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The Role of Marine Foods in Ancient Diets Across a Coastal to Inland Transect of Monterey County, California

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We examine the role of marine food across a transect of sites in Monterey County, California, from the Pacific Coast to 70 km. inland. This study presents new stable carbon, nitrogen, sulfur, and strontium isotope data from human bone, and serial samples of teeth, as well as baseline data from a range of plant and animal remains. We estimate dietary contributions using two different mixing models. Results indicate that marine foods contributed between 65–75% of protein budgets on the coast, 30–40% in locations 10 km. from the coast, and just 1–6% 70 km. inland. Serial sampling of teeth, which estimates diet at 0.5–2.0 year intervals, shows that access to marine foods 10 km. from the coast was not marked by high-amplitude pulses, but was more continual and consistent, demonstrating the strong and persistent interconnections of coastal and near-coastal groups. By contrast, people living 70 km. inland were dependent almost entirely on terrestrial foods, consistent with consumption of resources such as pine and manzanita. Although they traded with coastal people for objects such as shell beads, the movement of marine foods themselves was minimal.

Marine environments were, and continue to be, an important source of food for many of California's diverse Indigenous peoples. In ancient times, the Pacific Ocean provided a wide range of shellfish, crustaceans, seabirds, kelp, fish, and sea mammals, and coastal sites typically contain high densities of shells and bones of marine vertebrates, reflecting this emphasis. However, the remains of seafoods are a notable component of many more inland sites as well (e.g., Boone 2012; Eerkens et al. 2016a; Hildebrandt 2004; Hildebrandt et al. 2009; Jones et al. 2002). Such foods were either acquired through trade with coastal villages or hauled back to inland locations through direct access to the coast.

While marine foods were clearly important for more inland inhabitants, what is less clear is how often people accessed coastal resources (i.e., every day, only in certain seasons, or only in some years), what role they played in local economies (staples of diet, feasting foods,

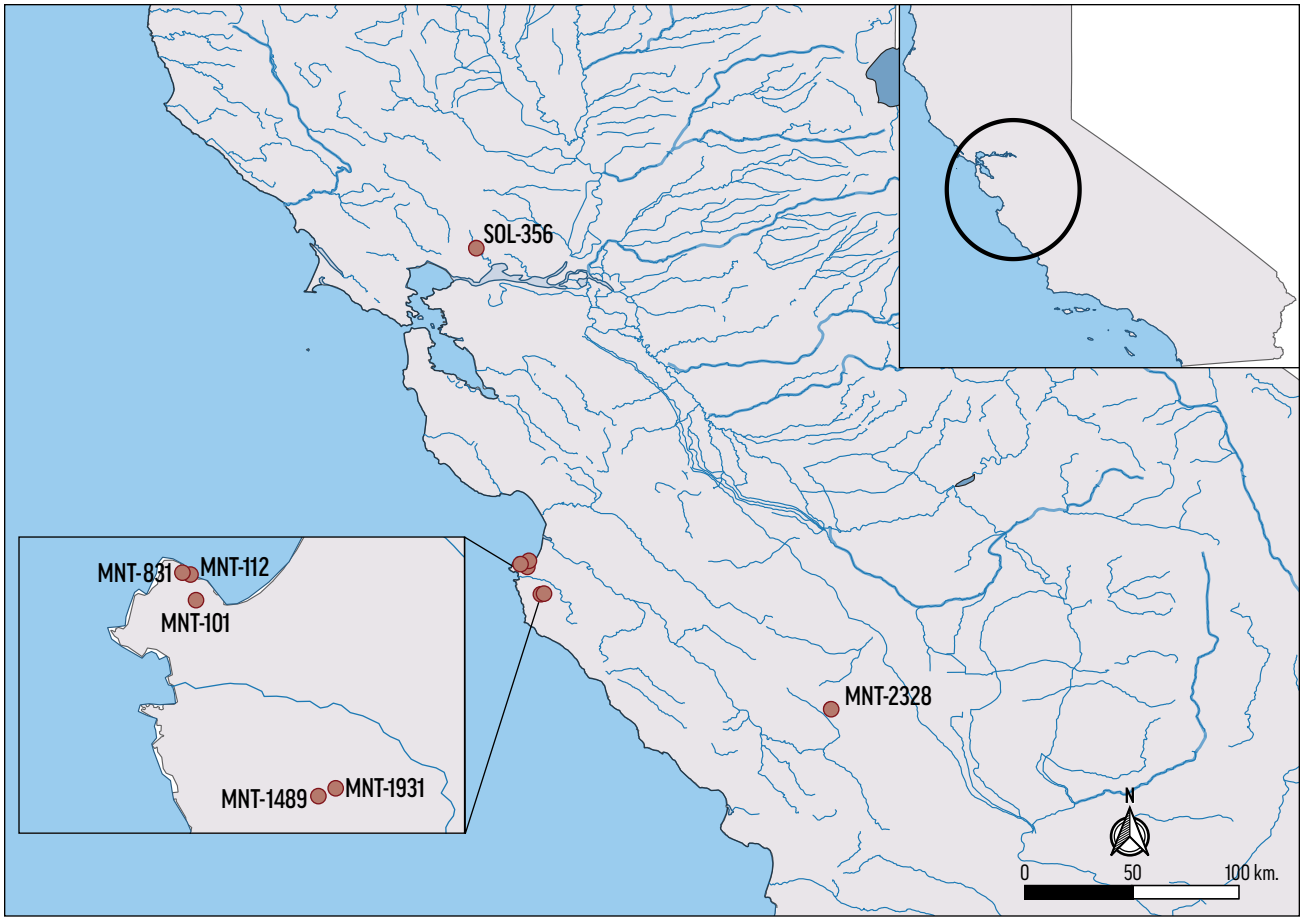

Figure 1. Map showing the location of the archaeological sites discussed.

or fallback foods), and how widespread such access was (available to everyone, or only to some individuals within a community). Because sites reflect the accumulation of materials involving many individuals over long periods of time, analysis of midden constituents is unlikely to answer these questions.

An alternative means to explore these questions is through isotopic analysis of human remains. Because foods are digested and reassembled to form skeletal tissues (bones and teeth), they contain traces of ancient diets. With support from descendant communities, we can explore the dietary and mobility behaviors of individual people through such approaches, allowing the ancestors to reveal particular details about their life experiences, even from thousands of years ago.

We compare stable isotope analyses of teeth and bone representing seven pre-contact-period individuals in Monterey County across a transect of sites located at various distances from the Pacific Coast. Remains include two individuals buried directly on the coast (CA-MNT-112 and CA-MNT-831), two buried inland but within a day's walk of the coast (10 km.; CA-MNT-1489 and CA-MNT-1931), and three buried inland far beyond a single day's walk (70 km.; CA-MNT-2328). Figure 1 shows the location of these sites within Monterey County. We explore how these ancestral Ohlone, Esselen, and Salinan ancestors accessed marine foods, and whether such access was regular, occasional, or rare.

A significant component of this research was the collaboration between Indigenous representatives of central-coastal California groups, contemporarily known as "Ohlone" (as some Indigenous peoples of the Bay Area use their languages to identify as "People"), Esselen, and Salinan tribes, and CRM and university archaeologists. While many tribes support scientific archaeological studies, sometimes even of human remains (as was the case here, which we recognize can be a culturally sensitive request), archaeologists should not assume this

is the case. Tribal partners in this study said that working together was an important part of the process. Different tribes, and individuals within tribes, recognize that they do not speak for all Indigenous peoples nor all the ancestors resting on occupied land. They have a range of views about and relationships with science, archaeology, ancestors, and the past. Destructive analysis of ancestral remains to study or glean information is sometimes viewed as disrespectful. Many Indigenous ancestors-in-training do not abide by these remains being seen and treated as objects to fuel western settler science's pursuit of knowledge, superseding respect for and desire to honor ancestors, resulting in a desecration of cultural protocols.

