DENTAL PATHOLOGY DISTRIBUTION AND SEX RATIOS IN

WINDMILLER POPULATIONS FROM CENTRAL

CALIFORNIA

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A Thesis

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Master of Arts

in

Anthropology

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by

Katharine E. Kolpan

Spring 2009

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Lastly, I would like to thank my family for their love and support. You have been with me every step of the way and I'm grateful for your unwavering faith in me and your dedication to my education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

DENTAL PATHOLOGY DISTRIBUTION AND SEX RATIOS IN

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This thesis focuses on how dental pathologies may be used to make

inferences about the subsistence patterns of a prehistoric hunter-gatherer population.

Dental caries and dental attrition are often used as markers to indicate subsistence

changes, such as the transition from foraging to agriculture. However, pathological

changes to teeth may also be used to indicate differences in subsistence and dietary

patterns among non-agricultural populations. Previous investigations in California and

beyond have suggested that females display higher rates of dental caries than their male

counterparts. Various lines of evidence have been used to explain the disparity in dental

caries prevalence between men and women. Some have argued that it may be, in part,

physiological, with female hormone production decreasing salivary flow and increasing

the risk of developing dental caries. Others have suggested it is due to female's position as gatherers allowing them greater access to plant resources, which they may have consumed in larger quantities, both at meal times and in between meals. In this study, I analyze rates of dental caries among males and females from archaeological sites associated with Windmiller skeletal assemblages (ca. 4500-2500 B.P.) in California's Central Valley to test whether females exhibit statistically higher proportions of dental caries than males.

I analyzed 138 and 111 individuals from the Windmiller (CA-SAC-107) and Phelps (CA-SJO-56) Mounds, respectively. The final sample included 11 individuals from the Windmiller Mound and 45 individuals from the Phelps Mound. These data were compared to 93 individuals from two previously analyzed Windmiller sites, the Blossom Mound (CA-SJO-68) and the McGillivray #1 Mound (CA-SJO-142). While females exhibited a higher proportion of dental caries at all four sites, the difference was significant only in the Phelps and Blossom Mound samples. However, when caries rates for all four sites were combined females exhibited significantly more caries than males. While some of this disparity is likely due to physiological differences, I argue that the majority of the differences between the sexes in terms of dental caries may be due to female's roles as gatherers and their differential access to plant resources.

CHAPTER I

INTRODUCTION

Dental analysis plays an important role in physical anthropology due to the fact that teeth preserve well in the archaeological record and retain information about patterns of behavior in ancient humans. Analyses of dental pathologies are used by bioarchaeologists and paleopathologists to shed light on diet, subsistence, nutritional status, tool usage, and the health of prehistoric populations (Darias-Delgado et al. 2004; Larsen et al. 1991; Scott and Turner 1988). Studies of dental disease focus on patterns and rates of dental attrition, antemortem tooth loss, dental caries, dental calculus, periodontitis, and alveolar abscesses.

Increasingly, the dental disease process known as dental caries is often used as evidence to argue for a population's transition from foraging for native terrestrial resources to heavier reliance on agriculture (Schollmeyer and Turner 2004; Beckett and Lovell 1994; Lukacs and Pal 1993; Larsen et al. 1991). The presence of dental caries indicates that resources conducive to *Streptococcus mutans*, the bacteria responsible for dental caries, are being consumed. Carbohydrates and sugars tend to be more cariogenic than greens, nuts, seeds, meat, and fish (Newbrun 1982). A shift toward greater reliance on carbohydrate rich resources and monoculture increases the risk of dental caries; this is particularly true in prehistoric North America, where an agricultural reliance on maize, a crop high in carbohydrates and sugars, is associated with an increase in the prevalence of

dental caries (Sciulli 1997; Larsen et al. 1991; Larsen 1981). However, dental caries cannot be used to indicate shifts in subsistence strategies all over the globe. Many Old World crops, such as wheat and rice, are not cariogenic and some studies conducted on the teeth of Old World farmers and hunter-gatherers from Asia and the Middle East suggest that dental caries did not increase with the advent of agriculture (Eshed et al. 2006; Tayles et al. 2000).

Hunter-gatherers, in contrast to agricultural populations, tend to have low proportions of dental caries (Turner 1979). However, this does not make hunter-gatherers immune to carious involvement (Hollimon 1992; Walker and Erlandson 1986; Turner and Cheuiche Machado; Schulz 1981). The teeth of some hunter-gatherer societies also reflect a trend seen in some agricultural populations, where women have higher proportions of dental caries than men (Lukacs and Thompson 2008; Bartelink 2006; Fujita et al. 2007; Cucina and Tiesler 2003; Larsen et al. 1991; Walker and Erlandson 1986; Schulz 1981.)

Hunter-gatherer societies, while participating in food sharing, are not completely egalitarian (Jackson 2004; Bird 1999; Hurtado et al. 1985; Ember 1978; Wallace 1978; Willoughby 1974; Merriam 1918). Most hunter-gatherers practice a sexual division of labor with men doing the majority of the hunting and women majority of the gathering (Bird 1999; Wallace 1978). Thus, access to resources, even if they are shared, is differentially distributed. Women as primary gatherers would have had greater access to plant resources that may have contributed to the proportionally higher rates of dental caries exhibited in the archaeological record. The need to sample food for ripeness and thorough cooking, hunger, and the energy needed to carry large amounts of gathered food

from a foraging patch back to camp, would have allowed women to eat larger proportions of potentially carious plant resources at intermittent intervals throughout the day (Schulz 1981). Men, in contrast, spend more time hunting and fishing and may only have consumed plant resources during meals, decreasing their intake of potentially carious foods (Wohlegemuth 2004).

Indigenous societies in precontact Central California did not practice agriculture. However, evidence has been found to suggest both a demarcated sexual division of labor and differential distribution of dental caries among male and female hunter-gatherers (Bartelink 2006; Jones 1999; Walker and Hollimon 1989; Walker and Erlandson 1986). Thus, differences between men and women in regard to caries rates may be due differential consumption patterns and access to resources.

Little is known about the prehistoric California Central Valley culture known as the Windmiller Pattern (ca. 4500-2500 B.P.) Previous research by Bartelink (2006) found higher caries rates in Early Period Windmiller females than males[1]. However, archaeologists have an incomplete view of the types of subsistence practices and daily activities in which the Windmiller people engaged. Due to their link with foods high in carbohydrates and sugar, dental caries rates may illuminate the possible types of food Windmiller people consumed and offer clues into the types of activities in which Windmiller men and women participated.

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[1] Referring to the Windmiller "people" or Windmiller "individuals" is a bit of a misnomer due to the fact that archaeologists have yet to establish cultural continuity between sites associated with material goods and burial practices ascribed to the Windmiller Pattern.

Research Design

In order to address the interpretations and implications inherent in sex differences in caries prevalence, I analyzed data from four Windmiller sites in the lower Sacramento (Windmiller Mound, CA-SAC-107 (3075-2540 B.P.)) and the upper San Joaquin Valleys (Phelps Mound, SJO-56, (ca. 2855-2600 B.P.); Blossom Mound, CA-SJO-68 (4350-3000 B.P.); McGillivray Mound, CA-SJO-142 (ca. 2800-2200 B.P.)) The aims of this research study are to evaluate the following questions:

1.   Do the populations at Early Period Windmiller sites in the California Central Valley conform to the pattern of high rates of dental caries in females as found in many other prehistoric populations from California?

2.   If females are found to exhibit higher incidences of dental caries, what factors would result in females exhibiting more dental caries?

3.   What types of locally available plant resources would have potentially contributed to dental caries development?

In order to evaluate these questions, I applied standard skeletal aging, sexing, and dental procedures to an Early Period skeletal sample that in order to evaluate differences between males and females using non-parametric statistical methods. Aging and sexing each skeleton ensured that only adult individuals of known sex were used. Assessing each dentition for dental pathologies and dental attrition created a research database of the numbers and types of dental conditions present for males and female at each site. Research has shown that caries scores tend to underenumerate the proportion of dental caries present in archaeological populations because teeth lost antemortem may have been carious (Lukacs 1995). The Lukacs (1995) caries correction factor was applied

to each skeletal assemblage at each site to correct for the potential underenumeration of carious teeth. All teeth were analyzed using chi-square tests in order to test for statistically significant sex differences in the rate of dental caries displayed. I hypothesized that there should be an overall difference in the proportion of carious teeth seen in males and females from this sample of individuals from the Windmiller Early Period, with females exhibiting a higher prevalence of caries than males.

I also considered the causative factors that contribute to sex related disparities in dental caries prevalence. I evaluated claims that fluctuations in females hormone levels contribute to oral pathogenesis (Lukacs and Largaespada 2006). I consider the sexual division of labor in prehistoric California and how male and female access to different resources could have contributed to differences in dental caries rates. Should a disparity in caries prevalence be found, I hypothesize that physiological processes predispose women to dental caries, but that differential food consumption patterns are strongly linked to dental caries.

Finally, I assessed the types of resources that would have been readily available to the individuals who from the Delta region of the Central Valley. I suggest foods that would have been easiest to obtain and most abundant within a five kilometer radius of the site area and the types of foods that would have been most likely to contribute to the formation of dental caries (Jones and Madsen 1989).

Organization of the Thesis

In Chapter II, I discuss the Central Valley, prehistoric Windmiller culture, and the Miwok Native Americans who inhabited the area during the historic period. The first

part of chapter II is devoted to the Central Valley, its formation, climate, geography, landscape, and native species. The middle section focuses on what is known about the people who characterize the Windmiller Pattern. The last section focuses on the types of subsistence strategies employed by the Plains Miwok, the Native American population that inhabited the same area during historic times.

Chapter III focuses on the literature relevant to dental pathologies, with a particular emphasis on dental caries. This chapter covers the etiology of dental caries, as well as the relationship between caries and shifts in subsistence, and sex differences in caries rates. Chapter III also discusses the relationship between dental wear and dental caries and outlines the literature on archaeological sex differences in caries prevalence in agricultural and non-agricultural societies.

Chapters IV and V contain a brief overview of my materials and methods and the results of my analysis. Chapter IV provides a brief overview of each archaeological site, a description of skeletal aging, sexing, and dental analysis methods used, and an outline of the statistical tests used to obtain my results. Chapter V focuses on the results of my data analysis. The skeletal populations that I analyzed, SAC-107 and SJO-56, are discussed before they are compared to two populations, SJO-68 and SJO-142, that had been evaluate previously by Bartelink (2006).

Chapter VI provides a discussion of my results and their overall implications. I discuss the various meanings of the data in a more general sense. Afterward, I discuss differences in male and female hormone production, the sexual division of labor and access to resources, and the types of plants that could have contributed to differential

caries pathogenesis. I also outline the limitations of the study and their impact on my interpretations.

Finally in Chapter VII, I summarize my data and discuss future research that might further illuminate the subsistence practices and activity patterns of Windmiller individuals.

CHAPTER II

PREHISTORIC CALIFORNIA

LANDSCAPES AND NATIVE

AMERICAN COMMUNITIES

In this chapter I discuss the physical and cultural landscape inhabited by the

prehistoric populations of the Delta region of the California Central Valley. I begin with

an overview of the spatial distribution, formation, and current physical landscape of the

California Central Valley. Next, I discuss temporal chronology in prehistoric Central

California in order to provide a frame of reference in regard to the Windmiller Pattern.

This is followed by a definition and discussion of the material culture and possible

subsistence practices of the people who comprised the Windmiller Pattern. Lastly, I

address the material culture and subsistence practices of the modern Plains Miwok, a

historic native California population who inhabited the area in order to gather a greater

understanding of subsistence practices.

Prehistoric Sacramento-San Joaquin
Delta Area

The Central Valley

The California Central Valley is a flat intermontane basin that extends 650

kilometers between the Siskiyou Mountains in the North and the Tehachapis Mountains

in the South (Rosenthal et al. 2007). The Valley is bordered by the Sierra Nevada and the

Cascade Mountains to the east and the Pacific Coast Ranges to the west. For the most part, the Valley floor remains at sea level, although it rises to elevations of around 100 meters at its northern and southern limits (Moratto 1984).

The Central Valley is composed of a northern section, known as the Sacramento Valley and a southern section, known as the San Joaquin Valley. The Sacramento River runs 260 kilometers southeast along the Sacramento Valley, while the San Joaquin River runs 440 kilometers northwest along the San Joaquin Valley (Moratto 1984). Both rivers swing to the west and converge around the center of the Central Valley in the channels, marshes, sloughs, canals, and streambeds that comprise the 750 square-mile (1900 km^2) Sacramento-San Joaquin Delta (Schoenherr 1992; Moratto 1984). The Sacramento and San Joaquin Valleys are bisected by the Mokelumne and Cosumnes Rivers, which originate in the Sierra Nevada before joining the San Joaquin River in the Delta. Currently, groundwater from the Sacramento-San Joaquin Delta is pumped into the California aqueduct where it is redistributed to the citizens of Southern California (Schoenherr 1992).

Geologically, the flat, lowland area that is thought of as the Central Valley is a structural trough (syncline) formed between the Pacific Coast Ranges and the Cascades-Sierra Nevada Mountains (Thompson 1961). This trough developed between a volcanic arc to the east and a marine trench and subduction complex to the west, during the Late Jurassic and Early Cretaceous Periods (ca. 150-120 million years ago) (Presser and Ohlendorf 1987). However, the Central Valley remained inundated with sea water until the middle Tertiary Period (ca. 30-35 mya), when the sea withdrew from all areas of the Valley except the southern end of the San Joaquin Valley (Presser and Ohlendorf 1987).

Twenty-five million years ago the motion of the convergence between the North American Continental Plate and the Pacific Plate changed from a head-on motion to a sideways motion, known as a transform system (Schoenherr 1992). This sideways motion created faults, which are deep cracks in the earth's crust, and motion along these faults caused some geologic blocks to sink while others rose (Schoenherr 1992). The rising and falling of blocks along these fault lines is responsible for the uplift of the mountain ranges surrounding the Central Valley.

Uplift has caused the mountainsides to erode, depositing thousands of layers of sediment on the Central Valley floor (Thompson 1961). Continued subsidence, the downward shifting of the Earth's surface, has lowered the Valley, reduced stream gradients and encouraged alluviation (Thompson 1961:297). Large proportions of the sands and gravels currently found on the Valley floor are the result of periods of uplift and sedimentation during the Pliocene (5-1.8 mya) and the Pleistocene (1.8 mya-10,000 kya) epochs (Schoenherr 1992). Today, in the Valley basin, sands and gravels over 30,000 feet (9500 m) deep lie on top of Sierran basement rocks (Schoenherr 1992).

During the early to middle Pleistocene (~1 mya-750 kya), uplift of the Coast Ranges cut off the Valley's southern outlet, turning it into a closed drainage system and causing most of the Valley to be covered by an inland lake known as Lake Clyde (Meyer and Rosenthal 2008). The disappearance of Lake Clyde between 600,000 and 450,000 years ago appears to mark the beginnings of the current drainage through the Carquinez Strait, which connects Suisan Bay with San Pablo Bay near the modern city of Vallejo (Meyer and Rosenthal 2008). As the continental ice sheets began to melt around 19,000 years ago, sea levels rose rapidly, creating the lower San Francisco Bay and inundating

the lower reaches of the Central Valley (Meyer and Rosenthal 2008). Around 7000 years ago rates of sedimentary deposition in the Delta began to equal or outpace the rise in sea level (Meyer and Rosenthal 2008). Following this period of sedimentary deposition approximately 5,550 years ago, the flood plain around the Sacramento-San Joaquin Delta stabilized, while the slowly encroaching sea allowed the Sacramento-San Joaquin Delta to expand (Rosenthal et al. 2007).

While the Central Valley is currently one of the richest agricultural centers in the world, the Valley is actually quite dry, with the upper Sacramento Valley averaging a little above 75 cm, the lower Sacramento Valley averaging 46 cm, and the southern San Joaquin averaging less than 25 cm of precipitation per year (Schoenherr 1992; Moratto 1984). Average temperatures range from 70 to 90° Fahrenheit in July and 40 to 50° Fahrenheit in January (Moratto 1984:171).

The habitats of the Central Valley have traditionally included riparian forest, marshes, alkali basins, oak savannas, and foothill woodlands, all of which can be found within a day's walk of each other in the Valley basin (Rosenthal et al. 2007). In 1842, Theodore Cordua, the founder of Marysville, noted the presence of oaks (*Quercus sp.*), willows (*Salix sp.*), alders (*Alnus rhombiflora*), sycamores (*Plantanus racemosa*) and grape vines (*Vitis californica*) along the riverbanks (Thompson 1961). Before 1850, riparian forest is estimated to have been 10 miles (16 km) wide in some areas and covered 900,000 acres of the Central Valley (Anderson 2005; Shoenherr 1992). The riparian environment also would have included cottonwoods (*Populus fremontii*), Oregon ash (*Fraxinus latifolia*), elderberry (*Sambucus sp.*), rose (*Rosa californica*), button berry (*Cephalanthus occidentalis*), and honeysuckle (*Lonicera sp.*) (Schulz 1981).

Much of the Valley was covered in grassland and included annuals such as tomcat clover (*Trifolium willldenowii*), gilia (*Gilia sp.*), fiddleneck (*Amsinckia menziesii*), blow-wives (*Achyrachaena mollis*), and false monkey flower (*Mimetanthe pilosa*) and perennials like gumweed (*Grindelia sp.*) and California poppy (*Eschscholzia californica*) (Moratto 1984). Perennial bunchgrasses, such as purple needlegrass (*Nassella pulchra*), nodding needlegrass (*N. cernus*), one-sided bluegrass (*Poa secunda* subsp. *secunda*), poverty three-awn (*Aristida divaricata*), and deergrass (*Muhlenbergia rigens*), would have dominated the valley grassland (Anderson 2005; Madden et al. 2005). In the arid southwestern part of the Valley, vegetation would have been sparse, being limited to sagebrush (*Artemisia sp.*), salt grass (*Distichlis sp.*), yerba mansa (*Anemopsis californica*), nitrophilia (*Nitrophilia mojavense*), alkali heath (*Frankenia sp.*), salt brush (*Atriplex sp.*) and short grasses (Moratto 1984:170).

A study of nine archeological sites along the Sacramento floodplain provided faunal evidence for the presence of fish, such as cyprinids, catostomids, and perch (*Archoplites interruptus*) (Broughton 1994). Archaeological research also uncovered the remains of anadromous fish such as, Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), and white sturgeon *Acipenser transmontanus*), as well as the western pond turtle (*Clemmys marmorata*) (Broughton 1994). The Valley streambeds would have also provided an abundance of freshwater mussels (*Margaritifera sp.*).

Broughton's 1994 faunal study also analyzed the remains of mammals such as cottontail rabbits (*Sylvilagus sp.*), tule elk (*Cervus elaphus nannodes*), black-tailed deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), black-tailed jackrabbits

(*Lepus californicus*), squirrels, and beaver (*Castor canadensis*). The Central Valley was home to mink (*Neovison vison*), weasels (*Mustela sp.*), river otters (*Lutra canadensis)*, raccoons (*Procyon lotor)*, coyotes (*Canis latrans)*, badgers (*Taxidea taxus)*, skunks (*Mephitis sp.)*, mountain lions (*Puma concolor*), wolves (*Canis lupus*), kit foxes (*Vulpes macrotis)*, bobcats (*Lynx rufus*), and grizzly bears (*Ursus arctos horribilis*) (Moratto 1984).

Faunal evidence suggests that archaeological populations consumed various migratory anatids (ducks and geese). The Valley riparian environment also housed various resident birds such as, white pelicans (*Pelecanus erythrorhynchos*), great blue herons (*Ardea herodias*), black-crowned herons (*Nycticorax nycticorax*), ibis (*Plegadis chihi*), cranes (*Grus sp.*), cormorants (*Phalacrocorax sp.)*, and eagles (*Aquila sp.*) (Moratto 1984).

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Prehistoric Native Americans Communities
in the Central Valley

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<u>Windmiller Pattern Chronology</u>

Efforts to provide a chronology for the Windmiller cultural sequence began with the first excavations of Windmiller sites in the late 1920's and 1930's. In 1929, Schenck and Dawson published a monograph which stated that the ten Windmiller sites excavated by Dawson along the Cosumnes-Mokelumne river region indicated a brief cultural occupation that extended as far back as 1500 years at most, and that could be divided into 3 groups: I, Late Historic (post 1848 AD); II, Late Prehistoric and Early Historic (between group I and group III); and III, Prehistoric (maximum age of 500 AD). Heizer (1974) notes that Dawson recognized that the artifacts recovered from these

prehistoric sites could be seriated by time period, indicating cultural change over time, but that Schenck refused to accept this idea, leading to the inaccurate conclusions that the cultural sequence was brief and recent.

In the 1930s, Lillard and Purves (1936), Lillard et al. (1939), and Heizer and Fenenga (1939) used the relative depth and grave good associations of Consumnes river sites to establish a cultural sequence of: Early, Intermediate (later replaced by Transitional) and Late Periods. Beardsley (1948) amended this system of classification, calling each period a Horizon and reclassifying the Transitional Period as the Middle Horizon. Beardsley (1948) split each Horizon into provinces, which are defined as areas of cultural similarity that showed geographic consistency whose cultural units are known as facies. Facies are composed of groups of related settlements known as components. In 1949, Robert F. Heizer published a monograph on the Early Horizon of Central California and assigned dates to each Horizon as follows: Early Horizon (2500 B.C.); Middle Horizon (1500 B.C.); Late Horizon, Phase I (500 A.D.); Late Horizon, Phase II (1700 A.D.); and Late Horizon, Phase III (1800 A.D.)

During the early 1950s, Cook and Heizer (1953) attempted to use chemical analysis of fossilized bone to chronologically date the central California cultural sequence with little success. In 1956 and 1957, J.B. Griffin and W.F. Libby, the inventor of ^{14}C dating, radiocarbon dated samples from the Windmiller site of SJO-68, known as the Blossom Mound (yielding dates of 4052 ± 160 years B.P., 4100 ± 250 years B.P., and 4350 ± 250 years B.P.; Heizer 1974). In 1958, Heizer conducted a review of the available radiocarbon dates and suggested that the Middle Horizon began 4000 years ago (2000

B.C.) and ended around A.D. 300, pushing back the beginning of the Early Horizon to 4000 B.C.

Using grave lots as the basic unit of analysis, Bennyhoff and Hughes (1987) created *Olivella* shell bead typologies in order to track trade networks between California and the Great Basin over time and space. Analyzing stratigraphy, burial context, seriation, and comparative sets of radiocarbon dates, Bennyhoff and Hughes (1987) created dating scheme B1. In order to create a chronological system that could potentially be used throughout California, the authors chose to move away from the culturally linked horizons, which vary even among adjacent regions, in favor of temporal periods (Bennyhoff and Hughes 1987:99). The Bennyhoff and Hughes (1987) chronological sequence consists of an Early Period (3000-500 B.C.), a Middle Period (200 B.C.-A.D. 700) and a Late Period (A.D. 900-1800), with a Early to Middle Period Transition between 500 and 200 B.C and a Middle to Late Period Transition between A.D. 700 and 900. Although this chronology has flaws, such as its use of radiocarbon dates provided from different material and obtained from multiple contexts, it is still the predominate chronology used by many archaeologists in Central California. A study by Groza (2002) attempted to evaluate and refine the B1 dating scheme by recalibrating 162 of the original dates and AMS-dating an additional 103 *Olivella* shell beads. While the new dates by and large supported the Bennyhoff and Hughes (1987) chronology, Groza (2002) found that the Middle Period extended for a longer period of time than previously thought, pushing back the dates for the beginnings of the Middle to Late transition and the Late Period. Therefore, in striving for greater accuracy, I use Groza's scheme D chronology (Table 1).

Table 1. California cultural chronology.

Period	Approximate Dates (Scheme B1) (Bennyhoff and Hughes 1987)		Calibrated Dates (Scheme D) (Groza 2002)	
	B.P	B.C./A.D.	B.P.	B.C./A.D.
Late Period	1050-200 B.P.	A.D. 900-1800	740-230 B.P.	A.D. 1210-1720
Middle/Late Transition	1250-1050 B.P.	A.D. 700-900	940-740 B.P.	A.D. 1010-1210
Middle Period	2150-1250 B.P.	200 B.C.-A.D. 700	2160-940 B.P.	210 B.C.-A.D. 1010
Early/Middle Transition	2450-2150 B.P.	500-200 B.C.	2450-2160 B.P.	500-210 B.C.
Early Period	4950-2450 B.P.	3000-500 B.C.	>3450-2450 B.P.	>1500-500 B.C.

