Hildebrandt 1990, 1994; Nims et al. 2016). The first part of the paper synthesizes fisheries data from previous investigations using  $\geq 3.2$  mm or larger mesh. The second part of the chapter describes the findings from our current project employing small-scale excavations with fine-grained ( $\geq 2$  mm) and coarse-grained ( $\geq 3.2$  mm) recovery methods. The study, conducted at the landscape level through the theoretical framework of historical ecology, offers an exceptional opportunity to trace long-term human fishing practices (Balée 1992, 1998, 2006, 2010, 2018). I situate the findings of this case study in relation to previous studies reporting fish remains from Santa Cruz County. The ultimate goal of the research is to determine the fishes used by the Native peoples and to employ knowledge of past fisheries in modern conservation and tribal cultural revitalization efforts.

#### Background

##### *Previous Research and Fisheries Data of the Santa Cruz Coast*

Previous studies reporting fish remains from archaeological sites on the Santa Cruz County coast have been limited. The lack of fisheries data from this region is likely driven by a history of coarse-grained excavations and the use of large mesh sieves. As described below, even when large volumes of sediments are sampled and analyzed most, if any, fish remains are recovered from 3.2 mm mesh sieves rather than 6.2 mm screens. In this section, I summarize the findings from these previous Santa Cruz coast excavations and studies including field methods, recovery techniques, excavation volume, and fish remains recovered, (Appendix B).



Figure 4.1. An overview map of the California coast with an inset map showing the sites discussed. ▲ represent sites sampled in this study while sites previously sampled are designated by ⊕.

#### *CA-SCR-7*

CA-SCR-7 also known as the Sandhill Bluff site is an archaeological locality that contains shell midden deposits intermingled in remnant sand dunes, (Fig. 4.1). Previous investigations indicate the site may have been inhabited from 5,880-6,410 to 3,400-2,830 cal BP (Jones and Hildebrandt 1990). The site contains three loci with shell midden deposits that appear to represent discrete, short-term, or multiple occupation episodes dispersed across a large site area. Early excavations at the site occurred in the late 19<sup>th</sup> century by A. W. Saxe from the California Academy of Sciences (Moratto 1984). In 1950 the site was formally documented by surveyors from the University of California (Jones and Hildebrandt 1990). In 1989 fieldwork

was conducted in loci 1 and 2 of the site with most materials recovered from 6.4 mm mesh sieves. However, a 100 cm x 50 cm control unit and a 20 cm x 20 cm column sample for shellfish analysis taken from unit 9, both from locus 1, were sifted using 3.2 mm sieves. Locus 2 was sampled through three 3 m x 3 m units excavated with 6.4 mm mesh sieves. The fish remains recovered from the excavations by Jones and Hildebrandt (1990) totaling 3 NISP were recovered from a control unit from locus 1 (unit 12) recovered with 3.2 mm mesh (2 NISP) and the 20 cm x 20 cm shell column sample (taken from unit 9) recovered with 3.2 mm mesh (1 NISP).

#### *CA-SCR-10*

CA-SCR-10 is located adjacent to Baldwin Creek and was recorded by researchers from the Department of Anthropology, University of California, Berkeley in 1950. During that initial fieldwork, the site produced projectile points, scrapers, and ground stone artifacts. Human remains were also encountered and buried in an undisclosed location within the site. The site was excavated in the 1990s by Jones and Hildebrandt (1994), and while the site excavations sifted 8,000 liters of sediment through 6.4 mm (6,700 l) and 3.2 mm (1,300 l) mesh sieves, only 25 bone fragments were recovered with no fish remains reported.

#### *CA-SCR-123/38*

Site CA-SCR-123/38 is located within Wilder Ranch State Park and adjacent to Wilder Creek. The site includes CA-SCR-123 which is the primary shell midden among the basal deposits. Shell midden CA-SCR-38 is upslope of CA-SCR-123, but due to erosion these deposits now overlay CA-SCR-123. Built upon and within these two shell midden deposits is a Mexican/American period (1830s-1850s) adobe. CA-SCR-123/38 was excavated by Jones and Hildebrandt (1994) in the 1990s, and while over 15,250 liters of sediment was recovered using 6.4 mm (12,250 l) and 3.2 mm (3,000 l) mesh sieves, only 3 NISP fish remains were recovered from these excavations.

#### *CA-SCR-9*

CA-SCR-9 lies in the Santa Cruz mountains ~6 km from the Pacific Ocean. The site dates from 3,080-2,750 cal BP to 1,190-905 cal BP. However, caution should be used in interpreting these dates as they are based on composite shell and charcoal samples (Nims et al. 2016). Fish remains are reported by Nims et al. (2016) and include 18 NISP. Gobalet et al. (2004) reported on the fish remains from the site as did Cristie Boone in Nims et al. (2016). These remains are from excavations that employed 6.4 mm and 3.2 mm mesh sieves. The bony and cartilaginous fishes represented at the site are medium- and large-bodied organisms, likely a result of the large mesh sieves used during excavation. Nonetheless, these data suggest that people harvested fishes from the rocky intertidal coastline and possibly nearby streams to capture surfperches, including pile perch, salmon and trout, monkeyface pricklebacks, lingcod, and cabezon.

Table 4.1. Summary of fish remains from previous excavations from the Santa Cruz coast.

| Site               | Liters  | Sieve (mm) | Fish NISP | Density (Per Liter) | Source                       |
|--------------------|---------|------------|-----------|---------------------|------------------------------|
| CA-SCR-7 (locus 1) | 11600.0 | 6.4        |           |                     | Jones and Hildebrandt (1990) |
| CA-SCR-7 (locus 1) | 500.0   | 3.2        |           |                     | Jones and Hildebrandt (1990) |
| CA-SCR-7 (locus 2) | 8100.0  | 6.4        |           |                     | Jones and Hildebrandt (1990) |
| CA-SCR-7 (locus 2) | 0.0     | 3.2        |           |                     | Jones and Hildebrandt (1990) |
| <b>Total</b>       | 20200.0 |            | 3.0       | 0.0001              |                              |
| CA-SCR-9           | 8550.0  | 6.4        |           |                     | Nims et al. (2016)           |
| CA-SCR-9           | 5300.0  | 3.2        |           |                     | Nims et al. (2016)           |
| <b>Total</b>       | 13850.0 |            | 18.0      | 0.0013              |                              |
| CA-SCR-10          | 6700.0  | 6.4        |           |                     | Jones and Hildebrandt (1994) |
| CA-SCR-10          | 1300.0  | 3.2        |           |                     | Jones and Hildebrandt (1994) |
| <b>Total</b>       | 8000.0  |            | 0.0       | 0.0                 |                              |
| CA-SCR-60/130      |         |            |           |                     | Culleton et al. (2005)       |
| <b>Total</b>       | 5900.0  | 3.2        | 196.0     | 0.0332              |                              |
| CA-SCR-123/38      | 12250.0 | 6.4        |           |                     | Jones and Hildebrandt (1994) |
| CA-SCR-123/38      | 3000.0  | 3.2        |           |                     | Jones and Hildebrandt (1994) |
| <b>Total</b>       | 15250.0 |            | 3.0       | 0.0002              |                              |

*CA-SCR-35*

CA-SCR-35 is a shell midden site adjacent to Majors Creek that lies between the city of Santa Cruz and the town of Davenport—initially recorded in 1950 as part of the California survey by archaeologists of the University of California, Berkeley. Formal excavations at the site have occurred in two phases. First, in 1967 Gordon O'Bannon of Cabrillo Community College excavated the site. However, the materials from this excavation and field notes have never been relocated (Gifford and Marshall 1984). Second, in 1971 John Fritz of the University of California, Santa Cruz conducted salvage excavations after the property owner encountered human remains during construction. The work by Fritz was a large-scale excavation with at least 69 1 m x 1 m units excavated with sediments screened over 6.4 mm mesh sieves (Gifford and Marshall 1984). Gifford and Marshall (1984) reported a formal analysis of less than a quarter of the site assemblage with no fish remains reported. However, subsequent analyses by Sweeney (1986) reports on the fish remains from the site. W.I. Follett and Stuart Poss of the California Academy of Sciences identified the fish specimens for Sweeney. These remains suggest that the fishes are comprised of New World silversides along with skates, herrings, trout and salmon, and surfperches.

### *CA-SCR-44*

Research at CA-SCR-44 situated near Watsonville has been conducted since the 1950s through the 1990s; the latter work was part of a cultural resource management mitigation project. Radiocarbon dating of deer (*Odocoileus* sp.) remains, and an abalone artifact from the site suggest occupation from 2,950-2,750 cal BP to 380-130 cal BP (Breschini and Haversat 2000). Faunal remains from the site were recovered with 1.59 mm mesh sieves (Gobalet and Jones 1995; Langenwalter 2000). These data suggest that a variety of freshwater and marine organisms are present with the majority of the assemblage comprised of night smelt, suckers, and cyprinids including hitch and Sacramento sucker. Sacramento perch and tule perch also make up a portion of the freshwater assemblage.

### *CA-SCR-60/130*

Site CA-SCR-60/130 is located in dune remnants in the Pajaro River floodplain near the confluence of Watsonville and Harkins sloughs near Watsonville (Culleton et al. 2005; Gobalet et al. 2004). The site contains an Early Holocene component dated between 7,650-6,400 cal BP and a Middle Holocene component that dates between 4,790-4,150 cal BP (Culleton et al. 2005). The site was excavated using 3.2 mm mesh sieves as part of a mitigation project due to development. Four control units (CU18A-D) were analyzed to establish which fishes were present (Culleton et al. 2005). A total of 196 NISP, including cartilaginous fishes and marine and freshwater bony fishes, were recovered.

### *Summary*

In total five sites along the Santa Cruz coast have fish remains reported; most of these have high excavation volumes with a low density of fish remains recovered per liter, (Table 4.1). The overall pattern from these previous excavations is a trend toward low fish densities, and low specimen counts. These issues affect archaeological interpretations regarding human-environmental relationships, and the use of archaeological fish remains to inform fisheries management and cultural revitalization efforts among local indigenous groups

### *Sampling Biases and Fisheries Studies*

Sampling biases in the field of archaeology, especially those derived by the use of coarse-grained recovery methods (e.g.,  $\geq 6.4$  mm and 3.2 mm sieves) and their effects on the representation of archaeological materials and interpretations derived from these assemblages, have been a concern for decades (Barker 1975; Casteel 1970, 1972, 1976; Colley 1990; Fitch 1969; Gobalet 1989; Meighan 1950; Payne 1972; Thomas 1969; Wheeler and Jones 1989). In general, zooarchaeological studies demonstrate that fisheries-based research requires the use of fine-grained recovery techniques with at least  $>2$  mm or  $>1.59$  mm mesh sieves (Cannon 2000; Gobalet 1989; Fitch 1969; Moss et al. 2017; Sanchez et al. 2018). Archaeological research conducted with coarse-grained methods will typically recover a reduced range of organisms, over-representing large-bodied fishes and underrepresenting small- and medium-bodied fishes (Casteel 1972, 1976; Colley 1990; Moss et al. 2017; Ross and Duffy 2000; Sanchez et al. 2018; Shaffer 1992; Thomas 1969; Tushingham and Bencze 2013; Wheeler and Jones 1989). Research conducted with fine-grained recovery approaches is essential for identifying the full suite of fish species harvested and for understanding capture techniques and technologies, such as mass-harvesting and net fishing. As past research in the study area has resulted in the limited recovery of fish remains (Culleton et al. 2005; Jones and Hildebrandt 1990, 1994; Langenwalter 2000;

Nims et al. 2016), consideration of recovery methods and their effects on fish representation in the region is highly relevant.

### *Introduction to Current Research*

During the summers of 2016-17 fieldwork was conducted at five sites—CA-SCR-7, CA-SCR-10, CA-SCR-14, CA-SCR-15, and CA-SCR-123/38—along the Santa Cruz coastline as part of a collaborative eco-archaeological project involving students and faculty from UC-Berkeley and UC-Santa Cruz, the Amah Mutsun Tribal Band, including members of the Amah Mutsun Native Stewardship Corps, and staff from California State Parks. The project was designed to assess the temporal and material record of sites threatened by sea level rise, ongoing disturbance, coastal erosion, and destruction from agricultural activities, as well as to assess two sites largely protected from significant impacts that lie on private property. These sites were studied to contribute to the ongoing landscape and seascape management research. As part of this project, crew members surveyed, recorded, and tested the five archaeological sites, sampling from major habitats along the coast (i.e., open coast, reef sites, inland localities, and sites situated in the coast range) with all sites located adjacent to Laguna Creek, except for CA-SCR-123/38, which lies in Wilder Ranch State Park.

Given the previous coarse-grained excavations histories for three of the five sites sampled in this study—CA-SCR-7, CA-SCR-10, and CA-SCR-123/38—the most recent iteration of field research at these sites offer an opportunity to examine the kinds of sampling biases that exist in the coarse-grained assemblages in comparison to the fine-grained data derived from our field research. While variation between earlier excavations and assemblages and those recovered from this project may be driven by differences in excavation unit placement and context, a general illustration of sampling biases may be revealed through a broad comparison of fish NISP and density data.

### **Methods and Materials**

The sites in this study were surveyed and sampled using low-impact and minimally invasive archaeological methodologies summarized in Lightfoot (2008). Through low-impact diagnosis of surface and near-surface materials supplemented by focused geophysical survey—including ground penetrating radar (GPR), resistivity, and magnetometry inspection—the research design sought to avoid disturbing human burials while guiding the placement of excavation units. All field research was conducted in close collaboration between University of California, Berkeley faculty, post-doctoral fellows, and graduate and undergraduate students and members of the Amah Mutsun Tribal Band and the Amah Mustun Native Stewardship Corps. Through in-field discussion and consultation we evaluated sensitive contexts and findings with the Amah Mustun Tribal Band before initiating or continuing archaeological fieldwork or excavation.

To conduct surface and near-surface sampling of materials we applied the ‘dog-leash’ method (Binford 1964) along with ‘catch and release’ or in field analysis of archaeological materials. The ‘dog-leash’ technique serves as an expedient survey tool. When combined with in-field documentation of artifacts that are returned near their original context, this approach has been called the ‘catch and release’ method (Gonzalez 2016; Gonzalez et al. 2006). The results of the catch and release and geophysical survey guided where we placed excavation units, column samples, and auger units. The fieldwork conducted at each site is outlined below.

CA-SCR-7

CA-SCR-7, otherwise known as the Sand Hill Bluff site, 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. The most visible of these occur on the seaward face of the dune where we observed dense shell midden deposits. Following a visual inspection of the site, a GPR survey detected additional cultural deposits in loci 1 and 2. To better understand how and when people occupied the dune formation, we mapped the visible cultural deposits and those highlighted by the GPR survey and initiated an intensive sampling of cultural materials through column and auger sampling. Therefore, the results of the GPR survey and mapping guided the sampling of the site, (Fig. 4.2).

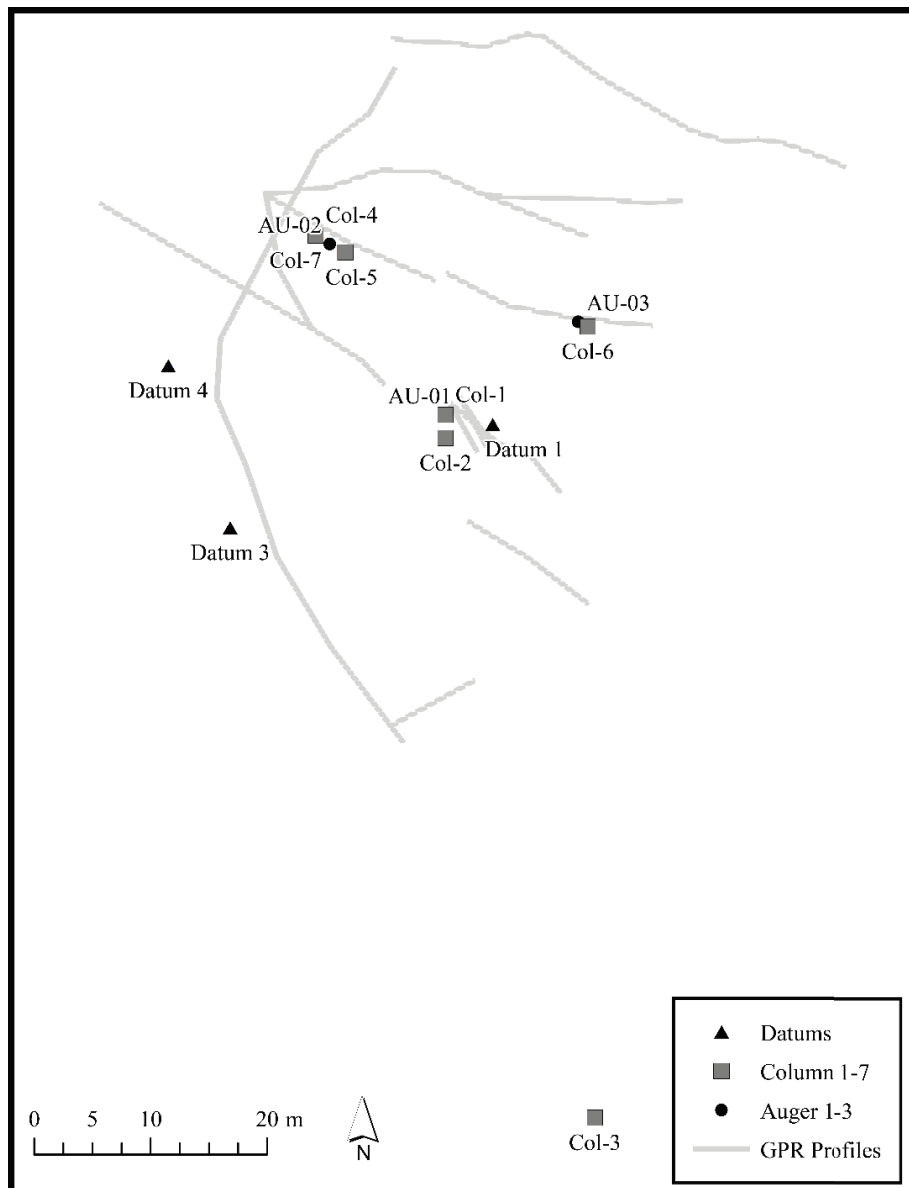


Figure 4.2. Schematic map of CA-SCR-7 depicting the placement of ground penetrating radar survey and column and auger samples.

Crew members excavated column samples along exposed strata and employed soil augers to test deeply buried deposits. We excavated two column samples from the stratigraphic profile of the upper face of the site, column samples 1 and 2. Another column sample (column 3) was excavated from the lower deposit of the dune. After cleaning and exposing cultural layers in the mid-section of the site, we collected four additional column samples (column 4-7). Also, three auger samples (auger 1-3) were placed in the dune to reach deeply buried deposits. Auger levels with cultural materials were retained, and sterile sand deposits were not collected.

#### *CA-SCR-10*

CA-SCR-10 lies to the north of Baldwin Creek and is located on an uplifted marine terrace. Previous research of the site resulted in the recovery of dense shell midden materials. Since the site has been farmed for many years, excavation work took place in the south margins of the site. Little investigation has taken place in the central area of the site that is under agricultural production. Our investigation involved four tasks. First, during the fallow season, we initiated a systematic surface collection of 38 surface units (40 cm radius) across the site. Second, at the same time, we conducted a GPR survey across three 20-by-20 m blocks. Third, during the fallow season, field crews excavated three auger units from across the mounded area of the site. The fourth task was to excavate a second excavation unit, which unfortunately could only be completed during the growing season when the rest of the site was under production. For our study, we attempted to place our excavation unit in the south area of the site adjacent to the previous excavation unit designated “unit 2.” To locate unit 2 and to identify the nature of the buried deposits we employed GPR, magnetometry, and resistivity survey. Using these methods, we were able to identify unit 2 and nearby deposits that appeared to be deeply buried. Therefore, we established a 1 m x 1 m unit (unit 1) for our study, (Fig. 4.3).

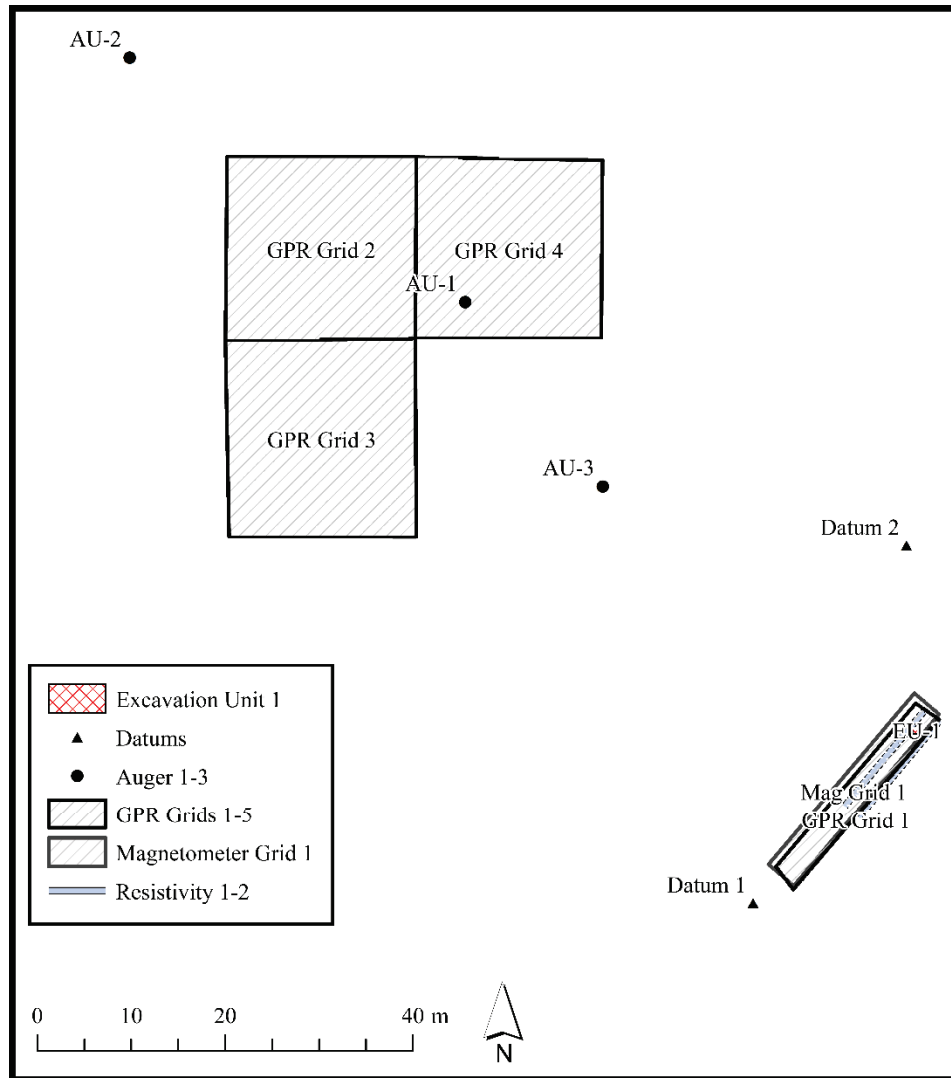


Figure 4.3. Schematic map of CA-SCR-10 depicting the placement of ground penetrating radar, magnetometry, and resistivity survey, auger samples, and excavation unit.

#### *CA-SCR-14 and CA-SCR-15*

CA-SCR-14 and CA-SCR-15 are two sites located in the uplands adjacent to Laguna Creek that were formally recorded by the surveyors with the Department of Anthropology, University of California, Berkeley in 1950. Before 1950, avocational archaeologists and collectors had gathered ground stone artifacts and other materials from the sites. Both sites have been impacted by the development of a road and by plowing of the deposits for agricultural activities. However, no controlled excavations have ever occurred at these sites.

Fieldwork at CA-SCR-14 included GPR and magnetometry survey, the collection of 35 surface units (40 cm radius) distributed along several transects across the site. The results of the surface survey and geophysical survey guided the placement of two 50 cm x 50 cm excavation units, (Fig. 4.4).

