

DIETARY VARIATION IN NINETEENTH CENTURY SAN FRANCISCO: STABLE ISOTOPE ANALYSES OF TWELVE INDIVIDUALS FROM THE YERBA BUENA, GOLDEN GATE, AND LONE MOUNTAIN CEMETERIES

NIKOLETTA D. KARAPANOS
UNIVERSITY OF CALIFORNIA, DAVIS

JELMER W. EERKENS
UNIVERSITY OF CALIFORNIA, DAVIS

THOMAS OSTRANDER
ENVIRONMENTAL SCIENCE ASSOCIATES

MATTHEW A. RUSSELL
ENVIRONMENTAL SCIENCE ASSOCIATES

AJA M. SUTTON
UNIVERSITY OF WASHINGTON

MIKE LENZI
GARCIA AND ASSOCIATES

JOSIE TWIGG
GARCIA AND ASSOCIATES

During the middle to late 1800s, several large cemeteries operated in the growing city of San Francisco. Though closed and moved in the early twentieth century, it is apparent that exhumation processes were incomplete as human remains are occasionally discovered during modern, ground-disturbing activities. While much is known about San Francisco's upper-class, less is written and known about the histories of underrepresented segments of the population. Fortunately, modern archaeometric techniques can be applied to these remains to reveal new insights into human health, disease, diet, and behavior during the early historic period. This study reports stable carbon ($\delta^{13}\text{C}$), nitrogen ($\delta^{15}\text{N}$), and sulfur ($\delta^{34}\text{S}$) from the bone collagen of 15 samples representing 12 individuals from three historic cemeteries: Yerba Buena, Golden Gate, and Lone Mountain. Results indicate a wide range of isotopic values consistent with significant inter-individual variation in diet. Two main isotopic clusters emerged. One of these is consistent with a diet based on C_3 plants and animals consuming C_3 plant products. A second cluster represents a C_3 -based diet but with significant marine food input. One outlier has a C_4 plant signature (likely maize), and that individual may have been living in the eastern or southern United States before immigrating to San Francisco.

The discovery of gold during the mid-nineteenth century brought rapid change to the social fabric and population density of California, especially the San Francisco Bay Area. With adobe structures and a few stores, the village known then as Yerba Buena rapidly evolved into the city of San Francisco. The city's harbors welcomed the crowded ships of immigrants and imported goods to supply the burgeoning market that emerged as a result of the hope that gold brought. The Gold Rush transformed California's agricultural economy into a more complex system that revolved around mining. Tens of thousands of migrants reshaped the landscape as they created a market that required places of commerce (Holliday 2015). As the only deep-water port that connected the rest of the world to the gold mining region, San Francisco quickly became the prevailing center for financial and commercial trade (Rohrbough 1998). The transformation prompted the

city's development of infrastructure and the cultivation of a social and cultural lifestyle to sustain its diverse population.

While newspapers and biographies provide a wealth of information concerning the city's upper class and those with greater societal influence, less is known about the day-to-day life of other citizens. Historical archaeology plays an important role in situations such as this one because it can inform on the lives of the marginalized groups. The bioarchaeological research below is one step in that direction as it has provided insights on a set of human remains recovered from former cemeteries in the city.

HISTORICAL CONTEXT

This historic era summoned the immigration of more men than women. According to census records for San Francisco from the 1860s, men outnumbered women by a ratio of 3:2. Although women lived relatively anonymously, they contributed significantly to the economy through their initiatives of transitory opportunities. Many more women stayed in San Francisco rather than leaving for the mines, largely as a result of cultural values, but also because of the supplementary amenities and the better employment prospects in the growing city (Taniguchi 2000). Women worked various occupations and were able to achieve a decent individual standard of living, own property, and gain a sense of independence that was otherwise uncommon during that time period (Hurtado 1999). The market for domestic skills soared due to a low supply of women and a high demand among men who had an aversion to domestic chores. Women benefitted from their proficiency in these skills, which further encouraged them into positions as entrepreneurs and business owners of boarding houses. The scarcity of women inflated their social and economic values, and men with gold or other businesses had the resources to fund their expenses (Hurtado 1999). With financial stability came freedom and independence for women. California law allowed women to instigate divorce, and between 1850 and 1890, Santa Clara County led the nation in the highest number of divorces filed by women (Taniguchi 2000).

As a port city, San Francisco was simultaneously a multicultural frontier and a pioneer in the country's societal reformation. Drinking, gambling, and open prostitution were satisfiable habits in the budding cosmopolitan center, but it came at the cost of many women's individuality and freedom. Native American women disproportionately suffered from violent acts such as murder and property arson, and their lack of economic opportunity drove them to prostitution and heightened the spread of diseases (Hurtado 2001). African American women who arrived in California as slaves were able to purchase "Freedom Papers" from their slaveholders for large sums of money. However, a majority of African American women held low wage jobs and were institutionally marginalized, so much so that the census records underrepresent their presence in San Francisco (Taniguchi 2000). Californio (i.e., Catholic Spanish-speaking people of Latin American descent that were born in Alta California) and Hispanic women and families lost rights to their land and status due to the introduction of United States laws in California (Riley 1999). There were relatively few Asian women at the time, but Chinese women were treated as slaves and prostitutes, many of whom escaped the city to settle in Asian fishing villages along the coast (Riley 1999). Men and women of ethnic minorities were heavily devalued, and their narratives of maneuvering through this new frontier have historically been overshadowed by those with greater societal influence.