Source: Adapted from Groza, Randall G., 2002, An AMS Chronology for Central California Olivella Shell Beads. Unpublished Master's Thesis, Department of Anthropology, California State University, San Francisco, p. 95.; Bennyhoff, James A. and Richard E. Hughes, 1987, Shell Bead and Ornamental Exchange Networks Between California and the Great Basin. Anthropological Papers of the American Museum of Natural History 64(2).

The Windmiller Pattern

Before discussing the Windmiller Pattern at length, it should be noted that the Windmiller are not a "people" with a cohesive culture. Individuals assigned to the Windmiller of the Early Period, are tied to each other through commonality in burial practices and artifact assemblages. Currently, we know very little about the people who inhabited these sites. At present, there is not enough evidence to solidly suggest that shared cultural ties such as shared language, oral history, ceremonial practices, common kin, or religion, at Windmiller sites.

The Windmiller cultural complex is primarily defined by burial patterns. Windmiller burials are characterized by the body lying ventrally in an extended position with the head oriented to the west. Although no one is certain of the exact reason for this particular burial pattern, Schulz (1970; 1981) proposed that the westward orientation of the burials follows the arc of the setting sun throughout the winter and that it is possible that a large majority of these deaths

occurred during the winter months. Heizer (1949) also noted that nearly all of the burials

excavated from the Windmiller sites such as the Windmiller Mound (CA-SAC-107), the

Blossom Mound (CA-SJO-68), the McGillivray Mound (CA-SJO-142) and the Phelps

Mound (CA-SJO-56), exhibited bound ankles as part of the burial ritual. The significance

of this mortuary practice is unclear.

The majority of Windmiller sites were initially discovered on raised mounds

overlooking marshland and riparian forest near the confluence of the Mokelumne and

Cosumnes Rivers in the Sacramento-San Joaquin Delta (Heizer 1949; Ragir 1972;

Rosenthal et al. 2007). However, several sites from the San Joaquin Valley, including

CCO-18/548, CCO-637, CAL-237, and CAL-629/630, all contain ventrally and dorsally

extended burials that are contemporaneous with Delta Windmiller settlements (Rosenthal

et al 2007:154). This suggests that the Windmiller pattern was not confined strictly to the

area surrounding the Delta.

Though the climate of the area is Mediterranean, the Cosumnes River

watershed is characterized by periods of drought and flooding (USDA Natural Resources

Conservation Service 2002). Heizer (1949) proposed that the locations of the mound sites

excavated in the 1920's and 1930's were strategically placed on high ground to avoid

flooding.

The B1 dating scheme devised by Bennyhoff and Hughes (1987) places the

Windmiller period from 3000-500 B.C. Windmiller sites in the Central Valley date from

1850-750 cal B.C., with the exception of part of the Blossom Mound which dates to 3050

cal B.C. (Rosenthal et al. 2007). Two sites from the Diablo Ranges that are

contemporaneous to the Windmiller culture appear to share some of its mortuary

practices and have been dated to between 4950 and 3050 cal B.C., suggesting that the Windmiller pattern may be even older than previously thought (Rosenthal et al. 2007).

In regard to material culture, sites associated with the Windmiller pattern are characterized by phallic charmstones, cylindrical or flattened spindle-shaped charmstones with end perforations, large projectile points with concave bases or contracting stems, rectangular abalone (*Haliotis*) beads, quartz crystals, square *Mytilus* beads, spire ground olive shell (*Olivella*) beads and an assortment of abalone pendants (Schulz 1981). Bone awls, needles, bird bone tubes, bone scrapers and flakers are present, although not in abundance (Beardsley 1948; Ragir 1972). Additionally, a few human bone tools, notably a container made from a calvarium, a proximal radius whistle, and a fibula dagger, have been recovered from a few Windmiller sites (Heizer and Fenenga 1939; Heizer 1949). Leaf-shaped, concave-base, or stemmed and shouldered projectiles are associated with the Windmiller pattern (Heizer and Fenenga 1939). The size and weight of these large, heavy duty obsidian, quartzite, flint, chert, slate, basalt, or quartz crystal projectiles and knife blades may indicate that the Windmiller people favored the atlatl as a hunting tool (Heizer 1949). Impressions left on baked clay objects indicate that the Windmiller people also made use of twined basketry (Beardsley 1948).

Moratto (1984) remarks that the Windmiller people must have engaged in some form of trade because many artifacts are not native to the Valley; obsidian would likely have come from the Coast Ranges and *Haliotis* and *Olivella* shell beads would have been transported from the coast. The presence of quartz crystals, alabaster, calcite, and amphibolite schist, all of which are found in the foothills of the Sierra Nevada, led Moratto (1984) to posit that some Windmiller populations may have occupied the Sierra

Nevada foothills during the summer and returned to the Valley during the winter.

Although it has yet to be tested, if this theory is correct, it may explain why so many of

the Windmiller people buried in the Valley may have been buried there in mid-winter.

<u>Windmiller Cultural Material and Patterns</u>
  <u>of Subsistence</u>

In his 1949 report on the Early Period sites belonging the Windmiller culture,

Heizer suggested that a few of the mound sites were cemeteries, while others, such as

SJO-68, were village midden sites. Meighan (1987) later questioned the idea of SJO-68

as a village midden site. He noted that the material remains and domestic refuse

indicative of a village midden (manos, metates, mortars, fishing and hunting implements,

faunal remains, etc.) collected at SJO-68 were meager in comparison to the size of the

site (Meighan 1987). While the paucity of artifactual data related to occupation is partly

due to limited excavation, Meighan (1987) concluded that the mound sites used to define

the Windmiller village complex were not indicative of everyday living because artifacts

recovered from these sites were probably all from funerary contexts. Earlier Schulz

(1981:90) had drawn a similar conclusion, stating that,

> The absence of plant remains, the paucity of faunal materials, the low levels of
> baked clay or stone debris and charcoal, and even the fact that the vast majority of
> the most abundant utilitarian artifacts-flaked stone bifaces-are complete specimens,
> all differ from the pattern which should result from domestic occupation.

Thus, it is difficult to use the material culture excavated from several of the Mokelumne-

Cosumnes area Windmiller sites to fully understand the daily lives of the people

associated with Windmiller pattern because they are most likely from a mortuary context

and are not indicative of village occupation.

Regardless of the dearth of material evidence linking certain types of subsistence strategies to the Windmiller Pattern, there is artifact evidence that may link the Windmiller population to particular subsistence economies. The bones of anadromous fish, such as salmon and sturgeon, bipointed bone gorge hooks, single-piece curved bone fish hooks, fishing tridents made of antler, and pecan-sized baked clay objects that may have served as fishing lures all attest to some form of fishing (Rosenthal 2007; Moratto 1984; Ragir 1972; Heizer 1949). Bones of thick-tailed chub (*Gila cranssicavada*), hardhead (*Mylopharodon conocephalus*), and the western pond turtle (*Clemmys marmorata*) have been recovered from SJO-68 (Broughton 1994; Ragir 1972). Historical accounts have documented the presence of Chinook (king) salmon (*Oncorhynchus tshawytscha*) in both the Mokelumne and Cosumnes Rivers, with a fall and spring run occurring in the Mokelumne and a fall run occurring in the Cosumnes respectively (Yoshiyama et al. 1996). Chinook salmon are the largest salmon found in California and historical accounts recall salmon that may have weighed an excess of 20 lbs. (Madden et al. 2005; Yoshiyama et al. 1996). The presence of animals that would have provided large quantities of food, archaeological evidence of fishing, and the close proximity of Delta Windmiller sites to riverine environments suggests the potential inclusion of fish in the Windmiller diet.

However, the archaeological record indicates that anadromous fish were rarely exploited by prehistoric populations in the Delta. Broughton (1994) found that early prehistoric sites, such as SJO-68, were dominated by medium and large sized mammals, and that freshwater fish were overwhelmingly more abundant than anadromous fish. Broughton (1994) noted that salmon are actually less abundant at archaeological sites

closest to the river mouth and the San Francisco Bay estuary, where relative abundance

would be expected to be highest. A 2004 study by Gobalet et al. examined 29,265 fish

bones recovered from several archaeological sites in the Central Valley. Gobalet et al.

(2004) found that native species of Sacramento perch (*Archoplites interruptus*),

Sacramento sucker (*Catostomus occidantalis*), thick-tail chub (*Gila crassicauda*),

Sacramento blackfish (*Orthodon microlepidotus*), hitch (*Lavinia exilicauda*), and tule

perch (*Hysterocarpus traskii*) accounted for 84.9% of the fish bone found at sites in the

Central Valley, while salmonids accounted for only 6.3%. The conclusions of Gobalet et

al. (2004) are further supported by carbon and nitrogen analysis from human skeletal

remains in the Sacramento Valley, which suggests that the prehistoric diet relied heavily

on C3 terrestrial resources and freshwater fish, while overlooking anadromous fish

(Bartelink 2006). Broughton (1994) has suggested that the lack of anadromous fish found

at Delta sites may have been due to the fact that the quantity of water was too massive to

effectively use fishing weirs to catch anadromous fish. Hence, the people who inhabited

Windmiller sites may have been more likely to focus their attention on terrestrial plant

resources and freshwater fish.

　　　　In addition to fish bones, animal bones have been recovered from Windmiller

sites. In her 1972 dissertation chronicling the Early Horizon in Central California, Ragir

(1972) included a list of faunal remains excavated from SJO-68 that had been identified

by May Lou Perry in 1952. Tule elk (*Cervus elaphus nannodes*), deer (*Odocoileus sp.*),

and pronghorn antelope (*Antilocapra americana*) were the most well represented species,

although California ground squirrels (*Spermophilus beecheyi*), jack rabbits (*Lepus sp.*),

and marsh rabbits (*Sylvilagus auduboni*) were recorded (Ragir 1972). Several species of

swamp and tule marsh dwelling birds, such as teal (*Anas sp.*), tule goose (*Anser albifrons*), mud hen (*Fulica americana*), Canada goose (*Branta canadensis*), raven (*Corvus corax*), cormorant (*Phalacrocorax sp.*), and turkey vulture (*Catarites aura*), were also identified (Ragir 1972). Heizer (1949) used this distribution of animal bones, as well as the large number of heavy projectile points, to argue that the Windmiller culture relied primarily on large game hunting. While evidence of game hunting is apparent, assuming the Windmiller population practiced a subsistence economy based primarily on hunting should be treated with caution due to the fact that the Windmiller Delta sites upon which Heizer based his conclusions have not yielded substantial quantities of faunal remains. Furthermore, many of the large projectile points that are commonly associated with heavy spear throwers and atlatls are from Windmiller funerary contexts, meaning they could instead have had a ceremonial function (Meighan 1987).

Archaeological evidence pertaining to terrestrial resource processing technology and archaeobotanical evidence has yielded mixed interpretations about the importance of plant resources in Windmiller subsistence patterns. During the initial excavation period, the paucity of mortars, milling stones, pestles and other artifacts associated with plant food production, bolstered the conclusion that hunting, not gathering was the primary mode of subsistence throughout the Windmiller Pattern (Heizer 1949). However, continued excavation revealed that mortars and pestles were actually fairly common (Heizer 1974; Ragir 1972). Metates, which are thought to have been used for seed grinding, were recovered from the Early Period deposits at SAC-107, while mortars and pestles appear as early as 4050 cal B.C. at some sites in the southern Sacramento and northern San Joaquin Valleys (Rosenthal et al. 2007; Heizer 1949).

Heizer (1974:188) points out that "the stone mortar is practically a necessity to the recent California Indians for grinding acorns into meal." Therefore it is tempting to associate the presence of mortars and pestles with some form of acorn pounding. Nevertheless, Schulz (1981) suggested that ochre staining found on Early Period mortars meant that they were used for activities that had little to do with subsistence.

Furthermore, there is no archaeobotanical evidence of acorn usage from Windmiller sites excavated in the Delta during the 1920's and 30's (Rosenthal et al. 2007). Basgall (1987) attributes this to factors such as poor preservation and the fact that many early excavation projects did not use screens. However, pine nuts and acorn shells are common to archaeobotanical assemblages recovered from CCO-637 and CCO-18/548, sites in Central California which are thought to be contemporaneous with Windmiller sites (Rosenthal et al. 2007).

There has also been speculation that the high proportion of baked clay balls found at Windmiller sites were used for cooking in much the same way fire heated rocks were used in other areas of California (Fagan 2003; Ragir 1972; Heizer 1949; Beardsley 1948). Fagan (2003) proposes that the heated baked clay balls were used to cook acorn mush. During historic times, acorn mush was cooked by heating stones in a fire and placing them in baskets filled with water (Buonasera 2005; Merriam 1918). The Miwok apparently used the same technique to make *Godetia* mush (Segerstrom 1973). Evidence of twined basketry has been recorded from clay impressions found at the Windmiller sites of SJO-68 and SJO-142 (Heizer 1949). Therefore, it is possible that the Windmiller people used heated baked clay balls and baskets to cook terrestrial foods such as acorn mush.

Potential Dietary Reconstruction: Ethnographic
and Ethnobotanical Evidence from the
Historic Plains Miwok

In the past, contemporary populations have been used as replacements for extinct populations by members of the anthropological and archaeological community. However, it is incorrect to assume that modern and historic native populations, their subsistence strategies, and their activity patterns are comparable to those of prehistoric societies. For example, a shell artifact that was not actually used as a spoon in the past may be labeled as a spoon if it is found in close proximity to a modern community that possesses a shell spoon that looks very similar to the artifact.

While no modern or historic population is an adequate analogy for an archaeological population, sometimes it is useful to evaluate ethnographic data and ethnohistoric accounts of native peoples in order to understand the possible resources available. At the present time, these Windmiller sites have not been associated with a living California Native American tribe. However, it is known that the Plains Miwok inhabited the same geographic area during historic times. In the case presented below, ethnographic evidence of the lifeways and food knowledge of the Plains Miwok is used as a means of understanding the local edible resources and technologies that could have been available to people inhabiting sites associated with the Windmiller Pattern in the Delta region of the Central Valley.

The Plains Miwok

The Miwok are a collection of linguistically related California Native Americans tribes that, during late prehistoric and historic times, inhabited the Delta area from which Windmiller Pattern sites have been excavated. The Miwok have traditionally

inhabited areas along the San Francisco Bay, the mid-Central Valley, and the Sierra Nevada. A 1974 report on the Native Americans of California, subdivided the Miwok into the Coast Miwok, Lake Miwok, Plains Miwok and Sierra Miwok (Beals and Hester 1974).

In the Miwok language, the word Miwok means "The People" (Segerstrom 1973). The Miwok language belongs to the Yok-Utian branch of the Penutian language family which, in California, also includes the Maiduan and Wintuan language branches. The speculation is that Yok-Utian speakers migrated to California from the northern portion of the Great Basin by crossing the Sierra Nevada (Golla 2007). Golla (2007) has suggested that the plant and animal lexicon of proto-Utian language was spoken in the Sacramento-San Joaquin Delta around 4500 years ago, making it contemporary with the Windmiller Pattern. This Delta lexicon, along with archaeological continuity between the northern Great Basin and Columbia plateau traditions and the Windmiller Pattern, have led to the suggestion that there is a correlation between the Windmiller Pattern and the Yok-Utian language branch (Golla 2007).

The Plains Miwok would have inhabited the area where Windmiller sites are commonly found. Beals and Hester (1974) have estimated that the Plains Miwok inhabited an area of 1060 square miles between the San Joaquin and Sacramento Valleys, near the confluence of the Sacramento and San Joaquin rivers. Bennyhoff (1977) envisions this area as a trapezoid delimited by the Yolo basin in the west, the American River in the north, the Sierra Nevada Mountains in the east and the Calaveras River in the south, at a latitude of 38˚ north and a longitude of 121˚ west.

Relatively little is known about the Plains Miwok due to the fact that the majority of their population was decimated before studies of California Native American populations began. In the early 18th century, the Spanish described villages of over 1000 Plains Miwok (Heizer and Elsasser 1980). In 1833, an epidemic of disease devastated the Native American populations of the Sacramento and northern San Joaquin Valleys (Cook 1955). Cook (1955) estimated the mortality rate from the epidemic, which may have been malaria, to be around 75% (20,000 people) among the Central Valley Native American populations. After the epidemic, many of the Miwok continued to live in the foothills and on the mountainsides of the Sierra Nevada. Unfortunately, the California Gold Rush of 1849 brought further problems for the Miwok. The gold miners sluiced rivers and destroyed native fish populations (Conrotto 1973). Farmers fenced in aboriginal land, denying the Miwok access to many sources of food. Miwok villages were pillaged and burned, while many of the Miwok were murdered or enslaved, and many more were left to starve after miners took over the Miwok's traditional lands, cutting off their resources (Burrows 2000; Maniery 1987; Conrotto 1973). In his account of how the intrusion of whites during the California Gold Rush impacted the lives of the Miwok people, Segerstrom (1973) notes that Miwok access to their deer and antelope hunting grounds, insect, bird, snake, and lizard trapping areas, their beetle, grub, and worm digging spots, and the marshes where the *Godetia* grew was disrupted by white gold diggers. The Plains Miwok were concentrated at the western edge of the Mother Lode and very few of them survived the Gold Rush (Bennyhoff 1977). In addition to declines based on disease and the aftermath of the Gold Rush, Bennyhoff (1977) suggests that the cultural obscurity of the Plains Miwok is due to the fact that most of the Native Americans from adjacent

tribes who were settled on missions never returned to their native lands, robbing the area of almost all knowledgeable informants.

The Plains Miwok belonged to the Kuksu religious cult and their family groups were patrilineal and patrilocal (Bennyhoff 1977). Bennyhoff (1977) has suggested that the Plains Miwok were divided into approximately 28 tribelets, each ruled by a headman. The Miwok lived in tule-thatched houses on the banks of watercourses and used tule balsas to navigate waterways (Conrotto 1973; Mooney 1890). The Miwok utilized basic wood tools, wove twinned and coiled baskets, and also shaped clay into various useful objects, such as cooking stones (Bennyhoff 1977). On the open plains of the grasslands heavy stones would have been hard to come by and stone pestles were more than likely lineage property belonging to all the women of a communal household (Bennyhoff 1977). The Plains Miwok traded grass seeds and fish to the northern Miwok in exchange for finished arrowheads, digger (gray) pine nuts, salt, and obsidian (Conrotto 1973).

In regard to the sexual division of labor, men hunted and fished, while women did almost all of the gathering (Wallace 1978; Willoughby 1974). With the exception of the initial gathering stage where men climbed trees and knocked down pine cones and acorns with sticks, the lengthy process of carrying, leaching, and pounding acorns, as well as gray pine nuts, fell exclusively within the domain of women (Willoughby 1974). Miwok women also collected all seeds, berries, and roots (Willoughby 1974). Plains Miwok men were responsible for the manufacture of all of the industrial goods pertaining to hunting, fishing, and ceremonies, while women most likely made all of the basket utensils, tule mats, cradles, waist aprons, and baked clay cooking stones (Bennyhoff

1977). Basketry was solely the domain of Plains Miwok women, although, interestingly, men made all of the string and cordage and did all of the weaving (Bennyhoff 1977; Willoughby 1974).

Plains Miwok Subsistence

Before European settlement, the Plains Miwok were considered the "wealthy" or the "lucky" Miwok because their environment was "rich with waterfowl, delta vegetation, and deep-water fish" (Conrotto 1973:2-3). As a hunter-gatherer economy, the relative abundance of food in the Delta and grassland environment would have given the Plains Miwok an advantage over their Sierra kin in terms of providing for their families.

Protein Resources

Historic accounts mention that the people who lived on the Cosumnes and Mokelumne rivers gathered seeds, caught salmon, and ate an unidentified species of pounded root (Schenck 1926). Schenck (1926) quotes a statement made by explorer Otto von Kotzebue that deer were so abundant that a person could ride among them without frightening them and geese and ducks could be knocked over with a stick. Dwarf (tule) elk were found in the Delta and pronghorn were abundant on the plains in Plains Miwok territory (Barrett and Gifford 1933). Parties of 10 to 15 men would divide themselves up and drive the pronghorn toward a waiting contingent of the hunting group (Barrett and Gifford 1933). The Plains Miwok men often hunted jointly and used nets to capture prey. Black-tailed jackrabbits and cottontails were communally driven into nets and clubbed, while fish were netted with weirs and ducks were netted with bait (Barrett and Gifford 1933). Fires were used to lure geese into close proximity of men with waiting clubs, while squirrels were shot with bows and arrows (Barrett and Gifford 1933). Beaver were

hunted by burning the tule around their ponds and hitting them with clubs (Anderson 2005). It appears that small mammals, such as lagomorphs and rodents, were of more economic significance to the Plains Miwok than larger prey such as elk and pronghorn (Bennyhoff 1977). Barrett and Gifford (1933) observe that the Plains Miwok were also known to eat river mussels and fresh-water clams.

Fire was also employed in the hunting of grasshoppers (Anderson 2005). The Plains Miwok would light fires at intervals throughout a certain radius of their territory in order to drive the grasshoppers into a particular area where another fire singed their wings, while women picked them up, crushed them between their thumb and forefingers and threw the dead grasshoppers into burden baskets (Mooney 1890). Mooney (1890) noted that the men would take bows and arrows and shoot small mammals as the heat from the grasshopper fire drove them out of the underbrush.

Terrestrial Plant Resources

The lowlands and eastern uplands of the Sacramento Valley would have provided the Plains Miwok with an abundance of terrestrial resources. The tidal plain was inundated with tule reeds and cat-tail rushes (*Typha sp.*), while the river bottoms were home to cottonwoods, poplars, sycamores, valley oaks (*Quercus lobata*), live oaks (*Quercus wislizeni*), buckeyes (*Aesculus californica*), laurels (*Umbellularia californica*), grapevines, willows, alders, and rose thickets (Bennyhoff 1977). Lupines (*Lupinus sp.*), soaproot (*Chlorogalum pomeridianum*), tarweed (*Madia sp.*), and many forms of Lilacaea (lilies), all of which were consumed by the Miwok, grew close to watercourses (Bennyhoff 1977; Barrett and Gifford 1933). The Valley plain was covered with bunch grasses, clover, sunflowers, and Valley oaks, while the eastern uplands supported gray

pines (*Pinus sabiniata*), live oaks, blue oaks (*Quercus douglasii*), and chaparral

(Bennyhoff 1977). Terrestrial plant resources, such as seeds, nuts, roots, bulbs, greens,

and berries[1], constituted the bulk of the Plains Miwok diet, while hunting and fishing,

despite the documented abundance of large game animals, remained a secondary activity.

Despite the amount of processing required, acorns remained the staple food

(Basgall 1987; Bennyhoff 1977). The Cosumnes river (Plains Miwok) Native American

culture was also noted to be fond of digger pine (also known as grey pine or foothill pine)

nuts, which they would knock down with short sticks, in addition to clover and wild oats

(*Avena fatua*)[2], which they would eat raw, and miner's lettuce (*Claytonia perfoliata*),

which they would steam or boil in earth ovens (Mooney 1890). All denominations of

Miwok were given the derogatory name of "diggers" by Europeans because they were

observed to carry digging sticks with them in order to dig out edible roots and bulbs

(Conrotto 1973).

The Miwok were known to harvest the seed of the *Godetia* flower, commonly

known as "Farewell-to-Spring" (currently designated as *Clarkia amoena*) in the foothills

during the beginning of summer (Segerstrom 1973). The seeds would be collected in flat

baskets, transferred into burden baskets, taken to the village, and stored for later usage

(Segerstrom 1973). Segerstrom (1973) notes that it was common for a hungry woman to

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[1] In Barrett and Gifford's 1933 study of the Miwok, the authors suggest that berries played only a minor part in the diet, being secondary to seeds, bulbs, and roots. Manzanita (*Arbutus sp.*) were almost always used to make cider, while other berries such as chokecherries (*Prunus virginiana* var. *demissa*), wild Sierra currents (*Ribes nevadense*), and gooseberries *(Ribes roezlii)* were eaten raw. Elderberries (*Sambucus sp.*) and a few others were cooked or dried (if dried they were usually reconstituted before being eaten.)

