

INFANT AND CHILDHOOD DIET IN THE LATE MIDDLE AND MIDDLE-LATE TRANSITION PERIODS IN THE CALIFORNIA DELTA: NEW TOOTH COLLAGEN ISOTOPE DATA FROM CA-CCO-139, SIMONE MOUND

ALEXANDRA C-GREY
UNIVERSITY OF CALIFORNIA, DAVIS

JELMER W. EERKENS
UNIVERSITY OF CALIFORNIA, DAVIS

ERIC J. BARTELINK
CALIFORNIA STATE UNIVERSITY, CHICO

We examine infant and childhood diet, including estimating the age of weaning at a Late Middle and Middle-Late Transition Period site in central California, CA-CCO-139, known as the Simone mound. Stable isotope analyses of serial samples of permanent first molars record information about the diet of an individual when they were between approximately 0 and 9 years of age, during the temporal window these teeth were growing. Nitrogen and carbon stable isotope ratios across successively-growing serial samples allow us to construct dietary curves for a sample of eight individuals, including five females, one male, and two individuals of indeterminate sex. Results indicate relatively late ages of weaning, on average 3.3 years, which is consistent with high parental investment in children. Additionally, we examine a cyclical $\delta^{13}C$ pattern in the only male individual included in the sample that potentially represents seasonal access to resources.

Site CA-CCO-139, also known as Simone Mound, is situated in the California Delta near the modern town of Oakley (Figure 1). The site is located in proximity to a number of archaeological sites (e.g., CA-CCO-20), including the better known Hotchkiss Mound (CA-CCO-138), and is likely part of a complex of related mounds in the Delta. Simone Mound lies on a large Pleistocene sand dune at an elevation of three meters above sea level. Such relict dunes are common in the Delta, and many contain precontact habitation sites, presumably because these locations served as high spots that provided protection from annual flooding

Simone Mound was excavated in the 1930s by an amateur named Ernest N. Johnson. Much of the collection has been curated at the Phoebe A. Hearst Museum of Anthropology (PAHMA) since then. Despite playing an important role in early culture historical chronology-building research in the 1940s and 1950s (e.g., Bennyhoff and Fredrickson 1994), very little follow-up research using modern methodology has been conducted. Although surrounded by suburban development, we are aware of only one small excavation on the flanks of the mound within the last 30 years (Childress 2000). PAHMA granted two of us (JWE and EJB) access to sample tooth and bone in order to conduct limited archaeometric analyses, including radiocarbon dating and the stable isotope analyses reported here. Occupation date estimates for Simone Mound are based on the presence of temporally diagnostic artifacts, especially *Olivella* shell F3 series beads (Groza et al. 2011) and 45 individual bone collagen radiocarbon dates (Eerkens and Bartelink 2019). The bone collagen dates are on the same individuals analyzed below.

In central California, chronology is generally divided into several larger “periods,” many of which are divided further into subphases within periods. Of relevance to Simone Mound are the Middle Period, which dates between 2,150 and 930 cal BP, and the Middle-Late Transition Period, which ranges between 930 and 685 cal BP. Recent radiocarbon dating shows that F3 beads date to the M2 (1,530-1,365 cal BP), the M3 (1,365-1,200 cal BP), and the M4 (1,200-930 cal BP) subphases of the Middle Period, as well as the Middle-Late Transition Period (930-685 cal BP) (Groza et al. 2011). The direct accelerator mass spectrometry (AMS) dates on human bone collagen from Simone Mound resolve the chronological ascription even further, as all