The influx of people in the densely populated city beckoned serious health concerns as the city was administrated by a laissez-faire government that made it difficult to establish centralized public control and adequate sanitation systems (Roth 1997). Diseases were common and life expectancy was short. For example, cholera caused a widespread epidemic in 1850, killing about five percent of San Francisco's population (Roth 1997). Likewise, waves of deadly smallpox epidemics in 1868, 1876, 1881, and 1887 caused panic among citizens. Throughout this formative period, malaria and various other causes of fevers were also rampant (Baur 1949; Craddock 1995). The mortality rate in young children was especially high, and the leading causes of death were from bacterial-borne illnesses, such as diphtheria, croup, and scarlet fever (Eerkens et al. 2017).

In hindsight, it is clear that widespread disease resulted from a combination of factors that were present in cities around the world, such as lack of vaccines, antibiotics, sewage treatment, and crowded urban conditions. Municipal water supplies and the need for the separation of potable water and waste streams were revolutionary practices in urban development and public health (Snow 1855). However, these practices were not implemented in Gold Rush era San Francisco. The city suffered from the rapid explosion of urban centers which overwhelmed the rudimentary infrastructure and existing natural buffers to pollution. These circumstances characterized rapid industrialization during the period.

Medical knowledge about disease in the nineteenth century was in its infancy and was usually attributed to foul smells (“miasma” theory) rather than microscopic organisms (“germ” theory). Because so little was known about diseases, symptoms were not diagnosed or considered to be characteristics of disease (Baur 1949). With no recognizable underlying cause of disease, symptoms were treated with substances such as opium- or cocaine-based medicines.

Immigrants were often blamed for importing diseases, which further facilitated discriminatory practices against particular segments of the population (Craddock 1995). For instance, during the nineteenth century, health officers of San Francisco communicated in their reports on smallpox that the disease originated from the city’s Chinese population. Because this interpretation was articulated by seemingly educated professionals, it was accepted by residents and used as justification to advance anti-Chinese sentiment and legislation. Subsequently, disease was symbolically and politically understood and applied in the classist realm. As the connection between waste and disease was ultimately being addressed, attempts were made by the city’s upper classes to initiate a sanitation movement. Although the aim of this movement was to clean up the streets, it also succeeded in further stigmatizing poor people who inhabited crowded and impoverished urban enclaves as the primary transmitters of diseases like tuberculosis, typhoid, and dysentery.

Historic Cemeteries

The increasing population of San Francisco necessitated the establishment of formal cemeteries. Originally, a number of cemeteries was built on the edges of the city, including Odd Fellows, Calvary, and Laurel Hill (previously known and referenced in this article as Lone Mountain Cemetery), among others. However, rapid urbanization and gentrification expanded beyond these city limits, deeming cemeteries as obstacles rather than desired features of the urban landscape (Shelton 2008). Residents claimed that cemeteries in the city were detrimental to property values, and the removal of such cemeteries would emit signals that the city was undertaking necessary progressive development (Shelton 2008). As such, exhumation projects commenced in the late nineteenth and early twentieth centuries.

Among these nineteenth century cemeteries was the Golden Gate Cemetery at Lands End, where three of the 12 individuals in this study (labeled with the prefix SFPUC in Table 1) were originally buried. Between 1868 and 1906, this municipal cemetery interred about 18,000 of San Francisco’s impoverished population (Buzon et al. 2005; Shelton 2008). Of the 200-acre cemetery, about 54 acres was dedicated to the U.S. Army, with the remainder dedicated to 24 religious and ethnic minority groups, including Chinese, Jewish, and Italian (Chatten et al. 1997). The earthquake of 1906 caused considerable damage to the cemetery. Tombstones toppled and city records regarding the cemetery were likely lost in the subsequent fires.

A city ordinance passed in 1900 ordered the relocation of the Golden Gate Cemetery to Colma by 1911 (Buzon et al. 2005). According to surviving records, a majority of the headstones was removed but only about 1,000 bodies were exhumed, leaving thousands of bodies still buried at what is known today as the California Palace of the Legion of Honor. It is not uncommon for human remains to surface during construction, as happened with the remains used for this analysis.

Two of the 12 individuals in our study (labeled with the prefix USF in Table 1) were discovered in the Lone Mountain Cemetery. Along with the Golden Gate Cemetery, Lone Mountain Cemetery was publicly dedicated in 1854 and designated as a municipal cemetery, deeming it a chief burial place for San Francisco citizenry. With an average of 75 people interred per month, about 7,000 bodies had been buried

Table 1. Stable Isotope Data for the 15 Bone Samples in the Study.

PROJECT/ CEMETERY	BURIAL	SEX	AGE	ELEMENT SAMPLED	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	C/N	$\delta^{34}\text{S}$
SFPUC, GG	Burial 1	F	30-40	rib	-17.8	12.6	3.3	5.3
SFPUC, GG	Burial 2	M	40-50	fibula	-19.1	10.0	3.3	5.8
SFPUC, GG	Isolated cranium	M	35-50	mandible	-14.4	9.6	3.3	8.0
USF, LM	Burial 1	I	adult	left rib	-17.7	12.4	3.3	6.5
USF, LM	Burial 2	I	adult	right 1st metatarsal	-17.0	12.8	3.3	7.2
AAM, YB	Burial 1	M	20-35	right radius	-19.1	12.1	3.2	2.3
AAM, YB	Burial 2	M	30-39	right femur	-17.4	11.2	3.3	8.5
AAM, YB	Burial 3*	M	25-29	left tibia	-16.7	13.2	3.1	9.1
				left radius	-17.4	13.5	3.1	9.2
AAM, YB	Burial 4	I	35+	left femur	-19.2	11.7	3.2	7.6
AAM, YB	Feature 7*	I	adult	right humerus	-17.6	13.0	3.8	5.5
				right radius	-17.7	12.9	3.7	5.3
AAM, YB	Feature 7	I	adult	left fibula	-18.8	10.5	3.6	13.2
AAM, YB	Isolate*	I	adult	femur - dark	-19.5	12.4	3.6	-0.7
				femur - light	-19.5	12.4	3.6	-0.3

* Based on context, both samples appear to represent the same individual. For plotting purposes, we use the first value. GG = Golden Gate cemetery; LM = Lone Mountain cemetery; YB = Yerba Buena cemetery. For sex, F = female, M = male, I = indeterminate.

at the Lone Mountain Cemetery by 1862. Because Lone Mountain Cemetery was part of San Francisco's Big Four Cemeteries, its removal from the heart of the city was contested for decades. It was renamed Laurel Hill Cemetery, and its prolonged closure allowed it to continue accepting interments until 1941.