[2] Wild oats are an introduced species which probably arrived in California during Spanish exploration.

come home from seed collecting and make herself a small meal of *Godetia* mush. While

the community Segerstrom (1973) described was located in the foothills, his observations

are mentioned here because *Godetia* seeds have been recovered from pre-Windmiller

Strata II at the Marsh Creek site, indicating that the use of *Godetia* seeds was common in

the Central Valley even before the Windmiller pattern (Rosenthal et al. 2006). Therefore,

it does not seem unlikely that *Godetia* seeds would have remained important during the

Windmiller pattern.

Summary

The Sacramento Valley is an intermontane basin formed by tectonic activity

that encompasses the area between the Siskiyou, Tehachapis, Pacific Coast Ranges, and

Sierra Nevada mountain ranges. Though the area is fairly arid, the landscape is varied

and, in the past, would have provided abundant resources for its inhabitants. Beginning in

the 1920's and 30's, archaeologists began to attempt to figure out who inhabited the

Valley during prehistoric times. Archaeologists noted that burials unearthed from several

sites in the Sacramento-San Joaquin Delta shared the practice of burying the dead in an

extended position with the anterior of the body positioned ventrally and the head facing

west, leading all of the individuals who were buried this way to fall under the auspices of

what has become known as the Windmiller Pattern. However, the common occurrence of

flooding and alleviation in the Delta has made it difficult to ascertain enough material

evidence to create a picture of how the Windmiller People may have lived. Evidence of

their subsistence, recreational, and ceremonial activities is limited, although some

artifacts, such as mortars, metates, bone fishing hooks, baked clay balls, charmstones,

blades, and faunal remains do provide glimpses into the activities that may have been important. While direct comparisons between prehistoric and historic populations are tenuous at best, looking at the kinds of food hunted by the Plains Miwok, a modern native population that inhabited the same geographic area as the Windmiller people, may provide insight into the food and raw materials that would have been available to the Windmiller population.

CHAPTER III

LITERATURE REVIEW ON DENTAL

PATHOLOGIES

Dental pathologies often provide insight into the diet and activities of
prehistoric peoples. Dental pathologies can be used to make inferences about the kinds of
foods people consume, while wear patterns observed on the occlusal surface of the tooth
may provide information on particular kinds of activities, such as hide tanning, where the
teeth are used as tools. This chapter addresses the dental pathology known as dental
caries. I discuss the etiology of dental caries, as well as the subsequent dental infection
which, in its more advanced state, we commonly think of as "cavities." I address the
contested inverse relationship between dental caries and dental attrition, while providing
background on what dental attrition rates and pattern may suggest about the activity
patterns of modern and archaeological populations. This chapter also describes the
relationship between dental caries and dental abscesses and dental caries and antemortem
tooth loss (AMTL). After addressing the relationships between dental caries, attrition,
AMTL, and abscesses, I provide an overview on how dental caries can be used to infer
changes in diet. This general section on caries rates and subsistence is followed by a
summation of scholarly research conducted on differences in dental caries rates in males
and females, both archaeologically and in the modern era.

The Etiology of Dental Caries

Streptococcus mutans

      Streptococcus mutans are microbacteria that are found in the dense accumulations of tooth surface micro-organisms commonly known as dental plaque (Hillson 1996). *S. mutans* bacteria were first isolated and described by J.K. Clark in 1924 (Balakrishnan et al. 2000). However, a direct relationship between the bacillus and dental caries was not established until the 1960's when experiments conducted by Keyes illustrated that hamsters with no previous history of dental caries acquired dental caries when exposed to hamsters carrying caries active bacteria (Balakrishnan et al. 2000). While no one bacteria is considered solely responsible for the formation of dental caries, most carious lesions are thought to be related to the presence of the *S. mutans* group of streptococci, usually referred to as the mutans streptococci (MS) (Hillson 1996).

      S. mutans produces vast amounts of acids including lactic acid, which is known to rapidly lower plaque toward more acid pH by fermenting sucrose and other carbohydrates (Featherstone 2000; Hamada 1986). *S. mutans* fermentation of sucrose allows for the synthesis of water-insoluble glucan which adheres to the tooth surface (Hamada 1986). Although *S. mutans* can ferment other dietary sugars such as glucose and lactose, these sugars are less cariogenic than sucrose because only sucrose is used in extracellular polysaccharide synthesis (Balakrishnan et al. 2000: 237). Van Houte and Russo (1985:166) suggest that the relatively high acid tolerance and glucan-synthesizing ability of *S. mutans* may enhance the bacteria's total cell numbers and plaque concentration on smooth tooth surfaces.

Dental Caries

Dental caries is the process that causes the dissolution of hydroxyapatite crystals by organic acids which are produced through the fermentation of sugars by mutans streptococci (Larsen 1997; Newbrun 1982). The organic acids diffuse through dental plaque and into the porous subsurface enamel where they produce hydrogen ions that dissolve the mineral, freeing calcium and phosphate into solution (Featherstone 2000). The process that produces acidogenesis which leads to dental caries may be reversed through bacterial production of alkali products which, when redeposited by saliva, leads to remineralization (Featherstone 2000; Hillson 1979). However, ingesting large amounts of carbohydrates creates a dental environment that is unbalanced in favor of acid producing byproducts which leads to demineralization and dental caries (Hillson 1979).

Usually dental caries are detected at the point of cavitation of the tooth surface (Loesche 1986). However, this stage is preceded by subsurface lesions known as white spots which are visible with the naked eye and subsurface demineralization of the tooth which is only detectable microscopically (Loesche 1986:357). During the early stage, the spot lesion is composed of four zones (the intact surface layer, the lesion body, the dark zone and the translucent zone) and occupies a triangular area with its base at the crown surface and its apex facing the enamel-dentin junction (Hillson 1996:269-270). As the lesion develops, the surface layer breaks down forming an indentation in the tooth surface known as a cavity. If left untreated, dental caries may lead to destruction of the tooth enamel and invasion of the pulp chamber resulting in alveolar abscesses (Brook 2003).

There are four different types of dental caries: pit and fissure caries, smooth surface caries, root caries and deep dentinal caries (Newbrun 1982). Pit and fissure caries and smooth surface caries are considered to be coronal caries because both types occur on the crown on the tooth. Pit and fissure caries occur on the occlusal or chewing surface, while smooth surface caries occur on the side of the tooth, typically at the approximal (interproximal) surface (Hillson 2001). Hillson (1996:275) defines root surface caries as broad, shallow craters that extend around the circumference of the tooth root. Dentinal caries are dental caries involving exposure, demineralization and destruction of the dentin (Hillson 1996).

Sheiham (1997) has suggested that there is a defined hierarchy in regard to the susceptibility of particular tooth types and areas to dental caries. While both the left and right sides and the upper and lower cheek teeth are, for the most part, equally affected by coronal caries, the mesial upper crowns are affected more often than the lower crowns (Hillson 2001). The occlusal surface is the most common site of dental caries, with the first molar typically being the most commonly affected tooth (Carvalho et al. 1989). As the propensity towards dental caries rises in a population, the occlusal surface of the second molar is affected, followed by the upper and then lower approximal molar crowns, the occlusal surface of the first premolar, the occlusal surface of the second premolar, approximal sites on the upper incisors and lower first premolars, and the upper canines respectively (Hillson 2001:252). Histological experiments conducted by Juhl (1983) found that dental caries is localized around fissures on the occlusal surface of premolars. The pits and fissures found in the occlusal surface of the cheek teeth and the approximal surfaces between teeth have a higher incidence of dental caries due to the fact

that they are "prone to plaque formation, food retention and reduced salivary flow" (van

Houte 1994:677). Saliva raises the pH levels found in the mouth, thus counteracting the

pH lowering properties of *S. mutans* found on dental plaque (van Houte 1994). Therefore

when salivary flow is reduced, the mouth becomes more receptive to dental caries.

<u>Sex Patterns</u>

A number of researchers have also noted a disparity in dental caries

prevalence between males and females. Overall, dental caries are more common and

occur with greater frequency in females than in males, both in modern populations and

archaeological skeletal assemblages (Lukacs 2008; Bartelink 2006; Lukacs 1996; Larsen

et al. 1991; Walker 1988; Hollander and Dunning 1939).

Hollander and Dunning (1939) analyzed dental data from 12,753 employees

of the Metropolitan Life Insurance Company in New York City. Hollander and Dunning

(1939) argued that the this data was superior to other previous data collection methods

because the sample was composed of every single employee at Metropolitan Life,

meaning that all types of occupations, from bricklayers to executives, all age groups and

both sexes were represented. Moreover, due to the company's policy that all of its

employees have a dental examination, the sample was not skewed in favor of individuals

who were in need of dental care. These results indicated that the prevalence of dental

caries was almost always significantly higher in females than in males aged 17 to 65,

with the difference being very slight below age 34, but increasing markedly from 34

onward.

In 1938, Klein and Palmer tested the hypothesis that notable differences in the

frequency of dental caries in boys and girls was due to greater susceptibility of girls to

caries. Analyzing the dental records of 4,416 elementary school aged children (2,232 boys and 2,184 girls) from the community of Hagerstown, Maryland, Klein and Palmer (1938) found that girls did not have a greater susceptibility to dental caries than boys, but rather that the higher prevalence noted in girls was due to the fact that the female dentition erupts earlier, creating a longer period of exposure to the bacterial processes that lead to dental caries. Hadjimarkos and Storvick (1948) drew the same conclusion when analyzing the higher prevalence of dental caries in all age groups of female freshmen from Oregon State College. In a more recent study, González et al. (1993) cited earlier dental eruption as the possible cause of the skewed distribution of dental caries observed in middle school aged girls (ages 11-17) from the Tlalpan region of Mexico City.

Taking a different approach, Walker and Hewlett (1990) conducted a study in Zaire that compared the dental health of Aka, Mbuti and Efe pygmies to each other and to their Bantu village neighbors. Dental examinations revealed that Aka and Mbuti women have a higher rate of dental caries than Aka and Mbuti men, especially after age 30. Walker and Hewlett (1990) suggested that Mbuti and Aka women had a higher rate of dental caries and antemortem tooth loss as a result of eating a higher proportion of starchy plant foods than the men who ate more meat. Walker and Hewlett (1990) found that the Aka and Mbuti women's habit of snacking while gathering and preparing food contributed toward higher rates of dental caries in women than men, who tended not to eat between meals.

In contrast, Lukacs and Largaespada (2006) proposed that the disproportionate number of dental caries found in women is at least partially due to inherent biological

changes that are caused by the relationship between hormone levels and salivary flow.

While the authors contend that behavioral and cultural mechanisms have an influence on

caries rates among the sexes, Lukacs and Largaespada (2006) believe that anthropologists

too often ignore the role that biology plays in human maladies. Citing evidence from

several clinical studies on hormone production and salivary flow and using the prehistoric

Guanche of the Canary Islands as an example, Lukacs and Largaespada (2006) suggested

females possess greater amounts of dental caries as a result of fluctuations in estrogen

levels that are correlated with dental caries because of the fact that hormone shifts cause

the mouth to produce less saliva. As saliva is responsible for distributing the calcium and

phosphate ions needed for the remineralization of teeth, a reduction in salivary flow leads

to an oral environment that is more receptive to the bacteria responsible for causing

dental caries (Lingström and Moynihan 2003). In accord with the idea of low salivary

flow being correlated with sex, a study of xerostomia (dry mouth) conducted in Halland

province, Sweden found that women, regardless of age, all reported higher proportions of

symptoms associated with xerostomia than men (Nederfors et al. 1997). Laine (2002)

also highlighted the association between dental caries, reduced salivary flow and reduced

levels of calcium and phosphorous found in the saliva of women during pregnancy,

although the author believes that multiple factors, such as increased snacking, contribute

to the poorer dental health recorded in pregnant women. It should be noted that sex

differences related to hormone production may not become a factor until puberty, when

changes in hormone level differ markedly for males and females.

      While part of the disparity in caries prevalence between males and females

may be explained through inherent physiological differences in hormones levels and

saliva production, intrinsic etiological predispositions toward dental caries probably do not provide the entire basis for sex based disparities in modern and archaeological human populations (Lukacs and Largaespada 2006). Thus, differences in dental caries prevalence rates by sex are important because they may enlighten bioarchaeologists about sex differences in the types of food consumed in prehistory. Furthermore, sex based variation in food consumption may shed light on differences in male and female activity patterns.

Dental Abscesses

A dental abscess is a lesion found on the alveolar bone resulting from the accumulation of pus due to inflammation (Hillson 1996). Typically, abscessing occurs when bacteria invade exposed tooth pulp, which leads to pulp death which produces pus (Scott and Turner 1998; Hillson 1996). When the pocket of fluid breaks through the alveolar wall it forms an abscess (Scott and Turner 1998). Abscesses involving the alveolar bone are often linked to the presence of dental caries, although abscessing may also occur in situations involving dental attrition, trauma and periodontal disease (Herrera et al. 2001; Scott and Turner 1998; Clarke and Hirsch 1991).

Antemortem Tooth Loss

Antemortem tooth loss is the loss of teeth during an individual's lifetime. Antemortem tooth loss is often differentiated from postmortem tooth loss by assessing the alveolus (tooth socket) for evidence of bone remodeling (Costa 1980). Antemortem tooth loss may be due to many factors including periodontitis, rapid/high rates of dental wear, pulpal exposure, excessive plaque and dental caries (Larsen 1995). Dental caries

that has exposed the pulp chamber makes it possible for *S. mutans* to travel down the root canal and through the apical foramen causing periapical inflammation in the surrounding bone, which can lead to bone loss that may loosen the tooth (Hillson 2001). More commonly, the presence of micro-organisms, such as *S. mutans*, contributes to inflammation which disrupts the periodontal ligament that is responsible for holding the tooth in the socket, resulting in loss of the alveolar bone lining the tooth socket (Hillson 2001:269). Antemortem tooth loss due to dental caries contributes to the underestimation of dental caries prevalence in prehistoric populations due to the fact that dental caries that were present on teeth cannot be evaluated by virtue of the fact that the tooth is no longer present (Lukacs 1995).

Dental Attrition

Dental attrition is the reduction (wearing away) of the enamel and dentin found on the occlusal surface of the tooth (Molnar 1971). Dental attrition can be looked at "as the result of a complex of interactions between the teeth, their supporting structures and the functioning of the chewing apparatus" (Molnar 1972:511). Dental attrition can be caused by a number of factors including habitual chewing of foreign materials, consuming a coarse diet, and repeated exposure to air containing high amounts of abrasive dust particles (Bowles et al. 1995). For instance, querns in stone-ground flour can grind against the occlusal surface and wear down the teeth (Hillson 1979). Bowles et al. (1995) even found that tobacco products contain minute particles of silica that can, over time, wear down an individual's teeth.

Rates of dental attrition have been used to argue for differences in subsistence practices due to the fact that hunter-gatherer populations tend to have higher rates of dental wear than agriculturalists (Larsen 1997; Molnar 1971). Hunter-gatherers tend to eat larger proportions of fibrous and hard foods. Chewing tough or fibrous food requires an individual to put greater amounts of stress on the teeth during mastication, which, ultimately, increases attrition (Richards 1984). A longitudinal study conducted by Teaford and Oyen (1989) found that Vervet monkeys who were fed soft foods had significantly less dental attrition than monkeys who were fed hard foods. Teaford and Oyen (1989) suggested that the difference in attrition between the monkey test groups was potentially due to the increased amount of time the hard food monkeys spent chewing. Smith (1984) examined the dentitions of prehistoric hunter-gatherers and agriculturalists. Smith (1984) found that hunter-gatherer's molars were often worn flat due to the greater amount of puncturing and crushing needed to chew harder, more fibrous foods; agriculturalists tended to develop an oblique molar pattern because their more refined diet allowed near or actual tooth to tooth contact during chewing.

However, grinding or pounding food in a stone basin, an activity practiced by both hunter-gatherers and agriculturalists, can also contribute to attrition. Grinding or pounding food tends to result in the unintentional consumption of small particles of stone (Molnar 1972). For instance, querns found in stone-ground flour tend to contribute to abrasion (Hilson 1979). Overtime, the stone particles abrade the teeth, wearing down the enamel.

Grit adhering to animal meat may also contribute to higher rates of attrition. For example, Lovejoy (1985) speculated that dental wear observed at the Libben site in

northern Ohio was caused by sandy grit adhering to dried fish. Littleton and Frohlich (1993) argued that dried fish were the contributing factor to dental wear observed on the Oman Arabian coast. Sand and silt particles are also often found in the shells of shellfish which would be relevant to wear patterns in areas, such as the San Francisco Bay, where large amounts of shellfish were consumed (Jurmain 1990).

Dental attrition from using teeth as tools tends to be localized and result in specific types of wear patterns. Molnar (1971) suggested that the unique wear pattern found on the maxillary incisors of women from the prehistoric site of CA-SJO-17 was likely due to pulling fibrous material between the teeth in order to make baskets. Schulz (1977) noted similar types of grooves on the anterior teeth in another prehistoric California population. Deep bucco-lingual grooving observed from the population of Atlit-Yam indicated that a pulling action was occurring between the 1st and 2nd molars, suggesting that the population may have been using their molar teeth as holding staves when making baskets and fishing nets (Eshed et al. 2006). Attrition found on the anterior teeth is often due to the using the teeth as a kind of third hand (Eshed et al. 2006). Teeth are also used to work hides (Molleson 1994; Merbs 1983).

Dental Caries in Archaeological Context

The relationship between dental caries and subsistence change has been extensively covered in the literature. Researchers in many parts of the world have documented shifts in dental caries rates during important economic transitions, most notably the shift to agriculture (Schollmeyer and Turner 2004; Beckett and Lovell 1994; Lukacs and Pal 1993; Larsen et al. 1992; Lukacs 1992; Larsen et al. 1991; Larsen 1981;

Hillson 1979). Dental evidence has also been used to argue that particular dental

pathologies, such as dental caries, may not have occurred with the same frequency in

males and females from the same prehistoric population and same region (Lukacs and

Thompson 2008; Lukacs 1996; Larsen et al. 1991; Walker 1988).

Dental Caries and Subsistence

      The Old World. Dental caries occurs in higher frequencies among populations

that rely on foods high in carbohydrates. The shift from a hunter-gatherer diet of mostly

terrestrial or marine meat protein to one of higher proportions of vegetal resources should

influence the amount of dental caries present in a prehistoric population. The protein rich,

highly varied diets of hunter-gatherer societies are thought to contribute to the low

incidence of dental caries among these groups, while the high proportion of

carbohydrates found in sedentary agricultural populations contributes to higher

frequencies of dental caries (Larsen 1997; Lubell et al. 1994; Sealy et al. 1992; Larsen et

al. 1991; Cohen and Armelagos 1984; Truswell 1977). This shift may also be true for

non-agricultural populations that adopt foraging patterns that are high in terrestrial

resources (Sealy et al. 1992; Walker and Erlandson 1986). For example, Sealy et al.

(1992) noted that prehistoric populations of Cape Province, South Africa living inland

from the coast and practicing a mixed marine and terrestrial subsistence diet exhibited a

caries rate of 8.7%, while the caries rate was only 2.6% for populations living on the

coast and relying heavily on marine resources.

      Working with Predynastic through Christian Egyptian and Nubian burials

(5000 B.C.-A.D. 640), Hillson (1979) noted that while dental caries frequencies were low

for all of the ancient sites included in the study, the Predynastic period (5000-3000 B.C.)

sites showed a lower evidence of caries than later assemblages. Hillson (1979) suggested that the increase in dental caries may be due to a shift from consumption of a primarily meat based diet to increased reliance on vegetal resources which would have been higher in sugars known to cause dental caries.

Lillie (1996) argued that the high rate of dental calculus and enamel hypoplasias in relation to the low frequency of dental caries at several Mesolithic and Neolithic sites in the Dneiper region of Ukraine suggests that there was no evidence to indicate that these populations adopted agriculture. Lillie (1996) asserted that the inverse relationship between dental caries and dental calculus was indicative of a protein-based subsistence economy that remained unchanged even after the adoption of agriculture in other areas of Neolithic Europe.[1]

Eshed et al. (2006) achieved similar results when comparing rates of dental caries for populations of Natufian hunter-gatherers and Neolithic agriculturalists, though the authors concluded that the low prevalence of caries seen in Neolithic populations was likely due to the fact that Neolithic agriculturalists consumed cereals that are not cariogenic.

Using isotopic and dental evidence, Lubell et al. (1994) suggested that the Neolithic transition to a terrestrial, agricultural based diet at varying sites, such as Moita de Sabastião and Cabeço de Arruda, in Portugal actually began during the Mesolithic. The isotopic evidence suggested that there was a shift from a mixed subsistence economy relying on terrestrial and marine resource to a greater focus on terrestrial resources

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[1] Dental caries and dental calculus are thought to be mutually exclusive because the processes that lead to carious lesions are caused by great acidity of plaque pH which dissolves tooth enamel, while dental calculus is associated with alkaline protein waste products that cause mineral deposits to form on the surface of the tooth.

around 7000 B.P. However, patterns of dental wear and dental pathology indicated that while wear decreased, caries rates remained consistent with the rate for the Mesolithic populations, suggesting that the transition to terrestrial based resources began during the Mesolithic. Lubell et al. (1994) entertained two possibilities as to why similarities in dental caries rates were found in Mesolithic and Neolithic Portuguese archaeological populations: 1) European plant domesticates were not as cariogenic as maize was in the New World; and 2) Mesolithic communities may have had access to dried fruits, such as figs, which are highly cariogenic if eaten in large quantities, and this practice of eating sticky dried fruit may have continued into the Neolithic.

Lukacs (1992) found that the prehistoric population at Harappa in the Punjab Province of Pakistan exhibited dental caries rates akin to those seen in agricultural populations. Lukacs (1992) suggests that dental disease increased in the Indus Valley as methods of food production became more intensive and efficient. Interestingly, work carried out in Thailand by Tayles et al. (2000) and Pietrusewsky and Douglas (2002) suggests that there is no relationship between increasing rates of rice based prehistoric agriculture and higher rates of dental caries. Comparing early hunter-gatherers from the site of Khok Phanom Di (2000-1500 B.C.) with the cemetery sites of Ban Lum Khao (Iron Age, c. 1000-500 B.C.) and Noen U-Loke (Bronze Age, c. 300 B.C.-A.D. 300), Tayles et al. (2000) concluded that caries rates actually decreased over time with the advent of rice agriculture. Tayles et al. (2000) proposed that the decline in dental caries may have been due to the fact that unpolished rice is less cariogenic than local Thai

plants such as taro and bananas, which may have been eaten in greater proportions by the early hunter-gatherer population of Khok Phanom Di.[2]

The New World. In contrast to Old World studies, several studies on New World populations have noted that dental caries prevalence increased as prehistoric peoples began to consume carbohydrate rich resources, such as maize. Larsen (1981) analyzed preagricultural skeletons from the Georgia Bight and compared their dental health to the skeletons of individuals from later agricultural groups. Larsen (1981) found that overall dental health declined and that rates of dental caries increased with agriculture, primarily due to a maize-based diet rich in carbohydrates. Later dental analysis conducted by Larsen et al. (1991) concluded that there was a shift in subsistence practices between the pre-agricultural and late agricultural and historic periods that led to a greater reliance on nutritionally deficient, cariogenic plants, such as maize. Stable carbon isotope analysis of human bone collagen by Larsen et al. (1992) supported earlier dental caries rate analyses, suggesting a transition between a locally based terrestrial subsistence economy and an agriculturally based subsistence economy heavily reliant on cariogenic plants, such as maize.

Hoping to address the question of whether the pithouse to pueblo transition was influenced by greater reliance on maize agriculture, Schollmeyer and Turner (2004) used dental caries prevalence from sites in Southern Colorado in an attempt to pinpoint whether agricultural intensification occurred during the Basketmaker period in the American Southwest. Their results suggest that the rate of dental caries in Basketmaker

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[2] Unpolished rice refers to rice in which the outer layer of bran has been left on. It is often known as brown rice or red rice.

and post-Basketmaker individuals is high, indicating that individuals from both periods were heavily reliant on agricultural resources (2004).[3] Therefore there was no evidence to substantiate the claim that agricultural intensification began in the post-Basketmaker period.

