

**THE POTENTIAL EFFECTS OF CLIMATE CHANGE ON
CULTURAL RESOURCES WITHIN
POINT REYES NATIONAL SEASHORE
MARIN COUNTY, CALIFORNIA**



Prepared for:

National Park Service
Point Reyes National Seashore
Point Reyes Station, California

Prepared by:

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Sonoma State University
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The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or interpretations, either expressed or implied, of the U.S. Government.

ABSTRACT

The Anthropological Studies Center of Sonoma State University has undertaken a study of the potential effects of climate change on indigenous archaeological sites at Point Reyes National Seashore, as part of Interagency Agreement H8537070194. This study is based heavily on Geographic Information System (GIS) models, prepared for the State of California by the Pacific Institute, and global assessments of the effects of climate change prepared by the Intergovernmental Panel on Climate Change, an international organization of 194 member countries supporting thousands of scientists in their efforts to track and predict climate change. Their conclusions are supported by dozens of field studies, several of which are discussed in this report. The potential effects on indigenous archaeological sites described herein have been projected based on the Pacific Institute's GIS models, observations from other archaeologists on the effects of past climate events and modern impacts that simulate such events on archaeological sites, and the studies of the effects of inundation conducted by maritime archaeologists. This report presents a literature review and GIS modeling that are followed by in-field analysis of 19 sites, most of which are along the coastal or bay margins. The report concludes with a bulleted list of observations and park-wide recommendations.

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CHAPTER 1. INTRODUCTION



Figure 2. Wave and tidal erosion zone within Tomales Bay, north of Marshall Beach. View to the north (Accession # 70-10-D01-02).

THE PURPOSE OF THIS DOCUMENT

Point Reyes National Seashore contains 88 recorded extant indigenous archaeological sites and likely many more unrecorded ones. Much of Point Reyes National Seashore, as the Park's name implies, is bordered by the Pacific Ocean, Tomales Bay, Drakes Bay, and a number of small estuaries and lagoons. Over the past three decades, climate scientists, oceanographers, and geologists have tracked evidence for rising sea levels, warmer global temperatures, receding glacial and polar ice, and increased amounts of carbonic acid in the ocean. There is abundant evidence that suggests that the planet's climate is changing.

This document looks at that evidence, describes the threats climate change poses to the Parks' indigenous archaeological resources, ranks the sites that seem to be the most in harm's way, and proposes some options for treating these impacts in a way that can help minimize their effect. As these resources are directly related to ancestral use of these lands by the Coast Miwok and are important places to their descendants, representatives from the Federated Indians of Graton Rancheria (FIGR) reviewed this document, participated in the field research, and contributed to the ranking of impacts and prioritization of treatment. While a host of cultural resources, including ranching, maritime, and recreational features dating to the historic era are within the park, this study is focused only on the indigenous resources, as these are numerous along the bay and ocean margins and have been shown to be already eroding under current conditions, exposing culturally sensitive artifacts and human remains.

DEFINING CLIMATE CHANGE

What is climate change? The Intergovernmental Panel on Climate Change (IPCC) has been working on a definition, as well as deciding what constitutes evidence for climate change, what causes it, what the short- and long-term effects of it might be, how to slow or stop it, and how to mitigate its effects. The IPCC is the leading international body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to "provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts" (IPCC 2007). Thousands of scientists and 194 countries participate in the IPCC's assessments, contributing the most recent scientific, technical and socio-economic information relevant to the understanding of climate change so that the IPCC can reach informed decisions. In 2007, the IPCC was awarded the Nobel Peace Prize "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change" (IPCC 2011).

The IPCC defines climate change as

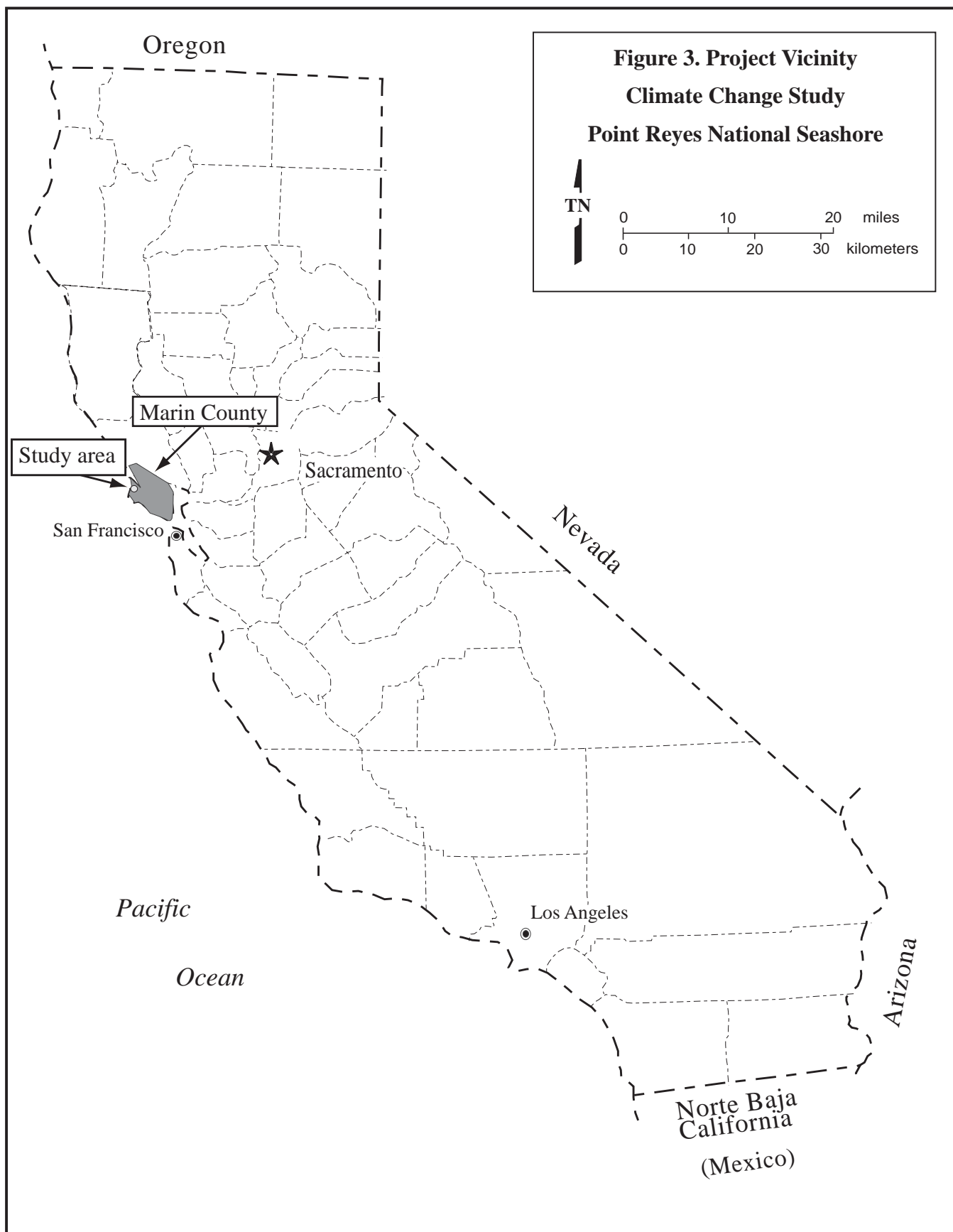
a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity [IPCC 2007:30].

The causes of climate change are one of the most complicated and politically charged research topics in science today. However, recent review of the existing literature published in the Proceedings of the National Academy of the Sciences of the United States of America shows that there is near world-wide consensus within the scientific community that climate change is human caused (Anderegg et al. 2010). In 2007, IPCC released a 4-volume assessment of the current state of climate change world-wide, their fourth such assessment. For the purposes of this study, the IPCC assessments will form the backbone of the discussion on evidence for, causes, and world-wide effects of climate change.

POINT REYES NATIONAL SEASHORE: CURRENT NATURAL SETTING AND CLIMATE

Point Reyes National Seashore is located on the west side of Tomales Bay, in the northwestern corner of Marin County. It is bordered by the coastal town of Bolinas to the south, Tomales Bay and the San Andreas Rift Basin to the east, and the Pacific Ocean to the west and north (Figures 3 and 4). Despite its relatively small size, Point Reyes National Seashore has a wide range of geologic formations and an unusual geologic history. Much of Point Reyes consists of ancient sandstones, the results of sediments deposited at the bottom of a shallow sea more than 80 million years ago. A mass of molten granitic rock uplifted and compacted some of the sedimentary material, fusing it through heat and pressure into limestone, quartzite, and schists. The Point Reyes landform has been gradually moving north along the San Andreas fault line over the millennia, and was at one time at least as far south as Santa Cruz (Galloway 1977:59).

PRNS is made up of several formations. Along Tomales Bay and the crest of Inverness Ridge, most of the bedrock is granitic rocks with pockets of Laird sandstone and Monterey shale. The western half of the Point Reyes Peninsula consists of Monterey shale, Drakes Bay Formation siltstone, and Laird sandstone, with Tomales Point composed of the granitic rocks. The southern tip of Point Reyes Peninsula is made up of a mix of pockets of granitic rocks, Point Reyes conglomerate, and Drakes Bay Formation siltstone. The bedrock bordering the interior of Drakes Bay consists of Drakes Bay Formation siltstone and Monterey shale. The edges of Olema Valley within PRNS have inclusions of Franciscan Formation. All along the coastal edges of the park and within the drainage basins are Quaternary alluvial deposits (Galloway 1976).



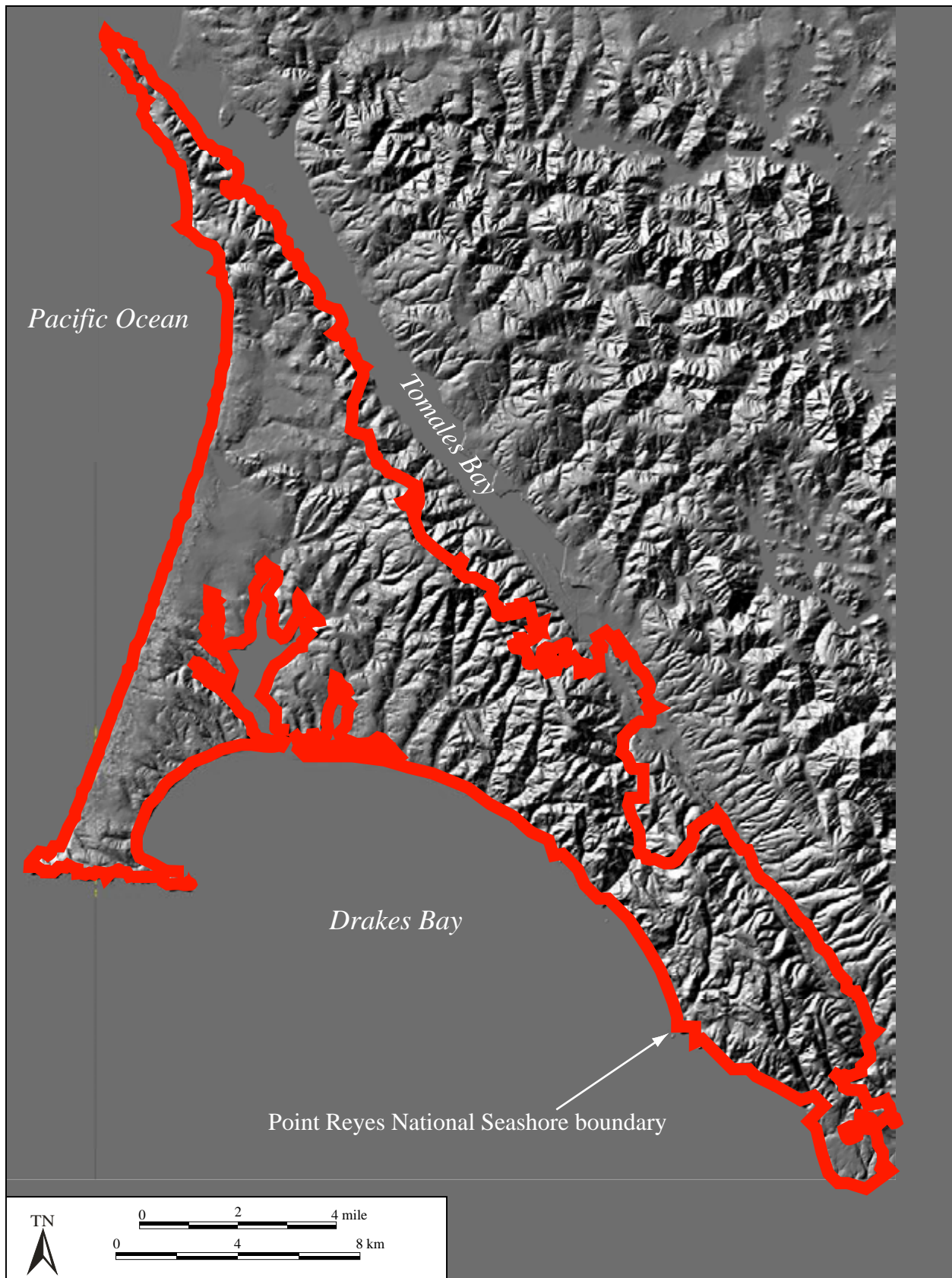


Figure 4. Location of Point Reyes National Seashore showing topography using 10 meter or better elevation model (USDA-NRCS 2000)

These different bedrock formations have eroded to form a mosaic of over 30 soil types throughout PRNS. Most are primarily loams, with clay and silt deposits found only in the bottoms of the largest drainages (NRCS 2011). The marine silt and sandstone formations provide sandy material to replenish the beaches along the Drakes Bay and southern half of the western edge of PRNS. At the north end of the western edge, along the granitic cliffs, the beaches are very small and are inaccessible in places save from the ocean side. Drakes Estero and Tomales Bay were created some 6,000 years ago as sea levels rose (Meyer 2003).

The range of topographic features, geologic formations, micro climates, and setting—ocean vs. bay, inland valley vs. ridgeline—combined with historic-era land-use patterns have resulted in several different vegetation communities. These communities are delineated in the park’s GIS database and include: needle-leaved evergreen forest, winter-deciduous broad-leaved forests and woodlands, winter-rain evergreen Sclerophyllous forest and woodland, active pasture or agriculture, beaches or mudflats, built-up urban disturbance, chaparral vegetation, coastal scrub vegetation, disturbed, dunes, native and non-native grassland, temperate cold deciduous shrublands, and vegetation dominated by annual or perennial forbs. The unique combination of geology, bay vs. open ocean, and estuary, forest, and grassland environments provided a host of food resources for indigenous peoples, including elk and black tailed deer, waterfowl, jack rabbit, and a host of maritime resources, including clam, mussel, oyster, shorefish, sea mammals, and seaweed.

CULTURAL SETTING

PREHISTORIC CONTEXT

The first archaeological surveys of the Tomales Bay/Point Reyes area were conducted in the early 1900s by Nels Nelson of the University of California, Berkeley, as part of a greater effort to identify and record shellmounds along San Francisco Bay and portions of the Pacific coastline (Nelson 1909). These surveys identified 425 prehistoric archaeological sites, several of which were located along the eastern shore of Tomales Bay. Jesse Peter, between 1911 and 1913, conducted surveys from the southern border of Sonoma County south into Marin County, while S.F. Bryant, in 1927, explored the west shore of Tomales Bay and the Drakes Estero areas (Moratto 1970:98). Much of the subsequent archaeological study of the Point Reyes area focused on the question of Sir Francis Drake's presence in the area.

The first prehistoric archaeological excavations at Point Reyes were undertaken in 1940 by U.C. Berkeley, with R.F. Heizer in charge. The next year, R.F. Beardsley ran the investigations, with major work conducted at 4 sites, while 9 additional sites were also excavated (Moratto 1970:98-99). Beardsley (1954) framed a cultural sequence for the area, relating it to the greater San Francisco Bay/Sacramento Delta areas; the earliest recognized culture on coastal Marin at that time was the McClure complex, which corresponds to central California's Middle period, ca. 500 B.C. to A.D. 500.

The next major prehistoric archaeological research was conducted during the late 1960s by Adán Treganza and other San Francisco State College archaeologists as part of a National Park Service (NPS) contract in conjunction with the creation of the National Seashore (Moratto 1970:101-102). Work included extensive excavations on Limantour Spit. Also resulting from this work was a settlement-pattern hypothesis for the area, in which Rob Edwards (1970) identified three site groups that he considered to be archaeological manifestations of distinct tribelets. Within the Tomales area, Alvarez and Bramlette (1988) surveyed several hundred acres of California Department of Parks and Recreation land, recording 13 previously identified and 4 newly discovered prehistoric and historic-era archaeological sites. More recently, the Point Reyes peninsula has been the subject of two master's theses in Cultural Resources Management (Compas 1998; Polansky 1998). Aside from linear roadside surveys and small property studies along Tomales Bay, very little study has been conducted in the study area vicinity in the past decade.

Suzanne Stewart prepared a synthesis of the indigenous cultural chronology for PRNS in her 2003 overview of indigenous archaeological issues in the volume *Archaeological Research Issues for the Point Reyes National Seashore-Golden Gate Recreation Area*. The overview presented below is adapted from her work, with minor changes.

Summary of Bay Area Sequence

The nature and timing of initial human use of the coast is discussed under Settlement and Subsistence. Below is a simplified review of the course of human events from the Early Holocene to the historic period of the Late Holocene era, which will be given more substance under various themes in the chapters that follow.

Paleoindian Period: 10,000–6000 B.C.

This earliest documented period of human use of California occurred at a time of variable climate, rising sea levels, and other broad-scale environmental change. It is assumed that people living in this early period were organized into small, highly mobile groups occupying broad geographic areas, suggesting that most occupations would not have been of sufficient intensity or duration to leave significant remains. More importantly, many occupation surfaces dating to this time depth have been buried by alluvium or other deposits. Most of the known Paleoindian sites in northern and central California were found in lacustrine environments, where deposition may have been slower. This period starts at the interface of the Pleistocene and Early Holocene, a time of great environmental change. Moratto (1984:90–103) labels the culture that appears at this time as the Western Pluvial Lakes Tradition (WPLT). The WPLT may have evolved out of the Fluted Point tradition, as woodlands and deep lakes gave way to grasslands and shallow lakes after about 10,000 B.C. Recent finds in California, however, have exhibited more varied environmental settings and more complex occupations than are proposed in the traditional model of Paleoindian lacustrine adaptation (see below).

A Paleoindian occupation in the North Coast Ranges was first identified at the Borax Lake site (CA-LAK-36) in the Clear Lake basin. Called the Post pattern in that locale, it is manifested by fluted points, single-shoulder points, and flaked-stone crescentics. This assemblage is thought to reflect an adaptation to lacustrine gathering and hunting of large and small game, including fowl. In the Sonoma and Marin districts, evidence of Paleoindian occupation is limited to a few finds, with all but one discovered in the past quarter century. (The exception is a crescentic in the Rose Gaffney collection from Bodega Head.) At the Laguna de Santa Rosa, a lacustrine setting in central Sonoma County, small, chert crescentics similar to those from the Borax Lake site were found by Origer and Fredrickson (1980) at CA-SON-977. On the coast, at Duncans Landing north of Bodega Bay, a spectacular find for the whole region is SON-348/H, which possesses extensive cave deposits, the bottom layers of which have yielded dates of ca. 7000 B.C., suggesting Paleoindian occupation with an estuarine adaptation before sea-level rise encroached (Schwaderer 1992). Further north, on the Mendocino coast, a lone fluted point representing this period was exposed by a bulldozer in a shell midden near Casper (Simons, Layton, and Knudson 1985).

South of the San Francisco Bay is CA-SCR-177, the Scotts Valley site north of Santa Cruz, in a valley with the remnants of a Pleistocene lake. Radiocarbon dates indicate an initial occupation at about 10,000 B.C.; an eccentric crescent was another Paleoindian indicator (Cartier ed. 1993:5). The recent discovery of the Cross Creek site near the coast in San Luis Obispo County revealed unexpected complexity for the time period. Here, a buried deposit contained milling equipment, cobble core tools, and flaked-stone tools within a stratigraphically discrete paleo-shell midden radiocarbon-dated between ca. 10,300 and 7500 B.P. (dates corrected to roughly 8250 and 5450 B.C.)—one of the oldest milling assemblages in North America (Fitzgerald 2000; Jones et al. 2002). According to Fitzgerald, the site lends support to the premise of a coastal migration into North America, a migration that involved not the big-game hunting of the Folsom culture, but a profoundly different assemblage, and opens up “perhaps more complex and intriguing possibilities to the peopling of western North America” (2000:132).

Evidence of Paleoindian occupation of the Central Valley and the San Francisco Bay Area would be buried beneath many meters of alluvium in the Delta or submerged under bay or coastal waters. As noted in the geoarchaeological study by Meyer (2003) there is considerable potential for buried sites in the PRNS-GGNRA study area—particularly along the submerged coast and in alluvial valleys found along the San Andreas Rift.

Lower Archaic Period: 6000–3000 B.C.

The gradual warming of the Paleoindian period accelerated during the Lower Archaic, altering the extensive wetlands that would have characterized the coastal valleys in the study area. At the same time, sea-level rise inundated various coastal locales that would have been available for human use, including the inferred estuary at Duncans Point Cave. This period, also referred to as the Altithermal (although the dating of that environmental event has been disputed), was a time of persistent warm and dry climatic conditions. Adaptations to these more arid conditions, as available water decreased and grasses became more abundant, included relatively widespread use of millings and handstones—tools that continued in use in some areas. The culture was first identified as the Borax Lake aspect of the Borax Lake pattern at Clear Lake, present at the site type CA-LAK-36 and other sites. The assemblage is unique in the massiveness of the points and the wide variety of forms, occurring in all four of the North Coast Ranges’ obsidians. The signature projectile point is the Borax Lake wide stem, which has been found throughout the uplands of the North Coast Ranges and occurs singly or in small numbers in central California sites. Little can be inferred about the lifeways of these people, although a few burials have been recovered that add some information.

At Clear Lake, burials from the Mostin site, also dating to this period, had relatively low frequencies of burial-associated artifacts. Included were a few dorsally extended and semi-extended individuals, but the majority was buried in loosely to tightly flexed positions (White and Fredrickson 1992:56). In the deeply buried Early Holocene site at Los Vaqueros (Meyer and Rosenthal 1997), site CA-CCO-696 yielded one of the oldest human burials in northern California (7400 cal B.P., or around 5350 B.C.). Artifacts from the Lower Archaic component included millingslabs and handstones, a wide-stem point, and cobble core tools.

No sites dating to this period have been uncovered within the PRNS-GGNRA, again probably due to conditions that would have submerged or buried some or all such deposits. One early site on the Bay, however, is of interest: CA-MRN-17 on De Silva Island, just offshore from the Tiburon peninsula, yielded the oldest date from San Francisco Bay. The site exhibited Late-period materials in the upper midden, but the 6-meter-deep deposits yielded an uncalibrated radiocarbon date of 5480 B.P. years (or about 3430 B.C.) from the submidden component (Moratto 1984:275). The lower deposits contained handstones and heat-treated chert, according to Breschini (1983:78); publication on the site is pending.

Middle Archaic Period: 3000–500 B.C.

The Middle Archaic-period archaeological culture identified in the North Coast Ranges is the Mendocino pattern, which appears at numerous sites in the Clear Lake area, the Napa area, and in Sonoma County, where it is the first well-represented culture in the Santa Rosa area, the Black Hill aspect. The increase in the number of sites at this time probably reflects larger, more sedentary populations but may also be a function of landscape evolution. The assemblage is distinguished by obsidian or chert concave-base points, obsidian or chert narrow leaf-shaped points, chert stemmed points, obsidian biface blanks, biconically drilled schist charmstones, and a continuation of angular obsidian cores. The millingslab and handstone continue, while some mortars and pestles appear at this time.

The Middle Archaic is the time period of the first documented occupation of the Central Valley–Delta area: the Windmill pattern, named for the type site CA-SAC-107. This is the classic Early Horizon of the Central California Taxonomic System, with occupation of extensive mounds suggesting large, semi-sedentary populations. Windmill mortuary practices included scrupulous adherence to burial position, and burial-associated artifacts in the form of perforated charmstones and distinctive abalone ornaments; there is little evidence, however, for status differentiation or formal ceremonialism. In the Sonoma district where the artifact assemblage is present, there is no information from site features (e.g. housepits, ovens, hearths) or burials to allow inferences regarding demography, settlement practices, social structure, or status differentiation during this period. On the coast just north of the PRNS, the Duncans Point Cave (CA-SON-348/H) continued in use, as it had since the Paleoindian period. In the Lower and Middle Archaic, the occupants at the cave were gathering nuts and seeds, milling plant materials, hunting sea mammals, and producing or repairing baskets and nets and attendant fiber-working activities (Schwaderer 1992).

On San Francisco Bay, no known occupation contemporaneous with the Windmill pattern had been confirmed until the early 1960s, when Gerow, with Force (1968) identified the Early Bay culture at the University Village site (CA-SMA-77) and at various components of previously excavated sites suspected as being early by Beardsley (1954) (Ellis Landing, CA-CCO-295; West Berkeley, CA-ALA-307; Emeryville, ALA-309; Ponce, CA-SCL-1; Newark, or Patterson, ALA-328). Far more similar to the succeeding Berkeley pattern of the Upper Archaic than it was to contemporaneous Windmill in the Delta, the pattern on the Bay has been called Lower Berkeley in the Fredrickson scheme. (ALA-17, located in West Oakland in a buried dune radiocarbon-dated to 5400 cal B.P., or around 3400 B.C. (Meyer 2003), is a contender.) No evidence of occupation of any kind at this time period has been recovered directly from the southern portion of the GGNRA, although such use can be inferred, given the proximity of the University Village site at SMA-77 on the southwestern corner of the Bay and the early radiocarbon date from the BART skeleton at San Francisco's Civic Center.

At the PRNS, no Lower Berkeley occupation has been confirmed, although the lower, unexcavated levels of the McClure site (CA-MRN-266) are believed to date to that time (Bennyhoff 1994; Van Dyke 1972). Elsewhere in Marin, the Pacheco site (CA-MRN-152) north of San Rafael, was originally assigned to the Middle horizon (Upper Archaic) by Goerke and Cowan (1983) but has since been recognized as a Middle Archaic-period site with Lower Berkeley affiliation. Likewise, lower levels at CA-SON-299 on Bodega Bay were considered to be possible Lower Berkeley deposits. The intensive occupation at Duncans Point Cave, just a few miles north of Bodega Bay, lends good support for assuming that there was active, widespread use of the coast at this time.

Upper Archaic Period: 500 B.C.–A.D. 1000

Significant changes during this period may represent a series of local adaptations to changing (cooler, wetter) climatic conditions in the North Bay, the Central Valley, and at Clear Lake. More likely, according to Fredrickson (1984:524–525), the appearance of Berkeley pattern traits and mode of settlement may reflect Proto-Miwokan expansion from the San Francisco Bay—a response to intensified resource competition along the bayshore and the expansion of minimally populated wetlands in the north. In the Great Valley, a new adaptation and a genetically distinctive population carrying Berkeley traits (the Utian-speaking group) replaced the (possibly Hokan-speaking) Windmill. The displaced Windmill appear to have retreated to the south (the Stockton district), where the Meganos aspect of the Berkeley pattern—a hybrid of both cultures—appeared.

At the same time as this initial expansion, on the Bay itself and along the coastal terraces of the PRNS-GGNRA there was a proliferation of archaeological sites dating to the Upper Archaic period, with substantial shellmounds intensively occupied at Ellis Landing (the Middle-period type site), Emeryville, West Berkeley, and Newark, and innumerable smaller sites. The pattern also appears, along with increased population, in the North Bay as the Laguna culture near Santa Rosa and at Clear Lake as the Houx aspect. The situation along the bays of coastal Marin and Sonoma counties is unclear: with an absence of archaeological information from this area

dating to the Middle Archaic, is uncertain whether the substantial Upper Archaic sites at Point Reyes (McClure, CA-MRN-266, and Cauley, CA-MRN-242) and north at Bodega Bay (CA-SON-299) are the result of in situ development or Miwokan intrusion. Greater study of this period, including attempts to isolate the period in the Duncans Point Cave site (CA-SON-348/H), could yield significant information on this obscure point in the area's history. It is clear, however, that the ancestors of the ethnographic-period Coast Miwok were occupying the study area by that time. Recent work on shell midden within the park indicates that oyster harvesting by indigenous people began no later than 2170 B.P. (Konzak and Praetzelis 2011:26).

North of the PRNS-GGNRA, the Berkeley pattern did not extend north of the Russian River; instead, there was a continuation of the Middle Archaic Mendocino pattern until about A.D. 1000 (Dowdall 2003:302). South of San Francisco, on the coast of San Mateo County, there was also no Berkeley influence; instead, Hylkema (2003:250) identifies an unbroken assemblage for both the Early and Middle periods (i.e., the Middle and Upper Archaic), similar to Dowdall's finds on the northern Sonoma coast.

Appearing with the Berkeley pattern were changes in settlement and artifact assemblage, suggesting fairly large, semi-sedentary populations; the beginnings of clear social differentiation; and the appearance of formalized exchange. Although the mortar and pestle first appear in any numbers in assemblages from the Middle Archaic period, it is in the Berkeley pattern of the Upper Archaic that a focus on acorn-processing becomes a dominant subsistence trait. Mortuary practices during this period reflect widespread Berkeley-pattern customs: loosely and tightly flexed burials with no obvious orientation, usually in midden sites; frequent occurrence of red ochre in graves; and differential distribution of burial-associated artifacts, including moderately high frequencies of specific *Olivella* shell beads, indicating status distinctions based on wealth. A reliance on a diversity of bone tools is a hallmark of the Berkeley pattern.

In the Delta and on San Francisco Bay, a Middle/Late Transition dating from around A.D. 700 to 900 (Fredrickson 1994:74), or A.D. 700 to 1100 (Milliken and Bennyhoff 1993:386), has been identified based on significant changes in grave accompaniments. The time marks a period of disruption in much of central California, perhaps reflecting Patwin speakers from the north, who forced various Berkeley pattern groups to retreat from their expanded distribution (Bennyhoff 1994:83). The new population is suspected of bringing northern traits into the region: harpoons, the bow and arrow, and grave-pit burning.

Lower Emergent: A.D. 1000–1500

Unsettled climatic conditions and widespread population movements, as noted above, have been hypothesized for much of California and the western Great Basin at roughly the transition from the Upper Archaic to the Emergent period (Moratto 1984:560). The northern traits brought by the Patwin were readily adapted through central California by the Lower Emergent period; the ensuing culture was the Augustine pattern, named for a Central Valley site. In addition to a Patwin intrusion, the time may also mark the arrival from the north and east of Pomoan-speaking peoples into the Santa Rosa Plain, and westward to the coast, forcing

some of the Miwok south again. Along the coast, however, the Miwok appear to have maintained their hold to the land up to the Russian River.

The Emeryville Mound (CA-ALA-309) is the Lower Emergent type site on the San Francisco Bay. An important innovation in the new assemblage is the introduction of the bow and arrow, replacing the earlier atlatl and dart point; the predominant Lower Emergent (or Phase 1) projectile point here and throughout much of central California is the small, serrated, corner-notched point. The rectangular *Olivella* bead, another widespread marker for the Lower Emergent period, also appears. Mortars and pestles become especially abundant during this time period, apparently attesting to a well-developed acorn economy.

During the Lower Emergent, burials were loosely flexed, accompanied by moderate quantities of *Olivella* beads and *Haliotis* ornaments; the so-called Banjo ornament that appeared at this time is believed to represent the introduction of the Kuksu cult, which continued in various forms into the historic period. Some sites appear in previously little-used areas, perhaps suggesting the firming up of tribelet territories and, with it, a more formalized seasonal round that would result in regular use of outlying areas. At Point Reyes and bayshore Marin, most of the datable sites were used for the first time during this period; this is also the case for many of the San Francisco sites, and for the significant village on Sweeney Ridge (CA-SMA-125). As the Point Reyes Mendoza aspect is believed to consist of at least two phases (Van Dyke 1972), use of the coast may have been sporadic at this time. The first occupation sites on Angel Island east of the Marin Headlands appear to be dated to Phase 1, or the Lower Emergent, indicating a desire to fill out a variety of niches.

This is the time period of the Medieval Climatic Anomaly, which is so distinctive in the Sierra foothills. Here, it is assumed that the final eastern and southern expansion of Miwokan peoples occurred, with the filling in of the ethnographic territory of the Sierra Miwok, who may have displaced Yokutsan people.

Upper Emergent: A.D. 1500–Historic Period

The lifeways represented by the Upper Emergent Augustine pattern, also termed the Protohistoric period or Phase 2 of the Late horizon, are believed to be similar to those at the time of historic contact. Included in the assemblage are obsidian non-serrated corner-notched points, the obsidian notchless point preform, chert bead drills, clam disc beads, *Olivella* lipped beads, and the hopper mortar and pestle. Clam disc beads were manufactured at Sonoma and Marin sites and used as a form of currency for exchange in a network that ranged throughout California and into the Great Basin. These beads were also a major marker of wealth, worn in life to indicate status and buried in great quantities with their owners at death. Cremation was generally preferred for the wealthy, with remains placed in the midden, while persons of lesser status were usually buried in flexed positions, often away from the village. Aggregating large crowds for ceremonial purposes, a significant feature of the social and economic life during the ethnographic period, is reflected in Upper Emergent sites by the elaborate ornaments and other regalia and the presence of large-scale housefloors.

Some very large villages are inferred for this period, especially in the Delta and Central Valley where a mound might be occupied by several hundred people. On San Francisco Bay, a virtual abandonment of the bayshore was initially inferred, indicating a new emphasis on terrestrial resources. Accordingly, the type site for the Upper Emergent in the Bay Area is the Fernandez site (CA-CCO-259), a dark midden set well back from the Bay. While such a wholesale shift is no longer supported, a generally greater reliance on inland resources is suggested.

At Point Reyes, the Estero aspect is the marker for the first contact with Europeans. The descriptions of the native people gathered from Francis Drake's visit, in fact, served to date Phase 1 of the Late horizon. With Drake's visit taking place in 1579, it was arbitrarily assumed that the lifeways in place at that time had existed since at least A.D. 1500.

ETHNOGRAPHIC CONTEXT

The study area is within the traditional territory of the Coast Miwok. The people collectively called the Coast Miwok by ethnographers were actually several distinct groups who spoke dialects of one of the California Penutian languages. These speakers of the Coast Miwok language occupied a territory centered in Marin and adjacent Sonoma counties (Kelly 1978:414). The primary sociopolitical unit was the tribelet, or village community, which was overseen by one or more chiefs. The closest village to the study area was Olema-loke, approximately 2 miles south of the current study area, which may have been a regional political center (Kroeber 1925:273). The total Coast Miwok population prior to missionization was relatively small, around 2,000 according to Kelly (1978:414). In general, the Coast Miwok were culturally similar to their Pomo neighbors to the north (Kroeber 1925:276).

The Coast Miwok engaged in hunting and plant-gathering strategies in a variety of environments. The Coast Miwok territory held both coastal and open valley environments. The latter contained a wide variety of resources, including grass seeds, bulbs and tubers, bear, deer, elk, antelope, several bird species, and rabbits and other small mammals. Marine foods were particularly important: surf and bay fish, bullhead, steelhead, and salmon were captured, and shellfish, including mussels and clams, were gathered from rocks and beaches (Kelly 1978:415–416).

The Coast Miwok built above-ground conical dwellings constructed of a grass-covered frame of two forked, interlocking poles of willow or driftwood, with a slightly excavated central hearth. Large villages had a sizeable sweathouse, dug roughly 1.5 m into the ground, with a large central post that supported a roof of poles, earth, brush, and grass. In large villages, additional ceremonial chambers, or dancehouses, were constructed by secret societies; they were smaller versions of the sweathouse, being perhaps 5 m in diameter and excavated to a depth of 0.75 m. Female secret-society chambers were even smaller (Kelly 1978:417).

The Coast Miwok recognized private ownership of goods and songs, and village ownership of rights to land and/or natural resources; they appear to have aggressively

protected their village territories, requiring monetary payment in the form of clamshell beads for access rights, and sometimes even shooting trespassers. Clamshell disc beads were used as a form of currency and appear to have played a central role in the Coast Miwok economy. The beads were used to purchase obsidian and yellow paint from the Wappo, and obsidian and venison from the Pomo. Within families or among members of the same tribelet, beads could be used to purchase access to privately held hunting or fishing areas, admission to dances, medical attention, initiation into secret societies, even training and instruction in dancing, singing, curing, and crafts from one's own relatives (Kelly 1978:418). Magnesite cylinders, purchased probably from a Lake County Pomo group, served a similar function. While beads were regularly used as currency among the Coast Miwok, the group as a whole did not appear to trade vigorously with other groups and may instead have bartered for access rights to resources (Kelly 1978:418).

After European contact, the Coast Miwok were significantly disrupted by missionization, disease, and displacement. With the establishment of the Mission San Francisco de Asis, or Mission Dolores, in 1776, local Native American groups were drawn into the mission system and dislocated from their traditional territory (Kelly 1978:414). A second wave of disruption came with the acquisition of California by the U.S. in 1846, and the subsequent lumbering, dairying, and agriculture that boomed to feed the mining industry and the following growth of California. The few surviving Coast Miwok found work in the lumber mills and fields of the region (Kelly 1978:414).

HISTORICAL CONTEXT

The Point Reyes region was one of the earliest areas described by European explorers in Alta California. The Point Reyes cape was probably discovered by Cabrillo in 1542; almost four decades later, in 1579, Francis Drake dropped anchor along the California coast, possibly in what was to become known as Drakes Bay, just east of Point Reyes (Hoover et al. 1990:96-97, 172-173). Sixteen years after Drake's landing, the *San Augustin*, a Manila galleon piloted by Sebastián Rodríguez Cermeño, entered Drakes Bay. The ship, loaded with Asian trade goods and heading for Acapulco, was wrecked by a violent storm after its arrival in November of 1595. Before returning to the sea in a surviving launch, the crew explored inland from the bay a distance of four leagues (about three and a half miles), making contact with several Coast Miwok villages and obtaining acorns from them (Hoover et al. 1990:172-174; Moratto 1974:5).

The Vizcaíno expedition passed the point in 1603 and named it Punta de los Reyes after the day of *los reyes magos*, the "three holy kings" (Gudde 1998:315). The Vizcaíno expedition discovered Tomales Bay that same year, though they assumed that the narrow bay was a river (Gudde 1998:396). Tomales Bay may be named either for the Tamal Indians, a group of Coast Miwok who appear in the baptismal records of Mission Dolores in 1801, or for the Coast Miwok word *tomales*, or bay (Gudde 1998:396; Hoover et al. 1990:180).

Many of the traditional lifeways and land-use patterns that had served the Coast Miwok for centuries changed with the establishment of Spanish missions in the Bay Area. Native Americans were brought to the missions, both willingly and by force, to be converted to Christianity, to learn farming and other “civilized” skills, and to serve as laborers. Many of the native people at the missions died of diseases introduced by the foreign settlers and from malnutrition. By the mid-1800s, foreign settlement within the Marin County region had not only displaced the Coast Miwok from the villages and lands from which they had traditionally obtained their livelihood, but had also disrupted culturally and economically significant seasonal gathering strategies and trade (Gerike et al. 1996).

