INSIGHTS INTO INTRAGROUP VARIATION IN PRECONTACT PALEODIET: A MIDDLE PERIOD EXAMPLE FROM SAN MATEO COUNTY

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This article reports new carbon, nitrogen, and sulfur isotope data for 10 individuals on the San Francisco Peninsula from CA-SMA-78 (Hamilton Mound 20; n = 6), CA-SMA-160 (Hiller Mound; n = 3), and a previously unrecorded site in downtown San Mateo (n = 1). We also report seven new bone collagen accelerator mass spectrometry radiocarbon dates, three from CA-SMA-78 that fall during the Early-Middle Transition and early Middle Period (ca. 2,400 and 1,700 cal BP), three from CA-SMA-160 that fall during the late Middle and Middle-Late Transition periods (ca. 1,080 and 770 cal BP), and one from the unrecorded site that falls during the Late Middle Period (ca. 1,260 cal BP). Dietary isotopes show a bimodal pattern, with most individuals (n = 8) consuming a mixed marine-terrestrial diet and two a terrestrial-dominant diet (n = 2). We propose two hypotheses to explain this variation, the first suggesting independent family-level hunting and gathering territories combined with little intra-group sharing of food, and the second suggesting exogamous marriage patterns with people migrating from regions to the south. Future isotopic research could provide support for one (or both) of these hypotheses.

The San Francisco Bay Area of central California was densely populated by Ohlone people for millennia (Milliken 1995). As one of the largest estuaries in the Americas, the bay itself contains an expanse of ecological habitats, including pelagic waters, brackish and freshwater marshes, and tidal mudflats (Margolin 1978; Milliken 2009). The bay is also surrounded by a range of terrestrial habitats, including grasslands, riparian forests, and redwood fir forests. With such diversity in environments, ancestral Ohlone people had a wide array of foods to exploit, including fish, shellfish, seeds, nuts, tubers, large and small game, and birds (Margolin 1978; Milliken 2009). Many of these foods are seasonal in their availability at particular locations on the landscape. These necessitated some annual mobility on the part of Ohlone groups.

What remains unclear is the extent to which all individuals within a village participated in the same annual round, and thereby consumed the same or a different set of foods or were independent of one another and exploited different foods. It is possible, for example, that some individuals or families focused their subsistence activities on more inland locations while others focused on the bay shore. Our study attempts to address this issue by examining intrasite and individual variation in diets, as represented by stable isotope signatures in human bone.

SITE AND SAMPLE BACKGROUND

The Middle Period (2,000-1,000 cal BP) marks an interesting time in California's history and its people, particularly in the San Francisco Bay Area. Many large shellmounds developed during this period, some rising many meters above the bay shore marshes (e.g., Broughton 1999; Hudson and Broughton 1999; Nelson 1909). A network of interconnected villages extended from the bay shore into the interior, leaving behind a rich archaeological record. Many well-connected individuals seem to have been part of this network and were buried with large quantities of exotic materials, such as marine shell beads, charmstones, large quartz crystals, and obsidian tools (Milliken and Bennyhoff 1993).

This study focuses on two sites along the southern San Francisco Bay Peninsula: CA-SMA-78 (Hamilton Mound 20), CA-SMA-160 (Hiller Mound), and an isolated fragment of a human ulna from an unrecorded site approximately 2.6 km southeast of CA-SMA-78 (Figure 1). The two sites were recently test excavated as part of urban development projects, while the isolated ulna was collected by the San Mateo medical examiner's office many years ago. A small number of burials and isolated human remains were encountered during these excavations. Following discussions with the Most Likely Descendants (MLD), the Amah Mutsun Tribal Band of Mission San Juan Bautista (MLD for all of the remains), permission was granted to sample small pieces of bone to support the analyses here. Below, we summarize the previous findings at the sites that relate to subsistence practices. The findings from the midden are then compared to the results from the stable isotope studies.

CA-SMA-78 is a small habitation site with artifacts and debris that dates primarily to the Middle Period, using the Scheme D chronology for the region (2,150-930 cal BP; Groza et al. 2011). Three new accelerator mass spectrometry (AMS) radiocarbon dates (see below) support this general interpretation, but extend occupation back to approximately 2,400 cal BP, within the Early-Middle Transition Period (2,450-2,150 cal BP; Groza et al. 2011). The site sits on the west bank of San Mateo Creek in the modern-day town of Hillsborough (Bever et al. 2018), 7 km from the bay shore. Although first documented in the 1930s by Jerome Hamilton, it was not officially recorded until 1952. The site was excavated in 2018, producing a range of artifacts and ecofacts that inform on paleodiet (discussed below), as well as the human remains that were included in the study.

Just under 9,000 items were recovered during the excavations at CA-SMA-78, nearly 91 percent of which consist of unmodified shells and animal bones (Bever et al. 2018). Overall, the majority of bones was unidentified mammals (80 percent) (Table 1). The high volume of unidentified material is due to the fragmentary nature of the bones, most likely because they were processed for marrow and grease extraction. Additionally, 13 percent of the faunal remains exhibited heat alteration resulting in blackened (charred) and calcined bone. Of the 1,159 pieces of bone, 29.1 percent represent vertebrates. The animals were divided into several categories: large mammals, medium mammals, small mammals, unknown mammals, birds, and fish. Of the large mammals (4 percent), 40 percent were mule deer, 4 percent were tule elk, and the rest were indeterminate (56 percent). Of the medium mammals (8 percent), most are indeterminate except for 1 percent belonging to the genus *Canis* (coyote, wolf, or domesticated dog). Of the small mammals (4 percent), all were identified as rodent. Birds comprise 3 percent of the total faunal assemblage and less than 1 percent are fish. Essentially, while small mammals, birds, and fish were present, they only account for 8 percent of the total remains identified (Bever et al. 2018).

In addition to vertebrate remains, a large number of invertebrate remains was reported, nearly all of it shell. In total, there were 397 specimens identified to species, of which 92 percent were oyster (*Ostrea lurida*), 6 percent mussel (*Mytilus* spp.), 2 percent clam (*Macoma* spp.), 0.5 percent cockle (*Clinocardium nuttallii*), and less than 0.2 percent each for barnacle (*Balanua* spp.), abalone (*Haliotis* spp.), and other indeterminate species of snails (Bever et al. 2018).