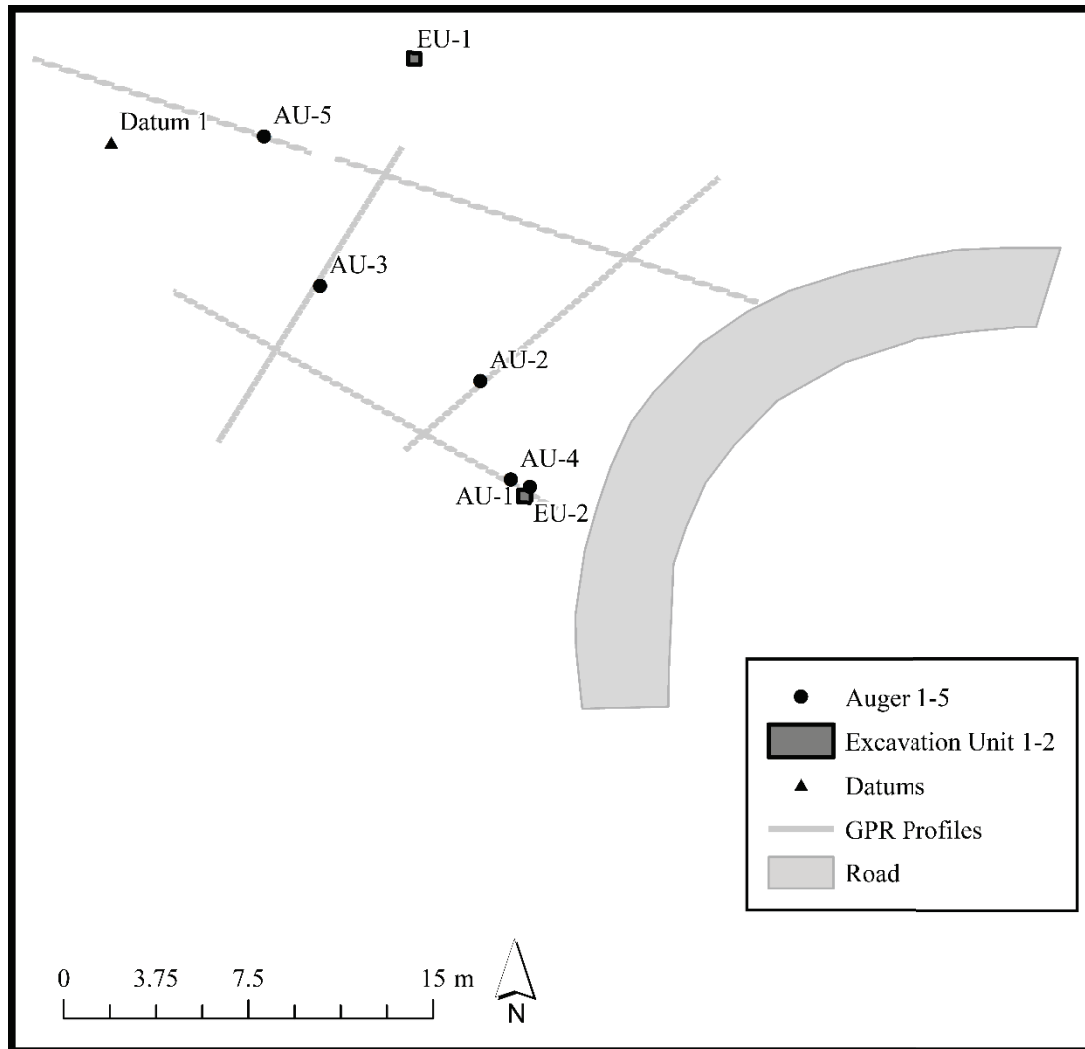


Figure 4.4. Schematic map of CA-SCR-14 depicting the placement of ground penetrating radar survey, auger samples, and excavation unit.

CA-SCR-15 is situated near SCR-14. Fieldwork at the site included topographic mapping, GPR, magnetometry, and surface surveys to record its extent and diversity of material. Systematic transects were established to collect 44 surface units (40 cm radius). Based on the results of the surface units and geophysical survey, two 50 cm x 50 cm excavation units were established for site sampling, (Fig. 4.5).

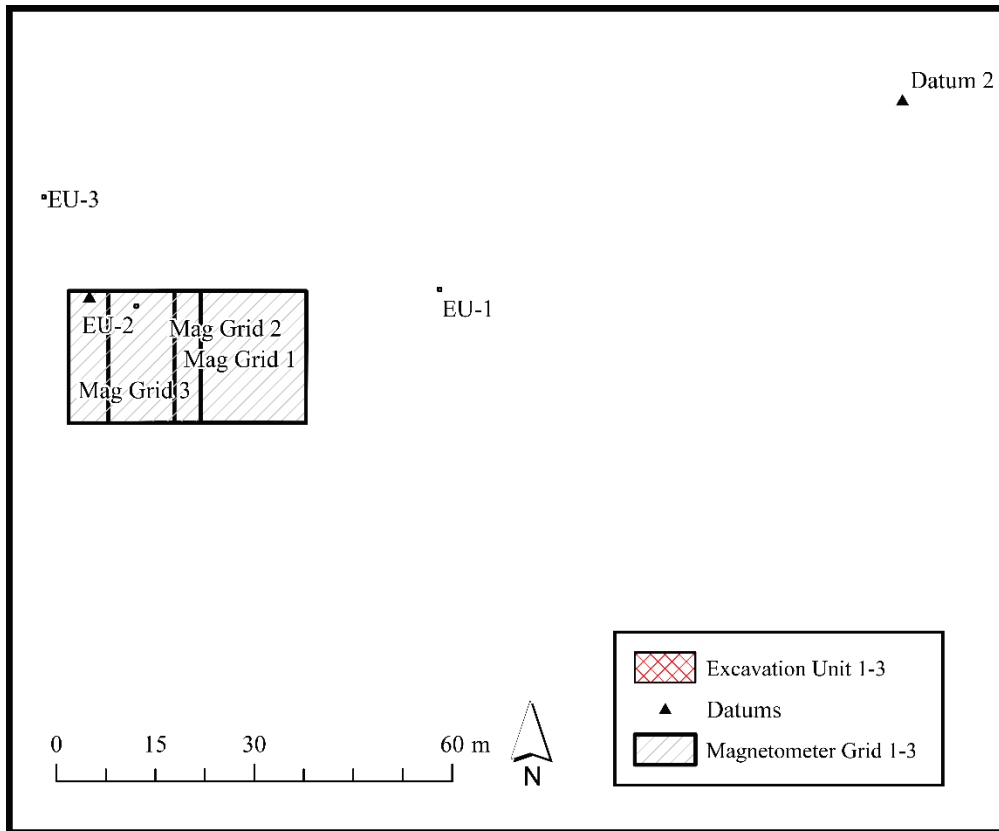


Figure 4.5. Schematic map of CA-SCR-15 depicting the placement of ground penetrating radar, magnetometry survey, and excavation unit.

#### *CA-SCR-123/38*

CA-SCR-123/38 consists of a Mexican/American period (1830s-1850s) adobe. Portions of the Adobe sit upon a pre-colonial shell midden. The site is heavily disturbed by active rodent bioturbation. A GPR survey was completed inside the two rooms of the existing adobe structure to assist in locating deposits for excavation. However, given the presence of a 20<sup>th</sup>-century house floor, the results of the GPR survey were inconsistent. Therefore, we decided to excavate a 1 m x 1 m unit in one room of the adobe for site sampling. Given the extreme disturbance of the site deposits by active rodent bioturbation, the presence of multiple occupation episodes, and the likelihood that the materials derived from CA-SCR-123/38 are highly disturbed, the site was excluded from the zooarchaeological analysis.

#### *Field and Laboratory Processing of Bulk Sediment Samples*

Previous research by Casteel (1970, 1976), Cannon (2000), and others suggests flotation samples derived from column and auger sampling serve as an accurate and efficient method for accessing the focus and intensity of site-specific and regional fisheries. Subsequently, we collected column samples, auger samples (10 cm diameter) and bulk sediment samples from each excavation unit and individual levels, features, or contexts, and these samples were bagged *en toto*, (Table 4.2).

Table 4.2. Site, the volume of flotation samples, and volume of dry screen samples from Santa Cruz archaeological sites.

| Site         | Flotation Volume Analyzed (Liters) | Dry Screen (3.2 mm) Volume (Liters) |
|--------------|------------------------------------|-------------------------------------|
| CA-SCR-7     | 370.5                              | 60                                  |
| CA-SCR-10    | 41.6                               | 1300                                |
| CA-SCR-14    | 48.5                               | 250                                 |
| CA-SCR-15    | 77.5                               | 275                                 |
| <b>Total</b> | 538.1                              | 1885                                |

Bulk sediment samples and associated artifactual materials were separated from matrix through water flotation at Wilder Ranch State Park, dividing materials into the light and heavy fraction samples. In total, 538.1 liters in volume of heavy fraction materials were analyzed in this study, (Table 4.2). Samples were processed using a modified SMAP-type tank (Pearsall 2000) with 1 mm heavy fraction mesh and ca. 0.2 mm light fraction mesh.

After drying the heavy fraction materials, samples were sieved at the California Archaeology Laboratory, University of California, Berkeley, into the following size fractions through nested geologic sieves: >4 mm, 2-4 mm, and 1-2 mm. Heavy fraction materials were separated into artifact classes, and all archaeofaunal remains were sorted based on size classes. Archaeofaunas were further sorted if they could be identified as fishes, mammals, or birds in the >4 mm and 2-4 mm size fractions.

The recovered fish remains were identified using comparative skeletons from the California Academy of Sciences, San Francisco. Laboratory protocols and faunal identifications were conservative in identifying all elements (Driver 2011; Gobalet 2001). Sanchez completed the faunal analysis, and Gobalet confirmed or revised Sanchez's identifications.

A dissecting stereomicroscope was used to discern diagnostic features that allowed designation to the most exclusive taxon, usually a family. I follow Page et al. (2013) in the use of scientific and common names. Osteological and provenience data were recorded for each skeletal specimen, with the results cataloged in Microsoft Excel and quantified, using the measure of number of identified specimens (NISP) (Grayson 1984; Lyman 2008). With the minor exception of some elasmobranch remains, non-diagnostic specimens were identified as Actinopterygii.

Five measures are applied in this study. First, I calculated the relative abundance of identified skeletal specimens of a particular taxon in relation to the total number of identified specimens (%NISP) (Grayson 1984; Lyman 2008). Second, I calculated the number of identified specimens per liter (NISP/l) to measure density. Third, I measured the diversity of the samples by calculating the taxonomic richness, or the number of genera identified within the samples (Grayson 1984; Harper 1999; Lyman 2008), through the Shannon Index in Paleontological Statistics software (PAST) version 3.22. The Shannon-Weiner Index typically ranges from 1.5-3.5 and rarely exceeds 4.5, with larger values signifying greater diversity or heterogeneity (Harper 1999; Lyman 2008; Magurran 1988). Fourth, I calculated the equitability of organism relative abundance—or evenness in PAST (Faith and Du 2017; Harper 1999; Grayson 1984; Lyman 2008; Magurran 1988). In measuring equitability through the Shannon-Weiner Index, values are between 0 and 1, with a one indicating that all genera are equally abundant or even (Lyman 2008; Magurran 1988). Lastly, I compared the recovery rates of fish remains, and the

diversity of organisms recovered from the sample excavation levels between paired coarse-grained (>3.2 mm) and fine-grained (>2 mm) mesh recovery methods.

Rob Cuthrell identified terrestrial paleoethnobotanical remains for radiocarbon dating. Rhytidome and parenchymous tissue of terrestrial vegetation were selected, to avoid biases or the ‘old wood’ effect (Ashmore 1999; Schiffer 1986; Stuiver et al. 1986). At least, one basal and one upper deposit radiocarbon sample were selected from each of the archaeological sites and contexts. Specimens for radiocarbon dating were selected from light fraction materials. Radiocarbon samples were processed and analyzed by the Keck Carbon Cycle AMS Facility, Earth System Science Department, University of California, Irvine. Radiocarbon dates were calibrated using the program CALIB 7.0 and the IntCal13 calibration curve (Reimer et al. 2013; Stuiver and Reimer 1993).

## Results

### *Radiocarbon Dating*

Radiocarbon dates from CA-SCR-7 suggest an occupation from 6,740-6,660 cal BP to 4,240-4,090 cal BP, with stratigraphic reversals present, (Fig. 4.6). CA-SCR-10 spans from 5,850-5,650 cal BP to 730-670 cal BP and includes stratigraphic reversals, (Fig. 4.7). CA-SCR-14 from 940-800 cal BP to 260-30 cal BP, (Fig. 4.8). CA-SCR-15 from 1,180-1,000 cal BP to 470-310 cal BP, with stratigraphic reversals present, (Fig. 4.9).

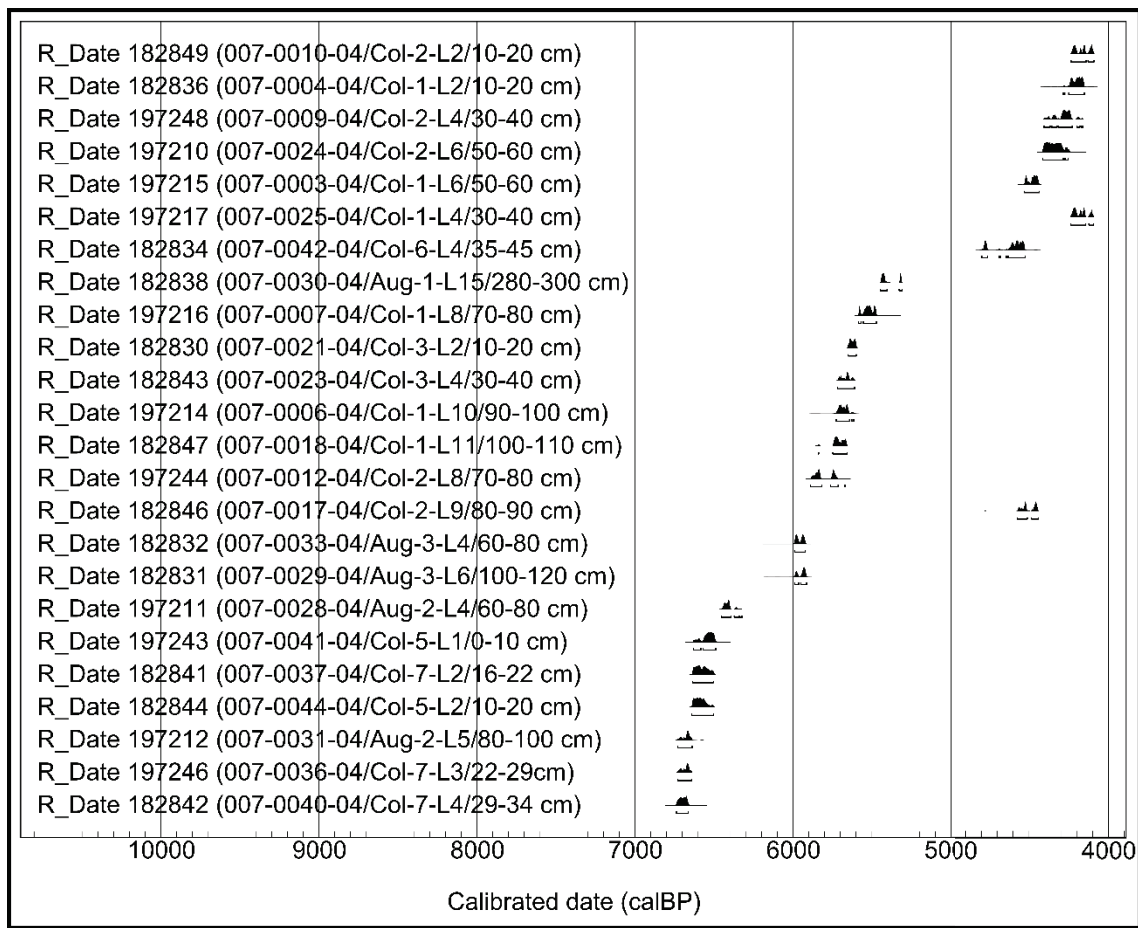


Figure 4.6. Radiocarbon dates for CA-SCR-7 organized stratigraphically.

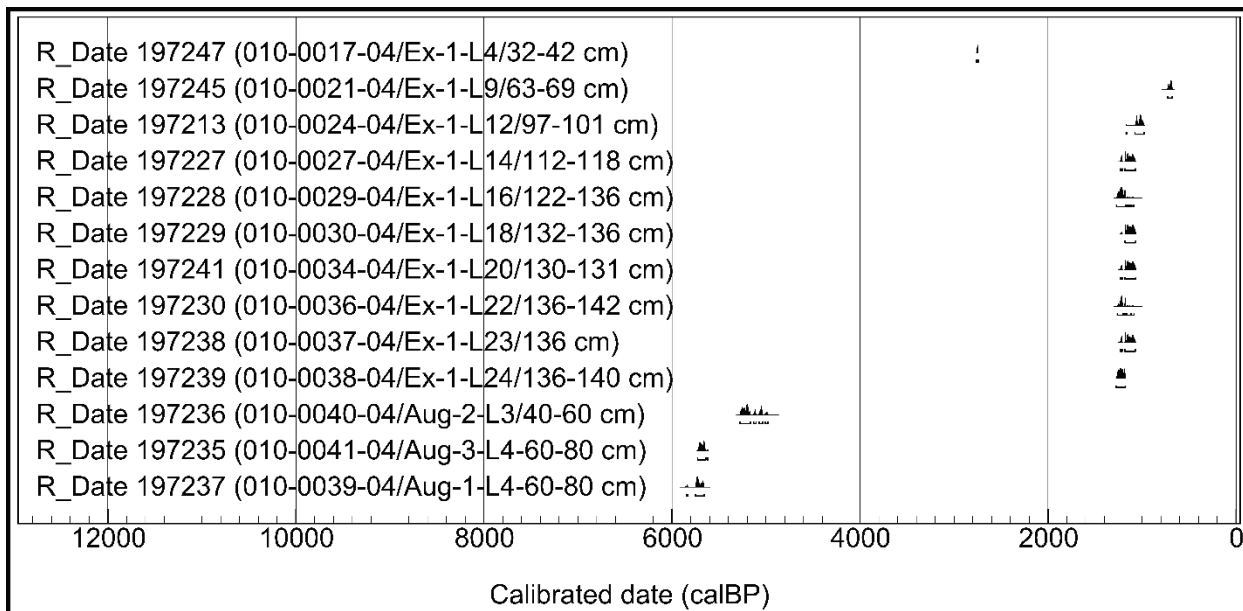


Figure 4.7. Radiocarbon dates for CA-SCR-10 organized stratigraphically.

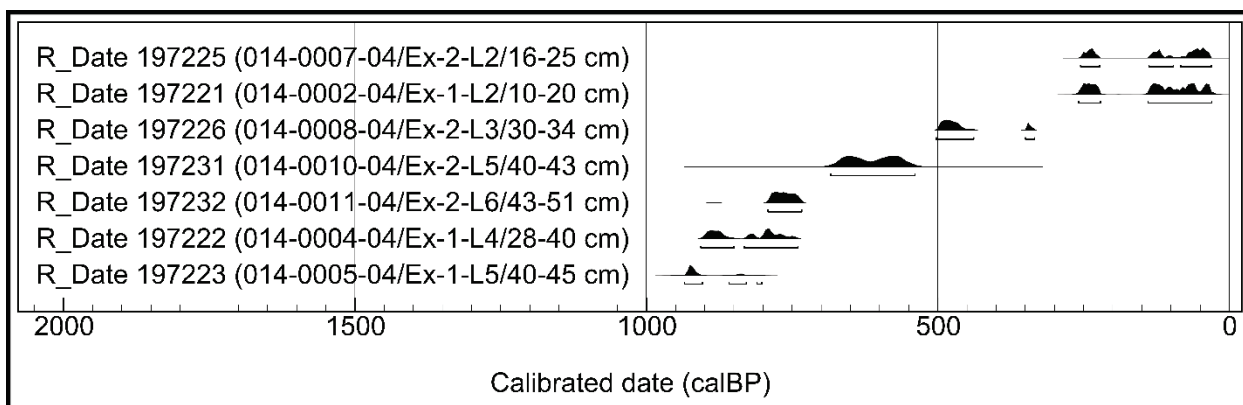


Figure 4.8. Radiocarbon dates for CA-SCR-14 organized stratigraphically.

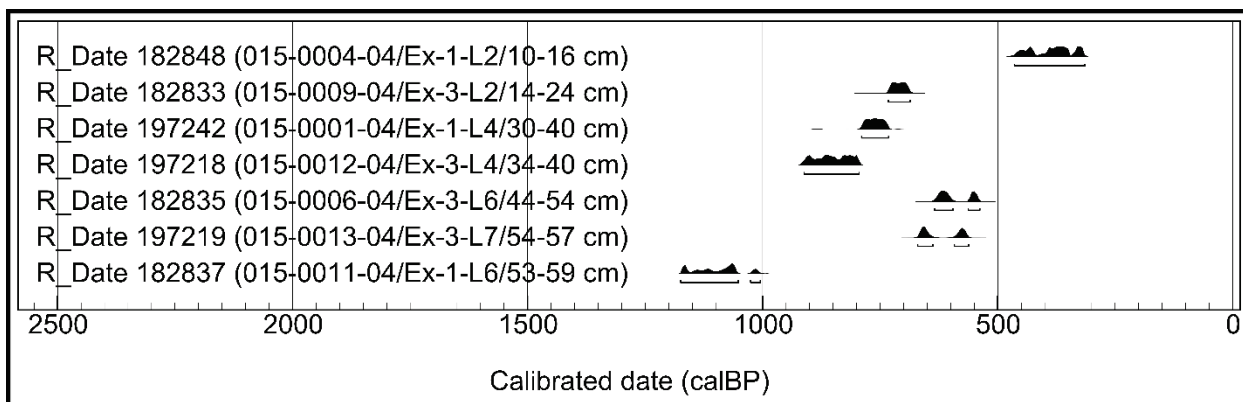


Figure 4.9. Radiocarbon dates for CA-SCR-15 organized stratigraphically.

### *Zooarchaeological Analyses*

The results of the faunal analyses suggest that the >3.2 mm and >2 mm Santa Cruz County assemblage includes 2,041 NISP. Much of the assemblage or ~63% is comprised of non-identifiable specimens that could only be classified as Actinopterygii or ray-finned fish, (Table 4.3).

Table 4.3. Faunal analysis results with NISP by site, context, screen size, and taxon total across sites.

|                                    |                       | CA-SCR-7 Column 1 | CA-SCR-7 Column 2 | CA-SCR-7 Column 3 | CA-SCR-7 Column 4 | CA-SCR-7 Column 5 | CA-SCR-7 Column 6 | CA-SCR-7 Column 7 | CA-SCR-7 (Auger 2) | CA-SCR-7 (Auger 3) | CA-SCR-10 | CA-SCR-10 | CA-SCR-10 (Auger) | CA-SCR-14 | CA-SCR-14 | CA-SCR-15 | CA-SCR-15 | CA-SCR-123/38 | Taxon Total |
|------------------------------------|-----------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|--------------------|--------------------|-----------|-----------|-------------------|-----------|-----------|-----------|-----------|---------------|-------------|
|                                    | Screen size           | >2 mm             | >2 mm             | >2 mm             | >2 mm             | >2 mm             | >2 mm             | >2 mm             | >2 mm              | >2 mm              | >2 mm     | >3.2 mm   | >2 mm             | >2 mm     | >3.2 mm   | >2 mm     | >3.2 mm   | >2 mm         |             |
| Taxon                              | Common name           |                   |                   |                   |                   |                   |                   |                   |                    |                    |           |           |                   |           |           |           |           |               |             |
| <b>Salt Water Fishes</b>           |                       |                   |                   |                   |                   |                   |                   |                   |                    |                    |           |           |                   |           |           |           |           |               |             |
| Elasmobranchiomorphi               |                       |                   | 2                 |                   | 8                 |                   |                   | 2                 | 1                  |                    |           |           |                   |           |           |           |           |               | 13          |
| <b>Rajidae</b>                     | Skates                |                   |                   |                   | 5                 | 1                 |                   | 10                |                    |                    | 3         |           |                   |           |           |           |           |               | 19          |
| <i>Raja</i> sp.                    | Skate                 | 1                 |                   |                   | 19                | 7                 |                   | 12                | 5                  |                    | 1         |           |                   | 2         |           |           |           |               | 47          |
| <b>Myliobatidae</b>                | Eagle rays            |                   |                   |                   |                   |                   |                   |                   |                    |                    |           |           |                   |           |           |           |           |               |             |
| <i>Myliobatis californica</i>      | Bat ray               |                   | 1                 |                   |                   |                   |                   |                   |                    |                    |           |           |                   |           |           |           |           |               | 1           |
| <i>Squalus suckleyi</i>            | Spiny dogfish         |                   |                   |                   |                   |                   |                   | 1                 | 1                  |                    |           |           |                   |           |           |           |           |               | 2           |
| <b>Lamnidae</b>                    | Mackerel sharks       |                   |                   |                   |                   |                   |                   |                   |                    |                    |           |           |                   |           |           |           |           |               |             |
| <i>Isurus</i> sp.                  | Mako                  |                   |                   |                   |                   |                   |                   |                   |                    |                    |           |           |                   |           | 1         |           |           |               | 1           |
| <b>Actinopterygii</b>              | Ray-finned fishes     | 59                | 47                | 5                 | 442               | 62                | 2                 | 212               | 64                 | 1                  | 195       | 10        | 1                 | 104       | 14        | 56        | 4         | 14            | 1292        |
| <b>Engraulidae</b>                 | Anchovies             |                   |                   |                   |                   |                   |                   |                   |                    |                    |           |           |                   |           |           |           |           |               |             |
| <i>Engraulis mordax</i>            | Northern anchovy      | 1                 | 2                 |                   |                   |                   |                   |                   |                    |                    | 17        |           |                   | 45        |           | 1         |           | 3             | 69          |
| <b>Clupeidae</b>                   | Herrings              | 5                 | 2                 | 1                 | 1                 |                   | 2                 | 2                 | 1                  |                    | 44        | 1         |                   | 8         |           | 4         |           |               | 71          |
| <i>Clupea pallasii</i>             | Pacific herring       |                   |                   |                   | 1                 |                   |                   |                   |                    |                    | 1         |           |                   |           |           |           |           |               | 2           |
| <i>Sardinops sagax</i>             | Pacific sardine       |                   |                   |                   |                   |                   |                   |                   |                    |                    | 6         |           | 1                 |           |           |           |           | 1             | 8           |
| <b>Osmeridae</b>                   | Smelts                |                   |                   |                   |                   |                   |                   |                   |                    |                    | 2         |           |                   |           |           |           |           |               | 2           |
| <i>Spirinchus starksi</i>          | Night smelt           |                   |                   |                   |                   |                   |                   |                   |                    |                    |           |           |                   | 1         |           |           |           |               | 1           |
| <b>Gadidae</b>                     | Cods                  |                   |                   |                   |                   |                   |                   |                   |                    |                    |           |           |                   |           |           |           |           |               |             |
| <i>Microgadus proximus</i>         | Pacific tomcod        | 1                 | 3                 |                   |                   |                   |                   |                   |                    |                    |           |           |                   |           |           |           |           |               | 4           |
| <b>Batrachoididae</b>              | Toadfishes            |                   |                   |                   |                   |                   |                   |                   |                    |                    |           |           |                   |           |           |           |           |               |             |
| <i>Porichthys notatus</i>          | Plainfin midshipman   |                   |                   |                   |                   |                   |                   | 1                 |                    |                    | 5         | 1         |                   |           |           |           |           |               | 7           |
| <b>Atherinopsidae</b>              | New World silversides | 2                 |                   |                   |                   |                   | 1                 | 1                 |                    |                    | 12        |           |                   |           |           |           |           |               | 16          |
| <i>Atherinopsis californiensis</i> | Jacksnelt             |                   |                   |                   |                   |                   |                   | 1                 |                    |                    |           |           |                   |           |           |           |           |               | 1           |
| <b>Scorpaenidae</b>                | Scorpionfishes        |                   |                   |                   |                   |                   |                   |                   |                    |                    |           |           |                   |           |           |           |           |               |             |
| <i>Sebastes</i> sp.                | Rockfishes            | 1                 |                   |                   | 16                | 7                 |                   | 12                | 4                  |                    | 4         | 3         |                   | 2         | 8         | 2         | 1         | 3             | 63          |
| <b>Hexagrammidae</b>               | Greenlings            | 6                 | 5                 | 1                 | 8                 | 8                 | 4                 | 19                | 6                  |                    | 4         |           |                   | 6         | 7         | 8         | 2         | 1             | 85          |
| <i>Hexagrammos</i> sp.             | Greenlings            |                   |                   |                   | 4                 | 1                 |                   | 9                 |                    |                    | 2         | 1         | 1                 |           | 1         | 2         |           |               | 21          |
| <i>Ophiodon elongatus</i>          | Lingcod               | 1                 |                   |                   | 9                 | 1                 |                   | 1                 | 1                  |                    | 1         |           |                   | 2         |           |           |           |               | 16          |
| <b>Cottidae</b>                    | Sculpins              | 4                 | 8                 | 1                 | 2                 |                   | 1                 | 1                 |                    |                    | 1         |           |                   | 1         |           | 2         |           |               | 21          |