The remaining seven individuals in the study (labeled with the prefix AAM in Table 1) were found during construction activities at the Asian Art Museum in San Francisco. The Asian Art Museum location is known to be associated with the former Yerba Buena Cemetery (CA-SFR-126H), a poorly situated 13-acre plot encompassing the sand dunes less than three miles east of Lone Mountain Cemetery. Since its opening in 1850, the human remains at Yerba Buena Cemetery were often left exposed from winds blowing the sand, and the growth of the city provoked the exhumation and transfer of the remains of 5,000 to 10,000 individuals to the Golden Gate Cemetery in 1870. The San Francisco City Hall, Main Library, and Asian Art Museum were later constructed where Yerba Buena Cemetery once existed (Shelton 2008). Figure 1 plots the locations of these cemeteries within San Francisco.

Diet

Not only was the climate in California beneficial for the production of a wide array of crops, the location of San Francisco made it a convenient hub for local fishing and food imports by land and sea. Chinese immigrants began to fish in California in the early 1850s, and any marine foods they could not obtain locally were imported from China (Chan 1989). Likewise, many orchards and wheat fields produced enough crops to sustain California's demand during the early 1850s.

The influx in population, however, challenged traditional subsistence agriculture and stimulated a surplus-crop economy (Holliday 2015). The need to feed mining communities and growing cities required cattle ranching to evolve from open-range grazing to feedlots. As a result, many open spaces and native plants were replaced with annual crops to feed both livestock and the human population (Jelinek 1998). Mutton gained popularity and surpassed the cattle industry until wheat became even more essential than livestock. Just like mutton replaced cattle, wheat replaced barley as it became a vital and profitable export.



Figure 1. Spatial distribution of the three historic cemeteries in San Francisco that are associated with this study.

THEORETICAL AND ISOTOPIC CONTEXT

Although bone structure is largely contingent upon our mammalian evolutionary history and genetics, certain intrinsic and extrinsic factors, particularly food and environment, influence the more detailed organic composition of bone. About 70 percent of the weight of adult bone is comprised of inorganic, mineral components, which are mostly carbonates and phosphates. The remainder consists of organic materials, lipids, and proteins, the most common of which is the complex fibrous protein known as collagen (Lee-Thorp 1989). Bone maintains an ionic equilibrium with blood and undergoes continual remodeling to sustain the structural and metabolic functions of the skeleton. This activity transpires continuously throughout life, and most of the adult skeleton is fully replaced about once every 10 years. Since collagen is formed entirely from ingested food, especially the proteinaceous component of food, isotopic signatures of bone collagen reflect an average of the cumulative dietary patterns of an individual over the last 10 years of life (Fernandes et al. 2014; Garvie-Lok et al. 2004).

Carbon

The consumption of C₃ and C₄ plants is commonly evaluated using the ratios of carbon isotopes ¹³C/¹²C, expressed as δ¹³C relative to an international standard. C₃ and C₄ plants use different photosynthetic processes that cause fractionation of atmospheric carbon, such that each group of plants has a distinctive δ¹³C signature (Klepinger 1984). Plants use fixated carbon to synthesize a wide range of organic compounds, including carbohydrates, lipids, and proteins.

Instead of gaining carbon through fixation of atmospheric carbon dioxide, terrestrial animals derive their carbon by ingesting plants or other animals. Metabolic processes within the animal fractionate the ingested carbon isotopes which leads to predictable changes in δ¹³C from the diet to the resulting animal's tissues.

In marine environments, carbon diffuses into water from the atmosphere and is incorporated into a range of organisms such as photosynthesizing planktons (Descolas-Gros and Fontugne 1985). As a result of this process, δ¹³C values in marine organisms are distinctive from those in C₃ plants and animals consuming C₃ plants. Marine carbon is often closer to that recorded in C₄ plants.

The main crops in California during the 1800s are associated with the C₃ category and include wheat, barely, rice, and potatoes. By contrast, C₄ plants such as maize, millet, sugar cane, and sorghum were less important in California's nineteenth century agricultural economy. As a result, higher δ¹³C values are typically associated with consumption of marine foods such as fish, shellfish, and crustaceans. This is observable when high δ¹³C is simultaneously associated with higher δ¹⁵N (see below).

Nitrogen

The general trophic level of a consumer is reflected in nitrogen isotope ratios ¹⁵N/¹⁴N, expressed as δ¹⁵N relative to an international standard. Legumes are primarily nitrogen-fixating plants with a nitrogen isotope ratio similar to that in the atmosphere (0‰). These plants use nitrogen to synthesize proteins. Non-legume plants cannot fixate nitrogen and must gain it by uptake from the soil (Klepinger 1984). When animals ingest and break down plant proteins, they use the lighter ¹⁴N to create waste, such as urea, and retain the heavier ¹⁵N to generate bodily proteins, including collagen (McCutchan et al. 2003). Therefore, ¹⁵N becomes concentrated higher in the food chain, and δ¹⁵N in biological tissues is highly correlated with the trophic level of a particular animal in the local food web (Minagawa and Wada 1984). A higher δ¹⁵N value indicates a person with a diet enriched in animal-derived protein, while a lower value indicates a diet with more plant protein. Because aquatic environments contain many more trophic levels than terrestrial ones, δ¹⁵N of aquatic-food consumers tend to be higher than terrestrial herbivores and carnivores.