Point Reyes National Seashore is adjacent to the town of Point Reyes Station, the town of Bolinas, and the community of Olema. Point Reyes Station is in the Punta de los Reyes (Sobrante) land grant, near its southeastern border with the Tomales y Baulenes land grant and the Nicasio (Black) land grant. The nearby Rancho Punta de Los Reyes, an earlier grant separate from the Sobrante property, consisted of a 35,000-acre grant made in 1836 to James Richard Berry, an Irishman, who shortly thereafter sold a portion of the rancho to Joseph Snook, who in turn sold his portion to Antonio María Osio in 1843. Osio obtained the rest of the original grant and was granted the remaining 48,000 acres of land on Point Reyes, titled the Rancho Punta de los Reyes Sobrante—“surplus,” or “leftover land” (Hoover et al. 1990:181). The town of Olema was originally a Coast Miwok village, recorded as Olemos or Olemus in the baptismal records at Mission Dolores. The town’s post office was established in 1852 (Gudde 1998:268; Hoover et al. 1990:181).

Among the first non-native buildings near the study area were probably the Snook cabin site that today consists of stone foundations and a cellar, likely built in the early to mid-1800s (Erickson 2010). These were followed by four lime kilns built south of Olema by James Shorb and William Mercer (California Historical Landmark #222, within PRNS property and still partially standing at the time of this report), and the warehouse of the 1856 Taylor Paper Mill, one of the first such mills in the region (Hoover et al. 1990:180-181). The historic Point Reyes Lighthouse was constructed more than a decade later, in 1870. The first railroad was completed in 1882, spurring the growth of the small community (Patterson 1976:6). The town began as a train station stop called Olema Station; it changed its name to Point Reyes and was formally established in 1887 (Gudde 1998:315; Livingston 1995:15). When a post office on the headland was named Point Reyes in 1891 as well, the town changed its name to the current Point Reyes Station (Gudde 1998:315). The town has historically served as a shipping and service area for the North Pacific Coast Railroad (abandoned in 1933), the Point Reyes Lighthouse, and several of the nearby dairy ranches (Patterson 1976:4-7). Today the town is a tourist destination that also serves to support the recreation economy of the Point Reyes National Seashore.

CHAPTER 2. CLIMATE CHANGE AND POINT REYES NATIONAL SEASHORE



Figure 5. Field team assessing condition of CA-MRN-286, west side of Tomales Bay, view to the north (Accession # 70-10-D01-03).

INTRODUCTION

The world's major scientific organizations are united in their assessment that the climate change now occurring is likely the result of anthropogenic greenhouse gas emissions (IPCC 2007; National Academy of Sciences 2011; Royal Society 2005). The evidence for climate change is pervasive and can be seen through several indicators, from sea level rise to ocean acidification to changing global temperatures. Evidence also suggests that climate change may be affecting terrestrial forest communities, making them more susceptible to disease and infestation. Some of the studies supporting this evidence, the different indicators of climate change, and their potential implications, are discussed below.

CLIMATE CHANGE AS A GLOBAL PHENOMENON

Climate change has been an ongoing event for all of our planet's history. There are many reasons the world's climate could be dramatically altered—volcanic eruption, solar flares, changes in the earth's magnetic fields, or objects from space such as comets. Some are short term: the massive dinosaur extinction that took place 65 million years ago is widely thought to have been caused by a single comet impact leading to a nuclear winter-type freeze (Kerr 2005: 335; Perkins 2001;). Others are long term: a catastrophic series of massive volcanic eruptions 250 million years ago that spanned several hundred thousand years resulted in the largest terrestrial and marine species die off on record (Sephton et al. 2005).

The rise and fall of sea levels can be both a response to, and a trigger for, climate change. The melting and drainage of the massive Lakes Ojibwa and Assazi about 8,200 years ago caused the relatively rapid introduction of 105,000 to 164,000 km³ of fresh water to the North Atlantic, resulting in an average 3.0 (+/- 1.2 m) sea level rise worldwide on top of the post-Pleistocene glacial thawing (Gornitz 2007; Hijma and Cohen 2010:275). Recent studies tracking sea level curves, based on soil cores from mangrove-fringed embayments around Singapore, now show as much as -16 m to +2 m (- 52 ft. to -6 ft.) fluctuation over the past 8,800 years (Bird et al. 2010:804). Similar, smaller scale changes have been noted along the Brazilian, British, and Antarctic coastlines at a similar time depth (Edwards 2001; Martin, Dominguez, and Bittencourt 2003:101; Zwartz et al. 1998:131).

Even within the Late Holocene, changes in relative sea level (RSL) as a result of polar ice melt have been identified along the North American coasts (Long 2000:419) as have rapid ocean temperature increases by as much as 3°C (5.4°F) within a 50-year time span (Euler and Ninnemann 2010:647). On a larger scale, at least four to five major global climate changes have occurred over the past 5,800 years (Billeaud, Tessier, and Lesueur 2009:1033). Studies of sediment deposits along the Atlantic seaboard indicate sub-meter changes in oceanic mean high-water levels over the past 1,500 years (Edwards et al. 2004; Van de Plassche 2000; Van de Plassche, Van der Borg, and de Jong 1998). However, in general, sea levels changes have been incremental during the Late Holocene (Gornitz 2007).

PALEOCLIMATIC CHANGES AT POINT REYES PENINSULA

Meyer (2003) provides a geoarchaeological overview for Point Reyes National Seashore that includes a summary of broad landscape history of the park and elsewhere in the Bay region during the Holocene. His work is paraphrased and abridged below.

Over the past 15,000 years, sea levels at PRNS have risen at least 100 meters (about 328 feet), covering a continental shelf that was once a sloping plain extending some 10 kilometers (6.2 miles) west of the current mouth of the San Francisco Bay (Bard et al. 1996). This occurred relatively rapidly at first, with the first 55 m (160 ft.) occurring between 15,000 and 11,000 years ago, at an average rate of about 13 m (42.6 ft.) every 1,000 years worldwide (Bard et al. 1996).

Sea level rise slowed between 11,000 and 8,000 years ago to an average rate of about 8.3 m (27.2 ft.) every 1,000 years. Between about 8,000 and 6,000 years ago, the speed of sea-level rise rapidly decreased to only about 7.0 m (23 ft.) over 2,000 years, for an average rate of 3.5 m every 1,000 years (Atwater 1979; Atwater, Hedel, and Helley 1977; Stanley and Warne 1994; Wells 1995; Wells and Goman 1994). Over the past 6,000 years, sea level rose 8.0 m (26.2 ft.), slowing to an average rate of about 1.3 m (4.3 ft.) every 1,000 years, or 1.3 mm a year. Over the past 1,000 years, sea levels in the Pacific have fluctuated, including a 200 year-period during which sea level fell in response to the Little Ice Age, starting around 690 B.P. Sea levels have risen overall since that event (Nunn 1998:23).

Fossil plant remains (pollen and macrofloral) found along the California coastline suggest that significant climatic changes have occurred over the past 15,000 years (Adam, Byrne, and Luther 1981:255). The Late Pleistocene appears to have been cooler and/or wetter than current conditions, with cypress, pine, and fir trees far more common in the region, with a closed canopy forest dominated by pine and fir trees covering Point Reyes Peninsula (Adam, Byrne, and Luther 1981; Rypins et al. 1989). A warmer and/or drier climate during the Early and Middle Holocene led to a transition from pine/fir forests to grass/oak woodlands across the bay region (Rypins et al. 1989, West 1993, 2000).

EVIDENCE FOR CLIMATE CHANGE OCCURING TODAY

Geologists, geographers, and researchers reconstructing paleoenvironmental conditions have found abundant evidence for naturally occurring climate change during the Holocene. There are several key indicators for climate change, including changes in sea level, loss or expansion of polar ice and mountain glaciers, major changes in vegetation regimes, changes in solar energy absorption and reflection from the earth's surface and atmosphere, consistent and long-term seasonal temperature changes, and changes in precipitation.

Rising Sea Levels

The stability of the world's sea levels is changing. Sea levels began to rise in the mid-to-late 19th century to early-20th century at a rate of roughly 1.7 to 1.8 mm/yr (.06 to .07 inch), and appear to be related to a global warming event (Kemp et al. 2009:1035). Numerous studies show evidence of this, ranging from assessment of sea level changes in salt water marshes in North Carolina (Kemp et al. 2009), the effects of rising sea levels on dune formations along the Baltic Sea (Pruszek and Zawadzka 2005), to erosion on pocket beaches on the French Mediterranean (Brunel and Sabatier 2006:77). Water runoff from receding mountain glaciers worldwide, warmer ocean waters, and a dramatic doubling of the rate of ice loss from Greenland glaciers by the end of the 19th century have led to estimates of 2.8 mm/yr (0.11 inch) sea level rise in the early 1990s (Gornitz 2007). Since the 1990s, sea level rise has jumped to 3.8 mm (0.15 inch) a year, and sea level rise now appears to be a global phenomenon (IPCC 2007:30). In the early-21st century, Greenland meltwaters and ice continue to contribute to sea levels at an increasing pace, and the West Antarctic Ice Sheet is thinning. Vivian Gornitz (2007), special research scientist with the NASA Goddard Institute for Space Studies and Columbia University Center for Climate Systems Research states that

Either ice sheet, if melted completely, contains enough ice to raise sea level by 5-7 m [16. to 23 ft.]. A global temperature rise of 2-5°C might destabilize Greenland irreversibly. Such a temperature rise lies within the range of several future climate projections for the 21st century.

Increased Temperatures and Weather Changes

According to the IPCC (2007:30) assessment, in eleven of the twelve years immediately prior to their study, global surface temperatures were among the highest recorded in the past century and a half. The temperature increase is a global phenomenon and appears to be greater in the higher northern latitudes, particularly in the Arctic, where temperatures have increased at almost twice the global rate over the past century. Research on ocean temperatures indicates that, globally, ocean temperatures have increased to a depth of 3000 m (9,842 ft.) and that the oceans have been taking on over 80 percent of the heat added to the climate system. Land masses are heating up faster than the ocean, and lower- and mid-tropospheric temperatures appear to be warming at a rate similar to that of the surface. The IPCC note that, in general, it appears that cold days, cold nights, and frosts have decreased while hot days and nights have increased, and that heat waves have increased (IPCC 2007:30). The increased temperatures have resulted in the IPCC (2007:31, 33) stating that

There is a *high confidence* that recent regional changes in temperature have had discernible impacts on physical and biological systems... There is a *very high confidence*, based on more evidence from a wider range of species, that recent warming is strongly affecting terrestrial biological systems, including such changes as earlier timing of spring events, such as leaf-unfolding, bird migration and egg-laying; and poleward and upward shifts in ranges in plant

and animal species...There is *high confidence*, based on substantial new evidence, that observed changes in marine and freshwater biological systems are associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels, and circulation. These include: shifts in ranges and changes in algal, plankton and fish abundance in high-latitude oceans; increases in algal and zooplankton abundance in high-latitude and high-altitude lakes; and range changes and earlier fish migrations in rivers [italics in original].

The terms *very high* and *high confidence* refer to the likelihood that the associated studies, taken as a whole and assessed by third-party reviewers, are correct. *Very high confidence* indicates that the assessment has a 9 out of 10 chance being correct; *high confidence*, about 8 out of 10.

In addition, the IPCC (2007:30) note that some parts of the world are seeing high increases in heavy precipitation, particularly in the upper Northern Hemisphere; in other locations, such as the Mediterranean and the equatorial belt, the extent of areas affected by drought have increased. In an editorial discussing climate change and droughts effecting the U.S. heartland, physicist Joseph Romm (2011) forecasts that what he terms as the “dust-bowlification” of this region—increased evaporation, baked topsoil, and loss of water during the dry months as a result of earlier snowmelt. In some locations, such as the Iberian Peninsula, the seasonal annual rainfall has shifted dramatically to be predominantly in the fall rather than winter or spring (de Luis et al. 2010). Across the rest of the Mediterranean, ten of the twelve driest winters in over a century have been seen in the last 20 years (Hoerling et al. 2011). Precipitation simulations for the southern Canadian prairie systems for the next century show signs of dramatic increases in drought (Sushama et al. 2010). Conversely, the number of pre-monsoon tropical cyclones in the northern Indian Ocean and Arabian Sea have been increasing and have been shown to be the result of anthropogenic aerosols (Evan et al. 2011)

Glacial heating signals

Several important studies have been done looking at the rates of shrinking glaciers and models predicting future glacial retreat. Oerlemans (2005) of the Institute for Marine and Atmospheric Research at Utrecht University conducted a study on glacial climate signals of 169 different glaciers from around the world. His research concluded that they universally showed temperature increases starting in the middle of the 19th century and accelerating into the 20th century (Oerlemans 2005:675). Brown, Harper, and Humphrey (2010:98) have projected retreat rates for the Sperry Glacier in the Rocky Mountains and have found that, across the range of IPCC temperature increase projections, glacier retreat can be expected to continue through the next century.

Changes in Physical and Biological Systems

For the purposes of the IPCC study, physical systems include snow, ice, and frozen ground cover, hydrology, and coastal processes (2007:32). Worldwide, between 1970 and 2004, over 765 separate data sets show evidence of changes in the physical systems of the planet's surface, the vast majority of which are consistent with impacts expected specifically with global warming (IPCC 2007:32). Arctic ice cover is shrinking on an average of 2.7 percent per decade since 1978, with larger average percentages during summer months. Permafrost layers in the northern hemisphere have shrunk by 7 percent since 1900, and soil temperature has increased by as much as 3° C in some areas. Average snow and glacier cover have receded in both the Northern and Southern hemispheres (IPCC 2007:30). There is a marked increase in glacier lakes, representing melted glaciers, rock avalanches and ground instability as a result of thawed permafrost, and changes in the Arctic and Antarctic ecosystem. The resulting melt-off is also changing stream dynamics and water quality of rivers and lakes (IPCC 2007:31).

While studies of some other indicators that might suggest climate change (significant permanent loss of the Antarctic ice sheet, shifts in major ocean circulatory patterns, increased events such as tornadoes, dust storms, and hurricanes/typhoons) are so far inconclusive, overall, the IPCC (2007:33) concludes that “[o]f the more than 29,000 observational data series, from 75 studies, that show significant change in many physical and biological systems, more than 89 percent are consistent with the direction of change expected as a response to warming”.

The term “biological system” used by the IPCC simply means the totality of life forms living in terrestrial, fresh water, or marine environments (2007:32). Globally, between 1970 and 2004, nearly 29,000 data sets collected by researchers around the world show evidence of changes to biological systems. One of the major impacts that is linked to increased temperatures and subsequent lessening of precipitation is the widespread increase in tree mortality seen across the U.S. Joint research between U.S. and Canadian universities and government agencies and universities indicates that

...[A]nalyses of longitudinal data from unmanaged old forests in the western United States showed that background (noncatastrophic) mortality rates have increased rapidly in recent decades, with doubling periods ranging from 17 to 29 years among regions. Increases were also pervasive across elevations, tree sizes, dominant genera, and past fire histories [van Mantgem et al. 2009: 522].

This massive tree die-off can be at least in part attributed to raising temperatures and increased bark beetle infestations due to stressed conditions, which, in some stands, has resulted in the complete loss of adult tree stands. Like the physical systems, the vast majority of changes are consistent with global warming trends (van Mantgem et al. 2009:523).

Ocean acidification

Recent studies and risk assessments of global ocean pH levels indicate that the world's oceans and estuaries are becoming more acidic (Blackford 2010; Dupont, Dorey, and Thorndyke 2010; Fabry et al. 2008; Feely et al. 2010; Shi et al. 2010). Acidification is currently occurring as a result of CO₂ being absorbed by seawater; over the past 200 years, the world's oceans have absorbed roughly half of anthropogenic CO₂ (Royal Society 2005:vi). Water near the ocean's surface is typically slightly alkaline, with an average pH of about 8.2. Inorganic carbon is critical to ocean life and is largely responsible for controlling the pH of seawater; naturally occurring CO₂ is an important source of that carbon (Fabry et al. 2008:414; Royal Society 2005:iv). When CO₂ dissolves in seawater, it forms carbonic acid. Normally, part of the carbonic acid is neutralized by the slightly basic nature of the ocean water. The increase in atmospheric CO₂ is altering the pH balance of the world's oceans (Royal Society 2005:iv., 1). Higher concentrations of carbonic acid are binding calcium, needed by the world's coral reefs and shellfish species, as well as oxygen, making it more difficult for fish and other marine life to breath (Kerr 2009:459).

Ice cores from Antarctica indicate that CO₂ in the atmosphere dating back 650,000 has been stable, ranging between 160 and 290 parts per million by volume (ppmv) (Siegenthaler et al. 2005:1316). Currently, atmospheric CO₂ concentration is 380 ppmv and is rising at a rate of 0.5 percent a year. Fabry et al (2008:427) in their "Impacts of Ocean Acidification on Marine Fauna and Ecosystem state that "[S]ufficient information exists to state with certainty that deleterious impacts on some marine species are unavoidable, and that substantial alteration of marine ecosystems is likely over the next century". Perhaps more grimly, in a general public article in *Scientific American*, marine biologist Marah Hardt and ecologist Carl Safina summarized the situation in this way:

Marine life has not experienced such a rapid shift in millions of years. And paleontology studies show that comparable changes in the past were linked to widespread loss of sea life. It appears that massive volcanic eruptions and methane releases around 250 million years ago may have as much as doubled atmospheric CO₂, leading to the largest mass extinction ever. More than 90 percent of all marine species vanished. A completely different ocean persisted for four million to five million years, which contained relatively few species... Alarmingly, the pH drop observed so far and the predicted trajectory under current emissions trends are 100 times faster than any changes in prior millennia. Left unchecked, CO₂ levels will create a very different ocean, one never experienced by modern species [Hardt and Safina 2010].

While the studies of the effects of ocean acidification on the ocean biosphere are underway, less clear are the effects of an increasingly acidic ocean on bedrock and cliff faces. Further study needs to be done to assess the effects of ocean acidification and landform stability, the responses of different bedrock formations to ocean acidification, and what potential mitigation options are available on a site-specific basis.

CAUSES OF CLIMATE CHANGE

Climate change originating from natural phenomenon has been a reoccurring process throughout the history of the planet. Cyclical changes in the earth's orbit, or Milankovitch Cycles, have been a driving force behind the major glacial periods that took place throughout the Pleistocene (Helama et al. 2010:1981. Certainly, within the Holocene, some triggers for climate change have been identified. The substantial release of over 160,000 km³ fresh waters from Lakes Agassiz and Ojibwa into the North Atlantic may have contributed to a world-wide cooling event that started 8200 years B.P., or 6200 B.C., and lasted some 600 years (Gornitz 2007; Hijma and Cohen 2010:275). Sun spots and similar changes in the sun's surface may have triggered substantial climate changes over the past 12,000 years, and may have been at least partially responsible for two important Late Holocene climatic events, the Medieval Climatic Anomaly and the Little Ice Age (Helama et al. 2010:1981).

However, the vast majority of recent research indicates that the current climate change phenomena are the results of human activity (Anderegg et al. 2010). Specifically, the introduction of massive amounts of greenhouse gases into the atmosphere. The IPCC (2007:37-40) has released the following synopsis of the driving forces behind climate change:

Global atmospheric concentrations of CO₂, CH₄ and N₂O have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years... The atmospheric concentrations of CO₂ and CH₄ in 2005 exceed by far the natural range over the last 650,000 years. Global increases in CO₂ concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution. It is *very likely* that the observed increase in CH₄ concentration is predominantly due to agriculture and fossil fuel use. The increase in N₂O concentration is primarily due to agriculture... There is *very high confidence* that the global average net effect of human activities since 1750 has been one of warming... The combined radiative forcing due to increases in CO₂, CH₄ and N₂O...and its rate of increase during the industrial era is very likely to have been unprecedented in more than 10,000 years... Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG [greenhouse gas] concentrations... It is *likely* that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica)... discernible human influences extend beyond average temperature to other aspects of climate, including temperature extremes and wind patterns.

This finding is reiterated by the international team of researchers assembled by the Royal Society (2005:iv) in their review of the effects of atmospheric CO₂ and ocean acidification: “All the evidence collected and modeled to date indicates that acidification of the oceans, and the changes in ocean chemistry that accompany it, are being caused by emissions of CO₂ into the atmosphere from human activities.”

This has been more recently voiced by the U.S. National Academy of Sciences, Division of Earth and Life Studies:

Climate change is occurring, is very likely caused primarily by the emission of greenhouse gases from human activities, and poses significant risks for a range of human and natural systems. Emissions continue to increase, which will result in further change and greater risks. In the judgment of this report's authoring committee [Board on Atmospheric Sciences and Climate], the environmental, economic, and humanitarian risks posed by climate change indicate a pressing need for substantial action to limit the magnitude of climate change and to prepare for adapting to its impacts [National Academy of Sciences 2011].

Recent independent studies are now coming forth that is quantifying the amount of human contribution to climate change—at least 74 percent of observed global warming can be attributed to human activities (Schiermeier 2011b). These human activities have sparked a positive feedback loop. Global warming trends lead to increased water vapor in the air, greater cloud cover, and, as a result, warmer air temperatures that continue to feed the global warming cycle (Stanhill and Moreshet 1992:57). There is currently a high risk of permafrost thaw in the high latitudes, which is expected to release carbon at the same rate as current levels of global deforestation, and will include significant amounts of methane, resulting in an impact 2.5 times greater than that of deforestation (Schuur and Abbott 2011).

EXPECTED LONG-TERM IMPACTS OF CLIMATE CHANGE

The impacts that result from climate change are extraordinarily difficult to predict. Changes in sea level within the Late Holocene have not, perhaps counter-intuitively, been uniform across all coastlines as a result of salinity, ocean temperatures, subsidence, and changes in the gravity field as a result of uneven in-flow of meltwater from the poles (Long 2000:419). Overall increases in air temperature have a direct effect on raising sea levels, and not just in terms of melting glaciers or polar ice formations. Raised air temperatures result in changes in atmospheric pressure, wind regimes, ocean circulation, ocean surface topography, and ocean thermohaline structure—essentially, the density of the ocean water (Van de Plassche 2000:96).

According to the IPCC (2007:44), under the current climate change mitigation policies and sustainable economic and energy development practices, global greenhouse gas emissions will continue to grow. Over the next 20 years, greenhouse gas emissions are expected to increase anywhere between 40 to 100 percent. Over the next century, temperatures can be expected to change anywhere between 1.1 and 6.4° C (IPCC 2007:45). These temperature increases are most likely going to be over land masses in the northern hemisphere. Snow levels and sea ice formations are expected to continue to contract. Extreme heat events and heavy precipitation are very likely to occur with greater frequency. The size, number, and range of typhoons and hurricanes are likely to increase (IPCC 2007:46). Base sea level can be expected to rise 0.18 to 0.59 m over the next century as well, though more localized models suggest that this amount can be up 1.0 to 1.4 m (Heberger et al. 2009:5–6; IPCC 2007:45). Locations with Mediterranean climates and along coasts are specifically singled out as areas where the effects of climate change will hit hardest (IPCC 2007:52).

The IPCC (2007:48-52) outlines a number of expected impacts from climate change including:

1. The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g. flooding, drought, wildfire, insects, ocean acidification) and other global change drivers (e.g. land use change, pollution, fragmentation of natural systems, overexploitation of resources).
2. Over the course of this century, net carbon uptake by terrestrial ecosystems is likely to peak before mid-century and then weaken or even reverse, thus amplifying climate change.
3. Approximately 20 to 30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5°C.
4. For increases in global average temperature exceeding 1.5 to 2.5°C and in concomitant atmospheric CO₂ concentrations, there are projected to be major changes in ecosystem structure and function, species' ecological interactions and shifts in species'

geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services, e.g. water and food supply.

5. Coasts are projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas.
6. Precipitation can be expected to decrease by 10 to 30 percent over some dry regions at mid-latitudes and dry tropics, due to decreases in rainfall and higher rates of evapotranspiration.
7. The large amounts of CO₂ in the atmosphere have led to increased acidification of ocean waters. While research on this is still beginning, it is expected to have a negative effect on the biosphere (IPCC 2007:52).

CLIMATE CHANGE AND POINT REYES NATIONAL SEASHORE

Climate change is a critical issue in California. Heavily populated coastal areas, developed flood plains and desert locations, chronic water shortages, and sensitive high elevation, forest, and desert biological communities are all directly threatened by climate change. Scientists have been actively studying the effects of climate change across the state for more than a decade, and have found substantial shifts in snowpack, temperatures, sea level, and ecological zones (California Natural Resource Agency 2009:15). The State of California is responding to this threat through the creation of the California Climate Change Center and the preparation of state-wide risk assessments that use existing and developing studies to predict the long and short-term impacts of climate change and provide guidance for mitigating those effects. Three important guidance documents are discussed below and are used to assess the potential effects to PRNS.

The California Climate Change Center and the Pacific Institute have prepared *The Impacts of Sea-Level Rise on the California Coast*, an assessment of what can be expected in terms of sea level rise over the next century, its root causes, potential mitigation options, and cost predictions both in terms of damage and in mitigation (Heberger et al. 2009:xi). Phillip Williams & Associates (PWA 2009) have concurrently prepared *California Coastal Erosion Response to Sea Level Rise: Analysis and Mapping*. The California Natural Resources Agency (CNRA) has also produced a more general statewide planning document, the *2009 California Climate Adaption Strategy* which covers a broad range of expected impacts from climate change statewide. These studies form the backbone of public education on climate change at the PRNS website (NPS 2010). A more detailed look at the studies, the GIS impact and erosion models prepared as part of them, and their implications for the PRNS, are presented below. The models these studies present include detailed impact projections for the PRNS shorelines. They will be the models used for anticipating the extent of impact caused by climate change at PRNS and for prioritizing the locations and levels of work needed to mitigate the effects of climate change.

The Impacts of Sea-Level Rise on the California Coast covers some 1,100 miles of shoreline, and an additional 1,000 acres within the San Francisco Bay Region. About 930 miles of coastline, stretching from Santa Barbara to the Oregon border, was assessed for potential erosion. Southern California was excluded so as to not duplicate ongoing efforts there (Heberger et al. 2009:5). The Pacific Institute compiled existing data from NOAA, FEMA, USGS, and NASA, with recent data collected by NASA, NOAA, and USGS using Light Detection and Ranging (LIDAR) remote sensing equipment (Heberger et al. 2009:12).

California Coastal Erosion Response to Sea Level Rise: Analysis and Mapping employs new models of how cliffs erode in times of rising water levels. The models, designed by PWA using data from Scripps and the Coastal Data Information Program, were designed specifically for the California coastline as part of climate change impact predictions (Heberger et al. 2009:16). The total study covers almost 1,450 km, or 900 miles, of coastline (PWA 2009:3). About 720 linear miles of cliff faces were included in their models. Also included in their models were dune systems, which formed an additional 170 miles of coastline. Dune system erosion and shifting were based on the water level models, USGS shoreline data was based on historic shoreline change trends from the USGS National Shoreline Change Assessment study, and impact estimates were derived from 100-year flood event models (Hapke, Reid, and Borrelli 2007; Heberger et al. 2009:16). While *California Coastal Erosion Response to Sea Level Rise* has limits, the analysis by PWA is one of the first to address coastal erosion and is the most comprehensive to date (Heberger et al. 2009:17–18; PWA 2009:2, 3).

The 2009 *California Climate Change Adaption Strategy* was prepared by the CRNA following Executive Order (EO) S-13-08, signed by then Governor Schwarzenegger in 2008. The order called on State agencies to develop state-wide strategies for preparing for climate change. Their report summarizes the current scientific research on the effects of climate change across California and outline potential solutions that can be implemented within and across state agencies. The CNRA is leading the development teams for the strategy, and has created seven sector-specific working groups led by 12 state agencies, boards and commissions, and stakeholders. The resulting strategy received public commentary and has been finalized: the current version “proposes a comprehensive set of recommendations designed to inform and guide California decision makers as they begin to develop policies that will protect the state, its residents and its resources from a range of climate change impacts” (CNRA 2009:4).

RISING SEA LEVELS

The world’s sea levels are constantly changing, subject to the influence of astronomical forces from the sun, moon, and earth, and meteorological effects like El Niño. The ongoing measurement and assessment of sea levels is a global effort, with a worldwide network of more than 1,750 tidal gages continuously collecting data on water levels, each gauge measuring against a nearby geodetic reference, compared against measurements from new satellite-based sensors (Heberger et al. 2009:5).

During the peak of the last ice age, roughly 20,000 years ago, sea levels were 120 m lower than they are today (Gornitz 2007). Since then, sea levels have risen, peaked, and dropped slightly to their current levels (Bird et al. 2010:804). There have been time periods when this sea level rise has occurred rapidly over a few decades; generally, sea levels have gradually, and, incrementally, dropped over the past 6,000 years (Bird et al. 2010:804; Gornitz 2007).

This pattern is changing. Recent assessment by the California Climate Change Center and Pacific Institute has found that sea level rise has increased 20 cm since 1897, at an average rate of 2.2 mm per year (Heberger et al. 2009:5-6). They predict that sea levels will continue to rise at an accelerated rate, to 1.0 to 1.4 m (4.6 ft.) along the California coastline over the next century. This conclusion of acceleration is based on comparison of IPCC predictions made in their 2007 assessment of sea level changes with current measurements, based on medium to high greenhouse gas emissions scenarios also from the IPCC (Heberger et al. 2009:6). Statewide, the loss of coastline is estimated at 41 square miles, or some 26,000 acres (Heberger et al. 2009:xi).

This change can also be expected to affect coastal wetland areas. A sea-level rise of 1.4 m would flood approximately 150 square miles of land immediately adjacent to current wetlands (Heberger et al. 2009:3). About 478 acres of coastal wetlands, representing the combined areas covered by freshwater wetlands herb and saltwater marsh mesocluster vegetation communities exist within the PRNS (NPS 2010). The 1.4 m sea level rise would expand this considerably (Heberger et al. 2009:GIS data).

The measurements do not, however, reflect the worst case sea level rise should global temperatures increase such that the Greenland, Antarctic, and Arctic ice masses melt (CNRA 2009:21; Heberger et al. 2009:xi). Should abrupt climate shifts occur that release the water held in these areas, a sea level rise of 7 to 14 m (23 to 40 ft.) could occur (CNRA 2009:21). In such a scenario, PRNS and the local community would lose considerable infrastructure, including all of the PRNS coastal visitor facilities, long stretches of Sir Francis Drake Blvd., portions of Highway 1, and downtown Point Reyes Station. In general, as the potential occurrence and timing of this and other extreme worst-case scenarios are difficult to predict, the more conservative estimates used by the IPCC, CNRA, and Pacific Institute are used for this study.

Even with modest sea-level rise, inundation could be a problem. Studies done on barrier islands along the Pacific Coast on Colombia show that minor sea level rises combined with El Niño weather patterns have resulted in wave washover into low-lying landforms (Morton et al. 2000:85-86). Such events could occur at archaeologically sensitive areas within PRNS such as Limantour Spit and Horseshoe Pond.

ACCELERATED EROSION

While the sea cliffs of the PRNS are not vulnerable to inundation, they are highly susceptible to erosion. The projected higher sea levels are likely to accelerate shoreline erosion due to increased wave energy against the cliff face (PWA 2009:2). In addition, erosion of some sand spits and dunes may expose previously protected areas to flooding (Heberger et al. 2009:15). A projected sea-level rise of 1.4 m is predicted to result in a statewide loss of 41 square miles of coastline as a result of direct erosion from wave energy and flooding (Heberger et al. 2009:3). PWA notes that coastal erosion

is a complex response to many processes... including marine processes (water levels, waves, sediment supply and transport, etc.), terrestrial processes (rainfall, runoff, wind, etc.), and other (seismic, biologic, etc.) as well as geology and antecedent topography [2009:5].

Broad assessments of cliff faces along European shores conducted as part of the European Land–Ocean Interaction Studies (ELOISE) created by the Commission of the European Union, have concluded that the effects of climate change will “lead to the ‘removal’ or inland migration of sea cliffs, shingle beaches, sandy shores, and salt marsh habitats, resulting in wide-spread loss of coastal habitat and dune systems across the Arctic, Baltic, Black, Mediterranean, and North seas (Nunneri et al. 2005, in Vermaat and Gilbert 2006:31; Vermaat and Gilbert 2006:28-29). Within PRNS, cliff erosion is expected to take place along 29 miles, resulting in the potential loss of about 2,425 acres of cliff environs (Heberger et al. 2009). Eroded cliff faces will collapse into the ocean, resulting a progressing strip of coastal retreat followed by complete wave erosion and removal, as can be seen currently along the coastal strip bordering cliff faces.

One impact that is expected to be somewhat limited is the increase in size and strength of coastal storms along the California coastline. That said, the level of damage from storms is still expected to increase. Assessing the likelihood of extreme storm events, the CNRA (2009:20) states that

According to the 2009 Scenarios Project, the frequency of large coastal storms and heavy precipitation events do not appear to change significantly over the 21st century. However, even if storm intensity or frequency were not to change, storms will impact the California coast more severely due to higher average sea levels that can result in higher storm surges, more extensive inland flooding, and increased erosion along the state’s coastline.

Sea cliffs, particularly the sandstone formations along much of the PRNS, are eroded from both wave action and precipitation. Recent studies of sandstone formations south of San Francisco have quantified the increased rates of erosion caused by above-average waves and the role of precipitation, particularly large storm events, in undermining cliff faces through ground and surface water flow (Collins and Sitar 2008:488-489). Storm events can erode cliff faces from above and below, independent of sea level rise. Increased sea levels will only accelerate the erosion.

CHEMICAL WEATHERING

One potential effect that appears to be little studied is the potential effect of increased ocean acidification on the cliffs, beaches, and archaeological deposits within the coastal erosion and inundation zone. Studies have shown that ocean acidification has a deleterious effect on the growth and formation of marine shellfish and coral, particularly in their production of calcareous skeletal structures and sexual reproduction (Royal Society 2005:27). Research has also shown that the upper 30 cm of the ocean's surface is the most acidic and can be one pH level lower than deeper waters. Portions of the southern coast of PRNS belong to the Purisma Formation of uplifted marine sandstone and siltstone formed during the upper Miocene to lower Pliocene. The gray siltstone of the Purisma Formation is diatomaceous and contains carbonate concretions that form prominent discontinuous beds (Clark and Brabb 1997:3). The remainder of the southern coast falls into the Monterey Formation, consisting of middle- to upper-Miocene porcelanite and chert. Across Tomales Point, the bedrock consists of tonalite, an igneous, granitic mass that formed in the late Cretaceous (Clark and Brabb 1997:2).

It would seem likely, given the increase in carbonic acid expected as a result of climate change and rising concentrations of greenhouse gases, and that this increase is expected to be at its highest concentration within the upper 30 cm, that chemical erosion as well as physical erosion could take place along the cliff faces of western Drakes Bay. Even without rising sea levels, more frequent and powerful storms, and changing wind and wave patterns, the increasing acidic nature of the ocean water itself could react with the diatomaceous siltstone carbonate concretions that could speed cliff erosion and collapse. The Monterey Formation along the southeastern edge of the park also contains fossilized foraminifera shells and could possibly be susceptible to chemical weathering. It seems unlikely that exposed cliffs of tonalite would be as susceptible to chemical weathering as the Monterey or Purisma formations, but further study is warranted.

TEMPERATURE CHANGES, PRECIPITATION, VEGETATION, AND FIRE

In their assessment of the next century of the effects of climate change in California, based on data synthesized by the IPCC for North America, the CNRA predicts a 4- to 9-percent increase in temperature and, over the next 50 years, a 12- to 35-percent decrease in precipitation (CNRA 2009:15). The temperatures are expected to increase more in the summer months than the winter, and inland areas are expected to be hit harder than coastal locations. The number, size, and duration of heat waves are predicted to increase; even if greenhouse gas emissions were brought to a low level today, the existing conditions are expected to propel temperature increases and precipitation decreases forward for decades (CNRA 2009:16-17). The CNRA(2009:19) predicts that “ significant increases in the frequency and magnitude of both maximum and minimum temperature extremes are possible in many areas across the state... it is likely that the state will face a growing number of climate change-related extreme events such as heat waves, wildfires, droughts, and floods.” Elsewhere around the world, changes in intensity in storm patterns have been noted (Pruszek and Zawadzka 2005).

Rising sea levels can also be expected to change the vegetation regime of coastal wetland areas. Across California, sea-level rise of 1.4 m would flood approximately 150 square miles of land immediately adjacent to current wetlands (Heberger et al. 2009:3). Within PRNS, sea-level rise could account for a substantial increase in wetlands (Heberger et al. 2009). This will result in areas not only being inundated, as discussed above, but also becoming densely vegetated with riparian grasses along the bordering areas. This will change the surface visibility of, and access to, any sites within these border areas.

On a larger scale, the general biodiversity of the park can be expected to change. The CNRA (2009:46) predicts that several factors critical to a healthy biological community could be severely disrupted. Barriers, either natural as a function of increased inundation or desertification, or man-made, such as sea walls and levees constructed to stem rising sea levels, can interfere with species movement and migration. Increases in temperature could be expected to have immediate effects on a vegetation community. The loss of native species makes such environments susceptible to invasive species, as well as causing major damage to fragile ecosystems. Rare, threatened, or endangered species might be exceptionally susceptible to such changes. Phenological events—those naturally occurring flowering, pollinating, or breeding events triggered by climatic cycles—could be greatly impacted, as could predator-prey and pollinator-plant interactions (CNRA 2009:46).

Access to, and quality of, surface water may be dramatically affected as well. Less precipitation not only affects the overall water table but the surface water available to plants and animals. Just as terrestrial species might change, runoff will be lessened and riparian communities could be altered. Water temperature, sediment load, and pollution could change, also effecting wildlife. The worsened environmental conditions and reduced water availability will likely increase the susceptibility of native plants and animals to pests, disease, and wildfire (CNRA 2009:49). Additionally, there may be changes to the amount of coastal fog. Coastal fog plays a critical role in supplying moisture to coastal forest communities, and is expected to decrease as a result of climate change (CNRA 2009:67).

Recent research has shown that, across the western U.S., unmanaged old forests have shown dramatic increases in tree mortality. This increase spans elevations, trees sizes, dominant species, and past fire histories. Climate change has been targeted as the main contributing factor to this tree mortality (van Mantgem et al. 2009:521). As one would expect, the potential for fire, and the size, frequency, and rate of spread will be greater if the fuel load is high and drought years that dry out accumulated fuel occur in greater frequency. This change in the previous fire regime could result in substantial impacts to local habitat, and could lead to species displacement or eradication.

Species shifts to higher elevations have already been recorded, and invasive species are on the rise (CNRA 2009:107). For example, a major contributor to fire threats across the western United States is the dramatic increase in bark beetle populations. Recent research has shown that bark beetle populations are greater than at any time over the past 125 years (Raffa et al. 2008:521). This population boom appears to be directly tied to climate change; once critical thresholds in the impact of climate change on forests are reached, conditions are right for an explosive, and self-sustaining, bark beetle population expansion. While the beetle and similar

eruptive species typically only cause minor disruptions in forest biomes, current conditions have negated many of the limiting factors to these insects (Raffa et al. 2008:515).

Another potential impact is a change in the woody vegetation and grasslands along the edge of the cliff faces. This vegetation helps stabilize slope faces, and in test areas where cattle have been kept away from cliff edges, recovered vegetation growth appears to have helped anchor the cliff face while grazed edges continued to degrade (Meyer 2005). Research on coastal sandplain heathlands along the northeastern U.S. and eastern Canadian coastline has shown that increases in salt spray can limit vegetation growth, particularly of woody species (Griffiths 2006:69). It would seem likely that higher sea levels and greater erosion of the cliff edges would result in sea spray reaching further inland, possibly impacting the existing woody plants currently helping stabilize cliff faces.