Although some of the results here have taken over 15 years to reach publication, in this case, all individuals involved felt that the information produced by the studies would be of benefit to both tribes and the archaeological community, and supported publication. We find it necessary and nonnegotiable to emphasize that these "remains" are ancestors. Today, the physical remains of the departed are only so used when consent is provided to donate our organs and body to science; these ancestors did not consent. It is only respectful to consider and receive input from the Indigenous communities impacted in studying these remains. For several of the ancestors discussed in this paper, co-author Ann-Marie Sayers, who sought California Indigenous relations' insight and consulted with elders in her lifetime, stated that "We enter this world without teeth, and sometimes we leave this physical world without teeth." Co-author Kanyon Sayers-Roods of Indian Canyon Nation further elaborated that "(t)his allows us the opportunity to learn from our ancestors, while simultaneously respecting some community considerations. It is with this perspective that it is highly favorable to subject only the teeth of the departed to destructive analysis, leaving other remains' decomposition to nature's hand, as opposed to humankind's."

Samples for the studies described below represent ancestors discovered inadvertently during the course of cultural resource management (CRM) projects. They do not derive from curated University of California collections. All analyses were carried out with permission from the Most Likely Descendants (MLDs). All ancestors in this study have been reburied, and the samples retained for the analyses discussed below were consumed in their entirety during the research.

ISOTOPE ANALYSES

Carbon (C), nitrogen (N), and sulfur (S) are needed to grow healthy bones and teeth and are incorporated into human bodily tissues via the foods we consume. Bone continually grows and remodels, and therefore reflects the diet of an individual close to the time of death. On the other hand, dental tissues are laid down in layers, and once formed, do not remodel, locking in dietary behaviors from earlier phases in life. The different elements are effective at recording different aspects of human behavior. C and N isotopes are largely reflective of different food types a person eats, and as such, help trace certain aspects of paleodiet. Thus, the same food will have nearly identical C and N isotopic composition across space, but two different food items available in the same location may vary significantly in C and N. By contrast, S and strontium (Sr) are more reflective of underlying geological landscapes, and as such, record information about where a person was living. Thus, two food items that vary in C and N are likely to be similar for S and Sr if they are collected in the same location, while the same food item (e.g., acorn) may vary significantly in S and Sr over space. In this respect, marine foods are very similar in underlying S and Sr values, while terrestrial foods are more variable from region to region.

Carbon Isotopes

In many areas of the world, carbon isotopes ($^{13}C/^{12}C$, expressed as $\delta^{13}C$, see below) provide an estimate of the consumption of C_3 vs. C_4 plants. The majority of economically important plants around the world are C_3 plants that discriminate against the heavier ^{13}C during photosynthesis, resulting in $\delta^{13}C$ values between –30‰ and –22‰ (Cerling et al. 1998; Ehleringer et al. 1993; Farquhar et al. 1989). By contrast, C_4 photosynthesis produces tissues with $\delta^{13}C$ values typically between –16‰ and –10‰. While the number of C_4 photosynthesizers globally is low, several important crop plants, such as maize, millet, sugar cane, and sorghum, fall in this category (Ehleringer et al. 1991; Tipple and Pagani 2007), allowing archaeologists to estimate their importance in local diets.

In central California, there are few native C_4 plants, and the majority of them were not important sources of food (Bartelink 2006; Cloern et al. 2002). However, perennial plants under significant water stress produce

tissues that are enriched in ^{13}C, leading to $\delta^{13}C$ values that are typically 1–4‰ higher than unstressed plants (e.g., Picon et al. 1996; Van de Water et al. 2002). In central California, most plant foods important for humans are either annual in nature (e.g., many grass seeds) or grow on waterways where water stress is not an issue (e.g., oaks). However, some perennial and economically important plants, including manzanita and pine, are found away from water courses, and undergo periodic water stress. Empirical studies using archaeological remains in California (i.e., charred plant material) show that these foods are consistently higher in $\delta^{13}C$ than other common food resources (Eerkens et al. 2020; Hull et al. 2017).

Carbon enters marine environments mainly through exchange with atmospheric CO_2 and is present as dissolved inorganic carbon (DIC). This carbon can then be absorbed into organisms through photosynthesis, especially by phytoplankton (Boutton 1991), and enters the food chain. The $\delta^{13}C$ values of biologically available carbon in marine environments is typically elevated relative to terrestrial environments, and largely overlaps with values recorded in C_4 plants. Thus, we can also use $\delta^{13}C$ in central California as a discriminator of terrestrial- vs. marine-derived carbon, with heavier (less negative) $\delta^{13}C$ indicating a greater contribution of marine organisms to the diet rather than C_4 plants (Bartelink 2009; Newsome et al. 2004; Schwartz and Schoeninger 1991; Schoeninger et al. 1983). Elevated $\delta^{13}C$ values in human skeletal tissues due to a consumption of resources such as pine nuts can be differentiated from that arising from the consumption of marine foods by the examination of nitrogen isotopes, as discussed below.

Nitrogen Isotopes

Nitrogen isotopes ($^{15}N/^{14}N$, expressed as $\delta^{15}N$, see below) reflect the general trophic level of consumed foods. Nitrogen fractionates during the synthesis of biological tissues, favoring the retention of the heavier ^{15}N. As a result, $\delta^{15}N$ increases by about 3–4‰ with each trophic level. In terrestrial systems in central California, there are essentially three trophic levels—plants, vegetarians, and carnivores—with omnivores typically falling between the latter two. By contrast, in aquatic environments there are more trophic levels, resulting in a greater enrichment of ^{15}N at the top of the food chain. The latter includes large fish, predatory birds, and aquatic mammals.

In humans, consumed protein is differentially routed to collagen (Ambrose and Norr 1993; Kellner and Schoeninger 2007; Tieszen and Fagre 1993). Research shows that 72% of the carbon in collagen comes from dietary protein, with the remaining 28% derived from carbohydrates and lipids (Fernandes et al. 2012). Combined, $\delta^{13}C$ and $\delta^{15}N$ of human collagen can be used to discriminate foraging, especially for protein, in different environments. In general, foragers in coastal environments tend to have elevated levels of $\delta^{13}C$. In addition, because nitrogen isotopes fractionate with each trophic level, and marine environments tend to have more trophic levels, $\delta^{15}N$ also tends to be elevated in these settings. By contrast, foragers in terrestrial environments typically display non-overlapping ranges of C and N isotopes. Where C_4 plants dominate local landscapes, $\delta^{13}C$ values in collagen can overlap values for coastal foragers, but $\delta^{15}N$ will be lower due to the lower trophic level of plants. In landscapes where C_3 plants dominate, both $\delta^{13}C$ and $\delta^{15}N$ are lower than for coastal foragers. In lacustrine and riverine settings, where there is no marine carbon but there are many trophic levels, foragers display elevated $\delta^{15}N$ values but lower $\delta^{13}C$ values. In environments where pine nuts are especially important in the diet, $\delta^{13}C$ will be only slightly enriched, but $\delta^{15}N$ will be low. Finally, brackish-water environments are intermediate between marine and lacustrine/riverine environments (Eerkens et al. 2013). These predictions are summarized in Table 1.

Table 1

EXPECTATIONS FOR $\delta^{13}C$ AND $\delta^{15}N$ FOR DIETS DOMINATED BY PARTICULAR FOOD GROUPS OR ENVIRONMENTS

		$\delta^{13}C$		
		Low	**Med**	**High**
$\delta^{15}N$	**High**	Riverine	Brackish aquatic	High trophic marine
	Med	Terrestrial mammal	Mixed diet	Low trophic marine
	Low	C_3 plants	C_3/C_4/Pine nuts	C_4 plants

Strontium Isotopes

^{87}Sr and ^{86}Sr are both stable isotopes of Strontium; however, ^{87}Sr is radiogenic, and is the daughter byproduct of radioactive ^{87}Rb (with a half-life of 48.8 billion years). As a result, the ratio of ^{87}Sr to ^{86}Sr slowly increases in rock formations over time (Capo et al. 1998; Faure

1986). Strontium is passed up the food chain and is easily incorporated into human tissues, including bone and teeth, as it can substitute for calcium in the calcium-phosphate biomolecules that comprise the mineral component of skeletal tissues. The diverse geology of central California ensures that there is much regional variation in strontium isotopes.