Sulfur

Sulfur is an essential element for most living organisms. As the seventh most abundant element in human body tissues, sulfur is vital for protein structure (Ingenbleek 2006). It is found in the hydrosphere and is derived from a range of sulfur-bearing minerals in soils or in oceanic environments as dissolved sulphates (Nehlich 2015). Plants uptake sulfur from soil and pass it up the food chain to animals.

When complemented by carbon and nitrogen isotopes, sulfur isotope ratios can differentiate between freshwater and terrestrial diets. Sulfur isotope ratios can also distinguish the consumption of foods originating from different geographic regions with different underlying soil sulfur isotopic ratios. Because sulfur is a compound that the body cannot produce, δ³⁴S will reflect the biological source in which it originated (Hobson 1999). These sources are correlated with geological signatures and, when combined with other isotopic data, provide archaeologists with insights on identifying where a person obtained their food.

Marine environments around the world show highly elevated $\delta^{34}\text{S}$ values, typically greater than 5-10‰. By contrast, $\delta^{34}\text{S}$ in most terrestrial environments are between -20 and +5‰. In archaeological studies, $\delta^{34}\text{S}$ is sometimes used as a tracer of migration patterns of individuals as they cross between geological zones or dietary changes if they consume foods harvested from different environments (Richards et al. 2003; Nehlich and Richards 2009).

METHODS

Samples

The samples discussed in this analysis include 15 bone fragments representing 12 individuals from three different historic cemeteries. These burials were discovered inadvertently during recent trenching work in San Francisco. Because they can provide significant historical information about populations in the area during and after the Gold Rush era, and with approval from the City of San Francisco, bone samples were sent to the Archaeometry Lab at the University of California at Davis (UCD) for stable isotope analyses.

Bone Preparation

To isolate collagen for analysis, a modified Longin procedure was followed (Longin 1971). Each bone sample comprised about one gram of cortical bone. Periosteum, soil, and extraneous debris from the surface and any other exposed parts of the bone were removed using a handheld drill with a diamond coated bit. Each sample underwent sonication in deionized water (three five-minute baths, with the deionized water replaced after each bath) and air-dried prior to placement in 0.5 M hydrochloric acid (HCl). The samples demineralized in a refrigerator set at 5°C, and the HCl was replaced every 48 hours until the sample ceased to react. The rationale of this portion of the preparation method is to remove as much labile carbonate and phosphate that could contain soluble carbon, nitrogen, and sulfur deposited during bone formation or diagenesis (Garvie-Lok et al. 2004).

The samples were rinsed five times with deionized water and placed in 0.125M sodium hydroxide (NaOH) for 24 hours to dissolve any humic acids introduced from the soil. NaOH was replaced after 24 hours to soak for another day, totaling 48 hours in NaOH. Each sample was rinsed five times with deionized water to remove any residual NaOH. Samples were placed in acidic pH3 water in an 80°C oven to solubilize collagen. After 24 hours, the fluid was pipetted into a clean vial, leaving any residual solids behind, and freeze-dried to remove all remaining water, isolating the collagen.

Collagen samples of 1 mg were processed at the Stable Isotope Facility at UCD where they were measured by continuous-flow mass spectrometry (PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer). The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotopic ratios are relative to the Pee Dee Belemnite standard, which are both arbitrarily set at 0‰. Instrument precision, evaluated by long-term analysis of the same internal standard, is 0.2‰ for both isotopic measures. To measure $\delta^{34}\text{S}$, 10 mg of collagen was analyzed using an Elementar vario ISOTOPE cube interfaced to a SerCon 20-22 IRMS (Sercon Ltd., Cheshire, UK). Instrument precision for $\delta^{34}\text{S}$ is 0.4‰.

RESULTS

The bone samples produced adequate collagen returns consistent with satisfactory preservation. With the exception of the right radius and humerus from AAM Feature 7, all samples produced C/N values between 2.9 and 3.6, the range suggested by DeNiro (1985) for well-preserved archaeological collagen in

samples (Table 1). $\delta^{13}\text{C}$ ranges between -14.4‰ and -19.5‰, with a mean of -17.9‰ and standard deviation of 1.4‰. $\delta^{15}\text{N}$ ranges between 9.6‰ and 13.5‰, with a mean of 11.8‰ and standard deviation of 1.2‰. $\delta^{34}\text{S}$ ranges between -0.7‰ and 13.2‰, with a mean of 6.2‰ and standard deviation of 3.6‰. Overall, these values suggest a rather diverse dietary range which we interpret further in the discussion below.

As mentioned above, three samples are believed to represent repeat analyses from the same individual. The two samples (left tibia and left radius) from AAM Burial 3 produced $\delta^{15}\text{N}$ values that are isotopically indistinguishable, meaning they are within the range of instrument precision. However, $\delta^{13}\text{C}$ is 0.7‰ higher in the tibial element, a difference that is greater than instrument precision. This could indicate slight shifts in this individual's diet during their adult years, and differences in the turnover rate of collagen between the tibia and radius could suggest that one of these bones may retain more collagen from an earlier phase in their life.