Flaked stone (n = 981) included approximately 80 percent unmodified debitage, 94 percent of which represents Franciscan chert and 4 percent Monterey chert, with the last 2 percent consisting of metavolcanic rock, obsidian, quartz, and quartzite (Bever et al. 2018). In addition, 52 cores, 140 edge-modified flakes, five bifaces, and six projectile points were identified. Four of the projectile points were made of obsidian and two

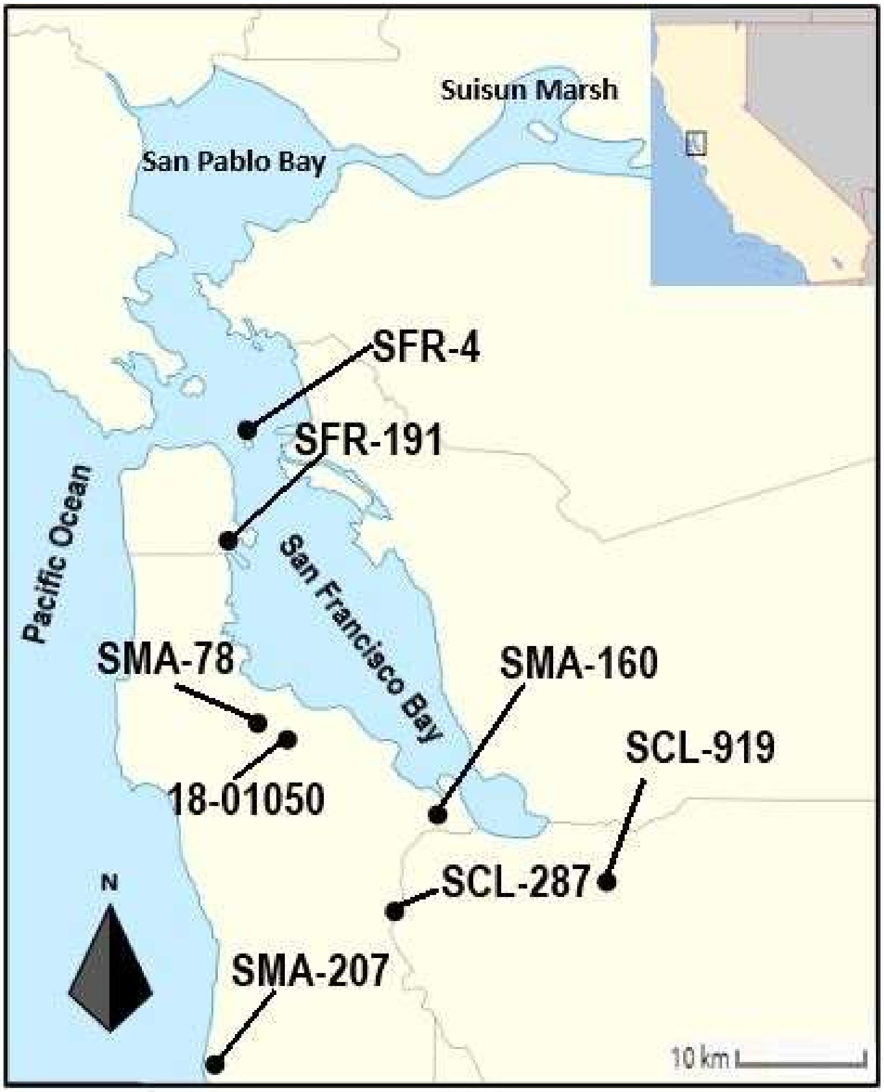

Figure 1. Map showing locations of CA-SMA-78, CA-SMA-160, and other sites mentioned in this study.

Table 1. A Summary of the Faunal Remains from CA-SMA-78 and CA-SMA-Measured by Percentage of Remains and Number of Identified Specimens (NISP).

Faunal Category	CA-SMA-78		CA-SMA-160	
	%	NISP	%	NISP
large mammal	4.0	48	23.0	280
medium mammal	8.0	92	8.0	95
small mammal	4.0	47	28.0	336
unknown mammal	80.0	927	12.0	140
bird	3.0	39	25.0	295
fish	1.0	6	4.0	49
Total Remains	1,159		1,196	

were made of Franciscan chert. The flaked stone tools, especially the broken projectile points, support the hypothesis that hunting was an important activity (Bever et al. 2018), although it is difficult to quantify the relative importance of hunting versus other subsistence-related activities from such limited data. In another indication of diet, 12 groundstone tools were also recovered, including pestles (n = 4), a mano (n = 1), mortars (n = 2), mano/pestle/battered stone (n = 2), and nondiagnostic fragments (n = 3) (Bever et al. 2018). These items indicate that plant processing was also a somewhat common site activity. Unfortunately, no flotation studies were conducted, providing little insight into the types of plant species that could have been processed with these tools.

This study also includes the human remains of five individuals from CA-SMA-78. In addition, we also provide results from a previous analysis of Burial 1, reported in Bever et al. (2018:Appendix J). The newly reported remains represent two formal burials (Burials 2 and 3), as well as three isolated bones that were found within the midden. Based on unit and stratigraphic context, we believe these remains represent five distinct individuals. Table 2 summarizes the samples included in the study.

Table 2. Samples from CA-SMA-78 and CA-SMA-160 Included in This Study.

Site (CA-)	Sample Name	Element	Age	Sex
SMA-78	Burial 1	--	35-45	female
SMA-78	Burial 2	right rib	45-60	female
SMA-78	Burial 3	right rib	35-55	male
SMA-78	Iso – Pile A	thoracic vertebra	--	--
SMA-78	Iso – Pile I-1	thoracic vertebra	--	--
SMA-78	Iso – Pile I-frags	n/a	--	--
SMA-160	Adult 1	left rib	25<	--
SMA-160	Subadult 1	left ulna	0-4	--
SMA-160	Subadult 2	left mandible	7-10	--
Unrecorded	18-01050	left ulna	--	--

Note: Dashed lines indicate that information was not available.

The Hiller Mound (CA-SMA-160) is located in Palo Alto, about 22 km south of CA-SMA-78 (Basin Research Associates, Inc. 2017). It lies 2 km from the bay shore next to what used to be Ravenwood Slough (since canalized and diverted). The site was excavated several times between the late 1940s and 1990s (Bocek 1990), resulting in the discovery a large number of burials (these materials were not available for analysis here). Temporally diagnostic artifacts indicate that the site also falls within the Middle Period. Three new radiocarbon dates (see below) support this interpretation, with occupation extending into the earliest part of the Middle-Late Transition Period (930-685 cal BP).

Based on previous reports, the majority of faunal remains by count from CA-SMA-160 belong to small mammals and birds, while by weight the majority is made up of medium and large mammals (Bocek 1990). Remains from the 1978 and 1995 excavations combined produced 1,196 bones and bone fragments (see Table 1). Of these, 4.6 percent were identified as mule deer and tule elk. However, it is almost certain that these two species are underrepresented as a large percentage (21.5 percent) of bones are unidentified due to burning (n = 134) and splintering. There was also a large quantity (n = 295) of avian faunal bone, including 87 percent identified as duck and geese (Anatidae). This could be indicative of a winter occupation as most anatids in this area are seasonal occupants between October and April.