The prehistoric transition to agriculture in North America is furthermore reflected in populations from the Ohio Valley. Dental caries analysis conducted by Sciulli (1997) on forty Native American populations from the Ohio Valley suggests that populations from the agriculturally associated Late Prehistoric period (after 1000 B.P.) display significantly higher rates of dental caries than earlier populations from the Late Archaic (3500 B.P.) and Woodland periods (2500-1000 B.P.) (Sciulli 1997). Sciulli (1997) found that frequencies of dental caries averaged around 18.2 percent and coincided with the adoption of maize agriculture in the Ohio Valley at around 1000 B.P. The rates of dental caries in the agricultural late prehistoric population are noticeably higher than the averages for both the Late Archaic (2.4-4.8 percent) and the Woodland skeletal assemblages (5.8-7.0%), suggesting that the greater reliance on maize agriculture contributed to significantly higher rates of dental disease (Sciulli 1997).

Comparisons of marine and agriculturally based groups in the Azapa Valley of northern Chile yielded similar results. Analyzing dental disease from five different populations, Kelley et al. (1991) determined that dental caries increased markedly in the populations who practiced agriculture. The two marine hunter-gatherer populations showed negligible amounts of dental caries (0.6 and 2.5% respectively), while the mixed

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[3] The rate of dental caries is 12.3% for the Basketmaker population and 11.1% for the post-Basketmaker population.

crop agriculturalists expressed increasing rates of dental caries and antemortem tooth loss (11.5, 14.4, and 48.1% respectively in terms of dental caries) (Kelley et al. 1991). Increases in the rate of dental caries are probably related to agricultural intensification, although Kelley et al. (1991) could not rule out change in the structure of trace elements as a possible cause of the higher prevalence of dental caries in the agricultural communities.

California. Subsistence transitions may also have an impact on the dental health of non-agricultural societies. Walker and Erlandson (1986) noted a shift in dental caries prevalence in their assessment of skeletal material from the northern Channel Islands of Santa Barbara, California. Analyzing the dentition of populations buried at the Canada Verde cemetery (3000-4000 B.P.) and Skull Gulch cemetery plots A (1820-900 B.P.) and B (A.D. 1100-1500), Walker and Erlandson (1986) found that caries rates declined from 80 percent in the Canada Verde sample to 47 percent at Skull Gulch. Walker and Erlandson (1986) attribute the decline in caries rates to a shift from consumption of local terrestrial foods, such as roots and tubers, to a diet based mainly on marine resources.

Comparing sites from the Sacramento Valley and the San Francisco Bay Area, Bartelink (2006) found that the Valley Populations exhibited a higher proportion of carious teeth than individuals in the Bay. Chi-square and Fisher's exact tests revealed that the Sacramento Valley populations exhibited significantly higher rates of caries for both males and females during the Early, Middle, and Late Periods (Bartelink 2006). Bartelink's (2006:204) uncorrected caries prevalence data indicated that dental caries

were twelve times more common in males and three times more common in females from the Valley than their male and female counterparts in the Bay.[4]

Jurmain (1990) examined the dentitions of 298 skeletons from the Costanoan Bay Area mound site of CA-ALA-329. In accordance with Bartelink's (2006) Bay Area data, dental analysis revealed that the majority of individuals in the population were subject to high rates of dental attrition, while only ten individuals throughout the entire sample exhibited dental caries. However, dental caries frequencies may be underrepresented because the teeth are so worn that any carious lesion present on the enamel may have been obliterated by the severity of the dental attrition (Jurmain 1990). The high rates of moderate and severe attrition are even more interesting when one considers that the mean age at death is approximately 30 years of age. Jurmain (1990) postulated that the high rate of attrition was due to abrasive materials making their way into the diet. Grit could have been introduced from mortars and pestles, spalled fragments of cooking stones, and shellfish processing (Jurmain 1990). Additionally, teeth may have been used to make baskets and cordage further exacerbating the severity of dental wear (Jurmain 1990).

Temporal analysis of 902 individuals from 24 sites conducted by Schulz (1981) in the Sacramento Valley, found that there was no significant difference in caries rates over time. Even when the analysis included 3rd molars and a reduced geographic area, there was no temporal increase in caries prevalence (Schulz 1981). Schulz (1981) used his findings as justification to refute the idea that the Windmiller population shifted

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[4] The "corrected" numbers are higher with Sacramento Valley males exhibiting a 7.7% caries rate and females exhibiting an 18.5% caries rate, while their Bay Area counterparts exhibit a .4% and a 3.2% rate respectively.

from a diet primarily reliant on meat to one reliant on plant foods high in carbohydrates, such as acorns. Schulz (1981) also found that dental attrition was more common than dental caries across all sites and all time periods.

Sex Differences in Dental Caries Rates

In addition to indicating possible subsistence transitions in past populations, a large proportion of dental caries research has identified sex differences. The pattern of higher dental caries rates in females has been noted in both modern and archaeological contexts (Lukacs and Thompson 2008; Fujita et al. 2007; Cucina and Tiesler 2003; Walker 1988; Schulz 1981; Hollander and Dunning 1939).

A world-wide review of dental caries rates for several archaeological samples was conducted by Lukacs and Thompson (2008) in order to address the hypothesis that females tend to exhibit higher rates of dental caries than males. Employing the tooth count method for counting caries as well as chi-square tests of significance for all samples and regions, Lukacs and Thompson (2008) found that women exhibit a higher prevalence of dental caries than men in Asia, Central and South America, and North America.[5] When the archaeological site data were pooled, females, once again, exhibited a higher frequency of dental caries than males (Lukacs and Thompson 2008). The overall study conducted by Lukacs and Thompson (2008) was influenced by an earlier study in which Lukacs (1996) found that the female dentition exhibits significantly higher rates of dental caries than that of men at the Mesolithic sites of Damdama and Mahadaha, the

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[5] Lukacs and Thompson found that the African bioarchaeological samples suggest that females display higher rates of caries but, small sample size prevented the results from reaching statistical significance.

Chalcolithic site of Mehrghar, and the Bronze Age site of Harappa in Pakistan, South Asia.

In accordance with Lukacs (1996) findings from prehistoric South Asia, a study conducted by Fujita et al. (2007) on 271 individuals from the six subperiods of the Jomon Period (12,000-2300 B.P.) found that females had statistically higher rates of dental caries than males for every age category. Fujita et al. (2007) concluded that the higher rate of dental caries exhibited by women was due to a female preference for sweet foods and the possibility of between meal food consumption.

Male and female dental caries rates were also found to be disproportionate in the New World. Analyses of caries rates and antemortem tooth loss at the Classic Maya sites of Calakmul, Dzibanché, and Kohunlich (A.D. 250-900), yielded data that suggested that there was no difference in caries prevalence between low status males and females, whereas caries rates were found to be statistically significantly different between males and females of high status (Cucina and Tiesler 2003). Cucina and Tiesler (2003) suggest that the significantly higher prevalence of dental caries in high status females may be due to consuming a diet of soft cariogenic foods that more closely resembled the food consumed by commoners than the more protein rich diet enjoyed by elite males.

Work conducted by Cucina et al. (2003) for the Late Classic Maya site of Xcambó (A.D. 600-900) also conformed to the pattern of females exhibiting a greater prevalence of dental caries than males, with the notable exception of the Asentamiento Periferico Este Compound where the pattern was reversed. Cucina et al. (2003) believe that the sex based disparities in dental caries found throughout the majority of Xcambó may be attributed to females ingesting a diet higher in carbohydrates, and also consuming

carbohydrate rich foods while preparing meals. Larsen et al. (1991) used a similar argument in their analysis of the high rate of dental caries observed for females in the prehistoric periods of the Georgia Bight.

Sex differences in caries prevalence also manifest in archaeological populations that never developed agriculture during the prehistoric period. Walker and Erlandson (1986) and Hollimon (1992) noted that females among the Chumash of the California Santa Barbara Channel Islands displayed higher rates of dental caries than their male counterparts. Walker and Erlandson (1986) found that females buried in the early period cemetery of Canada Verde (3000-4000 B.P) had a much higher rate of dental caries in all four tooth types. Using observations of the historic Chumash sexual division of labor as a guideline, Walker and Erlandson (1986) suggested that the inequalities in dental caries rates may have been related to early Chumash women gathering the majority of the food, while men went out and hunted.

Recently, Bartelink (2006) conducted an assessment on several archaeological populations from the lower Sacramento Valley and the San Francisco Bay. When focusing on the prevalence of dental caries within the Valley and the Bay Area, Bartelink (2006) noted that the rate of dental caries was higher in females than in males for both samples. Bartelink (2006) found that the dentition of individuals from the Sacramento Valley sites exhibited a significant difference between caries prevalence in males and females (the totals from the pooled period corrected data were 6.8% and 18.5% respectively). Surprisingly, Bartelink (2006) found that the stable isotope ratios were almost the same for both male and female pre-contact groups in the Sacramento Valley.

This suggests that the difference seen in caries prevalence by sex is not due to differences in isotopically distinct resources consumed by each sex.

While he found no differences in caries frequencies over time, Schulz (1981) noticed that the males and females from the prehistoric populations that he studied in the Sacramento Valley exhibited marked difference in caries severity. Females exhibited significantly more severe caries than men. Schulz (1981) attributes this disparity in caries severity to the sexual division of labor whereby men hunted, while women gathered.

> When we consider the necessary processes of sampling ripeness, determining completeness of cooking, satisfying hunger, and, maintaining the energy needed to carry large loads of gathered produce, it seems safe to assume that women's work in these societies was compatible with, and even necessitated, the intermittent consumption of food items throughout the day. (Schulz 1981:163).

Schulz (1981) further suggests that differences between males and females may have been influenced by food taboos and fasting rituals men imposed on themselves before, during, and after hunting.

Wallace (1978) has also argued that male and female activity patterns may have contributed to the sex disparity in dental caries rates. Wallace (1978) contends that beginning around 3000 B.C., California cultures experienced a diversification in subsistence strategies shifting away from earlier period subsistence strategies characterized by hunting (9000-6000 B.C.) and food collecting (6000-3000 B.C.). For example, the Early Period Windmiller assemblages in the Sacramento Valley (circa 2000 B.C) contained artifacts, such as projectile points, fish hooks, clay impressions of basketry, milling stones, and stone mortars and pestles, which indicate that the Windmiller people were participating in both game hunting and gathering of terrestrial resources (Wallace 1978). It has been suggested that in the absence of agriculture, gender

still contributed to the types of activities in which men and women participated (Jackson 2004[1994]; Basgall 1987; Walker and Erlandson 1986). McGuire and Hildebrandt (2004[1994]) have contested the idea of gender role separation in prehistoric Cahuilla populations representing the mid-Holocene Milling Stone horizon (ca. 6000-4000 B.P.). However, the authors concede that later periods were characterized by zooarchaeological evidence of large mammal procurement, an activity which falls into the "exclusive domain of men" (McGuire and Hildebrandt 2004[1994]: 167). Thus, the hunting strategy suggested by Wallace (1978) based on archaeological evidence, may have been an exclusively male activity.

If men hunted regularly, it is likely that women provided a large proportion of the diet through gathering local terrestrial resources. Jackson (2004[1994]) has argued that acorn processing in the southern Sierra Native Americans cultures (Western Mono, Miwok and Yukot) was primarily a female activity. While all members of these communities have historically helped to collect acorns as a means of maximizing efficiency and total acorn yield, the incredibly time consuming activity of acorn processing was reserved solely for women (Jackson 2004[1994]). Jackson (2004[1994]) has suggested that the increased reliance on acorns created a greater need for partial sedentism in hunter-gatherer populations due to the fact that acorn processing would have required long hours of leaching and grinding to produce edible, storable foodstuffs. Pine nut processing, another documented practice of native northern California populations, was less intensive, but followed similar activity patterns whereby men procured the seeds from the pine tree and women attended the labor involving processing and cooking (Farris 1993). Thus, it is possible that a sexual division of labor where men hunted and

women gathered and processed plants may have created an environment in which women living in a semi-sedentary environment consumed more cariogenic plant material and thus exhibited higher rates of dental caries than men.

Dental Attrition in Archaeological Context

In the early 1970s, Molnar (1971; 1972) advocated using patterns of dental attrition as a means of assessing the cultural and dietary practices of archaeological skeletal populations. Molnar (1971) assessed the dental wear patterns of Native Americans in California, the Southwest, and the Valley of Mexico, and concluded that the higher rates of dental attrition present in the California prehistoric population had to do with the fact that the California Native Americans of the Sacramento Valley were hunter-gatherers who ate a wide variety of food, while the populations in the Southwest and Mexico were agriculturalists who ate a less abrasive diet.

In the late 1970s, Hillson (1979) suggested that the lower incidence of dental wear found in predynastic Egypt reflected the idea that predynastic populations consumed more meat and less vegetable based food products. Hillson (1979) based his conclusions on the fact that meat is found to be less abrasive than vegetable foods. Smith (1984) also argued that the mastication of tough, fibrous foods leads to differing patterns of dental wear among hunter-gatherers when compared to agriculturalists.

Molleson et al. (1993) used dental microwear patterns from different cultural horizons at the stratified site of abu Hureyra in Syria to track possible changes in diet that could have occurred due to the rise of pottery culture during the Neolithic. Molleson et al. (1993) concluded that the pattern of dental microwear seen in the raw seed and course-

ground grain reliant earlier Mesolithic/Pre-Pottery Neolithic abu Hureyra populations was statistically significantly different from later Neolithic populations who probably ate cooked food and therefore had teeth that were less subject to wear.

Eshed et al. (2006) have suggested that in addition to attrition being linked to grit in the diet, patterns of dental wear may also be indicative of teeth being used as tools. Patterns of grooving present on the anterior teeth are used as evidence to suggest that Natufian foragers at Ain Mallaha in the southern Levant were using their anterior teeth to process animal skins. The authors further propose that abrasion of the mesial aspect of the first molar, the dislocation of teeth and deep bucco-lingual grooving on the occlusal surfaces of some molars exhibited by the inhabitants of the Neolithic site of Atlit-Yam is indicative of the practice of using teeth as tools in the making of baskets and fishing-nets (Eshed et al. 2006:153). Eshed et al. (2006) point out the deep bucco-lingual grooves as an indication that basketry and fishing net production required a type of pulling action across the first and second premolars. An earlier study conducted by Schulz (1977) of a prehistoric population from Stone Lake in the Sacramento Valley produced similar conclusions. Using ethnographic evidence as a basis for comparison, Schulz (1977) found that abraded grooves on the occlusal and approximal surfaces of the teeth indicated habitual activity patterns and were potentially the result of cordage manufacture for basketry and fishnets.

While dental attrition is vital in regard to its potential ability to shed light on past lifeways of archaeological populations, the proportion of dental attrition exhibited in archaeological skeletons is important due to the fact that there is often an inverse relationship between dental caries and dental attrition whereby when caries rates are high,

dental attrition is low and vice versa. Maat and Van der Velde (1987) found this inverse

relationship between caries and attrition to be true when they evaluated a population of

Dutch whalers from the 17th and 18th century. The Dutch population who preceded the

whalers was characterized by heavy amounts of dental attrition, while the population that

followed the whalers exhibited reduced dental attrition (Maat and Van der Velde 1987).

Maat and Van der Velde (1987) found that this intermediate population continued the

trend toward reducing dental attrition, while at the same time exhibiting an increased

prevalence of dental caries. In their analysis of Iron Age skeletal assemblages at Wadi

Samad in Oman, Nelson et al. (1999) found that their sample exhibited marked amounts

of dental caries and AMTL, while displaying very little molar dental attrition. Nelson et

al. (1999) attributed this dental pattern of slight molar wear and increased dental caries to

a greater reliance on agricultural resources as well as dates, a fruit known to be highly

cariogenic. The competitive relationship between caries and dental attrition may be due

to the fact that attrition tends to wear away the grooves and fissures found on the occlusal

surface of the tooth which are common sites of plaque and cariogenesis (Larsen 1997;

Kaifu et al 2003). Conversely, Eshed et al. (2006) proposed that a low carbohydrate diet

of grainy food was responsible for the inhibition of dental caries development in Natufian

hunter-gatherer and Neolithic farming populations from the southern Levant.

However, caution should be exercised when suggesting that high rates of

dental wear predispose populations toward low incidence of dental caries. Larsen (1997)

is quick to point out that if the carbohydrate content of the diet is high enough,

populations who consume highly abrasive foods will also exhibit notable amounts of

dental caries. Meiklejohn et al. (1993) reached a similar conclusion in their assessment of

Portuguese Mesolithic sites where the relationship between dental caries and dental attrition was suggested to be dependent on the types of food consumed by the population.

Summary

Dental caries are pathological conditions brought on primarily by *Streptococcus mutans* bacteria. Dental abscesses are often present in populations with high prevalence of dental caries, though abscesses may be caused by other dental conditions. Modern and prehistoric populations that tend to have high rates of dental attrition, oftentimes have lower rates of dental caries. Dental caries can be found in both modern and archaeological contexts. In the case of the latter, their presence, absence, and proportion are often used to infer the diet and activity patterns of past populations. Disparities in dental caries rates and the severity of dental attrition are often used as indicators of the transition from hunting and gathering to agricultural societies; hunter-gatherers tend to have high rates of dental attrition and a low prevalence of caries, while in agricultural populations the situation is often reversed. This inverse relationship is due to the fact that hunter-gatherers tend to eat tough, fibrous foods that wear down their tooth enamel, while agriculturalists tend to eat soft, mushy, often sugary, foods that get caught in their teeth, causing infection, which leads to dental caries. Differences between the amount and severity of dental caries for males and females have also been noted in modern and archaeological populations. Women, in both modern and archaeological populations, tend to exhibit more severe caries in greater frequencies than men. While some of the difference between men and women is physiological, the majority of the dental caries disparity may be due to differences in food consumption practices. Most of

the time men hunt, while women gather. Gathering food allows women greater access to terrestrial plant resources that could potentially be higher in sugars. Hunting often has food taboos, fasting, and dietary restrictions that accompany it, meaning that men are less likely to eat terrestrial foods as they encounter them, thus, decreasing likelihood of dental caries.

CHAPTER IV

MATERIALS AND METHODS

In this chapter I discuss the four sites that comprise my dataset and the methodology behind my statistical analysis. The chapter provides a brief overview of the history and material culture of each archaeological site, discusses the methods employed in my analysis of the skeletal material, and provides insight into the organization of the comparative analysis between my research and earlier research conducted by Bartelink (2006).

Archaeological Sites

All of the archaeological sites used in this analysis are from sites associated with the Windmiller Pattern in the Sacramento-San Joaquin Delta area (Figure 1). The Windmiller and Phelps Mound osteological data were compiled and analyzed at the Phoebe Apperson Hearst Museum at the University of California, Berkeley during the summer of 2008. Although the cultural affiliation of the Windmiller individual's remains unclear at present, all skeletal materials were subject to NAGPRA protocol before they were carefully analyzed. The skeletal data were later compared to similar work on the Blossom Mound and the McGillivray #1 Mound sites conducted by Dr. Eric Bartelink (2006) at the Hearst Museum in 2005.
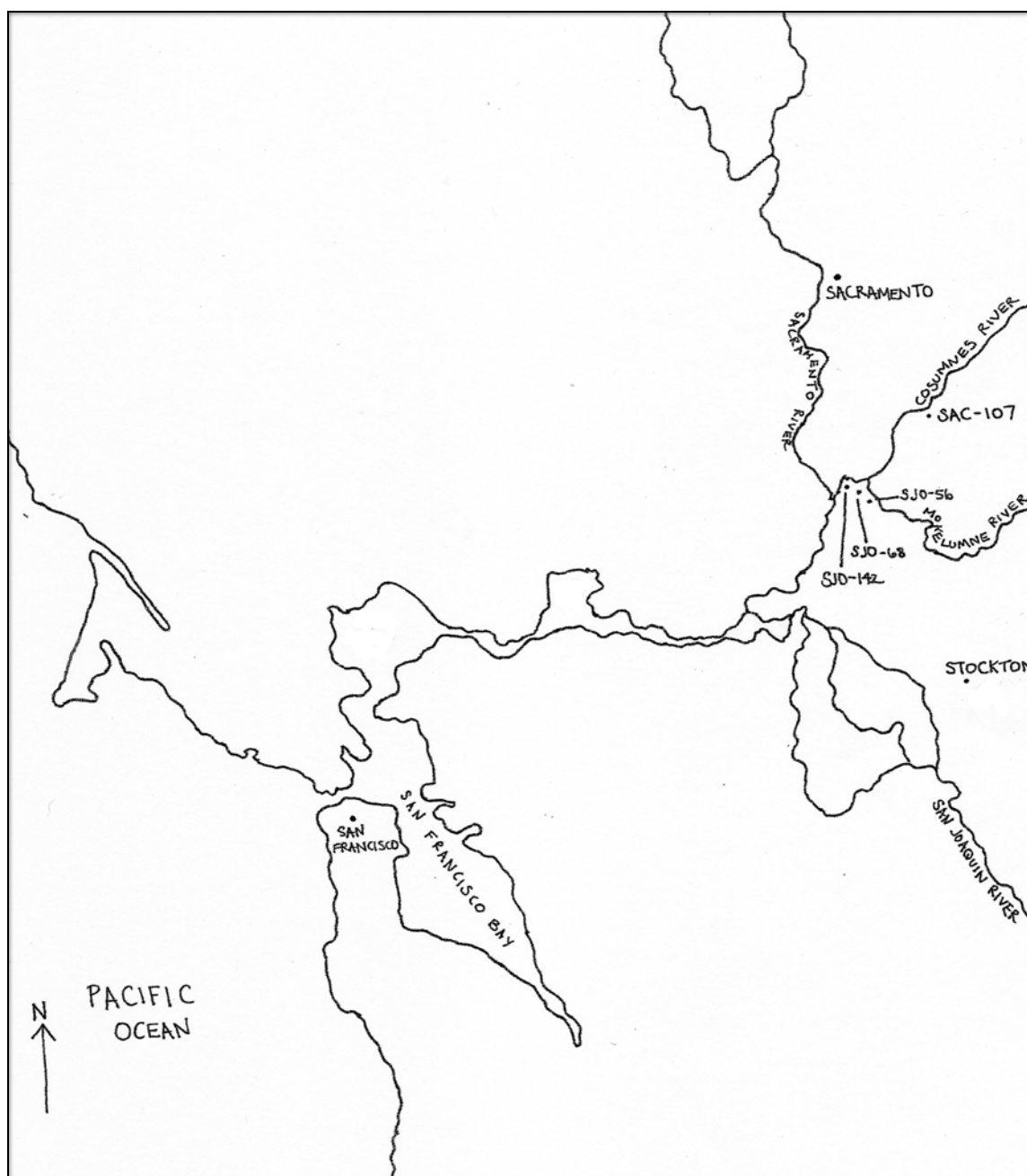
Figure 1. Map of central California showing the locations of archaeological sites from the lower Sacramento and upper San Joaquin Valleys.

The Windmiller Mound (CA-SAC-107)

        The Windmiller Mound (CA-SAC-107) is the type site of the Central Valley

Windmiller Culture, after H.H. Windmiller, the property owner. The Windmiller Mound

(3075-2540 B.P.) is a stratified site found in the Cosumnes River Valley within the ethnographic boundary of historic Plains Miwok territory (Heizer 1949). The site is located approximately four miles southeast of the town of Elk Grove, within the Cosumnes River Preserve. Lillard et al. (1939) recorded that the original mound was 9 feet high (from ground level) and 270 by 285 feet in dimensions. Excavation of CA-SAC-107 was conducted by Jeremiah B. Lillard and William K. Purves of Sacramento Junior College in 1935 (Heizer 1974). The skeletal collection was later donated to the University of California, Berkeley under the care of archaeologist Robert F. Heizer. In total, Heizer (1949) recorded 168 burials from the site: 59 from the Early Period, 15 from the Middle Period, and 94 from the Late Period. Almost all of the Early Period burials were found extended with the body lying ventrally and the head facing west, while the Middle and Late Period burials were interred in a flexed position and included cremated remains (Lillard et al 1939; Heizer 1949). Heizer (1949) initially believed the Windmiller Mound to be the oldest of the Windmiller sites, but later data analysis of the archaeological evidence conducted by Ragir (1972) suggests that the site is younger than the lower level of the Blossom Mound (CA-SJO-68).

The Windmiller Mound is stratified, with the lower level composed of highly compacted, reddish-brown sandy clay and the upper layer with soft, ashy, black kitchen refuse accumulation which Heizer (1949) attributed to habitation.[1] All of the burials in the lower level were from the Early Period and heavily mineralized. The upper level contained Middle and Late Period burials and the skeletal material did not exhibit the

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[1] Meighan (1987) has questioned Heizer's assumption that this was a habitation site, citing the paucity of accumulated detritus as evidence that the Windmiller Mound probably only a burial mound and not a habitation site. Moreover, the frequency of certain ritual objects such as charmstones, make it more probable that this was primarily a burial site.

degree of mineralization found in the lower level. The burial pits in the lower level were dug into the surface of the clay; while only the outline of the pit was present in the upper level burials (Lillard et al. 1939).