Figure 6. [REMOVED FROM PUBLIC VERSION]

Disease is also already taking its toll on coastal forests. Sudden Oak Death (SOD) is triggered by the fungus-like pathogen *Phytophthora ramorum*, and can strike mature trees of many different species, often resulting in the death of the tree. Bark and ambrosia beetles colonize the open wounds caused by the disease; fungal infections soon follow (Kelly et al. 2008 312–313). Tanoaks (*Lithocarpus densiflorus*), an important acorn food source to native peoples along the north coast, are especially susceptible (Nettel, Dodd, and Afzal-Rafii 2009:2224). Research by Monahan and Koenig (2006:151, 154) on SOD and California coastal live oak (*Quercus agrifolia*) has led to algorithmic models predicting the potential future extent of SOD and has concluded that some 17,570 km² of California coastline will be potentially impacted by SOD, including portions of PRNS. The disease has reached epidemic proportions in coastal oak communities in California and has spread to California black oak, Shreve oak, and over two dozen other tree and shrub species, including Pacific madrone (*Arbutus menziesii*), redwood (*Sequoia sempervirens*), California bay laurel (*Umbellularia californica*) and Douglas-fir (*Psuedotsuga menziesii*) (Kelly et al. 2008:312; Kleijunas 2010:5; Moritz and Odion 2005:07). Sudden Oak Death is not as prevalent in areas that have burned in the last 60 years; forest management practices that have not actively included controlled burns may have resulted in forest stands now susceptible to SOD (Moritz and Odion 2005:106).

This potential for worsening drought conditions, warmer weather, and diseased and infected vegetation communities all increase the chance of fire. The CNRA (2009:51) has assessed fire studies over the past three decades and has arrived at the following conclusion:

Since the 1980s, the state has recognized apparent changes in the frequency, intensity, and duration of wildfire, especially in conifer-dominant ecosystems in the Sierra Nevada and chaparral ecosystems in coastal and interior southern California. Land-use, land management, and fire suppression policies, particularly in conifer forest and chaparral communities, are thought to have affected attributes of fire regimes throughout human history. In recent years, researchers have determined that changes in climate have had an important role in altering fire regimes. Current information suggested an extension of the fire season and increasing the number of large wildfires, as well as wildfire intensity. Particularly, higher spring and summer temperatures and earlier spring snowmelt are thought to have contributed to these changes. Wildfire occurrence statewide could increase from 57 percent to 169 percent by 2085.

While occasional wildfires are an important and necessary part of many healthy habitats, when they occur naturally they are of a low to moderate intensity. As a result of both climate change and past forest management practices, recent and predicted future wildfires show a change to more frequent, high intensity wildfires. In some areas, wildfire is not common and the increased fire frequency risks the stability of the habitat (CNRA 2009:110).

How, where, and to what extent each of these issues plays out within the natural diversity of the park is difficult to predict, but some changes can be hypothesized. According to the park GIS database (NPS 2010), over 20,000 acres, nearly half of the park, is in either deciduous or evergreen forest. If sudden oak death, bolstered by warmer weather and drought conditions, infects the majority of oak species in the park, and temperature changes make the park uninhabitable by redwoods, California bay laurel, and Douglas-fir, the park's forest lands will both lose their ability to support associated plant and animal species and become a tinderbox. This in turn could result in unstable slopes, as the tree and brush species that anchor soils on steep terrain would be lost during fires. The potential temperature changes could therefore not only have an effect on the vegetation communities, they could also trigger geomorphic processes that change topography, dam creeks, cause property damage, or other bi-products of land and mudslides.

It is less clear how impacted the chaparral and brush communities will fare, or how well the agricultural areas and native grass lands will hold up. If the temperature changes result in changes to coastal fog, these communities, along with the forests, would see an altering in the water regime not accounted for in the loss of precipitation in the form of rain, possibly resulting in less water if coastal fog is less common. The combination of less water and greater temperatures could result in major vegetation die-offs in the park. At the time scale discussed for climate change in this report, it seems unlikely that all of the park's vegetation communities will have time to shift to new locations or adapt to the new environmental conditions.

DUNE EROSION AND SEDIMENTATION

The projections for dune erosion hazard by PWA (2009) predict that roughly 650 acres within PRNS will be directly affected. Their model for dune erosion was based on projected sea level rise combined with 100-year storm flood events (PWA 2009:11). Sediment budget and geomorphic controls were factored in using data collected with LIDAR after the 1997-1998 El Niño event and USGS data.

In locations such as Limantour Spit, dunes have been favored places for resource collection and processing for millennia. Six prehistoric archaeological sites have been recorded on the Spit alone; these sites are occasionally buried and then re-exposed as dune formations shift across the landscape as a result of wind and storm events. The dune erosion hazards as presented by PWA should not be construed as being limited only to these areas; their projected impacts reflect primary damage done by sea level rise. The potential exists for the stability of the entire dune systems along the PRNS beaches to change if wind patterns are altered as a result of sea level rise, water temperature changes, or changing water current direction and force. Areas particularly hard hit would be the above-mentioned Limantour Spit, Drakes Beach, the mouth of Horseshoe Cove, and North/Point Reyes Beach.

Two important factors in dune formation and stability are wind velocity and direction. Recent studies in Poland along the Baltic Sea have shown that storm intensity along the Polish coastline, which has extensive dune systems, has increased dramatically (Pruszek and Zawadzka 2005:134). One of the results of this increase is that dune and beach formations are eroding or retreating from the ocean edge at a rate of 0.3 m a year; in some areas along the coastline, portions of dune systems are expected to be destroyed by encroaching sea level (Pruszek and Zawadzka 2005:143; 147). Also important is the water table; higher fresh water tables that are accessible to dune plants help stabilize dune systems. Studies of climate change and dune structures along the Sefton Coast in the United Kingdom show that climate and geomorphological models will result in lower water tables and endangered dune habitat (Clarke and Ayutthaya 2010:123-124). Not all of the dune habitat has to be lost in order for dune ecological systems to collapse; models of dune habitat evolution vs. rapid sea-level rise along the dunes of Galveston Island, Texas, show that even moderate sea level rise models can significantly disrupt the life cycle of dune plants, which in turn directly impacts wildlife and habitats further inland (Feagin, Sherman, and Grant 2005:362-363).

Changes in sediment deposition upstream from the dune systems can also have a dramatic effect on dune stability. Research on coastal erosion within Tangier Bay, Morocco, have noted that a combination of a loss of sediment upstream as a result of industrialization and channelization with accelerated sea level rise has resulted in the complete loss of some dune structures (Snoussi et al. 2009:39). Studies of recent dune formations along the northwestern corner of the Nile Delta have found similar results, and in fact argue that the stabilization of the sand dunes could be a more effective, and less expensive, means for protecting coastlines from the inland effects of rising sea levels. It has recently been suggested that an increased sediment load from upstream sources might help mitigate the effects of eroding dunes and beaches (Psuty and Silveira 2010:159).

Young, Belknap, and Sanger (1992:46) were able to demonstrate, through a large-scale study of John's Bay in Maine, that site preservation along estuarine environments varied greatly during times of rising sea levels. Protected locations in the inner bay areas received the greatest amount of sedimentation and the least amount of erosion. Studies of coastal marshes in Cape Cod have shown that the complicated dynamics of marsh vegetation, outflowing water, and shape of the coastal marsh reduce the mean high-water level as one measures inland (van der Molan 1997:232). This suggests that not only wave energy, but the actual elevation of inundation may be less in the upper reaches of the marshes than at the ocean edge. It seems likely that these conditions contribute to the sediment accumulation and reduced erosion.

TRIBAL PERSPECTIVE ON CLIMATE CHANGE AND POTENTIAL IMPACTS ON CULTURAL RESOURCES

The following section has been prepared by the Federated Indians of Graton Rancheria as part of their ongoing collaborative efforts to protect the indigenous cultural heritage at Point Reyes National Seashore. Their material has been submitted verbatim.

The Federated Indians of Graton Rancheria have many reasons to protect all of the different elements that comprise our cultural resources. These elements include areas of habitation, usually marked by midden soil, burial areas, areas of specific use, such as tool making, resource gathering (plants, animals, quarries, etc.), trails, ceremonial locations and areas where a singular element or a collection of these elements are found, known as Traditional Cultural Properties (TCP).

Specific cultural resource locations were sometimes traditionally used during different seasons, sometimes abandoned for periods of time and then reoccupied. The occasional abandonment did not decrease its importance as part of the cultural landscape. The land was blessed and considered sacred by our ancestors and remains so today.

Native people have lived here during many periods of dramatic environmental change that altered their world significantly. As the natural resources varied and adapted to climate change over the thousands of years, we have migrated to other areas, changed our diets, developed new technologies and learned to live with what natural resources nature provided. Adapting to some type of environmental change has always been necessary for our survival. Today many new forces are emerging and have affected our gathering of the natural resources provided by the land and our use of ceremonial or sacred sites.

In the past few hundred years European contact and colonialism have forced our ancestors and current Tribal people to move further from their spiritual connection to the land. Prior to the dramatic effects caused by the European arrival, there was a slow adaption to the natural forces that changed over time, requiring our ancestors to change the location of habitation, their trading patterns, their diets, gathering areas and the technology used to process their food. Our ancestors saw many of the physical locations of sacred areas and locations altered or even destroyed by these natural forces. This did not diminish the spiritual significance of the area and the objects revealed by soil disturbance. Environmental changes were viewed by them as part of the natural order of the world.

Today we are faced with a different pace of environmental change that is detrimentally affecting our cultural resources. Modern society has contributed to climate change that is causing the physical landscape and the weather patterns to rapidly change. The soil disturbing effects of erosion, rainfall, droughts, sea level rise, rise in sea temperatures and extreme weather patterns have or are about to destroy many of the Tribe's sacred sites. The Tribe is now faced

with a predicament concerning how to advise responsible agencies to protect our cultural resources from these newest environmental threats brought about by modern society.

Recent discussions of climate change and its probable causes require consideration of some modern perspectives of this destructive process for Tribe resources. We now can no longer allow the natural forces to affect cultural resources in the 'traditional' way. It is no longer only nature that is the cause of climate change and this fact is the problem. Our traditional ceremonies and ways of interacting with nature cannot be continued because of our industrial society's intervention in the climate process. We can no longer leave artifacts exposed. People are finding, removing or collecting sacred items exposed by 'natural' events. National Parks and all other agencies must, in collaboration with the Tribe, understand the importance of these resources to the long term health of Tribal members and develop policies and methods for their preservation for future generations of Tribal members. The formation of new public and Tribal policies for the protection of cultural resources from destruction due to climate change is critical for the Tribe's survival.

In the traditional and historical cultural order, the destruction of cultural resources occurred and this loss was permitted because the spirits in nature have power over them. Now, natural climate change and its effects are cannot be separated for modern contributions to the change by pollution from modern life and industry. Therefore the destructive effects of climate and water level changes and their effect on cultural resources should be actively prevented or mitigated by agencies through developing and instituting plans and protective measures for cultural resources, in consultation with Tribes.

The scope of future environmental change will be dramatic. We understand it will be difficult and expensive to protect all resources with physical barriers. Therefore, discussions and consultation on how decisions will be made should begin immediately. There are two main factors for these discussions: National Parks' mission of preserving a 'wilderness' and all of its cultural resources, and selecting the type and cost of creating structures and physical barriers to protect the cultural resources within their jurisdiction.

How to preserve the spiritual nature of cultural resources, preserving the physical components of resources, mitigating other resources where feasible and developing appropriate prayers or ceremonies for what we can no longer protect are some of the cultural challenges the Tribe is facing.

Following is a partial list of questions which the Tribe and National Parks must address as we develop a formal set of policies and/or MOA for the preservation of cultural resources, including individual sites, archaeological districts and Park as a whole. A discussion of them will help to consider the many ramifications of the effects of climate change on our Tribe's cultural resources.

QUESTIONS FOR CONSIDERATION: POINT REYES NATIONAL SEASHORE AND THE FEDERATED INDIANS OF GRATON RANCHERIA

- Is this site sacred (using the guidelines of the Native American Religious Freedom Act)?
- Does the site contain human remains and burial related items?
- Can the human remains and burial related items be safely left 'in situ'?
- Can the human remains and burial related items be protected from the public?
- What is NPS' technical ability to protect the site from further physical damage?
- Will inundation disturb or change the spirituality of the site?
- Will covering the site with soil/concrete/rock disturb or change the spirituality and archaeological significance?
- Will plantings disturb or change the spirituality of the site?
- How can we determine the vulnerability of the site due to the geologic substrate?
- If the site is left to erode or degrade, what would the monitoring plan look like?
- If sites are left to erode or degrade, should a priority plan be developed?
- What is the criterion for prioritization if we can only protect some sites, (lithic scatters, habitation, camping sites, etc.)?
- If the site is left to erode or degrade, should a data recovery effort be requested?
- What research, if any, should the recovery be focused on?
- Where would we deposit the cultural materials from the data recovery effort?
- What plant gathering areas do we protect?
- How do we protect the gathering areas?
- How do we protect districts and or TCP's?
- What types of information should we be gathering regarding methods of site protection?
- What other agencies or sources of information should we be consulting?
- What budgetary method best suits a preservation plan?

CONCLUSION

The IPCC (2007:65) states that

There is *high confidence* that neither adaptation nor mitigation alone can avoid all climate change impacts. Adaptation is necessary both in the short term and longer term to address impacts resulting from the warming that would occur even for the lowest stabilization scenarios assessed. There are barriers, limits and costs that are not fully understood. Adaptation and mitigation can complement each other and together can significantly reduce the risks of climate change.

Identifying key players in the increase in global greenhouse gases, and the ways and means to prevent climate change, or to at least stem it, are beyond the scope of this study. Rather, the purpose of this overview was to demonstrate the overwhelming consensus in the scientific community that climate change is occurring, that the effects of climate change are numerous, severe, and will be felt globally, that climate change appears to be primarily fueled by human-generated greenhouse gas emissions, and that stemming those emissions is unlikely to halt the current climatic trajectory, although it will slow the process.

The IPCC (2007:44) proposed six different global scenarios, each containing different variables on population growth, expansion of sustainable and renewable energy sources, and elimination of greenhouse gas production. As suggested above, even in the best-case scenario, greenhouse gases will continue to increase for at least the next 40 years. Climate change will occur, though the extent of the change is still a matter of considerable discussion and will be dependent on commitments from governments, private sector business, and the world's human population. It is critical, therefore, that government agencies, including NPS, prepare for the effects of climate change even though the full extent of their impacts are still being studied and will be dependent on social and governmental actions that have yet to occur.

NPS acknowledges the threat that climate change poses to its natural and cultural resource base, as well as to its park infrastructure. The Federated Indians of Graton Rancheria have clearly stated their concerns regarding the protection of their ancestral heritage in the face of a changing climate. In an effort to mitigate the effects of climate change on cultural resources, ASC has assessed the potential threats posed by climate change to cultural resources; this assessment appears in the next chapter. As discussed above, the models for impacts prepared by the Pacific Institute for the California Climate Change Center are the models favored by NPS. These models take into account the analysis conducted by the IPCC and expand upon this analysis for the California coastline.

CHAPTER 3. PREDICTED IMPACTS OF CLIMATE CHANGE ON ARCHAEOLOGICAL RESOURCES WITHIN POINT REYES NATIONAL SEASHORE

Figure 7. Overview of sites threatened by cliff erosion and high flood levels by year 2100 (using 1.5 m elevation sea rise and erosion model by Heberger et al. 2009; USGS 1976 *Drakes Bay* 1:24000 scale in original).

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INTRODUCTION

Point Reyes National Seashore has been home to human populations for at least 3,000 years (Bennyhoff 1994; Stewart 2003). Evidence further north along the coast at Duncans Landing points to a coastal presence dating back at least 9,000 years (Schwaderer 1992). The wide range of both marine and terrestrial resources, combined with the relatively short distances between bay, rocky shore, and inland valley resource collection areas would have made the Point Reyes peninsula an attractive landscape to indigenous populations. This chapter focuses on identifying the kinds of indigenous archaeological resources that are known or might be present, and some predictions on how climate change might impact those resources.

THE ARCHAEOLOGICAL RECORD AT POINT REYES NATIONAL SEASHORE

Archaeological investigation within PRNS stretches back to the coastal shell mound studies of Nels Nelson in the early 1900s (Nelson 1909). Since then, over 160 indigenous archaeological sites have been recorded within the park. Some of these have been lost as a result of human activities or erosion (Edwards 1970). Only a small fraction—5,822 acres, or about 8 percent of the total park area—has been surveyed. A handful of excavations took place prior to the 1970s, many of which were in search of evidence for the landing of Sir Francis Drake. However, a few focused on indigenous sites, specifically at Mendoza (CA-MRN-275), Cauley (MRN-242), Estero (MRN-232), and McClure (MRN-266) (Stewart 2003:52-53). Recently, a National Register of Historic Places (NRHP) district nomination has been prepared for the indigenous sites within PRNS and is under review (Rudo 2011, pers. comm.; Stewart 2008). Suzanne Stewart's extensive indigenous archaeological overview and research design for PRNS and the GGNRA include indigenous archaeological site types that have been found within PRNS and those that can be expected, and specific research questions one could ask of identified sites. These site types and questions are covered below and in the next chapter.

INDIGNEOUS ARCHAEOLOGICAL SITE TYPES

Indigenous archaeological site types represent the general range of locations containing physical evidence of use by native peoples. This evidence can consist of a number of different constituents, including bedrock mortars, shell midden, projectile points, and other resources. Certain artifacts and features found in association with each other, such as midden, tools, beads, and house pits, suggest longer-term residential occupation, while others appear more task

specific, such as hunting camps or plant-processing stations. Each property type can be expected to be found in certain geographic areas that contain the natural characteristics—such as stable landforms, access to fresh water, and proximity to desired plant or animal species—necessary to support that property type.

Stewart (2003:64-66) has prepared a table outlining the different property types expected within Point Reyes National Seashore and the adjacent Golden Gate National Recreation Area. Included in her table are sites within PRNS that demonstrate the property types being discussed. The table has been modified to reflect only sites within Marin County but is otherwise consistent with the original version.

**Table 1. Indigenous Archaeological Property Types in the PRNS-GGNRA Study Area
(after Stewart 2003:64-66)**

Property Type	Constituents	Anticipated Locations	Examples in the Point Reyes Parklands and Environs
Multi-use Occupation Sites: Residential base, or Village site	Habitation debris (earth middens containing shell, bone, plant remains including charcoal, heat-affected rock); facility and structural remains (housepits [possibly including dancehouse and sweathouse remains], postholes, storage pits, hearths, earth ovens); food-processing and consumption artifacts (including milling equipment and other pounding and cutting tools) and artifacts reflecting a wide range of activities (e.g., flaked, ground, and battered stone tools for fishing and hunting, net- and basketry-making, shell-bead manufacturing, etc.); and other artifacts reflecting ceremonial activities (stone and shell pendants and beads, baked-clay effigies, charmstones); diversity of lithic debris from a range of sources and representing varied techniques. Human burials, some with associated grave goods, may be present. Site area extensive, suggesting sizable population.	Sheltered locations at coastal canyon mouths on terraces; inland on creek terraces or mid-slope terraces near springs; access to year-round fresh water, good outlook; near ecotones, with access to a variety of resources.	CA-MRN-266, the McClure site; CA-MRN-242, the Cauley site; CA-MRN-232, the Estero site
Hamlet	Same intensity and diversity as above, but small size, supporting a few extended families; no evidence of large-scale community structures.	Same as above, but may be less central, on more restricted landforms, and on smaller watercourses.	Various throughout study area

Property Type	Constituents	Anticipated Locations	Examples in the Point Reyes Parklands and Environs
Multi-use Occupation Sites (cont.): Camp site	Similar to above, but with less intensity, depth, areal distribution, and diversity. Features probably limited to hearths; flaked, ground, and battered stone tools for food-procuring, processing, consuming activities, but diversity moderate; little or no evidence of ceremonial use; lithic debris of more limited range; human remains rare. Site area varies, from small and relatively dense, to extensive but sparse deposits.	Variety of locations with access to at least seasonal fresh water.	MRN-258, MRN-273,
Special-use Sites: Shell Midden	Deposit of shellfish remains, of one or a variety of species, with few artifacts.	On beaches or sand dunes adjacent to bays and estuaries; on terraces near mouths of creeks; on ocean terraces above open beaches.	CA-MRN—216, -278; -298, --394
Bedrock Milling Station	Bedrock outcrops or boulders with one or more mortar cups or other milling areas; small areas of adjacent organically darkened soil (midden) may be present; artifacts limited to pestles (and possibly handstones) and (less commonly) a few expedient tools.	At outcrops of suitable sedimentary, metamorphic, or igneous rock, near watercourses and plant resources	CA-MRN-226 is only recorded bedrock milling station; others likely exist

Property Type	Constituents	Anticipated Locations	Examples in the Point Reyes Parklands and Environs
Special-use Sites (cont.): Lithic Scatter	Stone-tool making debris, which may be accompanied by battered-stone tools for flaking and abrading and broken or discarded flaked-stone tools.	On saddles, mid-slope terraces, and other locations that may have served as hunting and/or butchering locations	CA-MRN-222, -287, -293, -379;
Quarries	Rock outcrops or boulders of chert, other cryptocrystalline rocks, or fine-grained volcanic or metamorphic rock, exhibiting quarrying scars; quarry shatter and lithic-reduction debris; hammerstones; may contain some discarded stone tools.	At appropriate outcrops near living sites or travel routes ; in general, bedrock type non-conductive, however , see comment below.	Unknown in PRNS;
Rock Art	Bedrock outcrops or boulders containing scratched or pecked design elements; extensive stone alignments; tools related to manufacture or use.	At suitable outcrops; locations may be along ridgetop trails, in saddles.	One cupule petroglyph possibly located at or near CA-MRN-291
Isolated Human Remains	Intentionally interred human remains, with few or no burial-associated artifacts; isolated human bone.	Locations unpredictable	Unknown in PRNS
Historic-era Native American Sites: Any or all of the above	Ethnographic sites may be identified through archival, oral-history, or other sources; artifacts may be primarily native items, with occasional historic-era pieces, or assemblages of non-native items used in traditional ways. Special site types: refuge sites, historic work camps.	Various, based on historical circumstances	CA-MRN-232/H, the Estero Site; MRN-242

One important property type which has been added to Stewart's list on this table is "quarry." In general, the geology of PRNS consists of marine sandstones, granite, or dune and beach formations, none of which are conducive for making edged tools such as projectile points, knives, or expedient cutting tools. Pockets of Monterey chert exist in upland areas within PRNS but to date quarries in these formations have yet to be identified (Galloway 1976). There is the

possibility that raw granite could have been quarried for groundstone tools; however, one could expect that rounded cobbles could be pulled from the creek beds throughout the park that would be better suited. It also seems likely that expedient tools were fashioned from creek cobbles recovered from active creeks, uplifted creek beds, or beach deposits. Site CA-MRN-287 had several well-rounded crypto-crystalline cobbles that had been knapped into choppers and used as cores for expedient tool material. Many of the cobbles appeared unmodified, lending to the possibility that an uplifted creek bed underlies the site. In this sense, the uplifted creek bed may have been quarried for tool material and other such locations may be present within the park.

POTENTIAL IMPACTS OF CLIMATE CHANGE ON ARCHAEOLOGICAL SITES WITHIN POINT REYES NATIONAL SEASHORE

RIISING SEA LEVELS, INUNDATION, AND WAVE EROSION

Research on the effects of rapid sea-level rise on archaeological sites is relatively rare. A handful of authors have looked at the topic of researching inundated archaeological sites, a sub-field of archaeology generally referred to as “wet site archaeology” (Coles 1988:xi). These sites are “found in permanently saturated deposits that entomb and preserve organic objects that seldom survive elsewhere. This description distinguishes wet sites from shipwrecks and from inundated terrestrial sites where degradation preceded submergence” (Coles 1988:xi). For the purposes of current discussion, it is acknowledged that, in many cases, some degree of degradation is likely to have preceded submergence. The question then becomes, what happens to these sites after inundation?

Wet site archaeology can offer some clues as to what to expect. Archaeological sites along coasts subject to large waves, long fetch, and strong winds—i.e., a high energy coast—can be expected to be severely damaged or destroyed. Coastlines with steep terrain offer little in the way of protection for sites. Locations along coastal marshes, barrier islands, and sand bars can offer some protection for archaeological deposits (Ruppé 1988:59).

While wet site archaeology generally takes place in locations where preservation has been excellent, another field of study, wherein the broad range of preservation conditions following inundation have been researched, is maritime archaeology. The landmark volume on the subject, *Maritime Archaeology*, by Muckelroy (1978), is primarily concerned with shipwrecks; however, his discussion on what he calls “scrambling devices” i.e. post-depositional processes that effected site formation, could apply to any submerged archaeological site (Muckelroy 1978:175-182; Stewart 1999:567). Muckelroy (1978:181) argues for the importance of geomorphological research in determining the potential effects at individual sites and that “the processes involved are very different from those operating in a terrestrial context.”

In particular he notes the difference between wave action and tidal currents. Stewart (1999:582) also discusses submerged site formation processes and the effects of wave and tidal forces. Wave action can lift coarse-grained sand and gravels to scour shallow submerged

surfaces (Muckelroy 1978:177). While wave action is confined to the near surface, tidal currents can occur at any depth, with any force; inundated sites that might be protected from wave action could still be eroded by tidal currents in the right conditions. Generally, a strong current is necessary to move anything larger than coarse sand, but through a process known as “kelp rafting”, ocean flora growing on stone can act as a sail, lifting and dragging larger particles over the surface of a site and removing larger sediments already deposited there (Muckelroy 1978:176).

Another concern is the changes that occur in the upper layers of inundated surfaces and marine sediments. Up to several meters of sediments can transition into a “state of semi-suspension” as a result of the individual sediment particles being lubricated by the surrounding water (Muckelroy 1978:176). In his review of excavations at the wrecks of the *Trinidad Valencera* (1588) and the *Mary Rose* (1545) he found that this suspension has resulted in a sorting of artifacts, where cultural materials dropped through this suspended layer into deeper strata, destroying the chronological stratigraphy (Muckelroy 1978:176-177). There may be horizontal sorting as well, as Muckelroy (1978:178) noted in his discussion of the wreck of the *Kennermerland* (1664), where artifacts not only settled to the bottom of the semi-suspended matrix, they also shifted to locations around larger rocks and boulders, where presumably they were protected from additional shifting. In other cases, such as at the wreck of the *Adelaar* (1728) the context of the entire artifact deposit was destroyed as a result of full exposure to the Atlantic swells and a rocky ocean floor. Only battered and distorted metal objects survived, and only then if they landed in a protected location within the fissured ocean bottom (Muckelroy 1978:180). The size and shape of artifacts will also exasperate the situation; rounder, lighter, larger objects with greater surface area, are more susceptible to horizontal from wave energy and gravity (Stewart 1999:583-584).

As noted above, ocean flora can be indirectly associated with erosion and damage to submerged sites by facilitating the movement of larger particles. Most ocean flora only grow within the photic zone, the depth at which enough sunlight penetrates to allow for photosynthesis, typically no more than 100 m (Stewart 1999:581). In some instances, as with terrestrial vegetation, ocean flora growing below the surface of marine sediments can help anchor deposits and protect sites (Muckelroy 1978:177; Stewart 1999:581). Sea grass beds, in particular, can help stabilize ocean floors and prevent artifacts from shifting, though their roots do present a possible bioturbation impact (Stewart 1999:581).

While ocean floors do not have the equivalent bioturbation that terrestrial sites do, some burrowing marine species, particularly crabs, can have a deleterious effect on sites (Muckelroy 1978:43). Burrowing fish species can have a similar effect (Stewart 1999:581). Members of the *Teredinidae*, commonly referred to as shipworm, are notorious for the damage they cause to wood. Interestingly, octopuses can impact sites, operating as “‘packrats’ of the underwater world” by dragging small artifacts, particularly shiny ones, into their homes (Stewart 1999:580).

Stewart (1999) provides a general overview of the effects of inundation and subsequent site formation processes on shipwreck and terrestrial sites that become inundated. He notes that the study of site formation processes of submerged archaeological sites trails behind similar studies on terrestrial sites (Stewart 1999:566). Sites that are rapidly buried by sediment are the

most likely to be preserved; sites that are slowly inundated are more likely to be destroyed. Wave energy and alternating periods of wetness and dryness are more likely to impact sites that are inundated slowly. Sites that are on steep cliffs will be susceptible to collapse; as the cliff face collapses, the context for artifacts is lost, even if the artifacts themselves become quickly inundated and covered as a result (Stewart 1999:572, 573). Damage to sites is not just restricted to the tidal zone and flood events; the entire fair weather wave base—i.e., the point where the energy of a wave first hits the ocean floor—is within the zone of erosion. Wind direction also affects how this erosion occurs—changing climatic conditions may change wind patterns (Stewart 1999:582). It is possible that even a detailed analysis of current wind patterns may be rendered obsolete under a different climate regime.

By comparison, sites that are inundated quickly are better preserved, both in terms of the condition of the artifacts and their archaeological context (Stewart 1999:573). Citing work by Galali et al. (1993:133, cited in Stewart 1999:573) Stewart describes excavation efforts at Athlit-Yam, a Pre-Pottery Neolithic village radiocarbon dated to ca. 8100 to 7500 B.P. (around 6100-5500 B.C.) Athlit-Yam was inundated rapidly, resulting in not only good artifact preservation, but intact feature distribution across the site, including lithic concentrations, faunal bone indicating butchering locations, and *in situ* burials. Whether individual surface features (i.e. those features that were surface phenomena prior to inundation) remained entirely within situ had yet to be explored at the time of the Galali et al. study (Stewart 1999:573).

Similarly, the work of Belknap and Kraft (1981, cited in Young, Belknap, and Sanger 1992:239), and Kraft, Belknap, and Kayan (1983, cited in Young, Belknap, and Sanger 1992:239) based on geologic research conducted along the Atlantic seaboard, informed a later project in Johns Bay in Maine by Young, Belknap, and Sanger (1992). The earlier work allowed them to project that they would find better preservation at sites that were inundated rapidly during the Early Holocene than at those sites that spent a greater period of time within the high-energy wave erosion zones during periods of slow sea-level rise. Their study also showed that preservation of sites was highest in the upper reaches of the bay estuaries, where sedimentation occurred faster than erosion. This is likely an important factor in deciding which sites to focus on for treatment (Young, Belknap, and Sanger 1992:239).

Their findings were mirrored by those of Bell and Neuman (1997) who found the preservation of archaeological sites and stratigraphic integrity of sediment deposits spanning the Holocene in the Severn Estuary in Wales to be exceptional. Architectural elements, including wood associated with oval huts dating to 1678–1521 cal. B.C., were preserved, and even the interface between peat and clay deposits still held hoof prints from domestic cattle dating back to 1200 cal. B.C. and 300 cal. B.C. (Bell and Neuman 1997:108).

The effects of inundation on coastal archaeological sites have been studied by Dickenson and Green (1998). In their research on submerged archaeological sites at Upolu, Samoa, Dickenson and Green (1998:257-258) identified subsidence as a result of volcanic activity as a major contributor to site inundation. Sinking coastlines mirror the effects of raising sea levels, and they note that erosion of coastal landforms from subsidence and subsequent inundation may have a greater impact than traditional human impacts, such as the removal of coastal vegetation, on-going sand mining, and the construction of seawalls, groins, and piers (Dickenson and Green 1998:257-258).

While the number of studies of the effects of coastal erosion and inundation on sites are limited, several studies have been conducted on the effects of inundation on archaeological sites along man-made reservoirs. Several inundation studies were conducted from the late 1970s to early 1980s as part of the National Reservoir Inundation Study. The study, funded by NPS in conjunction with several other federal agencies, found that “the overall effects of reservoir inundation on archaeological resources in any given drainage area are unquestionably detrimental in nature” (Lenihan et al. 1981:4). Thirteen different research groups conducted this study, observing the impacts of inundation on archaeological sites at fifteen different reservoirs. Foster et al. (1977:20, 22), looking at the effects of inundation at CA-ELD-201, a prehistoric habitation site with midden and housepits at Folsom Lake, noted that the site exhibited “the dramatic effects that 20 years of inundation and water fluctuation can have on an archeological site” and that “the most obvious and destructive agent is direct wave erosion...Perennial wave action induces bank erosion and slumping of unconsolidated site material... Intermittent deflation and sedimentation within the wash zone obscures the vertical separation of artifacts.”

Several other authors have described geomorphic processes and post-depositional disturbances that could occur within the study area, specifically on the archaeological sites. Butzer (1990:104-122) identified a number of factors contributing to archaeological site damage or destruction through environmental phenomena, including: mass movements, compaction, expansion, and oxidation due to changes in water content within clay soils; landscape deformation and instability due to abrupt changes in soil type; and geobiochemical damage to organic artifacts. Foster et al. (1977:23), pointing out the findings of the Inundation Study Core Team (1976, cited in Foster et al. 1977:23), state that increased pressure and water saturation on the site due to the mass of standing water “causes the soil matrix to weaken and differential consolidation of the cultural strata”. Ramiller and Fredrickson’s 1983 study of site protection at Lake Sonoma concluded that inundation could be “extremely deleterious,” where the exposed areas around the lake could see the “destruction of archaeological sites... through vandalism, or unintentionally, through recreational activity, movement of stock, or intrusions of burrowing animals”; where submerged sites along the fluctuation zones of the lake could see “persistent wave action, wind-driven near shore currents, and saturation and slumping of embankments” that would give rise to “the disturbance of cultural deposits”; and where completely inundated sites may suffer from “underwater slumping or compression of cultural strata beneath deep columns of water and accumulated sediment” (1983:12).

More recent studies and observations have been undertaken at reservoirs in northern California. Subsequent research by Newland (1999) of sites at Lake Sonoma found areas of substantial erosion as a result of both inundation and wave energy. Similar observations have been made at Lake Oroville, where many archaeological resources are eroding as a result of repeated inundation and wave action (e.g., Newland, Markwyn, and Douglass 2006; Praetzelis et al. 2006; Selverston, Newland, and Markwyn 2006). Sedimentation as a result of slumping and low energy sediment deposition were clearly visible at CA-BUT-362/H, -1872/H, and -2570/H, , while direct wave erosion could be seen as stripping portions of these sites down to bedrock. Even at Clear Lake, a natural reservoir with a relatively minor (5.6 ft.) fluctuation zone, densely matted protective riparian grasses, and limited wave erosion, substantial components of CA-LAK-160, -156, and -576 were found completely deflated and stripped from their original context and embedded in eroded mud (Lake County Water Resources Department 2010; Smirnoff 2011).

Summary

With the exception of well-protected upper estuary locations, inundation will have a dramatic and deleterious effect on coastal archaeological sites. Subsurface erosion from wave action and tidal currents, facilitated by sediments alone and attached to kelp and other suspended ocean flora, can be expected to scour and shift surface features and artifacts. Artifacts can be expected to drop through layers and collect around larger buried boulders or outcrops as a result of the top layers of ocean sediment being in a state of semi-suspension due to saturation and lubrication by salt water.

CHEMICAL WEATHERING

Increased acidification of ocean water as a result of dissolved CO₂ could result in increased rates of erosion along certain cliff faces. It seems likely that the Purisma Formation cliff faces along Drakes Bay, which consists of a diatomaceous gray siltstone, would be particularly susceptible to damage from a lower ocean pH level. Several important sites are along this stretch of coastline, including CA-MRN-394, which has been proposed as a potential landing point of Sir Francis Drake; the Mendoza Site (CA-MRN- 275/302), a type site for Middle Period settlement along the coastline with known burials; the Estero Site (CA-MRN-232), also with known burials, and many others. Around these sites, the cliff faces could be expected to erode more quickly. In some cases, such as at the Mendoza site, this may result in the site eroding into the ocean at a faster pace. On others, such as at CA-MRN-394, it may result in increased slumping from nearby cliffs changing the immediate coastline and affecting the patterns of wave energy against this beach; additionally, the beach, which is made up of material from these cliffs, may be subject to chemical weathering and may not afford as much protection to the buried midden deposit here.

COASTAL CLIFF EROSION

Coastal cliff erosion can be expected in areas where inundation, wave erosion, and chemical weathering all combine to force the collapse of cliff faces and other areas previously above the high water mark. In these locations, not only will sites become inundated, the entire matrix around the sites will be moved, mixed, and spread across the ocean floor. Coastal cliff erosion will, in all likelihood, result in the complete destruction of the site's archaeological context. Artifacts could reappear and wash ashore as they are exposed during storm events, but the data potential of the site as a whole will likely be lost.

Coastal inundation, and cliff erosion, may not have equal effects. There are some situations, particularly in the upper reaches of the bays and lagoons, where the physical topography of the bay coupled with rapid inundation could result in burial and preservation of archaeological sites. Inundation along a coast directly exposed to high wave energy, will likely result in cliff erosion and can be expected to have a much greater impact on archaeological sites.

Cliff erosion is highly destructive to archaeological sites. For this reason, this report emphasizes the sites that appear to be most susceptible to erosion as well as those that may suffer complete inundation. These sites received the highest consideration for field visit and recommendations for management action.



Figure 8. Ongoing erosion along the base of cliff faces near CA-MRN-272. Seaweed indicates that high tide levels are eroding, the bases of cliffs (Accession # 70-10-D01-04).

TEMPERATURE CHANGES, VEGETATION, AND FIRE

Rising sea levels can also be expected to affect coastal wetland areas within PRNS. A sea-level rise of 1.4 m would flood large areas immediately adjacent to current wetlands (Heberger et al. 2009). The vegetation regime bordering this new wetland acreage can be expected to change, particularly with riparian grasses. While these grasses, which typically have densely matted root structure, may help protect any archaeological sites, surface visibility of the sites will be lost. For this reason, border areas around the numerous wetland areas in the park—e.g., Drakes Estero Horseshoe Cove, the Tomales Bay border area, etc.—should be surveyed for cultural resources.

The PRNS website contains a sobering summary of the potential effects of increased temperatures on vegetation with PRNS:

The State of California predicts mean temperatures to rise at least 1.7° C (3° F) by 2100, if humans significantly reduce greenhouse gas emissions. On the other hand, mean temperatures could rise by as much as 5.8° C (10.5° F) if we don't modify our behavior much. To give an illustration of what such a change in mean temperature might be like, consider the following.

A change of least 1.7° C (3° F) may not seem like much, but it would be similar to relocating Point Reyes National Seashore to Monterey Bay. The mean annual temperature at the Bear Valley Visitor Center is 12° C (53.6° F), while that of Monterey is 13.7° C (56.6° F). A change of 5.6° C (10° F) would be akin to moving Point Reyes National Seashore to south of San Diego. The mean annual temperature at the San Diego airport is 17.3° C (63.1° F). No location along the California coastline currently has an annual mean temperature of 17.8° C (12° C + 5.8° C) (64.1° F).

Warmer temperatures would result in greater rates of evaporation, as well as increased transpiration from plants. Large trees that now exist in the Point Reyes area, like the Douglas-fir, California bay, and California redwood, would not likely survive the warmer temperatures. In and of itself, this would drastically change the scenery and ecosystems here at Point Reyes. On top of that, with the increased dryness combined with the fuel provided by dying trees, the chance of wildfire would increase [NPS 2010].

With this increasing fire danger in mind, one may ask 'how many acres of forested areas are within PRNS, and how many sites fall within that acreage?' Using the park's GIS vegetation shapefile and sorting by vegetation group, this study concludes that over 20,000 acres of parklands are covered in some sort of deciduous or needle forest:

Table 2. Number of Recorded Indigenous Sites by Vegetation Group

Vegetation group	Number of acres	Percentage of Park (62,750 acres)	Number of recorded indigenous sites per group
Needle-leaved Evergreen Forest	16,129	25.7%	0
Winter-deciduous broad-leaved forests and woodlands	1,398	2.2%	0
Winter-rain Evergreen Sclerophyllous Forest and Woodland	2,598	4.1%	9
Active Pasture or Agriculture	3,357	5.3%	2
Beaches or mudflats	419	0.7%	0
Built-up urban disturbance	435	0.7%	5
Chaparral Vegetation	313	0.5%	0
Coastal Scrub Vegetation	16,535	26.4%	34
Disturbed	61	0.1%	0
Dunes	463	0.7%	1
Native and non-native grassland	18,979	30.2%	32
Temperate cold deciduous shrublands	772	1.2%	9
Vegetation dominated by annual or perennial forbs	1291	2.1%	14
Totals	62,750	99.9%	106

In looking at the vegetation cover, over 20,125 acres, or about 32 percent of terrestrial PRNS contains forests and woodlands. As will be discussed later in this document, almost no survey has been done of the needle-leaved evergreen forest community, which makes up the bulk of this acreage, and little is known about the presence of indigenous archaeological sites in this vegetation zone. If the NPS projections come to pass, these parts of the park will be highly susceptible to fire as a result of the loss of arboreal species. Similar effects may occur within the grassland and brush environments, which make up another 41,250 acres, roughly most of the remaining acreage.