|                                   |                                       |     |     |    |     |    |    |     |     |   |     |    |   |     |    |    |    |     |      |
|-----------------------------------|---------------------------------------|-----|-----|----|-----|----|----|-----|-----|---|-----|----|---|-----|----|----|----|-----|------|
| <i>Artedius</i> sp.               |                                       | 1   |     |    |     |    |    |     |     | 1 |     |    |   |     |    |    |    | 2   |      |
| <i>Clinocottus</i> sp.            |                                       | 1   | 3   | 1  | 1   |    |    |     | 1   |   |     |    |   |     | 1  |    |    | 8   |      |
| <i>Oligocottus</i> sp.            |                                       | 1   |     |    |     |    |    |     |     |   |     |    |   |     |    |    |    | 1   |      |
| <i>Scorpaenichthys marmoratus</i> | Cabezon                               | 1   | 2   |    | 4   |    |    | 2   |     |   | 1   | 1  |   | 2   | 5  | 2  | 1  | 21  |      |
| <b>Sciaenidae</b>                 | Drums and croakers                    |     |     |    |     |    |    |     |     |   |     |    |   |     |    |    |    |     |      |
| <i>Genyonemus lineatus</i>        | White croaker                         |     |     |    |     |    |    |     |     |   |     |    |   | 1   |    |    |    | 1   |      |
| <b>Embiotocidae</b>               | Surfperches                           | 20  | 21  | 3  | 24  | 6  | 1  | 19  | 9   | 1 | 31  | 3  |   | 19  | 12 | 15 | 1  | 185 |      |
| <i>Amphistichus</i> sp.           |                                       |     |     |    |     |    |    |     | 1   |   | 1   |    |   |     |    | 1  | 1  | 4   |      |
| <i>Damalichthys vacca</i>         | Pile perch                            | 3   | 1   |    | 1   |    |    |     |     |   |     |    |   | 6   | 1  | 3  |    | 15  |      |
| <i>Rhacochilus toxotes</i>        | Rubberlip seaperch                    |     |     |    |     |    |    |     |     |   |     | 1  |   |     |    |    |    | 1   |      |
| <b>Stichaeidae</b>                | Pricklebacks                          |     |     |    |     |    |    |     |     |   |     |    |   | 1   |    |    |    | 1   |      |
| <i>Cebidichthys violaceus</i>     | Monkeyface prickleback                |     |     | 1  |     |    |    |     |     |   | 1   | 1  |   | 1   | 2  |    |    | 6   |      |
| <i>Xiphister</i> sp.              | Black or Rock prickleback             | 1   |     |    |     |    |    |     |     |   | 1   |    |   |     |    |    |    | 2   |      |
| <b>Clinidae</b>                   | Kelp blennies                         |     |     |    |     |    |    |     |     |   | 1   |    |   |     |    |    |    | 1   |      |
| <i>Gibbonsia</i> sp.              | Spotted, Striped, or Crevice kelpfish | 1   |     |    | 1   |    |    |     |     |   |     |    |   |     |    |    |    | 2   |      |
| <b>Pleuronectiformes</b>          |                                       | 1   | 1   |    |     | 1  |    | 1   |     |   |     |    |   |     |    |    |    | 4   |      |
| <i>Platichthys stellatus</i>      | Starry flounder                       |     |     |    |     |    |    |     | 1   |   |     |    |   |     |    |    |    | 1   |      |
|                                   |                                       |     |     |    |     |    |    |     |     |   |     |    |   |     |    |    |    |     |      |
| <b>Fresh or Salt Water Fishes</b> |                                       |     |     |    |     |    |    |     |     |   |     |    |   |     |    |    |    |     |      |
| <b>Salmonidae</b>                 | Trouts and salmons                    |     |     |    |     |    |    |     |     |   |     |    |   |     |    |    |    |     |      |
| <i>Oncorhynchus</i> sp.           |                                       | 1   | 4   |    |     | 1  | 2  |     | 1   |   | 1   |    |   | 1   |    |    |    | 11  |      |
| <i>Oncorhynchus mykiss</i>        | Rainbow trout                         |     |     |    |     |    |    |     |     |   |     |    |   |     |    |    | 1  | 1   |      |
| <b>Gasterosteidae</b>             | Sticklebacks                          |     |     |    |     |    |    |     |     |   |     |    |   |     |    |    |    |     |      |
| <i>Gasterosteus aculeatus</i>     | Threespine stickleback                |     | 1   |    |     |    |    |     |     |   | 1   |    | 1 | 1   |    |    |    | 4   |      |
| <b>Cottidae</b>                   | Sculpins                              |     |     |    |     |    |    |     |     |   |     |    |   |     |    |    |    |     |      |
| <i>Leptocottus armatus</i>        | Pacific staghorn sculpin              |     | 3   |    | 1   |    |    |     | 2   |   |     |    |   |     |    |    |    | 6   |      |
| <b>Embiotocidae</b>               | Surfperches                           |     |     |    |     |    |    |     |     |   |     |    |   |     |    |    |    |     |      |
| <i>Cymatogaster aggregata</i>     | Shiner perch                          |     |     |    |     |    |    |     | 2   |   |     |    |   |     |    |    |    | 2   |      |
| <b>Total</b>                      |                                       | 112 | 106 | 13 | 547 | 95 | 13 | 306 | 100 | 2 | 337 | 22 | 4 | 201 | 53 | 97 | 10 | 23  | 2041 |

CA-SCR-7

At SCR-7 in the >2 mm samples, the most abundant organisms are surfperches, which comprise ~28% of the assemblage, (Table 4.4). The surfperches include pile perch, shiner perch, and barred, calico, or redbtail surfperch. Greenlings make up 21% of the assemblage by relative abundance and include lingcod and kelp, rock, or masked greenling. Skates make up 15% of the assemblage. Rockfishes 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 level of genera is 2.4, suggesting greater heterogeneity, with evenness or equitability measured at 0.85, signifying an assemblage closer to equal distribution.

The dry-screened materials from CA-SCR-7 were from highly disturbed contexts within the plow zone of agricultural fields. Given that the context of the >3.2 mm samples are not paired with the >2 mm samples as is the case at the other sites, I exclude the fish remains from CA-SCR-7 dry-screening from further consideration.

Table 4.4. Results of fish analysis for CA-SCR-7 from the >2 mm recovery method with NISP by context.

|                          |                                    | CA-SCR-7 Column 1 | CA-SCR-7 Column 2 | CA-SCR-7 Column 3 | CA-SCR-7 Column 4 | CA-SCR-7 Column 5 | CA-SCR-7 Column 6 | CA-SCR-7 Column 7 | CA-SCR-7 (Auger 2) | CA-SCR-7 (Auger 3) | Total | Total w/o RFF | Relative Abundance w/o RFF |
|--------------------------|------------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|--------------------|--------------------|-------|---------------|----------------------------|
|                          | Screen size                        | >2 mm             | >2 mm             | >2 mm             | >2 mm             | >2 mm             | >2 mm             | >2 mm             | >2 mm              | >2 mm              |       |               |                            |
| Taxon                    | Common name                        |                   |                   |                   |                   |                   |                   |                   |                    |                    |       |               |                            |
| <b>Salt Water Fishes</b> |                                    |                   |                   |                   |                   |                   |                   |                   |                    |                    |       |               |                            |
| Elasmobranchiomorphi     |                                    |                   | 2                 |                   | 8                 |                   |                   | 2                 | 1                  |                    | 13    | 13            | 0.03                       |
| <b>Rajidae</b>           | Skates                             |                   |                   |                   | 5                 | 1                 |                   | 10                |                    |                    | 16    | 16            | 0.04                       |
|                          | <i>Raja</i> sp.                    | 1                 |                   |                   | 19                | 7                 |                   | 12                | 5                  |                    | 44    | 44            | 0.11                       |
| <b>Myliobatidae</b>      | Eagle rays                         |                   |                   |                   |                   |                   |                   |                   |                    |                    |       |               |                            |
|                          | <i>Myliobatis californica</i>      |                   | 1                 |                   |                   |                   |                   |                   |                    |                    | 1     | 1             | 0.00                       |
| <b>Squalidae</b>         | Dogfish sharks                     |                   |                   |                   |                   |                   |                   |                   |                    |                    |       |               |                            |
|                          | <i>Squalus suckleyi</i>            |                   |                   |                   |                   |                   |                   | 1                 | 1                  |                    | 2     | 2             | 0.01                       |
| <b>Actinopterygii</b>    | Ray-finned fishes                  | 59                | 47                | 5                 | 442               | 62                | 2                 | 212               | 64                 | 1                  | 894   |               |                            |
| <b>Engraulidae</b>       | Anchovies                          |                   |                   |                   |                   |                   |                   |                   |                    |                    |       |               |                            |
|                          | <i>Engraulis mordax</i>            | 1                 | 2                 |                   |                   |                   |                   |                   |                    |                    | 3     | 3             | 0.01                       |
| <b>Clupeidae</b>         | Herrings                           | 5                 | 2                 | 1                 | 1                 |                   | 2                 | 2                 | 1                  |                    | 14    | 14            | 0.04                       |
|                          | <i>Clupea pallasii</i>             |                   |                   |                   | 1                 |                   |                   |                   |                    |                    | 1     | 1             | 0.00                       |
| <b>Gadidae</b>           | Cods                               |                   |                   |                   |                   |                   |                   |                   |                    |                    |       |               |                            |
|                          | <i>Microgadus proximus</i>         | 1                 | 3                 |                   |                   |                   |                   |                   |                    |                    | 4     | 4             | 0.01                       |
| <b>Batrachoididae</b>    | Toadfishes                         |                   |                   |                   |                   |                   |                   |                   |                    |                    |       |               |                            |
|                          | <i>Porichthys notatus</i>          |                   |                   |                   |                   |                   |                   | 1                 |                    |                    | 1     | 1             | 0.00                       |
| <b>Atherinopsidae</b>    | New World silversides              | 2                 |                   |                   |                   |                   | 1                 | 1                 |                    |                    | 4     | 4             | 0.01                       |
|                          | <i>Atherinopsis californiensis</i> |                   |                   |                   |                   |                   |                   | 1                 |                    |                    | 1     | 1             | 0.00                       |

|                                   |                                       |     |     |    |     |    |    |     |     |   |      |     |      |
|-----------------------------------|---------------------------------------|-----|-----|----|-----|----|----|-----|-----|---|------|-----|------|
| <b>Scorpaenidae</b>               | Scorpionfishes                        |     |     |    |     |    |    |     |     |   |      |     |      |
| <i>Sebastes</i> sp.               | Rockfishes                            | 1   |     |    | 16  | 7  |    | 12  | 4   |   | 40   | 40  | 0.10 |
| <b>Hexagrammidae</b>              | Greenlings                            | 6   | 5   | 1  | 8   | 8  | 4  | 19  | 6   |   | 57   | 57  | 0.14 |
| <i>Hexagrammos</i> sp.            | Greenlings                            |     |     |    | 4   | 1  |    | 9   |     |   | 14   | 14  | 0.04 |
| <i>Ophiodon elongatus</i>         | Lingcod                               | 1   |     |    | 9   | 1  |    | 1   | 1   |   | 13   | 13  | 0.03 |
| <b>Cottidae</b>                   | Sculpins                              | 4   | 8   | 1  | 2   |    | 1  | 1   |     |   | 17   | 17  | 0.04 |
| <i>Artedius</i> sp.               |                                       | 1   |     |    |     |    |    |     |     |   | 1    | 1   | 0.00 |
| <i>Clinocottus</i> sp.            |                                       | 1   | 3   | 1  | 1   |    |    |     | 1   |   | 7    | 7   | 0.02 |
| <i>Oligocottus</i> sp.            |                                       | 1   |     |    |     |    |    |     |     |   | 1    | 1   | 0.00 |
| <i>Scorpaenichthys marmoratus</i> | Cabezon                               | 1   | 2   |    | 4   |    |    | 2   |     |   | 9    | 9   | 0.02 |
| <b>Embiotocidae</b>               | Surfperches                           | 20  | 21  | 3  | 24  | 6  | 1  | 19  | 9   | 1 | 104  | 104 | 0.26 |
| <i>Amphistichus</i> sp.           |                                       |     |     |    |     |    |    |     | 1   |   | 1    | 1   | 0.00 |
| <i>Damalichthys vacca</i>         | Pile perch                            | 3   | 1   |    | 1   |    |    |     |     |   | 5    | 5   | 0.01 |
| <b>Stichaeidae</b>                | Pricklebacks                          |     |     |    |     |    |    |     |     |   |      |     |      |
| <i>Cebidichthys violaceus</i>     | Monkeyface prickleback                |     |     | 1  |     |    |    |     |     |   | 1    | 1   | 0.00 |
| <i>Xiphister</i> sp.              | Black or Rock prickleback             | 1   |     |    |     |    |    |     |     |   | 1    | 1   | 0.00 |
| <b>Clinidae</b>                   | Kelp blennies                         |     |     |    |     |    |    |     |     |   |      |     |      |
| <i>Gibbonsia</i> sp.              | Spotted, Striped, or Crevice kelpfish | 1   |     |    | 1   |    |    |     |     |   | 2    | 2   | 0.01 |
| <b>Pleuronectiformes</b>          |                                       | 1   | 1   |    |     | 1  |    | 1   |     |   | 4    | 4   | 0.01 |
| <i>Platichthys stellatus</i>      | Starry flounder                       |     |     |    |     |    |    |     | 1   |   | 1    | 1   | 0.00 |
| <b>Fresh or Salt Water Fishes</b> |                                       |     |     |    |     |    |    |     |     |   |      |     |      |
| <b>Salmonidae</b>                 | Trouts and salmon                     |     |     |    |     |    |    |     |     |   |      |     |      |
| <i>Oncorhynchus</i> sp.           |                                       | 1   | 4   |    |     | 1  | 2  |     | 1   |   | 9    | 9   | 0.02 |
| <b>Gasterosteidae</b>             | Sticklebacks                          |     |     |    |     |    |    |     |     |   |      |     |      |
| <i>Gasterosteus aculeatus</i>     | Threespine stickleback                |     | 1   |    |     |    |    |     |     |   | 1    | 1   | 0.00 |
| <b>Cottidae</b>                   | Sculpins                              |     |     |    |     |    |    |     |     |   |      |     |      |
| <i>Leptocottus armatus</i>        | Pacific staghorn sculpin              |     | 3   |    | 1   |    |    |     | 2   |   | 6    | 6   | 0.02 |
| <b>Embiotocidae</b>               | Surfperches                           |     |     |    |     |    |    |     |     |   |      |     |      |
| <i>Cymatogaster aggregata</i>     | Shiner perch                          |     |     |    |     |    |    |     | 2   |   | 2    | 2   | 0.01 |
| <b>Total</b>                      |                                       | 112 | 106 | 13 | 547 | 95 | 13 | 306 | 100 | 2 | 1294 | 400 |      |

### CA-SCR-10

For CA-SCR-10 the quantification and analyses were separated by screen size and recovery method. Therefore, I divide those samples recovered through dry-screening with >3.2 mm mesh sieves and those recovered through flotation methods with >2 mm sieves. At SCR-10 the most abundant organisms recovered through flotation and with >2 mm sieves were herrings at 34%, which include Pacific herring and Pacific sardine, (Table 4.5). Surfperches comprise 23% of the assemblage and include rubberlip seaperch and barred, calico, or redtail surfperch. Northern anchovy comprises 11%, and New World silversides 8% of the site assemblage. In total, herrings, surfperches, and New World silversides amount to 75% of the site assemblage with 11 genera making up the remaining 25%. The density of fish remains recovered and identified within the assemblage to at least Actinopterygii is 8.2 NISP/l. The Shannon Index for the assemblage, calculated at the level of genera is 2.3, suggesting greater heterogeneity, with evenness or equitability measured at 0.85, signifying an assemblage closer to equal distribution.

For the dry-screen materials at SCR-10, the most abundant organisms recovered with >3.2 mm sieves are surfperches. They comprise 33% of the assemblage and include rubberlip

seaperches and rockfishes at 25%, (Table 4.6). Together surfperches and rockfish make up 58% of the assemblage. Herrings, plainfin midshipman, greenlings, cabezon, and monkeyface pricklebacks make up the remaining 42%, and their relative abundance is evenly distributed among these organisms. The density of fish remains recovered and identified within the >3.2 mm assemblage to at least the level of class is 0.2 NISP/l. The Shannon Index for the assemblage, calculated at the level of genera is 1.7, suggesting less heterogeneity, with evenness or equitability measured at 0.78, signifying an assemblage that is moving away from equal distribution.

Table 4.5. Results of fish analysis for CA-SCR-10 from the >2 mm recovery method with NISP by context.

|                                   |                           | CA-SCR-10  | CA-SCR-10 (Auger) | Total      | Total w/o RFF | Relative Abundance w/o RFF |
|-----------------------------------|---------------------------|------------|-------------------|------------|---------------|----------------------------|
|                                   | Screen size               | >2 mm      | >2 mm             |            |               |                            |
| <b>Taxon</b>                      | <b>Common name</b>        |            |                   |            |               |                            |
| <b>Salt Water Fishes</b>          |                           |            |                   |            |               |                            |
| <b>Rajidae</b>                    | Skates                    | 3          |                   | 3          | 3             | 0.02                       |
| <i>Raja</i> sp.                   | Skate                     | 1          |                   | 1          | 1             | 0.01                       |
| <b>Actinopterygii</b>             | Ray-finned fishes         | 195        | 1                 | 196        |               |                            |
| <b>Engraulidae</b>                | Anchovies                 |            |                   |            |               |                            |
| <i>Engraulis mordax</i>           | Northern anchovy          | 17         |                   | 17         | 17            | 0.11                       |
| <b>Clupeidae</b>                  | Herrings                  | 44         |                   | 44         | 45            | 0.29                       |
| <i>Clupea pallasii</i>            | Pacific herring           | 1          |                   | 1          | 1             | 0.01                       |
| <i>Sardinops sagax</i>            | Pacific sardine           | 6          | 1                 | 7          | 7             | 0.04                       |
| <b>Osmeridae</b>                  | Smelts                    | 2          |                   | 2          | 2             | 0.01                       |
| <b>Batrachoididae</b>             | Toadfishes                |            |                   |            |               |                            |
| <i>Porichthys notatus</i>         | Plainfin midshipman       | 5          |                   | 5          | 6             | 0.04                       |
| <b>Atherinopsidae</b>             | New World silversides     | 12         |                   | 12         | 12            | 0.08                       |
| <b>Scorpaenidae</b>               | Scorpionfishes            |            |                   |            |               |                            |
| <i>Sebastes</i> sp.               | Rockfishes                | 4          |                   | 4          | 7             | 0.04                       |
| <b>Hexagrammidae</b>              | Greenlings                | 4          |                   | 4          | 4             | 0.03                       |
| <i>Hexagrammos</i> sp.            | Greenlings                | 2          | 1                 | 3          | 4             | 0.03                       |
| <i>Ophiodon elongatus</i>         | Lingcod                   | 1          |                   | 1          | 1             | 0.01                       |
| <b>Cottidae</b>                   | Sculpins                  | 1          |                   | 1          | 1             | 0.01                       |
| <i>Artedius</i> sp.               |                           | 1          |                   | 1          | 1             | 0.01                       |
| <i>Scorpaenichthys marmoratus</i> | Cabezon                   | 1          |                   | 1          | 2             | 0.01                       |
| <b>Embiotocidae</b>               | Surfperches               | 31         |                   | 31         | 34            | 0.22                       |
| <i>Amphistichus</i> sp.           |                           | 1          |                   | 1          | 1             | 0.01                       |
| <i>Rhacochilus toxotes</i>        | Rubberlip seaperch        |            |                   | 0          | 1             | 0.01                       |
| <b>Stichaeidae</b>                | Pricklebacks              |            |                   |            |               |                            |
| <i>Cebidichthys violaceus</i>     | Monkeyface prickleback    | 1          |                   | 1          | 2             | 0.01                       |
| <i>Xiphister</i> sp.              | Black or Rock prickleback | 1          |                   | 1          | 1             | 0.01                       |
| <b>Clinidae</b>                   | Kelp blennies             | 1          |                   | 1          | 1             | 0.01                       |
| <b>Fresh or Salt Water Fishes</b> |                           |            |                   |            |               |                            |
| <b>Salmonidae</b>                 | Trouts and salmons        |            |                   |            |               |                            |
| <i>Oncorhynchus</i> sp.           |                           | 1          |                   | 1          | 1             | 0.01                       |
| <b>Gasterosteidae</b>             | Sticklebacks              |            |                   |            |               |                            |
| <i>Gasterosteus aculeatus</i>     | Threespine stickleback    | 1          | 1                 | 2          | 2             | 0.01                       |
| <b>Total</b>                      |                           | <b>337</b> | <b>4</b>          | <b>341</b> | <b>157</b>    |                            |

Table 4.6. Results of fish analysis for CA-SCR-10 from the >3.2 mm recovery method with NISP.

|                                   |                        | CA-SCR-10 | Total w/o RFF | Relative Abundance w/o RFF |
|-----------------------------------|------------------------|-----------|---------------|----------------------------|
|                                   | Screen size            | >3.2 mm   |               |                            |
| Taxon                             | Common name            |           |               |                            |
| <b>Salt Water Fishes</b>          |                        |           |               |                            |
| <b>Actinopterygii</b>             | Ray-finned fishes      | <b>10</b> |               |                            |
| <b>Clupeidae</b>                  | Herrings               | <b>1</b>  | <b>1</b>      | <b>0.08</b>                |
| <b>Batrachoididae</b>             | Toadfishes             |           |               |                            |
| <i>Porichthys notatus</i>         | Plainfin midshipman    | <b>1</b>  | <b>1</b>      | <b>0.08</b>                |
| <b>Scorpaenidae</b>               | Scorpionfishes         |           |               |                            |
| <i>Sebastes</i> sp.               | Rockfishes             | <b>3</b>  | <b>3</b>      | <b>0.25</b>                |
| <b>Hexagrammidae</b>              | Greenlings             |           |               |                            |
| <i>Hexagrammos</i> sp.            | Greenlings             | <b>1</b>  | <b>1</b>      | <b>0.08</b>                |
| <b>Cottidae</b>                   | Sculpins               |           |               |                            |
| <i>Scorpaenichthys marmoratus</i> | Cabezon                | <b>1</b>  | <b>1</b>      | <b>0.08</b>                |
| <b>Embiotocidae</b>               | Surfperches            | <b>3</b>  | <b>3</b>      | <b>0.25</b>                |
| <i>Rhacochilus toxotes</i>        | Rubberlip seaperch     | <b>1</b>  | <b>1</b>      | <b>0.08</b>                |
| <b>Stichaeidae</b>                | Pricklebacks           |           |               |                            |
| <i>Cebidichthys violaceus</i>     | Monkeyface prickleback | <b>1</b>  | <b>1</b>      | <b>0.08</b>                |
| <b>Total</b>                      |                        | <b>22</b> | <b>12</b>     |                            |

#### CA-SCR-14

For CA-SCR-14 the quantification and analyses for the site were separated by screen size and recovery method. I divided those samples recovered through dry-screening with >3.2 mm mesh sieves and those recovered through flotation methods with >2 mm sieves. At SCR-14 the most abundant organisms recovered through flotation and with 2 mm sieves are Northern anchovies at 46%, (Table 4.7). Surfperches comprise 26% of the assemblage and include pile perch. Together Northern anchovies and surfperches make up 72% of the >2 mm assemblage. Eight genera make up the remaining 28% of the site assemblage. The density of fish remains recovered and identified within the assemblage to at least the level of class is 4.1 NISP/l. The Shannon Index for the assemblage, calculated at the level of genera is 1.1, suggesting less heterogeneity, with evenness or equitability measured at 0.45. This finding suggests an assemblage farther from equal distribution.