Results from the three bones analyzed from AAM Feature 7 suggest that they represent two different individuals. Based on nearly identical $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, we believe the right radius and right humerus in Feature 7 are from the same individual, while the values from the left fibula are divergent enough isotopically to suggest it represents a different individual. In the analyses below, we treat the humerus/radius as a single data point representing an individual, and the fibula as a second data point.

Finally, the AAM isolated femur element recovered in backdirt produced visibly distinct lighter and darker collagenous material in different parts of the bone. We separated these components and measured isotopes from both portions. The two portions returned isotopically identical values. The preservation indicators (C/N ratio, %C, and %N) are also nearly identical, indicating similar preservation. We treat these as a single analytical sample in the following discussion.

DISCUSSION

Bone stable isotope values are highly variable within this small sample of individuals from nineteenth century San Francisco. This is consistent with a population that practiced a wide range of dietary strategies. Figure 2 plots the 12 individuals for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$, color coded by cemetery. For comparison, in Figure 2 we add stable isotope data for other published nineteenth century cemeteries from North America (France et al. 2014; Katzenberg and Pfeiffer 1995; Wells 2014).

As shown in Figure 2, the historic period samples from North America vary regionally on $\delta^{13}\text{C}$ but overlap considerably on $\delta^{15}\text{N}$. This suggests differences in the quantity of C_3 and C_4 plants (or marine food), but there remains significant overlap in the amount of animal-derived meat in the diet. People that are more reliant on maize-based economies tend to fall on the right side of the graph, including confederate black soldiers and affluent white plantation farmers from the U.S. South (France et al. 2014). Conversely, wheat- and barley-based economies fall on the left side of the graph, including most nineteenth century Canadian farmers from Ontario. Mixed economies fall in the center of Figure 2, which include white affluent military and white farmers from Connecticut.

San Francisco samples (represented as circles in Figure 2) tend to fall into two-point clusters. The first group is composed of five individuals and falls on the left side of the figure. This is typically consistent with a diet centered on a C_3 plant-based economy, and given the historical context, this diet is most likely composed of wheat and barley. The second cluster comprises six individuals that fall within the more mixed C_3 - C_4 region. This is consistent with a C_3 plant-based economy with the incorporation of significant amounts of either C_4 or marine foods (see below). One additional individual from the Golden Gate Cemetery (the isolated cranium) falls outside both clusters and is more comparable to the North American communities with C_4 maize-based economies. It is most similar in isotopic composition to the rural Connecticut white farmers.

Figure 3 presents a comparison of the historic San Francisco samples to a diachronic sample of individuals buried on the San Francisco Peninsula. The figure includes a group of sailors from CA-SMA-207H who wrecked off Franklin Point in 1865 (Hylkema and Kindon 2018), a group of mission-period Native Californians from Sanchez Adobe (CA-SMA-71/H; unpublished data by one of us [JWE]), pre-

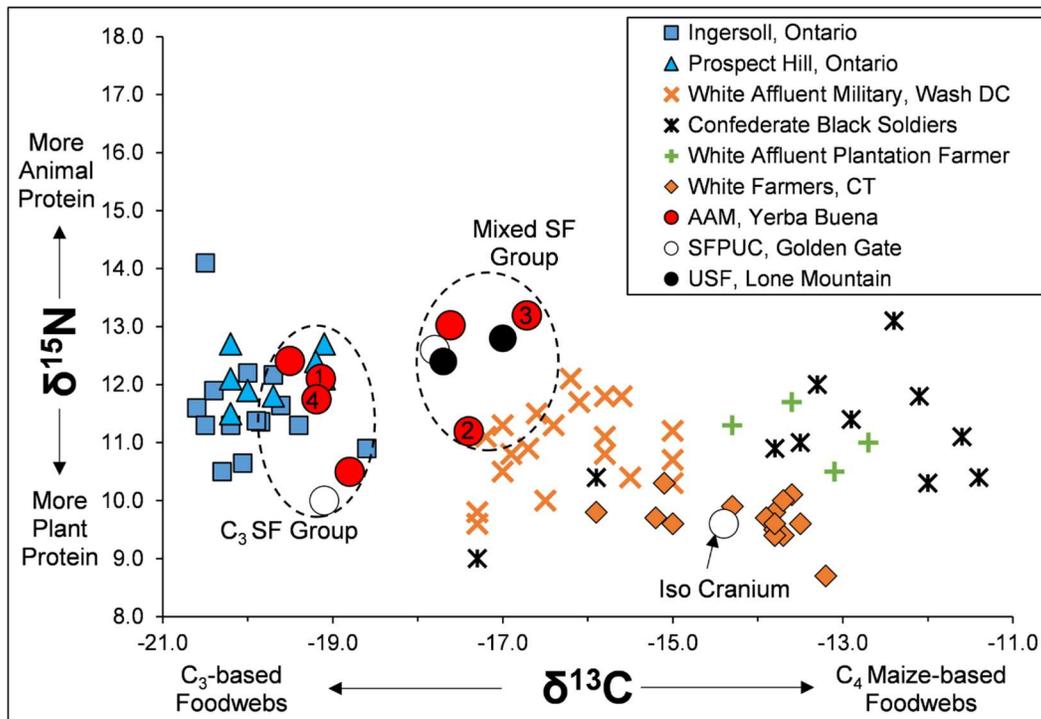


Figure 2. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ for historic San Francisco (circles), and selection of other nineteenth century North American populations (numbers for Yerba Buena symbols correspond to burial number).