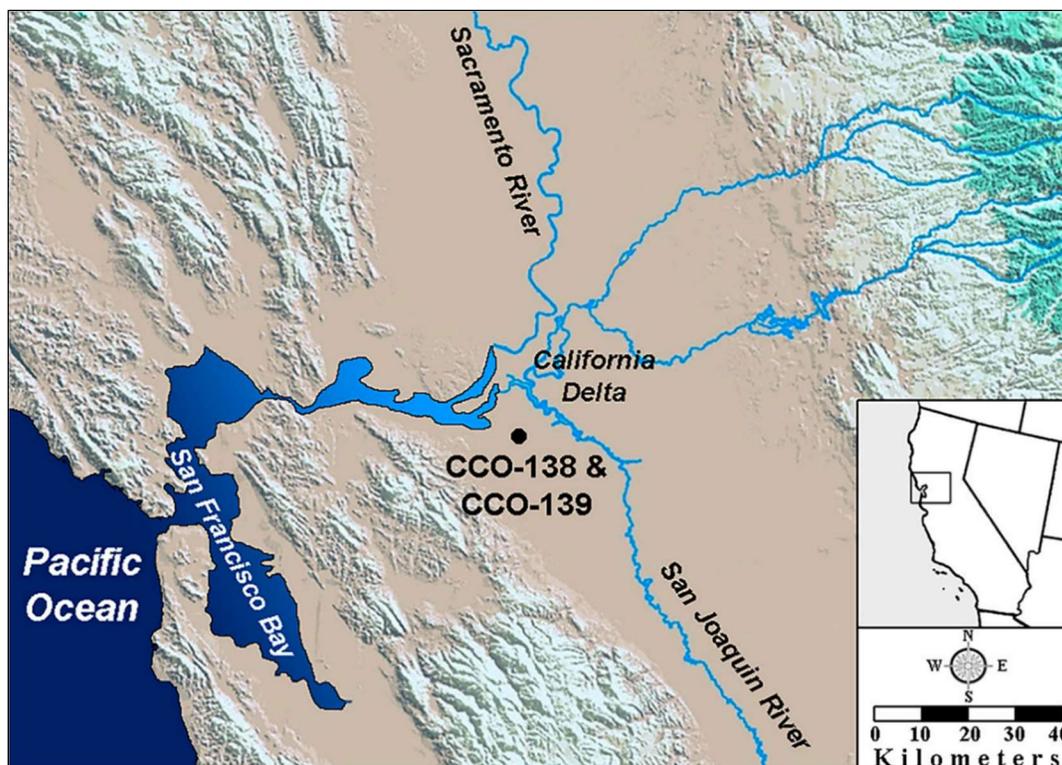


Figure 1. Map showing the location of CA-CCO-139 (Simone Mound) and CA-CCO-138 (Hotchkiss Mound).

the dates fall between 1,200 and 800 cal BP (Eerkens and Bartelink 2019). Together, the temporal data suggest that the primary occupation of the site was during the latter part of the Middle Period (ca. 2,150-930 cal BP) and into the first half of the Middle-Late Transition Period (ca. 930-685 cal BP).

Culturally, the Simone Mound is associated with the Meganos culture through a suite of characteristics. Most important among them is the contemporaneity of both flexed and extended burials, as well as the absence of crematory mortuary practices. Additionally, the site's location atop a sand mound is characteristic of Meganos culture (Bennyhoff and Fredrickson 1994). Bennyhoff originally described the influx of Meganos cultural traditions into the San Francisco Bay Area. These ideas were later tested and built upon by Eerkens and Bartelink (2020), who further described the gradual diffusion of Meganos culture from the California Delta into the San Francisco Bay area. This cultural expansion occurred between approximately 1,365 and 930 cal BP.

At the time of occupation, the immediate area surrounding Simone Mound was a tule-filled marsh teeming with fish and waterfowl. Based on faunal evidence at nearby sites, the broader area was also rich in artiodactyls (elk, pronghorn, and deer) and river clams (Cook and Elsasser 1956). Recent archaeo-ichthyological analyses at Simone Mound indicate that small- and medium-bodied fishes were a major component of the diet (Miszaniec et al. 2018). Due to a lack of flotation studies at Simone Mound, less is known about plant exploitation, although it is assumed that small seeds and likely acorns played an important role in subsistence practices. Based on the available evidence, the estuary provided a significant proportion of dietary resources.

ISOTOPIC ORIENTATION

Because human tissues such as bone and teeth are synthesized from the food and water we consume, they provide indications of diet, geolocation, and health. By performing analysis of the ratios of stable isotopes

of common elements in these tissues, such as carbon, nitrogen, oxygen, and sulfur, we can gain insight into the dietary life histories of individuals (Eerkens et al. 2011; Williams et al. 2011). Teeth, in particular, provide valuable information on the early stages of life because they form in successive layers between ages 0 and 22 years and do not remodel. This allows us to sample them sequentially and to analyze dietary or geographic changes on a linear timeline. By contrast, bone is a living tissue that constantly remodels, thus it erases earlier signatures and provides information on conditions only during the last five to 15 years of life.

This study focuses on carbon and nitrogen isotopes in permanent first molars of eight individuals buried at Simone Mound. Carbon isotopes, expressed internationally as $\delta^{13}\text{C}$, are often used in scientific studies to discern between C_3 plants and C_4 plants, as well as terrestrial and marine resources (Chisholm et al. 1982; Schoeninger et al. 1983). There is a measurable difference in the ratio of ^{13}C to ^{12}C in the atmospheric and marine carbon reservoirs. This difference is successively passed up the trophic chain from plants to herbivorous animals, and eventually to carnivores and/or people, who, as omnivores, may consume all of these. During photosynthesis, plants utilize either a C_3 or C_4 photosynthetic pathway. As plants fixate carbon from the atmosphere as CO_2 , they preferentially incorporate the lighter ^{12}C isotope into their tissues. Plants that utilize the C_3 photosynthetic pathway display a greater difference in the ratio of ^{13}C to ^{12}C relative to atmospheric carbon, while C_4 plants that have a less discriminant pathway. In marine environments, carbon is available to living organisms mostly in the form of bicarbonate with an equilibrium process that prefers ^{13}C . This results in an isotopic signature that is still lower in $\delta^{13}\text{C}$ compared to the atmosphere, but falls close to the $\delta^{13}\text{C}$ values typically observed in C_3 plants. In precontact California, the majority of plant resources consumed utilized the C_3 photosynthetic pathway, thus a lower $\delta^{13}\text{C}$ corresponds to more terrestrial-based subsistence regimes, while a higher $\delta^{13}\text{C}$ signature indicates a contribution of marine food resources.