With the exception of three flexed burials and two dorsally extended burials, all of the Early Period burials were placed in grave pits with their heads oriented west. An overwhelming majority of the burial pits were uncovered with associated grave goods. The burials are associated with *Olivella* and *Haliotis* shell beads, chipped flakes, flakes with contracting and parallel-sided stems, rounded drilled biotite pendants, quartz crystals, powered red ochre, charmstones made mostly of amphibolite, and one large, obsidian knife. Two metates, some mortar fragments, two manos, and a few antler fish spear points were also recovered. The Early Period burials were associated with baked clay balls which are common to other Early Period sites, as well as a receptacle made from a human skull and some animal bone tools.

The Middle Period burials were buried in a flexed position, with the head oriented in variable directions. Cremations were present, but uncommon and the majority of human remains were found with associated grave goods. The recovered remains were associated with *Olivella* shell beads, chipped flakes, flakes with contracting and parallel-sided stems, *Haliotis* ornaments, charmstones, and biotite pendants. Archaeologists also unearthed three chisel-pointed pestles, two shallow stone mortars, and a tubular bone whistle among the Middle Period burials.

Individuals interred in the Late Period were buried in a flexed position. There were many more cremations than in the Early or Middle Period, and interestingly, a few infant skeletons were found to have been buried in *Haliotis* shells. There were fewer

mortuary goods associated with the Late Period burials than with burials from the Early or Middle Period. The remains were associated with *Olivella* shell beads, chipped flakes, triangular points, flakes with contracting, parallel-sided, and expanding stems, *Haliotis* ornaments, obsidian flake knives, clamshell disc beads, bone tubes, steatite beads, a perforated stone discoidal, and two steatite pipes. The Late Period burials contained two chisel-pointed pestles, bi-pointed gorge hooks, a carbonized fishnet, and a grooved stone sinker which was probably used in fishing.[2]

Phelps Mound (CA-SJO-56)

The Phelps Mound (CA-SJO-56) is an Early Period mortuary site (ca. 2855-2600 B.P.) ascribed to the Windmiller Pattern. The site is located approximately 900 yards west of the "big bend" in the Mokelumne River approximately 1.75 miles from the Blossom Mound (CA-SJO-68) (Heizer 1949). Originally mentioned by Dawson in the 1920's, the site was fully excavated by Lillard, Fenenga and a team from Sacramento Junior College in December 1938 and January 1939. The top of the Phelps Mound is approximately 9 ft. above ground surface level (Heizer 1949). The mound is 100 feet in diameter and extends 2.5 feet above the surrounding landscape (Lillard et al. 1939). The site consisted of four types of soil strata: loose, dark brown, ashy, topsoil, calcareous hardpan, hardened, but less compacted refuse deposit, and undisturbed yellow sandy loam (Heizer 1949; Lillard et al. 1939).

A few burials were recovered from the hardpan strata, but the overwhelming majority of burials were from the refuse strata. All skeletal remains were recovered from

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[2] All of the information obtained on the artifacts and burial positions for the Windmiller Mound are from Lillard et al. 1939.

depths of 18 to 54 inches (Heizer 1949). The site contained the remains of 73 individuals, including two intrusive burials that differed in position, orientation, and degree of mineralization. All individuals except the intrusive ones were buried in the characteristic pattern associated with Windmiller mortuary sites. The body was buried in an extended position, face down, with the arms at the sides, feet together, and the head oriented to the west.

The artifacts associated with the remains were almost all ceremonial in nature; therefore it seems likely that the Phelps Mound was a mortuary site. The skeletal remains were associated with *Olivella* shell beads, chipped flakes, triangular points, flakes with contracting, parallel-sided, and expanding stems, *Haliotis* beads and ornaments, quartz crystals, and mostly marble charmstones (Lillard et al. 1939). Asphaltum residue was recorded on some of the bone remains, indicating that it had probably been used as an adhesive to adhere two materials together (Lillard et al. 1939). Also among the artifacts were bone pins, miscellaneous non-human bones and bone tools, turtle carapace ornaments, and bird bone tubes (Lillard et al. 1939).

The McGillivray #1 Mound (CA-SJO-142)

The McGillivray #1 Mound (CA-SJO-142) is an Early Period site located in San Joaquin county, approximately 1000 yards south of the Mokelumne River, just to the north of the tule and rush filled depression known as Fogg Lake (Heizer 1949). The site (ca. 2800-2200 B.P.) was excavated by the University of California, Berkeley in 1937 and 1938. The highest point of the site elevation is approximately one foot above the surrounding landscape (Heizer 1949). The top layer of soil was composed of grey, calcareous hardpan, while the layer underneath consisted of loose, brownish red soil

matrix (Lillard et al. 1939). The lowest level consisted of undisturbed yellow sandy loam (Heizer 1949).

All remains were recovered from the middle brownish, red soil stratum. The middle soil stratum contained 44 burials, of which five were intrusive remains from the Middle Period. The remaining 39 burials were all buried in the extended, ventrally facing, westward oriented position attributed to all Windmiller sites. Two individuals were dorsally oriented and, interestingly, they are the only individuals interred with tubular, conically drilled stone pipes (Lillard et al. 1939).

In regard to the artifacts, the site was associated with *Olivella* shell beads, chipped flakes, flakes with contracting, parallel-sided, and expanding stems, *Haliotis* beads and ornaments, quartz crystals, and charmstones (Lillard et al. 1939). Asphaltum residue was present on five implements. Very few animal bone fragments were present; large perforated bone implements were thought to be bone needles. The Early Period burials further included a bone whistle made from the proximal end of a human radius, continuing the trend of creating tools out of human bone elements.

The Blossom Mound (CA-SJO-68)

The Blossom Mound (CA-SJO-68) is an Early Period Windmiller site located in the alluvial plain that lies just 0.6 miles north of the McGillivray #1 Mound site (Lillard et al 1939). The site (4350-3000 B.P.) is located 1.2 miles south of the Mokelumne River and 1.5 miles northwest of the town of Thorton (Ragir 1972). The site was first excavated by Elmer J. Dawson in 1921 and reevaluated by the University of California, Berkeley in 1938. The site measures 93 by 68 feet with the long-axis running in a northeast-southwest direction (Heizer 1949). Heizer (1949) recorded that the mound

rose only 2 feet above the Valley floor, but it is more likely that the mound rose 3-3.5 feet above sea level before it was excavated (Ragir 1972). The site contains four distinct soil strata: a loose topsoil cover which is underlain by an extremely compacted, cement-like, calcareous hardpan, followed by 30 to 36 inches of compacted brown midden which overlays the red-yellow sandy clay that forms the base of the mound (Ragir 1972; Heizer 1949).

Human remains were recovered from both the calcareous hardpan and brown midden strata. Dawson's notes estimate that he unearthed 75-80 burials, while the University of California Archaeological Survey (UCAS) uncovered 154 burials (Ragir 1972). All of the burials excavated by Dawson were buried in extended position with their heads oriented to the west. Dawson did not record whether or not the head was oriented dorsally or ventrally. The burials uncovered by the UCAS maintain the same pattern; however there is variability as to whether the skulls were interred dorsally or ventrally (Lillard et al. 1939).

The Blossom Mound is associated with various artifacts indicative of a mortuary site. The dearth of animal bones, living floors, and bone and stone tools suggests that the Blossom Mound was not an occupation site (Ragir 1972; Meighan 1987). The burials were accompanied by *Olivella* shell beads, chipped flakes, triangular points, flakes with contracting, parallel-sided, and expanding stems, *Haliotis* beads and ornaments, quartz crystal points, charmstones, a few perforated biotite pendants, slate "pencils," and red ochre (Lillard et al. 1939). A mortar fragment, a metate fragment, animal bones (e.g. beaver, bird, canid), a curved bone fishhook fragment, pieces of an antler fishing trident, several notched antler points, and baked clay balls reminiscent of

those present at the Windmiller Mound are the only evidence pertaining to subsistence practices recovered from the Blossom Mound (Ragir 1972; Lillard et al. 1939). Most of the grave goods recovered from the site possess symbolic or ornamental significance, once again suggesting that the site was not a settlement site.

All of the skeletal material was analyzed at the PAHMA at UC Berkeley. I carefully analyzed all of the skeletal material recovered from the Windmiller and Phelps Mound sites. A partial biological profile of each individual's age and sex was obtained using standard method for skeletal analysis. Then each individual's teeth were inventoried, documented, and assessed for dental caries, dental attrition, and dental abscesses.

<div align="center">Sex Estimation</div>

Sex was estimated using methods in *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker 1994). To determine sex, sexually dimorphic features of the pelvis were used (sciatic notch, ventral arc, subpubic angle, subpubic concavity, ischiopubic ramus ridge) in conjunction with five sexually dimorphic features of the cranium (mastoid process, nuchal crest, supraorbital margin, supraorbital ridge and mental eminence). When postcranial remains were accessible and no other reliable criteria were available, osteometric measurements of the femur and humerus were used to differentiate sex (Dittrick and Suchey 1986). All osteometric measurements were conducted using an osteometric board, sliding or spreading calipers, or a tape measure, following *Standards for Data Collection* (Buikstra and Ubelaker 1994). Due to the fragmentary nature or absence of most of the postcranial remains, sexually dimorphic

features of the skull provided the most reliable sex estimation results for the majority of individuals. While the pelvis would have been the most ideal skeletal element for assessing sex, often the pelvis was not present or was too fragmentary. Adult skeletal material was the primary focus of the study, although subadults were analyzed to infer the earliest age of dental caries formation.

Age Estimation

Age was scored using the Suchey-Brooks pubic symphysis aging casts (Katz and Suchey 1986; Brooks and Suchey 1990), the auricular surface method (Lovejoy et al. 1985; Osbourne et al. 2004), and when the pelvis was unavailable, ectocranial suture closure (Meindl and Lovejoy 1985). It had been my intention to use a combination of all of these methods as a means of narrowing down the age range for most of the individuals in the sample. However, in many cases this proved impossible, as the pelvis was either unavailable or too badly damaged to aid in age estimation. Much of the skeletal material, particularly from SAC-107, was composed solely of skulls. This may have been due to the practice of excavating skulls and disregarding other skeletal material before standardized methods were commonplace; it could be due to differential preservation or the fact that, over the years, artifacts and materials from these collections have been loaned out to other institutions. Due to the dearth of postcranial material in many cases, ectocranial suture closure was used to attempt to provide a general age range for each individual when the pelvis was unavailable. When an individual's age could not be reliably estimated using any of the above methods, epiphyseal union was used to analyze whether the individual was an adult and, in the case of younger adult individuals (below

age 30), provide an estimation of their respective age. Once my analysis concluded that these individuals were in fact adults, they were divided into broader age categories based on observations of degenerative changes to their skeleton, such as osteophytic lipping and joint eburnation.

Dental Analysis

Once an individual had been aged and sexed, each dentition was inventoried using dental forms. This included numerical codes for the presence/absence and completeness of each tooth, as well as visual reconstructions of the each individual's dentition and a numerical scoring system for the type of dental caries present and the amount of dental attrition observed on each tooth. For the purposes of continuity and comparison, I used Bartelink's (2006) modified version of the caries and antemortem tooth loss scoring system found in *Standards for Data Collection* (Buikstra and Ubelaker 1994). Inventory of each tooth position in the modified system was scored as follows:

1. Present, unerupted.

2. Present, in occlusion (with enamel height > 2 mm from CEJ, surrounding at least 50 percent of the crown circumference).

3. Absent, unknown when tooth was lost.

4. Absent, lost antemortem (AMTL).

5. Absent, lost postmortem (PMTL).

6. Congenitally absent.

7. Present, with less than 2 mm of enamel remaining due to attrition.

8. Present, but not observable due to presence of adhesive or soil.

9. Partial root present, but most of tooth lost antemortem.

For a tooth to be considered lost antemortem, the alveolus had to show evidence of significant remodeling.

Dental Caries

Dental caries were evaluated on the basis of numerical scores modified by Bartelink (2006) from the *Standards for Data Collection* scoring system (Buikstra and Ubelaker 1994 after Moore and Corbett 1971). Scores were denoted as follows:

1. No caries.

2. Occlusal surface caries (see Figure 2).

Figure 2. Occlusal surface caries of the right mandibular M_1 and M_2 of an adult female from SAC-107. Courtesy of the Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California Catalogue No. 12-5610). Photograph by Katharine E. Kolpan.

3.   Cervical caries (affecting mesial or distal surfaces).

4.   Caries affecting the smooth surfaces of the buccal or lingual aspects of the tooth (excluding fissures).

5.   Cervical root caries.

6.   Large caries with severe crown destruction.

7.   Interproximal caries.

8.   Pulp exposure due to attrition (non-carious).

9.   Not scorable.

All potentially carious lesions were analyzed using a stainless steel dental probe and a 10x hand lens following protocols outlined by Hillson (1996, 2006). The 10x hand lens was used to more accurately assess the margins of the occual, interproximal, or root surface lesion. Dental caries were scored for each individual at each site and then the proportion of dental caries was compared to the total amount of teeth present in each sites skeletal population. For example, if the males at one site expressed three dental caries for 278 total teeth present then the ratio would be 3/278 or 1.1%.

To get a more accurate sense of the amount of dental caries present, caries scores, AMTL, pulp exposure due to attrition, and pulp exposure due to caries were recorded and then the Lukacs (1995) caries correction factor was applied in order to estimate the amount of AMTL due to dental caries versus the amount of AMTL due to pulp exposure from attrition. The caries correction factor is a simple four step method that allows the researcher to estimate the proportion of AMTL related to dental caries versus AMTL related to dental wear (see Figure 3). The method works as follows:

Figure 3. Severe dental attrition and pulp exposure expressed in an adult female from SAC-107. Courtesy of the Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California (Catalogue No. 12-7879). Photograph by Katharine E. Kolpan.

1. Estimated number of teeth lost due to caries (number of teeth lost antemortem) x (proportion of teeth with pulp exposure due to caries [number of pulp exposures due to caries/number of total pulp exposures]).

2. Total estimated number of teeth with caries (estimated number of teeth lost due to caries + number of carious teeth observed).

3. Total number of original teeth (number of teeth observed + number of teeth lost antemortem).

4. Corrected caries rates (total estimated number of teeth with caries/total number of original teeth) (Lukacs 1995:153).

Dental Attrition

Antemortem tooth loss may also occur as a consequence of dental attrition (Figure 3). Thus, dental attrition was noted and inventoried using the Smith (1984) scoring system for the incisors, canines and premolars and the Scott (1979) scoring system for the molars as detailed in *Standards for Data Collection* (Buikstra and Ubelaker 1994). Overall, the rates of dental wear are high for these samples.

Dental Abscesses

Due to the fact that alveolar abscesses tend to correlate with the presence of dental caries, as well as pulp exposure due to attrition, mandibular and maxillary abscesses were recorded using the methods denoted in *Standards for Data Collection* (Buikstra and Ubelaker 1994). The presence/absence of dental attrition and caries in surrounding teeth was used to infer the cause of both AMTL and abscesses (Figure 4).

Figure 4. Dental Abscess of the Right Mandibular C_1 Expressed in a Female from SJO-56. Courtesy of the Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California (Catalogue No. 12-7054). Photograph by Katharine E. Kolpan.

Guidelines for Inclusion in the Final
Skeletal Sample

In order to be included in the final skeletal sample, the skeletal remains had to be complete enough to allow me to identify them as an adult and reliably determine their sex. I did not include subadults in the sample on the basis that the bone morphology is too similar to distinguish between males and females. Since a comparative analysis of dental caries by sex relies on accurate sex estimation, subadults were excluded from the sample. I analyzed and recorded several individuals who either had no teeth or were represented solely by teeth. However, these individuals were not included in the final analysis or results due to the fact that I needed to be able to identify the individual's sex and they needed to have teeth. All teeth belonging to sexed and aged individuals were included in the total tooth comparison chi-square analysis due to the fact that the teeth were pooled and analyzed as a whole.

Final Sample Size: SAC-107 and SJO-56

SAC-107 contained the remains of 138 individuals, varying from single elements to complete skeletons. Only individuals who maintained at least part of their dentition and who could be reliably aged and/or sexed were retained for further analysis. This reduced the number of individuals to 70 and additional provisions that required individuals to be either adult males or females reduced the number to 52 individuals (22 males and 30 females.)

The sample size of the SAC-107 data was further reduced by the fact that the site is stratified. There were many individuals in the overall collection; however, very few of them could be reliably seriated using old data collection records, meaning that it is

highly probable that several of the individuals not included in the seriated data were from

the Early Period. However, since it is not possible to know which of these unseriated

individuals belong to which time period, only individuals who could be reliably seriated

to the Early Period were included in the Early Period data analysis. When the data were

seriated, the sample size was reduced to 11 Early Period individuals (3 males and 8

females) and eight Middle Period individuals (4 males and 4 females) (Schwitalla 2003).

No individuals could be reliably seriated to the Late Period. In the interest of continuity

when comparing dental caries ratios to each other for the Early Period, only the adult

male and female Early Period individuals were used.

SJO-56 contained the cataloged remains of 111 individuals, although only 45

of them fulfilled all of the requirements necessary for inclusion in my statistical analysis.

Of the 45 individuals, 22 were found to be adult males, while 23 were classified as adult

females. SJO-56 is an Early Period site and all of these individuals were included in the

final statistical analysis.

A total of 588 teeth were analyzed for the individuals found at SAC-107, 163

of which belonged to the dentitions of Early Period individuals. SJO-56 contained 690

assessable teeth, all of which were used in the following statistical analysis.

Statistical Methods

Initial analysis compared sex differences within and between the populations

at SAC-107 and SJO-56. In order to evaluate whether differences in caries rates were

statistically significant, chi-square tests were used. Fisher's exact test was used when the

expected cell frequencies were less than five and would have violated the assumptions of the chi-square test.

Chi-square results were calculated to test whether differences in caries rates between males and females were significant within each site and between sites. Comparative analysis of both observed and "corrected" caries rates was performed for the males and females at SAC-107 and SJO-56. The number of caries present in the maxilla and mandible was then recorded according to the individual's sex and tooth type (incisors, canines, premolars and molars). Since the proportion of caries in each individual tooth type was relatively small, the number of caries was pooled for all tooth types in order to make the sample more robust. The number of total caries present in the dentitions of males and females was used to evaluate whether statistical differences existed between males and females.

The relationship between an individual's sex and the prevalence of AMTL was briefly evaluated. Chi-square analysis was used to figure out if there were statistically significant differences between males and females in regard to AMTL at SAC-107 and SJO-56.

In order to account for differences in rates of dental wear between males and females and different site samples, I followed protocols in Walker et al. (1998) and subtracted the mean score of first and second molars (M1-M2=attrition rate). The logic behind using differences in the mean score between the first and second molars is based on the fact that the adult M1 erupts around age 6, while the M2 erupts around age 12. Due to the staggered eruption of the adult M1 and M2, the difference in the mean wear score can be used a proxy rate for attrition.

The results of my analysis were compared to osteological data from Bartelink (2006) from his assessment of skeletal material from the Blossom and McGillivray #1 Mound sites. Bartelink's (2006) earlier study indicated that Early Period Sacramento Valley females had significantly higher prevalence of dental caries and AMTL than Valley males. However, earlier analysis had not focused on site by site comparison to see if overall trends in the difference between male and female caries rates varied between sites from the Early Period. Therefore, I analyzed all four Early Period sites to see if the higher proportion of dental caries in females from the Early Period occurred at each site.

The skeletal sample from SJO-142 is composed of 34 individuals (18 males and 14 females) who fit the age and sex requirements for inclusion in the statistical analysis. The site dates to the Early Period, and therefore all 34 individuals were included in the final comparative analysis. SJO-68 consists of 59 individuals (28 males and 31 females) who fit the parameters of the study. All of the individuals from SJO-68 were included in the final statistical analysis. the samples from SJO-142 and SJO-68 included 454 and 856 teeth, respectively.

Just as in the initial analysis comparing SAC-107 and SJO-56, the four site comparison employed chi-square tests as a means of investigating whether the proportion of dental caries was statistically significantly different for males and females at Early Period sites. The number of carious teeth at each site was divided by the total number of teeth observable for each sex in order to find the proportion of dental caries present. This process was repeated a second time using the caries correction factor in order to account for potential underenumeration of dental caries that may have occurred due to AMTL. The correction factor is also useful because it is a good way of tracking AMTL due to

dental caries as opposed to AMTL due to attrition. The severe dental wear found at all four sites made using the caries correction factor all the more necessary. After each proportion was recorded, the number of males and females in each skeletal sample who exhibited carious lesions was compared using chi-square tests. The sample size was then augmented by combining the number of individuals who displayed dental caries at all four sites in order to evaluate whether an overall trend between the ratio of females who expressed carious lesions and males who displayed caries existed.

Each site was further evaluated by the number of carious teeth present in males and females. Carious teeth were grouped into tooth types and then all tooth types were pooled. The pooled or "total" number of caries was analyzed using chi-square in order to evaluate whether males or females expressed a higher rate of dental caries.

Samples were then compared to gain insight into whether the proportion of dental caries varied significantly between sites. Once again, chi-square tests were used to evaluate whether differences in the number of caries recorded at each site were statistically significant. The first chi-square tests compared the number of overall caries for all adult individuals at each site. Comparisons between sites were performed twice; once using the observed data and once using the caries corrected data. The fact that the comparison involved four sites resulted in six independent null hypotheses (SAC-107 = SJO-56, SJO-56 = SJO-68, SJO-142 = SAC-107, etc.), which increased the likelihood of selecting a statistically significant result to greater than 0.05. Therefore, the p-value was reduced to 0.0085 in order to retain a 5% chance ($\alpha = 0.05$) of randomly selecting a statistically significant result. For all site-to-site comparisons, any result between 0.0085

and 0.05 was treated as approaching statistical significance. This p-value was retained for all site to site comparisons.

Chi-square tests were performed by sex to see whether the males or females at one site exhibited a significantly higher proportion of dental caries than at another site. Again, chi-square tests were performed using uncorrected and corrected caries data and a p-value of 0.0085 was retained.

After chi-square analysis was performed on each sex from each site, the number of dental caries exhibited was pooled for each sex. Chi-square tests were run on the pooled results in order to test whether an overall Early Period trend existed in regard to sex difference in dental caries. Chi-square tests with the sexes pooled were performed twice, once with the uncorrected pooled data and once with the caries corrected pooled data.

Summary

My analysis focuses on two Early Period Windmiller sites, the Windmiller Mound (SAC-107) and the Phelps Mound (SJO-56). Both of these sites fit the characteristic ventrally extended, head facing west burial pattern associated with the Windmiller culture, although the Windmiller Mound is a stratified site which also included burials from later time periods. I analyzed the skeletal remains of individuals recovered from these sites in order to assess sex differences in dental caries. Due to the nature of my study, I was only interested in adult individuals, who could be reliably sexed, and were recovered with at least part of their dentition intact. Age-at-death was primarily assessed using ectocranial suture closure (Meindl and Lovejoy 1985) and the

Suchey-Brooks pubic symphysis aging casts (Katz and Suchey 1986; Brooks and Suchey 1990). Sex estimation was performed using sexually dimorphic skeletal indicators of the skull and pelvis, as well as measurements for the femur and humerus (Dittrick and Suchey 1986). The dentition of each individual was inventoried and scored for dental caries and dental wear. Dental wear scores were recorded using the Smith (1984) scoring system for the incisors, canines, and premolars and the Scott (1979) system for the molars. Due to their relationship with dental caries, dental abscesses were also recorded. Once the data were collected and the observed number of dental caries was recorded, the caries correction factor was applied to provide a more accurate picture of the proportion of AMTL due to caries versus the proportion of AMTL due to dental attrition.