Table 4.7. Results of fish analysis for CA-SCR-14 from the >2 mm recovery method with NISP.

|                                   |                        | CA-SCR-14  | Total w/o RFF | Relative Abundance w/o RFF |
|-----------------------------------|------------------------|------------|---------------|----------------------------|
|                                   | Screen size            | >2 mm      |               |                            |
| <b>Taxon</b>                      | <b>Common name</b>     |            |               |                            |
| <b>Salt Water Fishes</b>          |                        |            |               |                            |
| <b>Rajidae</b>                    | Skates                 |            |               |                            |
| <i>Raja</i> sp.                   | Skate                  | 2          | 2             | 0.02                       |
| <b>Actinopterygii</b>             | Ray-finned fishes      | 104        |               |                            |
| <b>Engraulidae</b>                | Anchovies              |            |               |                            |
| <i>Engraulis mordax</i>           | Northern anchovy       | 45         | 45            | 0.46                       |
| <b>Clupeidae</b>                  | Herrings               | 8          | 8             | 0.08                       |
| <b>Osmeridae</b>                  | Smelts                 |            |               |                            |
| <i>Spirinchus starksi</i>         | Night smelt            | 1          | 1             | 0.01                       |
| <b>Scorpaenidae</b>               | Scorpionfishes         |            |               |                            |
| <i>Sebastes</i> sp.               | Rockfishes             | 2          | 2             | 0.02                       |
| <b>Hexagrammidae</b>              | Greenlings             | 6          | 6             | 0.06                       |
| <i>Ophiodon elongatus</i>         | Lingcod                | 2          | 2             | 0.02                       |
| <b>Cottidae</b>                   | Sculpins               | 1          | 1             | 0.01                       |
| <i>Scorpaenichthys marmoratus</i> | Cabezon                | 2          | 2             | 0.02                       |
| <b>Embiotocidae</b>               | Surfperches            | 19         | 19            | 0.20                       |
| <i>Damalichthys vacca</i>         | Pile perch             | 6          | 6             | 0.06                       |
| <b>Stichaeidae</b>                | Pricklebacks           | 1          | 1             | 0.01                       |
| <i>Cebidichthys violaceus</i>     | Monkeyface prickleback | 1          | 1             | 0.01                       |
| <b>Fresh or Salt Water Fishes</b> |                        |            |               |                            |
| <b>Gasterosteidae</b>             | Sticklebacks           |            |               |                            |
| <i>Gasterosteus aculeatus</i>     | Threespine stickleback | 1          | 1             | 0.01                       |
| <b>Total</b>                      |                        | <b>201</b> | <b>97</b>     |                            |

For the dry-screen materials at SCR-14, the most abundant organisms recovered with >3.2 mm sieves are surfperches at 33%, which include pile perch, (Table 4.8). Also, the assemblage is comprised of greenlings at 21%, which may include kelp, rock, masked greenling. The assemblage also includes rockfishes at 21%. Together surfperches, greenlings, and rockfishes make up 75% of the site assemblage. Five genera which include trout and salmon, makos, cabezon, monkeyface pricklebacks, and white croaker make up the remaining 25% of the site assemblage, (Table 4.8). The density of fish remains recovered and identified within the >3.2 mm assemblage to at least the level of class is 0.2 NISP/l. The Shannon Index for the assemblage, calculated at the level of genera is 1.7, suggesting less heterogeneity, with evenness or equitability measured at 0.75, signifying an assemblage moving closer to equal distribution.

Table 4.8. Results of fish analysis for CA-SCR-14 from the >3.2 mm recovery method with NISP.

|                                   |                        | CA-SCR-14 | Total w/o RFF | Relative Abundance w/o RFF |
|-----------------------------------|------------------------|-----------|---------------|----------------------------|
|                                   | Screen size            | >3.2 mm   |               |                            |
| Taxon                             | Common name            |           |               |                            |
| <b>Salt Water Fishes</b>          |                        |           |               |                            |
| <b>Lamnidae</b>                   | Mackerel sharks        |           |               |                            |
| <i>Isurus</i> sp.                 | Mako                   | 1         | 1             | 0.03                       |
| <b>Actinopterygii</b>             | Ray-finned fishes      | 14        |               |                            |
| <b>Scorpaenidae</b>               | Scorpionfishes         |           |               |                            |
| <i>Sebastes</i> sp.               | Rockfishes             | 8         | 8             | 0.21                       |
| <b>Hexagrammidae</b>              | Greenlings             | 7         | 7             | 0.18                       |
| <i>Hexagrammos</i> sp.            | Greenlings             | 1         | 1             | 0.03                       |
| <b>Cottidae</b>                   | Sculpins               |           |               |                            |
| <i>Scorpaenichthys marmoratus</i> | Cabezon                | 5         | 5             | 0.13                       |
| <b>Sciaenidae</b>                 | Drums and croakers     |           |               |                            |
| <i>Genyonemus lineatus</i>        | White croaker          | 1         | 1             | 0.03                       |
| <b>Embiotocidae</b>               | Surfperches            | 12        | 12            | 0.31                       |
| <i>Damalichthys vacca</i>         | Pile perch             | 1         | 1             | 0.03                       |
| <b>Stichaeidae</b>                | Pricklebacks           |           |               |                            |
| <i>Cebidichthys violaceus</i>     | Monkeyface prickleback | 2         | 2             | 0.05                       |
| <b>Fresh or Salt Water Fishes</b> |                        |           |               |                            |
| <b>Salmonidae</b>                 | Trouts and salmon      |           |               |                            |
| <i>Oncorhynchus</i> sp.           |                        | 1         | 1             | 0.03                       |
| <b>Total</b>                      |                        | 53        | 39            |                            |

#### CA-SCR-15

In the quantification and analyses of materials for CA-SCR-15, I divided those samples recovered through dry-screening with >3.2 mm mesh sieves from those recovered through flotation methods with >2 mm sieves. At SCR-15 the most abundant organisms recovered through flotation and with >2 mm sieves are surfperches at 46%, which include pile perch and barred, calico, or redbtail surfperch, (Table 4.9). The assemblage is also comprised of greenlings at 21%, which may include kelp, rock, masked greenling. Herrings make up 10% of the site total. Together surfperches, greenlings, and herrings comprise 77% of the SCR-15 site assemblage. Four genera make up the remaining 23% of the site. The density of fish remains recovered and identified within the assemblage to at least the level of class is 1.3 NISP/l. The Shannon Index for the assemblage, calculated at the level of genera is 1.9, suggesting less heterogeneity, with evenness or equitability measured at 0.83, signifying an assemblage closer to equal distribution.

For the dry-screen materials at SCR-15, the most abundant organisms recovered with >3.2 mm sieves are greenlings at 33%, (Table 4.10). Surfperches also make up 33% of the assemblage, and these include barred, calico, or redbtail surfperch. In total, greenlings and surfperches make up 66% of the site assemblage. Lastly, rockfishes and cabezon make up the remaining 34% of the site assemblage. The density of fish remains recovered and identified within the >3.2 mm assemblage to at least the level of class is 0.04 NISP/l. The Shannon Index for the assemblage, calculated at the level of genera is 1.1, suggesting less heterogeneity, with

evenness or equitability measured at 0.67. These data signify an assemblage that is moving away from equal distribution.

Table 4.9. Results of fish analysis for CA-SCR-15 from the >2 mm recovery method with NISP.

|                                   |                   | CA-SCR-15 | Total w/o RFF | Relative Abundance w/o RFF |
|-----------------------------------|-------------------|-----------|---------------|----------------------------|
|                                   | Screen size       | >2 mm     |               |                            |
| Taxon                             | Common name       |           |               |                            |
| <b>Salt Water Fishes</b>          |                   |           |               |                            |
| <b>Actinopterygii</b>             | Ray-finned fishes | 56        |               |                            |
| <b>Engraulidae</b>                | Anchovies         |           |               |                            |
| <i>Engraulis mordax</i>           | Northern anchovy  | 1         | 1             | 0.02                       |
| <b>Clupeidae</b>                  | Herrings          | 4         | 4             | 0.10                       |
| <b>Scorpaenidae</b>               | Scorpionfishes    |           |               |                            |
| <i>Sebastes</i> sp.               | Rockfishes        | 2         | 2             | 0.05                       |
| <b>Hexagrammidae</b>              | Greenlings        | 8         | 8             | 0.20                       |
| <i>Hexagrammos</i> sp.            | Greenlings        | 2         | 2             | 0.05                       |
| <b>Cottidae</b>                   | Sculpins          | 2         | 2             | 0.05                       |
| <i>Clinocottus</i> sp.            |                   | 1         | 1             | 0.02                       |
| <i>Scorpaenichthys marmoratus</i> | Cabezon           | 2         | 2             | 0.05                       |
| <b>Embiotocidae</b>               | Surfperches       | 15        | 15            | 0.37                       |
| <i>Amphistichus</i> sp.           |                   | 1         | 1             | 0.02                       |
| <i>Damalichthys vacca</i>         | Pile perch        | 3         | 3             | 0.07                       |
| <b>Total</b>                      |                   | 97        | 41            |                            |

Table 4.10. Results of fish analysis for CA-SCR-15 from the >3.2 mm recovery method with NISP.

|                                   |                   | CA-SCR-15 | Total w/o RFF | Relative Abundance w/o RFF |
|-----------------------------------|-------------------|-----------|---------------|----------------------------|
|                                   | Screen size       | >3.2 mm   |               |                            |
| Taxon                             | Common name       |           |               |                            |
| <b>Salt Water Fishes</b>          |                   |           |               |                            |
| <b>Actinopterygii</b>             | Ray-finned fishes | 4         |               |                            |
| <b>Scorpaenidae</b>               | Scorpionfishes    |           |               |                            |
| <i>Sebastes</i> sp.               | Rockfishes        | 1         | 1             | 0.17                       |
| <b>Hexagrammidae</b>              | Greenlings        | 2         | 2             | 0.33                       |
| <b>Cottidae</b>                   | Sculpins          |           |               |                            |
| <i>Scorpaenichthys marmoratus</i> | Cabezon           | 1         | 1             | 0.17                       |
| <b>Embiotocidae</b>               | Surfperches       | 1         | 1             | 0.17                       |
| <i>Amphistichus</i> sp.           |                   | 1         | 1             | 0.17                       |
| <b>Total</b>                      |                   | 10        | 6             |                            |

## Discussion

### *Diachronic Shifts in Fish Relative Abundances*

The analysis of fish remains and radiocarbon dates for the four sites studied from the Santa Cruz coast suggest that our excavations encountered deposits dating from ~6,800 cal BP to the historic era. Diachronic examination of the results of the Shannon-Weiner Index measuring diversity and evenness suggests that the fish derived from fishing practices became less diverse

through time or that there was a general shift from broad-based fisheries to more specialized fishing practices in the >2 mm assemblage, (Fig. 4.10). However, at CA-SCR-15 we see a slight increase in the Shannon-Weiner Index. These data reflect the fact that the diversity index considers the number and quantity of organisms in the calculation. Therefore, the higher values observed at CA-SCR-7, CA-SCR-10, and CA-SCR-15 reflect communities with many species, each with few individuals represented. The Shannon-Weiner Index is lower at CA-SCR-14 suggesting an assemblage that has fewer organisms and that few organisms make up the bulk of abundance within the assemblage.

For instance, at CA-SCR-7 which dates from 6,740-6,660 cal BP to 4,240-4,090 cal BP, 74% of the site assemblage recovered with >2 mm sieves are comprised of surfperches, greenlings, skates, and rockfishes. The remaining 26% of the site assemblage is made of 18 genera. The Shannon-Weiner Index for the site was 2.4, suggesting an assemblage with greater heterogeneity or diversity of genera, with an evenness or equitability measured at 0.85. The density of fish remains in the site equals 3.5 NISP/l. Therefore, it appears that the fishery of CA-SCR-7 was a broad-based fishery and that these practices were in place for over 2,500 years.

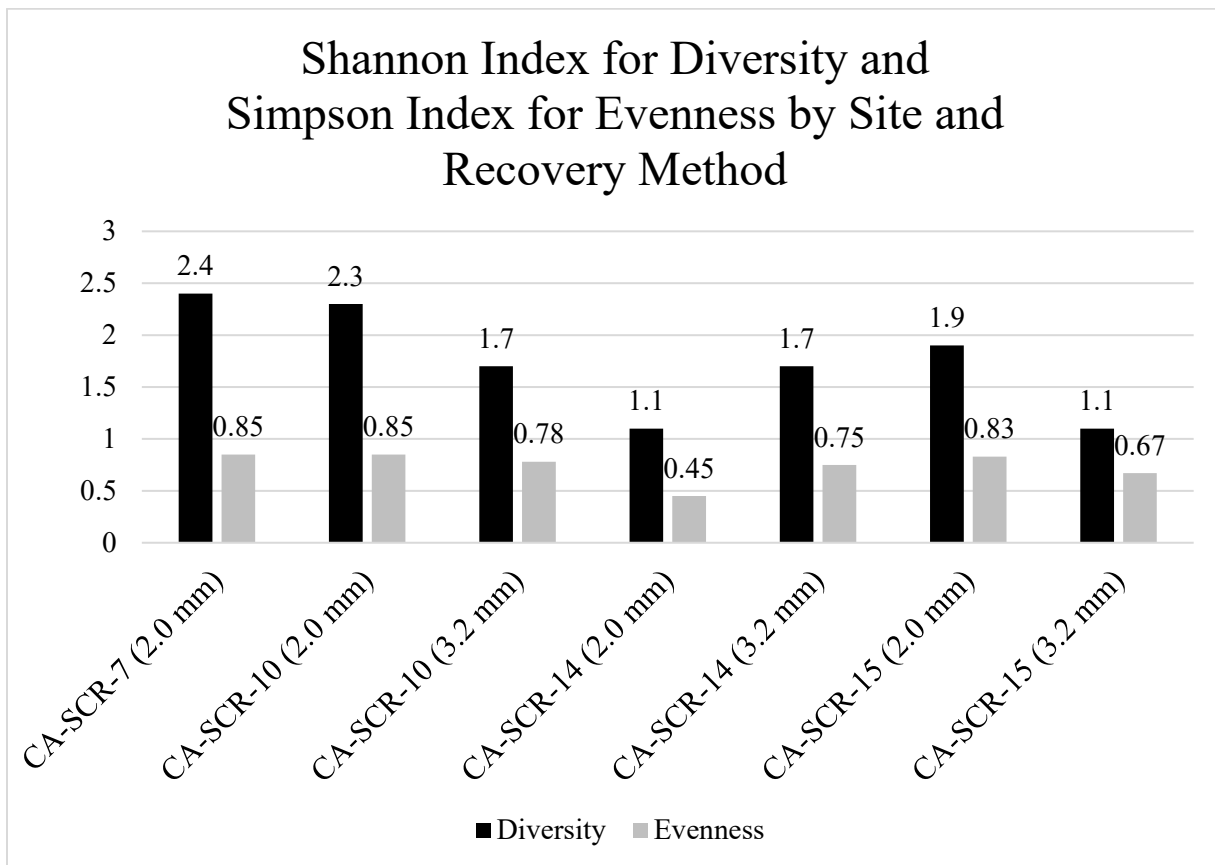


Figure 4.10. Shannon-Weiner Index for diversity and evenness by site and recovery method.

In the case of CA-SCR-10, the site deposits analyzed dated from 5,850-5,650 cal BP to 730-670 cal BP. The >2 mm assemblage suggests that herrings, surfperches, and New World silversides amount to 75% of the site assemblage with 11 genera making up the remaining 25%. However, the density of fish remains recovered per liter is 8.2 NISP/l, which is more than twice the amount recovered from CA-SCR-7, suggests more fish usage at the site. At CA-SCR-10 the

Shannon Index calculated at the level of genera is 2.3, suggesting greater heterogeneity. The evenness or equitability measurement at 0.85 signifies an assemblage closer to equal distribution.

For site CA-SCR-14, which dates from 940-800 cal BP to 260-30 cal BP, the >2 mm assemblage is primarily comprised of Northern anchovies and surfperches. They include 72% of fish remains by relative abundance. Eight genera make up the remaining 28% of the site assemblage. The density of fish remains recovered is 4.1 NISP/l, suggesting a decrease in fish remains when compared to CA-SCR-10 but are similar to the fish densities at CA-SCR-7. The Shannon Index for the assemblage, calculated at the level of genera is 1.1, suggests less heterogeneity, with evenness or equitability measured at 0.45, signifying an assemblage farther from equal distribution.

Lastly, at CA-SCR-15 which dates from 1,180-1,000 cal BP to 470-310 cal BP the >2 mm assemblage is made up of surfperches, greenlings, and herrings. They comprise 77% of the assemblage by relative abundance. Four genera make up the remaining 23% of the site assemblage. The density of fish remains recovered and identified is 1.3 NISP/l. The Shannon Index for the assemblage, calculated at the level of genera is 1.9, suggesting less heterogeneity, with evenness or equitability measured at 0.83, signifying an assemblage closer to equal distribution.

Before deriving interpretations of the significance of these patterns and their implications for regional history, cultural practices, or other factors it is essential to ensure that the results are not correlated with issues such as sample size (Grayson 1984). As noted by Grayson (1984) small samples sizes are not reliable for statistical inferences such as relative abundance given that changes in relative abundances of organisms may be a reflection of sample size, excavation, and analytical biases rather than a reflection of cultural, technological, or environmental variation. In essence, differences in relative abundances may reflect sample sizes rather than other circumstances.

In order to test if the changing relative abundances of organisms are a reflection of cultural, environmental, or technological variation or more a reflection of sample size, I conducted a Spearman rank correlation or Spearman's rho in R version 3.5.0, to test if the NISP counts of select taxa are correlated with sample size (see <sup>a</sup>, Table 4.11 for reproducible R code).

I began by exploring the relationship between surfperch NISP and the NISP of all other fishes. I hypothesized that there would be a positive correlation between sample size and surfperch NISP. Stated otherwise, it is expected that if the abundance of surfperch is correlated with sample size, surfperch NISP will increase in larger assemblages. The opposite would be true if there were a negative correlation, meaning that surfperch NISP would decrease as sample size increases.

The results of the test suggest that there is a strong correlation between surfperch NISP and sample size ( $r_s = 1, p < 0.05$ ). Therefore, it appears that surfperch NISP and sample size are associated or stated otherwise that as sample size increases surfperch NISP also increases. As a result, it is problematic to derive interpretations of changing relative abundances for the sites, as the information could be telling us about changing NISP or sample size per site rather than other factors.

Table 4.11. Surfperch NISP by site, their relative abundance, rank, the NISP of all other fishes, and fish rank.

| Site      | Embiotocidae NISP | Embiotocidae Relative Abundance | Embiotocidae Rank | NISP of All Other Fishes | Fish Rank |
|-----------|-------------------|---------------------------------|-------------------|--------------------------|-----------|
| CA-SCR-7  | 110               | 0.28                            | 1                 | 290                      | 1         |
| CA-SCR-10 | 36                | 0.23                            | 2                 | 121                      | 2         |
| CA-SCR-14 | 25                | 0.26                            | 3                 | 72                       | 3         |
| CA-SCR-15 | 19                | 0.46                            | 4                 | 22                       | 4         |

<sup>a</sup>R Code for Spearman's rho test:

```
Embiotocidae <- c(110, 36, 25, 19)
Other_Fishes <- c(290, 121, 72, 22)
cor.test(Embiotocidae, Other_Fishes, exact = TRUE, conf.level = 0.95, method =
"spearman", alternative = "greater")
```

To test if the patterns observed with the surfperches is consistent across other organisms in the assemblage, I conducted Spearman's rho in R, to test if the NISP counts of rockfishes are also correlated with sample size (see <sup>a</sup>, Table 4.12 for reproducible R code). The results of the test suggest that there is a strong correlation between rockfish NISP and sample size ( $r_s = .95$ ,  $p < 0.05$ ). Therefore, it appears that like the surfperch NISP, rockfish NISP and sample size are associated. As a result, it is problematic to derive interpretations of changing relative abundances for the sites, as the information could be telling us about changing NISP or sample size per site.

Table 4.12. Rockfish NISP by site, their relative abundance, rank, the NISP of all other fishes, and fish rank.

| Site      | <i>Sebastes</i> sp. NISP | <i>Sebastes</i> sp. Relative Abundance | <i>Sebastes</i> sp. Rank | NISP of All Other Fishes | Fish Rank |
|-----------|--------------------------|--|--------------------------|--------------------------|-----------|
| CA-SCR-7  | 40                       | 0.10                                   | 1                        | 360                      | 1         |
| CA-SCR-10 | 7                        | 0.04                                   | 2                        | 150                      | 2         |
| CA-SCR-14 | 2                        | 0.02                                   | 3                        | 95                       | 3         |
| CA-SCR-15 | 2                        | 0.05                                   | 4                        | 39                       | 4         |

<sup>a</sup>R Code for Spearman's rho test:

```
Rockfish <- c(40, 7, 2, 2)
Other_Fishes_R <- c(360, 150, 95, 39)
cor.test(Rockfish, Other_Fishes_R, exact = TRUE, method = "spearman", alternative =
"greater")
```

In an attempt to see if inferences regarding changes in the focus of the fisheries between sites was possible given the results of the Spearman's rho test, I conducted a chi-square ( $\chi^2$ ) test to measure if there were statistically significant differences in the NISP values of fishes that serve as proxies for net-based and mass capture fishing practices (i.e., Northern anchovies, herrings, Pacific tomcod, and smelts) and hook and line fishing (i.e., rockfishes, greenlings,

lingcod, and cabezon)—see chapter 2 and 3. These tests were conducted in an attempt to identify technological changes or variation in the focus of the fisheries across the four sites broadly.

In these analyses, I excluded New World silversides, and surfperches from consideration as previous research suggests these organisms can be captured using both technologies (Bertrando and McKenzie 2012; Sanchez et al. 2018). The  $\chi^2$  test was conducted in JMP version 7.0.1 based on the NISP values for net-based and mass capture fishes. The results suggest that the NISP values for these organisms do not meet expectations at CA-SCR-10 and CA-SCR-14 ( $p < 0.05$ ) suggesting that the fish remains from these two sites are primarily derived from mass-capture and net-based fishing rather than hook and line techniques and technologies, (Fig. 4.11) and (Table 4.13). It appears that CA-SCR-7 and CA-SCR-15 represent fisheries focused on hook and line rather than net-based fishing.

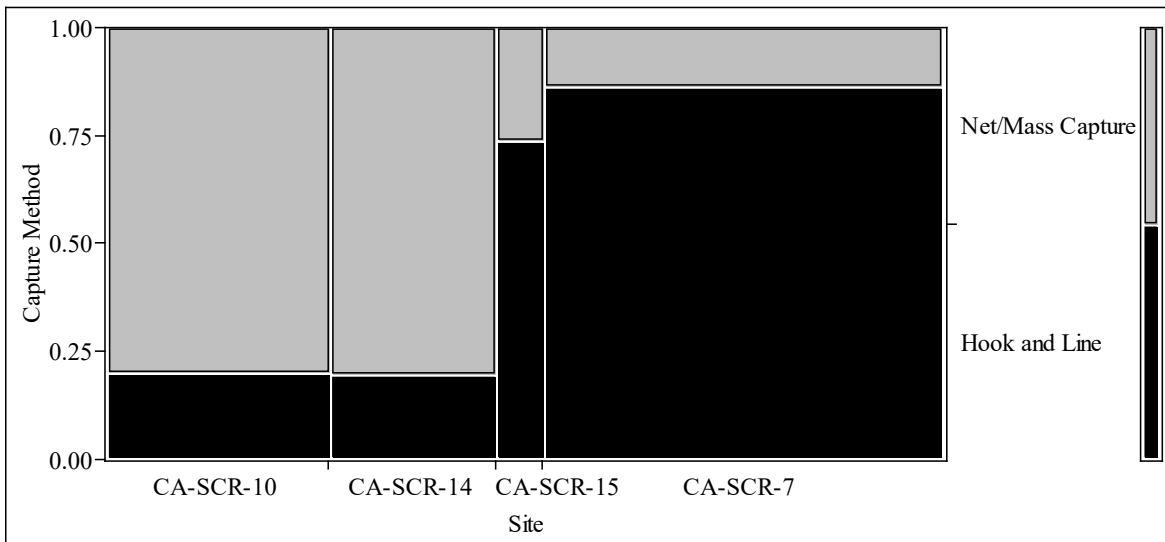


Figure 4.11. Results of the  $\chi^2$  test.