The $\delta^{15}\text{N}$ value provides an estimate of the average trophic level of dietary protein. Nitrogen occurs naturally in two isotopic forms, ^{14}N and ^{15}N , and is an essential component of proteins. Leguminous plants fixate nitrogen from the atmosphere through bacteria on their roots. This nitrogen is then passed up the food chain to non-leguminous plants, herbivores, and ultimately omnivores and carnivores. The ratio of these two nitrogen isotopes changes with each step in the food web. The lighter ^{14}N form is a major component of waste products, especially urea. As a result, the heavier ^{15}N is preferentially retained in the body in the form of proteins, including bone and tooth collagen. Because $\delta^{15}\text{N}$ increases with trophic level, $\delta^{15}\text{N}$ increases in human body tissue along with increased consumption of foods higher in trophic level (Minagawa and Wada 1984).

WEANING AND PARENTAL INVESTMENT

This article explores the early dietary life histories and infant and childhood dietary patterns for a subsample of the Simone Mound inhabitants. Generally, the most significant dietary change in one's life occurs during the weaning process, that is, the transition from breast milk to "solid" foods (here we include liquid and semi-liquid gruels within the "solid" food category). There is remarkable variation in weaning ages among different cultures and even among individuals within a society (Eerkens and Bartelink 2013). For example, delayed weaning has been observed in harsh conditions with low food security to increase a child's chance of survival, or in efforts to stave off infection and disease (Quinlan 2006; Sellen 2001; Vitzthum 1992).

While beneficial to an infant, lactation inhibits ovulation, and therefore increases the time spent breastfeeding, resulting in longer interbirth intervals, and potentially lowering reproductive success. Breastfeeding is a costly investment in childcare and is variably prolonged or reduced for multiple reasons in different cultures. Because prolonged breastfeeding has been shown to increase the health and fitness of a child, the age of weaning has been used as a proxy to measure parental investment (Eerkens and Bartelink 2013).

We use $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in serial sections of dentinal collagen to assess weaning ages in a set of eight individuals, including one male, five females, and two individuals of indeterminate sex. During nursing, an infant will show elevated $\delta^{15}\text{N}$ values relative to their mother due to the fractionation of nitrogen in the infant (i.e., preferentially excreting ^{14}N in urea while retaining ^{15}N). This places the infant one trophic level above the mother. If the child transitions to a diet similar in isotopic composition to the mother during the weaning process, this moves the individual to a lower trophic level. By comparing the infant and early childhood diets

represented in the tooth sections to those of the adult diet exhibited by the bone collagen samples, we can compare dietary variation in infancy and early childhood relative to that experienced as an adult.

METHODS

This study employs serial dental collagen microsampling following the basic approach described by Eerkens and Bartelink (2013) and Eerkens et al. (2011) (also see Fuller et al. 2003). Teeth are composed of three main tissues, enamel, dentin, and cementum (White and Folkens 2005). Enamel comprises the exterior of the crown, while the root consists of a thin layer of cementum coating what is mostly dentin. Dentin grows apically in successive layers throughout the early years of life, starting at the dentino-enamel junction. Thus, the dentin layers closest to the crown of the tooth represent the youngest years and layers closest to the apical end of the root represent the oldest.

Prior to collagen extraction, the teeth were measured, photographed, and weighed. The teeth were then cleaned with a handheld drill to remove any exogenous material, as well as enamel and cementum, to expose the dentin. They were then rinsed in deionized water, dried and demineralized in dilute 0.5M HCL in a lab refrigerator set at 5° C. The HCl was replaced every one to two days until the tooth was fully demineralized, typically lasting one to two weeks, and finished when the tooth was spongy and no longer visibly reacted with the HCL. Then it was rinsed in deionized water and placed in a solution of sodium hydroxide (NaOH) for 48 hours to remove humic acids, with the NaOH replaced after 24 hours. The tooth was rinsed again and sectioned with a scalpel in approximately 1-mm thick sections, cutting perpendicular to the growth axis and parallel with the occlusal surface. These segments were then placed in water with a pH of 3 in a lab oven set at 80° C for 24-48 hours to solubilize collagen and separate it from any residual tooth matter. Finally, the solubilized collagen samples were lyophilized in order to remove the water and isolate the collagen fraction.

One mg of collagen from each section was then submitted for stable isotope analysis by continuous-flow mass spectrometry at the Stable Isotope Facility at the University of California, Davis. The isotope ratios of the samples were corrected against the known values for the international reference materials. Instrument precision is 0.2‰ for $\delta^{13}\text{C}$ and 0.3‰ for $\delta^{15}\text{N}$.