Because people in pre-contact times obtained the majority of their food from their immediate environment, human populations from different parts of central California tend to display distinctive regional signatures in strontium isotopes (Eerkens et al., 2016b). Modern seawater, and animals subsisting on marine resources, have a relatively constant $^{87}Sr/^{86}Sr$ ratio of 0.70917 (Palmer and Edmond 1989). Unfortunately, to our knowledge, no previous archaeological studies involving Sr isotopes (i.e., "isoscapes") have been conducted in Monterey County to provide context. Likewise, although there are geological studies on specific geological formations (e.g., DePaulo and Finger 1991), we are not aware of fine-scaled region-wide geological surveys that map Sr isotopes at a scale useful to archaeologists that would allow us to carefully map migration patterns. Instead, this is baseline information that California archaeologists will need to build up over time. We hope this study contributes towards that goal.

Here, we are mainly interested in distinguishing marine from non-marine Sr. While we do not know the exact $^{87}Sr/^{86}Sr$ values in formations near the sites in question, inland geological complexes in Monterey County are mainly Mesozoic in age (ca. 250–65 million years ago). Previous studies have shown that these areas should have $^{87}Sr/^{8}6Sr$ lower than marine waters, in the range of 0.703 to 0.708 (Linn et al. 1992). From this, we should be able to distinguish marine from expected inland Monterey County $^{87}Sr/^{86}Sr$ values.

Sulfur Isotopes

Sulfur operates in a manner similar to Sr. It is derived from local geological formations and is present in various forms (e.g., sulfates, sulfides) in soils. It is taken up by plants from the soil and passed up the food chain to animals and humans (Nehlich 2015; Richards et al. 2003). Sulfur is essential in the formation of the amino acid methionine, which is present in small amounts in collagen. Marine environments have a relatively constant $\delta^{34}S$ value of 21.0±0.2‰, while terrestrial environments have a much greater range of variation, occasionally extending below 0‰. As in the case of $^{87}Sr/^{86}Sr$, detailed isoscapes for $\delta^{34}S$ do not exist in California, and to our knowledge, this is the first study reporting $\delta^{34}S$ values for humans in this county. Again, we are mainly interested in discriminating marine vs. terrestrial $\delta^{34}S$ for insight into marine food consumption.

METHODS

Isotopes incorporated into dental tissues, including dentin and enamel, are reflective of where a person was living and what they were eating when that tissue was forming. By analyzing teeth that form at different points in a person's life, it is possible to trace an individual's dietary changes, provided they consumed mainly local foods while living in a particular region. Furthermore, because teeth grow in layers over many years, it is possible to extract tissues from different layers and examine their isotopic content. For this study, we analyzed carbon and nitrogen isotopes from growth layers within the dentin of permanent molars (see below), and strontium from the enamel of those same molars.

Bone, on the other hand, is a living tissue and continually remodels throughout a person's life. The elements in bone, therefore, are a reflection of where a person was living during the last several years of life. The amount of time it takes for a bone to acquire a local isotope signature has not been measured empirically. However, estimates vary between 5 and 15 years, depending slightly on the type of bone and the age of the individual (Hedges et al. 2007; Manolagas 2000), with older individuals experiencing slower turnover (meaning that the isotopes in bone reflect a longer period of time). For this study, we extracted collagen from bone, and analyzed the carbon and nitrogen, as well as the sulfur and strontium isotopes when possible.

Together, isotopic analyses of bone and teeth can provide a sort of isotopic life history, or *isobiography*, for an individual. By comparing multiple individuals across a site, archaeologists can gain new insights into dietary and migration patterns of populations, including, for example, insight into post-marital residence patterns (e.g., patrilocality vs. matrilocality if one or the other sex is differentially moving from their natal village).

Dentin Serial Sampling

Dentinal and enamel tissues in human teeth grow in thin layers over time (Hillson 1996). Each layer forms over a number of weeks to months as tissues are initially deposited and subsequently mineralized. For dentin, the layers accumulate from the dentin-enamel junction in the crown downwards through the root over time. The age at which a tooth forms varies greatly by tooth, with some beginning growth in utero and finishing within the first year of life (e.g., deciduous teeth), and others beginning and ending much later in life (e.g., third molars). Although mineralization of a particular layer takes several weeks or months, once formed, these tissues do not remodel later in life (unlike bone). Because dentin and enamel are synthesized in the human body using biomolecules that are digested from foods, tissues from particular layers in teeth reflect diet during the window of time those layers were forming.

Advances in mass spectrometry now allow for the analysis of small samples. As a result, it is possible to isolate sections of teeth and determine their stable isotope composition (e.g., Beaumont et al. 2012, 2015; Burt 2015; Eerkens and Bartelink 2013; Eerkens et al. 2011; Fuller et al. 2003). This facilitates tracing certain aspects of diet over the window in which that section grew. By analyzing serial samples, it is possible to reconstruct those aspects of diet across successive windows of time for a particular individual.

Permanent first molars begin formation at the dentin-enamel junction (DEJ) and continue growing through age 9–10 years, when the apical root tip (ART) is completed (Hillson 1996). The cementum-enamel junction (CEJ) typically forms between age 2.5–3 years, when the crown is complete. Permanent second molars begin forming slightly later, around age 2.5–3 years at the DEJ, with the CEJ forming around 7–8 years, and continuing to grow through age 14–16 when the ART is complete. Finally, permanent third molars begin formation at the DEJ between 7–10 years of age, the CEJ finishes between 12–16 years, and the ART forms between 18–25 years of age (Hillson 1996).

In this study, we took serial micro-sections of first, second, and third molars to reconstruct diet across these windows of time, using these age-related landmarks to control for age within a tooth (see Fig. 2). For older individuals, the DEJ was occasionally not present, having been worn away. In those cases, only the CEJ and ART were used to establish an internal age for the tooth.

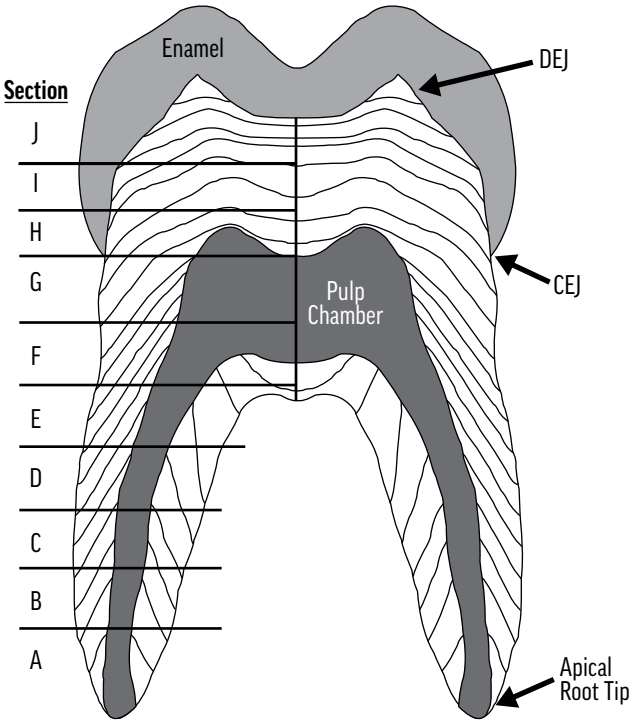

Figure 2. Tooth serial sampling strategy (after Eerkens et al. 2011).