Table 4.13. Results of the  $\chi^2$  test by site and capture method.

| Count<br>Total %<br>Expected<br>Cell $\chi^2$ | Hook and<br>Line                 | Net/Mass<br>Capture               |             |
|---|----------------------------------|-----------------------------------|-------------|
| <b>CA-SCR-10</b>                              | 18<br>5.36<br>49.0179<br>19.6277 | 72<br>21.43<br>40.9821<br>23.4763 | 90<br>26.79 |
| <b>CA-SCR-14</b>                              | 13<br>3.87<br>36.4911<br>15.1223 | 54<br>16.07<br>30.5089<br>18.0875 | 67<br>19.94 |
| <b>CA-SCR-15</b>                              | 14<br>4.17<br>10.3482            | 5<br>1.49<br>8.65179              | 19<br>5.65  |

|                 |                                    |                                  |              |
|-----------------|------------------------------------|----------------------------------|--------------|
|                 | 1.2887                             | 1.5414                           |              |
| <b>CA-SCR-7</b> | 138<br>41.07<br>87.1429<br>29.6806 | 22<br>6.55<br>72.8571<br>35.5003 | 160<br>47.62 |
| <b>Total</b>    | 183<br>54.46                       | 153<br>45.54                     | 336          |

*Sampling Biases in Santa Cruz Coast Archaeology*

As previously mentioned, in conducting this study I was interested in exploring the effects of recovery and sampling biases on the archaeology of fisheries along the Santa Cruz coast. In order to account for these biases paired bulk sediment samples and dry-screen >3.2 mm materials were collected from the majority of the sites, except for CA-SCR-7, where my work focused on the collection of bulk sediment samples from column and auger samples to minimize impacts on the site. In addition, dry-screening at CA-SCR-7 only occurred in highly disturbed contexts without paired >2 mm flotation samples. Therefore, the dry-screen samples from CA-SCR-7 are excluded in the analysis.

As indicated in the first section of this chapter recovery rates for fishes along the Santa Cruz coast from previous excavations of sites sampled in this study (CA-SCR-7 and CA-SCR-10) as well as other sites (CA-SCR-9, CA-SCR-35, CA-SCR-44, CA-SCR-60/130) suggest significantly low fish bones recovery rates and density values per liter sampled, (Table 4.1 and 4.2). For instance, at CA-SCR-7 fish bone density per liter was 0.0001 NISP/l. At CA-SCR-10 8,000 liters of sediment were sampled during previous excavations, and no fish remains were recovered or reported suggesting a lack of fishing in the local economies.

In order to visualize the density of fish bone recovered per liter excavated, I plotted the NISP/l in the paired samples from CA-SCR-10, CA-SCR-14, and CA-SCR-15, (Fig. 4.12). These data demonstrate that the use of >3.2 mm recovery methods along the Santa Cruz coast are significantly biasing the recovery of fish remains from these sites, supported by the findings from earlier phases of research, (Table 4.1). The >3.2 mm dry-screen recovery method at CA-SCR-10 and CA-SCR-14 yielded only 0.2 fish remains per liter, while at CA-SCR-15 it was only 0.04 fish remains. In contrast, the >2 mm heavy fraction materials from CA-SCR-10 include 8.2 NISP/l, with CA-SCR-14 at 4.1 NISP/l, and CA-SCR-15 at 1.3 NISP/l.

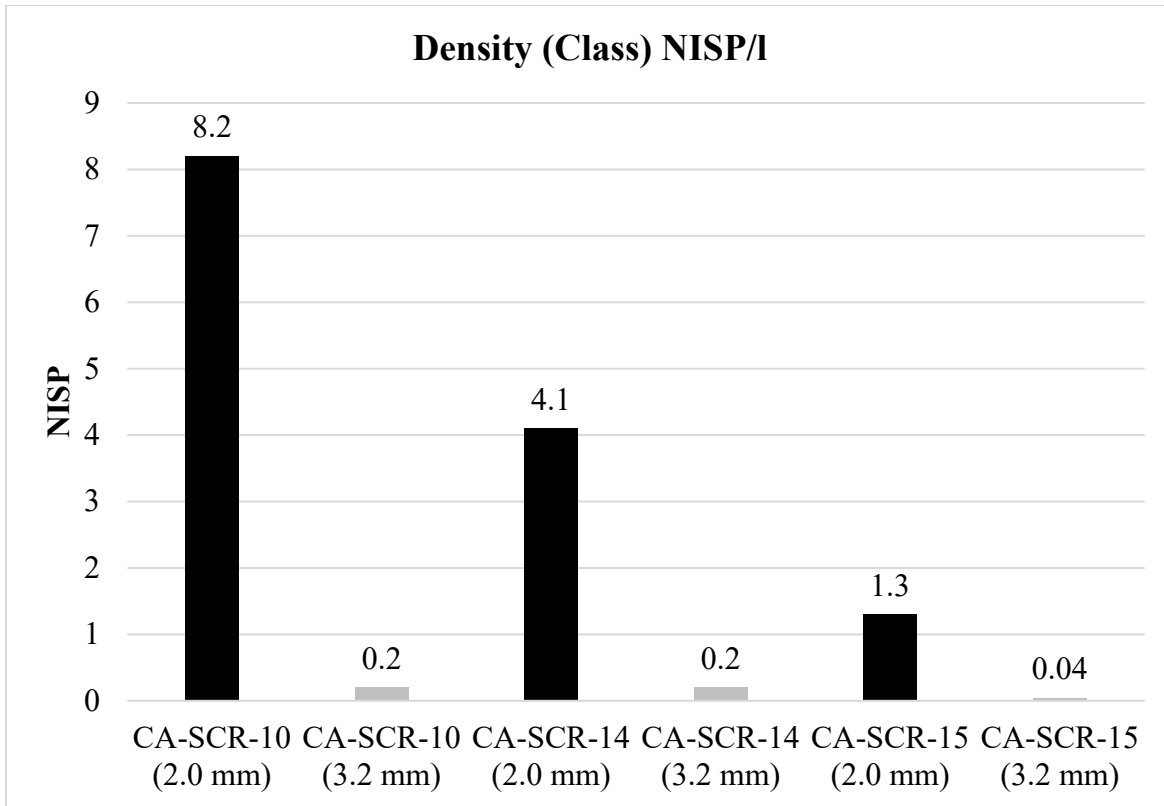


Figure 4.12. Density (Class) NISP/l for >3.2 mm and >2 mm recovery methods at CA-SCR-10, CA-SCR-14, and CA-SCR-15.

## Conclusion

The archaeology of fisheries of Santa Cruz County remains significantly understudied compared to other portions of the coastline and interior (Jones et al. 2007). While large-scale archaeological excavations within Santa Cruz County have taken place, most suffer from two serious issues. First, excavations were conducted with coarse-grained recovery methods— $\geq 6.4$  mm and 3.2 mm mesh sieves—affecting the representation of materials. Second, most excavated sites have never been systematically analyzed or formally published. Both factors affect our understanding of ancient and historical human-environmental relationships within Santa Cruz County.

In terms of ancient and historic era fisheries, there has been a dearth of data regarding human-fish relationships along the Santa Cruz coastline and the interior. This lack of information originates from the two biases reviewed above, but also from a lack of fisheries driven research, with some exceptions (Gobalet and Jones 1995). The scarcity of fisheries-related studies along the Santa Cruz coast affects not only our understanding of human subsistence practices and ancient and historic fish biogeography but also the relevancy of archaeological data in tribal cultural revitalization practices and fisheries conservation.

The findings of this case study suggest that the dearth of information regarding ancient and historic fisheries along the Santa Cruz coast is likely a result of significant recovery biases introduced through the standardization of  $>6.4$  mm and  $>3.2$  mm mesh sieves in local and regional archaeology and the lack of fine-grained analyses necessitated for the recovery of minute materials (Casteel 1970, 1972, 1976; Colley 1990; Fitch 1969; Gobalet 1989; Grayson

1984; Moss et al. 2017; Sanchez et al. 2018). These findings have relevance for Santa Cruz archaeology and the archaeological community broadly.

The results of the fish analysis for the coastline and interior suggest that from 6,740-6,660 cal BP to 4,240-4,090 cal BP at CA-SCR-7 the fishery was diverse with a variety of fishes represented. At CA-SCR-7 no single organism dominates the assemblage with the primary technology in fish acquisition likely being hook and line fishing. In contrast, at CA-SCR-10, where I analyzed fish remains from deposits dating from 5,850-5,650 cal BP to 730-670 cal BP, the fishery was predominantly comprised of fish derived from net-based and mass capture fishing, but the fish remains within site were still near to equal distribution. However, given the long-term occupation of the site and the stratigraphic reversals in the radiocarbon dates for CA-SCR-10, it is not possible to determine if net-based fishing practices commenced in the Early Period, Middle Period or Late Period.

By the Late Period at CA-SCR-14, which dates from 940-800 cal BP to 260-30 cal BP it appears that a net-based mass capture fishery that is dominated by Northern anchovy fishing is in place by this time, similar to fishery studies elsewhere in California (Boone 2012; Sanchez et al. 2018; Tushingham et al. 2013). These fishes of marine origin were being transported inland from the coast. At the nearby site CA-SCR-15, which dates from 1,180-1,000 cal BP to 470-310 cal BP we see evidence for a hook and line fishery focused primarily on marine organisms. There is limited evidence at CA-SCR-14 and CA-SCR-15 for anadromous fishes and euryhaline fishes, but we find no definitive evidence of the use of freshwater fishes.

The significant biases in previous fisheries studies have relevance for our collaborators including the Amah Mustun Tribal Band and California State Parks. As the Amah Mutsun are working to revitalize indigenous knowledge and cultural practices along the central California coast, the lack of material evidence from previous excavations cannot inform contemporary cultural revitalization. For instance, our study is the first within Santa Cruz County to identify Northern anchovy net-based fishing practices, as evidenced by faunal remains at CA-SCR-10 and CA-SCR-14. Based on the biases in previous analyses, these data would not be available to tribal collaborators unless fine-grained field and laboratory analyses are conducted. From the perspective of California State Parks, the results of our field studies can inform future archaeological permitting by providing mandatory field recovery methods, sampling strategies, and reporting procedures for fieldwork.

## Chapter 5

### Conclusion: The Archaeology of Ancient and Historic Fisheries

This dissertation investigated the eco-archaeology of ancient and historic fisheries at fourteen sites along the central California coast through the lens of historical ecology. Although the three case studies presented differ in their approaches, collaborative partnerships, methodology, and research outcomes they provide insights into the value of archaeology in understanding long-term human-fish relationships. As described in this dissertation, a growing body of literature highlights the critical role of the archaeological record in producing historical baselines, reference conditions, and in defining the historical range of variability in aquatic and terrestrial ecosystems. These data are essential for making informed resource management decisions that have relevancy for sovereign indigenous nations, state and federal agencies, conservationists, and the public. In addition to the importance of having the best available science to guide management decisions through a historical perspective of fisheries, these data are particularly pertinent for sovereign indigenous nations. As archaeological sites represent repositories of biological data and cultural knowledge and practices these data can contribute to indigenous cultural revitalization efforts and provide evidence to support Native American driven coastal and terrestrial conservation and restoration efforts. Furthermore, the continuation of indigenous cultural practices and foodways are directly tied to access to traditional foods and their presence and abundance in contemporary ecosystems.

The data presented in chapters 2 and 3 focused on the ancient and historic fisheries of Point Reyes National Seashore through the investigation of nine archaeological sites within the park. Chapter 2 outlined the findings that resulted from collaborative archaeology with the Federated Indians of Graton Rancheria and the National Park Service, and low-impact archaeological excavations. Through the analysis of bulk sediment samples taken from a series of auger probes and one column sample, I demonstrated that the Coast Miwok fishery within Point Reyes was predominantly focused on the mass-capture of Pacific herring and Pacific sardine. In contrast to the sustained fishery that the Coast Miwok maintained over many centuries, the current-day commercial fishery for Pacific herring within Tomales Bay is non-existent based on perceived reductions of these fishes.

In chapter 3, I created linear regression formulae to reconstruct the ancient size of Pacific herring from Point Reyes to understand Coast Miwok harvesting strategies and fishing technologies and techniques. I compared my findings to California Department of Fish and Wildlife data for the standard length of Pacific herring within Tomales Bay from 1972-80. The findings suggest that Coast Miwok fishers may have selectively harvested Pacific herring within Point Reyes for over 1,000 years. The archaeological datasets contrast significantly with the California Department of Fish and Wildlife data regarding Pacific herring harvests within Tomales Bay. In the conclusion of this chapter, I outline some of the implications for Coast Miwok fishing practices and their potential stewardship of seascape resources in contrast to modern commercial fishing techniques.

Chapter 4 outlined the results of collaborative research with the Amah Mutsun Tribal Band and California State Parks. Through an investigation of five archaeological sites, I demonstrated that earlier archaeological excavation and recovery strategies significantly biased the archaeological record against the recovery of fish remains within Native American sites in Santa Cruz County. The results support the use of fine-grained and low-impact excavation

methodologies in eco-archaeological analyses. However, my findings also suggest that the archaeology of fisheries within Santa Cruz County will require more robust sample sizes—or the excavation of a greater volume of sediments—to provide sufficient information to tribal and agency collaborators.

Integration of the three case studies provides insights into the ancient fisheries along the central California coast over the last 7,000 years. As evidenced at site CA-SCR-7 it appears that early indigenous fisheries may have been highly diverse with limited evidence for specialization in fishing strategies. However, by the Late Period at sites CA-SCR-14, CA-MRN-222, CA-MRN-224, CA-MRN-249, and CA-MRN-AL1 Native peoples focused primarily on the harvest of mass-captured forage fishes such as Pacific herring, Pacific sardine, and Northern anchovies within Tomales Bay and along the Santa Cruz coastline. At the inland sites CA-SCR-14, CA-SCR-15, and CA-MRN-659 I found evidence of human transportation of marine and estuarine fishes at least 13 km from their nearest source.

The shift in fisheries from broad-based to specialized is consistent with evidence from southern Oregon, northern California, and the San Francisco Bay Area (DeGeorgey 2016; Moss et al. 2017; Tushingham and Christiansen 2015; Tushingham et al. 2016). Further research is required to understand if the shift in fisheries is driven by increased human population densities, climatic anomalies, increasing territoriality and interpersonal violence, resource availability, and anthropogenic landscape modifications, among others. However, the timing of intensive fisheries within central California is closely correlated with the timing of anthropogenic landscape modifications as evidence by Cuthrell (2013), Gifford-Gonzalez et al. (2013), Lightfoot and Lopez (2013), and others in the Quiroste Valley. Nevertheless, the increased investment in the production and use of nets, a labor-intensive and materially expensive technology (Bettinger et al. 2006; Pletka 2012; Ugan et al. 2003), is consistent with resource intensification models derived from ancient fisheries studies (Boone 2012; Broughton 1997; DeGeorgey 2016; Tushingham and Christiansen 2015; Tushingham et al. 2016; Whitaker 2012), paleoethnobotanical evidence (Basgall 1987; Bettinger 2015; Bouey 1987; Wohlgenuth 1996), and zooarchaeological analyses of mammals and birds (Broughton 1994, 1999; Broughton et al. 2007).

The evidence in support of the use of fish nets within the three case studies is derived from the structure of the faunal assemblages, morphometric data, and the reconstruction of fish size through linear regression models. Changes in the relative abundance of fishes, decreased diversity values, and evenness measures also support the interpretation that a significant shift in fishing strategies occurred. As outlined by Ugan (2005) a mass collected resource may be identifiable by features within the faunal assemblage such as fish age or size structure. As outlined in chapter 3, the Pacific herring data from Point Reyes suggests the harvest of a standardized size class of fishes was likely a result of the use of gill nets to harvest these resources en masse. The use of fishing nets within Point Reyes and Santa Cruz suggests increased labor and time investment in gathering raw materials, in the production of net making tools, and the manufacture and maintenance of nets.

Research by Boone (2012) highlights the fact that many of the fishes which are abundant along the central California coast have relatively low oil content. The exceptions to these trends are forage fishes such as Pacific herring, Pacific sardine, and Northern anchovy (Boone 2012). Pacific herring flesh is reported to have high oil content at 13%, while a whole herring carcass can reach 24%. Pacific sardine has an oil content of 8-17%, and Northern anchovy is close to 9%. As highlighted by Moss (2016) dried herring roe offers high nutritional value with 294 cal

per 100 g, followed by herring meat at 270 cal. In terms of protein, dried herring roe offers 60.4 g per 100 g, followed by herring flesh at 45.7 g. Pacific herring is also rich in omega-3 fatty acids. Research by Huynh and Kitts (2009) support these conclusions demonstrating that Pacific herring had the highest fat content of all fish species sampled in their study and contained many times more total amounts of omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) than the other species. The exception is the Pacific sardine, which contains the highest amount of DHA (1.9 g per 100 g) and twice the amount that was measured in Pacific herring. Therefore, from a nutritional perspective, the emphasis of the mass-capture of forage fishes along the central California coast may have significantly increased the nutritive value for Native peoples reliant upon these fishes.

In conclusion, the archaeology of ancient and historic fisheries offer critical information that is relevant today for fisheries management, conservation biology, indigenous communities, and the public. The findings reported in this dissertation advocate for the investment of more intensive recovery and sampling strategies in the study of fisheries within archaeology, consistent with the recommendations of my predecessors (Cannon 2000; Casteel 1970, 1972, 1976; Colley 1990; Fitch 1969; Gobalet 1989; Moss et al. 2017; Tushingham et al. 2013). Through the application of these methodologies and more consistent reporting of zooarchaeological data the archaeological record can provide information that has significance far beyond the field of archaeology (Driver 2011; Gobalet 2001, 2017; Lauwerier and Plug 2004; Lyman 1996; Lyman and Cannon 2004; Wolverson and Lyman 2012; Wolverson et al. 2016). These data can inform the management of our aquatic and terrestrial ecosystems, which advance the protection of seascapes and organisms based on the best available science.

## References

Agrawal, Arun

1995 Dismantling the Divide Between Indigenous and Scientific Knowledge. *Development and Change* 26(3):413–439.

Alves, Rômulo Romeu Nóbrega, and Wedson Medeiros Silva Souto

2015 Ethnozoology: A Brief Introduction. *Ethnobiology and Conservation* 4(1):1–13.

Amorosi, Thomas, James Woollett, Sophia Perdikaris, and Thomas McGovern

1996 Regional Zooarchaeology and Global Change: Problems and Potentials. *World Archaeology* 28(1):126–157.

An, Heui-Chun, Jae-Hyun Bae, and Seonghun Kim

2013 Study on the Size Selectivity of a Gillnet for Pacific Herring (*Clupea pallasii*) in the Eastern Sea of Korea. *Journal of the Korean Society of Fisheries and Ocean Technology* 49(4):360–367.

Araral, Eduardo

2014 Ostrom, Hardin and the Commons: A Critical Appreciation and a Revisionist View. *Environmental Science & Policy* 36. Interrogating the Commons:11–23.

Armitage, Derek R., Fikret Berkes, and Nancy Doubleday

2007 *Adaptive Co-management: Collaboration, Learning, and Multi-level Governance*. Sustainability and the Environment. University of British Columbia, Vancouver.

Armitage, Derek R., Ryan Plummer, Fikret Berkes, Robert I. Arthur, Anthony T. Charles, Iain J. Davidson-Hunt, Alan P. Diduck, Nancy C. Doubleday, Derek S. Johnson, Melissa Marschke, Patrick McConney, Evelyn W. Pinkerton, and Eva K. Wollenberg

2009 Adaptive Co-management for Social-ecological Complexity. *Frontiers in Ecology and the Environment* 7(2):95–102.

Ashmore, Patrick J.

1999 Radiocarbon Dating: Avoiding Errors by Avoiding Mixed Samples. *Antiquity* 73(279):124–130.

Balée, William L.

1992 People of the Fallow: A Historical Ecology of Foraging in Lowland South America. In *Conservation of Neotropical Forests: Working from Traditional Resource Use*, edited by Kent Hubbard Redford and Christine Padoch, pp. 35–57. Columbia University Press, New York.

1998a *Advances in Historical Ecology*. The Historical Ecology Series. Columbia University Press, New York.

1998b Introduction. In *Advances in Historical Ecology*, edited by William L. Balée, pp. 1–10. The Historical Ecology Series. Columbia University Press, New York.

1998c Historical Ecology: Premises and Postulates. In *Advances in Historical Ecology*, edited by William L. Balée, pp. 13–29. The Historical Ecology Series. Columbia University Press, New York.

2006 The Research Program of Historical Ecology. *Annual Review of Anthropology* 35:75–98.

2010 Contingent Diversity on Anthropic Landscapes. *Diversity* 2(2):163–181.

2018 Brief Review of Historical Ecology. *Les nouvelles de l'archéologie*(152):7–10.

Balée, William L., and Clark L. Erickson

2006 *Time and Complexity in Historical Ecology: Studies in the Neotropical Lowlands*. The Historical Ecology Series. Columbia University Press, New York.

Barker, Graeme

1975 To Sieve or Not to Sieve. *Antiquity* 49(193):61–63.

Barrett, James H.

1997 Fish Trade in Norse Orkney and Caithness: A Zooarchaeological Approach. *Antiquity* 71(273):616–638.

Bartling, Ryan D.

2007 *Summary of 2006-2007 Tomales Bay Pacific Herring Commercial Fishery*. California Department of Fish and Wildlife, Belmont.

Basgall, Mark E.

1987 Resource Intensification Among Hunter-gatherers: Acorn Economies in Prehistoric California. *Research in Economic Anthropology* 9:21–52.

Bayham, Frank E.

1979 Factors Influencing the Archaic Pattern of Animal Exploitation. *Kiva* 44(2/3):219–235.

Beardsley, Richard K.

1948 Culture Sequences in Central California Archaeology. *American Antiquity* 14(1):1–28.

1954 *Temporal and Areal Relationships in Central California Archaeology*. Reports of the University of California Archaeological Survey no. 24-25. University of California Archaeological Survey, Department of Anthropology, Berkeley.

Beaton, John M.

1991 Extensification and Intensification in Central California Prehistory. *Antiquity* 65(249):946–952.

Beller, Erin, Loren McClenachan, Andrew Trant, Eric W. Sanderson, Jeanine Rhemtulla, Anita Guerrini, Robin Grossinger, and Eric Higgs

2017 Toward Principles of Historical Ecology. *American Journal of Botany* 104(5):645–648.

Berkes, Fikret

2007 Adaptive Co-management and Complexity: Exploring the Many Faces of Co-Management. In *Adaptive Co-management: Collaboration, Learning, and Multi-level*

- Governance*, edited by Derek R. Armitage, Fikret Berkes, and Nancy Doubleday, pp. 19–37. Sustainability and the Environment. University of British Columbia, Vancouver.
- 2009 Evolution of Co-management: Role of Knowledge Generation, Bridging Organizations and Social Learning. *Journal of Environmental Management* 90(5):1692–1702.
- 2018 *Sacred ecology*. Routledge, New York.
- Berkes, Fikret, and Carl Folke
- 2002 Why Systems of People and Nature Are Not Just Social and Ecological Systems. In *Panarchy: Understanding Transformations in Human and Natural Systems*, edited by Lance H. Gunderson and C. S. Holling, pp. 121–146. Island Press, Washington, DC.
- Bertrando, Ethan B., and Dustin K. McKenzie
- 2012 Identifying Fishing Techniques from the Skeletal Remains of Fish. In *Exploring Methods of Faunal Analysis: Insights from California Archaeology*, edited by Michael A. Glassow and Terry L. Joslin, pp. 169–186. Perspectives in California Archaeology. Cotsen Institute of Archaeology, University of California, Los Angeles.
- Bettinger, Robert L.
- 1991 *Hunter-gatherers: Archaeological and Evolutionary Theory*. Interdisciplinary Contributions to Archaeology. Plenum Press, New York.
- 2015 *Orderly Anarchy: Sociopolitical Evolution in Aboriginal California*. Origins of Human Behavior and Culture: 8. University of California Press, Oakland.
- Bettinger, Robert L., Bruce Winterhalder, and Richard McElreath
- 2006 A Simple Model of Technological Intensification. *Journal of Archaeological Science* 33(4):538–545.
- Binford, Lewis R.
- 1964 A Consideration of Archaeological Research Design. *American Antiquity* 29(4):425–441.
- Bird, Douglas W., and James F. O’Connell
- 2006 Behavioral Ecology and Archaeology. *Journal of Archaeological Research* 14(2):143–188.
- 2012 Human Behavioral Ecology. In *Archaeological Theory Today*, edited by Ian Hodder, pp. 37–61. Polity Press, Cambridge.
- Bocek, Barbara R.
- 1984 Ethnobotany of Costanoan Indians, California, Based on Collections by John P. Harrington. *Economic Botany* 38(2):240–255.
- Boivin, Nicole L., Melinda A. Zeder, Dorian Q. Fuller, Alison Crowther, Greger Larson, Jon M. Erlandson, Tim Denham, and Michael D. Petraglia
- 2016 Ecological Consequences of Human Niche Construction: Examining Long-term Anthropogenic Shaping of Global Species Distributions. *Proceedings of the National Academy of Sciences*:6388–6396.