For his Master's thesis, Sonoma State University student Richard Shultz prepared a fire management plan for cultural resources within PRNS. As part of his research, Shultz (2006) identified several threats to cultural resources posed by wildfires and controlled burns. These threats are broken down into three categories: Direct, meaning the physical impact of the fire itself; operational, meaning the impacts to sites resulting from the creation of fire breaks, access roads, and fire suppression; and indirect, meaning the post-fire impacts that arise within a newly burnt area. These effects include:

Direct threats

1. Flaked stone tools and debitage-- breakage, melting, discoloration, reduction of mass through water loss or increased porosity, and compromised obsidian hydration bands and chemical signatures (Schultz 2006:73-76);
2. Groundstone tools—sandstone and quartzite tools can fracture, basalt, andesite tools tend to fare better. In general, high-intensity fires can result in sooting, oxidation, or loss of structural integrity (Schultz 2006:77);
3. Rock art—while rock art appears to be rare in the park, the surfaces of rock would be particularly susceptible to exfoliation and spalling from heat. The organic compounds in pigments used in pictographs can be easily oxidized during fires (Schultz 2006:82);
4. Shell—marine shell, when heated to high temperatures, not only degrades but can have chemical reactions with the surrounding soil matrix. Shell also fractures and can disintegrate (Schultz 2006:82);
5. Bone—fire can have a number of effects on bone, from discoloration to macroscopic and microscopic morphological changes, and can be affected even when buried at a depth of up to 10 cm. Bone can calcify and carbonize, with all organic material being burnt out of it during heating, thus negating its usefulness as a dating tool (Schultz 2006:84);
6. Pollen and archaeobotanical materials—these material are important data sources for reconstructing past environmental conditions and human interaction with their surroundings. Pollen at the very least is affected, and perhaps outright destroyed, by fire (Fish 1990; Scott 1990). Pollen and archaeobotanical remains, like other organic materials, are best preserved in dry caves and waterlogged environments (Micsicek 1987:219). Plant materials fare better in low-oxygen environments, beginning to carbonize around 250° C and becoming completely carbonized by 500° C, but turn to ash if oxygen is introduced. Completely carbonized plant residues are resistant to further decay because the organic matter has been reduced to stable elemental carbon. Carbon contamination by burning roots, however, can compromise the research potential of organic samples (Schultz 2006:84);
7. Organic residues—these residues are the bi-products of preparing or cooking food, binding or decorating tools and other artifacts, preparing medicines or ceremonial materials—essentially anything that results in the application or processing of organic material. Such residues include lipids, proteins, carbohydrates, fatty acids, and other

biopolymers, which can adhere to, or be absorbed by artifacts, ecofacts, or features. These residues can reveal a great deal about past dietary patterns, tool preparation, and medicinal and ceremonial practices (Heron and Evershed 1993; Orna 1996). Different residues react differently to exposure from fire for reasons not yet fully understood (Schultz 2006:87);

8. Vegetation—Fires have the potential for impacting vegetation resources important culturally to the Coast Miwok and scientifically to archaeologists. The Coast Miwok have a long history of collecting plant resources within the park, and these resources continue to be important to tribal members today. Tree-ring data from both living trees and stumps are valuable in reconstructing the paleoclimate and paleoenvironment of the area, including the park's fire history (Arno and Sneek 1977; Barrett and Arno 1988). Fire could significantly damage these resources (Schultz 2006:89); and
9. Fibers and hides—these kinds of resources are typically found under very specific, field conditions, either in extremely dry locations such as caves or in anaerobic environments, such as the bottoms of wells or in waterlogged settings. When found in arid contexts, fibers and hides are extremely susceptible to fire, though there are few locations within the park where these contexts exist (Shultz 2006:90).
10. Packrat middens—"packrat" is a general term for wood rats who build nests out of collected vegetal material. Within PRNS, *Neotoma fuscipes*, or the dusky-footed wood rat, is common. Elsewhere, packrat middens and have been shown to be important data sources for reconstructing paleoenvironmental settings (Betancourt, Van Devender, and Martin 1990; Mehringer and Wigand 1987; Miller and Wigand 1994). As packrat middens often contain dead plant remains, they can be highly flammable.

It is clear that if the forested areas of the park are badly affected by climate change, the fire hazard will be great. Sites within those areas will be at high risk. Beyond the forested areas, the coastal scrub, grassland, temperate shrub land areas, and locations dominated by forbs will all be susceptible to increased fire risk due to higher temperatures and drier conditions. While the fuel load may not be as great as the forested areas, fire is still a major threat. For this reason, all areas above the dunes and coastal strips that are not expected to be inundated are listed as threatened by fire.

Operational Effects

A host of operational effects may impact archaeological sites during efforts to fight fires, including:

1. Staging—during instances of wildfires, the placement of equipment, people, heli-spots, camps, safety zones, fuel breaks, and safety zones are often made with little or no advance planning. Ground disturbance needed to clear these areas could be substantial. Even when areas that are previously disturbed, such as existing roads and parking lots, are used, their surface area may need to be expanded. Some areas, such as heli-spots,

need to be located on accessible, flat, open ground, areas that are often good locations for archaeological sites. The preparation and use of a staging area could impact any site within the staging area perimeter. Locations such as personnel camps may be located some distance from the fire itself; the footprint of preparing to fight a fire may be larger than the fire itself (Schultz 2006:92-93).

2. Fire Lines—these are cuts made into the vegetation to prevent fires from spreading. They can consist of handlines, which, as the name implies, are excavated by hand. Catlines are cut using tracked vehicles, such as bulldozers and can be substantial. Wetlines are created by wetting down fine fuel sources. Retardant lines are similar, in fire retardant is sprayed in strips, as are foam line, which use retardant foam. Fire lines can be created for both wild and planned fires, and help both the in limiting the fire and defining the area and scope of the effort. The creation of a fire line can result in the complete removal of vegetation and substantial ground disturbance (Schultz 2006:93-95).
3. Ignition Techniques—several techniques exist to start fires in such a way as to be manageable, as in the case of a prescribed burn, or to help contain an existing wildfire. These include heading fires, which are lit upwind of a fuel source; backing fires, which are lit downwind of a fire; flanking fires, which are lit downwind and are set in a series of lines that form growing triangles or chevrons, and center or ring fires, which are lit in the center of a proposed burn location and meant to spread in all directions. All of these fire lines may help prevent the spread of a wildfire or keep a prescribed fire from getting out of control. However, it does still involve the burning of on-site vegetation and the impacts can be similar to those described above under Direct Impacts. The use of ignition materials can also have effects on site, particularly the plastic sphere dispensers filled with jellied gasoline or ignition fuels dropped from airplanes, as these may cause damage when dropped onto sites (Schultz 2006:95).
4. Fire Retardants—these are divided into two categories, physical agents and chemical agents. Physical agents affect a fire's ability to spread and help lower fire temperatures, and generally include water and dirt. These solutions are short-term. Chemical agents affect how the fires ignite and the course of combustion, interrupting the combustion process. Some chemical agents (particularly PhosCheck) have fertilizer components that could increase vegetation growth following the fire, in turn increasing the risk for future burns. Some of these agents are also dropped from aircraft, either in the form of a slurry mixed with water or as a powder, and the velocity of the material at impact could disturb sites and topple built features. In addition, some fire retardants are corrosive and/or toxic, which may affect both the artifacts and future data recovery efforts (Schultz 2006:96).

5. Mop-up and Rehabilitation—once a fire has been brought under control and is nearly extinguished, targeted efforts at putting out remaining hot spots are made. These could include hand labor, ground patrol, or aerial reconnaissance. The hand labor particularly can be detrimental, as it may involve ground disturbance, tree felling, and removal of smoldering roots and stumps. Rehabilitation could include the re-grading of fire lines, removing evidence of fire breaks through brush removal and concealment of berms, and re-contouring push piles. Emergency actions are often taken to stabilize slopes now denuded of vegetation. Road and stream channels may also be in danger of damage as a result of unstable slopes. Stabilization can include re-vegetating the hillsides through grass seeding, mulches, fabrics, and silt fences. Straw bale, log, or rock check dams may be installed in creek beds to prevent downstream flooding. Culvert replacement, contour trenching, and water bars might be installed in and under roads to accommodate increased run-off. As part of all these efforts, heavy equipment might be employed that could potentially impact archaeological sites (Schultz 2006:97).

Indirect Threats

Once a fire has been extinguished and fire crews have left, a host of post-fire indirect threats can take place. These threats include:

1. Looting—fires can expose sites that had previously been covered by vegetation thus exposing them to looters and the public, who may casually collect artifacts. Even firefighters, who may be unaware of cultural resource laws protecting sites, might casually collect during fire suppression efforts. Landscapes newly opened by burnt off vegetation could be inviting to hikers, who may make new routes taking them across sites previously concealed.
2. Increased surface runoff and erosion—under good conditions, with intact vegetation and leaf cover, 98 percent of precipitation is absorbed through the soil rather than as surface runoff. After a fire, the absorptive qualities of the soil are compromised and the amount of runoff nearly doubles, while the effects of soil erosion triple. Soil changes from a fire can make the soil surface water repellant, contributing to the erosional effects and impacting surface deposits in particular. Differential erosion could also result in artifacts collecting in areas during erosion, mimicking the appearance of an activity area (Schultz 2006:102-103).
3. Increased tree mortality—while some tree species benefit from occasional low heat fires, high-heat fires can damage the cambium layers of trees and either kill them, or damage them enough to make them susceptible to disease or insect infestation. These trees are susceptible to future fires or to upheaving the soil when they collapse disturbing sites at both the root ball portion of the tree and anywhere the larger branches might penetrate the ground during collapse.

4. Increased burrowing rodent and insect populations—burrowing rodent populations have been shown to increase for a period of time after forest fires, feeding on the tubers, plant seeds, and bulbs from plant species that recover quickly from fire. The effects of burrowing animals on stratigraphy and artifact provenience and condition had been shown to be deleterious (e.g., Armour-Chelu and Andrews 1994; Bocek 1986; Erlandson 1984; Schiffer 1987; Wood and Johnson 1978). Disturbance from coyotes may also increase as these predators dig after the burrowing rodents.
5. Increased microbial populations—microbial populations may have a deleterious effect on organic materials within an archaeological site, particularly bone (Child 1995). Fires have been shown to increase nitrogen levels in the soil, which in turn can increase microbial populations (Bissett and Parkinson 1980; Romme, Floyd-Hanna, and Conner 1993; Schultz 2006:105).
6. Carbon contamination – forest fires can provide a ready supply of recent charred materials that may mimic prehistoric organic remains while burnt tree roots that extend into a site may introduce modern charcoal into archaeological contexts, increased rodent activity and erosion may additionally stir charcoal and organic materials into early contexts.

Treating the effects of indirect threats may be more difficult than treating those of other types of fire threats. For example, it may be that little can be done about microbial populations, increased rodent activity, or carbon contamination. That may be part of the unavoidable outcome of a forest fire, and it may be determined an acceptable risk of a controlled burn if it prevents larger, more dangerous fires later.

DUNE EROSION

A broad stretch of the PRNS coastline, along the western edge of Point Reyes as it faces the ocean, has a relatively narrow but lengthy system of dunes. A smaller area of coastline, including Drakes Beach, the mouth of Horseshoe Pond, and Limantour Spit, have dune formations within the portion of the park facing Drakes Bay. These dunes cover about 13.3 miles, 11.3 of which are shown by the Pacific Institute's model as being in a dune erosion zone. It is expected that high winds, changes in temperature, and high flood events may result in both the direct physical erosion of these dunes as well as the loss of vegetation stabilizing the dune structures.

Several archaeological resources are located within these dunes. There are at least five recorded sites at Limantour Spit, with others at Horseshoe and the North Beach side of PRNS. However, it is worth noting that very little of the North Beach side appears to have been surveyed; there may be many more sites there waiting discovery.

Shifting dunes could undermine and cause the collapse of some sites while completely covering and concealing others. While inundation may pose a more immediate threat, dune erosion can be expected to be potentially just as destructive in the long run, as the erosion could

result in the loss of site structure and the exposure of cultural material to looting as well as deterioration when exposed to sunlight and ocean water. The areas of the sand dunes expected to be subject to increased erosion as a result of climate change should be surveyed, and if sites are found, their eligibility to the NRHP should be evaluated so that NPS can make informed decisions about appropriate measures to protect NRHP-eligible sites within PRNS.

The combination of rising sea levels and sand dune erosion present a double threat to archaeological sites. Some sites on more solid landforms might fare better in cases of rapid sea level rise, but those on dune surfaces could fare much worse. In assessing the likelihood that dune sites on the Great Barrier Reef survived sea level rise during the end of the Pleistocene and Early Holocene, Beaton noted several decades ago that

coastal archaeological sites which are usually found on foreshores and deposited on unconsolidated sand dunes, often deflated by winds and eroded by rains, have only the action of surf and tide to look forward to as the sea envelops them. No archaeologist should have *a priori* expectations that the fragile elements that constitute an archaeological deposit could survive this exposure *in situ*. [1978:42].

Many sites within PRNS have multiple potential effects that may occur. Some of the sites will be subjected to direct wave erosion over the next 40 years and may subsequently be inundated and receive a different type of erosion. Others may see cliff erosion and chemical weathering simultaneously. Table 3 summarizes the different effects that are expected by site based on topography and elevation, proximity to the ocean, vegetation group, and bedrock type.

Table 3. Potential Impacts of Climate Change by Site

Site Designation	CE	CW	DE	DW	F	HF	I	S	SI	EL	Vulnerability
Abbotts Lagoon Field Site 1	X	X				X	X	X		X	High
Abbotts Lagoon Field Site 2	X	X				X	X	X		X	High
Bolinas Site (JM)	X	X							X		Low
C-1459(MRN)					X				X		Low
C-1464(MRN)					X				X		Low
CA-MRN-210	X	X	X	X		X	X				High
CA-MRN-211	X	X		X		X	X				High
CA-MRN-212					X				X		Low
CA-MRN-216	X	X	X	X		X	X				High
CA-MRN-222/H	X				X				X		Low
CA-MRN-223	X	X				X	X	X		X	High
CA-MRN-224/H	X				X	X			X	X	Low
CA-MRN-225					X				X		Low
CA-MRN-226					X						Low
CA-MRN-227					X						Low
CA-MRN-228	X	X				X	X	X	X	X	High
CA-MRN-229	X				X				X		Low
CA-MRN-230	X	X				X	X	X	X	X	High
CA-MRN-232	X	X		X						X	Low
CA-MRN-232B	X	X								X	Low

CA-MRN-233	X	X		X		X	X	X	X	X	High
CA-MRN-234	X	X		X					X		Low
CA-MRN-235					X						Low
CA-MRN-236		X	X	X		X	X				High
CA-MRN-237	X	X	X	X		X	X	X	X		High
CA-MRN-238	X	X	X						X		Low
CA-MRN-239	X	X	X	X		X	X	X	X		High
CA-MRN-240					X				X		Low
CA-MRN-242	X				X						Low
CA-MRN-242a	X	X				X	X	X		X	High
CA-MRN-243	X				X				X		Low
CA-MRN-244	X	X				X	X	X	X		High
CA-MRN-245	X	X				X	X	X		X	High
CA-MRN-246	X	X				X	X	X	X	X	High
CA-MRN-247	X	X				X	X	X		X	High
CA-MRN-248					X						Low
CA-MRN-249/H	X	X				X	X	X	X	X	High
CA-MRN-250	X	X				X	X	X		X	High
CA-MRN-252					X						Low
CA-MRN-256	X	X				X	X	X	X	X	High
CA-MRN-257	X	X				X	X	X		X	High
CA-MRN-258	X	X				X	X	X	X	X	High
CA-MRN-262	X	X				X	X	X	X	X	High
CA-MRN-263/H	X	X				X	X	X	X	X	High
CA-MRN-264					X						Low
CA-MRN-265/H	X	X				X	X	X	X	X	High
CA-MRN-266	X	X				X	X	X	X	X	High
CA-MRN-267	X	X				X	X	X	X	X	High
CA-MRN-268	X	X				X	X	X	X	X	High
CA-MRN-269	X	X				X	X	X		X	High
CA-MRN-270	X	X		X		X	X	X	X	X	High
CA-MRN-271					X				X		Low
CA-MRN-272	X	X		X		X	X	X			High
CA-MRN-273					X						Low
CA-MRN-274	X				X				X	X	Low
CA-MRN-275/302	X	X		X					X		Low
CA-MRN-275/302	X	X		X					X		Low
CA-MRN-276	X	X		X		X	X		X		High
CA-MRN-277					X						Low
CA-MRN-278	X	X							X	X	Low
CA-MRN-280	X	X		X		X	X	X			High
CA-MRN-285	x	X			X	X	X	X		X	High
CA-MRN-286	X	X		X		X	X	X	X	X	High
CA-MRN-287	X								X		Low
CA-MRN-288	X	X	X			X	X			X	High
CA-MRN-289	X	X	X			X	X			X	High
CA-MRN-290	X				X				X		Low
CA-MRN-291					X				X		Low

CA-MRN-292					X				X		Low
CA-MRN-293	X	X				X					Low
CA-MRN-294	X	X	X			X	X	X		X	High
CA-MRN-295	X	X	X			X	X	X		X	High
CA-MRN-296	X	X				X	X	X		X	High
CA-MRN-297	X	X				X	X	X		X	High
CA-MRN-298	X	X	X	X		X	X				High
CA-MRN-299					X				X		Low
CA-MRN-300	X	X				X	X	X	X	X	High
CA-MRN-301					X				X		Low
CA-MRN-303	X	X		X					X		Low
CA-MRN-304	X	X					X	X		X	Low
CA-MRN-305	X	X				X	X	X		X	High
CA-MRN-306	X	X				X	X	X		X	High
CA-MRN-307	X	X				X	X	X		X	High
CA-MRN-308	X	X				X	X	X		X	High
CA-MRN-341					X				X		Low
CA-MRN-375					x				x		Low
CA-MRN-376					X				X		Low
CA-MRN-377					X				X		Low
CA-MRN-378					X						Low
CA-MRN-379					X				X		Low
CA-MRN-386					X						Low
CA-MRN-387/H	X	X				X	X	X		X	High
CA-MRN-388					X				X		Low
CA-MRN-389		X	X	X		X	X				High
CA-MRN-390	X	X				X	X	X		X	High
CA-MRN-391		X	X	X		X	X				High
CA-MRN-392					X				X		Low
CA-MRN-394	X	X	X	X		X	X	X		X	High
CA-MRN-397	X	X				X	X	X		X	High
CA-MRN-467					X				X		Low
CA-MRN-468	X	X					X	X		X	High
CA-MRN-468 reburial					x				X		Low
CA-MRN-629/H					X				X		Low
CA-MRN-663	X				X				X		Low
Hog Island Field Site A	X	X				X	X			X	High
P-616					X				X		Low
Ranch A Field Site 2	X				X				X		Low
Ranch A Field Site 3					X				X		Low

I: Inundation

CE: Cliff Erosion

CW: Chemical Weathering

DE: Dune Erosion

DW: Direct open-ocean Wave Erosion across site

F: Fire

HF: Inundated during High Flood Water events

S: Sedimentation

SI: Slope Instability due to vegetation loss

WE: Wave Erosion

EL: Estuary/lagoon inundation

High: mitigation measures should be enacted within the next 10 years

Low: mitigation measure should be enacted within the next 50 years

CHAPTER 4. TREATING THE EFFECTS OF CLIMATE CHANGE ON PREHISTORIC RESOURCES WITHIN POINT REYES NATIONAL SEASHORE



Figure 9. Obsidian projectile point, CA-MRN-287, a site rapidly eroding at its cliff edge (Accession # 70-10-D01-05).

INTRODUCTION

The threats that climate change presents to park resources are formidable and span the entirety of the park in one form or another. Some of the impacts may be avoidable, others will not. Certainly, one of the issues is that predicting the effects of climate change is by no means an exact science, and while the scientific community has consensus regarding the reality of climate change and the potential effects that might occur as a result, the extent and timescale of those events are only projections and there remains disagreement. The models used here are conservative, in that the IPCC's projections probably reflect the minimal impacts one can expect over the next century. As discussed in the concluding chapter, more recent, though less conclusive, projections are already suggesting higher sea levels.

PARK-WIDE TREATMENT OF ENDANGERED SITES

The field study for this report focused on inundation and cliff erosion, as these are the most immediate, measurable threats. The park's GIS data indicate that only a small fraction of areas expected to be impacted by inundation, dune erosion, or bluff/cliff erosion have been surveyed (Table 4).

Table 4. Surface Area Predicted to be Impacted by Inundation, Dune Erosion, and Bluff/ Cliff Erosion.

	High Water/Flood(acres)	Dune	Bluff
Original Area	3179.02	649.3	2424.63
additional 200-m buffer	9347.03	965.85	1989.06
Surveyed Original Area	279.64	45.23	23.13
Surveyed 200-m Buffer	655.6	107.26	71.5

It is recommended here that the areas expected to be inundated or within the dune and bluff/cliff erosion areas, along with a buffer, should be surveyed by archaeologists so that PRNS managers have a more complete inventory to gauge what will be lost as a result of the effects of climate change. Following this effort, it is recommended that park managers plan, in consultation with FIGR and park archaeologists, where regularly maintained fire roads, breaks, and staging areas might be located, given the probability of an increased fire regime. Once these areas are targeted, it is recommended that they be surveyed and any cultural resources inventoried, so that future planning efforts can take these resources into account. Areas that are the most likely to burn should be also considered for inventory during this effort.

General recommendations and treatment options, provided in conjunction with the types of expected impacts, are provided below.

SITES THREATENED BY INUNDATION AND DIRECT WAVE EROSION

Several options exist for treating the effects of inundation on archaeological sites. These options include: data recovery, targeted removal and reburial of items subject to NAGPRA prior to inundation and erosion, removal and reburial of items subject to NAGPRA as they become exposed due to erosion, and no data recovery or removal and reburial of items—simply let the sites erode into the ocean or become submerged. Each of these options is discussed below.

Option 1: No Treatment

In this option, the sites are allowed to either erode into the ocean or become inundated. The eroded sites will be destroyed and, therefore, be forever unavailable for research. What about those sites that might possibly be preserved by inundation? How are they to be studied?

If no coastal systematic archaeological survey work is conducted prior to inundation, researchers will face the same challenges as archaeologists in other parts of the world when studying wet sites. Coles (1988:xi) describes some of the characteristics of these sites. Some of these features that would be applicable to prehistoric archaeological sites at PRNS are reproduced below, with minor paraphrasing:

1. They are invisible because they are entombed in organic sediments
2. They are usually discovered accidentally during development, which can destroy such sites
3. Innovative methods, particularly remote sensing, are required to locate and excavate wet sites
4. Innovative methods to analyze and preserve materials from wet sites are required
5. Organic remains recovered from wet sites are very fragile and must be preserved immediately to avoid degradation.

Recent research on inundated archaeological sites in Bass Harbor, Maine, by Kelly, Belknap, and Claesson (2010:695) indicates that , if sea-level rise is gradual, areas within bays or sheltered areas, near water courses that have a large sediment loads, will fare better than sites exposed to direct, open-ocean wave energy. Gradual sea-level rise will allow for the development of beaches, spits, and other alluvial landforms to form at the mouth of watercourses and can both cover sites slowly, with little erosive energy, and create wave and current barriers in front of and on top of sites (Kelley, Belknap, and Claesson 2010:697–698). As a pragmatic matter of ranking the sites most likely to be impacted by rising sea levels as a result of climate change, sites within bays or the back side of lagoons have therefore been ranked lower in the priority of sites to be treated. Those located along the ocean edge, either along the

western edge of the Point Reyes landform or within Drakes Bay, are the most likely to be directly hit by wave energy, scouring, sediment loss, and tidal currents. For this reason, those sites were ranked highest in priority, and of those, eight have been picked based on their perceived susceptibility and data potential. Each of the eight sites is discussed in detail below.

That said, once these sites are submerged, it will be much more difficult and dangerous to recover data from them. Muckelroy (1978:16-17, 37-41) describes the numerous pitfalls of underwater archaeology—loss of dexterity, inability to focus on peripheral stimuli necessary to stay safe, restricted visibility due to the mask and water turbulence, distorted vision as a result of the mask which results in a magnified view to the diver, loss of portions of the light spectrum due to the filtering effects of the water, loss of hearing and smell, inability to communicate easily, the cold conditions, nitrogen narcosis, air embolism, burst lungs, the bends—the list of work hazards is extensive and sobering. Muckelroy describes the situation in this way:

One of the most important points to emerge from these investigations into diver performance has been that almost any task takes longer to perform under water than on land. [The] mental retardation effect is reinforced where simple physical tasks are concerned by the fact that water resistance makes all heavy work slower and more tiring than it would otherwise be. It is particularly unfortunate, therefore, that while almost everything takes longer under water, the period of time anyone can spend there per day or per week is strictly limited...The archaeological consequences of these restrictions in the amount of time a diver can spend on the sea bed are legion [1978:37-38].

and

The point should be made that underwater work is not only expensive in terms of money; it is also prodigal of human resources. At the very least, this is because it may involve a highly trained archaeologist, be he a site worker or the director hanging around for a whole day in order to do an hour's work. But it is even worse than that: on several occasions... as when discussing the problems of communication underwater, it was suggested that the only way forward was to ensure that the whole of the team were trained to a higher level than would generally be considered necessary on land. While this happy situation will rarely prevail in practice, the point must be borne in mind; a properly conducted major maritime archaeological project in an area could place a severe strain on the available resources of trained personnel [Muckelroy 1978:48].

Underwater archaeology is a specialty in which few organizations have sufficiently trained staff. The combination of gear, insurance, wages, and significantly slower excavation coupled with the challenges and safety concerns of removing artifacts and excavating features in a submerged setting suggest that it would be both expensive and impractical to excavate sites once they are inundated. Daugherty (1988:25), in discussing the problems of excavating wet sites, notes that “because of the nature of wet site archaeology, these projects are relatively

expensive when compared with traditional dry site projects...Increased time in the field and the laboratory readily translates into a larger budget”.

With this in mind, the general recommendation for sites threatened with inundation is that any data recovery necessary to prevent the loss of significant data within NRHP-eligible sites be conducted prior to inundation and direct wave erosion. For this task to be carried out, PRNS should conduct a cultural resources survey of the entire coastal strip of the park, including all projected high-water and flooding zones, as well as a buffer (suggested here to be 200 m) set back from the cliff faces to address erosion as well as inundation. Currently, only a small fraction of this portion of the park has been formally surveyed. It is suggested that at least an updated surface recording of each site be conducted so that some documentation of what will be lost can be made.

Option 2. Construction of Sea-walls and Levees

In general, it is acknowledged that the construction of sea walls and levees is impractical. Hypothetically, the construction of sea-walls and levees to protect cultural resources could take place. Park administrators will have to consider whether the construction of such features is in keeping with NPS policy and with maintaining the aesthetic nature of the seashore. Heberger et al. (2009:36) estimate that the costs for new levee construction would run about \$1,500 per linear foot, while seawalls would be, on average, \$5,300 per linear foot. Most of the current PRNS has no vehicle access; either new roads would need to be constructed to get access to coastal stretches or the walls and levees will need to be constructed from the water by boat. Once in, costs will need to be set aside for maintenance of the levees or seawalls.

There may be some situations that are not conducive to the construction of seawalls. Limantour Spit, the mouths of Horseshoe Pond and Abbott Lagoon, and possibly other locations are in places where, unless substantial sea walls are built and pumping systems installed, the sites will be inundated from either side by both rising ocean and estuary levels. Other locations, such as those located on top of cliffs or bluffs, may benefit from the construction of seawalls along the base of the cliffs.

Option 3. Data Recovery

Where sites will be destroyed as a result of climate change, data recovery may be the only active option. Sites that will be inundated, particularly along the open ocean edge, will be subject to strong erosional forces that will likely compromise the archaeological context of artifacts and features. Where protection and preservation are not viable, retrieval of the site's data may be the only way to preserve some of the sites' values.

Data recovery should be undertaken in consultation with FIGR. Some sites or components may be inappropriate for data recovery due to tribal cultural concerns. Where data recovery is planned a location should be set aside for reburial either on site or the immediate vicinity that is not expected to be subject to the expected impacts of climate change.

BLUFF TOP SITES THREATENED BY ERODING CLIFF FACES

Option 1. Construction of Sea-walls and Levees

The challenges and costs of construction of sea-walls and levees is discussed above.

Option 2: Stabilization of Cliff Face

Some form of slope stabilization may appropriate for sites along the cliff edges. Revegetation of cliffs with brush with strong root systems and fencing to prohibit incursion by cattle could help stabilize cliff faces. In extreme examples, it may be possible to place rip-rap or concrete fortifications on or against the cliff face itself to help prevent direct wave erosion. On the Tomales Bay side of PRNS, sites (e.g. MRN-266, -268, -269, -270, and -286) that have long been fenced off now have dense vegetation anchoring the soil in place along the bay margins. While the erosional combination of sun exposure, wind, and sea spray will be greater on the open ocean side, stabilization through revegetation remains one of the best tools available for managing sites along coastal cliff edges.

Option 3: Data Recovery

Archaeological data recovery along cliffs can be challenging. Previous burial recovery efforts along the edge of CA-MRN-275/-302 required rappelling off the cliff edge and hand-excavating a 45-degree cut along short sections of the cliff to prevent further erosion (Meyer 2005; 2008). While these efforts were effective, they are labor intensive. Data recovery efforts may require safety precautions and may necessitate special training above and beyond traditional data recovery efforts.

Data recovery efforts should be prepared in consultation with FIGR representatives. Some sites, or some components of sites, may be inappropriate for data recovery due to tribal cultural concerns. Where data recovery is planned, a location should be set aside for reburial either on site or the immediate vicinity that is not expected to be subject to the expected impacts of climate change.

Option 4: Monitoring and Burial Recovery

As has been the case with CA-MRN-275/302, regular monitoring and burial recovery (if applicable) has been the preferred mitigation option. ASC staff has twice conducted burial recovery on eroding remains that were identified during monitoring efforts. If it is determined monitoring and burial recovery is the preferred mitigation route, a regular monitoring plan will need to be implemented so that exposed human remains can be identified and recovered quickly.

Option 5: No Treatment

Logistics, shoreline topography and geology, or the sensitive nature of some sites may result in some sites being poor candidates for data recovery, stabilization, or other active treatment options. No treatment may be then determined to be the most appropriate course. It is suggested that at a minimum an updated surface recording of each site should be conducted to document what will be lost.

DUNE SITES THREATENED BY SHIFTING DUNE FORMATIONS AND AEOLIAN PROCESSES

Stabilizing dune formations may be a challenging task. Dunes require contributions from wind-blown beach sand, which may be severely impacted if seawalls, levees, rip rap, or other stabilizations measures are installed, as the ocean would no longer be contributing fresh sand to the beaches. It may be, then, that stabilization of the dunes themselves, data recovery, monitoring, or no treatment would be the only options. The number of sites within a dune setting are relatively few in number, though in high density in places such as Limantour Spit. The loss of these landforms would correspond to a loss in a potentially rare site type if such sites reflect the gathering and processing of unique resources associated with dune formations.

Option 1: Stabilization of Dune System

The dune systems could be at least partially stabilized through the introduction of dune vegetation with root systems strong enough to keep dune surfaces in place. While some species, such as iceplant, have been used effectively in the past to do this, the widespread introduction of non-native species will not be an appropriate mitigation measure at PRNS. A high level of inundation along dune areas may completely destroy these formations. Dunes at a higher elevation may be preserved if sea levels stabilize and sufficient vegetation is in place.

Option 2: Data Recovery

Shifting weather patterns, rising sea levels, and other factors affecting the need for coastline fortification may make dune stabilization impossible. In such instances, data recovery may be a viable option for dune sites. Any data recovery effort should be prepared in consultation with FIGR representatives. Some sites, or some components of sites, may be inappropriate for data recovery due to tribal cultural concerns. Where data recovery is planned a location should be set aside for reburial either on site or the immediate vicinity that is not expected to be subject to the expected impacts of climate change.

Option 3: No Treatment

As a result of access problems, topography, or other considerations, no treatment may be the only option. As dune erosion can result in the complete deflation and shifting of a sand

dune, the archaeological contexts within that dune can be completely lost. It should be assumed that the data potential of sites in high erosion areas will be lost.

Option 4: Monitoring and Burial Recovery

Some sites associated with dunes are known to contain burials. While data recovery and/or dune stabilization may not be feasible, regular monitoring of dune sites should take place to ensure that human remains are recovered and treated in accordance with tribal custom, in consultation with FIGR.

SITES THREATENED BY FIRE

A host of artifacts, features, and cultural residues are impacted through the direct effects of fire. Some treatment options exist that may help to minimize damage to archaeological resources.

Option 1: Fire and Fuel Load Management

One important tool in mitigating the negative effects of fire is fuel load management. Thinning dead and unhealthy trees, brush build up, and controlled burns may be effective means of keeping fires from occurring or, when they do occur, from burning too hot, causing damage to sites. From a cultural resource standpoint, forested areas where known historic properties exist should be given priority for fuel load management over areas without sites or that contain sites not eligible for the NRHP.

Option 2: Data Recovery

In areas where surface temperatures from unchecked fires are expected to destroy or negatively affect features and artifacts, data recovery could take place. It is expected that different fuel loads will result in different levels of data recovery efforts. An entire deposit does not necessarily have to be excavated, only the depth to which fire may have an effect. Areas where fire management roads and fire breaks are likely to be graded and maintained should be surveyed, and any sites determined eligible for the NRHP should be part of a park data recovery program for fire management.

Option 3: Monitoring and Burial Recovery

Some sites that would not be considered candidates for data recovery, whether as a function of cultural sensitivity or logistical concerns, may have human remains, burial-associated artifacts, or items of cultural patrimony exposed as a result of surface erosion after fires, rodent disturbance in the newly exposed ground surface, or blading, grading, or firebreak construction during fire events. When controlled burns are expected, or wildfire outbreaks

occur, it is recommended that the suggestions for mitigation posed by Schultz (2006: 123-140) for resources within PRNS be followed.

Option 4: No Treatment

No action is a potential option. This may be the case where protection is not possible and data recovery is either inappropriate or not practical. During events such as crown or running surface fires occurring in areas where the fire is elevated off the ground surface, the type of resource present may be only nominally affected, especially if resources lie at a depth where damage from fire is expected to be limited.

Operational Effects

A host of operational effects can impact archaeological sites during efforts to fight fires, including the construction of staging areas, fire lines, different ignition techniques, the use of different fire retardants, and mop-up and rehabilitation efforts. Several mitigation options are available to help counter operational effects:

Option 1: Personnel Training

Training fire-prevention and firefighting personnel may be an appropriate means for combating many potential site impacts. By making fire personnel aware of the kinds of sites that are likely located within a burn area, their importance to the tribe and the archaeological community, and providing maps of sites to fire managers, decisions can be made to avoid or minimize the operational effects of a fire.

Option 2: Data Recovery

Impacts to some sites may be unavoidable due to their strategic location for access or the proximity of the fire. In such cases, the sites may be damaged during firefighting. Assessments of the damage to the archaeological record and attempts to recover data, if possible, occurs after the damage to the site. Areas where fire management roads and fire breaks have occurred should be surveyed and any sites determined eligible for the NRHP should be part of a park data recovery program for fire management.

Option 3: Monitoring and Burial Recovery

In some instances, sites may have been so impacted by firefighting efforts that formal data recovery is no longer worthwhile. Such sites, however, can still contain culturally sensitive artifacts and materials, particularly human remains. These remains should be recovered and treated in accordance with tribal wishes. It may be appropriate to investigate back dirt, blade berms, or other post-operational features that have lost archaeological context but may still

contain sensitive materials. Post-fire efforts to restore or rehabilitate an area that was a focus of operational activity may also re-disturb a site; monitoring of such activities may be warranted.

Option 4: No Treatment

No action is a potential option. This may be the case where protection is not possible and data recovery is either inappropriate or impractical. Some operational effects, such as the dropping of fire retardants, are done from the air, without there necessarily being any foot access to the areas of impact. Other areas may have been graded to bedrock or sterile soil layers, leaving nothing of a site from which to recover data.

Indirect Threats

Indirect threats can take place in a number of ways, including looting, increased surface runoff and erosion, increased tree mortality, increased burrowing rodent activity and insect populations, increased microbial populations that could result in the consumption or decay of organic material, and carbon contamination of archaeological deposits.

Treating the effects of indirect threats may be more difficult than treating those of other fire types. For example, it may be that little can be done about microbial populations, increased rodent activity, or carbon contamination. That may be part of the unavoidable outcome of a forest fire, and it may be determined an acceptable risk of a controlled burn if it prevents larger, more dangerous fires later.

Option 1: Fuel load Management

Archaeological sites in close proximity to increased fuel load from downed trees and insect infestation could be threatened by additional fire damage. It may be prudent to remove the excess fuel from these sites. Assessments of likelihood of materials catching fire, and the projected course of such fires can and should be part of the decision-making process. Similarly, the proximity of historic properties should be taken into account when decisions are made as to where and when to thin dead and diseased trees.

Option 2: Trail and Road Re-routing and Rehabilitation

In areas exposed by fire where hiking trails or roads pass by a known site, re-routing the trail or road away from the site could help in both keeping hikers and looters away and keeping runoff from the graded trail or roadbed from coursing over the site and causing erosional damage. The exposed site, or areas between an exposed site and a trail/route, could be reseeded, re-vegetated, boulders installed, and/or other measures taken to keep people on their path and away from the site, concealing it if necessary under vegetation.

Option 3: Data Recovery

Impacts to some sites may be unavoidable due to their strategic location for access or the proximity of the fire. In such cases, the sites may be damaged during firefighting, with assessments of the damage to the archaeological record and attempts to recover data, if possible, occurring after the damage to the site. Areas where fire management roads and fire breaks have occurred should be surveyed; any sites found should be evaluated, and any determined eligible for the NRHP should become part of a park data recovery program for fire management.

Option 4: Monitoring and Burial Recovery

Several levels of monitoring should take place to assess the impacts of indirect effects of a fire. Areas containing sites that are newly exposed as a result of a fire should be regularly monitored for evidence of looting or casual collecting. Sites that are likely to be locations of increased erosion as a result of the loss of leaf litter and erosion should similarly be regularly checked. Removal of downed or diseased trees to prevent future fires should be monitored on areas where known sites are located. In places where increased erosion or looting activities are exposing human remains, the tribe should be consulted regarding potential recovery and reburial elsewhere on site.

Option 5: No Treatment

In some cases, as with the increased rodent disturbance or increase in microbial populations, that little can be done to stem the damage done to archaeological sites. Remote sites or those with difficult access may not be good candidates for data recovery. On other sites that are primarily lithic scatters, microbial population growth may not be an issue; at other sites that are entirely single component without features, rodent disturbance may not have that great of an impact. It may therefore be decided that no action is a potential option. Other sites may have cultural values to FIGR that are not compatible with data recovery.