Each serial section represents a successive window of time in the individual's life, recording diet during the period that part of the tooth grew. The number of sections analyzed varies by tooth length, and to some extent collagen preservation, and averaged 14.6 sections per tooth (117 sections across eight teeth). Where a section did not produce at least 1 mg of collagen, adjacent serial samples were combined to reach the 1 mg minimum sample requirement. If collagen C/N ratios were not between 2.9 and 3.6, we rejected the sample from the analysis (per recommendations by DeNiro [1985]). Our final analysis includes 108 isotopic measurements across the eight teeth, for an average of 13.5 measures per individual, with a low of nine and a high of 20. Table 1 provides summary information for the eight individuals included in this study.

Table 1. Demographic and Associated Radiocarbon Information on Individuals Included in This Study.

Burial #	CAT #	Sex	Age	Posture	AMS Date BP	Calibrated Age Range BP
S2-1	12-6137	male	20-35	extended	1096 ± 26	918 - 1046
S3-10	12-6158	female	30-45	flexed	1055 ± 27	799 - 964
S1-16	12-6136	female	20-35	extended	1187 ± 34	987 - 1230
S3-11	12-6159	female	30-39	n/a	1071 ± 26	911 - 981
S1-8	12-6132	female	20-29	flexed	n/a	n/a
1	12-6291	female	20-29	semi-extended	949 ± 24	790 - 917
S3-4	12-6152	indet.	child	n/a	n/a	n/a
S2-9	12-6144	indet.	10-12	extended	1010 ± 23	794 - 918

Note: n/a = information not available; indet. = indeterminate sex.

The final estimated age of weaning for these individuals was assigned by assessing the associated drop in $\delta^{15}\text{N}$ values across the coronal sections within the first molars. Since breast milk is enriched in ^{15}N , the values representing the first few years of life typically show a distinct elevated $\delta^{15}\text{N}$ value. As weaning progresses, and solid food is increasingly introduced into the diet, $\delta^{15}\text{N}$ values typically decrease, indicating a shift away from breast milk. When $\delta^{15}\text{N}$ reaches a local minimum, we estimate that weaning is complete. Because weaning must have concluded between this section and the one immediately prior, we take the average of the median ages of these two sections, and assign that as the estimated age of weaning (per Eerkens et al. 2011).

RESULTS

Collagenous material was obtained from all eight Simone Mound individuals sampled using the above-mentioned serial sampling approach. From the resulting carbon and nitrogen stable isotopes, we reconstructed infant and childhood diets. We divided diet into four phases: pre-weaning, diet at weaning, diet between the ages of five and seven years, and diet between the ages of seven and nine years. Dietary curves depicting $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ throughout these temporal categories were constructed for each individual.

Figures 2, 3, and 4 depict examples of these curves from Burials S3-10, S3-11, and S2-1, respectively. These curves plot the median age of a serial section against $\delta^{15}\text{N}$ on the upper frame (with the left y -axis) and corresponding $\delta^{13}\text{C}$ in the lower frame (with the right-side y -axis). A decrease in $\delta^{15}\text{N}$ of approximately 2-4‰ between ages one and five years illustrates the weaning process, with local minima interpreted as completion of weaning. The “x” at the right-side end of the curve represents values from bone collagen, and hence, the adult diet closer to the time of death. Notable absences in our data include adult bone collagen values for Burial S3-4, which is not represented because this individual did not survive past childhood. Additionally, an adult $\delta^{15}\text{N}$ value from burial S1-8 was not available due to poor bone collagen preservation. While the $\delta^{15}\text{N}$ provides an estimate on the age of weaning, the $\delta^{13}\text{C}$ curve provides additional information on the source of dietary protein, whether more from terrestrial or marine sources. As we show below, for most individuals $\delta^{13}\text{C}$ changes only slightly during the first eight to nine years of life. However, for the only male individual there is an intriguing sinusoidal-like pattern in $\delta^{13}\text{C}$.

For example, Figure 2 shows the curve for Burial S3-10, a female. The changing diet over the first nine years follows a relatively straightforward pattern, wherein $\delta^{15}\text{N}$ starts high, about 3-4‰ above the adult dietary values, and drops over the first several sections to reach a low in the section with a median estimated age of 3.3 years. Weaning, then, must have completed between 3.3 years and the previous section at 2.6 years. We take the average of these two values (3.3 and 2.6 years) to assign an estimated age of weaning of 3.0 years. After being weaned, this girl continued to eat low trophic-level foods. The $\delta^{13}\text{C}$ changes very little across the entire first nine years.

Figure 3 shows a dietary curve for a highly worn first molar associated with Burial S3-11, also a female. Here, much of the crown had been lost due to attrition, removing the earliest dietary signature associated with ages prior to 2.2 years. Such heavy wear makes detailed dietary interpretation more difficult. In this case, the $\delta^{15}\text{N}$ minimum occurs in the section associated with 4.6 years, and thus weaning must have been complete between 3.8 and 4.6 years (median = 4.2 years). We assume that $\delta^{15}\text{N}$ was higher in the sections removed due to wear (indicated by the dashed line and question mark in Figure 3). While, it is possible that weaning completed at the section associated with 3.0 years, we interpret the slight increase in $\delta^{15}\text{N}$ just before four years of age as a slight dietary shift during the latest stages of weaning, and assume that the second drop at 4.6 years represents final weaning. As with the individual in Figure 2, Burial S3-11 shows very little change over time in $\delta^{13}\text{C}$.