Boone, Cristie

2012 Integrating Zooarchaeology and Modeling: Trans-Holocene Fishing in Monterey Bay, California. Unpublished Ph.D. Dissertation, Department of Anthropology, University of California, Santa Cruz, Santa Cruz.

Boserup, Ester

1965 *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure*. Aldine Publishing Company, Chicago.

Bouey, Paul D.

1987 The Intensification of Hunter-gatherer Economies in the Southern North Coast Ranges of California. *Research in Economic Anthropology* 9:53–101.

Braje, Todd J.

2007 Archaeology, Human Impacts, and Historical Ecology on San Miguel Island, California. Unpublished Ph.D. Dissertation, University of Oregon, Eugene.

Braje, Todd J., and Jon M. Erlandson

2013 Human Acceleration of Animal and Plant Extinctions: A Late Pleistocene, Holocene, and Anthropocene Continuum. *Anthropocene* 4. When Humans Dominated the Earth: Archeological Perspectives on the Anthropocene:14–23.

Braje, Todd J., and Torben C. Rick

2011 *Human Impacts on Seals, Sea Lions, and Sea Otters: Integrating Archaeology and Ecology in the Northeast Pacific*. University of California Press, Berkeley.

Braje, Todd J., Torben C. Rick, Paul Szpak, Seth D. Newsome, Joseph M. McCain, Emma A. Elliott Smith, Michael Glassow, and Scott L. Hamilton

2017 Historical Ecology and the Conservation of Large, Hermaphroditic Fishes in Pacific Coast Kelp Forest Ecosystems. *Science Advances* 3(2):e1601759.

Breschini, Gary S., and Trudy Haversat

2000 *Archaeological Data Recovery at CA-SCR-44, at the Site of the Lakeview Middle School, Watsonville, Santa Cruz County, California*. Coyote Press Archives of California Prehistory 49. Coyote Press, Salinas.

Broughton, Jack M.

1994a Declines in Mammalian Foraging Efficiency During the Late Holocene, San Francisco Bay, California. *Journal of Anthropological Archaeology* 13(4):371–401.

1994b Late Holocene Resource Intensification in the Sacramento Valley, California: The Vertebrate Evidence. *Journal of Archaeological Science* 21(4):501–514.

1997 Widening Diet Breadth, Declining Foraging Efficiency, and Prehistoric Harvest Pressure: Ichthyofaunal Evidence from the Emeryville Shellmound, California. *Antiquity* 71(274):845–862.

- 1999 *Resource Depression and Intensification During the Late Holocene, San Francisco Bay: Evidence from the Emeryville Shellmound Vertebrate Fauna*. University of California Publications. Anthropological Records v. 32. University of California Press, Berkeley.
- 2004 Pristine Benchmarks and Indigenous Conservation? Implications from California Zooarchaeology. In *The Future from the Past: Archaeozoology in Wildlife Conservation and Heritage Management*, edited by Roel C.G.M Lauwerier and Ina Plug, pp. 6–18. Oxbow, Oxford.
- Broughton, Jack M., Erik P Martin, Brian McEneaney, Thomas Wake, and Dwight D. Simons  
2015 Late Holocene Anthropogenic Depression of Sturgeon in San Francisco Bay, California. *Journal of California and Great Basin Anthropology* 35(1):3–27.
- Broughton, Jack M., Daniel Mullins, and Tamara Ekker  
2007 Avian Resource Depression or Intertaxonomic Variation in Bone Density? A Test with San Francisco Bay Avifaunas. *Journal of Archaeological Science* 34(3):374–391.
- Broughton, Jack M., and James F. O’Connell  
1999 On Evolutionary Ecology, Selectionist Archaeology, and Behavioral Archaeology. *American Antiquity* 64(1):153–165.
- Bürgi, Matthias, and Urs Gimmi  
2007 Three Objectives of Historical Ecology: The Case of Litter Collecting in Central European Forests. *Landscape Ecology* 22(S1):77–87.
- Butler, Virginia L.  
1996 Tui Chub Taphonomy and the Importance of Marsh Resources in the Western Great Basin of North America. *American Antiquity* 61(4):699–717.
- Butler, Virginia L., and Sarah K. Campbell  
2004 Resource Intensification and Resource Depression in the Pacific Northwest of North America: A Zooarchaeological Review. *Journal of World Prehistory* 18(4):327–405.
- Butler, Virginia L., and Michael G. Delacorte  
2004 Doing Zooarchaeology as if it Mattered: Use of Faunal Data to Address Current Issues in Fish Conservation Biology in Owens Valley, California. In *Zooarchaeology and Conservation Biology*, edited by Lee R. Lyman and Kenneth P. Cannon, pp. 25–44. The University of Utah Press, Salt Lake City.
- Butler, Virginia L., and Roy A. Schroeder  
1998 Do Digestive Processes Leave Diagnostic Traces on Fish Bones? *Journal of Archaeological Science* 25(10):957–971.
- Caldwell, Megan E., Dana Lepofsky, Georgia Combes, Michelle Washington, John R. Welch, and John R. Harper  
2012 A Bird’s Eye View of Northern Coast Salish Intertidal Resource Management Features,

Southern British Columbia, Canada. *The Journal of Island and Coastal Archaeology* 7(2):219–233.

California Department of Fish and Wildlife

2008 *Supplemental Environmental Document: Pacific Herring Commercial Fishing Regulations (Sections 163 and 164, Title 14, California Code of Regulations)*. State of California, The Natural Resources Agency, Department of Fish and Wildlife.

Callaghan, Catherine A.

1991 Encounter with John P. Harrington. *Anthropological Linguistics* 33(4):350–356.

Campbell, Breana, and Todd J. Braje

2015 Estimating California Mussel (*Mytilus californianus*) Size from Hinge Fragments: A Methodological Application in Historical Ecology. *Journal of Archaeological Science* 58:167–174.

Campbell, Greg

2015 “We Want to Go, Where Everyone Knows, Mussels Are All the Same...”: A Comment on Some Recent Zooarchaeological Research on *Mytilus californianus* Size Prediction. *Journal of Archaeological Science* 63:156–159.

Cannon, Aubrey

2000 Assessing Variability in Northwest Coast Salmon and Herring Fisheries: Bucket-Auger Sampling of Shell Midden Sites on the Central Coast of British Columbia. *Journal of Archaeological Science* 27(8):725–737.

Cartier, Robert

1989 Scotts Valley Chronology and Temporal Stratigraphy. *Proceedings of the Society for California Archaeology* 2(8):81–111.

Casteel, Richard W.

1970 Core and Column Sampling. *American Antiquity* 35(4):465–467.

1972 Some Biases in the Recovery of Archaeological Faunal Remains. In *Proceedings of the Prehistoric Society*, 38:pp. 382–388. Cambridge University Press, Cambridge.

1974 A Method for Estimation of Live Weight of Fish from the Size of Skeletal Elements. *American Antiquity* 39(1):94–98.

1976a *Fish Remains in Archaeology and Paleo-environmental Studies*. Studies in Archaeological Science. Academic Press, New York.

1976b Comparison of Column and Whole Unit Samples for Recovering Fish Remains. *World Archaeology* 8(2):192–196.

Colley, Charles C.

1970 The Missionization of the Coast Miwok Indians of California. *California Historical Society Quarterly* 49(2):143–162.

Colley, Sarah M.

1987 Fishing for Facts. Can We Reconstruct Fishing Methods from Archaeological Evidence? *Australian Archaeology*(24):16–26.

1990 The Analysis and Interpretation of Archaeological Fish Remains. In *Archaeological Method and Theory*, edited by Michael B. Schiffer, 2:pp. 207–253. University of Arizona Press, Tucson.

Cook, Sherburne Friend

1943 *The Conflict Between the California Indian and White Civilization III: The American Invasion 1848-1870*. University of California Press, Berkeley.

Cowart, Alicia, and Roger Byrne

2013 A Paleolimnological Record of Late Holocene Vegetation Change from the Central California Coast. *California Archaeology* 5(2):337–352.

Cronk, Lee

1991 Human Behavioral Ecology. *Annual Review of Anthropology* 20:25–53.

Crumley, Carole L.

1994 *Historical Ecology: Cultural Knowledge and Changing Landscapes*. School of American Research Advanced Seminar Series. School of American Research Press, Sante Fe.

2007 Historical Ecology: Integrated Thinking at Multiple Temporal and Spatial Scales. In *The World System and the Earth System: Global Socioenvironmental Change and Sustainability Since the Neolithic*, edited by Alf Hornborg and Carole L. Crumley, pp. 15–28. Left Coast Press, Walnut Creek.

2017 Historical Ecology and the Study of Landscape. *Landscape Research* 42:S65–S73.

Culleton, Brendan J., Robert H. Gargett, and Thomas L. Jackson

2005 *Data Recovery Excavations at CA-SCR-60/130 for the Pajaro Valley Water Management Agency Local Water Supply and Distribution Project*. Pacific Legacy Incorporated, Santa Cruz.

Cuthrell, Rob Q.

2013a Archaeobotanical Evidence for Indigenous Burning Practices and Foodways at CA-SMA-113. *California Archaeology* 5(2):265–290.

2013b An Eco-archaeological Study of Late Holocene Indigenous Foodways and Landscape Management Practices at Quiroste Valley Cultural Preserve, San Mateo County, California. Unpublished Ph.D. Dissertation, Department of Anthropology, University of California, Berkeley, Berkeley.

Cuthrell, Rob Q., Mark G. Hylkema, and Laurel Collins

2013 Natural Resources, Geomorphology, and Archaeology of Site CA-SMA-113 in Quiroste Valley Cultural Preserve, California. *California Archaeology* 5(2):247–264.

Cuthrell, Rob Q., Chuck Striplen, Mark G. Hylkema, Kent G. Lightfoot, Terry L. Jones, and Jennifer E. Perry

2012 A Land of Fire: Anthropogenic Burning on the Central Coast of California. *Contemporary Issues in California Archaeology*:153–172.

DeGeorgey, Alex

2016 *Archaeological Excavation of the Stege Mound (CA-CCO-297), A Late Period Shell Mound Located on the San Francisco Bayshore*. Alta Archaeological Consulting, Santa Rosa.

Denevan, William M.

1992 The Pristine Myth: The Landscape of the Americas in 1492. *Annals of the Association of American Geographers* 82(3):369-385.

Driver, Jonathan C.

2011 Identification, Classification and Zooarchaeology. *Ethnobiology Letters* 2:19–39.

Eerkens, Jelmer W.

1999 Common Pool Resources, Buffer Zones, and Jointly Owned Territories: Hunter-gatherer Land and Resource Tenure in Fort Irwin, Southeastern California. *Human Ecology* 27(2):297–318.

Egan, Dave, and Evelyn A. Howell

2005 *The Historical Ecology Handbook: A Restorationist's Guide to Reference Ecosystems*. The Science and Practice of Ecological Restoration. Island Press, Washington, DC.

Enticknap, Ben, Ashley Blacow, Geoff Shester, Whit Sheard, Jon Warrenchuk, Mike LeVine, and Susan Murray

2011 *Forage Fish: Feeding the California Current Large Marine Ecosystem*. Marine Forage Species Management off the U.S. West Coast. Oceana, Washington D.C.

Erickson, Clark L.

2003 Historical Ecology and Future Explorations. In *Amazonian Dark Earths: Origin Properties Management*, edited by Johannes Lehmann, Dirse C. Kern, Brund Glaser, and William I. Wodos, pp. 455–500. Springer, Dordrecht.

2008 Amazonia: The Historical Ecology of a Domesticated Landscape. In *Handbook of South American Archaeology*, edited by Helaine Silverman and William H. Isbell, pp. 157–183. Springer, New York.

Erlandson, Jon M., and Torben C. Rick

2008 Archaeology, Marine Ecology, and Human Impacts on Marine Environments. In *Human Impacts on Ancient Marine Ecosystems: A Global Perspective*, edited by Torben C. Rick and Jon M. Erlandson, pp. 1–19. University of California Press, Berkeley, CA.

2010 Archaeology Meets Marine Ecology: The Antiquity of Maritime Cultures and Human Impacts on Marine Fisheries and Ecosystems. *Annual Review of Marine Science* 2(1):231–251.

Erlandson, Jon M., Torben C. Rick, and Todd J. Braje

2009 Fishing up the Food Web?: 12,000 Years of Maritime Subsistence and Adaptive Adjustments on California's Channel Islands. *Pacific Science* 63(4):711–724.

Evvett, Rand R., and Rob Q. Cuthrell

2013 Phytolith Evidence for a Grass-dominated Prairie Landscape at Quiroste Valley on the Central Coast of California. *California Archaeology* 5(2):319–335.

Faith, Tyler J., and Andrew Du

2017 The Measurement of Taxonomic Evenness in Zooarchaeology. *Archaeological and Anthropological Sciences*:1–10.

Fine, Paul V. A., Tracy M. Misiewicz, Andreas S. Chavez, and Rob Q. Cuthrell

2013 Population Genetic Structure of California Hazelnut, An Important Food Source for People in Quiroste Valley in the Late Holocene. *California Archaeology* 5(2):353–370.

Fisher, John W. Jr.

1995 Bone Surface Modifications in Zooarchaeology. *Journal of Archaeological Method and Theory* 2(1):7–68.

Fitch, John E.

1969 Fish Remains, Primarily Otoliths, from a Ventura, California, Chumash Village Site (VEN-3). *Memoirs of the Southern California Academy of Sciences* 8:56–71.

FitzGibbon, Clare

1998 The Management of Subsistence Harvesting: Behavioral Ecology of Hunters and Their Mammalian Prey. In *Behavioral Ecology and Conservation Biology*, edited by Tim Caro, pp. 449–473. Oxford University Press, New York.

Folke, Carl, Steve Carpenter, Thomas Elmqvist, Lance Gunderson, C. S. Holling, and Brian Walker

2002 Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations. *Ambio* 31(5):437–440.

Follett, Wilbur Irving

1957 Fish Remains from a Shellmound in Marin County, California. *American Antiquity* 23(1):68–71.

1964 *Fish Remains from a Sixteenth Century Site on Drakes Bay, California*. Archaeological Survey Annual Report, 1963–1964. Department of Anthropology, University of California, Los Angeles.

Foster, David, Frederick Swanson, John Aber, Ingrid Burke, Nicholas Brokaw, David Tilman, and Alan Knapp

2003 The Importance of Land-Use Legacies to Ecology and Conservation. *BioScience* 53(1):77–88.

Fowler, Catherine S., and Dana Lepofsky

2011 Traditional Resource and Environmental Management. In *Ethnobiology*, edited by Eugene N. Anderson, Deborah M. Pearsall, Eugene S. Hunn, and Nancy J. Turner, 2011:pp. 285–304. Wiley-Blackwell, Hoboken.

- Frazier, J.  
2007 Sustainable Use of Wildlife: The View from Archaeozoology. *Journal for Nature Conservation* 15(3):163–173.
- Froehlich, Halley E., Nis Sand Jacobsen, Timothy E. Essington, Tyler Clavelle, and Benjamin S. Halpern  
2018 Avoiding the Ecological Limits of Forage Fish for Fed Aquaculture. *Nature Sustainability* 1(6):298–303.
- Gifford, Diane P., and Francine Marshall  
1984 *Analysis of the Archaeological Assemblage from CA-SCR-35 Santa Cruz County, California*. Coyote Press, Salinas.
- Gifford, Edward W.  
1916 *Composition of California Shellmounds*. Vol. 12(1). University of California Publications in American Archaeology and Ethnology, Berkeley.
- Gifford-Gonzalez, Diane, Cristie M. Boone, and Rachel E. Reid  
2013 The Fauna from Quiroste: Insights into Indigenous Foodways, Culture, and Land Modification. *California Archaeology* 5(2):291–317.
- Gobalet, Kenneth W.  
1989 Remains of Tiny Fish from a Late Prehistoric Pomo Site near Clear Lake, California. *Journal of California and Great Basin Anthropology* 11(2):231–239.  
1992 Inland Utilization of Marine Fishes by Native Americans along the Central California Coast. *Journal of California and Great Basin Anthropology* 14(1):72–84.  
1993 Additional Archaeological Evidence for Endemic Fishes of California's Central Valley in the Coastal Pajaro-Salinas Basin. *The Southwestern Naturalist*:218–223.  
2000 Has Point Conception been a Marine Zoogeographic Boundary Throughout the Holocene? Evidence from the Archaeological Record. *Bulletin of the Southern California Academy of Sciences* 99(1):32–44.  
2001 A Critique of Faunal Analysis; Inconsistency Among Experts in Blind Tests. *Journal of Archaeological Science* 28(4):377–386.  
2012 A Native Californian's Meal of Coho Salmon (*Oncorhynchus kisutch*) Has Legal Consequences for Conservation Biology. In *Exploring Methods of Faunal Analysis: Insights from California Archaeology*, edited by Michael A. Glassow and Terry L. Joslin, 9:pp. 87–96. Perspectives in California Archaeology. Cotsen Institute of Archaeology, University of California, Los Angeles.  
2014 Challenges of Using Archaeological Fish Remains to Establish the Ranges of Native California Freshwater Fishes with Emphasis on Fish Remains from the Cuyama Valley, California. In *Cuyama Valley-A Corridor to the Past*, 3, Appendix C: Published for Caltrans District 5, San Luis Obispo and Santa Barbara Counties, State Route 166 Post Miles R23.72-R35.73 EA/ID 0512000035-0(OF- 1A8800).  
2017 A Zoologist's Perspective on Presenting Archaeological Faunal Data. *Journal of California & Great Basin Anthropology* 37(1):79.

- Gobalet, Kenneth W., and Terry L. Jones  
1995 Prehistoric Native American Fisheries of the Central California Coast. *Transactions of the American Fisheries Society* 124(6):813–823.
- Gobalet, Kenneth W., Peter D. Schulz, Thomas A. Wake, and Nelson Siefkin  
2004 Archaeological Perspectives on Native American Fisheries of California, with Emphasis on Steelhead and Salmon. *Transactions of the American Fisheries Society* 133(4):801–833.
- Gonzalez, Sara L.  
2016 Indigenous Values and Methods in Archaeological Practice: Low-Impact Archaeology Through the Kashaya Pomo Interpretive Trail Project. *American Antiquity* 81(3):533–549.
- Gonzalez, Sara L., Darren Modzelewski, Lee M. Panich, and Tsim D. Schneider  
2006 Archaeology for the Seventh Generation. *The American Indian Quarterly* 30(3):388–415.
- Grayson, Donald K.  
1984 *Quantitative Zooarchaeology: Topics in the Analysis of Archaeological Faunas*. Studies in Archaeological Science. Academic Press, Orlando.  
2001 The Archaeological Record of Human Impacts on Animal Populations. *Journal of World Prehistory* 15(1):1–68.
- Greenspan, Ruth L.  
1998 Gear Selectivity Models, Mortality Profiles and the Interpretation of Archaeological Fish Remains: A Case Study from the Harney Basin, Oregon. *Journal of Archaeological Science* 25(10):973–984.
- Gunderson, Lance H., and C. S. Holling  
2002 *Panarchy: Understanding Transformations in Human and Natural Systems*. Island Press, Washington, DC.
- Hammer, Øyvind, David A. T. Harper, and Paul D. Ryan  
2001 PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4(1):109.
- Hardin, Garrett  
1968 The Tragedy of the Commons. *Science* 162(3859):1243–1248.
- Harper, David A. T.  
1999 *Numerical Palaeobiology: Computer-based Modelling and Analysis of Fossils and Their Distributions*. John Wiley & Sons, New York.
- Heino, Mikko, and Olav Rune God  
2002 Fisheries-Induced Selection Pressures in the Context of Sustainable Fisheries. *Bulletin of Marine Science* 70(2):639–656.

Heizer, Robert F.

1941 Archeological Evidence of Sebastian Rodriguez Cermeño's California Visit in 1595. *California Historical Society Quarterly* 20(4):315–328.

1974 *They were Only Diggers: A Collection of Articles from California Newspapers, 1851-1866, on Indian and White Relations*. Ballena Press Publications in Archaeology, Ethnology, and History no. 1. Ballena Press, Ramona.

Heizer, Robert F., and Albert B. Elsasser

1980 *The Natural World of the California Indians*. California Natural History Guides: 46. University of California Press, Berkeley.

Henn, Winfield G.

1970 Faunal Analysis of 4-MRN-216, A Seasonal Site on Limantour Sandspit, Point Reyes National Seashore. In *Contributions to the Archaeology of Point Reyes National Seashore: A Compendium in Honor of Adan E. Treganza*, edited by Robert E. Schenk, pp. 195–210. Treganza Museum Papers 6. Treganza Anthropology Museum, San Francisco.

Hill, Kevin T, Paul R. Crone, and Juan Zwolinsky

2017 *Assessment of the Pacific Sardine Resource in 2017 for U.S. Management in 2017-18*. US Department of Commerce.

Holling, Crawford S.

1978 *Adaptive Environmental Assessment and Management*. International Series on Applied Systems Analysis. Wiley, New York.

Hughes, Brent B., Ron Eby, Eric Van Dyke, M. Tim Tinker, Corina I. Marks, Kenneth S. Johnson, and Kerstin Wasson

2013 Recovery of a Top Predator Mediates Negative Eutrophic Effects on Seagrass. *Proceedings of the National Academy of Sciences of the United States of America* 110(38):15313–15318.

Hunn, Eugene S., Darryll R. Johnson, Priscilla N. Russell, and Thomas F. Thornton

2003 Huna Tlingit Traditional Environmental Knowledge, Conservation, and the Management of a “Wilderness” Park. *Current Anthropology* 44(S5):S79–S103.

Huntington, Brittany E., and Katharyn E. Boyer

2008 Effects of Red Macroalgal (*Gracilariopsis* sp.) Abundance on Eelgrass *Zostera marina* in Tomales Bay, California, USA. *Marine Ecology Progress Series* 367:133–142.

Huynh, Minh Dieu, and David D. Kitts

2009 Evaluating Nutritional Quality of Pacific Fish Species from Fatty Acid Signatures. *Food Chemistry* 114(3):912–918.

Hylkema, Mark G.

1991 Prehistoric Native American Adaptations Along the Central California Coast of San

Mateo and Santa Cruz Counties. Unpublished Masters Thesis, San Jose State University, San Jose.

2002 Tidal Marsh, Oak Woodlands, and Cultural Florescence in the Southern San Francisco Bay Region. In *Catalysts to Complexity: Late Holocene Societies of the California Coast*, edited by Jon Erlandson, Terry L. Jones, and Jeanne E. Arnold, pp. 233–262. Cotsen Institute of Archaeology, University of California, Los Angeles.

Hylkema, Mark G., and Rob Q. Cuthrell

2013 An Archaeological and Historical View of Quiroste Tribal Genesis. *California Archaeology* 5(2):225–245.

Ingólfsson, Ólafur Arnar, Haraldur Arnar Einarsson, and Svein Løkkeborg

2017 The Effects of Hook and Bait Sizes on Size Selectivity and Capture Efficiency in Icelandic Longline Fisheries. *Fisheries Research* 191:10–16.

Jacknis, Ira

1993 Introduction: Museum Anthropology in California, 1889-1939. *Museum Anthropology* 17(2):3–6.

Jackson, Jeremy B. C.

2008 Ecological Extinction and Evolution in the Brave New Ocean. *Proceedings of the National Academy of Sciences* 105:11458–11465.

Jackson, Jeremy B. C., Michael X. Kirby, Wolfgang H. Berger, Karen A. Bjorndal, Louis W. Botsford, Bruce J. Bourque, Roger H. Bradbury, Richard Cooke, Jon Erlandson, James A. Estes, Terence P. Hughes, Susan Kidwell, Carina B. Lange, Hunter S. Lenihan, John M. Pandolfi, Charles H. Peterson, Robert S. Steneck, Mia J. Tegner, and Robert R. Warner

2001 Historical Overfishing and the Recent Collapse of Coastal Ecosystems. *Science* 293(5530):629–638.

Jones, Deborah A., and William R. Hildebrandt

1990 *Archaeological Excavation at Sand Hill Bluff: Portions of a Prehistoric Site CA-SCR-7, Santa Cruz County, California*. Far Western Anthropological Research Group, INC., Davis.

1994 *Archaeological Investigations at Sites CA-SCR-10, CA-SCR-17, CA-SCR-304, AND CA-SCR-38/123 for the North Coast Treated Water Main Project, Santa Cruz County, California*. Far Western Anthropological Research Group, INC., Davis.

Jones, Terry L., Kenneth W. Gobalet, and Brian F. Coddling

2016 The Archaeology of Fish and Fishing on the Central Coast of California: The Case for an Under-exploited Resource. *Journal of Anthropological Archaeology* 41:88–108.