RESEARCH DOMAINS FOR ENDANGERED SITES WITHIN POINT REYES NATIONAL SEASHORE

In 2003, Suzanne Stewart prepared an extensive research design and archaeological overview and assessment for PRNS and GGNRA that identified important research questions that data from sites within PRNS could address. These questions help the park determine which are potentially eligible for the NRHP. Archaeological sites are commonly evaluated for their potential eligibility under Criterion D, which states that a site may be eligible if it has “yielded or may be likely to yield, information important in history or prehistory” (NPS 1997:2). While archaeological sites may have other aspects that allow them to be eligible for the NRHP under Criteria A, B, or C, it is under Criterion D that the eligibility of an archaeological site is typically

assessed. A draft National Register District Nomination form has been prepared for the proposed Point Reyes Peninsula Indigenous Archaeological District by Suzanne Stewart (2008) that includes 72 sites throughout the park which appear to be eligible for the NRHP as contributors to the district under Criterion D.

In her research design, Stewart delineated four broad research domains that appear to be applicable to indigenous archaeological sites within PRNS: Chronology/Culture History; Settlement and Subsistence; Social Organization and Complexity; and Culture Change. Stewart devotes a chapter to each of these domains within her research design. The domains are condensed below, with research questions posed by Stewart given verbatim, as well as a handful of additional research questions that have been introduced into the archaeological literature since the time of the preparation of Stewart's research design. This material can be used for developing new research designs for data recovery or sampling, as well as evaluating the research potential for newly discovered sites.

RESEARCH ISSUES ON CHRONOLOGY/ CULTURE HISTORY IN THE PRNS

Prior to addressing the research potential of a site, baseline data regarding a site's age, structure, and cultural affiliation need to be collected and assessed. Stewart (2003:79) outlines three steps toward this goal:

- determining site structure (the temporal and functional relationship of discrete site layers), both vertically and horizontally;
- dating the site or its *components* (discrete portions of an archaeological site, representing a specific time period or function); and
- identifying a sufficient sample of the site's contents (artifacts, features, dietary remains) to discern the nature of the site and what kind of research issues it might address.

Archaeologists can then take this baseline data and compare it to the area's *chronological sequence*, i.e., the temporal sequence of cultures that archaeologists generally agree have occupied an area. This sequence is derived through the study of artifact collections and through dating techniques, such as C14 dating and obsidian hydration band analysis, that allow archaeologists to put different artifact assemblages, believed to be generally associated with a particular culture, in rough chronological order.

Stewart (2003:119-121) identifies four broad categories of research questions have been posed for indigenous archaeological sites within the GGNRA-PRNS area:

1. Chronometrics
2. Earliest occupation
3. Linguistic prehistory
4. Refining the chronological sequence

Each category has an associated set of questions, some of which have been dropped or modified slightly to reflect sites just within PRNS and more recent trends in archaeology. Since

the preparation of Stewart's research design, Hildebrandt (2007:95-96) has highlighted the importance of defining occupations predating 1,000 B.C. along the northern California coastline. Hints of earlier occupations can be found at Duncans Landing and Bodega, but, unlike the central and southern coastlines, evidence for earlier occupation has been scarce. Hildebrandt (2007:96) in particular identifies Pleistocene landforms near extant estuaries; several small estuaries can be found within PRNS and a closer look at the geomorphology around the edges of these landforms could help identify sensitive areas for earlier occupation. As these are locations that are also likely to get inundated during sea-level rise, such studies should be conducted soon if this data is to be recovered.

Also of concern is the rise and collapse of the Berkeley Pattern culture, which is found throughout the southern North Coast Ranges and indeed much of the bay area between 600 cal B.C. and cal A.D. 800. One view of the origins of the Berkeley Pattern is that it appears to have been centered within the Clear Lake basin, where local obsidian sources and super-abundant spring fish runs helped fuel a robust trade economy tightly controlled by local populations and representing a continuous occupation from the earlier Borax Lake Pattern (White et al. 2002:523-524, 535). The Berkeley Pattern culture, marked by a more residentially focused settlement system, bone tools, and wide range of stone tool production, seems to make an early appearance in the basin (5000-300 cal B.C.) and appear more robustly from 300 cal B.C. to cal A.D. 800 (White et al. 2002:524). The transmission of the Berkeley Pattern cultural tradition would therefore be a function of Pomo contact with outside groups.

Moratto (1984:553) argues that the Berkeley Pattern arose from contact between Utian speakers, who eventually diverged into the Miwok, Ohlone, and Yokut language speakers, and Hokan speakers, whom he suggested may have been Esselen on the southern side of the San Francisco Bay. This fusion would have taken place sometime after 2000 cal B.C. following the Utian westward expansion (Moratto 1984:553-554). Golla's (2007:76) assessment of California's linguistic prehistory continues to support the Moratto scenario, though Golla chose not to emphasize the Esselen connection.

White et al. (2002:540-541) conclude that proto Western Miwok likely arrived in the Clear Lake basin sometime after 500 cal B.C., noting that there was extensive commerce between Coast Miwok and Lake Miwok, and while he does not explicitly state as such, it seems likely that the Berkeley Pattern may have been introduced to the bay area through that connection. If so, Coast Miwok populations may have played a critical role in helping the spread of his cultural tradition throughout the San Francisco Bay Area. Gaining a better understanding of its transmission and eventual collapse would assist research not only within PRNS but throughout the Bay Area and southern North Coast Ranges.

Chronometrics

1. What techniques will allow better definition of phases and time periods in PRNS-GGNRA archaeological sites? What opportunities are there for additional dating efforts? Will Accelerator Mass Spectrometry (AMS) dating allow temporal control in situations that were previously thought to be undatable?

2. What variables must be controlled in radiocarbon dating of shell to enhance the value of this technique in eroding coastal sites?
3. Are there extant collections containing ample obsidian and organic materials that might lead to refinement of dating techniques?

Data Requirements:

- Archaeological contexts with strongly associated datable pairs of shell and carbon for testing the Holocene changes in the reservoir effect.
- Archaeological contexts with strongly associated datable pairs of radiocarbon–obsidian specimen for testing the hydration curve.
- Curated collections from the study area with reasonably abundant obsidian items, datable organics, and typologically distinctive artifacts.

Earliest Occupation

1. Are there Early Holocene archaeological sites on accessible buried or submerged landforms in PRNS?
2. What accounts for the recognized greater complexity and diversity of Early Holocene occupation in California? Is it the result of greater site integrity (e.g., buried or cave deposits that have been protected)? Has our recognition of earlier cultural complexity than previously anticipated allowed us to "see" older sites more readily? Beyond seeking buried and inundated sites, what techniques might increase our inventory of older sites?
3. Will a re-examination of previously excavated assemblages reveal some "earlier" sites in the PRNS, once the greater complexity of the Early Holocene assemblage is recognized?

Data Requirements:

- Identification of paleosols that may contain Early Holocene archaeological deposits.
- Archaeological exploration of submerged locales that may contain Early Holocene archaeological deposits.
- Curated collections that may be candidates for Early Holocene reassignment.

Linguistic Prehistory

1. Is the appearance of the Berkeley pattern direct evidence of Miwokan expansion or of in situ development? Will Middle Archaic components in PRNS, if identified, demonstrate the presence of Lower Berkeley affiliations in coastal Marin County?
2. What evidence is available in the PRNS for the social and environmental stresses of the "Middle/Late Transition period?"

Data Requirements:

- A suite of archaeological occupation sites with secure dating to the time periods in question for testing dissemination of materials and ideas.
- Individual, stratified archaeological sites with secure dating to the time periods in question for testing in situ development.
- Artifact-rich deposits with diverse assemblages that will aid in determining the waxing and waning of various time-markers.

Refining the Chronological Sequence

1. In what ways might new dating techniques be used to sort out disparities in the archaeological record of the PRNS and environs? Will reassessment of time-markers based on new assignments help to interpret sites lacking in chronometric material?
2. Are some assemblages in the archaeological record better understood in terms of contemporaneous occupation of distinctive groups? Is this the case with the Mendoza aspect at Point Reyes, with its anomalous disjunctions?
3. Can refining the PRNS cultural sequence help in understanding culture-historical relationships in the greater Bay Area? Do inland–coastal patterns emerge from the new interpretation?
4. Will broader comparative research illuminate the population shifts in the PRNS? Can newly discovered sites dating to the Middle Archaic/Upper Archaic transition period help to identify conditions at this time?
5. Can typologies for the study area (e.g., projectile points, mortars and pestles, etc.) be updated by new data and reanalysis of older finds?
6. Can the new theoretical focus on cultural variability and individual historical shifts open up new approaches to the chronological sequence?

Data Requirements:

- Archaeological deposits with chronometrically datable organics (in the form of charcoal, ash, bone, antler, shell, or soil humates), obsidian artifacts suitable for hydration analysis, or other chronometrically datable materials.
- Archaeological deposits with intact features with datable material (above) and stylistically distinctive artifacts that can serve as time-markers.
- A suite of archaeological sites that demonstrate a range of datable assemblages; individual stratified sites for identification of fine-grained variation.
- Re-analysis of curated collections or data to refresh old interpretations with new data and approaches.

RESEARCH THEMES ON SETTLEMENT AND SUBSISTENCE IN PRNS

The geography and biological communities within what is now PRNS yielded a wide range of food and materials for indigenous populations, and as such is an ideal laboratory for investigating changing settlement and subsistence strategies through time and across space. Over 110 prehistoric archaeological sites are recorded within PRNS, and many more sites are yet undiscovered—in buried or submerged settings or in the rugged and densely vegetated hills that border much of the coastal zone. There is, therefore, the potential for ample comparative data from the study area for use in understanding why people settled where they did, and how they adjusted their occupations to factors of seasonal resource variability and the logistical demands of the group.

Settlement and subsistence can be thought of as a single, overlapping concept. “Subsistence,” as defined by Jackson, “refers to the suite of technological and cultural practices that supports a group’s basic nutritional needs” (1994:13-2). “Settlement” is defined as the way people occupy the land through a subsistence cycle, and includes the locations of subsistence activities and social events. “Technology” includes a logical series of actions: “the activity sets involved in the procurement of raw materials; the preparation, modification, and alteration of those materials to create tools and tool kits; the techniques and combination of activities involved in the use of those tools to perform economic tasks; and the maintenance and discard of those tools” (Jackson 1994:13-2). A culture’s adaptive strategy is made up of its technological, subsistence, and settlement choices. The social organization of the group is important in maintaining and transmitting their strategy.

To reveal information about subsistence and settlement, archaeological deposits must have intact stratigraphy. Stratigraphic processes are the results of both natural and cultural forces. Natural processes provide the medium in which a cultural deposit is created (e.g., alluvial sediments); later they may cover over or remove (via landslide deposits or erosion) some or all of the cultural deposit. Most archaeological work takes place at the level of a site or a small section of a site (e.g., an archaeological “unit,” such as a trench or other subsurface exploration), where distinguishing between cultural and natural processes is essential. The process of bioturbation, or the churning of soils by living organisms (roots or animals), also affects the site by distributing artifacts across stratigraphic layers.

Cultural deposits are often made by humans storing or discarding artifacts and non-artifactual cultural materials (most commonly, dietary bone and shell) on the soil surface, or in various receptacles in or on the ground. Humans actively create the spaces they use when they build dwellings, dance houses, and sun shelters, and dig firepits and ovens. They also actively transform existing cultural deposits as they dig human graves or storage pits. Therefore, consideration of the formation processes at work in a given deposit is a fundamental step in analysis and interpretation. A common problem ensuing from incorrect analysis of site stratigraphy is treating artifacts found in the same disturbed or mixed layer as contemporaneous. Making the reverse assumption can also be a mistake: assuming that ostensibly older artifacts found in more recent contexts indicate stratigraphic mixing when in fact they might mean poor taxonomic control or co-occurrence of adaptively dissimilar groups.

The phrase *site-formation processes* is often used to refer to these cultural and natural processes: it refers to the way the site is formed and transformed, during and after use. The activities associated with various human pursuits (e.g., processing plant products) are modeled to predict their archaeological correlates (Schiffer 1987).

THE NATURE OF SHELL MIDDENS

Some Definitions

The term *shell midden* is applied to a variety of deposits of different function and structure, particularly in California where the terms shell midden and shellmound are used almost exclusively and interchangeably. The phrase *shell-bearing site* has been proposed by Widner (cited in Claassen 1991:252), who argues that any more precise term would require subsurface assessment of the deposit. He advocates the following typology:

1. Shell midden site—secondarily deposited shell from food consumption with no other activities evident at the site
2. Shell midden—discrete lens or deposit of shell only
3. Shell-bearing midden site—a site composed of secondary refuse of many kinds of remains, including shell, generated by a wide range of activities
4. Shell-bearing habitation site—primarily shell debris in site matrix used for architectural needs; the shell may or may not have originated as food debris [cited in Claassen 1991:252].

Claassen notes that one of the most useful aspects of this typology is the recognition that shell debris need not be equated with food debris. Instead, shells might have been amassed as structural features, providing a firm, dry base for occupation (1991:253).

In contrast, Waselkov, in his worldwide review of shellfish gathering and shell-midden archaeology, defines *shell midden* quite generally: “a cultural deposit of which the principal visible constituent is shell” (1987:95). Stein (1992:6) acknowledges that using the term midden can be misleading, as it technically refers to refuse accumulating around a dwelling place; she has nonetheless chosen to use the phrase shell midden because of its long tradition in the discipline. Following her lead, this document uses the phrase shell midden for most purposes. Shellmound, however, is used herein when referring to the huge shell structures that still bordered San Francisco Bay around the turn of the 20th century, some attaining more 10 m in height and covering as much as 100,000 square meters (Schenck 1926:162).

The Nature of Shell Middens

1. What factors contributed to the variations in shell-midden structure in the study area? In what ways do shell middens in the PRNS contrast with those on the Bay? Are the differences related to temporal, functional, or geographic variables? Are changes in shellfish species targeted reflected in changes in the collection of other marine or terrestrial animals?

2. How does the structure of shell-processing sites differ from that of residential shell middens? Can structural differences in short- and long-term occupations be discerned in shell middens in the study area?
3. Can buried sites in PRNS provide information on shell-midden formation that is missing from the current record?

Data Requirements:

- Paleosols to test for buried shell middens; archaeological exploration of submerged locales that may contain early shell middens.
- Intact shell middens with stratigraphic integrity, especially deposits with datable assemblages of artifacts and dietary remains.
- Macrobotanical and zooarchaeological remains that allow reconstruction of environmental settings.

Coastal Settlement

1. What kinds of Early Holocene archaeological deposits occur on the submerged shelf adjacent to the PRNS or under the waters of Tomales Bay or Bolinas Lagoon? Are additional buried deposits present on the ocean terraces (such as the deep strata in the Duncans Cave site) and alluvial valleys? In what ways can this early chapter in coastal history be explored?
2. Can fuller assemblages from submerged or buried settings be used to make inferences about older surface sites with poor preservation?
3. In what ways might seasonal coastal sites relate to one another, and how can these relationships be viewed archaeologically? Is coastal settlement linked to inland land use—seasonally or as a regular part of the group’s catchment?
4. During the Middle/Late transition period, were coastal settlements buffered from the environmental stresses evidenced inland in the Bay Area? Were portions of the coast considered non-contested areas at this time due to the new focus on terrestrial resources?
5. What species, quantities, and proportions of animals were used or processed at the sites? How did this change over time?
6. What hunting strategies were employed by residents of the sites? How do these strategies compare with those carried out elsewhere in the region?
7. How do the subsistence strategies of the residents of these sites compare to those of the larger Bay Area?
8. Were these sites occupied year round or seasonally? How did diet vary by season?

Data Requirements:

- Buried or submerged archaeological sites with intact and varied assemblages.
- Sites with secure dating for testing dissemination of materials and ideas.
- Artifact-rich deposits with diverse assemblages that will aid in determining shifts in resource base in terms of toolkit.
- Dietary assemblages from coastal sites that will aid in determining shifts in resource base in terms of inland and coastal resources; seasonal indicators from both inland and coastal sites.

Site-formation Processes and Subsistence

1. Can a shift from forager to collector be seen in the study-area archaeological record? How can the archaeological correlates for these strategies be tailored to the study-area? In what ways can these behavioral modes be distinguished from seasonal strategies?
2. What variables might be operating to make a difference in timing of the shift from foraging to collector in the study area? Do portions of the PRNS retain foraging characteristics late in time, similar to findings to the north at Salt Point and south on the San Mateo/Santa Cruz coast? Would such a retention, rather than coastal site abandonment, explain the apparent absence of later sites in some localities? How might this retention be demonstrated in the archaeological record?
3. What is the environmental productivity in the various units in the parklands (patchy, or heterogeneous? homogeneous?). Do these assessments compare well with the site types represented?
4. What is the focus and/or breadth of prehistoric subsistence? Are subsistence systems intensive and selective, or broad-based? Is the variability reflective of different social groups, different functions, or different time periods?
5. How do the nature and breadth of subsistence activities and exploited resources correlate with environmental and archaeological patterns involving technologies, settlement, demography, and social organization?

Data Requirements:

- Archaeological deposits with datable, artifact-rich deposits.
- Analysis of well-dated deposits in order to confirm or refute retention of cultural assemblages or co-existence of adaptively dissimilar groups.
- Information on seasonality for archaeological deposits based on the nature of recovered faunal and floral resources.
- Flaked-stone or other assemblages of tools for use in blood-residue analysis.
- Information from a suite of well-dated sites to determine patterns of foraging and collecting strategies and their archaeological correlates.

Technology

1. Will application of formal flaked-stone tool analysis raise new questions regarding technology in the study area? Are there extant collections that could be examined for identifying coastal central California traits?
2. Did coastal people have access to quality lithic resources, or were flaked-stone assemblages pieced together from less than optimum materials? Is this behavior recognizable in the conservation of lithic materials and the modest nature of the toolkit?
3. Are there more local sources for the mortars found in the PRNS than the proposed 30-mile distant quarries of Sonoma County? If such long-distance importation of heavy stone did take place, what other factors (subsistence, social, or ritual) might have been related to this activity?

Data Requirements:

- Archaeological sites with well-developed flaked-stone assemblages; flaked-stone assemblages in curated collections.
- Geological analysis of the region to identify potential source locations.
- Identification of other exotic materials in the collection and their sources.

RESEARCH ISSUES ON SOCIAL ORGANIZATION, INTERACTION, AND COMPLEXITY

A broad category of research interests focuses on topics that deal with social systems and intergroup interaction—topics that are much less visible in the archaeological record than settlement and subsistence. Even less tangible are various themes that concern how people think and feel, and how they value different elements of their personal and communal lives. In some archaeological settings (e.g., Mesoamerica, Egypt, or the historic-era U.S.), where abundant written information on the ideology and social fabric of a group are available, these topics might be treated under a wide range of headings. In PRNS, as with most of prehistoric California, few studies have approached these subjects archaeologically, and good datasets for future studies are not expected.

This section covers a range of topics that relate to how people organized themselves and interacted among themselves and with other groups, and considers how social complexity increases with increasing population and sedentism. Some archaeologists may find situations in which these issues can be featured more prominently; lacking such opportunities, it is nonetheless wise to consider the full spectrum of human experience, even if only for its contextual value.

The term *social organization* is used to refer to the way in which society is structured in terms of agreed-upon statuses (recognized social positions) and roles (behavior patterns)

prescribed for these positions). Among the included topics are the degree of specialization within a society and the method of assuming various positions: either through accomplishment (achieved status) or inheritance (ascribed status). Further, the general domain of social organization looks at how social groups interact with one another, the level of complexity of these interactions, and how this interplay affects cultural change.

Often explored under this social dimension are the topics of exchange and complexity—the one a catalyst to the other, as exchange is one of the primary mechanisms that supports sedentism, which in turn requires a complex system of social roles and actions to mediate the stress inherent in crowding and staying in one place. Among the ways of mediating these stresses are various ceremonial and ritual practices, artistic expressions, and lore that bring meaning to life's circumstances. Other solutions to stress may be more negative, such as warfare and the fission of social groups.

MORTUARY ANALYSIS

Archaeology has long attempted to go beyond purely material questions of technology, settlement, and resource use in order to access the ideas and values that motivated actions in the past. No matter how symbolic or cerebral the subject of interest, it must have material correlates or patterns of the same that can be identified archaeologically. The most immediately accessible subjects for these studies have been human burials, which are concrete representations of human life in the past. They put the investigator in direct contact with the individual's physical remains and, often, the objects that defined the person in life. Matters of status and gender and notions of supernatural power may all be represented. Analyzing burial populations, one can see interactions among members of society expressed in material form.

For nearly a century, mortuary analysis—the interpretation of human burials, including skeletal remains and associated artifacts (called “burial-associated artifacts” here)—has been the primary archaeological means of examining prehistoric social life. The basic premise behind social interpretations from mortuary analysis is that, cross-culturally, death is a significant event that warrants special actions and that people treat their dead in ways that reflect their status in life.

The ways in which the body is interred and the distribution of different kinds of contemporaneous burials throughout a site have been relied on as indicators of the degree of social stratification in a society, of demography, and even of insight into worldview. Some of the variables are

- degree of flexure (from tight fetal position, suggesting minimal ceremonial expenditure, to fully supine, suggesting elaborate procedures reserved for those of high status; these traits can also serve as time-markers, as they went in and out of fashion over time);
- orientation (head to setting or rising sun, or variant thereof) of individual burials and patterning of orientation across the site (including no set orientation);

- the remains of body ornamentation (such as remnants of bead necklaces, pendants, beaded capes, abalone-shell gorgets, and red ochre body paint);
- the relative quantity and kind of burial-associated artifacts interred with the dead and the frequency of their associations in terms of age and sex (e.g., are males associated with wealth objects while females are associated with functional objects, such as basketry awls? Are burial-associated artifacts found only with adults or with children as well?); and
- burial-associated artifacts with apparent significance beyond economics or gender that may indicate the presence of ritual specialists (e.g., clusters of bat sting rays or raptor claws, exotic minerals, etc.).

Additional information on social organization can be inferred from osteological analysis of the human remains themselves, such as:

- the evidence of certain kinds of wounds, which can indicate warfare or suggest spousal abuse;
- types of bone deformation, reflecting specific occupations or frequently performed tasks;
- various nutritional deficiencies detected in bone and teeth, which may be correlated with differential diet in accordance with rank or age/sex; and
- various physical anomalies, such as a high occurrence of supernumerary teeth, suggesting inbreeding.

Changes in mortuary practices constituted one of the primary datasets for building the central California cultural chronology in the first half of the 20th century. Much of the work was done for the purpose of identifying analytically useful temporal divisions, but analysis of mortuary remains for the purpose of characterizing social variables had already had a long history in the archaeology of the Old World, and was used to contextualize the various aspects and patterns in culture historical sequences.

Beardsley's Analysis of Point Reyes Remains

In order to characterize the Point Reyes/Tomales Bay district and compare and contrast it with San Francisco Bay, Marin Bayshore, and the Delta, Beardsley (1954) conducted an analysis of the burial complex at Point Reyes. The analytical universe includes those sites listed as intensively excavated by Beardsley and Heizer in 1940 and 1941. Because of the relatively small sample size from the B components at Point Reyes, Beardsley also analyzed the burial complex recovered from nearby CA-SON-299, which was considered contemporaneous with the McClure aspect.

Burials: Position, Orientation, Burial-associated Artifacts

All but two of the burials were placed in a flexed position, from completely flexed to semi-flexed, with the two exceptions being semi-extended burials from the B components of both the McClure and Cauley sites. Most were oriented to the west.

There were 10 instances of intrusive burials into earlier interments, which make it apparent that grave markers were not used or were not permanent. A number of group burials were also present, invariably in B components, although burials of females with infants occurred in both levels. The groups generally appeared to represent portions of family units—a mature person coupled with an infant, child, or adolescent.

Burial-associated artifacts were not common in Estero site burials: 1 of 6 Component A burials and 1 of 4 Component B burials had artifacts. For the remaining three sites, burial-associated artifacts were present in more than one-half to three-quarters of the burials from both components. “A recurrent feature of B horizon burials in particular is the presence in the grave of unworked bones of sea mammals, birds, etc., and chunks of chert or rounded pebbles in considerably greater quantity than the general nature of the deposit would justify” (Beardsley 1954:29).

Cremations: Burial-associated artifacts and Modes

Three modes of cremation were represented: (1) in situ burning, represented by a large pit with ash lining and abundance of bones; (2) possible grave pit burning, in which the body is placed in a pit and exposed to high heat before burial; and (3) the most common form, burning the body elsewhere and bringing the ashes to the place of burial (evidenced by a small pit, lack of ash lining, and scarcity of bone fragments).

Only at the Mendoza site did cremations lack burial-associated artifacts. Given the overwhelming presence of burial-associated artifacts elsewhere, it is likely that these individuals were buried with perishable goods.

Beardsley’s (1954:30-57) discussion of artifacts from the site identifies those present in burials and cremations. They run the gamut of all artifact types, from the most elaborate and ceremonial to the most expedient. No analysis of social organization and demography represented by these distributions was attempted.

Comparison with San Francisco Bay Sequence

The PRNS burials reflect a similar pattern to that of the San Francisco Bay. The McClure facies equivalent on the Bay is the Ellis Landing aspect. Of greatest interest in light of their importance on the Bay at that time period, is the scarcity or total lack of shell beads and *Haliotis* ornaments that typifies the McClure and Cauley site burials.

Human Remains at Limantour Spit

The mortuary remains recovered from Limantour Spit about 25 years later by San Francisco State College archaeologists represent a small but interesting group. The remains include those from CA-MRN-216—7 inhumations and 5 cremations, and 1 cremation from MRN-298 west. A few anomalies are present among the inhumations, including an adult female with hands crossed in front of her face, a large angular granite boulder over her head, a small mammal radius at her left leg, and a complete set of elk antlers above her rib cage. An adolescent also had animal bone associated: in this case the process of a sea-mammal long bone and a bird bone, along with a clam valve. Three of the inhumations had no associations (King and Upson 1970: 133, Table 1). In contrast to the inhumations, all cremations had associations, many of them a mix of traditional native items and 16th-century artifacts. One adult cremation, for instance, had the following associations:

Complete porcelain cup, 2 porcelain sherds, mortar, pestle frag. Copper frags., obs. corner-notched pt., worked bone, polished & incised bird bone, cut bone, burned clay, poss. worked sandstone, clam shell disc beads, glass trade beads, bird, fish and mammal bones, shell as in midden deposit, burned and unburned redwood (*Sequoia sempervirens*) [King and Upson 1970:134, Table 2].

King and Upson suggested that the burials and cremations were the result of a single event—perhaps a foreign-introduced epidemic. It is important to note, however, that one of the male skeletons had a projectile point embedded in his tibia. Thus it is possible that one or all of the other six individuals represented by the inhumations were also the victims of an attack on Limantour Spit, perhaps even a case of rivalry with another native group over the salvage rights to the remains of the *San Agustin*. It is interesting that no 16th-century items were present with these inhumations, which either place the event(s) before Cermeño's wreck or at least before large-scale scavenging had begun.

For the cremation population, however, there appears to have been more time to dispose of the dead. Cremations are more time-consuming to execute. Furthermore, as noted above, all cremations had burial-associated artifacts; two of the five had 16th-century items. The deaths represented by this group may have occurred over a somewhat longer period (perhaps from epidemic disease), presumably while camping near the *San Agustin* in order to strip the wreckage of its desirable materials. It is interesting to speculate what conditions would have prevented the group from returning home with the deceased for proper burial or cremation in a village setting—perhaps at Olema Valley or Tomales Bay, or further into the interior.

INTERACTION AND EXCHANGE

Several systems were in place in California by the Emergent period that have been recognized as factors in creating a highly complex society in a nonagricultural setting. Fredrickson, in the first publication on his chronological scheme, described the Late-period situation:

I propose the concept of the Emergent as a nonagricultural equivalent to the [Mesoamerican] Formative. Evidence continues to accumulate that Californians modified the environment to increase its natural productivity..., that food storage and exchange relations served to equalize the distribution of resources unequally distributed in time and space...that complex forms of social, religious, and occupational organization were emerging...and that ranking societies and possibly chiefdoms were developing in several regions of the state [1974:48-49].

While these traits were flourishing in many areas of California in the Emergent period, their beginnings can be seen in the Upper Archaic period, where sedentism and specialization are first suggested. Considerably greater time depth, back to Middle or even Early Holocene, for semi-sedentary occupations is being evidenced at important sites in central California since the early 1990s [e.g., Fitzgerald 2000; Meyer and Rosenthal 1997; Pryor and Weisman 1991]. An associated shift—to different degrees in different regions—was the change from foraging to collecting strategies, with the greater complex coordination required for the latter.

REDUCING SOCIAL STRESS

The Price of Sedentism

When the topic was considered under the Settlement and Subsistence section, the proposed causes of intensification that led to increasing social complexity were seen as resource scarcity and/or competition. Here, under the social dimension, the question can be looked at in terms of the social stresses inherent in large population aggregations. Cohen (1986) cautions that economic vulnerability is not the only problem faced by humans when they are forced into relatively large and permanent social groupings. For the past several decades, researchers have recognized that interpersonal tensions tend to prevent egalitarian or non-complex groups from remaining in large aggregates for long periods, quite independent of problems of subsistence.

While seasonal shifts in settlement among foraging groups may seem to be motivated by changes in resource availability, Cohen proposes that these “seasonal rounds” might have been also (or primarily) prompted by the need to relieve intragroup stress. Once sedentism arises and is supported, other mechanisms must be devised to take the place of mobility as a means of relieving stress. Cohen (1986:106-107) identifies a number of features in the environment (in addition to resource scarcity) that must be addressed: *congestion*, *information load*, *loss of privacy*, and *loss of control*. He writes of the importance of perceived control over one’s situation as being at the base of various magical systems and formal religions that are found at all levels of cultural elaboration. Reducing information overload for an individual can be achieved if other people are “(1) similar to it and therefore predictable in their behavior, (2) clearly labeled and categorized (stereotyped) and abide by the category boundaries on their behavior, or (3) easily dismissed as inconsequential or as consequential only in specified kinds of interactions” (Cohen 1986:108).

The notion that mechanisms arose to reduce social stress is one of that group of questions that cannot be conclusively tested in the field, but which contribute to archaeological interpretation through the development of a richer context. It is possible to infer these mechanisms, however, if the necessary elements are in evidence: indicators of year-round occupation (based on faunal, floral, and other seasonal indicators, and the remains of relatively substantial structures) along with assemblages indicating stylistic elaboration of ceremonial regalia, personal adornment, or occupational toolkits.

Handling Growth and Complexity

Looking at archaeological site distributions around the San Francisco Bay and interior Marin, King (1974) proposes a model for the rise in complexity and concomitant status ascription in the Bay Area. While the dominant theme is one of settlement, the mechanisms at work have to do with social structure and interaction and ways of maintaining low-stress relationships in periods of increasing complexity.

Since populations generally increase with sedentism, groups adopting more settled lifeways must soon exert some control over the situation before all local resources are exhausted. King proposes that such a group has three options: reinstating the population-control measures that operated during more mobile times; developing new subsistence practices; or the group “can fission, usually along lineage lines . . . , ‘budding-off’ daughter populations into adjacent regions” (King 1974:40). There can follow a series of such fissions, involving increasingly marginal territories that place the daughter populations under increasing pressure to readapt. A less elaborate alternative than adopting agriculture, King contends, would be the development of exchange networks, especially in areas where resource distribution is both varied and abundant. Further population growth occurs, “until a point is reached at which the parent community is socially circumscribed by the presence of daughter communities.” At this point, according to King,

fission then becomes a decreasingly viable option for population adjustment; mechanisms must then be found to maintain a larger population in the home environment while neutralizing potential competitors in the home environment. Meanwhile, the daughter populations, occupying less stable environments than does the parent group, come under considerable adaptive stress. The needs of both parent and daughter communities can be met through increased interaction, either in the form of warfare or in the form of resource-sharing via exchange systems. Either form of interaction requires formal organization of the population which amounts to the development of formalized nonegalitarian political systems [King 1974:41–42].

Archaeologically, this scenario appears to be reflected in the relatively large number of somewhat evenly dispersed, usually Emergent-period, small occupation sites in relatively modest settings. While the resource-rich areas of the parent communities had allowed large settlements for some time, perhaps since earliest occupation of the area, the hinterlands where the daughter populations reside would have been formerly used only for short-term resource-procuring forays. The pattern can be seen on the Marin peninsula, and in other Bay Area counties including Sonoma, Napa, Solano, Contra Costa, and Alameda. At the survey level, it is essentially impossible to differentiate between these sites and seasonally used camps. Their identity should be more easily seen with excavation, where diversity of assemblage (indicating sedentism) and a rather high level of expensive trade goods (reflecting a mutual arrangement with the parent population) should be apparent. The dating of most daughter settlements to the Emergent period suggests not only a mechanism for reducing stress caused by population intensity, but also suggests an important aspect of complexity: the seasonal round may be eliminated, for example, when the parent group can get a daughter group to make that round for them, symbolically and literally, through exchange.

This is a settlement-related issue in that it calls into question the earlier assumption that such sites were seasonally occupied by the same group that held the dominant sites; it is a social issue, however, in the way that it requires thinking of site distributions and other archaeological phenomena as a consequence of a problem-solving mechanism on the group level—ameliorating potentially stressful situations, while setting up support networks for the future. In many of the inland portions of the study area in the historic period, for example, it would have been adaptive to have safe and familiar locations in place at the time that Euroamericans began disrupting settlement: essentially friends in the country, who could help out in times of need.

EXCHANGE SYSTEMS

Budding off daughter populations creates small, interrelated exchange networks may have been the earliest form of exchange as well as the most direct. Other systems sometimes involved the movement of materials over great distances, sometimes in a series of exchanges. Raw materials of utilitarian value, such as obsidian, moved across the landscape, as did items of more symbolic significance, to which the value added by the purveyor was the most important attribute.

The Clam Disc Bead Horizon

The Coast Miwok were producers—perhaps the inventors—of the clam disc bead, the focus of a sudden and extensive exchange system that gained popularity no earlier than the end of the 16th century and possibly not until the last century before contact. There is abundant bead-manufacturing debris, in the form of broken beads and nonperforated bead blanks, at most Emergent-period sites in Marin and southern Sonoma County. According to King, the disc beads acted not as currency, but as “the tangible element in a complex of social interactions that

facilitated the redistribution of food against periods of famine and shortage” (1970:285). King proposes an explanation of the inception of the clam disc bead industry in relation to his social circumscription model, described above. Over the past 2,000 years or more, populations living in large villages on the Marin bayshore would have opted for budding-off to occupy less favorable areas whenever the strain of sedentism became too severe; King singled out the interior of the Marin peninsula and Point Reyes as two likely candidates for daughter populations: locales with unstable resource bases—Point Reyes because of its lack of oaks, the interior because of its lack of shellfish (King 1970:285). As populations in these new settlements rose, a system that would facilitate the transfer of food surpluses into the marginal areas would have been highly adaptive: hence the inception of the clam disc bead trade. What is not explained, however, is the clam disc bead’s rise in popularity, nor why the clam disc bead and not some other item became the focus of the trade—both questions that King considers worthy of attention. He proposes two hypotheses to be archaeologically tested:

1. In areas where clam disc beads were developed and/or heavily utilized, we should find evidence of adaptive stress. Such stress might be evidenced by high infant mortality, recurrent childhood illnesses, indications of intergroup conflict, high incidence of disease, and indications of experimentation with new subsistence techniques and patterns of social organization.
2. Clam disc beads should be found in least numbers in sites such as those on San Francisco Bay, where resources were relatively stable, and in such sites there should be relatively little evidence of traumatic stress [1970:286].

Archaeologists have many questions about the clam disc bead horizon. There is an apparent 200-year gap between the inferred beginnings of clam disc bead manufacture in Marin and the use of the beads in the Sacramento Delta area. Present evidence implies, as Beardsley (1954) notes that the clam disc beads spread from the coast to the North Bay and no further for 200 years, then exploded across the state in the last 50 years before Euroamerican occupation. King and Upson (1970:180) propose that the clam disc bead industry may be a post-16th-century phenomenon, as suggested by excavations at CA-MRN-298 on Limantour Spit.

By the late-19th-century, clam disc beads had become highly important in terms of validating social statuses. Bead thicknesses and bore diameters increased, and quantities skyrocketed; Beardsley (1954:44) notes that individual burials in the Sacramento Valley possessed up to 15-foot lengths of strung beads. Photographs from the period attest to women being weighted down with thick ropes of the beads, which remained prized possessions in the 20th century (see photos of Bodega Miwok women in Collier and Thalman 1996:196-197). Prehistorically, use of the clamshell disc beads was more modest at Point Reyes, where 1,773 beads were divided between 9 burials and 15 cremations; they occur in groups of 5 to 590 beads, with very few burials having more than 100 beads (Beardsley 1954:44). In the 19th century, the beads were used as payment for training in various specialties or in exchange for shaman services; admission to ceremonies was paid for with the beads, while permission to pass over boundaries was also subject to bead payment (Collier and Thalman 1996:201-202). It is unclear how payment with clamshells operated in the protohistoric period.

OBSIDIAN EXCHANGE SYSTEMS

The Duncans Point Cave site north of Bodega Bay provides the first conclusive evidence for Early Holocene obsidian movement to the coastal region north of the San Francisco Bay, with just over half of the 89 specimens from the Annadel source, just under half from Napa Valley, and one each from Franz Valley and Borax Lake. Both Annadel and Napa Valley, however, could have been visited in a day or two, suggesting that people might have picked up obsidian on an ad hoc basis on their seasonal round. By the Emergent period, obsidian had come to be seen as a necessity: of the 510 projectile points recovered from Limantour Spit at Point Reyes, all but 3 were of obsidian (King and Upson 1970:136).

Obsidian Sources represented in PRNS

A breakdown of the distribution of obsidian sources at Point Reyes can be seen in Origer's (1987) sample of obsidian projectile points from Sonoma and Marin counties, as a part of his hydration-rate study. Six of the 36 sites were from Marin County. Samples from within or adjacent to the present study area include 20 corner-notched and serrated points, all of Annadel obsidian, from Toms Point [MRN-202] on Tomales Bay; 1 eccentric specimen of Annadel obsidian from MRN-216 at Limantour Spit; 13 corner-notched points of Napa and Annadel and 1 serrated specimen of Napa from MRN-230 on Bull Point on Drakes Estero; and 9 corner-notched, 6 serrated, and 2 concave-base specimens from MRN-396, north of Preston Point near the mouth of Tomales Bay. Points from the last-named site were mostly of Napa obsidian, while 2 corner-notched points and 1 serrate were of Annadel (Origer 1987). No obsidian from distant sources has been reported. This is similar to the situation in southern Sonoma County, which may have been Coast Miwok prior to contact. In solidly Pomoan country of central and northern Sonoma County, however, an active exchange with people in the Clear Lake interior is suggested by the appearance of Konocti and occasionally Borax Lake obsidian at Warm Springs Dam area sites and the Alexander Valley. Konocti, in fact, is a common obsidian type along the coast at Salt Point (Dowdall 2003), about 50 rugged miles from its source.

Obsidian Distribution Models

While many researchers equate the spread of Konocti obsidian use with the movement of the Pomoan people out of Clear Lake and into the Russian River drainage, there has been little discussion of the social means by which these materials might have moved through the area. The only model proposed is an informal one that suggests that the maintenance of kinship ties with Clear Lake Pomo groups would have allowed easy access to homeland resources (Layton 1990).

This is in keeping with Basgall's (1979) conclusions that direct access, usually without payment, was the ordinary means by which western Pomoan peoples obtained obsidian ethnographically. For the Dry Creek phase at Warm Springs Dam area sites, however, Basgall and Bouey contend that "the use of obsidian at Warm Springs during this phase reached a peak [around 2,500 years ago] that implies a systematic or regularized strategy of exchange relationships" (1991:178), but they do not offer a model for those relationships. Stewart (1993) proposed that the mechanism operating at Warm Springs involved an entrepreneurial

relationship between expanding Coast Miwok groups and the indigenous Proto-Wappo who had pioneered the Dry Creek drainage, resulting in the contemporaneous occupation of two adaptively dissimilar groups. The two groups would have been held together by their different roles in obsidian supply and production.