Within invertebrate remains, nine shellfish species were identified. Of the 28,633 g of shell, 52 percent were identified as *Ostrea lurida*, 39 percent *Cerithidea californica*, 5 percent *Mytilus edulis*, and 4 percent clams. The remaining 0.3 percent included small numbers of *Clinocardiun nuttallii*, *Haliotis rufescens*, and *Olivella biplicata*. The high abundance of shells suggest that shellfish were an important food resource. *Ostrea lurida* and *Cerithidea californica* together represent roughly 90 percent of the shellfish, demonstrating heavy reliance on these two species.

Flaked stone artifacts (n = 216) were primarily Franciscan chert (83 percent), but Monterey banded chert (8 percent), obsidian (3 percent), and chalcedony (6 percent) were also noted. These artifacts include waste flakes (81 percent), cores (2 percent), utilized flakes (3 percent0, bifaces (3 percent), burins (6 percent), gravers (4 percent), and drills (1 percent).

Ground stone tools include one mano, one pestle, one metate fragment, one mortar, and two unidentified fragments, all fashioned from greywacke sandstone. Given that these items date to the Middle Period, when acorns and small seeds were a major component of the diet in central California (Wohlgemuth 1996, 2010), it is likely that these tools were used for processing acorns and hard seeds. Two stones with grooves around the middle were also recovered, possibly used as weights for fishing nets (Bocek 1990).

Basin Research Associates, Inc. (2013) removed two individuals in 2013 during the construction of an equipment pad, including a middle-aged adult female (36-45 years) and a child (3-5 years old) found within a midden deposit. The remains were reburied on site. In 2017, additional human remains, representing one adult and two subadults, were encountered during building improvements. For our study, remains representing the three 2017 individuals were analyzed for stable isotope analysis. Demographic data for these individuals are summarized in Table 2.

Finally, an isolated fragment of a left ulna was included in the analysis. This bone was found on 10th Avenue in the city of San Mateo. The bone had been turned over to the San Mateo County medical examiner (Case #18-01050) and was determined to be precontact in age by preservation and context. The bone was then given to the MLD for reburial, but prior to this event a small fragment was removed for the analyses below. A new AMS date on collagen extracted from the bone (1,180-1,300 cal BP) supports the medical examiner's interpretation of an ancestral Ohlone bone, and places the individual within the late Middle Period (Groza et al. 2011). We are unaware of a site formally recorded at this location, although several recorded sites are within 0.5 km to the northwest and southwest. No additional information was available to us indicating the archaeological context.

STABLE ISOTOPE ANALYSIS

The human remains from CA-SMA-78, CA-SMA-160, and the isolated ulna provide an alternative means to examine diet and mobility patterns of ancestral Ohlone individuals of southern San Francisco Bay, relative to more traditional artifactual, faunal, and paleobotanical analyses. For diet, stable isotopes of nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) of human bone can be used to identify the trophic level of food sources and the terrestrial or marine origins of the sources of dietary protein. $\delta^{15}N$ is best used to estimate the trophic level of ingested foods. If individuals have high $\delta^{15}N$ values, then it can be assumed that they primarily consumed foods of high trophic level (e.g., marine mammals, marine and estuarine fish, piscivorous waterfowl). This is because nitrogen fractionates during digestion and the creation of biological tissues, causing more of the lighter ^{14}N to be excreted as urea and more of the heavier ^{15}N to be retained for tissue formation. This retention leads to a roughly 3-4‰ increase per trophic level (Heaton 1987; Howe and Simenstad 2011). In contrast, a low $\delta^{15}N$ value would indicate that a person consumed lower trophic level foods (e.g., herbivores, plants).

$\delta^{13}C$ is often used to differentiate between reliance on C_3 versus C_4 plants. C_3 plants make up the majority of plants around the world and use a three-carbon molecule during fixation of atmospheric carbon (Cerling et al. 1991; Ehleringer et al. 1993; Farquhar et al. 1989). With this type of photosynthesis, lighter ^{13}C molecules are preferred in the formation of sugars and other plant tissues. In plants, values fall in between −30‰ and −22‰ in C_3 photosynthesis (Cerling et al. 1998; Ehleringer et al. 1993; Farquhar et al. 1989). By contrast, C_4 plants incorporate more of the heavier ^{13}C molecules during photosynthesis. Through this, they produce a four-carbon molecule resulting in values between −16‰ and −10‰. Within central California, C_4 plants are rare and are infrequently mentioned as food in ethnographic records and are rare or absent in paleobotanical studies (Eerkens et al. 2013). This allows for differentiation between marine foods and terrestrial plants in the diets of individuals using stable isotope signatures. Since most central Californian terrestrial foods are C_3, they often have low $\delta^{13}C$ values. Conversely, marine plants and animals overlap with C_4 plants in their $\delta^{13}C$ makeup. Therefore, in central California, $\delta^{13}C$ can be used to differentiate between the use of marine and terrestrial sources. For humans, those who consumed more terrestrial sources demonstrate values consistent with C_3 terrestrial resources, whereas those who consumed more marine sources would demonstrate higher $\delta^{13}C$ values similar to the values of C_4 resources.

We also report $\delta^{34}S$ to examine the contribution of aquatic versus terrestrial foods in the diet. Oceanic sources of sulfur are elevated in ^{34}S relative to ^{32}S, with foods typically between +17 and +21‰ (Krouse 1988; Peterson and Fry 1987) due to sulphates (SO_4^{-2}) that exist within marine waters. By contrast, most terrestrial foods have lower values of $\delta^{34}S$ between −7‰ and +8‰ (Chukhrov et al. 1980; Nriagu and Coker 1978), with the exception of geological formations with uplifted marine sediments containing pyrite and sulfur-bearing evaporites, where $\delta^{34}S$ is highly variable (−19‰ and +30‰) (Holser et al. 1989; Krouse et al. 1987; Peterson and Fry 1987; Privat et al. 2007). Additionally, terrestrial plants growing near the coast may also have elevated $\delta^{34}S$ values due to sea spray and precipitation that is high in marine sulfur (Kusakabe 1976). In combination with $\delta^{13}C$, this can show signs of whether an individual consumed terrestrial or marine resources. Essentially, if $\delta^{13}C$ values are low (< −17‰) and $\delta^{34}S$ values are in the range of marine resources (17-21‰), then it can be assumed that the individual consumed mostly terrestrial resources but from near-coastal environments. In contrast, if there are high $\delta^{13}C$, $\delta^{15}N$, *and* $\delta^{34}S$ values, then this would suggest that a diet that emphasized marine resources.