Finally, Figure 4 shows the dietary curve for Burial S2-1, a male. Here, $\delta^{15}\text{N}$ shows a steady decrease over the first three to four years of life, with a median estimated age of weaning at 3.7 years. More interesting, however, are the $\delta^{13}\text{C}$ values, which follow a low-amplitude sinusoidal pattern that indicates shifting access to foods that vary in their underlying carbon isotopic composition.

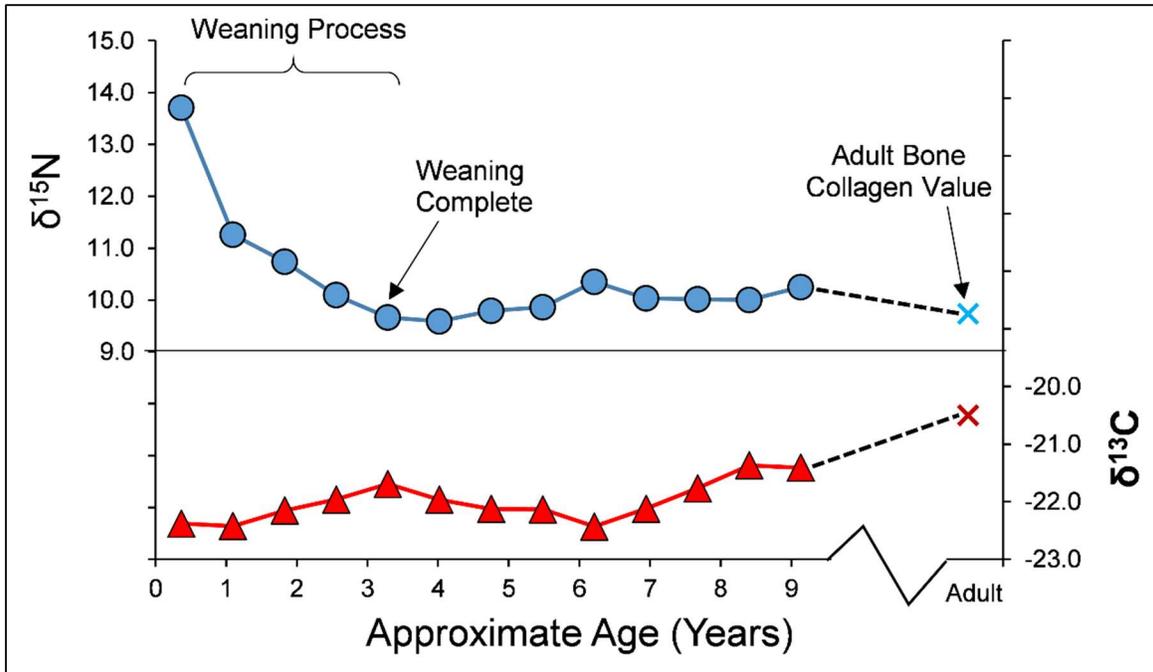


Figure 2. Individual dietary curve for Burial S3-10.