The most elaborate discussion of obsidian production and exchange in north-central California is presented by Jackson (1986, 1989). He notes that of nine chemically distinctive obsidians in the North Coast Ranges, there is archaeological evidence for the extensive use of only four sources: Annadel, Borax Lake, Mt. Konocti, and Napa Valley. One implication of this selective use, Jackson (1986:90) suggests, is that obsidian projectile point or arrow manufacturers must have had restricted access to the material. Furthermore, there is consistency in the percentages of obsidian sources in any given tribelet territory—evidence, he contends, that some mechanism for management must have operated at local and regional levels. On this basis, Jackson states:

Extrapolating from ethnography, we could conclude that the political and economic authority of village leaders was sufficient to exercise very explicit and pervasive control through the redistribution of resources. Also implied is a political unity and perhaps a class distinction among these social elites. Maintenance of that class and its authority may have been through the regulation of exchange in general, including the exchange of wealth items like clam disk beads [1989:90].

Jackson notes an interesting simplification of production of Emergent-period projectile points after A.D. 1500: the elaborately serrated corner notches of Phase 1 are replaced by simple, nonserrated corner-notched points, which Jackson notes “could be modified easily to accommodate the aesthetic/stylistic demands of a range of consumer societies” (1989:91). At the same time, the clam disc bead appears archaeologically, whose principal function, according to Jackson, was to maintain status among elites engaged in inter-tribelet exchange. Jackson concludes with a summary of exchange in the North Coast Ranges:

At present there is tantalizing evidence to suggest that obsidian exchange took place within closely regulated redistribution systems. There was no monolithic ‘obsidian exchange system.’ Obsidian was only one commodity moving in regional systems, and obsidian in different forms very likely was distributed in very different ways [1989:92].

Long-distance Interaction Model

In contrast to Jackson’s local model, Bouey and Basgall (1984) introduced the first formal call for recognition of broad-scale economic articulation as the appropriate approach to the interpretation of changing obsidian-source distributions in central California. Their focus is the Central Valley, adjacent foothills, and the obsidian sources in the eastern Sierra and the Napa Valley. They suggest that direct procurement by western Sierra foothill populations was likely the means by which Casa Diablo obsidian from the eastern Sierra entered the western slopes,

while foothill-valley exchange provided the avenue by which these materials entered Central Valley and Delta sites. This relationship continued for centuries, with the peak of Casa Diablo use occurring between ca. 3000 and 1600 B.P. (around 1000 B.C. to A.D. 400), when eastern obsidian virtually disappeared from the lower elevations in the west. Here a shift occurred, with Napa Valley obsidian—previously only minimally represented—becoming the dominant source, first as status markers and later used for utilitarian items after overproduction resulted in “swamping” the market.

While the details of this complex event are not pertinent to the current study, Bouey and Basgall’s basic premise is of interest:

If we are to grasp a more complete understanding of evolutionary prehistory, we must ultimately account for both internal developments and external contexts; evaluations must be made of economies in articulation and not in isolation [1984:150].

Also of interest are some of the exchange mechanisms Bouey and Basgall offer: (1) that direct procurement (e.g., visits to the source by the western foothill populations) may be inferred when the source population is organized on egalitarian, wide-ranging lines and, thus, less likely to set up long-term production systems; and (2) that a complex production system, such as that of Napa Valley, may be developed not simply to supply demand but to satisfy internal needs:

Residents of the Napa Valley may have begun to develop, completely on their own and without central California intercession, a greater productive capacity and thus of their own accord exported relatively more obsidian into the latter region [Bouey and Basgall 1984:150].

A feedback relationship may have developed between the two regions, with Napa residents exporting greater amounts of obsidian, “not to meet central California wants, but to support their own extant (or developing) sociopolitical structure” (Bouey and Basgall 1984:150). Another way of looking at Napa’s entrance into the central California exchange network is as a move by the Napa population to support their own sedentism. Stewart (1993) proposes a similar complex relationship for the expansion of Konocti obsidian in the Warm Springs locality.

The role that coastal peoples might have played in this complex socio-political scenario is poorly understood, primarily because of the limited number of scientifically framed excavations in the parklands. More about the Point Reyes area’s marginal setting in the Emergent period, and its implications for social change, is presented below.

BOUNDARY CULTURE: A MODEL OF SOCIAL CHANGE

In the broader sense of sharing material and information, exchange systems may have had a key role in the development of cultural complexity in prehistoric central California. This issue is explored in several alternative theoretical formulations (Bouey 1987; Ericson 1977; Fredrickson 1974). A model of social processes that looks at the interdependence of social systems in a region is posited by Fredrickson (1974,) and presented in White and Fredrickson (1992) and White and Meyer (1998:108-110); the model is derived and adapted to a large extent from the work of Yehudi Cohen (1968, 1969, 1983). Cohen postulates that every society—by virtue of living in contact with other societies—is characterized by two sets of processes: “inside culture” and “boundary culture.”

Inside culture corresponds to the traditional concept of culture and might be placed under the rubric “lifeways.” Boundary culture, on the other hand, represents the processes involved in the interaction between interdependent societies, and is conceived as being organized to regulate, control, or administer the movement of goods and ideas between societies. While both inside and boundary culture have characteristic role relationships and statuses, the organization of social relations embodied in a group’s inside culture will reflect the group’s boundary-culture relations. From this perspective, hunter-gatherer complexity and dynamics can be understood in terms of more than such basic constructs as mobility patterns, subsistence economy, and technology. Organization of the adaptive system also involves relationships with neighboring groups who control resources not available in the home territory due to natural absence or local crop failure.

Once centrally administered exchange systems emerge, positive feedback emphasizes their importance over time, with boundary personnel—through their administrative function—gaining social influence and administrative power. Since roles of social influence and political power frequently carry with them material representations such as wealth and status objects, it is possible archaeologically to observe the parallel development of exchange systems and social differentiation based upon wealth, and ultimately the appearance and maintenance of tribelet structure with its resultant occupation specialization, institutional differentiation, and overall social complexity.

The model predicts that, due to the pressure to administer resources to visitors, boundary-culture developments should have been most accelerated in those settings where localized (usually seasonal) resource surpluses existed. The model was developed for such resource-rich areas as Clear Lake and San Francisco Bay. What role would the indigenous people of the PRNS play in such a system? More detailed studies would be necessary to better characterize the resource value of these areas and the potential for abundant resources at some seasons. Comparing Point Reyes and even Tomales Bay with the apparently more resource-rich Bodega Bay to the north, opportunities to develop a more complex social system appear much greater in the latter area. Although evidence of exchange is clear in PRNS archaeological sites, the need for a complex suite of administrative positions during the Emergent period is not.

Social Organization

1. What evidence is there in PRNS site assemblages for the growth in status ascription and rise in specialization? Are reflections of social stratification indicated in earlier (Middle or Upper Archaic) cemeteries or site clusters?
2. Where data from cemeteries and human graves are available, is there evidence of differential treatment of burials in accordance with age, sex, or inheritance? Do osteological data indicate differential nutrition or health care? Can specialized occupations be identified, and are specialists treated differentially?
3. Can hierarchical village organization be demonstrated through analysis of site spatial distributions? Might buried sites contain more intact features related to village structure? Based on environmental reconstructions, do differently ranked sites exhibit differential access to resources? Are there elements of the site's setting, such as commanding views, that suggest expressions of status or other intra- or inter-group symbolic communication? Are these suggestions borne out by other archaeological evidence?
4. What indications are there of interaction with other groups? Can reproductive interaction with other groups be inferred from osteological data, or do clusters of distinctive traits suggest endogamy?

Data Requirements

- Archaeological deposits with adequate quantity and diversity of artifacts to address issues related to status and craft specialization, or variation in the relation between sociopolitical status and exchange wealth.
- Archaeological deposits with features such as living surfaces, house floors, domestic and external work areas, refuse piles and pits, or other markers of sedentary residential activity; comparative analysis of such features to track differential access to resources and facilities.
- Environmental reconstruction to determine resource value of site location.

Stress Reduction in Sedentary Contexts

1. Are there reflections of increased need to manage information overload (e.g., distinctive patterns or styles in common artifacts) for greater control through symbolic means?
2. Do site distributions provide evidence for population fission, with creation of daughter populations in less productive environments? Is the operation of this scenario evident in artifact assemblages that show differential exchange goods in associated communities—evidence of small-scale, direct exchange systems?

3. Are there stylistic markers that indicate these inter-tribelet relationships? Can these traits be seen as serving to separate or join associated groups?

Data Requirements

- Suites of archaeological sites in a range of adjacent environmental settings, with clear assemblages to allow identification of stylistic markers.
- Assemblages with adequate quantity and diversity of artifacts to address issues related to small-scale trade; good floral and faunal preservation that will allow identification of resource use in proposed parent and daughter communities.

The Role of Exchange Systems

1. In what ways do obsidian and other exotic goods pattern in study-area archaeological sites? Can they be seen as the result of ad hoc acquisition or more formal exchange? Is there a progression toward formality through time, or can a return toward local materials be seen in the Late period?
2. Do markers of tribelet structure (greater sedentism, status differentiation, and specialization) and evidence for the existence of production for exchange (such as features related to storage of surplus) co-occur with evidence of intensive exchange?
3. Did areas within the PRNS/GGNRA serve as centers for the production and exchange of clam disc beads? Is there evidence for specialization, in terms of individuals or sites? How do sites with bead-manufacturing evidence differ from those without? Do they contain evidence of full social units and a diversity of activities? Do they possess more or fewer exotic exchange items?
4. In what ways would the development of boundary culture be evidenced in study-area sites? Did the need to administer resource use in relation to other groups arise in PRNS–GGNRA settings? Can the resource value of parkland sites be estimated based on both environmental criteria and presumed indigenous values? Do artifact assemblages suggest that study-area people may have been visitors to other procurement areas that may have required social management?
5. What evidence is there of warfare or other intergroup violence in study-area mortuary populations? Are there other indicators of violent activity, such as increased quantities of weapons? Is evidence of reduced or increased mobility (see Settlement and Subsistence) associated with warfare?

Data Requirements for Addressing Exchange:

- Assemblages of obsidian artifacts over time.
- Archaeological deposits containing artifacts identifiable as trade or exchange markers (e.g., obsidian, other foreign stone, shell beads).
- Archaeological features indicative of greater sedentism, such as living surfaces, house floors, domestic and external work areas, refuse piles, and pits.
- Archaeological features and assemblages that reflect sociopolitical organization and ethnic affiliation.

CULTURE CHANGE: HISTORIC-ERA NATIVE AMERICAN ARCHAEOLOGICAL RESEARCH

In the first archaeological management plan for the newly fledged Point Reyes National Seashore in 1969, archaeologist Charles Bohannon established the primary archaeological theme for the PRNS: “the complete story of Northern California Indians ... from prehistoric, through European contact, to recent times” (1969:1). Taking this seamless approach to Native American history—instead of segmenting history into prehistoric and ethnohistoric periods—was well ahead of its time. Only recently did NPS produce its Revised Thematic Framework, which proposes that such themes as Peopling Places, Creating Cultural Institutions and Movements, and Expressing Cultural Values be used to address all times and cultures (NPS 1994, 2003).

As a standard component of archaeological research, ethnographic studies have used to identify direct analogies to lifeways and processes in the prehistoric past. This approach treats the native group as static—little changed from decades, or even centuries, of Euroamerican presence. More recently, archaeologists have come to view ethnographic analogy with considerable mistrust. Lightfoot, Wake, and Schiff, in their study of Fort Ross, argue for a different approach:

Rather than employing ethnographic observations to flesh out the prehistoric past, we advocate their use as part to the “direct historical approach” to develop a diachronic framework for comparing and contrasting native societies before, during, and after contact with European and American colonial institutions. It is important not to confuse the direct historical approach with direct historic analogy, as do most current textbooks.... The former is a straightforward study of cultural change, while the latter evokes analogy based upon the assumption of cultural continuity [1991:7].

Their approach is similar to what Bohannon proposed for the PRNS more than 30 years ago and is in keeping with the new thematic framework. It is an especially valuable approach in PRNS, where no detailed ethnographic information was gathered by anthropologists from people with close (two generations or fewer) links back to traditional lifeways. Because of the early and intensive interaction between native people and European colonists and American

settlers, however, there is much information for studying cultural change. There is also much information to recover for Coast Miwok and Ohlone descendants who are less interested in the interpretation of culture change and more interested in their own history. The approach taken in this research design separates out the ethnohistoric period from prehistory because of the nature of the data base and the differences in archaeological method for prehistoric and historic-era contexts.

THEORETICAL ISSUES AND ARCHAEOLOGICAL APPROACHES

The archaeology of acculturation is a large field that has shifted its perspective over the years. When *acculturation* first appeared in 19th-century anthropology, and for decades thereafter, the term referred to “the merging of cultures through prolonged contact, with the active interchange of cultural traits and material items” (Allen 1998:5). Then, in the many studies of culture contact in the mid-20th century, acculturation came to mean “that a subordinate group assumed the identity and values of a dominant, colonizing culture” (Allen 1998:5). The term, along with its near synonym *assimilation*, “connotes images of a people passively accepting European ideas and material culture” (Allen 1998:6) and, consequently, has fallen out of favor with many anthropologists. The phrase *culture change*, while not so specific in implied historical trajectory, more accurately reflects the reciprocal relationship between groups.

Agency and Culture Change

A traditional interpretation that views subordinate groups as subjects with little or no ability to affect their own history has been countered in recent years by an emphasis on individual and group agency (Dobres and Robb eds. 2000). Contrary to popular notions of culture contact, native people who have been thrust into subordinate positions by newly dominant cultures do not quietly submit to the new conditions. When behavior is interpreted from this perspective, native Californians may be seen as interacting with and affecting individuals and institutions of the dominant culture, and altering situations to their best advantage. The degree to which indigenous people could act independently to further their own goals, however, was restricted by the settings in which they found themselves: in early California, most contact settings were characterized by loss of rights to native lands, deterioration of the resource base, desecration of the cultural and spiritual landscape, physical confinement, monotony of activity, and in the worst cases, a total loss of autonomy. Early on in some mission settings, however, a “mutual accommodation” prevailed, wherein Indian men were free to hunt and fish and women worked in groups as they had traditionally (Milliken 1995:86-89).

Based on archaeological investigations at the Santa Cruz Mission, Allen (1998:97) finds that native people at the mission established their own economic network based on on-site shell-bead manufacture, which enabled them to maintain a separate cultural identity apart from the colonizers. While they also retained many traditional tools and ornaments despite the apparent availability of Hispanic substitutes, many other elements of the dominant culture at the missions were accepted. Looking at the archaeological and historical record through the perspective of agency can allow a new assessment of the effectiveness of native people's responses to colonization and, ultimately, to modern industrial society. As Lightfoot, Wake, and Schiff (1991) have demonstrated at Fort Ross, this is a dynamic relationship affecting the dominant culture as well as the subaltern one.

Historic and Prehistoric Archaeology

While different field techniques are sometimes employed at historic-era vs. prehistoric archaeological deposits, the principles of good stratigraphic analysis are appropriate to both. Perhaps the greatest concern in investigating multicomponent sites is to assure that the potentially significant aspects of both components of a site are appropriately addressed in the research design. Early archaeological work at the PRNS provides a clear example of what can go wrong when only one discipline's goals are considered; Compas (1998) notes that excavation of Exploration-period components paid only minimal attention to Native American components, especially subsistence data, due to research biases in favor of European artifacts, specifically time-markers (Compas 1998; Moratto 1974:61). In addition, a clear understanding of the artifact assemblages of both cultural components must be well understood to avoid misinterpretation; what appears to be intrusive mixture may be contemporaneous use of native and Euroamerican materials, while some apparent co-use may in fact be unlikely or impossible based on the nature of time-markers. Compas advocates taking a team approach to multicomponent sites in the future, in order to assure that each component is appropriately identified and treated.

Although many of the same techniques are employed in both prehistoric and historical archaeology, there is at least one aspect of the latter that is unique: the availability of precise dates of occupation, specific names and employment information, information on the sources and pricing of various consumer items in the assemblage, and even historic maps depicting the locations of structures and possible artifact-filled features. While the ability to securely associate an intact and diverse assemblage with a specific household is relatively rare, there is tremendous interpretive potential when these elements co-occur. In fact, an archaeological deposit can often be informative when the association can be made only to the level of the probable ethnic identity of the household. With U.S. Census lists of names and ages of Indian households in the community—along with archival information, including photographs of people and places and data on employment and land use—the archaeologically recovered information can be especially vital. This access to more detailed personal information also serves as an avenue into the less material dynamics of human interaction, since motivation and outcome of actions can often be discerned from documentary sources.

RESOURCES

There are innumerable references on the process of acculturation and the interpretation of culture change among native peoples; a review of the literature on contact-period archaeology will provide further sources. Focused studies of culture change in contact-period sites have been relatively rare in or near the study area. Among the exceptions are those briefly reviewed here and below (e.g., Allen 1998; Dietz 1976; Lightfoot, Wake, and Schiff 1997; and Silliman 2000, 2001).

A significant resource to guide indigenous historic-era archaeology on the California coast is forthcoming. The fourth volume in the California coastal series produced by the University of California at Los Angeles is being planned by Jon Erlandson and Kent Lightfoot “to deal explicitly with the archaeological approaches to the study of the Protohistoric and Historic periods in Alta California, and the dramatic sociopolitical, economic, and demographic changes that occurred as California was increasingly integrated into a global economy” (Erlandson and Jones eds. 2003:vi).

RESEARCH THEMES, QUESTIONS, AND DATA NEEDS

The list of questions below, presented under the three basic themes of this general research design, are only broadly suggestive of the vast number of approaches and studies that could be taken when identifying, evaluating, treating, and interpreting Native American historic-era archaeological sites.

Chronology

1. What time-markers of the various stages in the historic period can be identified in the absence of precise indicators (e.g., coins, tightly dated beads)? Can specific assemblages of mixed native and non-native artifacts be associated with particular periods?
2. Can the botanical indicators of contact identified by Duncan (1992) serve to date deposits that are otherwise indefinable?
3. Can new evidence of first encounters (e.g., Drake, Cermeño) be found through different ways of viewing culture change—away from the focus on Asian ceramics and metal artifacts, to an attempt to see how new information transforms traditional materials? How does the coastal village assemblage change after 1579?
4. To what degree did cultural accommodation proceed at different rates in authoritarian settings (the missions and ranchos) versus relatively consensual contexts (e.g., Fort Ross, Toms Point, and refuge sites)?

Data Requirements:

- Extant archaeological assemblages with good frequency and diversity of materials from contact-period sites.
- Buried or otherwise preserved archaeological assemblages with Native American and European assemblages.
- Well-dated, intact archaeological deposits from different institutional or occupational contact-period settings.
- Historic-era Native American sites with abundant and intact faunal and macrobotanical assemblages; analysis of subsistence artifact assemblages.
- Assemblages of exotic materials in contact-period Native American sites.

Settlement and Subsistence

1. To what degree can various archaeologically documented shifts in settlement and subsistence be attributed to the effects of first contact with Euroamericans?
2. What evidence is there for relocation or aggregation of native populations during the mission period? Can changes in resource use and seasonal movement be detected in the archaeologically derived settlement pattern?
3. Can native adjustments to a reduced resource base be identified in the archaeological record? Are new technologies and practices introduced as resources become restricted?
4. How did the physical organization of Native American settlements change after contact? Do innovations in internal site relationships (e.g., location of refuse disposal, and orientation of houses) reflect new ideas about proper village structure, social status, or occupational or gender-based accommodations?

Data Requirements:

- Suites of archaeological sites with good dating to specific intersections in the historic period.
- Historic-era sites with intact residential features.
- Individual historic-era sites with abundant and intact faunal and macrobotanical assemblages; similar dietary assemblages from multicomponent sites with stratified deposits.
- Analysis of subsistence artifact assemblages (food procuring, processing, and storing) and faunal/macrobotanical assemblages in remote locations.

Social Organization, Exchange, Interaction, and Symbolic Systems

1. Are changes in political alliances evident in the post-mission archaeological settlement pattern? Do changes in available exchange goods suggest these shifts?
2. What evidence is there of resistance to the dominant culture in native archaeological assemblages in various work settings (e.g., mission neophyte living quarters, mission outpost living sites; native domestic sites at ranchos)?
3. What evidence is there of maintenance of separate traditional economic systems (e.g., clamshell disc bead manufacture) within the mission or rancho complex? Did this situation manifest at different levels in authoritarian settings (the missions and ranchos) versus relatively consensual contexts (e.g., Fort Ross, Toms Point, and refuge sites)?
4. Were native political and ceremonial activities and social roles maintained after contact? Are they more in evidence in consensual contexts or in restricted living settings, such as the missions?
5. How well did individuals from different social, cultural, and linguistic groups fare under enforced co-habitation? Were intra-institutional alliances made along individual, racial, economic, or other lines? How do these present themselves archaeologically?
6. In what ways and in what settings does multicultural contact present economic and other opportunities? How are these seen in the archaeological record?
7. What elements of Coast Miwok and Ohlone culture seem more resistant to change than others? What was the role of material culture in this process of change and retention?
8. Following Lightfoot and Simmons (1998), what evidence is there of the symbolic significance of Euroamerican artifacts from the earliest period of culture contact with native peoples? Did certain artifacts or artifact complexes become symbols (even icons) representing either “Indian-ness” or the endorsement of change? Conversely to what degree might changes in artifact use or style be isochrestic rather than symbolic variations?

Data Requirements:

- Suites of archaeological sites with good dating to specific intersections in the historic period.
- Historic-era sites with intact residential features.
- Individual historic-era sites with abundant and intact faunal and macrobotanical assemblages; similar dietary assemblages from multicomponent sites with stratified deposits.
- Analysis of subsistence artifact assemblages (food procuring, processing, and storing) and faunal/macrobotanical assemblages in remote locations.

NATIONAL PARK SERVICE POLICIES REGARDING THE STEWARDSHIP OF ARCHAEOLOGICAL SITES

Section 110 of the National Historic Preservation Act of 1966, as amended, provides the regulatory framework for the stewardship of cultural resources on federal lands. Section 110 “sets out the broad historic preservation responsibilities of Federal agencies and is intended to ensure that historic preservation is fully integrated into the ongoing programs of all Federal agencies.” (NPS 2007). The U.S. Secretary of the Interior prepared guidelines for federal agencies to help them meet the preservation mandate established in Section 110. The guidelines, published in the *Federal Register* in 1998 are meant as formal guidance for every federal agency (NPS 2007).

Within the guidelines are seven standards, cited below (NPS 2007) with the associated components of Section 110, that the Secretary of the Interior has set forth, in consultation with NPS, for federal agency historic preservation programs:

STANDARDS FOR FEDERAL AGENCY HISTORIC PRESERVATION PROGRAMS PURSUANT TO THE NATIONAL HISTORIC PRESERVATION ACT

Standard 1. Each Federal agency establishes and maintains a historic preservation program that is coordinated by a qualified Preservation Officer, and that is consistent with and seeks to advance the purposes of the National Historic Preservation Act. The head of each Federal agency is responsible for the preservation of historic properties owned or controlled by the agency [Sec. 110(a)(1), Sec. 110(a)(2), Sec. 110(c), and Sec. 110(d)].

Standard 2. An agency provides for the timely identification and evaluation of historic properties under agency jurisdiction or control and/or subject to effect by agency actions [Sec. 110(a)(2)(A), and Sec. 112].

Standard 3. An agency nominates historic properties under the agency's jurisdiction or control to the National Register of Historic Places [Sec. 110(a)(2)(A)].

Standard 4. An agency gives historic properties full consideration when planning or considering approval of any action that might affect such properties [Sec.110(a)(2)((B),(C), and (E), Sec. 110(f) and Sec. 402(16 U.S.C. 470a-2)].

Standard 5. An agency consults with knowledgeable and concerned parties outside the agency about its historic preservation related activities [Sec. 110(a)(2)(D)].

Standard 6. An agency manages and maintains historic properties under its jurisdiction or control in a manner that considers the preservation of their historic, architectural, archeological, and cultural values [Sec. 110(a)(1), Sec. 110 (a)(2)(B), Sec. 110(b)].

Standard 7. An agency gives priority to the use of historic properties to carry out agency missions [Sec. 110(a)(1)].

To meet these standards, NPS has prepared *NPS-28: Cultural Resource Management Guideline* (1998). The guideline delineates the role of park managers in protecting cultural resources:

Park managers are responsible for ensuring that archeological resources under their jurisdiction are identified, protected, preserved, and interpreted. This is done through a systematic program of inventory, evaluation, documentation, curation of collections and associated records, nomination of eligible resources to the National Register of Historic Places, monitoring, protection, treatment, and interpretation (NPS 1998:Ch6). Project statements for needed archeological identification and evaluation studies and related activities are included in a park's resources management plan [RMP]. The RMP includes project statements for other studies and activities needed to preserve archeological resources. Such studies and activities will often include periodic monitoring of sites subject to damage from natural processes (e.g., floods and erosion) and human activities (e.g., looting and vandalism); stabilization of damaged or threatened sites; and data recovery for research or interpretive purposes, for documentation purposes in advance of site stabilization or other preservation treatments, or for mitigation of adverse impacts.

The guideline expands the standards established by the Secretary of the Interior for all agencies to a larger set of standards applicable to NPS. Among these are standards that pertain directly to ongoing effects of climate change:

- Park archeological resources are left *in situ* and undisturbed, unless removal of artifacts or intervention into cultural material is justified in the planning process by preservation treatment, protection, research, interpretation, or development requirements. They are preserved in a stable condition to prevent degradation and loss of research values or *in situ* exhibit potential.
- Park archeological resources are inventoried through systematic surveys and evaluated using the National Register criteria. Resources are placed within historical contexts using the NPS revised Thematic Framework (NPS 1994, 2003); complementary state, regional, and park contexts; and relevant preservation plans. Resource contexts are correlated with NPS objectives for management, interpretation, and regional planning.
- A park's eligible archeological resources are nominated for listing in the National Register of Historic Places. Site information is provided to the state historic preservation officer (SHPO), state archeologist, state underwater archeologist, and state archeological clearinghouse official. Information on the location, character, or ownership of archeological resources whose public disclosure would risk harm to the resources is kept confidential.
- A park's general management plan, development concept plan(s), environmental impact statements, environmental assessments, and other planning documents

describe the effects of proposed development, park operations, natural processes, and human activities on archeological resources. They also include explanations in support of decisions to preserve, stabilize, recover, avoid, destroy, monitor, and otherwise treat threatened resources.

- The effects of natural processes and human activities on archeological resources are assessed and documented. A schedule to monitor the condition of affected resources is established and implemented.
- Significant archeological and other scientific data threatened with loss from the effects of natural processes, human activities, preservation treatments, park operations, and development activities are recovered, recorded, or otherwise preserved (NPS 1998).

Prior to considering treatment options, the Secretary of Interior Standards outlined above should be reviewed and used to help guide treatment planning. In particular, each site should be evaluated for its potential eligibility to the NRHP. For sites that are eligible, as discussed above, NPS has ongoing responsibilities under Section 110 of the NHPA to manage and maintain NRHP eligible properties “in a way that considers the preservation of their historic, archaeological, architectural, and cultural values” (16 U.S.C. 470h-2). Also, NPS may decide to put into place treatment options for sites that do not meet any of the NRHP eligibility criteria but are important to FIGR; consultation with FIGR should help inform the level of effort and decisions regarding the types of appropriate treatment.

NATIVE AMERICAN GRAVES PROTECTION AND REPATRIATION ACT

Another important consideration in the ongoing stewardship efforts of PRNS is the Park’s responsibilities under the Native American Grave Protection and Repatriation Act of 1990, as amended, or NAGPRA. Under NAGPRA, PRNS is responsible for repatriating human remains, associated grave goods, and items of cultural patrimony to the appropriate federally recognized tribe. PRNS works closely with the Federated Indians of Graton Rancheria (FIGR) in pursuing the repatriation process and designing park-wide plans for the appropriate treatment of human remains.

NAGPRA contains requirements for agencies for dealing with the unanticipated discovery of human remains. This is a concern at PRNS, as several sites are known to both contain human remains and have such remains exposed as a result of erosion along coastal cliffs. As coastal erosion increases as a result of sea level rise, the park NAGPRA policies may need to be revised to accommodate a projected increase in exposed remains and more rapid erosion of sites known to contain remains. Such revisions should be prepared in close coordination with FIGR representatives.

CHAPTER 5. FIELD RESEARCH



Figure 10. Paul Engel, Archaeologist with Point Reyes National Seashore, on way to field studies of indigenous archaeological sites along Tomales Bay (Accession # 70-10-D01-06).

INTRODUCTION

For the purposes of this study, NPS initially requested that alternative treatments for six to seven of the most threatened sites be defined and discussed. As delineated in the previous chapter, while many, if not most, of the archaeological sites within PRNS are vulnerable to some form of impact as a result of climate change, inundation is considered to be the greatest impact, followed by cliff and dune erosion. The sites discussed below are therefore concentrated along the ocean cliff edges of Drakes Bay and Kehoe Beach, and at Limantour Spit and the mouth of Horseshoe Pond. These areas can be expected to either be completely eroded into the ocean and destroyed, as is the case with the sites reviewed at Drakes and Kehoe, or inundated and likely destroyed as a result of wave energy, tides, and storm surges, as is the case with the sites at Limantour and Horseshoe.

In addition to these sites, a handful of other areas were visited and surveyed in an attempt to get a better understanding of what kinds of sites in more upland areas might be threatened by other effects of climate change. Broad areas of PRNS have either not been formally surveyed or were last surveyed many decades ago and lack records documenting the boundaries of the survey work. A discussion is included below of these additional areas, the threats posed to them, and some thoughts on mitigating the impacts of those threats.

TREATING THE MOST ENDANGERED SITES: SITES ALONG THE COASTAL EDGE

A total of eight sites were assessed. Two sites on top of cliffs at the north end of Kehoe Beach, CA-MRN-278 and -287, were visited as part of this study, re-recorded, and explored archaeologically to get a sense of their composition, structure, and research values. CA-MRN-275/302, on the cliffs above Drakes Bay, was visited to assess ongoing efforts to stabilize the site through re-vegetation. Both the Kehoe Beach sites and CA-MRN-275/302 are located on top of diatomaceous sandstone formations that are rapidly eroding away, the Kehoe Beach sites as a result of salt spray, exposure, wind, and wind-blown water from the nearby spring, and MRN-275/302 as a result of exposure and direct wave action against the cliff faces during storm surges. These sites are on the edges of these cliffs and are currently eroding away even without the threats posed by climate change. Site MRN-272, located southeast of Limantour Spit near Coast Camp, on a low bench overlooking the beach, was also visited and assessed.

Dune and beach sites were also looked at. A series of sites on the north side of the narrow dune formations on Limantour Spit—CA-MRN-216, -298, -391, and -389—were visited and re-recorded. A second location, CA-MRN-394/H, at the mouth of Horseshoe Pond, was also visited. These areas are expected to be completely inundated during storm surges under the climate change scenario considered for the current study and can be expected to be destroyed. The results of the site assessments follow, in sequential order, by site number.

IMMEDIATELY THREATENED SITES

CA-MRN-216

CA-MRN-216 is a large indigenous shell midden located on Limantour Spit. The site measures 220 × 160 m and has previously been recorded as containing several pits. The site was first recorded by Dillingham in 1953 as part of the Drake Navigator's Guild's efforts to identify the landing location of Francis Drake. A bird point, bone beads, fire-affected rock, shell, and debitage were noted. Substantial excavations conducted by Adán Treganza followed over several seasons during the 1960s, comparable to work undertaken by Treganza at adjacent CA-MRN-298. Ming Dynasty ceramics were also reportedly found, as were large iron spikes, presumably related to ship construction. It is unclear whether these finds represent materials deposited on the beach following the wreck of the *San Augustin*, the landing of *The Hind*, or some other event. The site was found to extend at least 1.5 m below surface (Edwards 1967).

The site has been intensively excavated by the Drake Navigator's Guild (DNG), who located five housepits (Dillingham 1953). A large crater exists at the eastern end of the site. It is unclear whether the housepits truly represent such or were craters created as a result of WWII-era bombing practice. The large (7 m dia.) crater seems too large for either a housepit or roundhouse feature. Although the site has been disturbed by excavations and bombing target practice, sections of the site with good integrity may survive.

Several deep pits were noted during the early recordings that were hypothesized to be house pits. During the current field effort, it has been hypothesized that the pits may actually be from World War II-era bombing practice and possibly artillery fire on the site. The depressions have been mapped. More of the depressions likely associated with the Camp Hydley Skip and Dive Bombing Range are closer to the top of the fore dune and a few are in the marsh (Madsen 1999; United States Army Corps of Engineers 2001). There is a large depression between the site and the dune ridge with a few pine trees.

Large areas of the site are covered in iceplant. Shell and some lithics are visible in the open areas. It is not clear how much of the visible constituents are from 1960s backdirt. The site appears to extend from the marsh flats to a maximum elevation above the high water mark about 2 to 2.3 m. It is not clear whether the beach grass is building dune over an unrecognized component of the archaeological site.

Like all the sites along the Spit, it appears that the deposits extend just above the marsh, which is occasionally covered by 6 ft.-plus tides, to the edge of the dunes. The bombing and ordnance practice and possibly some historic construction may have adversely impacted these sites to the point one cannot determine the original topography.

A credible argument could be made for lumping CA-MRN-298 and -MRN-216 into a single unit; the sites as recorded in this study are only about 10 meters apart and, at least on the surface, have similar assemblages. However, for the purpose of this study, they have been kept separate and their individual trinomials retained, with the understanding that they may be contemporaneous and part of a larger interrelated activity area.

Threat Assessment:

As shown on the Pacific Institute projections for the Mean High Water (MHW) in 2100, portions of this site will be submerged, along with most of the Limantour Spit landform. During coastal flooding brought about by storm surges, the entire spit could be flooded. In addition, the Institute's model shows the portions of the spit above the MHW to be in the locations of dune erosion. The portions of the dunes that do not get inundated regularly can be expected to be locations of active high-energy erosion during storms and ongoing erosion from wind through the dunes.

Treatment Options:

1. Seawall/fortification: this site is expected to be completely inundated during high flood events and storm surges. The only way to effectively protect the site in situ would be to build a sea wall or fortification across the entire front of Limantour Spit and then install a pump to keep the water from the Estero de Limantour from flooding the site out from the north.
2. Monitoring and burial recovery/artifact collection: the site could be monitored during the transition between its current conditions and complete inundation, with human remains and formal artifacts recovered and reburied elsewhere on site if exposed. No attempt would be made at data recovery. The monitoring would cease if the site becomes completely submerged.
3. Data recovery: the information potential of the site could be realized through a data recovery program. The program could be co-designed and implemented with FIGR and NPS in such a way that tribal concerns are represented and that no artifacts or human remains are permanently removed from the site without consultation.
4. No treatment: the site would be allowed to be inundated and likely destroyed by wave action and erosion.

Figure 11. Sites at Limantour spit and projected sea level rise
(using 1.5 m elevation sea rise model by Heberger et al. 2009; USGS 1976 *Drakes Bay* 1:24000 scale) [REMOVED
FROM PUBLIC VERSION]

CA-MRN-272

This site is a small midden with shell and animal bone located southwest of the Coast Camp, along the low bluff overlooking the beach, on the west side of the unnamed creek passing through Coast Camp. The site was first recorded by Beardsley (1941) and has been revisited several times. For a period the site was thought to have been destroyed, but this may be a function of it being misplotted (Edwards 1967a; Ribeiro 1997; Upson 1977). The site was most recently recorded in 1999 by Jablonowski and Selverston of the ASC, who found it to be similar to its first recording.

CA-MRN-272 is currently covered under dense, woody brush, particularly poison oak, likely serving to protect the site from casual visitation. The site is located further back on the beach than the cliffs to the northwest/southeast of it, and it has a more gentle slope leading to the beach, resulting in brush growing on the downslope. This in turn is helping anchor and stabilize the site, and the erosional problems seen elsewhere were not witnessed here.

Threat Assessment:

As shown on the Pacific Institute projections for the MHW in 2100, this site is expected to be completely inundated. As it faces Drakes Bay and has no natural features that might offer protection from wave erosion, it is expected that this site will likely be destroyed in the process of inundation and during future storm events.

Treatment Options:

1. Seawall/fortification: this site is expected to be completely inundated during high flood events and storm surges. The only way to effectively protect the site in situ from this would be to build a sea wall or fortification across the entire front of the site.
2. Monitoring and burial recovery/artifact collection: the site could be monitored during the transition between its current conditions and complete inundation, with human remains and formal artifacts recovered and reburied elsewhere on site if exposed. No attempt would be made at data recovery. The monitoring will cease if the site becomes completely submerged.
3. Data recovery: the information potential of the site could be realized through a data recovery program. The program could be co-designed and implemented with FIGR and NPS in such a way that tribal concerns are represented and that no artifacts or human remains are permanently removed from the site.
4. No treatment: the site would be allowed to be inundated and, most likely, destroyed by wave action and erosion.

CA-MRN-278

This site is a lithic scatter located on a coastal bluff overlooking Kehoe Beach. It is adjacent to CA-MRN-287 and may be associated. The lithics appear to be primarily hammerstones, chert cores, and choppers. Some of the material here, represented by well-rounded stream cobbles, are unmodified and seem unlikely to be good toolstone materials. It is possible that there is an uplifted creek bed here and that the cobbles eroding out were sorted through, tested, and used on site or elsewhere in the park. CA-MRN-278 may therefore represent a type of quarry where raw toolstone is acquired, albeit in cobble form rather than broken out of bedrock. As such, it represents the only such quarry known in the park and is likely one of the few such locations identified along the Coast Miwok coastal territory. Most of the tested cobbles appear to be crypto-crystalline silicates. Several of the pieces have well-formed ground surfaces suggesting that they were used as handstones. No milling slab or mortar fragments were found, nor were any finished cutting tools or projectile points. Only a handful of flakes were noted.

There is a nearby spring or seep, which drains along the north edge of the site and separates CA-MRN-278 from -287. Water from the spring is draining over the cliff down to the ocean; the water, caught in the wind, sprays back against the cliff face and erodes it and the soils of CA-MRN-278 much in the same way the spray of a hydraulic monitor erodes uplifted or exposed creek beds. The cliff edge is deflating, with the soils washing over the cliff edge and the larger artifacts and rocks settling on the surface of the sandstone bedrock. These artifacts no longer have an association with their host stratigraphy and lack fine context.

Three shovel test units (Units 1, 2, and 4) and a surface scrape (Unit 3) were excavated at this site. The intent of the excavation was to characterize the nature of the site and to identify a datable context(s) for the artifacts found on the deflated bedrock. Units 1 through 3 were 50 by 50 cm and were taken to a depth of 40 cm below surface (cmbs; Unit 1), 50 cmbs (Unit 2), and 40 cmbs (Unit 4), with the bottom of Unit 2 augered down to 120 cmbs. All three shovel test probes had a handful of artifacts in the top 20 cm, with a single obsidian flake found 30 to 40 cmbs in Unit 2.

The surface scrape (Unit 3) was excavated to a depth of 20 cmbs, where a concentration of cobbles, several of them worked, was encountered. A soil sample for AMS dating was taken and the cobbles, found to lie between 20 and 25 cmbs, were removed. It seems likely that this layer is the source of cobbles found elsewhere on the site, as concentrations of cobbles were found directly downslope and appear to be from deflated matrix at about this depth.