Once an observed and "corrected" caries score was established for males and females from the Windmiller and Phelps Mounds, the number of male versus female caries were compared using chi-square tests. Chi-square tests were performed using both the number of individuals who displayed caries (four site comparisons only) and the number of total caries exhibited by each sex from each site. Once comparisons had been made between the Windmiller Mound and the Phelps Mound, my data was compared to other Early Period data collected by Bartelink (2006) in order to evaluate whether the observed trend of females exhibiting significantly more dental caries in the Early Period was supported by statistical analysis. The number and proportion of dental caries by sex was collected and then individual site chi-square tests were performed in order to see if there were significant differences in the caries rates of males and females at each site. Afterward, site comparison chi-square tests were performed in order to see if males or females from one site displayed significantly higher proportions of dental caries than

their counterparts at other Early Period Windmiller sites. Finally, the individuals from each site were pooled and compared by sex and chi-square tests were run to assess any general patterns that may have been overlooked due to sample size.

CHAPTER V

RESULTS

This chapter discusses the results of the dental caries data analysis. The first

part of the chapter focuses on dental caries comparisons for the Windmiller (SAC-107)

and Phelps Mound (SJO-56) sites. The second part of the chapter is a comparison

between my analysis of SAC-107 and SJO-56 and the McGillivray #1 Mound (SJO-142)

and the Blossom Mound (SJO-68) studied by Bartelink (2006). I conducted this

comparison in order to test whether the higher proportion of dental caries found in

Bartelink's previous analysis is valid for these four Early Period Windmiller skeletal

populations.

Age Comparisons

Table 2 summarizes the age and sex distribution of dental cavities for all

individuals from SAC-107 and SJO-56, in order to gain insight on the overall proportion

of dental caries present at SAC-107. Age estimation is broken down into early, middle

and late adulthood by sex as a means of investigating the proportion of dental caries

present in each age group. Teeth were grouped into tooth types in order to assess whether

dental caries were more common in any particular tooth type. Following typical dental

caries patterning (Hillson 2001), molars are the most commonly affected tooth type.

Table 2. Dental caries prevalence by age and sex for individuals from SAC-107 and SJO-56.

Age	Tooth Type	SAC-107 Males n	SAC-107 Males %	SAC-107 Females n	SAC-107 Females %	SJO-56 Males n	SJO-56 Males %	SJO-56 Females n	SJO-56 Females %
Maxillary									
18-29	Incisors	0/2	0.0	0/4	0.0	0/2	0.0	0/4	0.0
	Canines	0/5	0.0	0/5	0.0	0/3	0.0	0/3	0.0
	Premolars	0/7	0.0	0/6	0.0	0/4	0.0	0/6	0.0
	Molars	1/7	14.3	0/18	0.0	0/8	0.0	1/10	10.0
30-39	Incisors	0/5	0.0	0/12	0.0	0/0	0.0	0/4	0.0
	Canines	0/6	0.0	0/4	0.0	0/1	0.0	0/6	0.0
	Premolars	0/12	0.0	0/22	0.0	0/1	0.0	0/13	0.0
	Molars	1/15	6.7	3/28	10.7	0/2	0.0	0/12	0.0
40+	Incisors	0/7	0.0	0/3	0.0	0/10	0.0	0/4	0.0
	Canines	0/9	0.0	0/7	0.0	0/16	0.0	0/4	0.0
	Premolars	0/19	0.0	0/21	0.0	0/26	0.0	0/7	0.0
	Molars	0/15	0.0	0/21	0.0	2/36	5.6	1/13	7.7
Mandibular									
18-29	Incisors	0/0	0.0	0/7	0.0	0/1	0.0	0/7	0.0
	Canines	0/0	0.0	0/4	0.0	0/3	0.0	0/3	0.0
	Premolars	0/3	0.0	0/10	0.0	0/4	0.0	0/6	0.0
	Molars	0/4	0.0	4/18	22.2	0/7	0.0	0/8	0.0
30-39	Incisors	0/4	0.0	0/12	0.0	0/2	0.0	0/6	0.0
	Canines	0/2	0.0	0/6	0.0	0/1	0.0	0/5	0.0
	Premolars	0/4	0.0	0/17	0.0	0/3	0.0	1/11	9.1
	Molars	0/6	0.0	5/15	33.3	0/5	0.0	2/21	9.5
40+	Incisors	0/8	0.0	0/7	0.0	0/25	0.0	0/4	0.0
	Canines	0/4	0.0	0/4	0.0	0/15	0.0	0/4	0.0
	Premolars	0/8	0.0	0/13	0.0	0/38	0.0	0/6	0.0
	Molars	0/14	0.0	0/15	0.0	0/26	0.0	0/2	0.0

[1] Number of carious teeth/the total number of teeth present in the sample

Table 3 illustrates the distribution of dental abscesses for all individuals at SAC-107 and SJO-56. Abscesses were recorded because they are often found in conjunction with dental caries due to the accumulation of pus from bacterial invasion of the infected tooth's pulp chamber. Abscesses were assessed by tooth type and mandibular

Table 3. Abscess rates by sex for adult individuals from SAC-107 and SJO-56.

| | | SAC-107 | | | | | |
| | | Males | | Females | | Indeterminate | |
	Tooth Type	n	%	n	%	n	%
Maxillary							
	Incisors	0/66	0.0	1/104	1.0	0/2	0.0
	Canines	2/34	5.9	3/52	5.8	0/1	0.0
	Premolars	2/68	2.9	2/101	2.0	0/2	0.0
	Molars	6/93	6.5	6/145	4.1	1/4	25.0
Mandibular							
	Incisors	1/46	2.2	0/88	0.0	0/27	0.0
	Canines	0/23	0.0	0/44	0.0	0/15	0.0
	Premolars	0/46	0.0	0/85	0.0	0/31	0.0
	Molars	0/66	0.0	1/126	0.7	0/50	0.0
		SJO-56					
	Tooth Type	Males		Females		Indeterminate	
		n	%	n	%	n	%
Maxillary							
	Incisors	2/64	3.1	1/78	1.3	0/20	0.0
	Canines	3/36	8.3	2/40	5.0	0/10	0.0
	Premolars	2/70	2.9	2/79	2.5	2/18	11.1
	Molars	8/104	7.7	3/104	2.9	0/28	0.0
Mandibular							
	Incisors	0/72	0.0	0/76	0.0	0/22	0.0
	Canines	0/36	0.0	1/38	2.6	0/11	0.0
	Premolars	3/72	4.2	0/71	0.0	1/22	4.5
	Molars	0/109	0.0	5/107	4.7	1/33	3.0

[1] Number of abscesses/total number of tooth positions present in the sample

vs. maxillary in order to demonstrate which tooth types were most affected by dental abscesses. At both sites the maxillary teeth have more dental abscesses. However, SAC-107 has more individuals with maxillary canine abscesses than SJO-56 where abscessing is most common in the premolars.

Temporal Comparison: SAC-107

In order to account for the stratified nature of SAC-107, Table 4 illustrates age and sex comparisons from SAC-107 and SJO-56 using only the individuals at SAC-107 who could be reliable seriated to the Early Period. Table 5 displays the dental abscess data using only Early Period individuals. Only the Early Period individuals are used in the chi-square comparative analysis.

Sex Comparisons: SAC-107 and SJO-56

Figures 5 and 6 illustrate the percentage of carious teeth present in the Early Period population from each site. Figure 5 represents the observed proportion of carious teeth present by sex. Figure 6 represents the proportion of carious teeth present once the caries correction factor has been applied in order to account for the proportion of AMTL due to dental caries.

Both Figures 5 and 6 illustrate that females have higher percentages of dental caries in both archaeological populations. However, Table 6 illustrates that the sex differences in caries were found only to be statistically significant in the dentitions of individuals from SJO-56 (Observed χ^2=5.227, p=0.022; Corrected χ^2=15.132, p=0.000). However, small sample size for SAC-107 may have influenced these results. Figure 7 presents the proportion of AMTL present in SJO-56 and SAC-107.

Table 7 demonstrates that the rate of AMTL was significantly higher in females at SJO-56 (χ^2=4.214, p=0.040), while there was no significant sex difference at SAC-107. When the rate of AMTL was compared between sites, no significant difference was found (Table 8).

Table 4. Dental caries prevalence by age and sex for early period individuals from SAC-107 and SJO-56.

| | | SAC-107 | | | | SJO-56 | | | |
| | | Males | | Females | | Males | | Females | |
Age	Tooth Type	n	%	n	%	n	%	n	%
Maxillary									
18-29	Incisors	0/0	0.0	0/6	0.0	0/2	0.0	0/4	0.0
	Canines	0/0	0.0	0/4	0.0	0/3	0.0	0/3	0.0
	Premolars	0/0	0.0	0/5	0.0	0/4	0.0	0/6	0.0
	Molars	0/0	0.0	0/7	0.0	0/8	0.0	1/10	10.0
30-39	Incisors	0/0	0.0	0/0	0.0	0/0	0.0	0/4	0.0
	Canines	0/0	0.0	0/0	0.0	0/1	0.0	0/6	0.0
	Premolars	0/0	0.0	0/0	0.0	0/1	0.0	0/13	0.0
	Molars	0/0	0.0	0/0	0.0	0/2	0.0	0/12	0.0
40+	Incisors	0/4	0.0	0/4	0.0	0/10	0.0	0/4	0.0
	Canines	0/2	0.0	0/4	0.0	0/16	0.0	0/4	0.0
	Premolars	0/4	0.0	0/8	0.0	0/26	0.0	0/7	0.0
	Molars	1/6	16.7	1/8	12.5	2/36	5.6	1/13	7.7
Adult,	Incisors	0/3	0.0	0/0	0.0	0/0	0.0	0/0	0.0
Indeterminate	Canines	0/2	0.0	0/0	0.0	0/0	0.0	0/0	0.0
	Premolars	0/3	0.0	0/0	0.0	0/0	0.0	0/0	0.0
	Molars	0/1	0.0	0/2	0.0	0/0	0.0	0/0	0.0
Mandibular									
18-29	Incisors	0/0	0.0	0/7	0.0	0/1	0.0	0/7	0.0
	Canines	0/0	0.0	0/4	0.0	0/3	0.0	0/3	0.0
	Premolars	0/0	0.0	0/9	0.0	0/4	0.0	0/6	0.0
	Molars	0/0	0.0	1/15	6.7	0/7	0.0	0/8	0.0
30-39	Incisors	0/0	0.0	0/4	0.0	0/2	0.0	0/6	0.0
	Canines	0/0	0.0	0/2	0.0	0/1	0.0	0/5	0.0
	Premolars	0/0	0.0	0/4	0.0	0/3	0.0	1/11	9.1
	Molars	0/0	0.0	0/5	0.0	0/5	0.0	2/21	9.5
40+	Incisors	0/0	0.0	0/4	0.0	0/25	0.0	0/4	0.0
	Canines	0/0	0.0	0/2	0.0	0/15	0.0	0/4	0.0
	Premolars	0/1	0.0	0/7	0.0	0/38	0.0	0/6	0.0
	Molars	0/2	0.0	3/10	30.0	0/26	0.0	0/2	0.0
Adult,	Incisors	0/0	0.0	0/4	0.0	0/0	0.0	0/0	0.0
Indeterminate	Canines	0/0	0.0	1/3	33.3	0/0	0.0	0/0	0.0
	Premolars	0/0	0.0	1/6	16.7	0/0	0.0	0/0	0.0
	Molars	0/0	0.0	0/6	0.0	0/0	0.0	0/0	0.0

[1] Number of carious teeth/the total number of teeth present in the sample

Table 5. Abscess rates by sex for early period adult individuals from SAC-107 and SJO-56.

| | | SAC-107 | | | | | |
| | | Males | | Females | | Indeterminate | |
Tooth Position		n^1	%	n^1	%	n^1	%
Maxillary							
	Incisors	0/11	0.0	0/19	0.0	0/0	0.0
	Canines	0/5	0.0	1/10	10.0	0/0	0.0
	Premolars	0/9	0.0	0/17	0.0	0/0	0.0
	Molars	0/10	0.0	0/17	0.0	0/0	0.0
Mandibular							
	Incisors	0/2	0.0	0/32	0.0	0/0	0.0
	Canines	0/1	0.0	1/16	6.3	0/0	0.0
	Premolars	0/1	0.0	0/32	0.0	0/0	0.0
	Molars	0/3	0.0	0/48	0.0	0/0	0.0

| | | SJO-56 | | | | | |
| | | Males | | Females | | Indeterminate | |
Tooth Position		n^1	%	n^1	%	n^1	%
Maxillary							
	Incisors	2/64	3.1	1/78	1.3	0/20	0.0
	Canines	3/36	8.3	2/40	5.0	0/10	0.0
	Premolars	2/70	2.9	2/79	2.5	2/18	11.1
	Molars	8/104	7.7	3/104	2.9	0/28	0.0
Mandibular							
	Incisors	0/72	0.0	0/76	0.0	0/22	0.0
	Canines	0/36	0.0	1/38	2.6	0/11	0.0
	Premolars	3/72	4.2	0/71	0.0	1/22	4.5
	Molars	0/109	0.0	5/107	4.7	1/33	3.0

[1] Number of abscesses/total number of tooth positions present in the sample

Sex Differences: Molar Wear at SAC-107
 and SJO-56

Table 9 represents dental attrition rates which were calculated from the mean difference in wear score between M1 and M2.
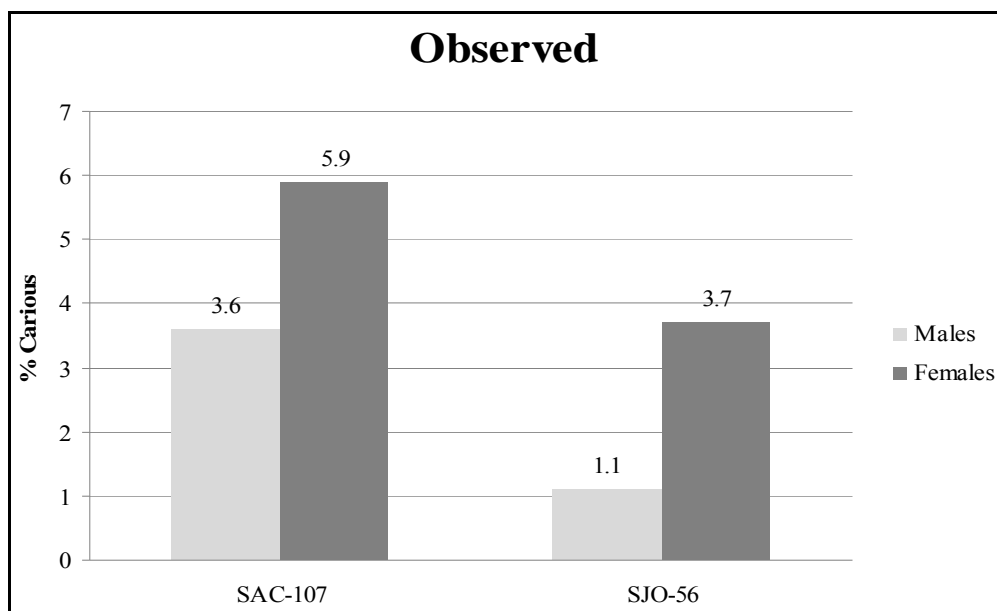
Observed

Figure 5. Observed caries rates for males and females by archaeological site.
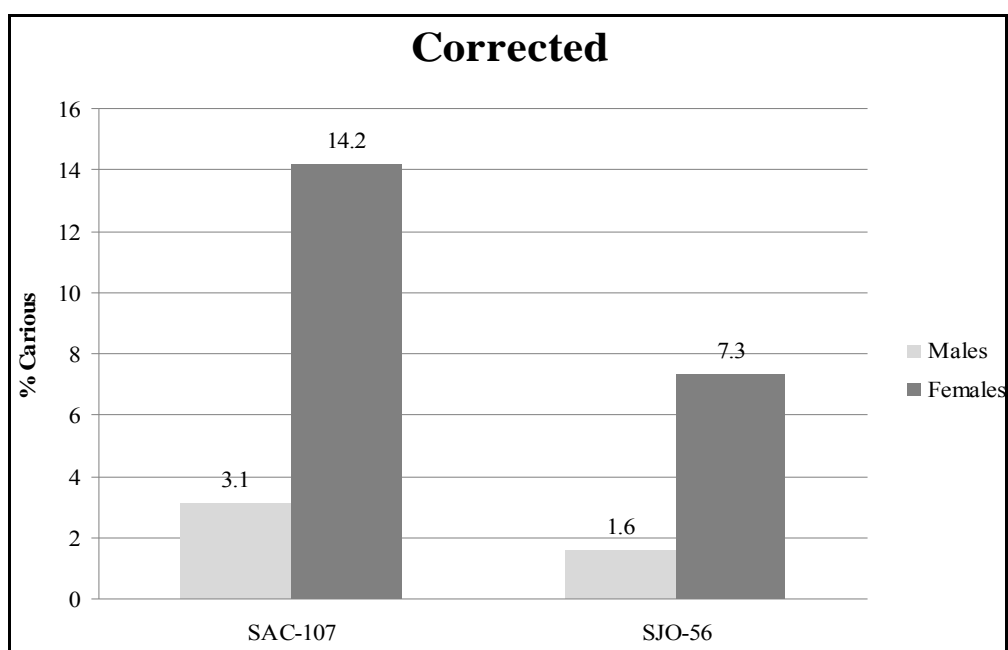
Corrected

Figure 6. Corrected caries rates for males and females by archaeological site.

Table 6. Chi-square results for males vs. females individual tooth analysis.

	Site	χ^2, F.E.	p value[1]	n^2 (Male vs. Female)	Trend
Observed	SAC-107	F.E.	1.000	1/28 vs. 8/135	
	SJO-56	5.227	0.022	4/367 vs. 12/323	F>M
Corrected	SAC-107	2.755	0.097	1/32 vs. 21/148	
	SJO-56	15.132	0.000	7/399 vs. 27/362	F>M

[1]Statistically significant results ($p \leq 0.05$) are indicated in bold face type.
[2] Number of caries observed/the number of teeth present which could be observed for caries.
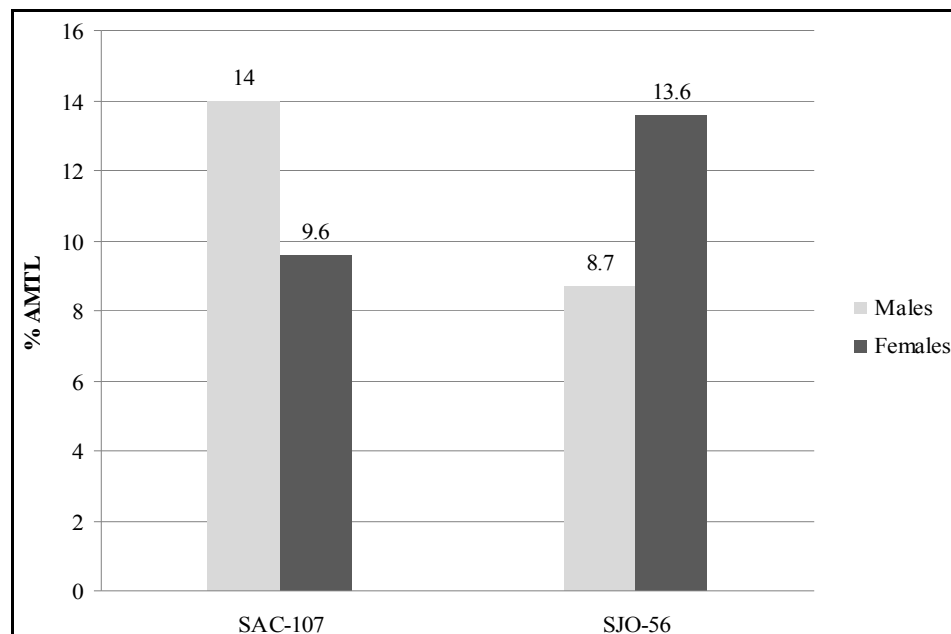
Figure 7. Rates of AMTL for males and females from SAC-107 and
SJO-56.

The mean M1 and M2 scores are lower for females at both sites, indicating

that females had lower mean rates of wear. The higher mean rate of dental wear exhibited

by males from SAC-107 and SJO-56 follows the typical hunter-gatherer pattern of high

Table 7. Chi-square comparisons of male and female AMTL rates at SAC-107 and SJO-56.

Site	χ^2, F.E.	p value[1]	n^2 (Male vs. Female)	Trend
SAC-107	F.E.	0.463	4/28 vs. 13/135	
SJO-56	4.214	0.040	32/367 vs. 44/323	F>M

[1] Statistically significant values (p≤0.05) are indicated in bold face type.
[2] Number of teeth lost antemortem observed/total number of teeth present which could be observed for AMTL. Males are always on the left.

Table 8. Chi-square comparisons of AMTL rates between SAC-107 and SJO-56.

	χ^2, F.E.	p value	n (Male vs. Female)	Trend
SAC-107 vs. SJO-56	0.046	0.829	17/163 vs. 76/690	

Table 9. Mean wear scores and M1-M2 differences.

Site	M1		M2		M1-M2 Differences	
	Male	Female	Male	Female	Male	Female
SAC-107	25.7	24.5	22.0	20.4	3.7	4.1
SJO-56	33.5	31.9	30.3	27.1	3.3	4.8

rates of wear and low rates of dental caries. Females have lower mean rates of wear and

higher rates of caries at both sites. Interestingly, differences in male and female dental

caries rates are not found to be significant at SAC-107, even though females display more

dental caries and less mean molar attrition. However, the sample size at SAC-107 is very

small in comparison to all other sites, meaning that the lack of difference in dental caries between sexes may be due to sample size.

Differences in the mean M1 and M2 scores indicate that females have greater differences between the mean rate of wear on the M1 and the mean rate of wear on the M2. At both sites, female's high rates of attrition may contribute to a lower prevalence of dental caries due to the fact that obliteration of the tooth's occlusal surface from attrition may have outpaced occlusal surface destruction from dental caries.

<div align="center">Regional Sex Comparisons: SAC-107,
SJO-56, SJO-142, and SJO-68</div>

Caries rates from SAC-107and SJO-56 were also compared to other Early Period Windmiller sites, which had been previously analyzed by Bartelink (2006). This larger comparison was conducted to examine sex patterns, and site differences in caries rates.

Chi-square analysis was performed using the number of males and females for each Early Period site with carious teeth (see Figure 8). SAC-107 was eliminated from this analysis because the sample size is too small to be valid. As Table 10 illustrates, chi-square analysis by individual yielded no significant results. When the data from all four Early Period skeletal assemblages was combined, chi-square analysis again revealed that there was no significant difference between the number of male and female individuals with dental caries ($\chi^2=0.955$, $p=0.328$).

Chi-square tests were next used to evaluate differences in dental caries rates between males and females by tooth type. First data from all the Early Period sites were combined in order to see if there was an overall statistically significant difference existed
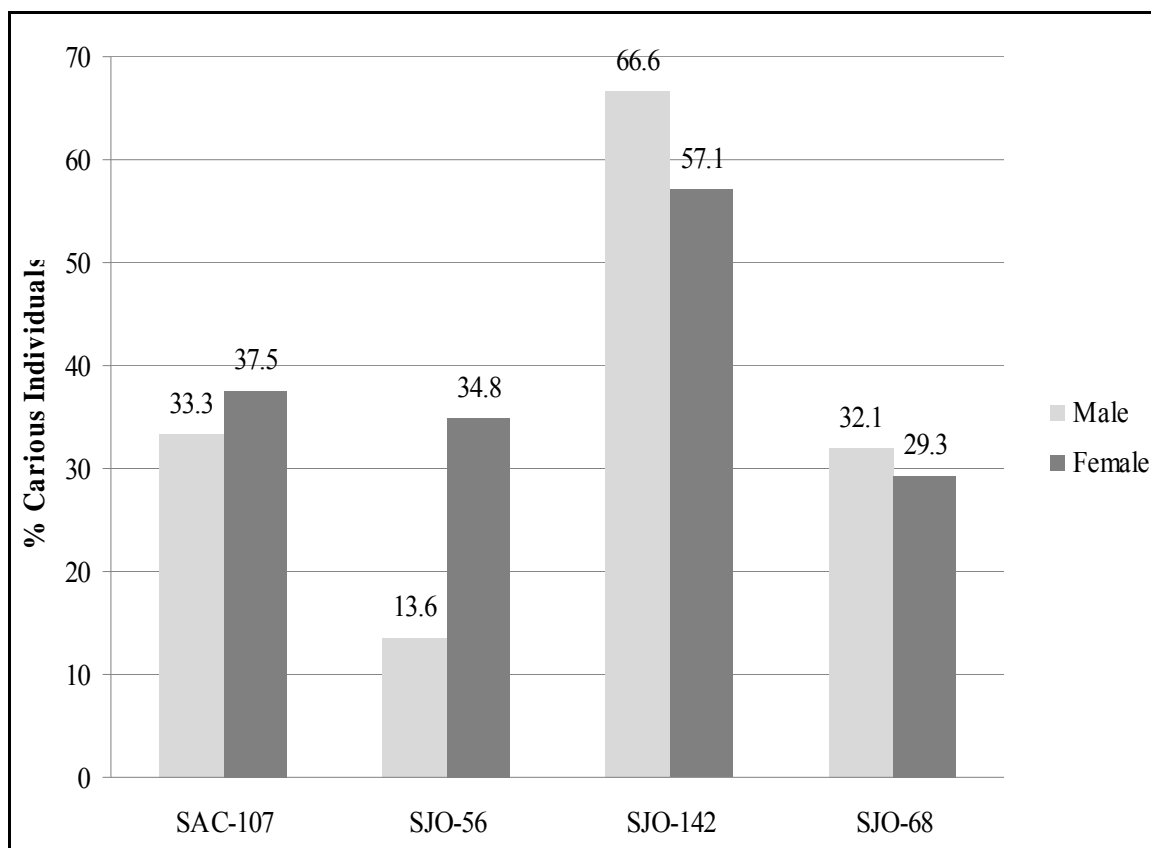
Figure 8. Percentage of male and female individuals with dental caries by archaeological site.