METHODS

For this study, we used bone collagen to reconstruct diet and followed procedures described in Eerkens et al. (2013). This process includes mechanical and chemical cleaning to isolate collagen from skeletal fragments. Bones were cleaned of any visible exogenous surface material using deionized (DI) water and a small brush. After drying, a handheld drill was used to remove all exposed surfaces, including the external surface and any cancellous bone, leaving only the cortical bone. Bones were then sonicated in DI water to remove any dust or other material unattached to the bone, with a series of 5-minute baths, until the water was clear. Bone samples were then left to dry, weighed, and demineralized in 0.5M HCl until they had a spongy texture. This took 10 to 30 days.

Once demineralized, samples were washed in DI water and placed in two 24-hr baths of 0.125M NaOH (sodium hydroxide) to remove any remaining soil-derived humic acids. Samples were again washed in DI water to remove NaOH, and then were solubilized in pH 3 water. To help with the solubilization, samples were sealed and placed in an oven set at 60-70°C. Once the samples were completely solubilized (1 to 7 days), three extractions were made for each bone sample, separating aqueous material from any residual solids. These extractions were then freeze dried to remove any water and to segregate the solid collagen.

Collagen samples were then taken from each vial (roughly 1 mg) and submitted for carbon and nitrogen isotope analyses at the University of California, Davis, Stable Isotope Facility (SIF) using continuous-flow mass spectrometry via a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer. Instrument precision is 0.2‰ for $\delta^{13}C$ and 0.3‰ for $\delta^{15}N$. When enough collagen remained, 10 mg samples were submitted to the SIF to measure $\delta^{34}S$. Instrument precision for $\delta^{34}S$ is 0.4‰.

Atomic C/N ratios were evaluated to determine sample quality. Previous analyses show that well-preserved collagen should display C/N ratios between 2.9 and 3.7 (Ambrose 1990; DeNiro 1985). In addition, to evaluate internal consistency in stable isotope measures, one sample from CA-SMA-78 (Iso – Pile I-frags, see Table 2) was analyzed twice for $\delta^{13}C$ and $\delta^{15}N$.

RESULTS

Seven new AMS radiocarbon dates and one previously reported date are listed in Table 3. The majority of AMS dates from CA-SMA-78 and CA-SMA-160 are as expected, within the Middle Period. However, two dates slightly extend site use into adjacent time periods. Thus, one date from CA-SMA-78 predates the Middle Period, extending occupation into the Early-Middle Transition Period, while one date from CA-SMA-160

Table 3. Summary of Each Study Sample and Their $\delta^{13}C$ and $\delta^{15}N$ Values.

Site (CA-)	Sample	$\Delta^{13}C$ (‰)	$\Delta^{15}N$ (‰)	%C	%N	C/N	$\Delta^{34}S$ (‰)	Est. % Marine Carbon	AMS Date	Cal BP (2Σ)
SMA-78	Burial 1	−17.1	10.8	--	--	3.3	--	31%	1,785*	1,860-1,710
SMA-78	Burial 2	−16.9	11.1	43%	15%	3.4	9.4	32%	2,206 ± 24	1,870-2,000
SMA-78	Burial 3	−18.0	10.3	39%	13%	3.4	8.0	25%	2,545 ± 24	2,340-2,480
SMA-78	Iso – Pile A	−16.8	11.4	43%	15%	3.3	11.2	33%	2,071 ± 37	1,710-1,900
SMA-78	Iso – Pile I-1	−20.3	5.7	37%	12%	3.6	--	11%	--	--
SMA-78	Iso – Pile I-frags	−19.9 −19.8	6.1 6.0	40% 40%	13% 13%	3.4 3.4	--	14% 14%	--	--
SMA-160	Adult 1	−17.9	9.5	43%	15%	3.4	3.9	26%	1,295 ± 25	940-1,070
SMA-160	Subadult 1	−16.6	11.1	44%	15%	3.4	9.6	34%	1,175 ± 41	770-960
SMA-160	Subadult 2	−16.7	11.4	43%	15%	3.4	9.4	33%	1,402 ± 23	990-1,170
Unrecorded	18-01050-ulna	−17.3	9.8	37%	13%	3.4	13.6	30%	1,508 ± 30	1,180-1,300

*The report listing this date (Bever et al. 2018) did not provide a margin of error or %C and %N for this sample.

post-dates the Middle Period, with occupation extending into the Middle-Late Transition Period. At the same time, AMS dates from the two sites indicate that they are not contemporaneous, with CA-SMA-78 dating earlier (ca. 2,480-1,710 cal BP) and CA-SMA-160 later (ca. 1,170-770 cal BP). The single bone from the unrecorded site dates between the two sites with a 2-sigma calibration between 1,300 and 1,180 cal BP.

Percent carbon, percent nitrogen, and C/N values are provided in Table 3, values often used as measures of bone preservation and sample quality (Ambrose 1990; DeNiro 1985; Van Klinken 1999). As shown, C/N is consistently between 3.3 and 3.6, indicating well-preserved collagen, and the percent carbon and nitrogen by weight is consistently over 37 percent and 12 percent, respectively, as expected of endogenous collagen. As well, the repeat analysis on the "Pile I-frags" sample produced nearly identical $\delta^{13}C$ and $\delta^{15}N$ values within 0.1‰ of each other, and identical C/N, %C, and %N measures, indicating consistent within-sample results within the expected range of instrument precision.

$\delta^{15}N$ and $\delta^{13}C$ for all 10 individuals in the study are provided in Table 3 and plotted in Figure 2. Two distinct isotopic groups are evident in Figure 2, suggesting two different diets among inhabitants of the San Francisco Peninsula. At CA-SMA-78, the two isolated individuals in Pile I show a distinct dietary pattern, with low $\delta^{13}C$ and $\delta^{15}N$. The two values are divergent enough from one another, much greater than the degree of instrument precision, to suggest they represent different individuals with distinctive dietary patterns. These low values are consistent with a terrestrial diet, with C_3 plant foods providing the bulk of protein.

The remaining four individuals from CA-SMA-78 plot higher for both $\delta^{13}C$ and $\delta^{15}N$, suggesting greater marine protein consumption. This higher marine-emphasis group also includes all three individuals from CA-SMA-160 and the isolated ulna from downtown San Mateo. Note that both CA-SMA-160 and the isolated ulna are closer to San Francisco Bay than CA-SMA-78. While $\delta^{15}N$ and $\delta^{13}C$ are higher among these individuals, they are still lower than individuals at archaeological sites in the north part of the bay (e.g., Bartelink 2009; Beasley et al. 2013; Martinez et al. 2015), as shown in Figure 3. Thus, the higher $\delta^{13}C$ and $\delta^{15}N$ group in this study is consistent with a more mixed terrestrial-marine diet (rather than a high marine diet). We used a linear mixing model to estimate the percentage of marine carbon in the diet (see Bartelink 2009). As shown in Table 3, we estimate between 25 and 34 percent of marine-derived protein for individuals in this dietary group.