Jones, Terry L., and Douglas J. Kennett

1999 Late Holocene Sea Temperatures Along the Central California Coast. *Quaternary Research* 51(01):74–82.

Jones, Terry L., Nathan E. Stevens, Deborah A. Jones, Richard T. Fitzgerald, and Mark G.

Hylkema

2007 The Central Coast: A Midlatitude Milieu. In *California Prehistory: Colonization, Culture, and Complexity*, edited by Terry L. Jones and Kathryn A. Klar, pp. 125–146. AltaMira Press, Lanham.

Kelly, Isabel

1978 Coast Miwok. In *Handbook of North American Indians*, edited by Robert F. Heizer, 8 California:pp. 414–425. Smithsonian Institution, Washington D.C.

Kelly, Isabel T.

1991 *Interviews with Tom Smith and Maria Copa: Isabel Kelly's Ethnographic Notes on the Coast Miwok Indians of Marin and Southern Sonoma Counties, California*. Edited by Mary E. T. Collier and Sylvia Barker Thalman. Marin Archaeological Preserve of Marin Occasional Papers 6. Miwok Archaeological Preserve of Marin, San Rafael.

Kelly, J. P., and S. L. Tappen

1998 Distribution, Abundance, and Implications for Conservation of Winter Waterbirds on Tomales Bay, California. *Western Birds* 29:103–120.

Kidder, Tristram R.

2013 Observations About the Historical Ecology of Small-Scale Societies. In *The Archaeology and Historical Ecology of Small Scale Economies*, edited by Victor D. Thompson and James C. Waggoner Jr., pp. 176–183. University Press of Florida, Gainesville.

Kimmerer, Robin Wall, and Kanawha Lake Lake

2001 The Role of Indigenous Burning in Land Management. *Journal of Forestry* 99(11):36–41.

Krech, Shepard

1999 *The Ecological Indian: Myth and History*. 1st ed. W.W. Norton & Co, New York.

Kroeber, Alfred L.

1925 *Handbook of the Indians of California*. Smithsonian Institution, Bureau of American Ethnology Bulletin 78. Government Printing Office, Washington, D.C.

Kroeber, Alfred L., and Samuel Alfred Barrett

1960 *Fishing Among the Indians of Northwestern California*. Vol. 21. Anthropological Records 1. University of California Press, Berkeley.

Laerhoven, Frank van, and Elinor Ostrom

2007 Traditions and Trends in the Study of the Commons. *International Journal of the Commons* 1(1):3–28.

Langenwaller, Paul E. II

2000 Vertebrate Animal Remains Recovered from CA-SCR-44 near Watsonville, Santa Cruz County, California. In *Archaeological Data Recovery at CA-SCR-44, at the Site of the Lakeview*

*Middle School, Watsonville, Santa Cruz County, California*, edited by Gary S. Breschini and Trudy Haversat, pp. 153–193. Coyote Press Archives of California Prehistory 49. Coyote Press, Salinas.

Langenwalter, Paul E. II, and Brenda Bowser

1992 Vertebrate Animal Remains from Three Inland Late Period Archaeological Sites (CA-MNT-1481, CA-MNT-1485/H, CA-MNT-1486/H), Carmel Valley, Monterey County, California. In *Baseline Archaeological Studies at Rancho San Carlos, Carmel Valley, Monterey County, California*, 36. Archives of California Prehistory. Coyote Press, Salinas.

Lauwerier, Roel C.G.M, and Ina Plug (editors)

2004 *The Future from the Past: Archaeozoology in Wildlife Conservation and Heritage Management*. Oxbow Books, Oxford.

Lepofsky, Dana

2009 The Past, Present, and Future of Traditional Resource and Environmental Management. *Journal of Ethnobiology* 29(2):161–166.

Lepofsky, Dana, and Chelsey Geralda Armstrong

2018 Foraging New Ground: Documenting Ancient Resource and Environmental Management in Canadian Archaeology. *Canadian Journal of Archaeology* 42(1):57–73.

Lepofsky, Dana, and Megan Caldwell

2013 Indigenous Marine Resource Management on the Northwest Coast of North America. *Ecological Processes* 2(1):12.

Lepofsky, Dana, Emily Heyerdahl, Ken Lertzman, Dave Schaepe, and Bob Mierendorf

2003 Historical Meadow Dynamics in Southwest British Columbia: A Multidisciplinary Analysis. *Conservation Ecology* 7(3).

Lepofsky, Dana, and Ken Lertzman

2008 Documenting Ancient Plant Management in the Northwest of North America. *Botany* 86(2):129–145.

Levy, Richard

1978 Costanoan. In *Handbook of North American Indians*, edited by Robert F. Heizer, 8 California:pp. 485–495. Smithsonian Institution, Washington D.C.

Lightfoot, Kent G.

2005 *Indians, Missionaries, and Merchants: The Legacy of Colonial Encounters on the California Frontiers*. University of California Press, Berkeley.

2008 Collaborative Research Programs: Implications for the Practice of North American Archaeology. In *Collaborating at the Trowel's Edge: Teaching and Learning in Indigenous Archaeology*, edited by Stephen W. Silliman, pp. 211–227. The University of Arizona Press, Tucson.

Lightfoot, Kent G., Rob Q. Cuthrell, Cristie M. Boone, Roger Byrne, Andreas S. Chavez, Laurel Collins, Alicia Cowart, Rand R. Evett, Paul V. A. Fine, Diane Gifford-Gonzalez, Mark G. Hylkema, Valentin Lopez, Tracy M. Misiewicz, and Rachel E. B. Reid

2013a Anthropogenic Burning on the Central California Coast in Late Holocene and Early Historical Times: Findings, Implications, and Future Directions. *California Archaeology* 5(2):371–390.

Lightfoot, Kent G., Rob Q. Cuthrell, Chuck J. Striplen, and Mark G. Hylkema

2013b Rethinking the Study of Landscape Management Practices Among Hunter-gatherers in North America. *American Antiquity* 78(2):285–301.

Lightfoot, Kent G., and Valentin Lopez

2013 The Study of Indigenous Management Practices in California: An Introduction. *California Archaeology* 5(2):209–219.

Lightfoot, Kent G., and Otis Parrish

2009 *California Indians and Their Environment: An Introduction*. California Natural History guides 96. University of California Press, Berkeley.

Lindsay, Brendan C.

2012 *Murder State: California's Native American Genocide, 1846-1873*. University of Nebraska Press, Lincoln.

Lopez, Valentin

2013 The Amah Mutsun Tribal Band: Reflections on Collaborative Archaeology. *California Archaeology* 5(2):221–223.

Love, Milton S.

2011 *Certainly More Than You Want to Know About the Fishes of the Pacific Coast: A Postmodern Experience*. Really Big Press, Santa Barbara.

Lyman, Lee R.

1996 Applied Zooarchaeology: The Relevance of Faunal Analysis to Wildlife Management. *World Archaeology* 29(1):110–125.

2008 *Quantitative Paleozoology*. Cambridge Manuals in Archaeology. Cambridge University Press, New York.

Lyman, Lee R., and Kenneth P. Cannon

2004 *Zooarchaeology and Conservation Biology*. The University of Utah Press, Salt Lake City.

Madley, Benjamin

2016a *An American Genocide: The United States and the California Indian Catastrophe, 1846-1873*. The Lamar Series in Western History. Yale University Press, New Haven.

2016b Understanding Genocide in California Under United States Rule, 1846-1873. *Western Historical Quarterly* 47(4):449–461.

- Madsen, David B., and Dave N. Schmitt  
1998 Mass Collecting and the Diet Breadth Model: A Great Basin Example. *Journal of Archaeological Science* 25(5):445–455.
- Magurran, Anne E.  
1988 *Ecological Diversity and its Measurement*. Princeton University Press, Princeton.
- Malamud-Roam, Frances P., B. Lynn Ingram, Malcolm Hughes, and Joan L. Florsheim  
2006 Holocene Paleoclimate Records from a Large California Estuarine System and its Watershed Region: Linking Watershed Climate and Bay Conditions. *Quaternary Science Reviews* 25(13–14):1570–1598.
- Mann, Michael E., Zhihua Zhang, Scott Rutherford, Raymond S. Bradley, Malcolm K. Hughes, Drew Shindell, Caspar Ammann, Greg Faluvegi, and Fenbiao Ni  
2009 Global Signatures and Dynamical Origins of the Little Ice Age and Medieval Climate Anomaly. *Science* 326(5957):1256–1260.
- Martin, Paul S., and Richard G. Klein (editors)  
1984 *Quaternary Extinctions: A Prehistoric Revolution*. University of Arizona Press, Tucson.
- Maschner, Herbert D. G., Matthew W. Betts, Katherine L. Reedy-Maschner, and Andrew W. Trites  
2008 A 4500-year Time Series of Pacific Cod (*Gadus macrocephalus*) Size and Abundance: Archaeology, Oceanic Regime Shifts, and Sustainable Fisheries. *Fishery Bulletin* 106(4):386–394.
- McClanahan, T. R., and S. C. Mangi  
2004 Gear-based Management of a Tropical Artisanal Fishery Based on Species Selectivity and Capture Size. *Fisheries Management and Ecology* 11(1):51–60.
- McClatchie, S., R. D. Vetter, and I. L. Hendy  
2018 Forage Fish, Small Pelagic Fisheries and Recovering Predators: Managing Expectations. *Animal Conservation* 21(6):445–447.
- McKechnie, Iain  
2007 Investigating the Complexities of Sustainable Fishing at a Prehistoric Village on Western Vancouver Island, British Columbia, Canada. *Journal for Nature Conservation* 15(3):208–222.
- McKechnie, Iain, Dana Lepofsky, Madonna L. Moss, Virginia L. Butler, Trevor J. Orchard, Gary Coupland, Fredrick Foster, Megan Caldwell, and Ken Lertzman  
2014 Archaeological Data Provide Alternative Hypotheses on Pacific Herring (*Clupea pallasii*) Distribution, Abundance, and Variability. *Proceedings of the National Academy of Sciences* 111(9):E807–E816.
- McKechnie, Iain, Gerald G. Singh, Todd J. Braje, and Breana Campbell

2015 Measuring *Mytilus californianus*: An Addendum to Campbell and Braje (2015) and Singh and McKechnie (2015) Including Commentary and an Integration of Data. *Journal of Archaeological Science* 58:184–186.

Meighan, Clement W.

1950 *Observations on the Efficiency of Shovel Archaeology*. Reports of the University of California Archaeological Survey 7(4). University of California, Berkeley.

Meilleur, Brien A.

2000 In Search of “Keystone Societies.” In *Eating on the Wild Side: The Pharmacologic, Ecologic and Social Implications of Using Noncultigens*, edited by Nina L. Etkin, pp. 259–279. University of Arizona Press, Tucson.

Meyer, Jack

2003 *An Overview of Geoarchaeological Research Issues for the PRNS-GGNRA*. Archaeological Research Issues for the Point Reyes National Seashore-Golden Gate National Recreation Area. Sonoma State University, Rohnert Park.

Mikkelsen, Patricia, Jack Meyer, Adrian R. Whitaker, Valerie A. Levulett, Eric Wohlgemuth, and Nathan Stevens

2014 *Cuyama Valley-A Corridor to the Past*. Published for Caltrans District 5, San Luis Obispo and Santa Barbara Counties, State Route 166 Post Miles R23.72- R35.73 EA/ID 0512000035-0(OFF- 1A8800).

Milberg, Per, and Tommy Tyrberg

1993 Naïve Birds and Noble Savages: A Review of Man-Caused Prehistoric Extinctions of Island Birds. *Ecography* 16(3):229–250.

Milliken, Randall

2009 *Ethnohistory and Ethnogeography of the Coast Miwok and Their Neighbors, 1783–1840*. National Park Service, Golden Gate NRA Cultural Resources and Museum Management Division, San Francisco.

Morales, Arturo, and Knud Rosenlund

1979 *Fish Bone Measurements: An Attempt to Standardize the Measuring of Fish Bone from Archaeological Sites*. Steenstrupia, Copenhagen.

Moratto, Michael J.

1984 *California Archaeology*. New World Archaeological Record. Academic Press, Orlando.

Morgan, Christopher

2015 Is it Intensification Yet? Current Archaeological Perspectives on the Evolution of Hunter-gatherer Economies. *Journal of Archaeological Research* 23(2):163–213.

Morgan, Penelope, Gregory H. Aplet, Jonathan B. Haufler, Hope C. Humphries, Margaret M.

Moore, and W. Dale Wilson

1994 Historical Range of Variability. *Journal of Sustainable Forestry* 2(1–2):87–111.

Morita, Shou

1985 History of the Herring Fishery and Review of Artificial Propagation Techniques for Herring in Japan. *Canadian Journal of Fisheries and Aquatic Sciences* 42(S1):222–229.

Morrison, Kathleen D.

1994 The Intensification of Production: Archaeological Approaches. *Journal of Archaeological Method and Theory* 1(2):111–159.

2007 Rethinking Intensification. In *Seeking a Richer Harvest: The Archaeology of Subsistence Intensification, Innovation, and Change*, edited by Tina L. Thurston and Christopher T. Fisher, pp. 235–247. Studies in Human Ecology and Adaptation 3. Springer, New York.

Morrow, Phyllis, and Chase Hensel

1992 Hidden Dissension: Minority-Majority Relationships and the Use of Contested Terminology. *Arctic Anthropology* 29(1):38–53.

Moss, Madonna L.

2012 Understanding Variability in Northwest Coast Faunal Assemblages: Beyond Economic Intensification and Cultural Complexity. *The Journal of Island and Coastal Archaeology* 7(1):1–22.

2016 The Nutritional Value of Pacific Herring: An Ancient Cultural Keystone Species on the Northwest Coast of North America. *Journal of Archaeological Science: Reports* 5:649–655.

Moss, Madonna L., Rick Minor, and Kyla Page-Botelho

2017 Native American Fisheries of the Southern Oregon Coast: Fine Fraction Needed to Find Forage Fish. *Journal of California and Great Basin Anthropology* 37(2):169–182.

Moss, Madonna L., Antonia T. Rodrigues, Camilla F. Speller, and Dongya Y. Yang

2016 The Historical Ecology of Pacific Herring: Tracing Alaska Native Use of a Forage Fish. *Journal of Archaeological Science: Reports* 8:504–512.

Nadasdy, Paul

1999 The Politics of TEK: Power and the “Integration” of Knowledge. *Arctic Anthropology* 36(1/2):1–18.

2005 Transcending the Debate over the Ecologically Noble Indian: Indigenous Peoples and Environmentalism. *Ethnohistory* 52(2):291–331.

Nagasawa, Kazuya

2001 Long-term Variations in Abundance of Pacific Herring (*Clupea pallasii*) in Hokkaido and Sakhalin Related to Changes in Environmental Conditions. *Progress in Oceanography* 49(1–4):551–564.

Nassauer, Joan I.

1995 Culture and Changing Landscape Structure. *Landscape Ecology* 10(4):229–237.

- Nelson, Nels Christian  
1909 *Shellmounds of the San Francisco Bay Region*. Vol. 4. University of California Publications in American Archaeology and Ethnology 7. The University Press, Berkeley.
- Nelson, Peter A.  
2017 Indigenous Archaeology at Tolay Lake: Responsive Research and the Empowered Tribal Management of a Sacred Landscape. Unpublished Ph.D. Dissertation, University of California, Berkeley, Berkeley.
- Newland, Michael  
2013 *The Potential Effects of Climate Change on Cultural Resources with Point Reyes Nation Seashore Marin County, California*. Anthropological Studies Center, Sonoma State University, Rohnert Park.
- Nims, Reno, and Virginia L. Butler  
2019 The Sablefish (*Anoplopoma fimbria*) of Čixwicən: Socioenvironmental Lessons from an Unusually Abundant Species. *Journal of Archaeological Science: Reports* 23:1187–1196.
- Nims, Reno, Diane Gifford-Gonzalez, Mark Hylkema, and Kara Potenzzone  
2016 The CA-SCR-9 Archaeofauna: Insights into Prey Choice, Seasonality, and Processing. *Journal of California and Great Basin Anthropology* 36(2):243–267.
- Olsen, Stanley J.  
1968 *Fish, Amphibian and Reptile Remains from Archaeological Sites: Southeastern and Southwestern United States*. Harvard University Press, Cambridge.
- O'Neill, Finbarr G., Jordan Feekings, Robert J. Fryer, Laurence Fauconnet, and Pedro Afonso  
2019 Discard Avoidance by Improving Fishing Gear Selectivity: Helping the Fishing Industry Help Itself. In *The European Landing Obligation: Reducing Discards in Complex, Multi-Species and Multi-Jurisdictional Fisheries*, edited by Sven Sebastian Uhlmann, Clara Ulrich, and Steven J. Kennelly, pp. 279–296. Springer International Publishing, Cham.
- Orchard, Trevor J.  
2003 *An Application of the Linear Regression Technique for Determining Length and Weight of Six Fish Taxa: The Role of Selected Fish Species in Aleut Paleodiet*. BAR international series 1172. Archaeopress, Oxford.
- Orth, Robert J., Tim J. B. Carruthers, William C. Dennison, Carlos M. Duarte, James W. Fourqurean, Kenneth L. Heck, A. Randall Hughes, Gary A. Kendrick, W. Judson Kenworthy, Suzanne Olyarnik, Frederick T. Short, Michelle Waycott, and Susan L. Williams  
2006 A Global Crisis for Seagrass Ecosystems. *BioScience* 56(12):987–996.
- Ortiz, Beverly  
1993 *We Are Still Here: A Coast Miwok Exhibit*. Bolinas Museum, Bolinas.

Ostrom, Elinor

1999 Coping with Tragedies of the Commons. *Annual Review of Political Science* 2(1):493–535.

2002 Reformulating the Commons. *Ambiente & Sociedade*(10):5–25.

Page, Lawrence M., Héctor Espinosa-Pérez, Lloyd T. Findley, Carter R. Gilbert, Robert N. Lea, Nicholas E. Mandrak, Richard L. Mayden, and Joseph S. Nelson

2013 *Common and Scientific Names of Fishes from the United States, Canada, and Mexico*. American Fisheries Society Special Publication: 34. American Fisheries Society, Bethesda.

Palkovacs, Eric P.

2011 The Overfishing Debate: An Eco-evolutionary Perspective. *Trends in Ecology & Evolution* 26(12):616–617.

Pauly, Daniel, Villy Christensen, Johanne Dalsgaard, Rainer Froese, and Francisco Torres

1998 Fishing Down Marine Food Webs. *Science* 279(5352):860–863.

Pauly, Daniel, Villy Christensen, Sylvie Guénette, Tony J. Pitcher, U. Rashid Sumaila, Carl J. Walters, R. Watson, and Dirk Zeller

2002 Towards Sustainability in World Fisheries. *Nature* 418(6898):689.

Pauly, Daniel, and Maria-Lourdes Palomares

2005 Fishing Down Marine Food Feb: It is Far More Pervasive Than We Thought. *Bulletin of Marine Science* 76(2):197–212.

Pauly, Daniel, and Dirk Zeller

2016 Catch Reconstructions Reveal that Global Marine Fisheries Catches are Higher Than Reported and Declining. *Nature Communications* 7(1).

Payne, Sebastian

1972 Partial Recovery and Sample Bias: The Results of Some Sieving Experiments. In *Papers in Economic Prehistory*, edited by E. S. Higgs, pp. 49–64. Cambridge University Press, New York.

Pearsall, Deborah M.

2000 *Paleoethnobotany: A Handbook of Procedures*. Academic Press, San Diego.

Pikitch, Ellen, Patricia Dee Boersma, Ian L. Boyd, David O. Conover, Philippe Cury, Timothy Essington, Selina S. Heppell, Edward D. Houde, Marc Mangel, Daniel Pauly, Éva Plagányi, Keith Sainsbury, and Robert S. Steneck

2012 *Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs*. Lenfest Ocean Program, Washington D.C.

Pinkerton, Evelyn

1989 Introduction: Attaining Better Fisheries Management through Co-management—

Prospects, Problems, and Propositions. In *Co-operative Management of Local Fisheries: New Directions for Improved Management and Community Development*, edited by Evelyn Pinkerton, pp. 3–36. University of British Columbia, Vancouver.

Pletka, Scott

2012 The Identification and Explanation of Intensified Fishing Practices. In *Exploring Methods of Faunal Analysis: Insights from California Archaeology*, edited by Michael A. Glassow and Terry L. Joslin, 9:pp. 149–168. Perspectives in California Archaeology. Cotsen Institute of Archaeology, University of California, Los Angeles.

Pomeroy, Robert S, and Fikret Berkes

1997 Two to Tango: The Role of Government in Fisheries Co-management. *Marine Policy* 21(5):465–480.

Poulsen, Søren, J. Rasmus Nielsen, René Holst, and Karl-Johan Staehr

2000 An Atlantic Herring (*Clupea harengus*) Size Selection Model for Experimental Gill Nets Used in the Sound (ICES Subdivision 23). *Canadian Journal of Fisheries and Aquatic Sciences* 57(8):1551–1561.

Quitmyer, Irvy R., and Elizabeth J. Reitz

2006 Marine Trophic Levels Targeted Between AD 300 and 1500 on the Georgia Coast, USA. *Journal of Archaeological Science* 33(6):806–822.

Rawls, James J

1984 *Indians of California: The Changing Image*. University of Oklahoma Press, Norman.

Redford, Kent H.

1991 The Ecologically Noble Savage. *Cultural Survival Quarterly* 15(1):46–48.

Reimer, Paula J., Edouard Bard, Alex Bayliss, Warren J. Beck, Paul G. Blackwell, Christopher Bronk Ramsey, Caitlin E. Buck, Hai Cheng, Lawrence R. Edwards, Michael Friedrich, and others

2013 IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years cal BP. *Radiocarbon* 55(4):1869–1887.

Reitz, Elizabeth J.

2004 “Fishing Down the Food Web”: A Case Study from St. Augustine, Florida, USA. *American Antiquity* 69(1):63–83.

Reitz, Elizabeth J., Irvy R. Quitmyer, H. Stephen Hale, Sylvia J. Scudder, and Elizabeth S. Wing

1987 Application of Allometry to Zooarchaeology. *American Antiquity* 52(2):304–317.

Reitz, Elizabeth J., Irvy R. Quitmyer, and Rochelle A. Marrinan

2009 What Are We Measuring in the Zooarchaeological Record of Prehispanic Fishing Strategies in the Georgia Bight, USA? *The Journal of Island and Coastal Archaeology* 4(1):2–36.

- Rhemtulla, Jeanine M., and David J. Mladenoff  
2007 Why History Matters in Landscape Ecology. *Landscape Ecology* 22(1):1–3.
- Rick, Torben C., and Jon M. Erlandson  
2000 Early Holocene Fishing Strategies on the California Coast: Evidence from CA-SBA-2057. *Journal of Archaeological Science* 27(7):621–633.
- Rick, Torben C., Jon M. Erlandson, and René L. Vellanoweth  
2001 Paleocoastal Marine Fishing on the Pacific Coast of the Americas: Perspectives from Daisy Cave, California. *American Antiquity* 66(4):595–613.
- Rick, Torben C., and Rowan Lockwood  
2013 Integrating Paleobiology, Archeology, and History to Inform Biological Conservation. *Conservation Biology* 27(1):45–54.
- Roberts, Callum M., Julie P. Hawkins, and Fiona R. Gell  
2005 The Role of Marine Reserves in Achieving Sustainable Fisheries. *Philosophical Transactions: Biological Sciences* 360(1453):123–132.
- Rodrigues, Antonia T., Iain McKechnie, and Dongya Y. Yang  
2018 Ancient DNA Analysis of Indigenous Rockfish Use on the Pacific Coast: Implications for Marine Conservation Areas and Fisheries Management. *PLOS ONE* 13(2):e0192716.
- Ross, Anne, and Ryan Duffy  
2000 Fine Mesh Screening of Midden Material and the Recovery of Fish Bone: The Development of Flotation and Deflocculation Techniques for an Efficient and Effective Procedure. *Geoarchaeology* 15(1):21–41.
- Sadovy, Yvonne  
2001 The Threat of Fishing to Highly Fecund Fishes. *Journal of Fish Biology* 59(sA):90–108.
- Sanchez, Gabriel M, Jon M Erlandson, and Nicholas Tripcevich  
2017 Quantifying the Association of Chipped Stone Crescents with Wetlands and Paleoshorelines of Western North America. *North American Archaeologist* 38(2):107–137.
- Sanchez, Gabriel M., Kenneth W. Gobalet, Roberta Jewett, Rob Q. Cuthrell, Michael Grone, Paul M. Engel, and Kent G. Lightfoot  
2018 The Historical Ecology of Central California Coast Fishing: Perspectives from Point Reyes National Seashore. *Journal of Archaeological Science* 100:1–15.
- Sanchez, Gabriel M., Torben C. Rick, Brendan J. Culleton, Douglas J. Kennett, Michael Buckley, Jon M. Erlandson, and Robert L. Losey  
2018 Radiocarbon Dating Legacy Collections: A Bayesian Analysis of High-precision AMS <sup>14</sup>C Dates from the Par-Tee Site, Oregon. *Journal of Archaeological Science: Reports* 21:833–848.