The organic sediment sample from the cobble layer was AMS dated to cal BP 650 to 540. It should be noted that this is a later date than expected, given the age of the adjacent shell midden at CA-MRN-287 and dearth of obsidian or formal projectile points. As so few dates have been obtained for CA-MRN-287 and -278, it is possible that CA-MRN-278 has other components that remain to be identified.

It is also worth noting here that the bedrock appears to be bedded sandstone and is tilted nearly vertically. As suggested above, there may be an uplifted paleo creek bed here which may

be the source of these cobbles. If so, the creek bed would be visible along the exposed bedrock as a strip along the horizontal plane of the bedrock, not in the vertical face, since such a creek bed would erode rapidly if exposed vertically. This strip may have been quarried and has subsequently been filled with sand, or it may be that runoff from the spring is cutting down into the paleo creek bed, as many of the stones, including some that appear to be natural, were found in the current creek bed.



Figure 12. Uplifted near-vertical bedding of sandstone bedrock on CA-MRN-278 (Accession # 70-10-D01-07).

A crevice in the exposed bedrock contained several surface artifacts that did not appear to be in situ. When the compacted sand of the crevice was cleared out, flakes, assayed cobbles, groundstone, and a large amount of unmodified rounded and subrounded cobbles were observed. There may be naturally-occurring collection points along the current creek bed where artifacts are settling and being covered by eroded sands and silt. While the artifacts are not in situ, if the surface scrape is any indication of the archaeological nature of the site, it is possible that the artifacts on the site are generally contemporaneous with each other and artifacts found on the deflated surface nevertheless come from a potentially well-defined single component upslope.



Figure 13. Excavated crevice in bedrock along creek bed between CA-MRN-278 and -287 (Accession # 70-10-01-08).

Threat Assessment:

At the time of recording, the site was eroding onto the beach below. While most of Tomales Point consists of granitic bedrock, a narrow stretch of coastline, including the cliffs above Kehoe Beach, is comprised of Laird sandstone. An exposed face of midden could be seen

along the cliff edge, which is in the process of slumping. Low grasses and brush appear to be providing only moderate slope stability above the site. A narrow band of sand dunes, representing the northernmost extent of the dune system that extends south to the tip of Point Reyes Peninsula, protects the base of the cliff from all but the largest of storm surges. This stretch of coastline faces the open ocean rather than Drakes Bay and could be expected to see larger wind- and current-enhanced waves.

The back-spray of water from the nearby spring, carried by high winds on this stretch of open coast, is a direct threat to this site, and is causing its destruction. It is unclear how much of the site has already eroded away in this manner but there is at least a 3.3 m stretch of exposed bedrock, upon which it is presumed midden and artifacts were once located. The spring, its source outside of our site boundary to the east of the nearby grazing fence, may be modified to increase water flow. The handful of historic-era artifacts suggests that this site has been visited by individuals conducting historic-era ranching activities and/or proto-historic indigenous peoples, and may suggest that this was a stopping location along this stretch of coast.

If a 1.5 m increase in mean sea level were to occur, it is likely that the dunes at the base of the cliff would be swept away, and that the sandstone cliff would be subject to direct wave erosion and chemical weathering from the ocean water. Were this to occur, the erosion of this cliff could be expected to accelerate and the destruction of the site to be likely. In addition, because the sandstone bedding is nearly vertical, the rate of the erosion may not be constant, as layers of soft stone can be expected to erode faster.

Treatment Options:

This site has a host of potential threats, from sea level rise to existing, ongoing slumping of the cliff face to potential chemical weathering of the cliff base once ocean levels rise. Treatment options include:

1. Seawall/fortification: construction of a seawall fortification at the base of the cliff, of concrete or imported rip-rap sturdy enough to withstand direct wave erosion is likely to be the only way to prevent the base of the cliff from eroding further.
2. Redirect or drain the spring: a different drainage pattern may help stabilize the slope and stem both down-cutting from runoff and erosion from the backspray of the spring.
3. Protect from spray erosion: place some sort of protective barrier between the cliff spray and the site to prevent wind-carried water from washing the slope.
4. Stabilize with vegetation: assess the local vegetation and plant species better suited for stabilizing the slope edge.
5. Data recovery: if the above measures are not considered feasible and if the site is found eligible to the NRHP, then data recovery should take place.

Figure 14. Location of sites along Kehoe Beach and projected sea level rise, with cliff erosion (using 1.5 m elevation sea rise model by Heberger et al. 2009; USGS 1976 *Drakes Bay* 1:24000 scale). [REMOVED FROM PUBLIC VERSION]

CA-MRN-287

This shell midden is located on a coastal bluff overlooking Kehoe Beach. It is adjacent to CA-MRN-278 and may be associated. The content appears to be primarily clam and barnacle with some mussel and snail. A handful of crypto-crystalline silicate tool production flakes were noted. There is a nearby spring (mentioned above), which drains along the south edge of the site and separates CA-MRN-287 from -278. Water from the spring is draining over the cliff down to the ocean; the water, caught in the wind, sprays back against the cliff face and erodes it and the soils of CA-MRN-278. A similar erosional effect is taking place on CA-MRN-287, though with much less impact.

Limited subsurface investigation was conducted at CA-MRN-287, consisting of a single 50 cm by 50 cm shovel test unit taken to an 80-cmbs depth. The unit was continued as an auger unit to a depth of 180 cmbs, at which point the unit was closed, as the maximum depth of the reach of the auger had been met. The augered material was bagged and wet-screened through 1/16th-inch mesh at the ASC lab to identify small beads and pressure flakes; one flake of green chert knapped from a rounded cobble, presumably from the material identified at CA-MRN-278, and a small amount of barnacle, mussel, and snail shell were recovered within the 160 to 180 cmbs auger level. The amount of shell dropped off noticeably at this depth but it seems likely that the site may extend further in depth. Fish vertebrae, some very small, were recovered throughout the unit levels; a portion of sea otter long bone was recovered in the 10- to 20-cmbs level.

In addition, several cobbles were noted within the creek bed separating CA-MRN-287 and -278. The CA-MRN-278 description above includes a discussion of the cobbles. However, it seems likely that eroded artifacts from CA-MRN-287 are also collecting in the creek basin and within crevices of the bedrock. While the recovered artifacts within the creek basin and excavated crevice were discussed under CA-MRN-278 since similar artifacts have been recovered there, it is entirely possible that these artifacts could have originated with CA-MRN-287. This would in turn suggest that a substantial artifact component to MRN-287 not represented in the surface assemblage is eroding from lower depths along the downslope edge of the site. This would be consistent with the interpretation that the artifact assemblage found at MRN-278 likely originates from a layer 20 to 30 cmbs that is eroding out onto the deflated bedrock surface.

Two samples were sent for AMS testing. The first sample was bone, probably sea otter, recovered from 10 to 20 cmbs and dated to cal 80 B.C. to cal A.D. 100; a shell sample recovered from an auger level 160 to 180 cmbs dated to cal A.D. 570 to 670. These dates, roughly 500 to 700 years apart, are reversed in the stratigraphic column but generally seem to reflect an Upper Archaic occupation.

Different dates were arrived at through obsidian hydration band analysis. Three samples were sent for obsidian hydration band analysis and for X-ray fluorescence identification. All obsidian samples were found to come from the Napa obsidian source. Obsidian hydration analysis indicates one sample in the 20- to 30-cmbs layer as being 1.2 microns, or 221 years B.P. (about A.D. 1790), a second flake from that same layer as being 2.8 microns, or 1,203 years B.P. (about A.D. 790), and a third flake, recovered from 160 to 180 cmbs, also hydrated to 2.8 microns. These dates point towards occupation of the site through the Upper Archaic and into the Emergent Period.

It is interesting to note the changes in shell concentration throughout the unit. The first two levels (0-20cmbs) were dry-screened in the field through 1/8 in. mesh screens; the bulk of broken shell was discarded along with the sandy matrix. However, the loss of shell was apparent by the end of the second layer, and the remaining levels were screened in the field, with the remaining matrix bagged and brought back to the ASC for wet screening through 1/16 in. mesh. Table 5 indicates the results of the shell yield. It is worth noting that shell count by weight increases or stays relatively unchanged at the lower depths.

Table 5. Shell weight by depth, STU-1, CA-MRN-287

Depth*	Mussel	Clam	Oyster	Barnacle	Limpet	Snail	Chiton	Fish Vert.	Undiff.
0-10	111.4	8.5	0.0	89.2	0.1	5.9	0.3	0.0	9.5
10-20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20-30	165.2	19.9	2.8	112.2	0.1	1.5**	0.1	0.0	5.2
30-40	89.1	6.0	0.0	77.0	0.0	0.5	0.1	0.0	4.4
40-50	606.1	16.9	0.0	144.3	0.4	3.2**	1.6	0.3	9.4
50-60	539.3	10.5	0.0	118.2	0.4	3.2	1.8	0.1	8.5
60-70	608.5	15.7	1.6	98.7	0.5	4.1	3.1	0.6	7.6
70-80	1440.4	30.7	13.9	247.7	1.3	9.9**	5.5	1.2	39.1

*centimeters below surface

** includes Olivella

Weight in grams

Mussel and barnacle clearly played an important role in the diet of the indigenous population at this site, while other shellfish species are present but played a lesser role. It is also interesting to note that fish vertebrae are present almost exclusively in the lower levels. While this sample is too small to say anything conclusive about the diet of the site's inhabitants, it does continue to suggest a strong ocean resource focus, particularly when compared to the relative dearth of terrestrial faunal species.

Threat Assessment:

At the time of recording, the site was already in the process of eroding onto the beach below. While most of Tomales Point consists of granitic bedrock, a narrow stretch of coastline, including the cliffs above Kehoe Beach, is comprised of Laird sandstone. An exposed face of midden could be seen along the cliff edge, which is in the process of slumping. Low grasses and brush appear to be providing only moderate slope stability above the site. Below the site, a narrow band of sand dunes, representing the northernmost extent of the sand dune system that extends south to the tip of Point Reyes Peninsula, protects the base of the cliff from all but the largest of storm surges. This stretch of coastline faces the open ocean rather than Drakes Bay and could be expected to see larger wind and current- enhanced waves.

If a 1.5-m increase in mean sea level occurs, it seems likely that the dunes at the base of the cliff would be swept away, and that the sandstone cliff would be subject to direct wave erosion and chemical weathering from the ocean water. Were this to occur, the erosion of this cliff could be expected to accelerate and the site would be destroyed.

Treatment Options:

This site is subject to a host of potential threats, from sea level rise to existing, ongoing slumping of the cliff face to potential chemical weathering of the cliff base once ocean levels rise. Treatment options include:

1. Seawall/fortification: construction of a seawall fortification at the base of the cliff, of concrete or imported rip-rap sturdy enough to withstand direct wave erosion is likely to be the only way to prevent the base of the cliff from eroding further.
2. Redirect or drain the spring: a different drainage pattern may help stabilize the slope and stem both down-cutting from runoff and erosion from the backspray of the spring.
3. Stabilize with vegetation: assess the local vegetation and plant species better suited for stabilizing the slope edge.
4. Data recovery: if the above measures are not considered feasible and if the site is found eligible to the NRHP, then data recovery should take place.

CA-MRN-275/302

This midden site is known to contain burials. The site has been monitored closely by NPS staff and repeatedly visited by ASC archaeologists to record the site, conduct burial recovery, and document site condition. The site is one of the few in Marin County that date to the Middle Archaic; while never formally evaluated for its potential eligibility for the NRHP, it is likely individually eligible. The site has two loci of midden and was originally recorded as two separate sites, CA-MRN-275 (northern locus) and CA-MRN-302 (southern locus) (Figure 15). The loci have been previously excavated (Beardsley 1954) with burial recovery conducted in 2004 and in 2008 (Meyer 2005; 2008). The two loci were visited in 2005 and recorded as one site (Redmond 2005).

Threat Assessment:

Areas of the cliff edge that were cut at a 45-degree slope during the 2004 burial removal at the MRN-302 locus appear to have fared better than other areas with sharper cliff edges. The edges appeared to be stable along a 5-m edge line. On either side of this portion of the edge, erosion has caused the loss of 1.5 horizontal meters of site matrix..

Below the site matrix, the base bedrock is a mix of stratified mudstone and shale. The mudstone appears to be spalling as it erodes, while the shale erodes in blocks, with ground water seeping out from the bottom of the shale. Large portions of the cliff edges within the CA-MRN-275 locus are slumping along this outflow line. As the slope erodes back, the midden appears to be getting thinner. The CA-MRN-275 locus contains a large slump and it appears that this portion of the locus will completely collapse soon.

Groundwater is contributing to the erosion caused by a far larger threat, coastal erosion along the cliff face. The high water line appears to be at the toe of the bluff. At the time of recording the site for this study (6 April 2011) waves were observed within 2 m of the base of the cliff. High tide for that day, estimated from a tide table, was about 0.75 vertical meters higher. All else being equal, the waves would have been very close to the cliff base at high tide.

Figure 15. Location of CA-MRN-275/302 and projected sea level rise, with cliff erosion
(using 1.5 m elevation sea rise model by Heberger et al. 2009; USGS 1976 Drakes Bay 1:24000 scale).
[REMOVED FROM PUBLIC VERSION]



Figure 16. CA-MRN-275/302, view to the northeast. Note beach scouring up to base of the cliff. (Accession # 70-10-D01-09).

In previous years, cattle grazing posed a direct threat to this site through the removal of soil-stabilizing vegetation and ground disturbance from trampling. Initial installation of a barbed wire fence in 2004 and recent installation of an electric fence to protect the site appears to have been effective in excluding cattle.

Rising sea level will accelerate erosion of the bluff, in particular where waves will impact the shale deposits. Another consideration is the effect of less frequent, but stronger storms. Higher concentrations of rain will likely blow the shale deposits from above through groundwater runoff. As was discussed earlier, the diatomaceous nature of the sedimentary bedrock makes this stretch of coastline particularly susceptible to chemical as well as physical erosion.

Treatment Options:

1. Seawalls and fortifications: Treatment options for this site are limited. Any effective seawall constructed here would need to be large enough to both contain the rising sea level plus storm surges and other annual large wave phenomena such as waves churned by high winds. It seems likely that such a wall would need to be nearly as tall as the cliffs themselves, and need to stretch for about 120 m long just to block the site edge, not including buffers on either side to protect surrounding cliff matrix. NPS would need to

weigh the values of the expense of such a wall and protecting this site from physical and chemical erosion versus the added public attention this site would receive with a wall present here and the visual effect of a concrete structure of such size within a national seashore. This option seems infeasible.

2. Monitoring and burial recovery: In this option, current treatment continues; continued monitoring, burial recovery during instances where human remains are uncovered, the site is otherwise allowed to collapse into the ocean. Human remains will be reinterred on or near the site, well away from the cliff edge.
3. Recontouring the cliff edge: In this option, the entire cliff edge of the site is excavated to a 45 degree angle and reseeded with local vegetation to help stabilize the cliff edge. This seems to have been effective on the site when employed previously and could be used in conjunction with other treatment options. Material removed could be screened to recover data in-field, with artifacts either collected or reburied on or near site along with the removed matrix.
4. Data recovery: The information potential of the site could be realized through a data recovery program. The program could be co-designed and implemented with FIGR and NPS in such a way that tribal concerns are represented and that no artifacts or human remains are permanently removed from the site.
5. No treatment: In this option, the site is allowed to erode into the ocean without any protective measures or attempt to conduct data recovery or monitor for burials.

CA-MRN-298

This site is a concentration of clam shell with pockets of shell midden and artifacts. DNG recorded and excavated two loci of the site as DNG#1 and DNG #2 in the 1950s; these were subsequently recorded as CA-MRN-298 in the 1960s. The site location within the NPS GIS database differs slightly from that in the site record prepared by Edwards (1967) and as depicted on what appears to be a more recent, but unattributed, digital map included in the site record. The site has been excavated numerous times—the first during the DNG efforts in 1956, followed by Treganza in 1959, Santa Rosa Junior College 1961 to 1965, and Treganza again throughout the 1960s (Edwards 1967). The site was found to extend to 120 cmbs; Moratto (1974:84) estimates that 90-95 percent of this site has been excavated.

As part of the current study, denser pockets of shell midden were identified at the far western and eastern end of the site, and it seems likely that these two pockets were what were originally recorded. Between them, a light scatter of shell, fire-affected rock, and a small number of chert flakes were noted. Historic-era metal, glass, and light bulb fragments were also identified. Previous field efforts noted that a historic-era steel rebar stake with a stamped aluminum cap designating the location as CA-MRN-298 was found near the site's western edge. It seems likely that at least some of the historic-era artifacts may be related to late historic-era beach houses that were located on the Limantour Spit, some of which were within 160 m of the site (Watt 2002).

A credible argument could be made for lumping CA-MRN-298 with CA-MRN-216; the sites as recorded in this study are only about 10 meters apart and, at least on the surface, have similar assemblages. However, for the purpose of this study, the sites have been kept separate and their individual trinomials retained, with the understanding that both sites could be contemporaneous and part of a larger interrelated activity area.

Threat Assessment:

As shown on the Pacific Institute projections for the MHW in 2100 (Figure 16), portions of this site will be submerged along with most of the Limantour Spit landform. During coastal flooding brought about by storm surges, the entire Spit could be flooded. In addition, the Institute's model shows the portions of the spit above the MHW to be in the locations of dune erosion. The portions of the dunes that do not get inundated regularly can be expected to be locations of active high-energy erosion during storms and ongoing erosion from wind through the dunes.

The site has been extensively excavated by the DNG, including 317 5 × 1.5 m (1.5 × 1.5 m) units between the two loci. A large depression exists at the eastern end of the site that is apparently a bomb crater. Although the site has been subject to excavation and bombing target practice, sections of the site may retain integrity. As the site is expected to be regularly inundated, it seems unlikely that a vegetation program would protect the site.

Treatment Options:

1. Seawall/fortification: This site is expected to be completely inundated during high flood events and storm surges. The only way to effectively protect the site in situ from this would be to build a sea wall or fortification across the entire front of Limantour Spit and then install a pump to keep the water from the Estero de Limantour from flooding the site out from the north.
2. Monitoring and burial recovery/artifact collection: The site could be monitored during the transition between its current conditions and complete inundation, with human remains and formal artifacts recovered and reburied elsewhere on site if exposed. No attempt would be made at data recovery. The monitoring would cease if the site becomes completely submerged.
3. Data recovery: The information potential of the site could be realized through a data recovery program. The program could be co-designed and implemented with FIGR and NPS in such a way that tribal concerns are represented and that no artifacts or human remains are permanently removed from the site without consultation.
4. No treatment: The site is inundated and destroyed by wave action and erosion.

CA-MRN-391

This site is a concentration of clam shell with pockets of shell midden and artifacts. It spans the area between what is recorded as CA-MRN-298 and CA-MRN-391 on the NPS GIS database. The site location on the NPS GIS database differs slightly from the field data collected as part of the current study, which follows closely the boundaries shown for CA-MRN-391 on what appears to be a more recent, but unattributed, digital map included in the site record for CA-MRN-298. The site recorded here as part of the current study falls in between what are shown as CA-MRN-391 and -298 in the NPS database but is close enough to probably represent CA-MRN-391. The distance between CA-MRN-391 and -298 is relatively small (~ 50 m) and it seems likely that the two may be related. Also, like CA-MRN-298, denser pockets of shell midden were identified at the far western and eastern ends of the site, and it seems likely that these two pockets were what were originally recorded. Between them, a light deposit of shell, fire-affected rock, and a small number of chert flakes were noted on the surface.

Threat Assessment:

As shown on the Pacific Institute projections for the MHW in 2100, portions of this site will be submerged, along with most of the Limantour Spit landform. During coastal flooding brought about by storm surges, the entire spit could be flooded. In addition, the Institute's model shows the portions of the spit above the MHW to be in the locations of dune erosion. The portions of the dunes that do not get inundated regularly can be expected to be locations of active high-energy erosion during storms and ongoing erosion from wind through the dunes. As the site is expected to be regularly inundated, it seems unlikely that a vegetation program would protect the site.

Treatment Options:

1. Seawall/fortification: This site is expected to be completely inundated during high flood events and storm surges. The only way to effectively protect the site in situ from this would be to build a sea wall or fortification across the entire front of Limantour Spit, and then install a pump to keep the water from the Estero de Limantour from flooding the site out from the north.
2. Monitoring and burial recovery/artifact collection: the site could be monitored during the transition between its current conditions and complete inundation, with human remains and formal artifacts recovered and reburied elsewhere on site if exposed. No attempt would be made at data recovery. The monitoring will cease if the site becomes completely submerged.
3. Data recovery: The information potential of the site could be realized through a data recovery program. The program could be co-designed and implemented with FIGR and NPS in such a way that tribal concerns are represented and that no artifacts or human remains are permanently removed from the site without consultation.
4. No treatment: The site is allowed to be inundated and destroyed by wave action and erosion.

CA-MRN-394/H

This site is a prehistoric midden located under the eastern end of a historic-era road and levee between Horseshoe Pond and Drakes Bay, with a historic-era shipwreck located near the site's western end (Figure 17). The site is periodically exposed and uncovered by storms and wave erosion. At the time of the current recording, a 5-m horizontal profile of the site deposit, 35 cm thick, was observed buried 1.1 m below the levee ground surface. At the west end of the exposed midden, a blow-out of sand left large clam, abalone shell, a handstone, and some heat-affected rock scattered amongst sandstone cobbles in front of the levee. At least some component of the levee is likely to be a natural sandbar, like Limantour, that has been built upon during the historic era.

At 1300 on 6 April 2011, the waterline was about 0.6 m below the base of the cobbles. The base of cobbles was about 0.6 m below the bottom of exposed midden. The high waterline appeared to be about the base of the cobbles. The tides are listed as 0.0 at 0722 and 1.3 m at 1404, indicating that at the time the tide was about 1 meter.

A shell bead was found in the east end of the drainage away from the midden. It was collected and returned to the park. The bead was thought to be either an eroded clam shell bead or possibly a natural occurrence from the chamber of a turban snail. As it was likely to be picked up by someone walking by, it was collected.

Threat Assessment:

This site is directly affected by rising ocean levels, storm surges, and wave action. The site is already impacted upon occasion during storm events and the midden has been gradually eroding away. If the climate change predictions of high water levels are correct, this site will be completely inundated as the ocean breaches the levee and backfills Horseshoe Pond with ocean water. The site can be expected to be completely destroyed during this process.

Treatment Options:

1. Sea wall/fortifications: A sea wall could be constructed around this site; However, as the mouth of the pond is expected to be entirely inundated, the fortification would need to cover the entire mouth of the pond, roughly 330 m, while still allowing for outflow from the pond at its current elevation above mean sea level so that the site doesn't become inundated from the pond side. This would likely require the installation of a pump large enough to drain the pond or to channel water away from the pond before it enters. The levee has been recently breached at its western edge to facilitate in and outflow, in efforts to return the pond to natural drainage.
2. Monitoring, burial recovery, and artifact collection: to date, no human remains have been identified at CA-MRN-394. The wide range of artifact types, from worked bone and beads to debitage and formal tools to a range of coastal food remains, suggest that

burials here are a possibility. The site could be monitored regularly, and burials, items of cultural patrimony, or burial-associated artifacts are uncovered, such finds could be collected and reburied at a nearby location chosen in consultation with FIGR.

3. Data recovery: Previous research at the site indicates that the midden has over a meter of overburden as a result of natural levee development and subsequent additions during the historic era (Newland 2003). The overburden would need to be removed, probably via backhoe. The program could be co-designed and implemented with FIGR and NPS in such a way that tribal concerns are represented and that no artifacts or human remains are permanently removed from the site.
4. No treatment: The site is allowed to erode naturally into the ocean and become submerged when ocean levels increase enough to submerge the levee.

Figure 17. Location of CA-MRN-394/H and projected sea level rise, with cliff erosion (using 1.5 m elevation sea rise model by Heberger et al. 2009; USGS 1976 *Drakes Bay* 1:24000 scale). [REMOVED FROM PUBLIC VERSION]

ADDITIONAL AREAS ASSESSED FOR POTENTIAL THREATS POSED BY CLIMATE CHANGE

There are broad areas of the interior of the park that have yet to be surveyed, and their sensitivity for cultural resources is still fairly unknown. In particular, the heavily forested areas and the upland grassland areas have received little study. Better studied are some of the drainages leading into the estuaries, lagoons, and bays leading into Drakes Bay and the Pacific Ocean.

A handful of upland areas and part of the western shore of Tomales Bay were visited as part of the background research for the current study. Each of these areas, the results of the review, and conclusions about archaeological sensitivity and potential threats are presented below.

SITES VULNERABLE TO GRASS FIRES: UPLAND AREAS

A small number of sites have been identified in the upland areas within open grasslands; two of these, CA-MRN-273 and -293, were visited. Records for the former were recently updated by ASC staff and interns in 2007; no new records were prepared for MRN-293. Both areas have been fenced off to keep cattle and visitors out, and are being allowed to revegetate naturally. The nature of the revegetation was noted and is discussed below.

CA-MRN-273

This site was recorded by Beardsley in 1941 as a shell midden and was subsequently revisited by Sonoma State University graduate student Barbara Polansky in 1997, followed by an updated recording of the site in 1999 by ASC archaeologists Michael Jablonowski and NPS archaeological technician Jessica Maxey; the site was fenced off to keep cattle out in 2004. The site was revisited again in 2007 by the ASC Site Survey Internship team lead by the current author, who found the site heavily revegetated with tall grass and brush.

CA-MRN-293

This site is a shell midden located on the western side of Pierce Point Road. The site was recorded by Edwards and Treganza in 1967. Recent slumping resulted in NPS fencing the site to keep cattle out and to allow revegetation by tall grasses and brush that would provide a stabilizing root structure. During visits in July and September of 2011, it was noted that the site had indeed naturally revegetated. Unlike the most-threatened sites, this site was not re-recorded.

Threat Assessments for CA-MRN-273 and -293:

The primary threat to both sites is fire. The sites are covered by tall grass and some woody brush species have started to return. While it is expected that a grass fire through here would be relatively low heat and represent a minor threat, the brush is expected to burn hotter. This in turn raises the question as to whether native woody species with low burn temperatures should be chosen for reintroduction on known archaeological sites instead of allowing naturally occurring woody brush to grow. The impacts of digging holes for transplanting native species rather than simply allowing native species to re-grow should be taken into account when deciding whether to transplant low temperature brush versus letting nature take its course.

Implications of Climate Change on Revegetating Sites

Archaeological sites in historically-grazed areas that are fenced off and allowed to revegetate naturally appear to do so rapidly, with tall grasses and adult brush apparent within ten years. Revegetation has proven to be a successful mechanism to help stabilize site matrices at several sites, including MRN 275/302, MRN-278, and MRN- 294, as well as helping to conceal sites, such as MRN-273.

With this in mind, it is suggested here that NPS take into account the species that are likely to pioneer revegetation at an archaeological sites, and study whether these species will pose a greater fire risk later. Over time, these sites may contain more dense mature brush vegetation than the surrounding grasslands and may actually become choked with woody brush. It may not simply be enough to fence these sites off and let nature do the rest, it may prove appropriate for the sites to be occasionally opened to grazing animals to help maintain a lower fire risk or use controlled burns at intervals.

CONSIDERATIONS OF GRASS FIRES AND DRAINAGE AREAS: A SURVEY OF SCHOONER CREEK BELOW H RANCH

A portion of the Schooner Creek drainage separating H and M ranches (Figure 18) was surveyed on 15 September 2011, in an effort to locate a valley floor site in an area thought to potentially be a travel corridor to the coast. No sites were identified within the approximately 17-acre study area. Some of the area had a thick covering of grasses; however, most of the parcel had good to complete ground visibility as a result of grazing.

There have been several other surveys starting at the head of the Schooner Creek drainage basin, and several more down along Schooner creek itself, all of them relatively small (fewer than 60 acres each), with approximately 284 acres of survey conducted at the mouth of Schooner Creek where it empties into marshland above Schooner Bay. No indigenous archaeological sites were found during these surveys despite this being a relatively gently sloping corridor along what seems likely to have been an area with several springs, marshy areas for tule elk and deer, and direct access to the mouth of Schooner Bay, around which are at least five known indigenous sites. It was hypothesized that this might be a travel corridor that contained indigenous sites; if so, such sites have not been observed during different survey efforts.

In viewing the topography, stripped vegetation, and number of springs and water from fresh water creeks, it is argued here that such indigenous sites likely exist but are covered by alluvial sediments. While the landscape history of this portion of PRNS is not well defined, it is likely that grazing has taken place here since the mid to late 1800s; tree and brush removal may have taken place early on and the slopes have likely been gradually eroding into Schooner Creek Basin. Until a geoarchaeological study can be conducted that would help clarify the landscape history and potential for occupation, the Schooner Creek vicinity cannot be ruled out for containing buried cultural resources.

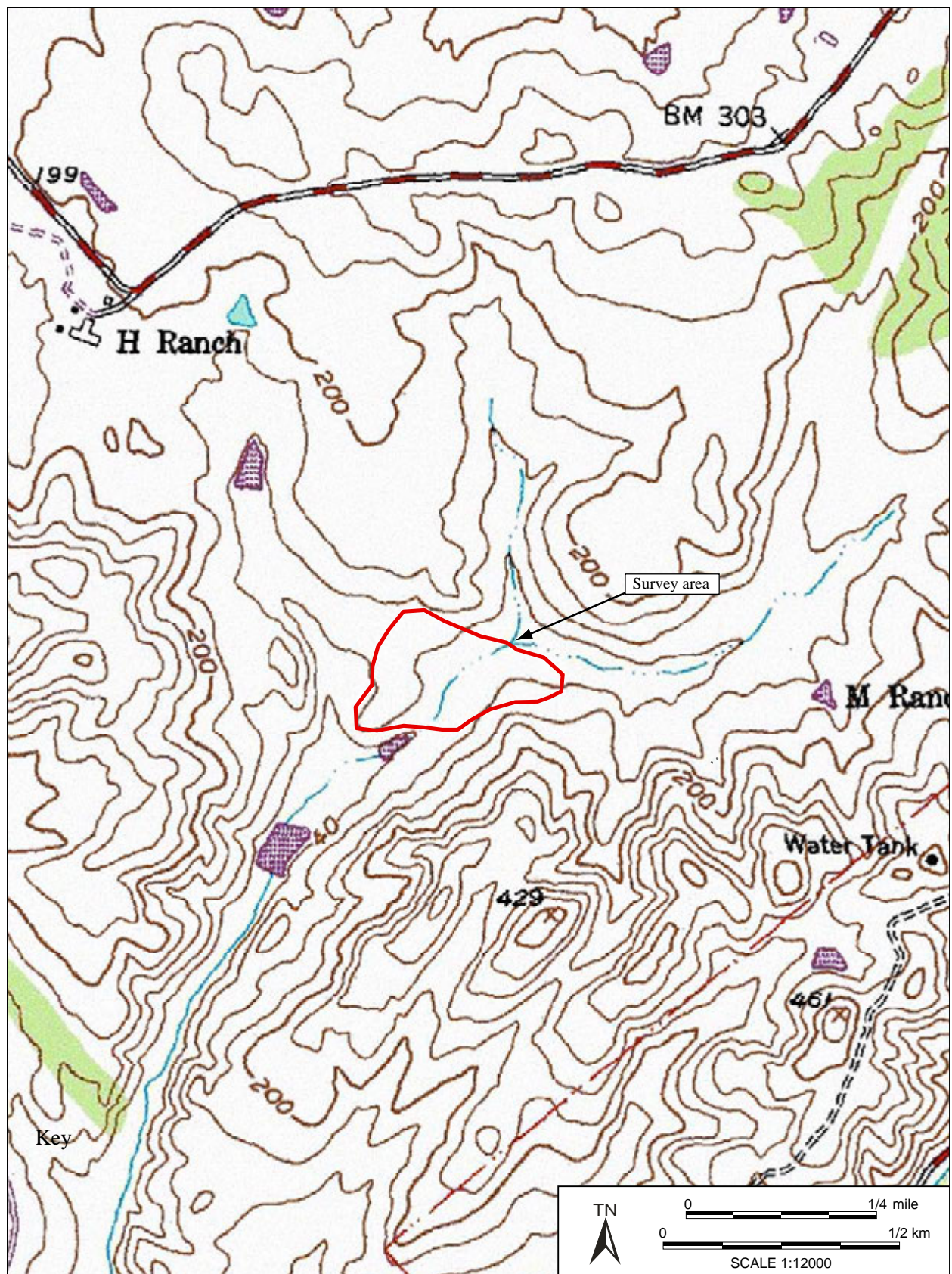


Figure 18. Location of sample survey area in Schooner Creek area (USGS 1976 Drakes Bay 1:24000 scale).

DISCUSSION OF ARCHAEOLOGICAL SITE SENSITIVITY, GRASS FIRES, AND CLIMATE CHANGE

The GIS database for PRNS shows a string of sites (CA-MRN-227 -291, -292, and -293) along the Tomales Point peninsula. These appear to be leading out to the cluster of sites located at Kehoe Beach (CA-MRN-278, -287, -288). This string of sites represents the northernmost upland sites, while the Kehoe Beach cluster represents the northernmost ocean-facing sites. It is argued here that Pierce Point Road roughly follows an indigenous trail that led from the Inverness, Tomales Bay, and Olema areas, and that indigenous travelers stayed along the upper grasslands rather than make their way to the coast and head north along the cliff edges. The age of this trail has yet to be determined, though preliminary dating at CA-MRN-287 and 278 suggests that indigenous populations were using that area no later than 80 B.C. to A.D. 100.

Less apparent is the route south along the Point Reyes Peninsula; very little survey work has been conducted through this area, and only two sites, CA-MRN-229 and -273, are along Sir Francis Drake Boulevard through here. Similarly, the routes taken by indigenous people down into Creamery Bay, Schooner Bay, and Home Bay have yet to be identified.

One possibility is that alluvial sedimentation and possibly landslide or slumping activity along the creek corridors leading into all of these bays has covered the evidence of indigenous occupation. Substantial survey has been conducted at the head of Home Bay with negative results (NPS 2010b). While the drainages leading into Limantour Estero and Creamery Bay have seen considerably less study, it seems possible that sites located along and at the heads of all of the drainages leading to these bays could be buried under alluvium and are not likely to be visible on the surface. A more rigorous assessment of these locations by a geoarchaeologist could clarify the sensitivity of these areas. If sites are in fact buried here, the potential for impacts from grassfire is relatively minimal. It is, therefore, recommended that future survey and site protection measures related to fire be focused on upland areas.

CLIMATE CHANGE AND SITES ALONG TOMALES BAY

Several sites along the western edge of Tomales Bay were visited in October of 2011 by the author and NPS personnel Mark Rudo, Gordon White, and Paul Engel (Figure 19). The sites—CA-MRN-266, -268, -269, -270, and -286—were all to the north of Tomales Bay State Park and represent shell middens either at the edge of the bay or within 100 m. Some of them, such as CA-MRN-266 (the McClure Site), are substantial middens that extend for dozens of meters horizontally and are at least a meter deep. Others, such as MRN-270, are small midden pockets that were difficult to identify from the surface. Each is discussed below.

Figure 19. Assessed sites along the western edge of Tomales Bay (using 1.5 m elevation sea rise model by Heberger et al. 2009; USGS 1976 Drakes Bay 1:24000 scale).

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CA-MRN-266

This site is known in the archaeological literature as the McClure Site after the nearby McClure Ranch. It was first excavated by Bryant in 1934. The site was described at the time as “one of the largest and most promising of all the mounds ...Beautiful, well-protected large site, good water” (Bryant 1934a). The site was found to contain burials, charm stones, and arrowheads. Beardsley returned to the site in the 1940s, followed by Edwards and the Bryant Family in 1967, who prepared an updated record. The last visitation to the site by archaeologists appears to be in August of 2001, when Hans Barnaal of NPS and Michael Jablonowski and Mark Selverston of the ASC conducted a preliminary site assessment.

Unlike most of the other sites along this stretch of the bay, CA-MRN-266 is situated at a relatively low elevation, in the drainage basin. Deposits this low have been found elsewhere along the bay margin but not of such size or complexity. Bryant and Beardsley’s excavations indicate that the site had considerable data potential and its importance as a type site affirms its place in the development of California indigenous archaeological theory.

Threat Assessment:

The site is some 6 to 7 m in elevation. A 1.5 m sea level rise is therefore unlikely to reach the site. The exclusion of cattle from this area over several decades has resulted in thick brush surrounding the site, including along the edge of the beach front. Based on the protection provided to sites by dense ground cover seen elsewhere along the Tomales Bay coastline, this site should remain protected unless sea levels exceed a 1.5-m rise.

CA-MRN-268

This is a shell midden on the north side of a small cove. The site was first recorded by Bryant in 1934b as a large shell mound with obsidian and mortar fragments visible on the beach at low tide. The site was revisited in 1964 by Rackerby, who noted fire-cracked rock and bone, and again in 1967 by Edwards and the Bryant family, who noted that a hammerstone, chert flakes, and mammal bones were also present. The site was again visited by Compas and Jablonowski in 1994, who noted the presence of mussel, oyster, and clam shell. The last field check was in 2001, when it was visited by Jablonowski and Barnaal.

This site has two components, horizontally contiguous but vertically at different levels. The lower level is in the drainage basin and sits roughly 1.5 meters above high tide. The upper level is on the northern side of the small cove, on a flat terrace roughly 4 meters above the current high tide level. The elevated portion of the site can be seen in profile along the eroding granite face facing the bay; the lower portion is visible from the surface.

Threat Assessment:

The lower portion of this site is directly threatened by sea level rise and is likely to be destroyed. It is expected to be within the tidal fluctuation zone and is likely to be completely stripped of vegetation and midden. The upper portions of the site appear to be clear of sea level rise; however, it is likely that the granite bedrock underneath the site will erode and that the site will be gradually undermined. This will likely increase in speed as a result of rising sea levels.

CA-MRN-269

This site was first recorded by Bryant in 1934, and again in 1964 by Rackerby as a large shell midden with mammal bone present. Bryant noted the presence of obsidian and many bowl mortar fragments. The site was revisited again by Edwards in 1967, who noted the presence of fire-affected rock. Compas (1994) attempted to return to the site but was unable to find it; it is suggested here that this was a result of her attempts to access the property from the land, and not the bay, where the site is clearly visible in profile but almost invisible upslope save near the water's edge.

At the time of visitation for the current study, the site was nearly concealed by dense vegetation and was only visible along the eroding coastal edge and in isolated spots upslope. Large pieces of barnacle, clam, and oyster shell could be seen along the coastal edge. The midden here appears to be a meter thick; and extends back from the edge at least 10 m. It seems likely that the remaining portions of the site are in good condition with excellent data potential. Currently, shell fragments are eroding out onto the beach and tidal zone.

Threat Assessment:

Sea level rise at this site will likely just clear the granitic bedrock and cut directly into the sandy soil above it. This can be expected to deflate the site even though most of the increased sea level rise will be against the granite, and presumably not occur until sea level rise reaches the 1.5 m mark. This site is therefore directly threatened but the threat is unlikely to take place for another 50 years or more, depending on the trajectory that climate change takes.

CA-MRN-270

This site is a small scatter of shell midden just above Avalis beach, on its north side on a low bench like most of the sites along the inside of Tomales Bay on the Point Reyes side. The site was first recorded by Bryant in 1934 and was revisited by Edwards in 1967 and again by Jablonowski in 2001. Very little of the site was visible, only a few shell fragments. The rest of the site is covered by dense brush.

Threat Assessment:

This site is directly threatened by sea level rise and is likely to be destroyed. It is expected to be within the tidal fluctuation zone and is likely to be completely stripped of vegetation and midden.