Table 10. Chi-square results by individual for all early period archaeological sites.

Site	χ^2, F.E.	p Value	n (Male vs. Female)
SJO-56	2.722	0.990	3/22 vs. 8/23
SJO-142	0.305	0.581	12/18 vs. 8/14
SJO-68	0.277	0.599	9/28 vs. 12/41
Combined Sites	0.995	0.328	27/90 vs. 36/98

between males and females. Table 11 reveals that the number of carious teeth observed

on the female dentition was significantly higher than for males.

Table 11. Chi-square results (observed and uncorrected) for male vs. female caries rates
for combined early period sites.

	χ^2, F.E.	p value	n (Male vs. Female)	Trend
Observed Combined Early Period Sites	10.253	0.001	35/1055 vs. 63/994	F>M
Corrected Combined Early Period Sites	47.125	0.000	63/1188 vs. 144/1207	F>M

Statistically significant differences were found between males and females in

both the uncorrected and corrected data samples (Observed χ^2=10.253, p=0.001;

Corrected χ^2=47.125, p=0.000), indicating that females overall have higher proportions of

carious lesions than males in the Windmiller populations examined.

Table 12 illustrates the observed and caries corrected proportion of carious

teeth present for each sex by site.

Figures 9, 10, and 11 suggest that in both the observed and caries corrected Early

Period skeletal samples, females have higher proportions of dental caries. At SJO-56 and

SJO-68, the proportion of dental caries recorded in females is more than twice that of

males. At SJO-56, males and females expressed caries rates of 1.1 and 3.7% respectively,

meaning that females display a rate of caries 3.4 times greater than their male

counterparts. Females as SJO-68 had a caries rate of 7.1%, while males displayed a caries

rate of 3.1%, making the female proportion of dental caries 2.3 times larger than

Table 12. Observed, corrected, and AMTL frequencies for four early period Windmiller skeletal assemblages.

Site	Observation Type	Males		Females	
		n	%	n	%
SAC-107	Observed	1/28	3.6	8/135	5.9
	Corrected	1/32	3.1	21/148	14.2
	AMTL	4/28	14.0	13/135	9.6
SJO-56	Observed	4/367	1.1	12/323	3.7
	Corrected	6.5/399	1.6	26.7/367	7.3
	AMTL	32/367	8.7	44/323	13.6
SJO-142	Observed	18/269	6.7	17/172	9.9
	Corrected	28.6/308	9.3	26.3/211	12.5
	AMTL	39/269	14.5	39/172	22.7
SJO-68	Observed	12/390	3.1	26/364	7.1
	Corrected	25.9/449	5.8	69.9/481	14.5
	AMTL	59/390	15.1	117/364	32.1

males from the same site. Figure 10 demonstrates this to be true for all sites with the exception of SJO-142 when the caries correction factor is applied to account for AMTL due to caries. When the corrected data are incorporated, females display 4.6 times more caries than males at SAC-107 and SJO-56 and 2.5 times more caries at SJO-68.

As Tables 13 and 14 illustrate, while females display larger proportions of dental caries than males at all of the Early Period sites in this study, disparities in dental caries rates between males and females are only significant at SJO-56 (Observed χ^2=5.227, p=0.022; Corrected χ^2=15.132, p=0.000) and SJO-68 (Observed χ^2=6.504, p=0.011; Corrected χ^2=18.529, p=0.000).

Site to Site General Comparison

The observed and corrected site comparisons for dental caries rates by tooth type are represented in Figure 12 and Table 15. As Figure 12 illustrates, when the carious
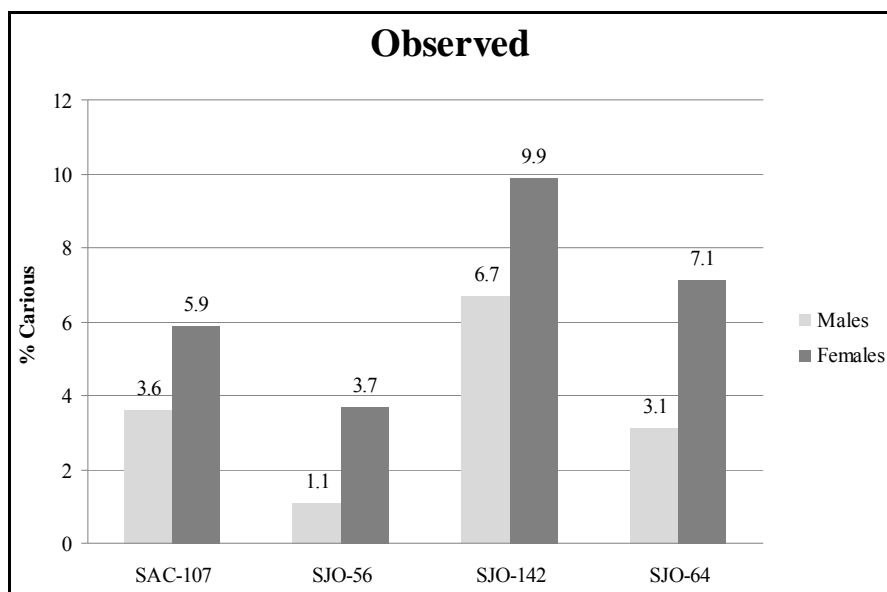
Figure 9. Observed caries rates for males and females by archaeological site.

correction factor is applied the proportion of dental caries more than doubles at each site except SJO-142, where the observed and corrected proportion of carious lesions remains similar.
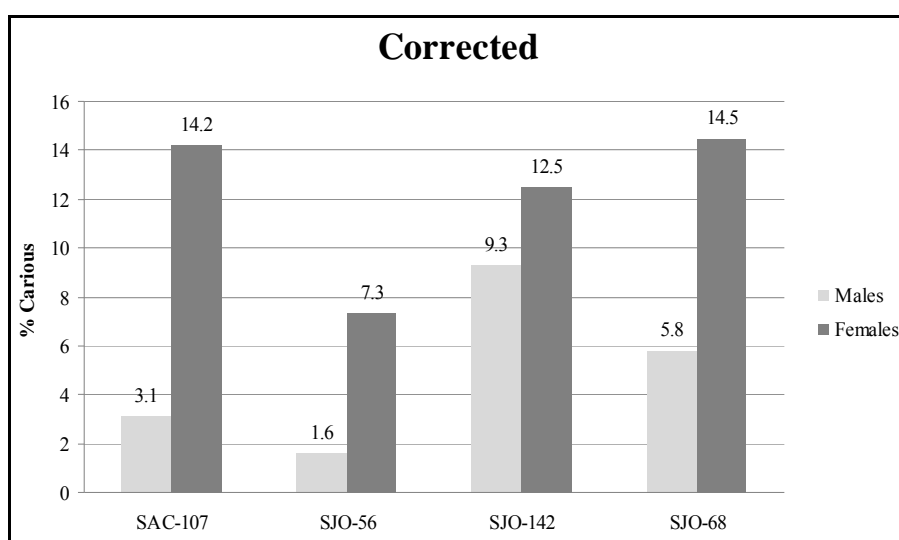
Figure 10. "Corrected" caries rates for males and females by archaeological site.
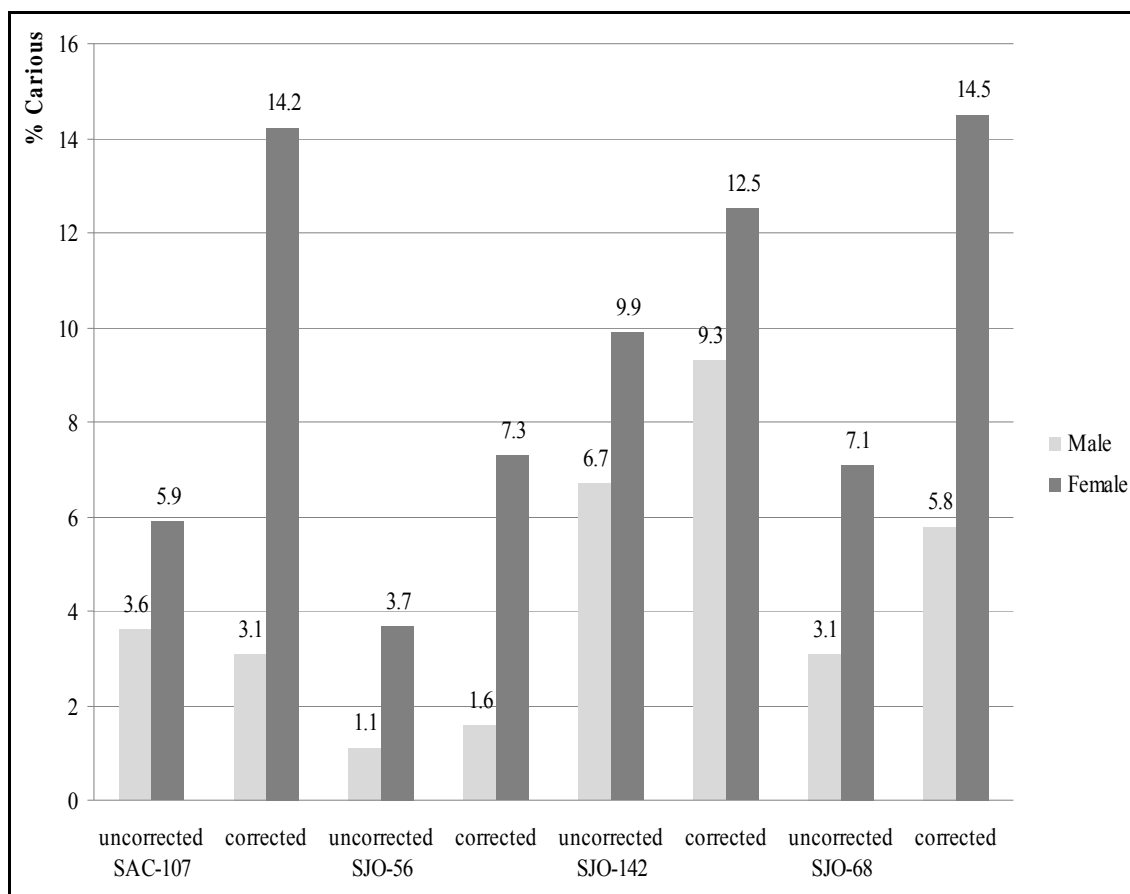
Figure 11. Male and female observed and corrected data by archaeological site.

Table 13. Observed chi-square results for males vs. females caries rates by archaeological site.

Site	χ^2, F.E.	p value	n (Male vs. Female)	Trend
SAC-107	F.E.	1.000	1/28 vs. 8/135	
SJO-56	5.227	0.022	4/367 vs. 12/323	F>M
SJO-142	1.463	0.226	18/269 vs. 17/172	
SJO-68	6.504	0.011	12/390 vs. 25/364	F>M

Table 14. Corrected chi-square results for males vs. female caries rates by archaeological site.

Site	χ^2, F.E.	p value	n (Male vs. Female)	Trend
SAC-107	2.755	0.097	1/32 vs. 21/148	
SJO-56	15.132	0.000	7/399 vs. 27/362	F>M
SJO-142	1.117	0.291	29/308 vs. 26/211	
SJO-68	18.529	0.000	26/449 vs. 70/481	F>M
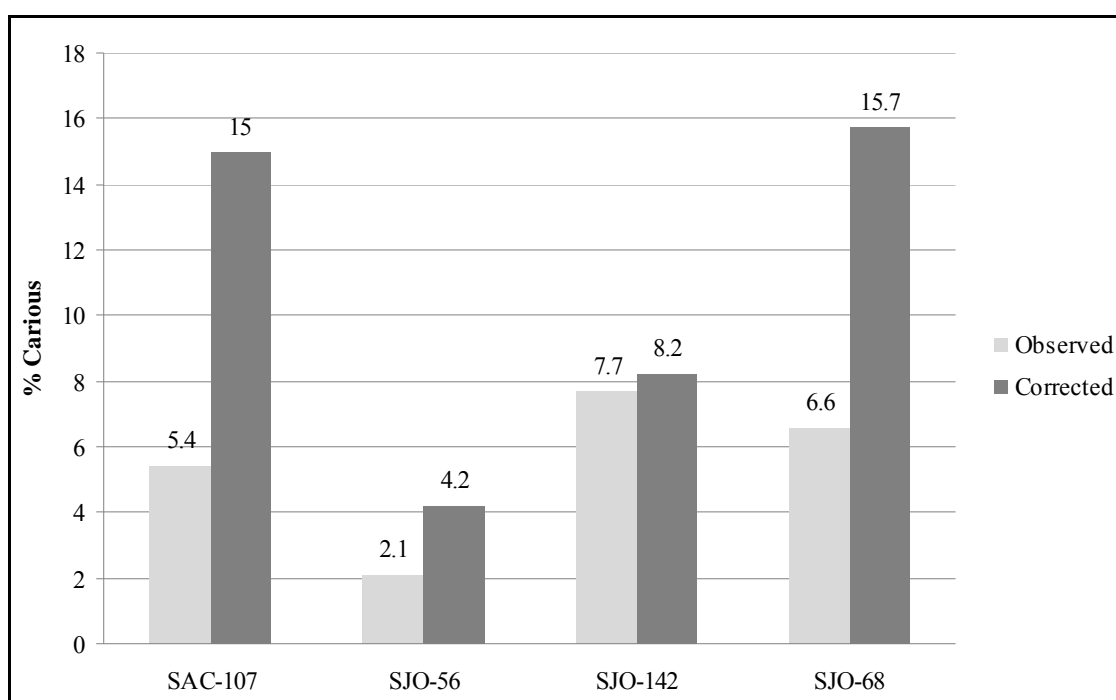
Figure 12. Site dental caries rate comparison with sexes pooled (observed and corrected).

When the proportion of dental caries present at all Early Period sites were compared, statistically significant differences were found between SJO-56 and SJO-142 (observed χ^2=19.718, p=0.000; corrected χ^2=18.203, p=0.000) and SJO-56 and SJO-68

Table 15. Chi-square results for dental caries site comparisons (observed and corrected).

	Site	χ^2, F.E.	p value[1]	n^2	Trend
Observed	SAC-107 vs. SJO-56	F.E.	0.038	9/163 vs. 16/690	
	SAC-107 vs. SAC-142	1.028	0.311	9/163 vs. 35/441	
	SAC-107 vs. SJO-68	0.064	0.800	9/163 vs. 38/754	
	SJO-56 vs. SJO-142	19.718	0.000	16/690 vs. 35/441	142>56
	SJO-56 vs. SJO-68	7.410	0.006	16/690 vs. 38/754	68>56
	SJO-142 vs. SJO-68	4.071	0.044	35/441 vs. 38/754	
Corrected					
	SAC-107 vs. SJO-56	13.906	0.000	21/180 vs. 34/766	107>56
	SAC-107 vs. SAC-142	0.158	0.691	21/180 vs. 55/519	
	SAC-107 vs. SJO-68	0.289	0.591	21/180 vs. 96/930	
	SJO-56 vs. SJO-142	18.203	0.000	34/766 vs. 55/519	142>56
	SJO-56 vs. SJO-68	20.547	0.000	34/766 vs. 96/930	68>56
	SJO-142 vs. SJO-68	0.027	0.870	55/519 vs. 96/930	

[1] Statistically significant results (p<0.0085) are indicated in bold-face type
[2] Number of carious teeth present/number of total teeth observable.

(observed χ^2=7.410, p=0.006; corrected χ^2=20.547, p=0.000). When the caries corrected data was used, a significant difference was also found to exist between the rate of caries at SAC-107 and SJO-56 (corrected χ^2=13.906, p=0.000) as well.

Inter-Site Sex Comparison

Due to the fact that combined site to site chi-square comparisons do not reveal whether statistically significant differences are found in males, females or both sexes, chi-square comparisons were conducted between the male and female dentitions in each skeletal assemblage in order to figure out whether statistically significant differences existed between the sexes at different Early Period sites (Tables 16 and 17).

Statistical analysis of comparisons between dentitions of males at SJO-56 and SJO-142 revealed that there was a significant difference in the proportion of dental caries rates in both the observed and corrected datasets (Observed χ^2=14.585, p=0.000;

Table 16. Observed chi-square results for site to site comparisons by sex.

	Site	χ^2, F.E.	*p* value	*N*	Trend
Male	SAC-107 vs. SJO-56	1.282	0.258	1/28 vs. 4/367	
	SAC-107 vs. SAC-142	0.412	0.521	1/28 vs. 18/269	
	SAC-107 vs. SJO-68	0.021	0.884	1/28 vs. 12/390	
	SJO-56 vs. SJO-142	14.585	0.000	4/367 vs. 18/269	142>56
	SJO-56 vs. SJO-68	3.608	0.057	4/367 vs. 12/390	
	SJO-142 vs. SJO-68	4.787	0.029	18/269 vs. 12/390	
Female					
	SAC-107 vs. SJO-56	1.114	0.291	8/135 vs. 12/232	
	SAC-107 vs. SAC-142	1.584	0.208	8/135 vs. 17/172	
	SAC-107 vs. SJO-68	0.230	0.632	8/135 vs. 26/364	
	SJO-56 vs. SJO-142	7.743	0.005	12/232 vs. 17/172	142>56
	SJO-56 vs. SJO-68	3.848	0.050	12/232 vs. 26/364	
	SJO-142 vs. SJO-68	1.189	0.275	17/172 vs. 26/364	

Table 17. "Corrected" chi-square and fisher's exact results for site-to-site comparisons by sex.

	Site	χ^2, F.E.	*p* value	*N*	Trend
Male	SAC-107 vs. SJO-56	F.E.	0.463	1/32 vs. 7/399	
	SAC-107 vs. SJO-142	F.E.	0.336	1/32 vs. 29/308	
	SAC-107 vs. SJO-68	F.E.	1.000	1/32 vs. 26/449	
	SAC-56 vs. 142	21.111	0.000	7/399 vs. 29/308	142>56
	SJO-56 vs. SJO-68	9.202	0.002	7/399 vs. 26/449	68>56
	SJO-142 vs. SJO-68	3.563	0.059	29/308 vs. 26/449	
Female					
	SAC-107 vs. SJO-56	4.820	0.028	20/148 vs. 27/367	
	SAC-107 vs. SJO-142	0.110	0.740	20/148 vs. 26/211	
	SAC-107 vs. SJO-68	0.100	0.752	20/148 vs. 70/481	
	SAC-56 vs. SJO-142	3.996	0.046	27/367 vs. 26/211	
	SJO-56 vs. SJO-68	10.641	0.001	27/367 vs. 70/481	68>56
	SJO-142 vs. SJO-68	0.611	0.434	26/211 vs. 70/481	

Corrected $\chi^2=21.111$, $p=0.000$), with males at SJO-142 exhibiting more carious lesions. Differences in caries rates also approach significance in observed comparisons between males from SJO-142 and SJO-68 ($\chi^2=4.787$; $p=0.029$), with males at SJO-142 displaying significantly more dental caries.

When caries rates were adjusted using the caries correction factor, significant difference also appeared among males ($\chi^2=9.202$, $p=0.002$) at SJO-56 and SJO-68, with males at SJO-68 exhibiting a significantly higher proportion of dental caries than their counterparts at SJO-56.

Statistically significant differences in rates of dental caries were found in comparisons of female dentition at SJO-56 and SJO-142 ($\chi^2=7.743$, $p=0.005$), with females at SJO-142 exhibiting more caries. Comparisons between females at SJO-56 and SJO-68 approach significance ($\chi^2=0.050$, $p=3.848$), with females at SJO-68 displaying more dental caries.

When caries rates were adjusted using the caries correction factor, significant difference appeared among females ($\chi^2=10.641$, $p=0.001$) at the sites of SJO-56 and SJO-68, females at SJO-68 exhibiting a significantly higher proportion of dental caries. This result is interesting considering that both sites are found in close proximity to each other. Corrected comparisons among females from SJO-56 and SJO-142 ($\chi^2=3.996$, $p=0.046$) and SAC=107 and SJO-56 ($\chi^2=4.820$, $p=0.028$), with females at SJO-142 and SAC-107 exhibiting more dental caries respectively.

<u>Sex Differences: Molar Wear at SAC-107,
  SJO-56, SJO-142, and SJO-68</u>

Table 18 summarizes the mean wear score and the difference between the M1

and M2 mean rate of attrition.

Table 18. Mean wear scores and M1-M2 difference for all sites.

	M1		M2		M1-M2 Differences	
Site	Male	Female	Male	Female	Male	Female
SAC-107	25.7	24.5	22.0	20.4	3.7	4.1
SJO-56	33.5	31.9	30.3	27.1	3.3	4.8
SJO-142	35.3	35.0	31.3	33.7	3.9	1.3
SJO-68	33.1	30.1	27.0	24.4	6.1	5.6

Mean molar wear scores of the M1 and the M2 indicate that females display

lower slightly lower rates of dental wear than males at all sites, with the exception of the

mean wear score of the M2 at SJO-142 where the pattern is reversed. Lower mean rates

of dental wear tend to indicate higher rates of dental caries and, for the most part, females

in all four samples do display a higher prevalence of dental caries than males.

Interestingly, while differences females displayed higher mean rates of dental

wear at SAC-107 and SJO-56, the exact opposite is true at SJO-142 and SJO-6, where the

difference between the M1 and M2 wear scores is higher in males. The difference in wear

rates at SJO-142 is actually three times greater in males than in females. However, at

SJO-142, differences in rates of wear between the M1 and the M2 are low for both sexes.

The high mean rates of wear and low differences in wear scores accord well with the non-

significant differences in caries rates for males and females found at SJO-142, due to the

fact that populations that display a lot of tooth wear often do not have many dental caries.

This could be due to eating a gritty, non-cariogenic diet or it could be due the rate of dental attrition outpacing dental caries development.

Summary

Sex differentiated proportions of dental caries rates seem to suggest that females have higher rates of dental caries than males. However, chi-square tests indicate that only the disparities between males and female at SJO-56 were significant, with females displaying more caries. Chi-square tests revealed that a significant difference was also present in the rate of AMTL at SJO-56, although, interestingly, males displayed more AMTL than females. Mean wear scores revealed that the teeth of both males and females were relatively worn, although more so at SJO-56 than SAC-107. The M1-M2 difference indicates that the rate of attrition was not particular high, although it is higher in females than in males at both sites. Caries rates from SAC-107 and SJO-68 were compared to Bartelink's (2006) data from SJO-142 and SJO-68. When caries rates were initially compared, once again, females appeared to have higher rates of dental caries. Chi-square analysis using the number of males and females with caries from each site revealed no statistical differences between males and females. This is probably due to small sample size. However, when the number of carious teeth present for males and females was compared, statistically significant differences were revealed at SJO-56 and SJO-68. Inter-site comparisons revealed significant differences between SJO-56 and SJO-142 and SJO-56 and SJO-68 in both the observed and corrected caries datasets, while significant differences were only seen in the caries corrected sample comparison between SAC-107 and SJO-56. When observed data for males and females from one site was

compared to their counterparts at another site, differences were found between SJo-56 and SJO-142 for both sexes, with SJO-142 males and females exhibiting more caries. When the corrected data were analyzed for inter-site comparisons by sex, only the males in the SJO-56/SJO-142 comparison remained significant. In the corrected sample chi-square results, significant differences were also noted between males and females at SJO-56 and SJO-68 with individuals at SJO-68 displaying more dental caries. When the data for males and females was pooled for all four Early Period sites, uncorrected and corrected chi-square results were found to be significant, suggesting that the overall trend at these Early Period Windmiller sites indicates that females have higher overall rates of dental caries than males.