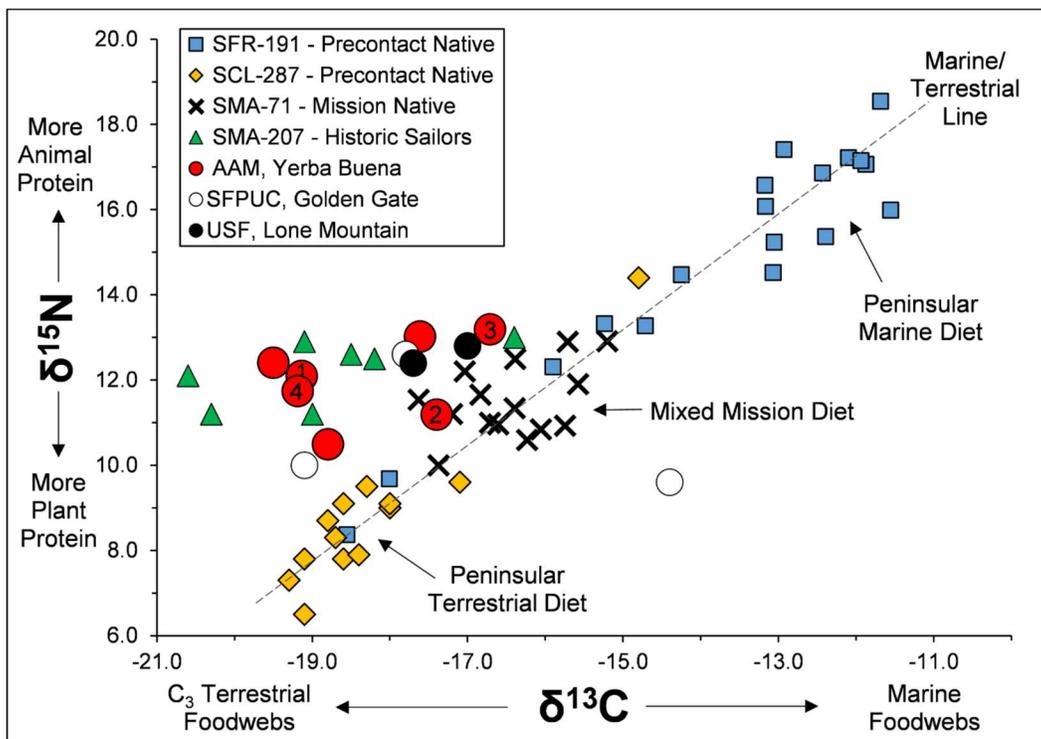


Figure 3. Comparison of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in historic San Francisco samples (circles) with other burial populations from the San Francisco Peninsula.

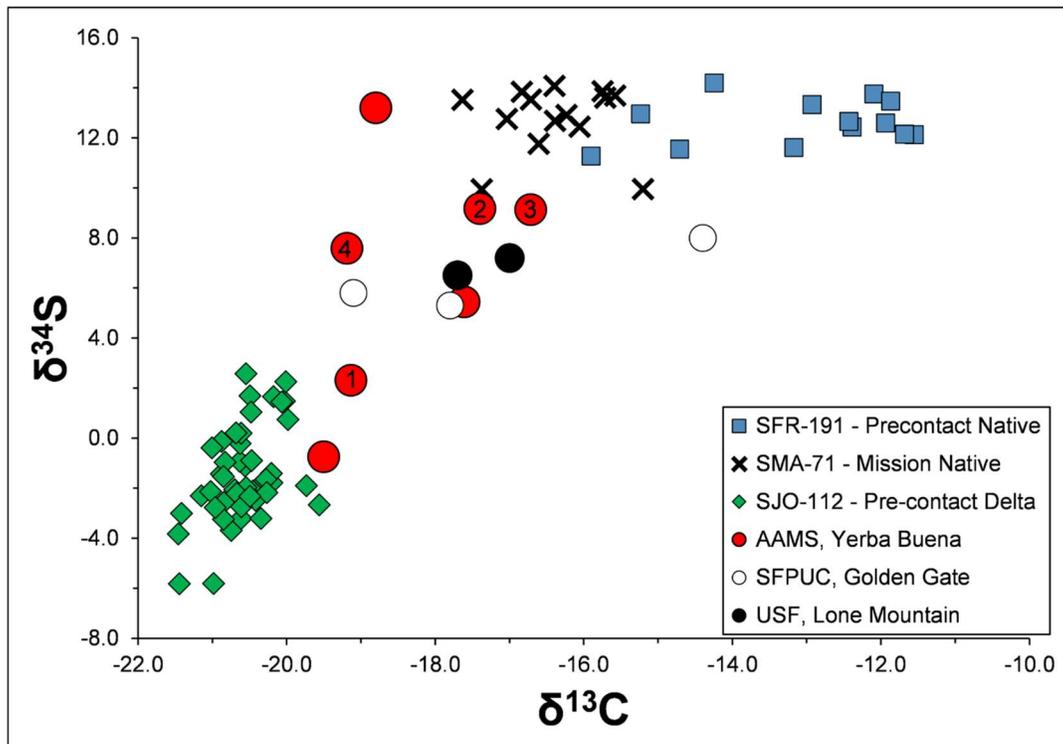


Figure 4. Comparison of $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ in historic San Francisco samples (circles) with other burial populations from central California.

contact Native Californians from CA-SFR-191 (unpublished data by JWE), and precontact Native Californians from CA-SCL-287 (Greenwald et al. 2016; Leventhal et al. 2011). The mission and precontact populations comprise a linear cluster that represents a continuum of dietary strategies between a more terrestrial-focused, plant-heavy diet in the lower left of Figure 3 (as at CA-SCL-287) and a more marine-heavy diet (as at CA-SFR-191) towards the upper right of the figure.