CA-MRN-286

This site is a two-locus shell midden, one locus on a benched terrace overlooking the bay, the other on the edge of the beach and just above the tidal fluctuation zone below a mat of iceplant. The site was first recorded in 1964 by Rackerby and was revisited in 1967 by Edwards and again in 2001 by Jablonowski and Barnaal (2001b).

Threat Assessment:

The lower locus of this site is completely within the inundation/ tidal fluctuation zone of the proposed sea level rise and will probably be destroyed. The upper locus is above the sea level rise but will likely be undercut by wave energy hitting the base of the soil profile.

CA-MRN-397

This site is located on Hog Island and consists of shell midden. Very few surface manifestations of the site are visible, only small pieces of shell eroding onto a gravelly beachhead on the northwest corner of the island. A slumped component of the hill above the beach contains what appears to be bedded shell midden, but the component is only about 1 m long and roughly 10 cm thick. On the slope above and about 20 m southeast of this beach, is a pocket of dense shell midden encased in the roots of a fallen eucalyptus tree. The shell pieces in this pocket are large, including whole clam shell, and indicate that below the root mat of the trees, some 20 to 30 cm down, concentrations of shell may be buried. Currently, the island serves as a wildlife preserve, and the large amount of bird feces and eucalyptus duff on the island suggest that the accumulation of organic material could be rapid. That said, gravels are apparent on the surface of the upland portion of the site; whether this is a function of material introduced during storm/large wave events or the result of less soil accumulation than one would expect from the organic material regularly applied to the ground surface is unclear. The island is separated from the mainland by over 700 m to the west and 1,200 m to the east, and there did not appear to be any rodents on the island that would suggest bioturbation as the source of the gravel.



Figure 20. Overview of eroding shell midden and beach front at CA-MRN-397. View to the northwest (Accession# 70-10-D01-10).

Threat Assessment

Sea level rise poses some unique threats to this site in general and to the island as a whole. The bedrock appears to be sandstone, rather than the granite seen on the peninsula, and slumping can be seen on all sides of the island. Eucalyptus trees, which are currently the main vegetation anchoring the soil on the island's top are falling over along the island's perimeter where slumping has undermined the root system. Rising sea levels at this site will likely just clear the sandstone bedrock and cut directly into the sandy, gravelly soil above it. The introduction of saltwater directly into the soil may kill off or dramatically change the existing vegetation on the island. In sum, both the site and the island are threatened by sea level rise, and both may be destroyed as a result.

Summary Considerations of Climate Change and Sites along Tomales Bay

Despite inundation in bay environments being shown as a potential agent of preservation in other studies (e.g. Belknap and Kraft 1981; Galali et al. 1993; Kelley, Belknap, and Claesson 2010; Kraft, Belknap, and Kayan 1983; Young, Belknap, and Sanger 1992) it is suggested here that inundation and rising sea levels at Tomales Bay would have negative impacts on the sites bordering the bay. Unlike the sites observed for other studies, these sites are not located at the back of an estuary or wetlands system, where sediments could be caught and allowed to accumulate by vegetation and a low energy environment. While not as active as the open ocean cliffs and beaches of the west side of PRNS, the Tomales Bay sites still see fluctuating tides and waves from boats and wind. There are still eroding granitic faces here, albeit not nearly as tall and cut as those on ocean side, and exposed midden is still eroding into the ocean at all of the sites save CA-MRN-268. Currently, erosion is likely going to continue at a much slower pace than the ocean-facing sites. With sea level rise, the lower elevation components to Tomales Bay sites are likely to suffer the same fate as those at Limantour—inundation and scouring as a result of wave energy and tidal forces. In some sites (particularly MRN-269) sea level rise might result in bay waters exceeding the height of the bedrock and flowing onto the soft sandy midden soils of the site. Were this to occur, rapid erosion could be expected. Therefore, the Tomales Bay sites are likely to be eroded, despite previous studies showing sites in bays and estuaries can sometimes be protected.

Working in favor of all these sites is the current land management strategy, which is based on (1) no land access, (2) no proposed development, and, most importantly, (3) no grazing. The lack of cattle grazing in particular has resulted in an abundance of dense vegetation, which both anchors the soils of the sites and makes them impassable, or, at the very least, undesirable to human visitors. The difficulty of access combined with the site's presence adjacent to the water suggests that the potential threat from fire is low. Whereas careful consideration of brush species to be reintroduced for revegetation was recommended for upland sites, here it seems that any brush type adapted to this environment would be appropriate.

Another important point to consider here is subsidence. As the San Andreas Fault runs through the center of the bay, what would the tectonic response be to this increased weight? Fish remains, from what are likely to be midden contexts, have been pulled from White Gulch at depths ranging from 3.3 to 3.6 m below mean lower low water (or 1.1 to 1.5 below the surface of the bay bottom), and at Manila Marina at depths ranging from 6.4 to 7.5 m below lower low water (or 1.5 to 2.5 m below the surface of the bay bottom). Carbon dating placed the dates of these deposits at roughly A.D. 1600 and A.D. 250, respectively (Follett 1968). The relatively recent burial of these deposits, in relationship to the rate of sea level rise during the Holocene, indicates that they were buried as a result of tectonic subsidence and not inundated as the result of rising sea levels. Were a large earthquake occur in this vicinity, subsidence combined with rising sea levels could threaten sites otherwise considered above expected high water levels. Like any natural disaster, the timing of such an event cannot be predicted, but park managers should consider potential impacts to even those sites elevated above flood waters.

Recommendations

Testing, Evaluation, and Treatment

The sites discussed above have been found eligible to the proposed Point Reyes Peninsula Indigenous Archaeological District for their information potential (Stewart 2008). The important data found in these sites should be recovered before sea levels rise. Those components above sea level rise should remain undisturbed.

Keep Existing Land Management Strategies

Nearly all of the small coves along Tomales Bay within PRNS contain indigenous archaeological sites. These areas should remain undeveloped and should be kept as boat-in locations only. Maintaining these areas as exclusion zones for cattle grazing also has proven effective in protecting the sites from both erosion and casual collection. None of the sites visited for the current study showed any indication of looting. As land management strategies change over time, should this part of the park be open to tule elk grazing, NPS should assess the effects of elk grazing and whether it may be appropriate to keep elk from grazing along the bay margins.

Wake Controls

Phase in wake controls on Tomales Bay: requiring low-speed access in and out of Tomales Bay could cut down on the size and number of damaging waves that are expected to pass over most of the sites under the climate change scenario considered here. In addition, barriers, such as marsh vegetation, riprap, downed and anchored trees, etc. between the sites and the rising waters could help break the wave energy before it reaches exposed cliff faces, and thus help protect the sites.

EVERGREEN FORESTS

Three higher elevation locations at the top of Mt. Vision and in the saddle between Mt. Vision and Point Reyes Hill were surveyed at the transition between the evergreen forests and open grasslands (Figure 21). No cultural resources were found. The thick duff of the Bishop Pine and chaparral in these locations prevented close ground inspection once in the forest cover. The survey areas were small, totaling roughly 2 acres combined, but this sample was enough to note the field conditions and likelihood of these areas to be sensitive for containing cultural resources.

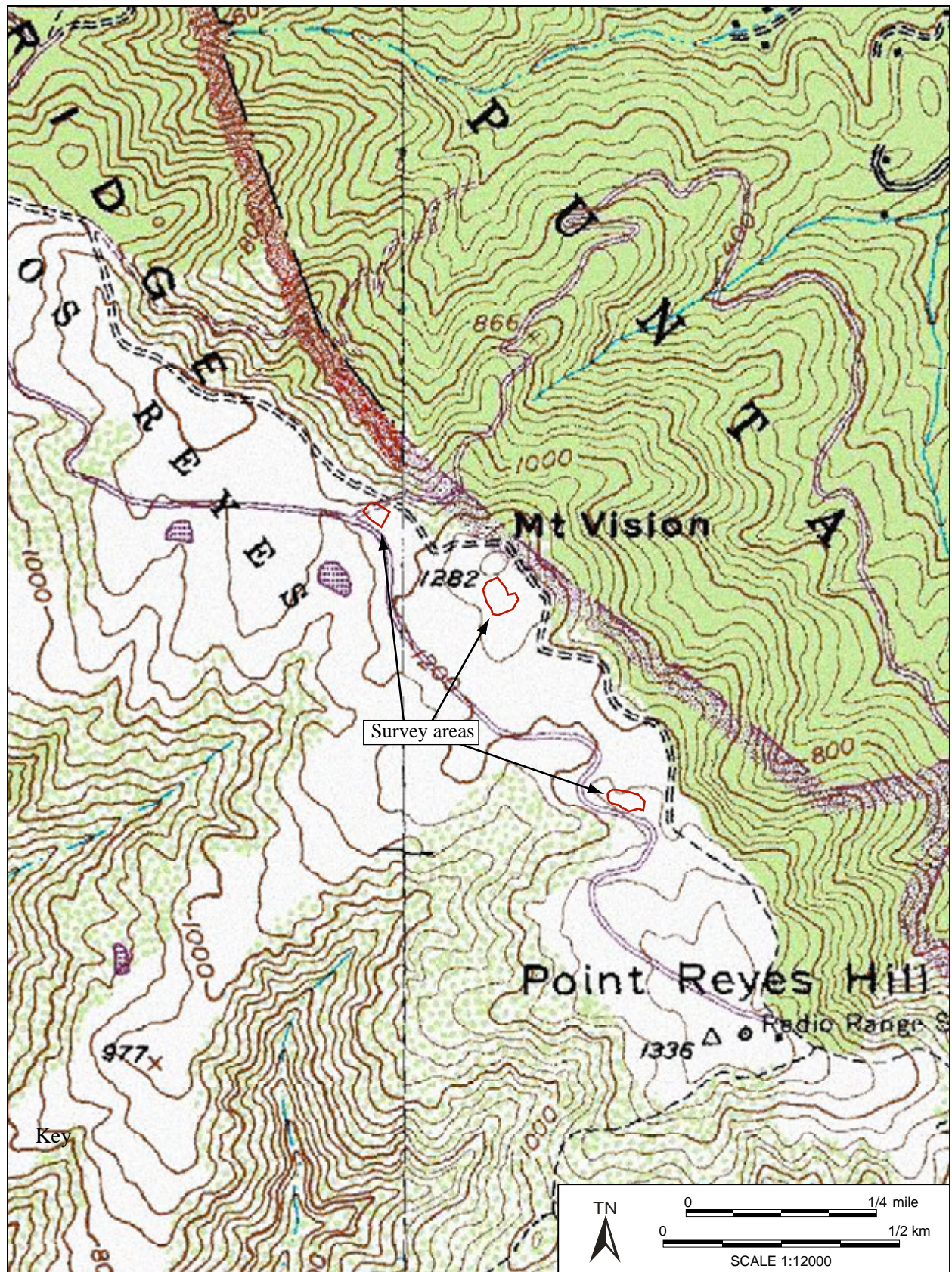


Figure 21. Survey areas in the evergreen forest/native/non-native grassland ecotone (USGS 1976 *Drakes Bay* 1:24000 scale).

Kroeber noted in the early-20th century that

Settlements clustered mostly about estuaries or their vicinity. Bodega Bay was surrounded by several. Others stretched along the sunny side of Tomales Bay. Point Reyes peninsula seems to have been uninhabited... The ridged and forested interior of the peninsula contained several villages, all on or near running streams; but the preponderating majority were in the bay districts... It was evidently more convenient to live in the open, close to the supply of mussels, clams, fish, and water fowl, and occasionally visit the hills to hunt, than to live in the shade inland and travel to the shore [1925:273].

Archaeological survey conducted since Kroeber's work has shown that there were many resource collection and processing areas throughout the park. It is currently unknown if, in the prehistoric era, anthropogenic and natural fires reduced forest cover and made areas more suitable for deer and elk grazing. However, while very little survey has been conducted within the forested slopes of PRNS, they may have been relatively undesirable settlement locations. A study conducted by Newland (2008:41–47) at the Willow Creek vicinity in Sonoma Coast State Park resulted in the location of several sites in the upland forested areas that seemed to be centered either immediately around springs or on proposed indigenous trail corridors, with few sites found outside of these landscape features. The Willow Creek area has other contributing factors, such as it being a boundary area between the Kashaya, Southern Pomo, and Bodega Miwok, that may have affected the limited site distribution. Newland (2008:47) posed other aspects, however, such as steep slopes, slopes, slope instability, and use of the area primarily as a travel corridor, and not as habitation area, as shaping the site distribution, aspects that the forested areas of PRNS shares.

In general, densely forested regions may not be conducive for habitation. In discussing the Central Pomo living in similar environs some 60 miles to the north, Barrett (1908:161), noted that the density of the redwoods and steep topography of the region limited mountain areas along the coast, restricting occupation to temporary encampments only.

This in turn suggests that there may be only a handful of sites in the densely wooded areas. If the indigenous use of the forested uplands is similar to that of Willow Creek, light lithic scatters may be on the main travel corridors, and small artifact scatters may be found around the spring locations near those corridors. Outside of these areas sites may be scarce or absent.

Summary Considerations of Climate Change and Sites within the Evergreen Forests

The primary threat to sites in this environment is fire. As climate change progresses, increased temperatures will threaten existing tree stands by both changing precipitation patterns, presumably through less rainfall and fog, and through heat, thereby stressing the forests and making tree species susceptible to diseases and parasites. It is possible that these areas may be subject to controlled burns in the near future, to reduce fuel load and keep parasitic species in check. It would be valuable to survey both before and after controlled burns, to help develop the archaeological database in this otherwise nearly unstudied portion of the park.



Figure 22. Evergreen forests along the high ridgelines within Point Reyes National Seashore, near Mt. Vision, looking north (Accession # 70-10-D01-10).

Recommendations

Survey Work

Additional study of this area is needed in order to assess what the potential impacts of climate change are. To date, no resources have been recorded within the evergreen forests, though it would seem likely that at least some exist, particularly near spring sites. Further field investigation is warranted.

OAK WOODLANDS OF THE SAN ANDREAS RIFT BASIN

Very little study has been conducted within the San Andreas Rift Basin between Bolinas Bay and Tomales Bay. This is likely due to the lack of development here as much, if not most, of the land on both sides of Highway 1 as it passes through this corridor is either within PRNS or the GGNRA. The obvious presence of the San Andreas Fault through the middle of the valley

indicates that it not suitable for large residential or financial developments. A few recent discoveries, however, suggest that there may be quite a few sites in the valley floor. Three sites were visited and are discussed below.

CA-MRN-386

This site is located at the park headquarters, and includes the management buildings, the Red Barn area, and a newly discovered locus between Red Barn and the maintenance shop. The site was first recorded by Edwards and King in 1966 as a site containing human remains and *Haliotis* fragments. A field visit to this site by the author and NPS archaeological specialist Paul Engel was conducted on 13 October 2011. Chert debitage, possible groundstone, and what appears to be knapped historic glass were noted. Most of the grounds are open with low grass; the artifacts were found under tree cover, in areas lacking brush.

Threat Assessment

As this site is located at the park headquarters, which consists of several historic structures, and the park has actively maintained the existing integrity of feeling here, it seems unlikely that the area will be developed or that the vegetation would be allowed to grow or dead vegetal matter accumulate to a point where it would present a fire hazard. It is also regularly grazed by deer, and its location suggests that it is unlikely to be looted. It seems likely that climate change presents little or no threat to CA-MRN-386.

CA-MRN-659

This site, also called the Five Brooks Site, is located east of the intersection of Highway 1 and the access road to the Five Brooks trailhead. The author visited the site on 13 October 2011 and noted the presence of fire-affected rock, shell midden, and chert debitage. The site is located on a flat terrace overlooking the intersection of an unnamed creek and Olema Creek.

Threat Assessment

This site is directly threatened by fire and flood. The site is surrounded by dense brush and trees, and is close to Highway 1, a potential fire source. Under expected climate changes, weather patterns may shift and the San Andreas Rift Basin may both see less water and be hotter, stressing the existing vegetation and making it more susceptible to disease, thereby increasing the fire hazard.

Stewart Horse Camp Site

This recently identified site has yet to be assigned a trinomial. As the name implies, it is located near the Stewart Horse Camp in a small clearing. The author visited the site location on 13 October 2011. No artifacts were seen during the cursory field visit but what appears to be a

cupule petroglyph boulder on site was noted. The site vegetation consists of a small grassy meadow fringed with oak and pine forest with dense brush.

Threat Assessment

This site is directly threatened by fire and, if the site has a buried component that extends to the nearby creek, flood. The site itself is in an open meadow that may dry out under the expected conditions resulting from climate change. The site is surrounded by dense brush and trees, and is close to Highway 1, a potential fire source, as is the nearby horse camp. Under expected climate changes, weather patterns may shift and the San Andreas Rift Basin may both see less water and be hotter, stressing the existing vegetation and making it more susceptible to disease, thereby increasing the fire hazard. In addition, it is worth noting that the existing horse trail appears to pass directly over the cupule rock. It is recommended that the trail be moved to reduce impact on it.

Summary Considerations of Climate Change and Sites within the San Andreas Rift Basin

These sites face a unique set of challenges when compared to other areas within PRNS. They are not expected to be inundated or eroded, as in the bay and ocean-facing sites, nor are changes in the wind direction expected to move the site substrate, as it may with those sites within the dune systems. Instead, it is argued here that the biggest threat is fire, both through increased traffic through this area by people on their way to the ocean during heat spells and through increased temperatures and species die-offs resulting in large fuel loads. The basin is protected from direct ocean winds and can be expected to be warmer in the summer time than other areas in PRNS. The presence of Highway 1 through the basin indicates that there will be a regular commute of both park visitors and local travel between the Bolinas, Olema, and Point Reyes areas. Aside from the ridgeline, which could be subject to lightning strikes, this area seems most vulnerable to fire within PRNS.

Flood also poses a significant threat to sites within this corridor. Flooding damage could increase by the loss of slope-stabilizing vegetation due to fire and changes in habitat. Sites that are close to the current alignment of Olema Creek are particularly vulnerable, with sites along the tributaries feeding into the creek also being susceptible.

Recommendations

The following recommendations may help prevent the sites being damaged through forest fire or visitation:

Concealment

It is recommended the public be kept off of the sites within the San Andreas Rift Basin. This may necessitate moving some trails (such as the horse trail at Stewarts Horse Camp Site) or maintaining existing vegetation barriers that conceal sites from the public (such as those at CA-MRN-386 and -659).

Vegetation Maintenance

It was interesting to note that all three sites visited occurred in relatively open areas. This may be somewhat of a circular argument—sites are found in open areas because they are not concealed by vegetation, which leads one to conclude that sites are only found in open areas—but it is possible that the site matrix encourages the growth of grasses and other plant species used by deer species for grazing. Deer were seen grazing adjacent to CA-MRN-386 and each of the three sites visited had low grasses growing on them. The vegetation on the sites themselves reflects a low fuel load, even as the surrounding vegetation is thick with brush and tall grasses. Keeping these areas accessible to deer, and encouraging deer to graze on and around the sites, could help keep fuel loads to a minimum. Alternatively, it may be necessary to manually clear sites of fuel load if sites with thick brush are identified.

Testing, Evaluation, and Treatment

Testing, evaluation, and treatment may be the preferred options for sites that are in areas that are likely to be burnt by fire, and for which vegetation management is not practical. Sites that are found to be eligible for the NRHP under Criterion D should be subject to data recovery.

Figure 23. Location of visited sites within the oak woodlands of the San Andreas Rift Basin
(USGS 1976 *Drakes Bay* 1:24000 scale).

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Figure 24. Location of the Stewart Horse Camp and CA-MRN-659 sites within the oak woodlands of the San Andreas Rift Basin (USGS 1976 *Drakes Bay* 1:24000 scale).

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CHAPTER 6. SUMMARY AND CONCLUSION



Figure 25. Beachfront at CA-MRN-275/302, looking west towards the southern tip of Point Reyes (Accession # 70-10-01-12).

FINAL CONSIDERATIONS OF EXISTING CLIMATE CHANGE MODELS

Predicting the long-term effects of climate change is a difficult challenge to climate researchers. The IPCC is on their fifth report since 1990, and with each report the prognosis on the evidence and predicted impacts, of climate change become increasingly grim. Even since the issuing of the last report in 2007 and the Pacific Institute's report in 2009, predictions of expected sea level rise are being revised upward, with what was a worst-case scenario of about 1.5 m over the next century in the Pacific Institute's report now being the likely outcome based on new studies of Arctic sea-ice melting (Flannery 2011). At the time of this writing, large holes in the ozone layer are being observed over Arctic regions for the first time and is now comparable to ozone loss in the Antarctic (Fogerty 2011; Manney et al. 2011).

Helama et al. (2010:1981) summarize the probable effects of sunspots on the global climate over the Middle and Late Holocene, and suggest that the current episode of high sunspot activity will likely have an effect of increasing temperatures over the next century in ways that, due to a lag in the effects of sunspots on climate, have yet to be accounted for. NASA Goddard Institute for Space Science meteorologists James Hansen and Makiko Sato (2011) note that

Polar warmth in prior interglacials and the Pliocene does not imply that a significant cushion remains between today's climate and dangerous warming, rather that Earth today is poised to experience strong amplifying polar feedbacks in response to moderate additional warming. Deglaciation, disintegration of ice sheets, is nonlinear, spurred by amplifying feedbacks. If warming reaches a level that forces deglaciation, the rate of sea level rise will depend on the doubling time for ice sheet mass loss. Gravity satellite data, although too brief to be conclusive, are consistent with a doubling time of 10 years...If the doubling time is as short as a decade, multi-meter sea level rise could occur this century [Hansen and Sato 2011:1, 19].

It appears that the full impacts of climate change are still unknown and, if the trend continues, will be larger than presented here. This in turn makes planning for climate change that much more difficult.

These sober forecasts are coupled with an equally troubling public perception regarding the basic reality of climate change. National climate policy and society action have been shown to be linked to prevailing public opinions on climate change (Ding et al. 2011). Ding et al. (2011) have shown that 1) a majority of U.S. citizens do not think addressing climate change should be a high priority for the U.S. government, and 2) that there is widespread disagreement amongst climate scientists about whether climate change is "real, human caused, serious, and solvable". This latter view has been shown to be patently false—climate change researchers worldwide are overwhelmingly in agreement that climate change exists, that it is serious, and is anthropogenic—and has been shown to be circulated by organized opponents of climate legislation (Anderegg et al. 2010; Ding et al. 2011). Recent research by Friedlingstein et al. (2011) indicates that a global 90% emission reduction will be necessary to limit worldwide temperature median increases to 2°C over the coming millennium—a goal considered nearly unattainable by

the authors of that study. Even tracking climate change is expected to get increasingly difficult, as the world's current generation of satellite systems are expected to retire over the next several years, with no replacements adequately planned for (Schiermeier 2011).

The IPCC is currently preparing its fifth assessment report, to be released in 2013; the report is expected to include an expanded review of the acceleration of climate change, whether the Greenland ice sheet is stable, and the nature of future extreme climate events (Qiu 2011). Already, the IPCC is releasing preliminary assessments, stating that it is "virtually certain", i.e. 99–100% probability — that this century will see an increase in the frequency and magnitude of warm temperature highs and a decrease in cold extremes' (Schiermeier 2011c).

The following, therefore, can be gleaned regarding the current state of climate change research and its general implications for Point Reyes Station:

- 1) Climate change is almost certainly mostly, if not entirely, caused by anthropogenic greenhouse gases;
- 2) The long-term effects of climate change are still being studied but can be expected to lead to increased temperatures and higher sea-levels within Point Reyes National Seashore;
- 3) National and international policy for addressing climate change is contentious, political, and is rife with misunderstanding, despite long-standing unified consensus within the scientific community on the reality of climate change and its causes by human means;
- 4) It seems unlikely this misunderstanding and contention will be resolved in sufficient time to negate much of the predicted climate changes in the worst case scenarios presented by the IPCC;
- 5) PRNS and NPS should not expect timely policy decisions that will be prevent the effects of climate change; rather, PRNS and NPS should proceed under the assumption that the worst case scenarios are correct and plan accordingly.

With this in mind, it seems likely that the sites along the coastal edge will be lost, either through inundation or erosion. It is recommended here that sites that fall outside of the current model of inundation and erosion be reassessed as soon as widely accepted new models are produced. The IPCC can be expected to continue to update and revise their estimates, with local, state, and federal agencies in turn following suit with their preparations for addressing climate change impacts. Of critical importance to PRNS will be assessments not just of sea-level rise but of temperature increases and changes in precipitation. The latter component of climate change is not as well understood but will have a dramatic effect on the vegetation and fire regime within the park. The threat of fire or extreme flood events may, at some point, overshadow the threat of inundation by sea level rise.

The implications of erosion within PRNS on sites outside of the PRNS boundaries are worth noting. Erosion studies of dune systems within the northwestern Nile Delta indicate that the loss of sediment reaching dune systems and the reclamation of dunes for buildings and fill material has resulted in areas being particularly vulnerable to sea-level rise and other climate

change impacts (El Banna 2007:1297-1298). Stabilization efforts of cliff faces along the Drakes Bay edge should only be done if there is an understanding of how sediments from these cliffs are carried, if at all, to other beach and lagoon formations down current, particularly Bolinas Lagoon. Sea wall construction at PRNS may keep sediments from reaching, and stabilizing, other beaches and estuary locations along the coast.

It is also acknowledged that the scope of treatment for affected sites may be daunting. Treating the impacts of climate change will necessarily take place at a scale typically reserved for the largest of federal projects—by acknowledging inundation as a threat, NPS is faced with looking at treatment of all potentially eligible sites within PRNS along the shoreline. If fire within the forest or coastal chaparral communities is accepted as a major threat, all sites within these communities would be at risk.

This report recommends that that coastal strip, including all areas predicted to be inundated and eroded along bluff edges or dunes, be surveyed. The sites within these areas should be evaluated for their potential eligibility to the NRHP, and treatment options for potentially eligible sites considered. For those sites that have been found eligible and are part of the Point Reyes Peninsula Indigenous Archaeological District, a district-wide plan should be designed that contains an overall strategy and prioritizes the efforts of PRNS staff. While the sites within potential fire areas are at risk, the effects of climate change on the vegetation are less well understood, and, depending on the type of fire, less destructive than inundation and coastal erosion. Once the coastal sites are addressed, inland areas should be surveyed based on the vegetation communities seen as being at the highest fire risk, with evaluation of identified sites to follow.

Finally, the level of effort proposed here to identify and treat the effects of climate change should be reevaluated in 10 years. As noted above, the extent of climate change impact is a challenging and evolving science. Predictions made now may be out of date within even a few years. Regular monitoring of significant sites, ongoing consultation with FIGR representatives, and frequent reviews of updated climate change literature will be necessary to head off the worst impacts of climate change on the indigenous sites of Point Reyes National Seashore.

SUMMARY OBSERVATIONS AND RECOMMENDATIONS

The following observations of the potential effects of climate change are based on field data and literature review.

SUMMARY OBSERVATIONS

1. Archaeological sites along the cliff edges next to open ocean, i.e., the western edge of PRNS and the cliffs above Drakes Bay, are in the process of eroding and can be expected to be completely destroyed within the next 100 years based upon cliff erosion models prepared by the Pacific Institute.
2. Low-lying sites along the coastal edge, such as those on Limantour Spit and at the mouth of Horseshoe Pond, can be expected to be completely destroyed as a result of wave energy, storm surges, and scouring, within the next 100 years based on inundation models prepared by the Pacific Institute.
3. Low-lying sites along the interior margins of bays, estuaries, ponds, and lagoons can be expected to become inundated and may have some impacts from wave energy as sea level rises. However, past studies of inundated sites suggest that these interior areas may see a rapid sediment build-up that could result in sites being buried rather than eroded. There are still biochemical impacts to the sites as a result of inundation, and soil and water pressure can be expected to have negative impacts, but the sites are not expected to be destroyed in the same manner as sites along the coastal edge.
4. Sites within the drainages leading to the bays, lagoons, ponds, and estuaries appear to either be absent or buried under alluvium. These sites are not expected to be inundated. Threats posed to sites within these areas mainly consist of grass or brush fires and continued burial as a result of fires or vegetation die-off as unstable upland slopes collapse into the drainages.
5. Indigenous sites seem more likely to be exposed or near surface within the upland grasslands, where previous studies found what appear to be potential trail networks and existing surface deposits. Some of these sites, once fenced off, develop woody brush communities that may raise the temperature of grass fires across the site, resulting in greater, and deeper, fire damage.
6. Little is known about site density within the evergreen forests of PRNS, which have received almost no archaeological study. If sites exist, they can be expected to be negatively impacted by what could be large tree species die-off, as the fuel load in these forests could be substantial;

7. Similarly, little survey has been conducted within the basin of the San Andreas Rift Zone along the eastern edge of the PRNS. A handful of indigenous archaeological sites have been identified here, indicating that some surface and near surface deposits exist. Additional survey is recommended to reveal previously unrecorded sites. Fires through here as a result of vegetation die-offs from climate change would likely impact these surface deposits.

RECOMMENDATIONS

Administrative

1. PRNS and FIGR should enter into a Memorandum of Understanding (MOU) that defines how FIGR and PRNS will collaborate to respond to threats posed to indigenous archaeological sites, including the development of a park-wide plan or strategy. If on-site or near-site reburial is a desired treatment option, the process for consultation and appropriate reburial should be described in an accompanying or park wide treatment plan.

Inventory

1. The coastal edges of PRNS should be surveyed in a 200-m swath from the cliff edges. Archaeological sites along these edges should be recorded and evaluated for their potential eligibility to the NRHP. Data recovery should be considered at those sites that are eligible for their data potential. It should be assumed that the entirety of these sites may be lost by year 2100;
2. The dunes, beaches, and marsh edges of PRNS should be surveyed back to the extent of projected inundation, with a buffer to accommodate storm surges and changes in the sea level model. Archaeological sites along these edges should be recorded and evaluated for their potential eligibility to the NRHP. Data recovery should be considered at those sites that are eligible for their data potential and are along the coastal edge. It should be assumed that these sites will be inundated by year 2100. The sites along the coastal edge may be expected to be destroyed; the interior sites will be inundated and unavailable for future study unless such studies were conducted underwater.
3. Upland grassland areas leading northwest to the McClure/Kehoe Beach/Tomales Point areas and southwest across the Point Reyes peninsula should be surveyed and archaeological sites recorded. Sites in these areas are susceptible to wildfire and may be vulnerable if climate change results in vegetation die-offs and increased air temperatures. The archaeological sites along these corridors should be evaluated for their eligibility to the NRHP, and those that are found to have data potential should at least have artifacts susceptible to damage from burning removed from the surface. Data recovery down to 50 cmbs should be considered.

4. A survey sampling strategy should be conducted for the forested and San Andreas Rift Zone areas that could provide a better understanding of archaeological site sensitivity in these locations. If these areas are shown to have a high possibility for containing significant surface or near surface deposits vulnerable to fire, they should be surveyed, any sites found recorded and evaluated for their potential eligibility to the NRHP. A surface collection of artifacts susceptible to damage from fire should be conducted, and excavations collecting data down to 50 cmbs should be considered.
5. Seawall fortifications, dikes, levees, or other water management features are not recommended for site protection. There is general consensus within the climate change research that sea level rise is occurring, at an increasing rate, but it remains unclear as to what sea level rise will eventually be by 2100. Much of the impact remains dependent on political and economic decisions yet to be made by US policy makers and international government agencies. The nature of future storm systems, both in terms of severity and direction, combined with changes in tides and ocean currents is likewise unknown and may greatly complicate designing sea fortifications. The chemistry of the ocean water itself, specifically the pH, is also changing and may compromise efforts to construct effective protection. In some cases rip-rap placed on low-lying sites may afford protection; these are presented below.
6. The drainages leading into the lagoons, estuaries, bays, and ponds should be studied by a geoarchaeologist to determine the likelihood for containing existing buried resources. Climate changes may make the upland areas more susceptible to fire, thereby increasing the risk of slope instability and landslides down into the drainage basin. Sites accessible now through geoarchaeological investigation may become inaccessible in the future. Assessments should also be made as to where landslides would most likely occur and how their sediments are likely to be re-deposited.
7. Brush that has a low fuel-load should be considered in areas that contain sites slated for re-vegetating. Different locations around PRNS can be expected to re-vegetate at different rates, with different brush species. PRNS personnel should consider identifying brush that burns at a lower temperature and seeding the re-vegetation areas with this brush rather than letting whichever seeds naturally germinate there repopulate.

Sites on Cliffs, Dunes, and Beaches Facing Open Ocean

1. These sites can be expected to be destroyed, either through inundation and wave erosion or the undermining of cliffs resulting in the sites eroding into the ocean. These sites should be evaluated for their potential eligibility for the NRHP. For sites that are eligible for the NRHP for their data potential, NPS should consult with FIGR to determine whether a data recovery program is appropriate and, if so, what methods could be used that take into account the cultural values these sites hold for FIGR.
2. In general, rip-rap or sea fortifications are not recommended. Much of the open coastline lacks road access and cannot be approached from the ocean side by heavy equipment. The sea-level rise is currently only an estimate and this estimate is under constant revision and is therefore impossible to anticipate.
3. At a minimum, it is recommended that the indigenous sites in these areas be regularly monitored. Erosion can be expected to accelerate, potentially resulting in human remains and artifacts eroding onto beaches or being exposed in dune faces. Regular monitoring can help ensure that these remains are treated appropriately and that remains or artifacts are not removed by the public.
4. Reburial locations near these sites should be identified in close consultation with FIGR representatives in concordance with existing management policies and the recommended MOU/treatment plan.

Sites on Cliffs and Beaches facing Tomales Bay

1. Those sites directly within the new tidal fluctuation zone are likely to be destroyed by wave energy. Though erosion is expected to be substantially less than at the ocean-facing sites, field observations conducted for this study indicate that wave erosion is still sufficient to strip all vegetation off the ground surface within the fluctuation zone and erode slopes down to bedrock. As with the ocean-facing sites, it is recommended that sites within this tidal fluctuation zone be evaluated for their NRHP eligibility and, if found eligible, treatment plans prepared and carried out.
2. It is unlikely that the slopes here will erode back to the extent seen along the ocean-facing sites. Limiting public access from the water, and keeping access from the land, particularly grazing, closed will promote dense vegetation growing here and will help secure the slopes. The proximity to the bay and the locations of the sites along marshy tributaries suggest that the sites may not be candidates for fire risk.

3. Unlike most areas along the coastal edges, some of the sites within Tomales Bay may be good candidates for protection by rip-rap. Road networks lead to some of the beachfronts, at some sites it may be possible to install rip-rap or small sea walls. In most cases the slope edges eroding along the bay were no more than 10 to 11.5 m tall and rip-rap could be installed that would protect these sites.
4. At a minimum, it is recommended that the indigenous sites in these areas be regularly monitored. Erosion can be expected to accelerate, potentially resulting in human remains and artifacts eroding onto beaches. Regular monitoring can help ensure that these remains are treated appropriately and that remains or artifacts are not removed by the public.
5. Reburial locations near these sites should be identified in close consultation with FIGR representatives in concordance with existing management policies and the recommended MOU/treatment plan.

Sites in the Upland Grasslands

1. These areas along ridgelines leading to the coast are likely to contain sites. They should be surveyed and identified sites recorded. It is likely that these upland areas will be more susceptible to fire as temperatures increase and vegetation regimes become stressed as a result to changing climates.
2. The grasslands are not expected to experience fires hot enough to damage or destroy buried components. However, surface artifacts vulnerable to the effects of fire should be collected.
3. Once surface collections are completed, these sites should be periodically monitored for new artifacts being exposed as a result of rodent disturbance.
4. As the upland grassland areas are used regularly for grazing, sites found within these areas should be closed off from grazing, as cattle can trample and break artifacts.
5. The risk of fire should be weighed against the damage done by grazing. It may be desirable to close off sites from regular grazing, but periodically open these areas up to reduce woody brush that might burn hotter and have a greater impact on surface and buried artifacts.
6. If areas are to be closed off for grazing and allowed to revegetate, it is recommended that plant species be reintroduced that burn at lower temperatures and do not have extensive root systems that might introduce charcoal into buried site components.

Sites in the Lowland Grasslands and along Drake's Estero

1. Few sites have been found in these areas beyond those bordering the lagoons and estuaries, suggesting that either they were not inhabited or, more likely, sites that were there are now buried as a result of alluvial deposition and soil development. These areas are often marshy and may have had year-round water. They would have been excellent hunting locations. While habitation or settlement may not have occurred, it seems reasonable to expect that hunting camps or butchering sites would be present. It is therefore recommended that a geoarchaeological study be conducted that may help identify buried sites before they become inaccessible due to inundation or increased sedimentation
2. Lowland sites bordering inland lagoons that are within the inundation zones anticipated with sea level rise can be expected to flood and accumulate sediment rather than experience the wave erosion seen along the ocean edge or Tomales Bay. That said, some wave energy may reach these sites and cause erosion. To facilitate deposition, and therefore better site protection, rather than erosion, it is recommended that riparian or coastal marsh vegetation be introduced that helps break wave energy in front of these sites. If the site location is not suitable for protective vegetation, the sites should be assessed for placement of protective rip-rap.
3. To date, thirteen sites bordering lagoons or estuaries have been identified, including CA-MRN-232 (the Estero site) ,that are likely to be eligible for the NRHP and are virtually at sea level. It is recommended that all of the lowland grassy areas bordering the inland lagoons and estuaries be surveyed along the inundation zones. Identified sites should be evaluated for their NRHP eligibility.

Sites in Dense Upland Forests

1. No indigenous archaeological sites have been found in the dense upland forest areas. However, very little in the way of survey has been conducted here. It is recommended that a sampling strategy be designed and implemented that would result in a better understanding of indigenous uses of these upland forests.
2. The upland areas are anticipated to be high risk areas for fire. In the event of a wildland fire, the mature tree stands and thick woody brush bordering the forested areas can produce very hot surface temperatures, and burning root systems extending deep into the ground. If cultural deposits are present in these forested areas, it can be anticipated that surface artifacts are likely to be damaged by fire and that the heat may extend down into the site through root systems. Charcoal may also be introduced into buried components, limiting the research values of sites. For this reason, archaeological sites identified within the upland forests should be evaluated for their potential eligibility to the NRHP, and, if found potentially eligible, a treatment plan prepared and carried out.

3. Areas that are susceptible to fire should be assessed for the likelihood of slope failure as a result of the loss of vegetation. An estimate of the extent of possible landslides or mudflows should be made, followed by an analysis of the likely trajectory of the landslide. Archaeological sites in the path of a landslide or that can be expected to be directly affected should be evaluated for their eligibility to the NRHP as well, and if eligible, a treatment plan prepared.
4. Fire roads, staging areas, helicopter pads, and other access points should be surveyed, as these areas can be expected to be used heavily during fire events and be graded, expanded, or otherwise altered on short notice.

Sites in the San Andreas Rift Basin

1. Very little is known about sites in this part of PRNS. Preliminary surveys in limited areas of the park suggest that there may be more indigenous archaeological sites along this corridor. It is recommended that the component of PRNS within the San Andreas Rift Basin that corresponds with the basin floor and along stream terraces leading into the basin be surveyed and any identified sites recorded.
2. Archaeological sites found in the basin are not expected to be inundated. However, the increased fire hazard as a result of higher temperatures put these sites at risk. Though containing different tree and brush species, the risks to sites from fire are similar to those in the upland forests. It is recommended that these sites be evaluated for the potential eligibility to the NRHP, and, if found eligible, a treatment plan prepared.
3. Where feasible, grazing by deer or cattle should be allowed periodically on some sites to reduce the woody fuel load. Sites should only be fenced if there appears to be a direct threat to the site from looting or casual collecting. If cattle grazing is not desirable and regular grazing by deer is not sufficient to keep down the woody brush, it is recommended that NRHP eligible sites are periodically hand-cleared.
4. At a minimum, surface artifacts should have their provenience recorded and collected from sites in this area to prevent damage from fire and fire suppression efforts.

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