The $\delta^{34}S$ values provide additional detail on diet. Only individuals from the higher $\delta^{15}N$ and $\delta^{13}C$ group produced enough collagen to also measure $\delta^{34}S$. All seven fall between 3.9‰ and 13.6‰, with five of the seven in a narrow range between 8.0‰ and 11.2‰ (see Table 3). With the exception of the low 3.9‰ $\delta^{34}S$ value taken from Adult 1 at CA-SMA-160, which falls more in the range expected of people dependent on terrestrial environments, these values are consistent with a mixture of terrestrial- and marine-derived sulfur.

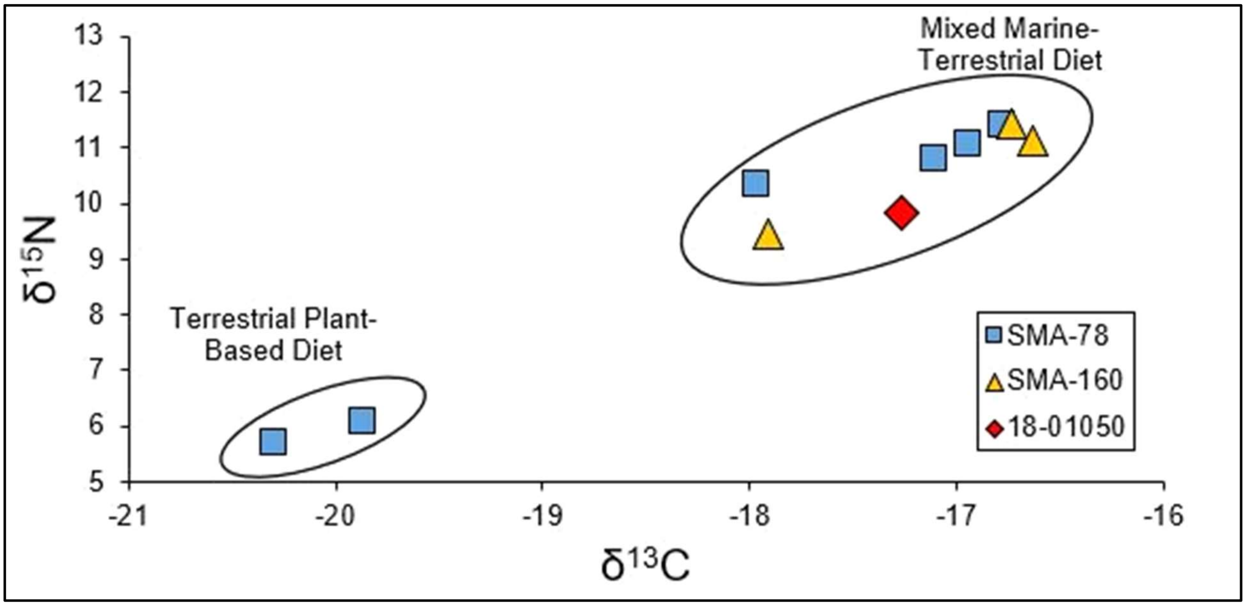

Figure 2. $\delta^{13}C$ and $\delta^{15}N$ values showing two dietary groups for CA-SMA-78 (blue squares) and two groups for CA-SMA-160 (yellow triangles). The individual from Case #18-01050 is also included in this figure (red diamond).

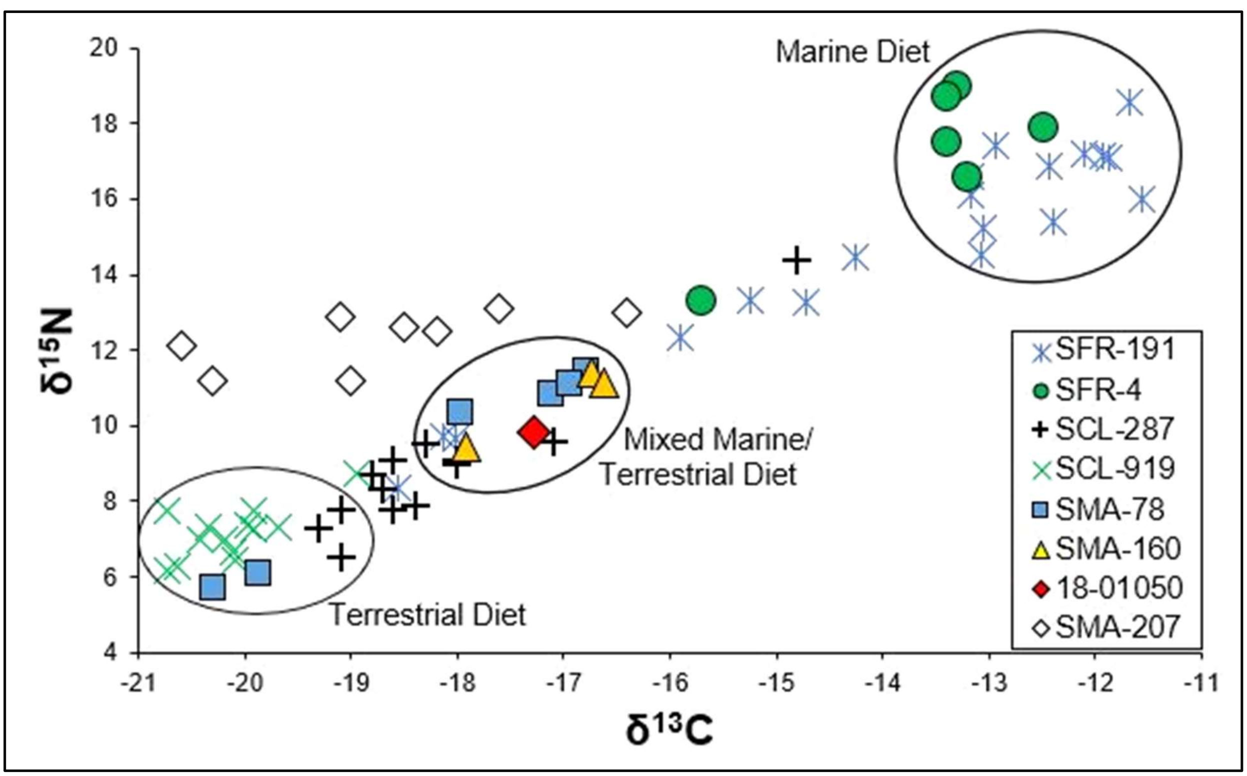

Figure 3. Comparison of $\delta^{13}C$ and $\delta^{15}N$ values from other Middle Period and historic sites in the San Francisco Bay region.