Overall, Figure 3 shows that the historic San Francisco samples compare best to the CA-SMA-207H sailors and partially with the mission period individuals from CA-SMA-71/H. They do not, however, overlap with the high- or low-marine diets observed in precontact populations. This suggests that historic diets in the San Francisco region were quite unlike precontact period diets and more like mission period diets, although with greater dietary variation between individuals.

Finally, Figure 4 plots $\delta^{13}\text{C}$ against $\delta^{34}\text{S}$. Sulfur isotope analysis has only sparingly been applied in North American archaeological studies. We do not have comparable data from other historic populations. However, data from mission period and precontact Californian populations are available.

As shown in Figure 4, the historic San Francisco burials are highly variable on $\delta^{34}\text{S}$, more so than the mission and precontact populations. This suggests that the foods accessed by these individuals in the nineteenth century were drawn from a much larger geographic region than those accessed by mission and precontact groups. This could be due to greater dietary diversity within the city of San Francisco in the historic period. Alternatively, some of the diversity may be due to the presence of individuals who immigrated to the city from a range of locations globally but died soon after reaching the city. Such individuals did not live in the city long enough to adjust to a “local” San Franciscan dietary signature and thus to retain a partially or fully nonlocal dietary signature in their bone collagen.

Additionally, the majority of individuals in the study have $\delta^{34}\text{S}$ values higher than 5‰. This is more consistent with the incorporation of some amount of marine food rather than C_4 terrestrial plants. For this reason, we suggest that the higher $\delta^{13}\text{C}$ observed in the “mixed” San Francisco dietary cluster in Figures 2

and 3 is mostly likely due to the incorporation of marine foods rather than C₄ plants such as maize or animals raised on maize.

CONCLUSIONS

Stable isotopic analysis of 15 bone collagen samples representing 12 nineteenth century individuals buried in San Francisco reveal new information about historic period diets and the dietary variation related to an individual's place of origin. First, repeat collagen samples from the same individual, drawn from either a different bone or a different part of the same bone, display similar isotopic values. This brings some degree of confidence in the consistency of stable isotope analyses.

Second, isotopic values are highly variable among the 12 individuals, suggesting a significant amount of variation in underlying dietary composition. Eleven of the 12 samples fall into one of two dietary clusters. One of these clusters (n = 5) is most consistent with a diet focused on C₃ terrestrial plants, such as wheat and barley, and animals consuming C₃ plants. The second seems to include C₃ terrestrial plants but mixed with a significant component of marine-derived foods such as fish and shellfish. A final individual seems to have been consuming significant amounts of C₄-derived plant protein, most likely maize. This individual could have been a recent immigrant to San Francisco from the southern or eastern U.S., where maize was more important in local subsistence economies.

Third, the sample size is quite small, which makes conclusions about patterns between the different cemeteries very tentative. However, even with the small sample available, the different cemeteries overlap in $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$. Hence, there do not appear to be any clear isotopic differences between individuals buried in the three cemeteries, which suggests similar dietary regimes. As remains left behind continue to become exposed, we hope to explore this trend in greater detail and with a larger sample size from the different cemeteries. Future studies with this assemblage will examine stable isotope analyses from teeth to reveal information about early childhood diet and ancient DNA. From these and other studies, we hope to gain a deeper understanding of the lives and behaviors of San Francisco's holistic society during the nineteenth century.

ACKNOWLEDGEMENTS

We thank Rachel Sliney, who helped prepare some of the Yerba Buena samples; Chris Canzonieri for help in the field identifying some of the individuals in our study; Allison Vanderslice, Principal Environmental Planner for the city of San Francisco, for supporting the research; and Joy Matthews and the UCD Stable Isotope Facility for assistance in weighing out and running the samples.

REFERENCES CITED

- Baur, John E.
1949 The Health Factor in the Gold Rush Era. *Pacific Historical Review* 18(1):97-108.
- Buzon, Michele R., Phillip L. Walker, Francine D. Verhagen, and Susan L. Kerr
2005 Health and Disease in Nineteenth-Century San Francisco: Skeletal Evidence from a Forgotten Cemetery. *Historical Archaeology* 39(2):1-15.
- Chan, Sucheng
1989 *This Bittersweet Soil: The Chinese in California Agriculture, 1860-1910*. University of California Press, Berkeley.
- Chatten, Cassandra, Katherine Flynn, and Dea Bacchetti
1997 Excavations at the California Palace of the Legion of Honor. *Abacus Archaeological Associates, Petaluma, California*.