Sample preparation followed procedures established in Eerkens et al. (2011). Teeth were cleaned with a small brush of any adhering soil or other exogenous material, sonicated in deionized water (dH_2O), and cut in half longitudinally (i.e., crown to root) with a slow-speed diamond-coated saw. All cementum and enamel was removed and the pulp chamber reamed out from one half of the tooth using a hand-held drill. This tooth half was then weighed and demineralized in a solution of 0.5M hydrochloric acid (HCl) in a refrigerator set at 5°C. The HCl was changed every other day until the sample was completely demineralized (generally 1–2 weeks).

The tooth was then rinsed with dH_2O and sliced into parallel serial sections (see Fig. 2), beginning at the apical root tip and working up towards the crown. Note that these cuts are generally parallel to growth layers within the crown but cut across diagonal growth layers in the root (see Eerkens et al. 2011). Because layers accumulate in a cone-like manner within the root, we are unable to manually cut cones out of the demineralized root but must cut horizontally across growth planes. As a result,

adjacent serial samples in the root include some material from the same layers of growth (i.e., adjacent sections do not represent mutually exclusive temporal windows). This will cause stable isotope fluctuations to be somewhat smoothed within the root sections; that is, if the isotopic composition of the diet abruptly changed while the root was forming, some of the abruptness would be smoothed out in the resulting serial section isotope data. However, we estimate that every other sample within the root has less than 10% of the same (synchronous) material, by volume. The number of serial sections produced varied slightly by tooth depending on the degree of occlusal wear, and the size, length, and structure of the tooth.

Following demineralization, any remaining secondary dentin was removed. Secondary dentin is typically separated from the primary dentin after demineralization. If the sample was large enough, this secondary dentin was run as a separate isotopic assay (data not reported here). Following slicing, each serial sample was placed in a separate vial and immersed in 0.125M NaOH (sodium hydroxide) for 24 hours to remove humic acids. The sample was rinsed with dH_2O to remove any residual NaOH and placed in slightly acidic pH3 water in an oven set to 70°C to solubilize collagen. Solubilized collagen was then freeze-dried to remove all remaining water, isolating the collagen fraction.

Between 0.8 and 1.2 mg. of collagen was weighed out from each serial section for stable isotope analysis. In some cases, there was not enough collagen from a serial sample, and adjacent section(s) had to be combined to achieve a total of 1 mg. Carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) for each serial sample was measured by continuous-flow mass spectrometry (PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20–20 isotope ratio mass spectrometer) at the Stable Isotope Facility, University of California Davis. Carbon isotope ratios ($^{13}C/^{12}C$) are reported as $\delta^{13}C$ and expressed in permil notation (parts per thousand) relative to the PeeDee Belemnite standard (arbitrarily set at 0‰), while N isotope ratios ($^{15}N/^{14}N$) are reported as $\delta^{15}N$ and expressed against N_2 in modern atmospheric air (also arbitrarily set to 0‰).

Bone Collagen

Bone collagen was extracted following a similar protocol as dentinal collagen. Bone was cleaned with a drill, drilling the outer 0.5 mm. of all exposed surfaces to remove potentially contaminated or degraded components of the bone. The bone was then washed and sonicated in deionized water, demineralized in HCl, treated with NaOH, and the collagen solubilized and freeze dried. Approximately 1 mg. was submitted for C and N isotope analysis. Where enough collagen was present, 10 mg. was submitted for S isotope analysis. Collagen from four individuals was also submitted for AMS radiocarbon dating.

Strontium Isotopes

Sr from bone and tooth samples was separated and purified. This process removes all isotopes of rubidium (Rb), one of which (^{87}Rb) can interfere with the measurement of ^{87}Sr. Bone and enamel (~0.05 grams of powder each) were treated with 2 milliliters (mL) of 15% hydrogen peroxide (H_2O_2), sonicated for 5 min, and then soaked for 24 hours to remove organic material. Samples were then rinsed in distilled water, dried down and treated with 2 mL of 0.1 N Acetic Acid and soaked for 24 hours to remove secondary non-biogenic carbonates. They were then rinsed two times with distilled water, dried down and dissolved with 4 mL of 2.5 N hydrochloric acid (HCl). All samples were dissolved completely (i.e., no residual solids remained) by placing them on a hotplate for 24 hours while soaking in HCl. Samples were dried down to evaporate HCl and brought up in 800 microliters (μL) of 8 N Nitric Acid (HNO_3) and centrifuged. The supernatant was loaded onto teflon columns containing Eichrom® Sr Spec resin. Rubidium (Rb), barium (Ba), lead (Pb), and most other elements were eluted in 2 mL 3 N HNO3. Sr was collected in 2.8 mL of 0.5 N HNO_3, dried down and reloaded onto the columns a second time (in 8 N HNO_3) to ensure complete purification of Sr from Rb. All acids used were distilled to ensure their purity and titrated to ensure the correct concentrations.

Sr isotope ratios were determined by Nu Plasma HR MC-ICP-MS at the UC Davis Interdisciplinary Center for Plasma Mass Spectrometry. Sample solutions were introduced through a DSN 100 desolvating nebulizer and isotope analyses were mass-fractionation corrected internally to the 'true' $^{86}Sr/^{88}Sr$ ratio of 0.1194. ^{85}Rb and ions with mass 84 (including ^{84}Kr and ^{84}Sr) were monitored to correct for ^{87}Rb interfering with ^{87}Sr and ^{86}Kr with ^{86}Sr, respectively. ^{85}Rb was only present at a few mV or less due to the double-pass of Sr through the columns. ^{84}Kr and thus ^{86}Kr interference on ^{86}Sr

was corrected by iterations using the assumption that $^{84}Sr/^{86}Sr = 0.00675476$.

The analytical protocol involves 3–4 samples bracketed by the Sr standard SRM 987 allowing for normalization of sample $^{87}Sr/^{86}Sr$ isotope measurements to an accepted value of 0.710249 for SRM 987. Sample uncertainties for SRM 987 were less than 0.00002, determined by measuring 2 standard deviations on repeated measures of ocean coral that was run with the human samples.

While enamel appears to be relatively conservative in relation to postmortem taphonomic processes, bone can sometimes undergo diagenetic change (Budd et al. 2000), though recent studies suggest some osteons in bone preserve the original signal (Scharlotta et al. 2013). To minimize the potential effects of diagenesis, we mechanically removed the outer layers of bone and tooth samples more susceptible to diagenetic change. We also subjected the remaining bone to chemical cleaning. As such, our study focuses on interior sections of well-preserved cortical bone and enamel, minimizing the potential effects of diagenesis of isotopic values (Knudsen et al. 2005). Our analyses at other sites in central California show that bone Sr isotopes of burials identified as non-locals based on other criteria (e.g., burial style) have not converged on the local value, despite being buried for hundreds to thousands of years (Eerkens et al. 2014, 2016b; Jorgenson et al. 2009). This suggests that human bone from central California cleaned in this manner can recover the original Sr-isotopic signature.

Faunal and Macrobotanical Samples

To contextualize the human isotope samples, we compare the human samples against reference samples from food items known to be important in ancestral diets in the region. Where possible, we use previously published data for species. However, data are lacking for many species, and therefore we analyzed a sample of faunal and floral samples from the same sites, or sites in the region. Original isotopic data for those samples are provided in the results section. The majority of large mammal species sampled from CA-MNT-2328 failed to produce adequate collagen. However, we report data from an inland Late Period terrestrial site, CA-SOL-356 (see Wiberg 1996), as representative of expected baseline isotopic values for deer, elk, and antelope.

Bone samples from animals were prepared in the same fashion as described above. For plant samples, we selected samples of the more ubiquitous genera represented in flotation studies from CA-MNT-2328, focusing especially on acorn nutshell, pine nut hulls, and juniper seeds. Previous studies show that charring of plant materials to temperatures typical in traditional cooking does not significantly alter $\delta^{13}C$ (Fraser et al. 2013; Vaiglova et al. 2014). Thus, charred plant materials can preserve important paleoenvironmental information. Samples were sonicated in a 0.5M HCl solution for five minutes to remove inorganic impurities. Samples were then drained and sonicated in dH_2O for an additional five minutes to loosen and remove any remaining debris. Once dH_2O was removed, samples were soaked in a 0.5M HCl solution for two hours at room temperature to complete the dissolution of any remaining inorganic materials. Samples were then rinsed to pH neutral in dH_2O and left to dry. After drying, samples were frozen, then freeze-dried to remove any remaining moisture. Between 0.3 and 0.8 mg. of carbonized material was analyzed by continuous-flow mass spectrometry (PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20–20 isotope ratio mass spectrometer) at the Stable Isotope Facility, University of California Davis.