The data show slight differences by demographic category. Although only three individuals have an evaluated sex (two females and one male), the values largely overlap between females and males. However, the data are suggestive of a slight isotopic difference by age. In particular, the two CA-SMA-160 subadults have slightly higher $\delta^{15}N$ values and $\delta^{13}C$ values than the adult. As discussed below, this could indicate slightly different dietary patterns for children than adults.

DISCUSSION

Results show that while bay resources were used, terrestrial resources were equally, if not more important, to individuals buried at these sites in San Mateo County. For eight of the 10 individuals, the $\delta^{13}C$ and $\delta^{15}N$ values show signs of a mixed marine and terrestrial diet, while two individuals from CA-SMA-78 show an almost completely terrestrial plant-based diet. The dietary patterns as reconstructed by the isotope values are consistent with the zooarchaeological findings, which show that 80 percent of the faunal remains at CA-SMA-78 belong to terrestrial mammals, with only a small number of fish bones. Additionally, most of the formal tool assemblage includes items typically used in land-based hunting and terrestrial plant processing, rather than fishing or sea mammal hunting. Similarly, while there are a few grooved charmstones that could be related to fishing, the preponderance of mammal bones, projectile points, and ground stone tools at CA-SMA-160 is consistent with terrestrial hunting and gathering.

Intra-Group Variation in Diet

The results show that while bay resources were used, terrestrial resources were equally, if not more important at these sites in San Mateo County. For eight of the 10 individuals, the $\delta^{13}C$ and $\delta^{15}N$ values show signs of a mixed marine and terrestrial diet, with approximately one-fourth to one-third of the protein in the diet coming from marine resources. By contrast, two individuals from CA-SMA-78 show an almost completely terrestrial plant-based diet, with less than 15 percent of dietary protein derived from marine resources.

The dietary patterns as reconstructed by the isotopic values mirror what is seen in the archaeological record, as 80 percent of the faunal remains at CA-SMA-78 belong to terrestrial mammals, with very few fish bones. Additionally, most of the formal tool assemblage included items typically used in land-based hunting and terrestrial plant processing, rather than fishing or sea mammal hunting. Similarly, while there are a few grooved charmstones that could be related to fishing, the preponderance of mammal bones, projectile points, and ground stones implements at CA-SMA-160 is consistent with terrestrial hunting and gathering.

We interpret the two distinct dietary strategies at CA-SMA-78 as reflecting one of two cultural behaviors. First, the data may signal different family-level subsistence strategies, with little intra-group sharing of food resources. Within this interpretation, some individuals living at the site exploited more interior regions of the San Francisco Peninsula, especially for plants, while others exploited the bay and bay shore environments. This suggests that while these people may have lived and were buried together, they did not always participate in the same annual rounds. If they had relied extensively on one another and shared foods, we would expect greater isotopic similarity between individuals. Additionally, this may indicate that people did not commonly engage in large-scale group hunting. Instead, it appears that different individuals and/or family groups from the same central village exploited different parts of the landscape. As discussed above, this squares with the high environmental variation in the region, which provided people with a wide array of food sources and supported a range of dietary types.

Alternatively, the isotopic differences could be due to a practice of mobility, including exogamy and postmarital residence shifts. The two individuals with low $\delta^{13}C$ and $\delta^{15}N$ values were of indeterminate sex. Their low $\delta^{13}C$ and $\delta^{15}N$ values could indicate they had recently lived in a different village and environment; for example, a village with a diet similar to individuals from CA-SCL-919 (see Figure 3), who show similarly low $\delta^{13}C$ and $\delta^{15}N$. The individuals with low $\delta^{13}C$ and $\delta^{15}N$ at CA-SMA-78 may have migrated to the San

Francisco Peninsula a short time before their deaths, thereby retaining a non-local dietary signature in their bone collagen. If so, they did not live at the site long enough to acquire a dietary signature similar to the other individuals at the site. Indeed, isotopic evidence for matrilocality has been noted in the San Francisco Peninsula (Eerkens et al. 2014; Greenwald et al. 2016). It is possible that the two low $\delta^{13}C$ and $\delta^{15}N$ individuals were males who recently married into the CA-SMA-78 community. Consistent with this interpretation, the only known male at CA-SMA-78 is between the ages of 35 and 55. Thus, he would have already adapted to a local dietary pattern years before he died. Additional isotopic analyses of other elements, such as oxygen and strontium, could help test this hypothesis.

While the three individuals from CA-SMA-160 are more similar to one another isotopically than those at CA-SMA-78, there does seem to be a division based on age at this site. In particular, the two subadults are higher in $\delta^{13}C$ and $\delta^{15}N$ than the single adult. For Subadult 1, this is most likely due to the child still breastfeeding at the time of death. A breastfeeding child is at a higher trophic level compared to the mother, resulting in higher $\delta^{15}N$ values (Fogel et al. 1989; Fuller et al. 2006). This has been observed archaeologically at other sites in the region, such as CA-CCO-548 and CA-SOL-11 (Eerkens et al. 2011:2013), where children between the ages of 0 and 4 years have higher $\delta^{15}N$. The higher $\delta^{15}N$ in Subadult 2, however, is unlikely to be explained by breast feeding. At 7 to 10 years at the time of death, this individual is expected to be several years past weaning. Therefore, there must be an alternate explanation for the dietary differences between Adult 1 and Subadult 2.

In the neighboring sites of CA-SCL-287 and CA-SMA-263, a different dietary pattern may explain what was observed for CA-SMA-160. The males at these two sites showed variance in their access to marine resources over time, while the females show less variability and lower $\delta^{13}C$ values (Greenwald et al. 2016). Perhaps the adult individual at CA-SMA-160 is female who consumed more local C_3 plants, and this is why we see lower $\delta^{13}C$ and $\delta^{15}N$ values. Likewise, Subadult 2 could be a young male with higher $\delta^{13}C$ and $\delta^{15}N$ values because he had greater access to terrestrial game as well as marine and anadromous fish resources. To test this hypothesis, more samples would be needed from the site.