- Scheffer, Marten, Steve Carpenter, and Brad de Young  
2005 Cascading Effects of Overfishing Marine Systems. *Trends in Ecology & Evolution* 20(11):579–581.
- Schiffer, Michael B.  
1986 Radiocarbon Dating and the “Old Wood” Problem: The Case of the Hohokam Chronology. *Journal of Archaeological Science* 13(1):13–30.
- Schneider, Tsim D., and Lee M. Panich  
2019 Landscapes of Refuge and Resiliency: Native Californian Persistence at Tomales Bay, California, 1770s–1870s. *Ethnohistory* 66(1):21–47.
- Shaffer, Brian S.  
1992 Quarter-inch Screening: Understanding Biases in Recovery of Vertebrate Faunal Remains. *American Antiquity* 57(1):129–136.
- Simons, Dwight D.  
2016 *Vertebrate Remains*. Archaeological Excavation of the Stege Mound (CA-CCO-297), A Late Period Shell Mound Located on the San Francisco Bayshore. Alta Archaeological Consulting, Santa Rosa.
- Singh, Gerald G., and Iain McKechnie  
2015 Making the Most of Fragments: A Method for Estimating Shell Length from Fragmentary Mussels (*Mytilus californianus* and *Mytilus trossulus*) on the Pacific Coast of North America. *Journal of Archaeological Science* 58:175–183.
- Smith, Bruce D.  
2001 Low-Level Food Production. *Journal of Archaeological Research* 9(1):1–43.  
2007 Niche Construction and the Behavioral Context of Plant and Animal Domestication. *Evolutionary Anthropology: Issues, News, and Reviews* 16(5):188–199.  
2009 Resource Resilience, Human Niche Construction, and the Long-term Sustainability of Pre-Columbian Subsistence Economies in the Mississippi River Valley Corridor. *Journal of Ethnobiology* 29(2):167–183.  
2011 General Patterns of Niche Construction and the Management of ‘Wild’ Plant and Animal Resources by Small-scale Pre-industrial Societies. *Philosophical Transactions of the Royal Society B: Biological Sciences* 366(1566):836–848.
- Sokolove, Jennifer, Sally K. Fairfax, and Breena Holland  
2002 Managing Place and Identity: The Marin Coast Miwok Experience. *Geographical Review* 92(1):23–44.
- Spratt, Jerome D.  
1981 *Status of the Pacific Herring, Clupea harengus pallasii, Resource in California 1972 to 1980*. State of California, The Resources Agency, Department of Fish and Game.

1992 The Evolution of California's Herring Roe Fishery: Catch Allocation, Limited Entry, and Conflict Resolution. *California Fish and Game* 78(1):20–44.

Steadman, David W.

1989 Extinction of Birds in Eastern Polynesia: A Review of the Record, and Comparisons with other Pacific Island Groups. *Journal of Archaeological Science* 16(2):177–205.

1995 Prehistoric Extinctions of Pacific Island Birds: Biodiversity Meets Zooarchaeology. *Science* 267(5201):1123–1131.

Stewart, Suzanne, and Adrian Praetzelis

2003 *Archaeological Research Issues for the Point Reyes National Seashore-Golden Gate National Recreation Area: For Geoarchaeology, Indigenous Archaeology, Historical Archaeology, Maritime Archaeology*. Unpublished National Park Service, Golden Gate National Recreation Area. Sonoma State University, Rohnert Park.

Stine, Scott

1994 Extreme and Persistent Drought in California and Patagonia During Mediaeval Time. *Nature* 369(6481):546–549.

Stuiver, Minze, Gordon W. Pearson, and Tom Braziunas

1986 Radiocarbon Age Calibration of Marine Samples Back to 9000 cal yr BP. *Radiocarbon* 28(2):980–1021.

Stuiver, Minze, and Paula J. Reimer

1993 Extended 14C Data Base and Revised CALIB 3.0 14C Age Calibration Program. *Radiocarbon* 35(1):215–230.

Sugaya, Takuma, Michihiro Sato, Emi Yokoyama, Yuta Nemoto, Tomonari Fujita, Hiroyuki Okouchi, Katsuyuki Hamasaki, and Shuichi Kitada

2008 Population Genetic Structure and Variability of Pacific Herring *Clupea pallasii* in the Stocking Area Along the Pacific Coast of Northern Japan. *Fisheries Science* 74(3):579–588.

Sweeney, Françoise MG

1986 Vertebrate Remains from CA-SCR-35, Santa Cruz County, California. In *Papers on California Prehistory*, edited by Gary S. Breschini and Trudy Haversat, 1:pp. 15–56. Coyote Press Archives of California Prehistory. Coyote Press, Salinas.

Swetnam, Thomas W., Craig D. Allen, and Julio L. Betancourt

1999 Applied Historical Ecology: Using the Past to Manage for the Future. *Ecological Applications* 9(4):1189–1206.

Swezey, Sean L., and Robert F. Heizer

1977 Ritual Management of Salmonid Fish Resources in California. *The Journal of California Anthropology* 4(1):6–29.

Szuwalski, Cody S., Gregory L. Britten, Roberto Licandeo, Ricardo O. Amoroso, Ray Hilborn,

and Carl Walters

2019 Global Forage Fish Recruitment Dynamics: A Comparison of Methods, Time-variation, and Reverse Causality. *Fisheries Research* 214:56–64.

Taiepa, Todd, Philip Lyver, Peter Horsley, Jane Davis, Margaret Brag, and Henrik Moller  
1997 Co-management of New Zealand's Conservation Estate by Maori and Pakeha: A Review. *Environmental Conservation* 24(3):236–250.

Takahashi, M, and D M Checkley

2008 Growth and Survival of Pacific Sardine (*Sardinops sagax*) in the California Current Region. *Journal of Northwest Atlantic Fishery Science* 41:129–136.

Thomas, David H.

1969 Great Basin Hunting Patterns: A Quantitative Method for Treating Faunal Remains. *American Antiquity* 34(4):392–401.

Thompson, Victor D.

2013 Whispers on the Landscape. In *The Archaeology and Historical Ecology of Small Scale Economies*, edited by Victor D. Thompson and James C. Waggoner Jr., pp. 1–13. University Press of Florida, Gainesville.

Thornton, Thomas F.

2015 The Ideology and Practice of Pacific Herring Cultivation Among the Tlingit and Haida. *Human Ecology* 43(2):213–223.

Thornton, Thomas F., and Harvey Kitka

2015 An Indigenous Model of a Contested Pacific Herring Fishery in Sitka, Alaska. *International Journal of Applied Geospatial Research* 6(1):94–117.

Thornton, Thomas F., Madonna L. Moss, Virginia L. Butler, Jamie Hebert, and Fritz Funk

2010 Local and Traditional Knowledge and the Historical Ecology of Pacific Herring in Alaska. *Journal of Ecological Anthropology* 14(1):81–88.

Treganza, Adan E., and Robert E. Schenk (editors)

1970 *Contributions to the Archaeology of Point Reyes National Seashore; A Compendium in Honor of Adan E. Treganza*. Treganza Museum. Papers, no. 6. Treganza Anthropology Museum, San Francisco.

Turner, Monica G.

2005 Landscape Ecology in North America: Past, Present, and Future. *Ecology* 86(8):1967–1974.

Tushingam, Shannon, and Jennifer Bencze

2013 Macro and Micro Scale Signatures of Hunter-Gatherer Organization at the Coastal Sites of Point St. George, Northwestern Alta California. *California Archaeology* 5(1):37–77.

- Tushingam, Shannon, and Colin Christiansen  
2015 Native American Fisheries of the Northwestern California and Southwestern Oregon Coast: A Synthesis of Fish-Bone Data and Implications for Late Holocene Storage and Socio-Economic Organization. *Journal of California and Great Basin Anthropology* 35(2):189–215.
- Tushingam, Shannon, Janet P. Eidsness, Tiffany Fulkerson, Justin Hopt, Colin Christiansen, Angela Arpaia, and Julielani Chang  
2016 Late Holocene Coastal Intensification, Mass Harvest Fishing, and the Historical Ecology of Marine Estuaries: The View from the Manila Site (CA-HUM-321), Humboldt Bay, Northwestern Alta California. *California Archaeology* 8(1):1–35.
- Tushingam, Shannon, and Justin Hopt  
2017 Animal Bones and Archaeology: A Reply to Gobalet. *Journal of California & Great Basin Anthropology* 37(1):89–95.
- Tushingam, Shannon, Amy M. Spurling, and Timothy R. Carpenter  
2013 The Sweetwater Site: Archaeological Recognition of Surf Fishing and Temporary Smelt Camps on the North Coast of California *Journal of California and Great Basin Anthropology* 33(1):25–37.
- Ugan, Andrew  
2005 Does Size Matter? Body Size, Mass Collecting, and Their Implications for Understanding Prehistoric Foraging Behavior. *American Antiquity* 70(1):75–89.
- Ugan, Andrew, Jason Bright, and Alan Rogers  
2003 When is Technology Worth the Trouble? *Journal of Archaeological Science* 30(10):1315–1329.
- Vale, Thomas R.  
1998 The Myth of the Humanized Landscape: An Example from Yosemite National Park. *Natural Areas Journal* 18:231–236.  
2000 Pre-Columbian North America: Pristine or Humanized - or Both? *Ecological Restoration* 18(1):2–3.
- VanPool, Todd L., and Robert D. Leonard  
2011 Linear Regression and Multivariate Analysis. In *Quantitative Analysis in Archaeology*, pp. 178–220. Wiley-Blackwell, Oxford.
- Voorhies, Barbara, G. H. Michaels, and G. M. Riser  
1991 Ancient Shrimp Fishery. *Research and Exploration* 7(1):20–35.
- Walker, Karen J.  
2000 The Material Culture of Precolumbian Fishing: Artifacts and Fish Remains from Coastal Southwest Florida. *Southeastern Archaeology* 19(1):24–45.

- Ware, Daniel M., and Richard E. Thomson  
2005 Bottom-up Ecosystem Trophic Dynamics Determine Fish Production in the Northeast Pacific. *Science* 308(5726):1280–1284.
- Watters, Diana L., and John Mello  
2001 *Pacific Herring*. California's Living Marine Resources: A Status Report. California Department of Fish and Wildlife.
- Weiser, Andrea, and Dana Lepofsky  
2009 Ancient Land Use and Management of Ebey's Prairie, Whidbey Island, Washington. *Journal of Ethnobiology* 29(2):184–213.
- Wheeler, Alwyne, and Andrew K.G. Jones  
1989 *Fishes*. Cambridge Manuals in Archaeology. Cambridge University Press, New York.
- Whitaker, Adrian R.  
2012 Mass Capture in Prehistoric Northwestern California, Energy-Maximizing Behaviors, and the Tyranny of the Ethnographic Record. In *Exploring Methods of Faunal Analysis: Insights from California Archaeology*, edited by Michael A. Glassow and Terry L. Joslin, 9:pp. 53–64. Perspectives in California Archaeology. Cotsen Institute of Archaeology, University of California, Los Angeles.
- Willis, Lauren M., and Andrew R. Boehm  
2014 Fish Bones, Cut Marks, and Burial: Implications for Taphonomy and Faunal Analysis. *Journal of Archaeological Science* 45:20–25.
- Willis, Lauren M., Metin I. Eren, and Torben C. Rick  
2008 Does Butchering Fish Leave Cut Marks? *Journal of Archaeological Science* 35:1438–1444.
- Winterhalder, Bruce, and Eric Alden Smith  
2000 Analyzing Adaptive Strategies: Human Behavioral Ecology at Twenty-five. *Evolutionary Anthropology Issues News and Reviews* 9(2):51–72.
- Wohlgemuth, Eric  
1996 Resource Intensification in Prehistoric Central California: Evidence from Archaeobotanical Data. *Journal of California and Great Basin Anthropology* 18(1):81–103.
- Wolverton, Steve  
2008 Harvest Pressure and Environmental Carrying Capacity: An Ordinal-Scale Model of Effects on Ungulate Prey. *American Antiquity* 73(2):179–199.
- Wolverton, Steve, James H. Kennedy, and John D. Cornelius  
2007 A Paleozoological Perspective on White-Tailed Deer (*Odocoileus virginianus texana*) Population Density and Body Size in Central Texas. *Environmental Management* 39(4):545–552.

Wolverton, Steve, and Lee R. Lyman

2012 *Conservation Biology and Applied Zooarchaeology*. University of Arizona Press, Tucson.

Wolverton, Steve, Lisa Ann Nagaoka, and Torben C. Rick

2016 *Applied Zooarchaeology: Five Case Studies*. Eliot Werner Publications, Clinton Corners.

Wright, Peter J., and Edward A. Trippel

2009 Fishery-induced Demographic Changes in the Timing of Spawning: Consequences for Reproductive Success. *Fish and Fisheries* 10(3):283–304.

**Appendix A:** Site, Material, and Context information for radiocarbon dates from nine HEALPR project sites.

| <b>Catalog #</b>  | <b>Site</b> | <b>Context</b>       | <b>Material Type</b> | <b>AMS Lab #</b> | <b>14C Age</b> | <b>14C Age Error</b> | <b>Cal Age 2-sig</b>   |
|-------------------|-------------|----------------------|----------------------|------------------|----------------|----------------------|--|
| 222-0008-04-AMS-1 | 222         | 140-160 cm; Flot #53 | Bark                 | 169142           | 935            | 15                   | 1,035-1,059 AD (0.20); 1,064-1,154 AD (0.80)   |
| 222-0003-04-AMS-1 | 222         | 40-60 cm; Flot #48   | Bark                 | 169143           | 255            | 15                   | 1,641-1,665 AD (0.96)  |
| 224-0006-04-AMS-1 | 224         | 100-120 cm; Flot #20 | Twig                 | 169137           | 210            | 15                   | 1,652-1,677 AD (0.32); 1,776-1,800 AD (0.53); 1,940-1,951 AD (0.12)                        |
| 224-0017-04-AMS-1 | 224         | 120-140 cm; Flot #31 | Twig                 | 169147           | 705            | 15                   | 1,271-1,294 AD   |
| 224-0010-04-AMS-1 | 224         | 180-200 cm; Flot #24 | Bark                 | 169136           | 1210           | 15                   | 769-882 AD   |
| 224-0014-04-AMS-1 | 224         | 60-80 cm; Flot #28   | Bark                 | 169146           | 235            | 15                   | 1,646-1,667 AD (0.70); 1,783-1,796 AD (0.30)   |
| 249-0003-04-AMS-1 | 249         | 40-60 cm; Flot #12   | Bark                 | 169134           | 190            | 15                   | 1,663-1,682 AD (0.22); 1,737-1,757 AD (0.11); 1,761-1,804 AD (0.45); 1,936-1,951 AD (0.21) |
| 249-0004-04-AMS-1 | 249         | 60-80 cm; Flot #13   | Bark                 | 169135           | 370            | 15                   | 1,452-1,521 AD (0.70); 1,591-1,620 AD (0.29)   |

|                   |     |                         |            |        |          |    |  |
|-------------------|-----|-------------------------|------------|--------|----------|----|--|
| 258-0002-04-AMS-1 | 258 | 20-40 cm;<br>Flot #62   | Bark       | 182839 | 510      | 15 | 1,409-1,435 AD   |
| 258-0003-04-AMS-1 | 258 | 40-60 cm;<br>Flot #63   | Bark       | 182840 | 575      | 15 | 1,316-1,354 AD (0.64); 1,389-1,411 AD (0.36)   |
| 277-0006-04-AMS-1 | 277 | 100-120 cm;<br>Flot #37 | Bark       | 169138 | 203<br>5 | 15 | 91-69 BC (0.09); 60 BC - 17 AD (0.91)  |
| 277-0004-04-AMS-1 | 277 | 60-80 cm;<br>Flot #35   | Bark       | 169139 | 125<br>5 | 15 | 687-773 AD   |
| 287-0019-04-AMS-1 | 287 | 20-40 cm;<br>Flot #7    | Parenchyma | 169133 | 215<br>5 | 15 | 351-300 BC (0.35); 210-162 BC (0.63)   |
| 287-0020-04-AMS-1 | 287 | 40-60 cm;<br>Flot #8    | Parenchyma | 169132 | 257<br>5 | 15 | 799-773 BC   |
| 379-0029-04-AMS-1 | 379 | 20-40 cm;<br>Flot #40   | Bark       | 169141 | 360      | 15 | 1,459-1,523 AD (0.58); 1,572-1,630 AD (0.42)   |
| 379-0030-04-AMS-1 | 379 | 40-60 cm;<br>Flot #41   | Bark       | 169140 | 425      | 15 | 1,437-1,470 AD   |
| 659-0017-04-AMS-1 | 659 | 20-40 cm;<br>Flot #2    | Bark       | 169131 | 520      | 15 | 1,406-1,433 AD   |
| 659-0019-04-AMS-1 | 659 | 60-80 cm;<br>Flot #4    | Parenchyma | 169130 | 195      | 15 | 1,661-1,681 AD (0.24); 1,738-1,755 AD (0.07); 1,762-1,803 AD (0.49); 1,937-1,951 AD (0.20) |
| AL1-0006-04-AMS-1 | AL1 | 100-120 cm;<br>Flot #59 | Parenchyma | 169144 | 595      | 15 | 1,306-1,363 AD (0.77); 1,385-1,404 AD (0.23)   |

|                   |     |                    |      |        |     |    |  |
|-------------------|-----|--------------------|------|--------|-----|----|--|
| AL1-0004-04-AMS-1 | AL1 | 60-80 cm; Flot #57 | Bark | 169145 | 355 | 15 | 1,466-1,524 AD (0.52); 1,568-1,631 AD (0.47) |
|-------------------|-----|--------------------|------|--------|-----|----|--|

**Appendix B.** Fish remains previously reported for the Santa Cruz coast with NISP and relative abundance in parentheses. Names follow Page et al. (2013).

| <b>Taxon</b>                | <b>Common Name</b>   | <b>CA-SCR-7</b>   | <b>CA-SCR-9</b>    | <b>CA-SCR-35</b>   | <b>CA-SCR-44</b>     | <b>CA-SCR-60/130</b> | <b>CA-SCR-123/38</b> |
|-----------------------------|----------------------|-------------------|--------------------|--------------------|----------------------|----------------------|----------------------|
|                             |                      | <b>6.4/3.2 mm</b> | <b>6.4/3.2 mm</b>  | <b>3.2 mm</b>      | <b>1.59 mm</b>       | <b>3.2 mm</b>        | <b>6.4/3.2 mm</b>    |
| <b>Elasmobranchii</b>       | Cartilaginous fishes |                   |                    |                    |                      | <b>40</b><br>(0.26)  |                      |
| <b>Triakidae</b>            | Hound sharks         |                   |                    |                    |                      |                      |                      |
| <i>Galeorhinus galeus</i>   | Tope                 |                   |                    |                    |                      | <b>2</b><br>(0.01)   |                      |
| <b>Carcharhinidae</b>       | Requiem sharks       |                   | <b>1</b><br>(0.07) |                    |                      | <b>34</b><br>(0.22)  |                      |
| <b>Rajiformes</b>           |                      |                   |                    |                    |                      | <b>8</b><br>(0.05)   |                      |
| <i>Raja</i> sp.             | Skate                |                   |                    | <b>5</b><br>(0.09) |                      | <b>14</b><br>(0.09)  |                      |
| <b>Clupeidae</b>            | Herrings             |                   |                    | <b>1</b><br>(0.02) |                      |                      |                      |
| <b>Carcharhinidae</b>       | Requiem sharks       |                   | <b>1</b><br>(0.07) |                    |                      | <b>34</b><br>(0.22)  |                      |
| <b>Rajiformes</b>           |                      |                   |                    |                    |                      | <b>8</b><br>(0.05)   |                      |
| <i>Raja</i> sp.             | Skate                |                   |                    | <b>5</b><br>(0.09) |                      | <b>14</b><br>(0.09)  |                      |
| <b>Clupeidae</b>            | Herrings             |                   |                    | <b>1</b><br>(0.02) |                      |                      |                      |
| <b>Osmeridae</b>            | Smelts               |                   |                    |                    |                      |                      |                      |
| <i>Spirinchus starksi</i>   | Night smelt          |                   |                    |                    | <b>102</b><br>(0.44) |                      |                      |
| <b>Merlucciidae</b>         | Merlucciid hakes     |                   |                    |                    |                      |                      |                      |
| <i>Merluccius productus</i> | Pacific hake         |                   |                    |                    |                      | <b>3</b><br>(0.02)   |                      |
| <b>Batrachoididae</b>       | Toadfishes           |                   |                    |                    |                      |                      |                      |
| <i>Porichthys notatus</i>   | Plainfin midshipman  |                   |                    |                    |                      | <b>4</b><br>(0.03)   |                      |

|                                   |                                      |  |                    |                     |                     |                     |  |
|-----------------------------------|--------------------------------------|--|--------------------|---------------------|---------------------|---------------------|--|
| <b>Atherinopsidae</b>             | New World silversides                |  |                    | <b>45</b><br>(0.83) |                     |                     |  |
| <b>Scorpaenidae</b>               | Scorpionfishes                       |  |                    |                     |                     |                     |  |
| <i>Sebastes</i> sp.               | Rockfishes                           |  |                    |                     |                     | <b>3</b><br>(0.02)  |  |
| <b>Hexagrammidae</b>              | Greenlings                           |  |                    |                     |                     |                     |  |
| <i>Hexagrammos</i> sp.            | Greenlings                           |  |                    |                     |                     | <b>1</b><br>(0.01)  |  |
| <i>Ophiodon elongatus</i>         | Lingcod                              |  | <b>2</b><br>(0.14) |                     |                     | <b>3</b><br>(0.02)  |  |
| <b>Cottidae</b>                   | Sculpins                             |  |                    |                     |                     | <b>2</b><br>(0.01)  |  |
| <i>Scorpaenichthys marmoratus</i> | Cabezon                              |  | <b>2</b><br>(0.14) |                     |                     |                     |  |
| <b>Embiotocidae</b>               | Surfperches                          |  | <b>2</b><br>(0.14) |                     |                     | <b>21</b><br>(0.14) |  |
| <i>Amphistichus</i> sp.           | Barred, Calico, or Redtail surfperch |  |                    |                     |                     | <b>1</b><br>(0.01)  |  |
| <i>Damalichthys vacca</i>         | Pile perch                           |  | <b>1</b><br>(0.07) |                     |                     |                     |  |
| <i>Rhacochilus toxotes</i>        | Rubberlip seaperch                   |  |                    | <b>1</b><br>(0.02)  |                     |                     |  |
| <b>Stichaeidae</b>                | Pricklebacks                         |  |                    |                     |                     |                     |  |
| <i>Cebidichthys violaceus</i>     | Monkeyface prickleback               |  | <b>3</b><br>(0.21) |                     |                     |                     |  |
| <b>Sphyraenidae</b>               | Barracudas                           |  |                    |                     |                     |                     |  |
| <i>Sphyraena argentea</i>         | Pacific Barracuda                    |  |                    |                     |                     | <b>1</b><br>(0.01)  |  |
| Pleuronectiformes                 |                                      |  |                    | <b>1</b><br>(0.02)  |                     | <b>1</b><br>(0.01)  |  |
|                                   |                                      |  |                    |                     |                     |                     |  |
| <b>Freshwater</b>                 |                                      |  |                    |                     |                     |                     |  |
| Cypriniformes                     |                                      |  |                    |                     |                     |                     |  |
| <b>Cyprinidae</b>                 | Carps and minnows                    |  |                    |                     | <b>70</b><br>(0.30) | <b>6</b><br>(0.04)  |  |
| <i>Lavinia exilicauda</i>         | Hitch                                |  |                    |                     | <b>14</b><br>(0.06) | <b>1</b><br>(0.01)  |  |
| <i>Orthodon microlepidotus</i>    | Sacramento Blackfish                 |  |                    |                     |                     | <b>1</b><br>(0.01)  |  |
| <b>Catostomidae</b>               | Suckers                              |  |                    |                     |                     |                     |  |

|                                 |                          |          |                    |                    |                     |                    |          |
|---------------------------------|--------------------------|----------|--------------------|--------------------|---------------------|--------------------|----------|
| <i>Catostomus occidentalis</i>  | <i>Sacramento sucker</i> |          |                    |                    | <b>12</b><br>(0.05) | <b>4</b><br>(0.03) |          |
| <b>Cyprinidae/Catostomidae</b>  |                          |          |                    |                    |                     | <b>1</b><br>(0.01) |          |
| <b>Salmonidae</b>               | Trouts and salmons       |          |                    |                    |                     |                    |          |
| <i>Oncorhynchus sp.</i>         |                          |          | <b>3</b><br>(0.21) |                    |                     |                    |          |
| <i>Oncorhynchus tshawytscha</i> | Chinook salmon           |          |                    | <b>1</b><br>(0.02) |                     |                    |          |
| <b>Centrarchidae</b>            | Sunfishes                |          |                    |                    |                     |                    |          |
| <i>Archoplites interruptus</i>  | Sacramento perch         |          |                    |                    | <b>31</b><br>(0.13) | <b>4</b><br>(0.03) |          |
| <b>Embiotocidae</b>             |                          |          |                    |                    |                     |                    |          |
| <i>Hysterocarpus traskii</i>    | Tule perch               |          |                    |                    | <b>3</b><br>(0.01)  |                    |          |
| Actinopterygii indet.           |                          | 3        | 4                  |                    | 366                 | 41                 | 3        |
| <b>Total</b>                    |                          | <b>3</b> | <b>18</b>          | <b>54</b>          | <b>598</b>          | <b>196</b>         | <b>3</b> |