SAMPLES INCLUDED IN THIS STUDY

Paleoethnobotanical samples for baseline comparison are from CA-MNT-2328 and include charred plant materials for a range of species. Many of these plant remains were found in flotation samples near individual burials discussed below. Charred plant remains were only measured for $\delta^{13}C$.

We attempted to extract collagen from a range of faunal bones from CA-MNT-2328. However, only two bones, both leporids, produced enough collagen with acceptable preservation of C/N indicators (between 2.9 and 3.6) to include in the analysis. To complement the faunal sample, we sampled pronghorn (*Antilocapra americana*), deer (*Odocoileus* sp.), and elk (*Cervus* sp.) remains from a site further north, CA-SOL-356. We believe that these ungulate diets would have been similar in composition. Because C and N are ultimately fixated from the atmosphere and incorporated into plant tissues, we argue that underlying C and N stable isotope signatures would be *similar* to those of ungulates in Monterey County.

Table 2

INDIVIDUALS INCLUDED IN THIS STUDY AND ANALYSES CONDUCTED

Site	Dist. to coast	Bur#	Sex	Age at death	Teeth Serial Sampled	Bone	AMS Date
MNT-112	1 km.	Isolate	Ind.	Adult	I2	n/a	n/a
MNT-831	1 km.	3	M	16–18	–	Rib	4,397 ± 20
MNT-1489	10 km.	1	Ind.	Adult	M1	n/a	n/a
MNT-1931*	10 km.	1	Ind.	Adult	M3	n/a	n/a
MNT-2328	70 km.	1	M	45–55	M1, M2	Rib	1,073 ± 23
MNT-2328	70 km.	2	M	12–16	M1, M2, M3	Rib	887 ± 21
MNT-2328	70 km.	4	Ind.	18–22	M1, M3	n/a	1,129 ± 24

Notes: *CA-MNT-1931 was formerly numbered CA-MNT-1482 (Breschini and Haversat 2008); Ind. = Indeterminate; "n/a" = Bone element was not available for analysis, or direct AMS date is not available to report. AMS dates reported as uncalibrated years B.P.

Finally, for the human remains, we examined seven individuals from five different archaeological sites. First, CA-MNT-112 is located on the coast in Pacific Grove (Deitz and Jackson 1981). From this site, the root of a second permanent incisor was analyzed for C and N isotopes reflecting childhood diet. The age of this particular sample is unknown; however, radiocarbon dates at the site span 4,500 through 500 cal B.P. Second, a single small bone fragment was analyzed for C, N, and S isotopes from CA-MNT-831, a site that is also on the coast in Pacific Grove, with dates spanning between 6,000 and 400 cal B.P. (Breschini and Haversat 2002). Third and fourth, CA-MNT-1489 and -1931 are in the Carmel Valley approximately 10 km. from the coast, and both sites date between 700 and 200 cal B.P. A single tooth was analyzed from an individual at each site for C and N isotopes, teeth that were also analyzed for ancient DNA (Breschini and Haversat 2008). Finally, three individuals from CA-MNT-2328 (70 km. from the coast) date to between 1,200 and 900 cal B.P. We include C, N, S, and Sr isotopic analyses of two bone samples and seven teeth. Table 2 shows the samples, demographic information, and isotopic studies conducted for each individual.

RESULTS

Table 3 presents the results of the carbon isotopic analyses of paleoethnobotanical remains from the site, including one wild barley seed (*Hordeum* sp.), three acorn nutshell fragments (*Quercus* sp.), three juniper seed fragments (*Juniperus* sp.), and two pine nut shell fragments (*Pinus* sp.). All samples had ample carbon for measurement of $\delta^{13}C$.

Table 3

RESULTS OF $\delta^{13}C$ ANALYSES ON CHARRED PLANT MATERIALS FROM CA-MNT-2328

Genus	Context	Sample Weight (mg.)	$\delta^{13}C$
Hordeum	Near Burial 2	0.35	–23.7‰
Quercus	Near Burial 2	0.31	–23.3‰
Quercus	Feature 2	0.29	–23.0‰
Quercus	Unit 7	0.32	–26.4‰
Juniperus	Near Burial 2	0.70	–22.8‰
Juniperus	Feature 2	0.61	–21.8‰
Juniperus	Unit 7	0.68	–19.4‰
Pinus	Feature 2	0.81	–23.3‰
Pinus	Unit 7	0.72	–20.1‰

We plot results of the $\delta^{13}C$ analyses on paleoethnobotanical remains from CA-MNT-2328 in Figure 3, with symbols coded by genus. As shown, the oak (acorn, squares in Fig. 3) and wild barley (diamond) samples are lower in $\delta^{13}C$, between –26.4‰ and –23‰. This is within the range expected of annual species or perennial species growing in well-watered locations. By contrast, the juniper (triangle) and pine (circle) samples are higher in $\delta^{13}C$, between –23.3‰ and –19.4‰ (Fig. 3). These higher values are in line with that expected of perennial species growing in poorly-watered locations, where water stress causes an increase in $\delta^{13}C$ values in plant tissues. Humans and animals consuming these plants, then, would incorporate these slightly higher $\delta^{13}C$ values into their own skeletal tissues.

Table 4 shows the data for faunal remains from regional sites. As shown, all terrestrial mammals have systematically low $\delta^{13}C$ bone collagen, below –19.7‰,

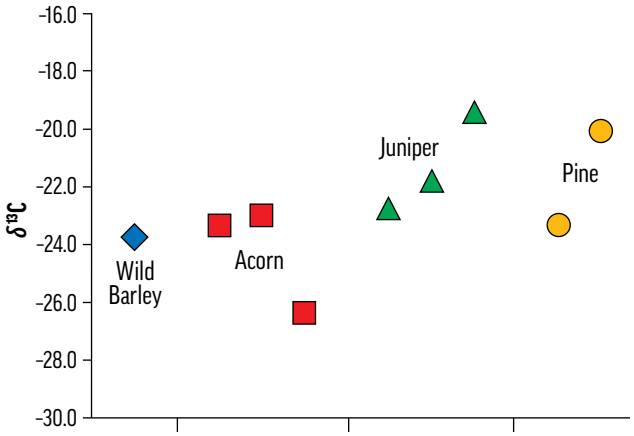

Figure 3. δ^{13}C values for paleoethnobotanical samples from CA-MNT-2328.