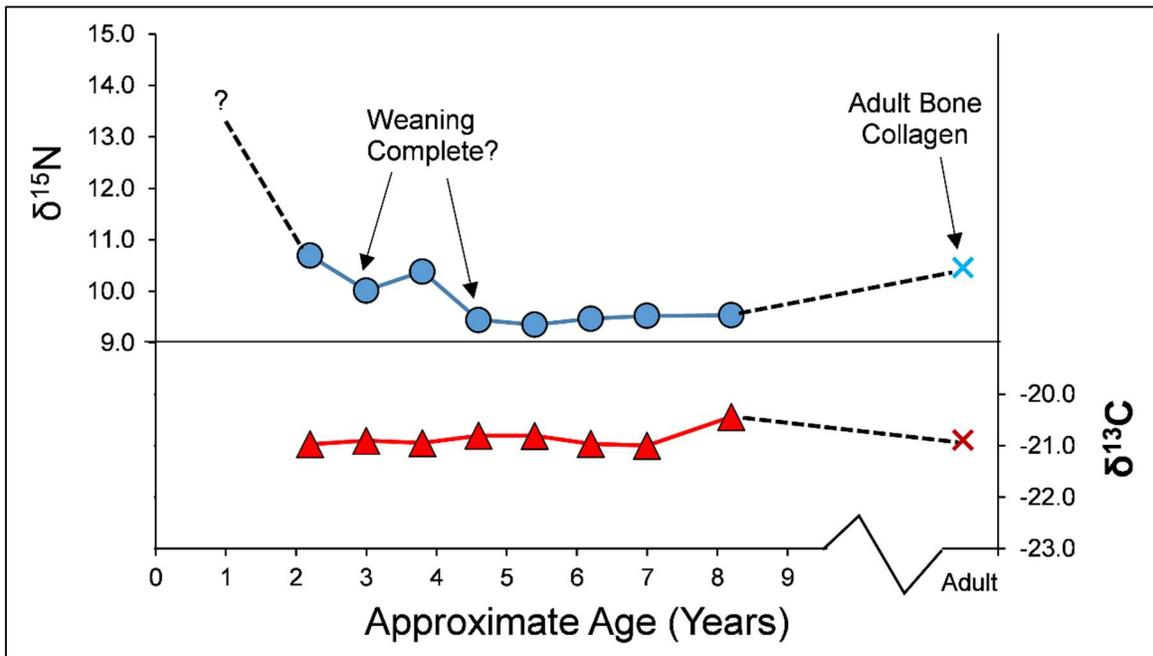


Figure 3. Individual dietary curve for Burial S3-11.

Table 2 provides summary statistics for the CA-CCO-139 population included in this study. This table gives estimated median ages of weaning (in years), as well as $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values at four life stages represented in the first molars, pre-weaning, at the age of weaning (representing the weaning food), between five and seven years, and between seven and nine years.

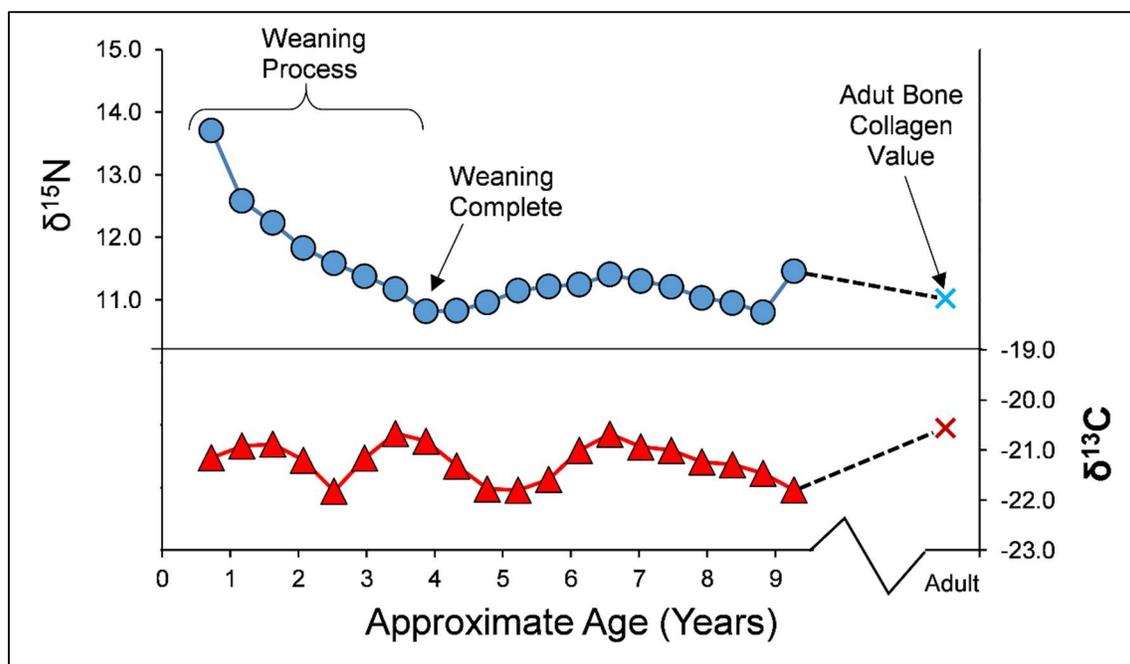


Figure 4. Individual dietary curve for Burial S2-1.

DISCUSSION AND CONCLUSIONS

Overall, the sample from CA-CCO-139 indicates high investment in children with relatively late ages of weaning. The average age at weaning of 3.3 years compares favorably with Early and Middle Period assemblages from California (Boyle et al. 2019; Eerkens and Bartelink 2013; Greenwald 2017), but is later than has been observed at Late Period sites (Eerkens et al. 2020). Thus, Greenwald (2017) reported an average age of weaning of 2.7 years for a number of Middle Period sites in central California, while Late Period sites average 2.3 years. In this regard, the data generated here do not support the hypothesis proposed by Eerkens and Bartelink (2020) that Meganos cultures had a lower average age of weaning that led to a higher intrinsic population growth rate. Interesting in this regard as well is that the two individuals who died as children show both a very late weaning age (Burial S2-9 at 4.5 years) and an early weaning age (Burial S3-4 at 2.2 years).

The presence of just a single male in our sample limits our ability to examine variation in childhood by sex. Dietary information from adult bone collagen shows $\delta^{13}\text{C}$ is higher in adult males than females by an average of 0.6‰ (Eerkens and Bartelink 2019). This is consistent with a slightly greater contribution of marine and/or brackish foods in the adult male diet. This could indicate slightly higher rates of consumption of anadromous fishes such as salmon and/or sturgeon. A higher percentage of dietary protein in adult males is consistent with sex-segregated foraging practices.