CA-SMA-78 and CA-SMA-160 Compared to Nearby Sites

We contrast the data here with a small subset of sites from the region, showing the range of diets. As seen in Figure 3, inhabitants of CA-SCL-919 in the southern San Francisco Bay had diets focused on more terrestrial foods. By contrast, CA-SCL-287 shows a more mixed terrestrial/marine diet, while CA-SFR-191 (unpublished data by JWE) and CA-SFR-4 (Mikkelsen et al. 2008) to the north show more of a marine signature with highly elevated $\delta^{13}C$ and $\delta^{15}N$ values. Note further that all sites display significant isotopic variation, with many demonstrating bimodal patterning.

The dietary patterns observed in $\delta^{13}C$ and $\delta^{15}N$ are also seen within $\delta^{34}S$ values. CA-SFR-191 has $\delta^{34}S$ ranging from 11.6‰ to 14.2‰, consistent with a greater dietary emphasis on marine resources. By contrast, $\delta^{34}S$ values at CA-SCL-919 are much lower, between −10.0‰ and 0.1‰, consistent with its terrestrial plant-based dietary focus. The $\delta^{34}S$ values at CA-SMA-78 (8‰ to 11.2‰) and CA-SMA-160 (3.9‰ to 9.6‰) fall between these two extremes, consistent with a mixture of terrestrial and marine foods.

The individuals of this study can also be compared to individuals who were buried in the same area but were not from the same geographic locality. At CA-SMA-207, there was a number of burials from an historic shipwreck (Hylkema and Kindon 2018). While they were buried in San Mateo County, they were not from the geographic region, and this is evident in their unique isotopic signatures. As seen in Figure 3, the individuals buried at CA-SMA-207 showed significant dietary variation. Some of the individuals have more marine diets, whereas others have diets that have large amounts of freshwater resources or high trophic level terrestrial foods (e.g., pigs, cows). Among all the individuals at CA-SMA-207, the high $\delta^{15}N$ suggests that they consumed high trophic-level foods. This is unlike the individuals in the Middle Period in the southern Bay Area because their dietary focus tended to be on terrestrial, low trophic-level resources, including many plants.

CONCLUSION

Stable isotope analysis of 10 precontact Ohlone individuals from San Mateo County shows a bimodal dietary distribution, with most (n = 8) consuming a mixture of terrestrial and marine resources, and two consuming a more terrestrial-based diet.

This pattern is likely the byproduct of one of two cultural behaviors. First, this could indicate distinct subsistence territories of families living in the region, with some individuals acquiring most of their food near the bay shore and others from more interior locales. A cultural practice wherein different family groups did not widely share the fruits of their labor, but instead consumed the foods they hunted and gathered, could then result in the isotopic pattern observed here, resulting in distinctive isotopic signatures among segments of the population. Alternatively, the pattern could be a byproduct of residential mobility and immigration. For example, changing residence during a practice of exogamous marriage could result in the bimodal pattern observed. In particular, if individuals from regions to the south (where terrestrial diets were the norm) married into the San Mateo County region but died shortly after making this migration, we would expect to see the bimodal isotopic pattern observed. To test these hypotheses, future strontium and/or oxygen isotope analyses could help narrow down the geographic origin of the individuals within these sites.

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REFERENCES CITED

Ambrose, Stanley H.

1990 Preparation and Characterization of Bone and Tooth Collagen for Isotopic Analysis. *Journal of Archaeological Science* 17:431-451.

Bartelink, Eric J.

2009 Late Holocene Dietary Change in the San Francisco Bay Area. *California Archaeology* 1(2):227-251.

Basin Research Associates, Inc.

2013 *Archaeological Closure Report - Pacific Biosciences, 1005 Hamilton Court, City of Menlo Park, San Mateo County*. Report on file at Basin Research Associates, Inc., and the Amah Mutsun Tribal Band of Mission San Juan Bautista, Galt, California.

2017 *MPK46 - Archaeological Monitoring Closure Report of MPK46 Building Improvements, City of Menlo Park, San Mateo County*. Report on file at Basin Research Associates, Inc., and the Amah Mutsun Tribal Band of Mission San Juan Bautista, Galt, California.

Beasley, M. Melanie, Antoinette M. Martinez, Dwight D. Simons, and Eric J. Bartelink

2013 Paleodietary Analysis of a San Francisco Bay Area Shellmound: Stable Carbon and Nitrogen Isotope Analysis of Late Holocene Humans from the Ellis Landing Site (CA-CCO-295). *Journal of Archaeological Science* 40(4):2084-2094.

Bever, Michael, R., Rebecca Allen, and Thomas Ostrander

2018 *Archaeological Monitoring and Data Recovery Excavations at CA-SMA-78 and CA-SMA-411 for the Crystal Springs/El Cerrito Phase II Sewer Improvements Project, Hillsborough, San Mateo County, California*. Report on file in Hillsborough, San Mateo County, California.

Bocek, Barbara
1990 Subsistence, Settlement and Tribelet Territories on the Eastern San Francisco Peninsula. *Proceedings of the Society for California Archaeology* 5:269-297.

Broughton, Jack
1999 *Resource Depression and Intensification During the Late Holocene, San Francisco Bay Evidence from the Emeryville Shellmound Vertebrate Fauna*. University of California Press, Berkeley.

Cerling, Thure E., D. Kip Solomon, Jay Quade, and John R. Bowman
1991 On the Isotopic Composition of Carbon in Soil Carbon Dioxide. *Geochimica et Cosmochimica Acta* 55(11):3403-3405. https://doi.org/10.1016/0016-7037(91)90498-T.

Chukhrov, F. V., L. P. Ermilova, V. S. Churikov, and L. P. Nosik
1980 The Isotopic Composition of Plant Sulfur. *Organic Geochemistry* 2(2):69-75.

DeNiro, Michael J.
1985 Postmortem Preservation and Alteration of *In Vivo* Bone Collagen Isotope Ratios in Relation to Palaeodietary Reconstruction. *Nature* 317:806-809.

Eerkens, Jelmer W., Ada G. Berget, and Eric J. Bartelink
2011 Estimating Weaning and Early Childhood Diet from Serial Micro-Samples of Dentin Collagen. *Journal of Archaeological Science* 38(11):3101-3111.

Eerkens, Jelmer W., Madeline Mackie, and Eric J. Bartelink
2013 Brackish Water Foraging: Isotopic Landscapes and Dietary Reconstruction in Suisun Marsh, Central California. *Journal of Archaeological Science* 40(8):3270-3281.

Eerkens, Jelmer W., Gry H. Barfod, Alan Leventhal, Gina A. Jorgenson, and Rosemary Cambra
2014 Matrilocality in the Middle Period in San Francisco Bay? New Evidence from Strontium Isotopes at CA-SCL-287. *Journal of California and Great Basin Anthropology* 34(2):211-227.