Table 4

δ^{13}C, δ^{15}N, AND δ^{34}S FROM BONE COLLAGEN FOR A RANGE OF FAUNAL SAMPLES IN MONTEREY AND SOLANO COUNTIES

Site	Species	δ^{13}C	δ^{15}N	δ^{34}S
MNT-101	Albatross (*Phoebastria albatrus*)	-15.1	17.5	17.4
MNT-2328	Jackrabbit (*Lepus californicus*)	-21.2	3.8	-0.3
MNT-2328	Cottontail (*Sylvilagus* sp.)	-20.7	3.9	n/a
SOL-356	Pronghorn (*Antilocapra americana*)	-20.4	7.2	n/a
SOL-356	Pronghorn (*Antilocapra americana*)	-21.1	6.0	n/a
SOL-356	Pronghorn (*Antilocapra americana*)	-20.6	7.0	n/a
SOL-356	Pronghorn (*Antilocapra americana*)	-20.0	6.8	n/a
SOL-356	Pronghorn (*Antilocapra americana*)	-19.9	6.5	n/a
SOL-356	Deer (*Odocoileus hemionus*)	-19.7	5.2	n/a
SOL-356	Deer (*Odocoileus hemionus*)	-20.9	5.3	n/a
SOL-356	Deer (*Odocoileus hemionus*)	-20.5	4.0	n/a
SOL-356	Elk (*Cervus* sp.)	-21.1	6.7	n/a
SOL-356	Elk (*Cervus* sp.)	-20.8	7.5	n/a
SOL-356	Elk (*Cervus* sp.)	-20.8	6.1	n/a
SOL-356	Elk (*Cervus* sp.)	-20.7	6.2	n/a
SOL-356	Elk (*Cervus* sp.)	-20.5	7.2	n/a
SOL-356	Elk (*Cervus* sp.)	-20.7	7.4	n/a

consistent with little to no access to marine-derived carbon. The single marine bird (albatross) has much higher δ^{13}C at –15.1‰, as expected of an animal consuming a high quantity of marine-derived foods. Likewise, small mammals (lagomorphs) tend to be low in δ^{15}N, below 4.0‰, indicative of a vegetarian diet, while large mammals (ungulates) are slightly higher, between 4.0‰ and 7.5‰, due to the effects of bacteria on plant foods during rumination in the gut prior to digestion, which increases δ^{15}N in tissues. Again, the single marine bird has greatly elevated δ^{15}N at 17.5‰ due to consumption of marine fish.

Table 5 provides the stable isotope data from human bone, and the strontium isotope data from teeth. Atomic C/N ratios on collagen were within the acceptable range for all samples (between 2.9 and 3.6; see DeNiro 1985). As a result of low collagen yield from some bones, it was not possible to directly radiocarbon date or run sulfur isotopes on every individual.

Table 5

STABLE ISOTOPE RESULTS FROM BONE COLLAGEN, AND STRONTIUM FROM BONE AND TEETH

Site		Bone	Bone	Bone	^{87}Sr/^{86}Sr				
MNT-	Ind.	δ^{13}C	δ^{15}N	δ^{34}S	Bone	M1	M2	M3	AMS Date (2σ cal B.P.)
831	3	-13.1	16.8	13.4	–	–	–	–	4,397±20 (4,567-4,807)
1489	1	–	–	–	–	.7085	–	–	
1931	1	–	–	–	–	-	–	.7084	
2328	1	-17.9	8.0	1.1	.7071	.7073	.7073	–	1,073±23 (932-1052)
2328	2	-18.0	9.0	0.6	.7072	.7074	–	.7074	887±21 (734-904)
2328	4	–	–	–	–	.7078	–	.7079	1,129±24 (963-1,171)

Table 6 shows the δ^{13}C and δ^{15}N values for the serial samples from teeth, along with the estimated median onto genetic age for each serial sample. These data are plotted in Figure 4, with δ^{15}N in the upper half and δ^{13}C in the lower half, and age on the X-axis. Each of the lines in Figure 4 traces changes in the isotopic composition of a person's diet over the years indicated. Note that the two individuals from sites 10 km. from the ocean (CA-MNT-1482 and -1931) are systematically elevated in δ^{13}C over individuals buried 70 km. from the coast.

In comparison to other sites in central California (cf. Bartelink 2009; Eerkens et al. 2011, 2013, 2015), collagen preservation at the coastal sites was excellent, fair to good at the near-coastal site, and fair to poor at the interior site. In many cases at the latter, we had to combine collagen from two or more adjacent serial samples in order to meet the 1 mg. minimum requirement for sample submission, reducing temporal resolution for studying dietary change within an individual's lifetime. As well, some samples produced high C/N ratios, outside the range of acceptable values recommended by DeNiro (1985), indicating poor preservation. These samples were eliminated from the analysis.

Table 6

$\delta^{13}C$ AND $\delta^{15}N$ FROM SERIAL DENTIN SAMPLES

Site MNT-	Indiv.	Tooth	Median Age (yrs.)	$\delta^{13}C$	$\delta^{15}N$	CN
112	iso	I2	5.0	-12.7	18.4	3.4
1482	1	M3	9	-15.1	12.9	3.2
1482	1	M3	10.1	-14.9	13.1	3.2
1482	1	M3	11.8	-15.9	11.4	3.2
1482	1	M3	14.5	-15.7	11.4	3.2
1482	1	M3	15.6	-15.9	11.8	3.1
1482	1	M3	17.3	-14.4	12.8	3.1
1482	1	M3	18.9	-14.6	13.0	3.1
1482	1	M3	20	-15.8	12.0	3.1
1931	1	M1	0.8	-16.1	12.2	3.1
1931	1	M1	1.7	-16.2	11.9	3.1
1931	1	M1	2.6	-15.6	12.6	3.1
1931	1	M1	3.5	-16.1	12.2	3.3
1931	1	M1	4.4	-15.7	12.5	3.2
1931	1	M1	5.3	-15.6	13.0	3.3
1931	1	M1	6.2	-14.7	13.8	3.2
1931	1	M1	7.1	-14.5	14.4	3.2
1931	1	M1	8	-15.3	13.4	3.2
2328	1	M1	1.8	-18.6	9.8	3.2
2328	1	M1	2.2	-18.6	9.9	3.3
2328	1	M1	3.8	-18.5	8.6	3.4
2328	1	M2	4.2	-18.3	9.2	3.2
2328	1	M2	5.5	-18.2	9.3	3.2
2328	1	M2	8.0	-18.9	6.9	3.1
2328	1	M2	9.0	-18.7	7.6	3.2
2328	1	M2	10.0	-19.0	8.7	3.4
2328	1	M2	12.0	-18.1	9.4	3.3
2328	2	M1	3.0	-17.4	11.4	3.2
2328	2	M1	5.0	-17.4	11.3	3.1
2328	2	M1	7.0	-17.8	8.8	3.2
2328	2	M2	6.0	-18.1	9.9	3.3
2328	2	M2	8.0	-18.4	8.9	3.3
2328	2	M2	10.0	-18.4	8.4	3.3
2328	2	M3	11.0	-17.4	12.2	3.2
2328	2	M3	14.0	-17.4	12.9	3.2
2328	4	M1	1.5	-17.5	12.8	3.2
2328	4	M1	2.0	-17.3	12.2	3.2
2328	4	M1	2.5	-16.8	10.8	3.3
2328	4	M1	4.5	-17.5	9.8	3.2
2328	4	M1	6.5	-17.8	9.0	3.3
2328	4	M1	7.5	-17.9	9.0	3.3
2328	4	M3	9.0	-17.3	10.5	3.2
2328	4	M3	10.0	-17.8	10.7	3.3
2328	4	M3	11.5	-17.7	11.4	3.2
2328	4	M3	13.5	-18.2	11.4	3.4
2328	4	M3	16.0	-18.4	9.2	3.2
2328	4	M3	17.5	-18.6	9.3	3.2
2328	4	M3	19.0	-18.5	9.7	3.2

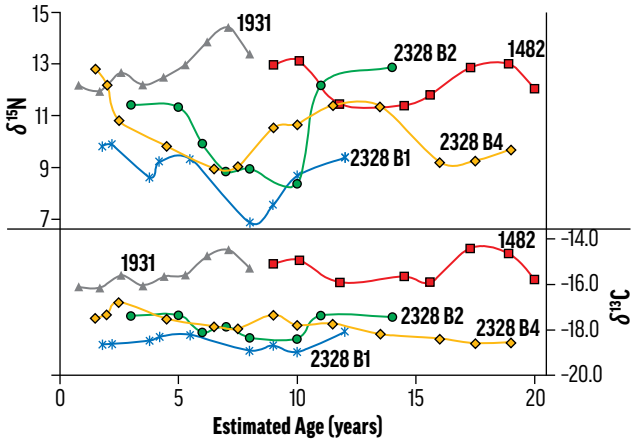

Figure 4. Tooth collagen serial samples for all five individuals included in the study, showing $\delta^{13}C$ vs. age in the lower half of the graph, and $\delta^{15}N$ vs. age in the upper half.