The cyclical $\delta^{13}\text{C}$ dietary pattern observed in Burial S2-1, the only male studied, is particularly interesting. A similar cyclical pattern has been observed in another California site (Talcott and Eerkens 2016) in a younger female, during her teenage years. One interpretation of this pattern is that the fluctuations indicate increased local but periodic access to marine foods, such as anadromous fishes. For example, this could indicate access to salmon during particularly productive years, when salmon runs were above average in volume, and people overharvested, stored, and consumed higher amounts of salmon over an extended period of time. In this regard, it is interesting that none of the females show this type of cyclical dietary variation in $\delta^{13}\text{C}$. A second interpretation is that the pattern indicates residential mobility on the part of this male during his early childhood years. Thus, he could have shifted residences between villages with greater and reduced access to marine foods. If so, based on the carbon patterns, it appears that he shifted residence five times over

the course of eight years, a seemingly large number of moves. However, if his parents practiced exogamy and were from different villages, he could have been moving with his parents between villages on an approximately two-year cycle. Finally, a third interpretation is that the shifts in $\delta^{13}\text{C}$ reflect periodic resource shortages that forced consumption of lower ranked foods with higher $\delta^{13}\text{C}$, such as shellfish. Additional research on this individual might provide more information that either supports or rejects these possible interpretations.

Table 2: Summary Information of Successive $\delta^{13}\text{C}$ Values for Each Individual in the Study.

Burial #	Age at Weaning	Pre-Weaning		Wean Food		5-7 years		7-9 years	
		$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
S2-1	3.7	-21.2	13.7	-20.8	10.8	-21.2	11.3	-21.4	11.1
S3-10	2.9	-22.4	13.7	-21.7	9.7	-22.2	10.1	-21.5	10.1
S1-16	2.0	-22.5	12.8	-22.3	11.0	-21.8	10.5	-21.8	10.9
S3-11	4.2	n/a	n/a	-20.8	9.4	-20.9	9.4	-20.7	9.5
S1-8	3.7	-22.4	13.7	-21.3	9.7	-21.3	9.9	-21.6	10.5
1	2.9	-21.9	12.7	-22.0	10.4	-22.1	10.3	-21.7	10.4
S3-4	2.2	-21.0	12.0	-21.3	11.1	-21.2	10.9	-21.4	11.3
S2-9	4.5	-18.4	14.3	-20.4	10.8	-20.3	11.7	-20.0	11.7
Average	3.3	-21.4	13.3	-21.3	10.4	-21.4	10.5	-21.3	10.7

Note: n/a = information not available.

Finally, there is very little evidence for an independent foraging signature. As outlined by Greenwald et al. (2016), independent foraging is often indicated by a secondary drop in $\delta^{15}\text{N}$, well after weaning, in the five- to nine-year age range, and lower than the adult dietary pattern. This secondary drop is consistent with foraging for low-ranked foods that small-bodied individuals (i.e., children) can pursue at an energetic gain, but large-bodied individuals (i.e., adults) forego due to sub-optimal return rates. It is important to note that this pattern may be invisible isotopically if child and adult diets are similar in isotopic composition. As shown in Table 2, $\delta^{15}\text{N}$ remains fairly constant for individuals, and on average at the site, from the age of weaning through nine years of age. These patterns are more consistent with a “parental provisioning” strategy, where a consistent diet was supplied to growing children. This too is consistent with high parental investment in children at CA-CCO-139, a pattern shown more broadly in central California during the Early and Middle Periods (Greenwald 2017).

ACKNOWLEDGEMENTS

We thank PAHMA for providing access to the samples. We also thank Angela Evoy and Samantha Cramer for their help in preparing some of the samples. Funding was provided by National Science Foundation awards (BCS-0819968 and BCS-0819975 for JWE and EJB, respectively).

REFERENCES CITED

- Bennyhoff, James. A., and David A. Fredrickson (editors)
 1994 *Toward a New Taxonomic Framework for Central California Archaeology*. Contributions of the University of California, Archaeological Research Facility, No. 52, Berkeley, California.
- Boyle, Erin A., Jelmer W. Eerkens, Tammy Buonasera, and Glendon J. Parker
 2019 Age of Weaning and Post-Weaning Childhood Diets in a Late Holocene Precontact Site, CA-SOL-11, Near Suisun Marsh. *Proceedings of the Society for California Archaeology* 33, pp. 196-210.