- Craddock, Susan
 1995 Sewers and Scapegoats: Spatial Metaphors of Smallpox in Nineteenth Century San Francisco. *Social Science & Medicine* 41(7):957-968.
- DeNiro, Michael J.
 1985 Postmortem Preservation and Alteration of *In Vivo* Bone Collagen Isotope Ratios in Relation to Palaeodietary Reconstruction. *Nature* 317(6040):806-809.
- Descolas-Gros, Chantal, and Michel R. Fontugne
 1985 Carbon Fixation in Marine Phytoplankton: Carboxylase Activities and Stable Carbon-Isotope Ratios; Physiological and Paleoclimatological Aspects. *Marine Biology* 87(1):1-6.
- Eerkens, Jelmer W., Bryna Hull, Jena Goodman, Angela Evoy, Joshua D. Kapp, Sidra Hussain, and Richard E. Green
 2017 Stable C and N Isotope Analysis of Hair Suggest Undernourishment as a Factor in the Death of a Mummified Girl from Late 19th Century San Francisco, CA. *PLOS One* 12(9):e0184921.
- Fernandes, Ricardo, Andrew R. Millard, Marek Brabec, Marie- Josée Nadeau, and Pieter Grootes
 2014 Food Reconstruction Using Isotopic Transferred Signals (FRUITS): A Bayesian Model for Diet Reconstruction. *PLOS One* 9(2):e87436.
- France, Christine A. M., Douglas W. Owsley, and Lee-Ann C. Hayek
 2014 Stable Isotope Indicators of Provenance and Demographics in 18th and 19th Century North Americans. *Journal of Archaeological Science* 42:356-366.
- Garvie-Lok, Sandra J., Tamara L. Varney, and M. Anne Katzenberg
 2004 Preparation of Bone Carbonate for Stable Isotope Analysis: The Effects of Treatment Time and Acid Concentration. *Journal of Archaeological Science* 31(6):763-776.
- Greenwald, Alexandra M., Jelmer W. Eerkens, and Eric J. Bartelink
 2016 Stable Isotope Evidence of Independent Child Foraging in Prehistoric Central California. *Journal of Archaeological Science: Reports* 7:146-154.
- Hobson, Keith A.
 1999 Tracing Origins and Migration of Wildlife Using Stable Isotopes: A Review. *Oecologia* 120(3):314-326.
- Holliday, James S.
 2015 *The World Rushed In: The California Gold Rush Experience*. University of Oklahoma Press, Norman.
- Hurtado, Albert L.
 1999 Sex, Gender, Culture, and a Great Event: The California Gold Rush. *Pacific Historical Review* 68(1):1-19.
 2001 Settler Women and Frontier Women: The Unsettling Past of Western Women's History. *Frontiers: A Journal of Women Studies* 22(3):1-5.
- 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, No. 35, Sacramento.
- Ingenbleek, Yves
 2006 The Nutritional Relationship Linking Sulfur to Nitrogen in Living Organisms. *The Journal of Nutrition* 136(6):1641S-1651S.
- Jelinek, Lawrence J.
 1998 "Property of Every Kind": Ranching and Farming during the Gold-Rush Era. *California History* 77(4):233-249.
- Katzenberg, M. Anne, and Susan Pfeiffer
 1995 Nitrogen Isotope Evidence for Weaning Age in a Nineteenth Century Canadian Skeletal Sample. *Bodies of Evidence: Reconstructing History Through Skeletal Analysis* 221-235.

- Klepinger, Linda L.
1984 Nutritional Assessment from Bone. *Annual Review of Anthropology* 13(1):75-96.
- Lee-Thorp, Julia Anne
1989 *Stable Carbon Isotopes in Deep Time: The Diets of Fossil Fauna and Hominids*. Ph.D. dissertation, University of Cape Town, South Africa.
- Leventhal, Alan, Diane DiGiuseppe, Melynda Atwood, David Grant, Rosemary Cambra, Charlene Nijmeh, Monica V. Arellano, Sheila Guzman-Schmidt, Gloria E. Gomez, and Norma Sanchez
2011 *Final Report on the Burial and Archaeological Data Recovery Program Conducted on a Portion of the Mission Santa Clara Indian Neophyte Cemetery (1781-1818)*. Available at http://works.bepress.com/alan_leventhal/96/.
- Longin, Robert
1971 New Method of Collagen Extraction for Radiocarbon Dating. *Nature* 230(5291):241-242.
- McCutchan, James H. Jr., William M. Lewis Jr, Carol Kendall, and Claire C. McGrath
2003 Variation in Trophic Shift for Stable Isotope Ratios of Carbon, Nitrogen, and Sulfur. *Oikos* 102(2):378-390.
- Minagawa, Masao, and Eitaro Wada
1984 Stepwise Enrichment of ^{15}N Along Food Chains: Further Evidence and the Relation Between $\delta^{15}\text{N}$ and Animal Age. *Geochimica et Cosmochimica Acta* 48(5):1135-1140.
- Nehlich, Olaf
2015 The Application of Sulphur Isotope Analyses in Archaeological Research: A Review. *Earth-Science Reviews* 142:1-17.
- Nehlich, Olaf, and Michael P. Richards
2009 Establishing Collagen Quality Criteria for Sulphur Isotope Analysis of Archaeological Bone Collagen. *Archaeological and Anthropological Sciences* 1(1):59-75.
- Richards M. P., B. T. Fuller, and R. E. M. Hedges
2001 Sulphur Isotopic Variation in Ancient Bone Collagen from Europe: Implications for Human Palaeodiet, Residence Mobility, and Modern Pollutant Studies. *Earth and Planetary Science Letters* 191(3&4):185-190. doi:10.1016/S0012-821x(01)00427-7.
- Riley, Glenda
1999 Feminizing the History of the Gold Rush. *The Western Historical Quarterly* 30(4):445-448.
- Rohrbough, Malcolm J.
1998 *Days of Gold: The California Gold Rush and the American Nation*. University of California Press, Berkeley.
- Roth, Mitchel
1997 Cholera, Community, and Public Health in Gold Rush Sacramento and San Francisco. *Pacific Historical Review* 66(4):527-551.
- Shelton, Tamara V.
2008 Unmaking Historic Spaces: Urban Progress and the San Francisco Cemetery Debate, 1895-1937. *California History* 85(3):26-70.
- Snow, John
1855 *On the Mode of Communication of Cholera*. John Churchill, London, UK.
- Taniguchi, Nancy J.
2000 Weaving a Different World: Women and the California Gold Rush. *California History* 79(2):141-168.
- Wells, Emily
2014 *Sacred Heart: A Stable Isotope Analysis of Childhood, Diet, and Mobility at a Nineteenth Century Ontario Cemetery*. Electronic document, Electronic Thesis and Dissertation Repository, 2353, <https://ir.lib.uwo.ca/etd/>.