AMS dates were calibrated using the Calib 8.2 program (Stuiver et al. 2020). The date for the MNT-831 individual returned a Middle Holocene age (Early Period), as expected. Using a linear mixing model (see Bartelink et al. 2020), we calculate 44% marine carbon for this individual, and used a marine reservoir of 260±35 (Groza et al. 2011) to produce a median calibrated age of 4,674 cal B.P. (2σ=4,807–4,567 cal B.P.). By contrast, the three MNT-2328 individuals were calibrated assuming no marine carbon (see below), producing Late Holocene median calibrated ages of 973 cal B.P. (Burial 1; 2σ=1,052–932 cal B.P.), 792 cal B.P. (Burial 2; 2σ=904–734 cal B.P.), and 1,023 cal B.P. (Burial 4; 2σ=1,171–963 cal B.P.).

DIETARY MODELING

We model diet in three ways: by comparison to other Native Californian populations, through a simple linear mixing model based only on $\delta^{13}C$, and through a more complex model based on $\delta^{13}C$ vs. $\delta^{15}N$. An important caveat here is that our dietary estimates focus on sources of *protein* within the diet (as the majority of the signal in collagen derives from dietary protein [Fernandes et al. 2012]). Because plant foods are generally low in protein density compared to meat, they will be under-represented in terms of the overall dietary estimates, which includes sources of carbohydrates, lipids, and protein (Ambrose et al. 2003). In other words, plants would have made an even

greater contribution to total kilocalories than the estimates drawn below.

First, Figure 5 compares the data in this study to data from previous studies in California. Ellipses represent the approximate isotopic range for individuals living in a variety of representative environments. Here, riverine environments are represented by the sites on the Sacramento River (data from Bartelink 2009), the California Delta is represented by data from CA-SJO-112 (data from Barton et al. 2020), an interior environment with a heavy exploitation of C_3 plants is represented by CA-SCL-919 (data in Eerkens et al. 2016c), foothills environments are represented by sites in Tuolumne County in the Sierra Nevada (data from Hull et al. 2016), marine estuarine environments are represented by CA-CCO-297 on San Francisco Bay (data from Martinez et al. 2015), and the Pacific Coast is represented by Santa Rosa Island (data from Rick et al. 2011).

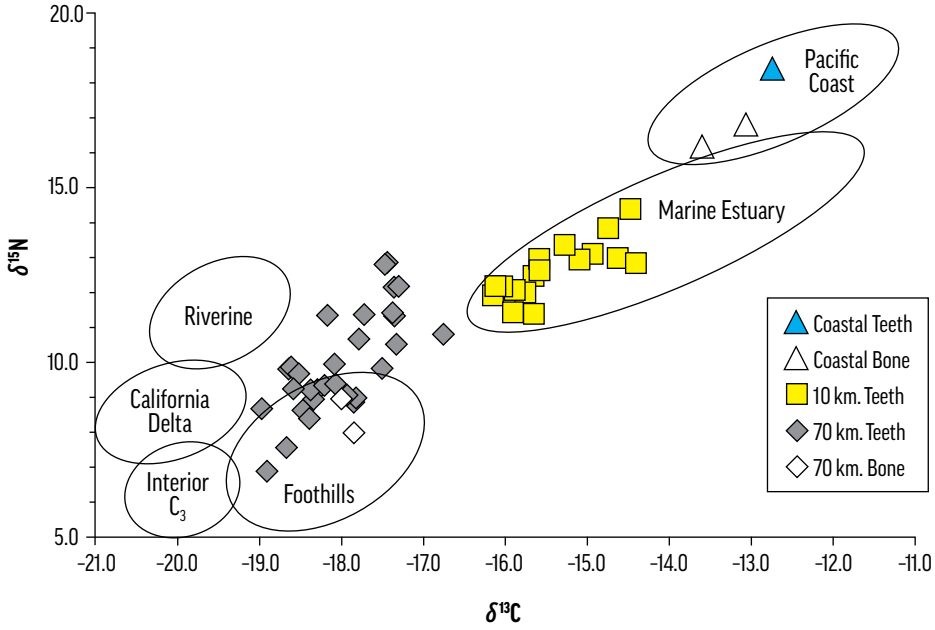

Figure 5. δ^{13}C vs. δ^{15}N for dentinal and bone collagen with symbols denoting distance from coast. Ellipses represent isotopic values observed empirically in other Native Californian populations.

As shown in Figure 5, the coastal samples in this study (as expected) fall directly within the range for other California Pacific Coast foragers. The samples from individuals buried 10 km. from the coast are similar to the lower end for people living on the shore of San Francisco Bay. Finally, the samples from individuals living 70 km. from the ocean fall in a somewhat unique range. Some of these samples fall into the range of individuals from the Sierra Nevada foothills, while others fall between those of riverine, foothill, and San Francisco Bay individuals, suggesting a diet that included significant terrestrial and riverine foods, perhaps including water-stressed plants.

Second, we apply the simple linear mixing model developed by Bartelink (2009). This model assumes a high of –5.5‰ for a pure marine consumer, and a δ^{13}C value of –27‰ for a pure terrestrial forager, and then places individuals within this continuum. Using this model, we estimate that the coastal individuals in this study gained between 50–55% of their dietary protein from marine environments. Likewise, individuals buried 10 km. from the coast obtained between 35–45% of their protein from marine environments.

By contrast, δ^{13}C in individuals buried 70 km. from the coast suggests marine protein contributed, at most, 25% of dietary protein. In fact, we believe this 25% figure considerably overestimates marine-derived protein in the inland population. As shown in Table 3, many of the plants in the CA-MNT-2328 midden are much higher in δ^{13}C than the –27‰ minimum assumed by the model. A diet heavy in pine-nut and juniper-berry protein, or animals consuming these items, would have a higher baseline δ^{13}C. If we take the average of the values in Table 3 as a minimum for δ^{13}C (μ=–23‰), rather than –27‰, this mixing model suggests a maximum of just 1% of marine carbon for these inland individuals.

Third, we used IsoSource to model a bivariate solution to diet (Phillips and Gregg 2001; Phillips and Koch 2002), given the empirically observed δ^{13}C and δ^{15}N in bone and dentinal collagen in this study. We model four potential sources of protein for consumers: acorns, pine nut/juniper berry, ungulates, and salmon, a common marine food that was available in both coastal and inland locations. We realize that people in the past

consumed a much broader range of foods than just items from these four sources. However, models such as IsoSource are not effective when there are too many input variables, and we therefore limit the model to these four food items, noting that they represent "stand-ins" for similar types of foods. Thus, acorns provide something of a stand-in for all non-water-stressed C_3 plant foods, while salmon provide a stand-in for all marine foods.

We use the empirical $\delta^{13}C$ values reported above for acorns ($\mu = -24.2‰$) and pine nut/juniper pits ($\mu = -21.5‰$) from CA-MNT-2328 and assume $\delta^{15}N$ values of 3.0‰ for these plant foods (based on previously published values; see Bartelink 2006). We use data from elk, antelope, and deer remains in Table 4 to estimate ungulate meat $\delta^{13}C$ and $\delta^{15}N$ values. Finally, we use previously published data on ancient salmon bones, adjusting for tissue-animal offsets (Bartelink 2006; Talcott 2019:114). For the humans, we assume diet to bone collagen offset of 5.0‰ for $\delta^{13}C$ (Fernandes et al. 2012) and 3.5‰ for $\delta^{15}N$ (DeNiro and Epstein 1981; Minigawa and Wada 1984). This offset is due to fractionation effects within the human gut, collagen synthesis, and routing of collagen proteins to locations of bone synthesis. These isotopic estimates for foods are provided in the second row of Table 7, and were used as input to IsoSource.