- Childress, M. R.
 2000 *Interim Technical Report: Archaeological Testing Within the Hotchkiss District CA-CCO-134, 138 and 139 Cypress Lakes Development Project Contra Costa County, California*. Report on file at the Northwest Information Center, Sonoma State University, Rohnert Park, California.
- Chisholm, Brian S., D. Earle Nelson, and Henry P. Schwarcz
 1982 Stable-Carbon Isotope Ratios as a Measure of Marine versus Terrestrial Protein in Ancient Diets. *Science* 216(4550):1131–1132.
- Cook, Sherburne F., and Albert B. Elsasser
 1956 Burials in the Sand Mounds of the Delta Region of the Sacramento-San Joaquin River System. *University of California Archaeological Survey Reports* 35:26-46.
- 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.
- Eerkens, Jelmer W., and Eric J. Bartelink
 2013 Sex-Based Weaning and Early Childhood Diet among Middle Holocene Hunter-Gatherers in Central California. *American Journal of Physical Anthropology* 152(4):471-483.
 2019 New Radiocarbon Dates from CA-CCO-138 (Hotchkiss Mound) and CA-CCO-139 (Simone Mound) and Insights into Mounds, Settlement Patterns, and Culture History in the California Delta. *California Archaeology* 11(1):45-63.
 2020 Revisiting the Central California Meganos Intrusion with New Stable Isotope and Radiocarbon Analyses at El Sobrante (CA-CCO-151). *California Archaeology* 12(1):33-57.
- Eerkens, Jelmer W., Ada G. Berget, and Eric J. Bartelink
 2011 Estimating Weaning and Early Childhood Diet from Serial Micro-Samples of Dentin Collagen. *Journal of Archaeological Science* 38(11):3101-3111.
- Eerkens, Jelmer W., Davis Watkins, Samantha Cramer, and Chris Beckham
 2020 Stable Isotope Measures from First and Third Molar Serial Samples. *Protohistoric Village Organization and Territorial Maintenance: The Archaeology of Sii Tuupentak (CA-ALA-565/H) in the San Francisco Bay Area*, edited by Brian F. Byrd, Laurel Engbring, Michael Darcangelo, and Allika Ruby, pp. 311-330. Center for Archaeological Research at Davis, Publication No. 20, University of California, California.
- Fuller, Benjamin T., Michael P. Richards, and Simon A. Mays
 2003 Stable Carbon and Nitrogen Isotope Variations in Tooth Dentine Serial Sections from Wharram Percy. *Journal of Archaeological Sciences* 30(12):1673-1684.
- Greenwald, Alexandra M.
 2017 *Isotopic Reconstruction of Weaning Age and Childhood Diet Among Ancient California Foragers: Life History Strategies and Implications for Demographics, Resource Intensification, and Social Organization*. Ph.D. dissertation, University of California, Davis.
- Greenwald, Alexandra M., Jelmer W. Eerkens, and Eric J. Bartelink
 2016 Stable Isotope Evidence of Juvenile Foraging in Prehistoric Central California. *Journal of Archaeological Science: Reports* 7:146-154.
- Groza, Randall G., Jeffrey Rosenthal, John Southon, and Randall Milliken
 2011 A Refined Shell Bead Chronology for Late Holocene Central California. *Journal of California and Great Basin Anthropology* 31(2):135-154.
- 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.
- Miszaniec, Jason I., Jelmer W. Eerkens, and Eric J. Bartelink
 2018 An Ichthyoarchaeological Study of Dietary Change in the California Delta, Contra Costa County. *Proceedings of the Society for California Archaeology* 32:269-278.

- Quinlan, Robert J.
2006 Human Parental Effort and Environmental Risk. *Proceedings of the Royal Society* 274:121-125.
- Schoeninger, Margaret J., Michael J. DeNiro, and Henrik Tauber
1983 Stable Nitrogen Isotope Ratios of Bone Collagen Reflect Marine and Terrestrial Components of Prehistoric Human Diet. *Science* 220:1381-1383.
- Sellen, Daniel W.
2001 Comparison of Infant Feeding Patterns Reported for Nonindustrial Populations with Current Recommendations. *The Journal of Nutrition* 131(10):2707-2715.
- Talcott, Susan D., and Jelmer W. Eerkens
2016 Exploring the Importance of Staple Aquatic Dietary Resources in Central California Using Compound-Specific Amino Acid Isotopic Analysis of $\delta^{13}\text{C}$ Values. In *Reconstructing Lifeways in Ancient California: Stable Isotope Evidence of Foraging Behavior, Life History Strategies, and Kinship Patterns*, edited by Alexandra M. Greenwald and Gregory R. Burns, pp. 109-121. Center for Archaeological Research at Davis, Publication No. 18, University of Davis, California.
- Vitzthum, Virginia
1992 Infant Nutrition and the Consequences of Differential Market Access in Nuñoa, Peru. *Ecology of Food and Nutrition* 28(1-2):45-63.
- White, Tim D., and Pieter A. Folkens
2005 *The Human Bone Manual*. Elsevier Academic Press, Burlington, Massachusetts.
- Williams, Lana J., Christine D. White, and Fred J. Longstaffe
2011 Improving Stable Isotopic Interpretations Made from Human Hair Through Reduction of Growth Cycle Error. *American Journal of Physical Anthropology* 145(1):125-136.