CHAPTER VI

DISCUSSION

The role of particular foods and their involvement in the production of dental

caries is fairly well understood in a broad sense. However, the role individual types of

plants play in aiding and promoting dental caries is not well-known. In this chapter, I

attempt to suggest which types of plant resources would have contributed to dental caries

and I discuss the reasons why women can exhibit more dental caries in populations in

which both sexes share the same resources. The first part of the chapter focuses on my

results and what they suggest about sex differences in dental caries in the Windmiller

population. This section is followed by a discussion of women's physiological

predisposition toward dental caries and how their role as gatherers creates unique

opportunities that contribute to caries pathogenesis. Finally, I consider how seeds, nuts,

roots, tubers, bulbs, and berries that were local to the Sacramento-San Joaquin Delta

region may have contributed or prohibited the formation of dental caries. I also discuss

some limitations of my study.

Discussion: Study Population Results and
Interpretations

Statistical analysis performed on the dentitions of individuals from SAC-107,

SJO-56, SJO-142, and SJO-68 indicated significant sex differences exist in the

prevalence of dental caries When dental caries was assessed by overall tooth count, the females at SJO-56 were shown to exhibit a higher proportion of dental caries than males.

At all four sites, females displayed a higher percentage of dental caries. When all four sites were combined and tooth counts were analyzed, females were found to exhibit a statistically higher prevalence of dental caries in both the observed and caries corrected samples. When the overall tooth counts at individual sites were assessed, females exhibited a higher proportion of dental caries at SJO-56 and SJO-68 in both the observed and corrected samples. The lack of significant sex differences in dental caries rates at SAC-107 is probably due to sample size. Non-significant results at SJO-142 may be due to the severe amount of dental attrition distorting the actual amount of dental caries present in the teeth.

When the rate of dental caries was compared between sites, individuals from SJO-56 were shown to exhibit significantly lower rates of dental caries than individuals at SJO-68 and SJO-142. Comparisons between the observed data from SAC-107 and SJO-56 and SJO-142 and SJO-68 approached significance, with individuals at SAC-107 and SJO-142 exhibiting more caries respectively. When the corrected data were analyzed, individuals at SAC-107 displayed significantly more dental caries than individuals at SJO-56.

When the males and females at each site were compared to each other, observed males and females at SJO-142 shared a greater prevalence of caries than their respective counterparts at SJO-56. However when the data were analyzed using the corrected sample, these differences were found only in males, although the disparity in caries rates between females approached significance. Observed comparisons between

males from SJO-56 and SJO-68 and SJO-68 and SJO-142 exhibited differences that approached significance, with males at SJO-68 displaying more dental caries than males at SJO-56, but fewer dental caries than males at SJO-142. The analysis also indicated that the higher prevalence of dental caries seen in the observed teeth of females from SJO-68 in comparison to SJO-56 approached significance.

The corrected data indicated that the males and females at SJO-68 exhibit significantly more caries than males and females at SJO-56. Comparisons between the observed rates of dental caries for females at SAC-107 and SJO-56 and males and females SJO-142 and SJO-56 approached significance, with females at SAC-107 and males and females at SJO-142 exhibiting more caries respectively.

The results of this analysis mimic those of a study conducted by Lukacs and Thompson (2008), who found that while females always exhibited a high percentage of dental caries than males, North American populations exhibited no significant differences in dental caries prevalence by individual. However, North American prehistoric females did exhibit significantly higher rates of dental caries than males when comparisons were made using the tooth count method (Lukacs and Thompson 2008).

Molar wear can mask damage caused by dental caries due to the fact that the occlusal surface wears down at a more rapid rate than the enamel destruction caused by carious lesions. The individuals at SJO-142 exhibit the highest mean wear scores (M1 and the M2,) with females actually exhibiting a higher mean wear score in the M2 than males. Though the wear scores at all four sites tend to be high, the mean wear scores of females at SJO-142 are so high that there is very little difference in the mean rate of wear between the M1 and the M2, even though the M1 erupts six years earlier. This is odd due

to the fact that the cemetery at SJO-142 is located in close proximity to SJO-56 and SJO-68 where females exhibit lower mean rates of wear than males and have higher differences in the rates of wear between the M1 and the M2. However, the dental wear data could reflect that the caries scores for both males and females at SJO-142 are being underenumerated due to the fact that the high incidence of dental wear is obliterating the physical evidence of dental caries.

Interestingly, the dental attrition at SAC-107 is noticeably lower than at all other sites. While SJO-56, SJO-68, and SJO-142, are all found within the big bend of the Mokelumne River in San Joaquin County, SAC-107 is found several miles away near the Cosumnes River in Sacramento County. It is tempting to argue that this may reflect slight differences in the abrasive quality and types of food consumed by individuals at these different sites due to the fact that SAC-107 is located closer to the foothills, which would have provided different plant resources. However, the small sample size at SAC-107 makes it impossible to suggest that any real differences in dental attrition exist between sites.

Turner (1979) noted that hunter-gatherer populations tended to express a dental caries rate of approximately 1-2%. The observed Windmiller populations included in this analysis display a rate of dental caries above 2%. However, males exhibit a percentage of dental caries only slightly above 2%, displaying an average of 3.6% when SJO-142 is included and an average of 2.6% when SJO-142 excluded. The male average of 2.6% is probably more accurate due to the fact that the males at SJO-142 exhibit twice as many caries as the males at SAC-107 and SJO-68 and six times as many caries as the males at SJO-56. In contrast, the rate of dental caries for observed females at SAC-107,

SJO-142, and SJO-68 all fall within the 5-10% dental caries range exhibited by individuals who engage in a mixed subsistence economy. When the dental caries rate at SJO-56 is considered and all four sites are combined, the mean rate of dental caries is 5.8%. When SJO-56 is not included, the mean percentage of dental caries jumps to 7.6%, well within the mixed subsistence rate. This suggests that the women buried at these archaeological sites were eating more cariogenic plant resources and more varied diets than their male counterparts.

The results of my research support the idea that Windmiller women had higher rates of dental caries than men. However, isotopic research in the Central Valley indicates that there is not a significant difference in the types of food consumed by Central Valley males and females (Bartelink 2006). Isotope values of bone collagen suggest that both sexes subsisted on terrestrial herbivores, C3 plants, and freshwater fish (Bartelink 2006). However a similar isotope value does not indicate whether sex difference exist in the specific types of foods consumed. Therefore, even though isotope evidence indicates both Windmiller males and females probably consumed meat, fish, and terrestrial plants, the proportions in which they consumed them may have varied. Women may have consumed more plant resources, while men may have eaten more meat. Depending of the types of plants consumed, women would have been at greater risk of developing dental caries. Some abundant native plant food, such as acorns, would have been unlikely to cause dental caries, while others, such as berries, may have been more likely to contribute to caries pathogenesis. Physiological and psychological factors already predispose women to caries. However, the Windmiller woman's likely role as the principal gatherer and food preparer for her group may have significantly contributed to

the higher proportion of dental caries seen in the females from Early Period Windmiller sites.

<center>Physiological and Psychological Factors</center>

As mentioned previously, fluctuations in hormone production among women can decrease salivary flow leading to an increased risk of dental caries (Lukacs and Largaespada 2006; Laine 2002; Nederfors et al. 1997). Hochberg et al. (1998) found that decreases in salivary production increased as with age for both sexes and were higher for women than men. This physiological difference makes women more predisposed to dental caries, although it is unlikely to be the sole cause of all dental caries exhibited by women.

Food cravings may also account for disparities in dental caries prevalence. A study on body mass index, food, and obesity found that obese women preferred high fat, high sugar foods (i.e., cake, doughnuts), while obese men liked high fat/high protein food (i.e. meat) (Macdiarmid et al. 1998; Drewnowski et al. 1992). Zellner et al. (1999) found that 65.9% of American women and 63.2% of Spanish women craved sweet foods, while 65.2% of American men and 60.3% of Spanish men craved savory foods. Therefore women may be physiologically disposed toward sweets. Pelchat (1997) found that women craved foods that were high in fat and sugar, while men craved entrée type foods which, for the most part, had high fat contents, but variable amounts of carbohydrates. Women were found to have statistically significantly higher cravings for sweets, especially during the period between ovulation and menstruation (Pelchat 1997).

Hunting, Gathering, and In-Between Meal
Resource Consumption

In hunter-gatherer societies, the division of labor is not evenly distributed (Wallace 1978; Willoughby 1974). With few exceptions, such as pine nut gathering (see Farris 1993), terrestrial plant resource collection is the principle domain of women. This means that women have differential access to plant resources. Ezzo (1995:479) writes, "If males were primarily responsible for hunting and marine resource acquisition and females for farming and plant collecting, then each sex would have had greater access to the types of food they procured." Hence, women would have had more access to the plant resources that cause dental caries. Segerstrom (1973) observed that foothill Miwok women would eat whenever they got hungry, consuming food whenever they felt like eating. Walker (1988) found the same to be true of female African pygmies. Therefore, if women were consuming foods, such as berries, which are high in sugars, as they gathered them, they would put themselves as greater risk of developing dental caries. Moreover, in hunter-gatherer societies, as men hunt they may kill small animals and eat them without sharing them with the women and children (Walker and Erlandson 1986). Thus, men may have had greater access to protein resources, creating an unequal meat consumption distribution between the sexes (Lambert and Walker 1991).

Resources

It is unlikely that all of the plant resources consumed by Windmiller individuals were cariogenic. In fact, many of the plant staples eaten by the Windmiller inhabitants of the Valley floor may have been cariostatic or neutral properties. Assessing

the types of seeds, nuts, roots, tubers, bulbs, and berries accessible to Windmiller hunter-gatherers may shed light on the types of plants that contributed to dental caries.

<u>Seeds and Acorns</u>

In addition to using teeth as tools, the high rates of dental attrition found in the Windmiller population can be, in part, attributed to processing acorns and seeds. The manos, metates, mortars, and pestles found at Windmiller sites indicate that the technology needed to process seeds and acorns was used by Windmiller groups (Glassow 1996; Ragir 1972; Heizer 1949). Material evidence suggests that other hunter-gatherer groups, such as the Natufians of the Levant, also used mortars to process grains and acorns (Wright 1971). Stone implements used in processing seeds and nuts are known to introduce small particles of grit into the food, creating an abrasive admixture which would aid in wearing down the tooth enamel (Deter 2009; Arnold et al. 2007). Moreover, a leaching basin may introduce fine particles of silt into acorn or seed mush.

There is little doubt that acorns were a dominant staple food throughout much of prehistoric California (Bettinger and Wohlgemuth 2006; Wohlgemuth 2004). The grassland environment would have provided ample access to seed resources and oaks would have kept the people supplied with acorns. Archaeological evidence from the Middle Archaic of interior central California indicates that acorns (*Quercus* spp.), as well as small seeds such as various species of *Clarkia*, fringed redmaids (*Calandrinia ciliata*), buttercup (*Rannuculus* spp.), and tarweeds (*Heizonia* spp. and *Madia* spp.) were present at prehistoric camps and settlements. Willow herb (*Epilobium densiflorum* and *Epilobium torreyi*) and attenuated Indian paintbrush (*Castilleja attenuata*) would also have been

found locally and were likely to have been collected for their seeds (Wohlgemuth 2004; Moerman 1998; Barrett and Gifford 1933).

While seeds and nuts were abundant and probably formed a large proportion of the diet, there is no convincing evidence to suggest that seeds and acorns are cariogenic (Hall 1945). In fact, many studies have argued that the opposite may be true. In a study focusing on betel nut chewers in Java, Möller et al. (1977) found there was an inverse relationship between betel nut chewing and dental caries. Women were the primary betel nut users and the more often they chewed, the less likely they were to have dental caries (Möller et al. 1977). Lillie (1996) argued that the predominately protein-based diet of meat, fish, and nuts was responsible for the low prevalence of caries recorded from Mesolithic and Neolithic hunter-gatherers in Ukraine. In addition, many experimental studies conducted on various types of seeds found that they actually helped prevent dental caries. Perilla seed polyphenols, seed extracts of *Nagilla sativa*, and the ground hulls of oats, rice, cottonseed, peanuts, and pecans were found to be preventative against the streptococci that cause dental caries (Yamamoto and Ogawa 2002; Aqel and Shaheen 1996; Namba et al. 1985; Madsen and Edmonds 1962). Cereals, such as wheat, have also been found not to be cariogenic (Eshed et al. 2006). Therefore seed and acorn eating would not be expected to account for the disproportionate amount of dental caries seen in female individuals.

<u>Bulbs, Roots and Tubers</u>

Foods high in starch are not necessarily cariogenic. Experiments conducted on hamsters indicated that raw starch plays little role in the initiation of gross dental caries, while diets high in sucrose result in high proportions of dental caries, and a diet of

glucose falls somewhere in between (Shafer 1949). Sheiham (1979) notes that the inhabitants of the British Isles showed a low prevalence of dental caries until the 19th century when taxes on sugar were removed and the consumption of sugar in the British Isles rose from 20 pounds per person per year to 60 pounds. Interestingly, the only time rates of dental caries fell was during World Wars I and II when rationing made sugar a difficult commodity to obtain (Sheiham 1979).

The interaction between starch and sugar may contribute to dental caries. Campain et al. (2003) found a relationship between foods high in starch and low in sugars that increased the probability of dental caries formation. Starchy foods are often sticky, causing them to adhere to the teeth. If the starch remains on the tooth, it may only take a small amount of sugar to create an environment conducive to *Streptococcus mutans*, a major bacterium responsible for causing dental caries.

Starchy foods low in sugars may also contribute to dental caries because they modify the composition and metabolic activity of oral flora (Caldwell 1962). For example, potato chips, although low in sugars, were found to be retained in larger amounts than foods with low starch contents and high levels of sucrose and other fermentable sugars (Lingström et al 2000). As the starches in the potato chips broke down, the retained potato starches exhibited a high cariogenic potential (Lingström et al 2000). A study conducted by Caldwell (1962) on food adhesiveness, found that boiled potatoes, a food high in starch, were more adhesive than sugar-coated cornflakes and chocolate caramel. Processing starches, such as wheat or potatoes, by methods like boiling also increases their cariogenic potential (Lingström et al. 2000). If consumed with sugary foods, such as berries, Seed and acorn mush, like root and tuber foods, could

potentially contribute to caries because the mush would adhere to the teeth, while the sugar would modify the oral environment in favor dental caries development.

Consumption of roots and tubers has been used to explain the presence of dental caries in other populations. Turner and Cheuiche Machado (1983) argued that the high incidence of dental caries reported at the archaic site of Corondó (4200-3000 B.P.) in Brazil was due to consumption of manioc or tule roots. Irish and Turner (1997) argued that high rates of caries and a particular type of anterior dental wear exhibited by a historic Senegalese population could have been due to manioc consumption and chewing sugarcane. Walker and Erlandson (1986) suggested that differences in caries rates at Canada Verde (ca. 4000-3000 B.P) and Skull Gulch (A: 1820-900 B.P., B: A.D. 1100-1500) in the Santa Barbara Channel Islands could have been due to roots and tubers playing a larger role in the diet at Canada Verde. Citing early European accounts of Channel Island root and tuber exploitation and the large proportion of digging stone weights recovered from prehistoric Channel Island sites, Walker and Erlandson (1986) argued that the individuals buried at Canada Verde consumed more roots and tubers, which contributed to their higher rate of dental caries. Valentin et al. (2006) theorized that cooking starchy tubers, such as yams and taro, contributed to the high rate of dental caries observed in a prehistoric/historic sample of Korotuku, Fiji. Cooking yams and taro would have softened them producing a sticky texture which would have adhered to the teeth (Valentin et al. 2006).

The key root species in the lowland region of the Central Valley would have belonged to the Liliaceae, Apiaceae, and the Cyperaceae families (Wohlgemuth 2004). Various forms of "Indian onion" or "Indian potato" such as yampah (*Perideridia* spp.),

fool's onion (*Triteleia hyacinthina*), pretty face (*Triteleia ixioides*), bluedicks (*Dichelostemma pulchellum*), mariposa lilies (*Calochortus* spp.), and Brodiaea are all bulbs and corms that are native to the area surrounding the Windmiller Delta sites (Bettinger and Wohlgemuth 2006; Wohlgemuth 2004; Anderson and Rowney 1999; Murphy 1959). Members of the genus Brodiaea have been identified archaeologically from the Middle Archaic of interior central California (Wohlgemuth 2004). Moreover, these plants were all known to the Sierra Miwok, who extracted them up with digging sticks and ate them either roasted or boiled. When referring to Indians, the derogatory term "digger" comes from the practice of using digging sticks to dig up roots and tubers (Conrotto 1973; Murphy 1959). Tule (*Scirpus* spp.) and Tule potatoes (*Sagitarria latifolia*) were also harvested around tule marshes in the lower Sacramento Valley (Wohlgemuth 2004; Murphy 1959).

Boiling and roasting bulbs, roots, and tubers increase their adherence to teeth (Caldwell 1962). Many starchy root foods are inedible or even toxic if eaten raw (Thoms 2009). Cooking starchy root foods makes them more easily digestible (Smith and Martin 2001). If the Windmiller population cooked their root foods, this may have especially contributed to dental caries. Thus, tubers and bulbs would have been available to the Windmiller population and may have contributed to the high rate of caries present among females at Delta Windmiller sites.

Berries

Foods which are high in sugars tend to be cariogenic due to the fact that the polysaccharide synthesis of sugars promotes acidogenesis and creates an oral environment conducive to the dental caries pathogenic bacteria, *Streptococcus mutans*.

The resources with the highest proportion of sugars in the lower Central Valley would have been likely to have been berries. Species of elderberry (*Sambucus* spp.), wild grape (*Vitis* spp.), nightshade (*Solanum* spp.), and blackberry (*Rubus* spp.) flourish in the riparian environment that would have been found along the riverbeds close to these Delta sites, particularly those found on the Big Bend of the Mokelumne River (Thompson 1961). Archaeological specimens of elderberry (*Sambucus nigra* ssp. *caerulea*), California wild grape (*Vitis californica*), and blackberry (*Rubus sp.*) have reported from Middle Archaic sites in the region of interior central California (Wohlgemuth 2004). Manzanita (*Arctostaphylos sp.*) has also been found at archaeological sites, but it is unlikely to have been easily accessible in the lowland region of the Sacramento-San Joaquin Delta. If women were the primary foragers, they would have had much greater access to berries than men. It is easy to imagine that women snacked on the berries as they picked them, which would have increased their consumption of sugar. Moreover, if berries were dried, they would have not only been sugary, but sticky as well, increasing the overall risk of dental caries.

<div align="center">Limitations of Study</div>

While the archaeologists who excavated and studied the sites included in my analysis took excellent field notes for the time period in which they worked, the lack of systematic organization and incompleteness of the recorded site data limits the amount that may be gleaned from the current analysis. Early 20th century archaeological writings and monographs on the Windmiller sites include no individual site records, instead classifying all of the information into summations of the Early Horizon. Incomplete

organization and a lack of site records made seriating these burials difficult or, in many cases, impossible.

Dating each site also proved complicated due to the fact that there are discrepancies about the relative antiquity of these Delta sites. A lack of good radiocarbon dates coupled with a complicated California chronology made pinpointing dates for these populations difficult.

The difficulties related to seriation and chronologies are unfortunate due to the fact that the amount of complete criteria needed to conduct any kind of analysis already reduces the sample size. Locating adult Windmiller Pattern skeletal individuals who could be reliably aged, sexed, and who retained at least part of their dentition proved challenging. This reduced the sample size. The smaller sample size limited the number of definitive conclusions and interpretations that could be made from the data.

The floodplain location of these sites also makes it unlikely that habitation sites will be excavated, meaning that artifacts indicative of everyday living are unlikely to be recovered. This makes it more difficult to discern the types of activities in which Windmiller hunter-gatherers would have participated. Thus, interpretation is somewhat speculative and is based on archaeological plant samples from sites in the general area, local native plant resources, foraging and subsistence trends noted in other hunter-gatherer groups, and comprehensive research from the current dental literature. When these sites were excavated, paleoethnobotany was not of concern and plant seeds were not recovered from early Windmiller excavations. Thus, I relied on later Windmiller studies in close proximity to my study area to approximate the kinds of plant resources that would have been utilized by Windmiller men and women. Moreover, detailed studies

of the sugar content of local indigenous plants have yet to be conducted by dental researchers. In future, a systematic study of the carcinogenicity of local plant resources would be useful.

Summary

While all sites did not exhibit statistically significant differences between the sexes, the data from this study support the idea that Windmiller females exhibited a greater prevalence of dental caries. Dental wear patterns and small sample size may account for the lack of significant difference found at SJO-142 and SAC-107, respectively. The individuals at SAC-107 exhibited lower molar wear scores which could indicate that their proximity to the foothills gave them access to food resources not available to the individuals from SJO-56, SJO-142, and SJO-56. However, the small sample size of SAC-107 prohibits any definitive conclusions. The higher proportion of dental caries exhibited by women is probably, in part, due to physiological factors having to do with hormone production and salivary flow. However, dental caries were most likely also caused by differences in diet. While the types of food consumed were probably similar for males and females, females, as the principle gatherers, probably consumed more vegetal foods. It is not difficult to imagine that women would have consumed food as they collected it and eaten more of the resources they collected. Meat, which is typically acquired by men, is non-cariogenic. Various plants, however, can promote dental caries. The primary resources available to these lowland Central Valley populations were probably acorns and seeds, which were unlikely to have contributed to caries. However, consuming starchy foods, like yampa, lily bulbs, and tule, and sugary

foods, such as elderberry and blackberry, may have played a role in increasing the

prevalence of dental caries in women.

CHAPTER VII

CONCLUSIONS

Summary

Throughout this thesis I have provided an overview of the dental caries process, its link to particular types of subsistence practices and kinds of food, and its relationship to oral health in prehistoric California. Using non-parametric statistical analysis, I evaluated whether sex differences in dental caries existed at four Early Period Windmiller sites in the lower Sacramento and upper San Joaquin Valleys of California. My results indicate that disparities exist between males and females when the rate of dental caries is considered.

Employing non-parametric statistical analysis, I demonstrated that, despite variability between sites, Windmiller females overall displayed a higher prevalence of dental caries than males. I suggested that while physiological differences in female could predispose them to greater amounts of dental caries, the sexual division of labor probably significantly contributed to the higher rates of caries exhibited by females. Females, as the primary food gatherer for their group, had greater access to potentially cariogenic resources. Moreover, the necessity of tasting food to ensure ripeness and thorough cooking and the energy expended in locating, processing, and transporting plant resources probably contributed to in-between-meal food consumption which would have increased the likelihood of developing dental caries.

122

Further Research

This thesis demonstrates that differential caries rates based on sex existed in central California. However, more in-depth studies of the cariogenecity of local plant resources are needed in order to offer more solid conclusions as to the types of food that may have contributed to dental caries in Early Period prehistoric populations in central California. A systematic study of the sugar and starch contents of various native local plants found in the region Windmiller would allow a better understanding of which foods are most likely to cause caries.

The potential cariogenecity of the diet would also be aided by better establishing the geographic parameters of the resource patches in which women would have foraged. Employing optimal foraging models, such as central place foraging and patch choice, would help to narrow down the distance women could travel, which plants were locally abundant, and which plants provided the larger amount of return for investment. When using these models, it was also be useful to attempt to figure out where the Windmiller habitation sites were most likely to have been.

The burial site context of these sites leads me to suggest that a broader study encompassing Early Period skeletal evidence from a greater amount of Windmiller sites should be undertaken to see if the results found in this study are upheld. Analyzing a broader spectrum of sites, hopefully some of which are from habitation contexts, will display biases in the current data should they exist and provide a wealth of new information.

This study has shown that Windmiller dentitions exhibit fairly high amounts of dental attrition. A more comprehensive study of the dental wear would be beneficial

because it would tell us something about the processes that contributed to dental attrition. Looking at the planes of dental wear would answer questions about whether attrition was primarily due to diet and food processing, using one's teeth as tools, or some combination of the two. This might suggest something about the types of activities in which Windmiller males and females participated.

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