We then took the empirical human isotopic data in Tables 4 and 5 and input those as well into IsoSource. Table 7 then reports the output from IsoSource, which are dietary estimates for those raw isotopic values. For example, as shown, pine/juniper is estimated to have a mean contribution of 48% to CA-MNT-2328 Burial 1's total protein budget, with a minimum estimate of 16% and a maximum 81%. By contrast, acorns (and other non-water-stressed C_3 plants) are estimated to have contributed 24% of the total protein (with a minimum of 7% and maximum of 40%), and ungulates 23% (with a minimum of 0% and maximum of 45%).

Table 7 confirms the suspicion that pine nuts and juniper berries were highly important to diets at far-inland sites such as CA-MNT-2328, contributing, on average, between 23% and 48% of the total protein budget. Likewise, ungulates are estimated to have been important contributors to the protein budget at this location, between 17% and 24%. By contrast, acorns seem to have been of lesser importance, between 2% and 24% at this inland site.

Table 7

ISOSOURCE INPUT VALUES (SECOND ROW) AND OUTPUT VALUES (ROWS 4–10) FOR PERCENT OF TOTAL PROTEIN CONTRIBUTION (MEAN, WITH MINIMUM AND MAXIMUM IN PARENTHESES) TO THE DIETS OF THE SEVEN INDIVIDUALS IN THIS STUDY

		Pine/Juniper	Acorn	Ungulates	Marine/Salmon
Model Input Value		$\delta^{13}C = -22‰$ $\delta^{15}N = 3.0‰$	$\delta^{13}C = -24.2‰$ $\delta^{15}N = 3.0‰$	$\delta^{13}C = -23‰$ $\delta^{15}N = 6.4‰$	$\delta^{13}C = -13.0‰$ $\delta^{15}N = 15.6‰$
Individual	Distance to Coast				
MNT-2328 B. 1	70 km.	48% (16–81)	24% (7–40)	23% (0–45)	5.8% (0–12)
MNT-2328 B. 2	70 km.	27% (8–46)	8% (0–18)	62% (47–75)	3.2% (0–7)
MNT-2328 B. 4	70 km.	23% (18–29)	2% (0–6)	71% (71–82)	4.2% (0–9)
MNT-1482	10 km.	6% (0–25)	16% (0–58)	47% (1–78)	31% (22–41)
MNT-1931	10 km.	5% (0–20)	12 (0–47)	44% (5–69)	39% (31–48)
MNT-112	0 km.	0.9% (0–3)	3.2% (0–9)	23% (17–29)	73% (71–74)
MNT-831	0 km.	7% (0–32)	10% (0–34)	16% (0–46)	65% (54–73)

By contrast, the site 10 km. from the coast, and the coastal sites, show much higher inputs of marine foods, 30–40% and 65–75% respectively. Ungulates (and other terrestrial game) also seem to contribute heavily to the protein budget in these locations, between 40–50% 10 km. from the coast, and 15–25% on the coast. Plants, on the other hand, contribute only minor amounts to the protein budget, systematically less than 25% for all individuals, with acorns approximately 2–3 times more important than pine and juniper.

S and Sr Isotopes

We were unable to gather S and Sr isotopes from every individual, either due to poor collagen yields in bone (for S) or lack of a large enough bone/tooth sample (for Sr). As well, we did not have access to a range of local geological and floral/faunal baseline samples, as we did for C and N, to be able to estimate what a "local" signature should look like at each location. Such baseline data would allow us to more accurately model dietary contributions from local terrestrial and marine environments. In spite of our inability to precisely model marine foods, isotopic results from S and Sr isotopes clearly conform to the patterns described above, and further support our interpretations.

The $\delta^{34}S$ for the coastal Individual 3 at MNT-831 are relatively high, at 13.4‰, close to values expected in seawater (21‰). By contrast, Burials 1 and 2 at the 70-km. inland site (MNT-2328) have much lower values at 1.1‰

and 0.6‰. This suggests much higher consumption of marine food on the coast. Likewise, $^{87}Sr/^{86}Sr$ values for the two individuals 10 km. from the coast, at 0.7084 and 0.7085, show tooth enamel values closer to the values expected for seawater (0.7092) than those at CA-MNT-2328, which range between 0.7071 and 0.7079.

DISCUSSION AND CONCLUSIONS

Results from this study provided some expected results, as well as some novel information regarding diet across a coastal-inland transect in Monterey County. For example, it is not surprising that individuals living on the coast of Monterey County were heavily dependent on marine environments for the majority of their protein, as indicated by C, N, and S isotopes. Isotopic results suggest that two-thirds to three-quarters of dietary protein came from the ocean. This result mimics that of Newsome and colleagues (2004), who estimated that a set of Early and Middle Holocene individuals buried in a coastal site in Santa Cruz County (about 2 km. from the modern coastline, and just to the north of our study area), also gained between 50 and 85% of their protein from marine sources.

More interesting, however, are the individuals who were buried, and presumably lived, 10 km. from the coast. These individuals were still gaining between 30 and 40% of their protein, on average, from marine environments. Furthermore, the serial samples from teeth, which provide dietary estimates averaged over roughly 0.5 to 2.0 years of time, indicate that this access was fairly consistent over time (see Fig. 4), not punctuated by high access in some years and little or no access in others. The isotopic data do not indicate whether such food was accessed via regular, such as daily or weekly, excursions to the coast, or if people in these near-coastal locations were engaged in regular trade for food (e.g., fish, shellfish) with people living on the coast. This finding corroborates the findings of excavations at inland sites in the region which contain significant amounts of marine shell and fish remains (Boone 2012; Breschini and Haversat 1992). Thus, at least some of this food was being carried from the coast to these inland locations for consumption.

Given the high volume and continual access to marine foods at the two sites 10 km. from the coast, we argue that these resources were not novelty or special foods only consumed during infrequent events such as feasts. Likewise, these foods do not appear to have served as fallback or "starvation" foods, in which case consumption would have been more variable from year to year. Instead, the isotopic data are most consistent with marine foods comprising a staple of the diet. The serial samples do not have the chronological control that would allow us to examine the seasonality of marine foods. Thus, it is possible that diet during certain seasons emphasized marine foods over others. Future sampling of marine shells and fish bone from such inland sites for seasonality using stable isotopes would help address this question.

Regardless, the isotopic findings here reinforce the importance of the connections that existed between coastal and inland villages, and the regional economies that were in place in antiquity. These results echo others elsewhere; for example, in northern Santa Barbara County (Hildebrandt 2004), large amounts of coastal foods were carried about 25 km. inland to supply local food economies (see also Hildebrandt et al. 2009 in Sonoma County).

On the other hand, our findings indicate that individuals living 70 km. from the coast were apparently outside this economic interaction sphere. They were not in regular contact with coastal groups, at least for food. Isotopic data do not indicate significant marine contributions to the protein budget, nor do these sites contain appreciable evidence of coastal resources within the midden (Price et al. 2020). Serial sampling of teeth does not even indicate occasional spikes in marine-derived protein, at least not over periods of time (ca. 3–4 months) long enough to have left an isotopic trace. This suggests that far-inland groups did not habitually visit coastal locations, even during particularly lean or difficult years, as a source for fallback foods (see Eerkens et al. 2016a). Similarly, if trade was responsible for marine foods moving inland 10 km. from the coast, such trading networks do not seem to have extended out to 70 km.

This does not mean, of course, that these communities were completely isolated from coastal people. Marine shell beads are present in sites 70 km. from the coast, including at CA-MNT-2328, indicating at least some interaction with coastal groups. The movement of food items from the coast, however, does not seem to have been a significant part of such interactions. Instead, these more inland communities appear to have depended almost entirely on terrestrial foods, even during harder years when local foods may have been sparser.

Figure 6. Ella Rodriguez (1932–2005) Fred Segobia (1960–2022) Gary Breschini (1946–2018)

Together, the findings provide important contextual evidence for the size of ancient interaction spheres in Monterey County. The isotopic evidence indicates that subsistence interaction spheres habitually included locations at least 10 km. from the coast, but did not extend out to 70 km. On the other hand, information from artifacts indicates that trading interaction spheres extended at least 70 km. from the coast.

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