Ehleringer, James R., Anthony E. Hall, and Graham D. Farquhar
1993 *Stable Isotopes and Plant Carbon-Water Relations*. Academic Press, San Diego.

Farquhar, Graham D., James R. Ehleringer, and K. T. Hubick
1989 Carbon Isotope Discrimination and Photosynthesis. *Annual Review of Plant Biology* 40(1):503-537.

Fogel, Marilyn L., Noreen Tuross, and Douglas W. Owsley
1989 Nitrogen Isotope Tracers of Human Lactation in Modern and Archaeological Populations. *Carnegie Institution of Washington Yearbook* 88:111-117.

Fuller, Benjamin T., James L. Fuller, David A. Harris, and Robert E. M. Hedges
2006 Detection of Breastfeeding and Weaning in Modern Human Infants with Carbon and Nitrogen Stable Isotope Ratios. *American Journal of Physical Anthropology* 129(2):279-293.

Greenwald, Alexandra M., Jelmer Eerkens, Eric Bartelink, Alan Leventhal, and Rosemary Cambra.
2016 Stable Isotope Evidence of Episodic Access to Marine Resources in the Santa Clara Valley. In *Reconstructing Lifeways in Ancient California: Stable Isotope Evidence of Foraging Behavior, Life History Strategies, and Kinship Patterns*, edited by Alexandra M. Greenwald and Gregory R. Burns, pp. 59-72. Center for Archaeological Research at Davis, University of California, Davis.

Groza, Randall G., Jeffrey S. Rosenthal, John R. Southon, and Randall T. Milliken
2011 A Refined Shell Bead Chronology for Late Holocene Central California. *Journal of California and Great Basin Anthropology* 31(2):135-154.

Heaton, T. H. E.
1987 The 15N/14 N Ratios of Plants in South Africa and Namibia: Relationship to Climate and Coastal/Saline Environments. *Oecologia* 74(2):236-246.

Holser, William T., J. B. Maynard, and Kenneth Cruikshank
1989 Modeling the Natural Cycle of Sulphur Through Geologic Time. In *Evolution of the Global Sulphur Cycle*, edited by Peter Brimblecombe and Alla Yu Lein, pp. 21-56. John Wiley & Sons, Hoboken, New Jersey.

Howe, Emily, and Charles Simenstad
2011 Isotopic Determination of Food Web Origins in Restoring and Ancient Estuarine Wetlands of the

San Francisco Bay and Delta. *Estuaries and Coasts* 34(3):597-617. doi:10.1007/s12237-011-9376-8.

Hudson, Jean, and Jack Broughton
1999 Resource Depression and Intensification during the Late Holocene, San Francisco Bay: Evidence from the Emeryville Shellmound Vertebrate Fauna. *American Antiquity* 66(3):546.

Hylkema, Mark, and Andrew W. Kindon
2018 *Shipwrecks and Lime Kilns: The Hidden History of 19th Century Sailors and Quarrymen of the Central Coast.* California Department of Parks and Recreation, Cultural Resources Division, Publications in Cultural Heritage, Publication No. 35, Sacramento.

Krouse, H. R.
1988 Sulphur and Carbon Isotope Studies of Food Webs. *Diet and Subsistence: Current Archaeological Perspectives*, edited by B. V. Kennedy and G. M. LeMoine, pp. 315-325. University of Calgary Archaeological Association, Calgary.

Krouse, H. R., A. A. Levinson, D. Piggott, and Akria Ueda
1987 Further Stable Isotope Investigations of Human Urinary Stones: Comparison with Other Body Components. *Applied Geochemistry* 2(2):205-211.

Kusakabe, M.
1976 Sulphur Isotopic Variations in Nature: 12 Isotopic Ratios of Sulphur Extracted from Some Plants, Soils and Related Materials. *New Zealand Journal of Science* 19(4):433-440.

Margolin, Malcolm
1978 *The Ohlone Way: Indian Life in the San Francisco-Monterey Bay Area*. Heyday Books, Berkeley, California.

Martinez, Marcos, Jelmer W. Eerkens, Alexandra M. Greenwald, and Alex DeGeorgey
2015 Weaning and Childhood Diet at CA-CCO-297. *Proceedings of the Society for California Archaeology* 29:6-12.

Mikkelsen, Pat, Brian F. Byrd, Jeffrey S. Rosenthal, and Sharon A. Waechter
2008 *Archaeological Analysis of CA-SFR-4/H, Yerba Buena Island*. Report on file at Far Western Anthropological Research Group, Davis, California.

Milliken, Randall
1995 *A Time of Little Choice: The Disintegration of Tribal Culture in the San Francisco Bay Area 1769-1810*. Ballena Press Anthropological Papers No. 43, Menlo Park, California.
2009 *Ethnohistory and Ethnogeography of the Coast Miwok and Their Neighbors, 1783-1840*. Report on file at the National Park Service, Golden Gate National Recreational Area, Cultural Resources and Museum Management Division, San Francisco, California.

Milliken, Randall T., and James A. Bennyhoff
1993 Temporal Changes in Beads as Prehistoric California Grave Goods. In *There Grows a Green Tree: Papers in Honor of David A. Fredrickson*, edited by Greg White, Pat Mikkelsen, William R. Hildebrandt, and Mark E. Basgall, pp. 381-395. Center for Archaeological Research at Davis, Publication No. 11, University of California, Davis.

Nelson, Nels C.
1909 Shellmounds of the San Francisco Bay Region. *University of California Publications in American Archaeology and Ethnology* 7(4):309-356.

Nriagu, J. O., and R. D. Coker
1978 Isotopic Composition of Sulfur in Precipitation Within the Great Lakes Basin. *Tellus* 30(4):365-375.

Peterson, Bruce J., and Brian Fry
1987 Stable Isotopes in Ecosystem Studies. *Annual Review of Ecology and Systematics* 18(1):293-320.

Privat, Karen L., Tamsin C. O'Connell, and Robert E. M. Hedges
2007 The Distinction Between Freshwater- and Terrestrial-Based Diets: Methodological Concerns and Archaeological Applications of Sulphur Stable Isotope Analysis. *Journal of Archaeological Science* 34(8):1197-1204. https://doi.org/10.1016/j.jas.2006.10.008.

Van Klinken, Gert J.
1999 Bone Collagen Quality Indicators for Palaeodietary and Radiocarbon Measurements. *Journal of Archaeological Science* 26:687-695.

Wohlgemuth, Eric
1996 Resource Intensification in Prehistoric Central California: Evidence from Archaeobotanical Data. *Journal of California and Great Basin Anthropology* 18(1):81-103.
2010 Plant Resource Structure and the Prehistory of Plant Use in Central Alta California. *California Archaeology* 2(1):57-76.