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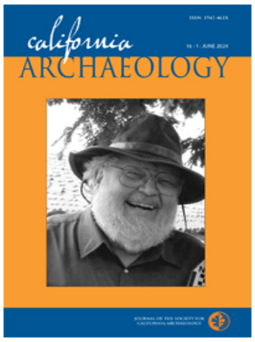

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Estimating the Seasonality of Bent-Nose Clam (*Macoma nasuta*) Harvesting at a 3,000-Year-Old Ancestral Ohlone Site (CA-ALA-11) on the San Francisco Bay

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ABSTRACT

This article investigates the harvest month for bent-nose clams (*Macoma nasuta*) at CA-ALA-11, an estuarine site in the modern-day city of Alameda along the San Francisco Bay. The archaeological deposit in which the clam shells were recovered dates primarily to the Early Period (3,350–2,550 cal BP) and Early-Middle Transition (2,550–2,150 cal BP), although some activity continues through 2,650 BP. Season of harvest estimates for clams offers insight into Indigenous use of estuarine resources and the degree of sedentism or length of habitation at this locality. Water salinity varies predictably in San Francisco Bay, from annual lows in winter to highs in summer. We used oxygen isotopes ($\delta^{18}O$) to estimate season of harvest by sampling at the intact terminal growth edge of the shell, which records salinity at the time of harvest. Three additional samples represent earlier periods of shell growth. Results show that while clams comprise a minority of the shellfish harvested, clamming took place between January and August, with a marked peak in mid-winter (February). There is no evidence for fall harvesting, which suggests that people were either not living at CA-ALA-11 during this time or focused on acquiring other seasonally available foods. We compare these results to previously published data on seasonality of clam harvesting from five other San Francisco Bay area sites.

RESUMEN

Investigamos el mes de cosecha de almejas de nariz torcida (*Macoma nasuta*) en CA-ALA-11, un sitio estuarino en la actual ciudad de Alameda en la Bahía de San Francisco. El depósito arqueológico en el que se recuperaron las conchas de almeja data principalmente del Período Temprano (3,350–2,550 cal BP) y Transición Temprano-Medio (2,550–2,150 cal BP), aunque alguna actividad continúa hasta el 2,650 BP. Las estimaciones de la temporada de cosecha de almejas ofrecen información sobre el uso indígena de los recursos estuarinos y el grado de sedentarismo o la duración de la habitación en esta

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localidad. La salinidad del agua varía de manera predecible en la Bahía de San Francisco, desde mínimos anuales en invierno hasta máximos en verano. Usamos isótopos de oxígeno (δ18O) para estimar la temporada de cosecha tomando muestras en el borde de crecimiento terminal intacto de la concha, que registra la salinidad en el momento de la cosecha. Los resultados muestran que, si bien las almejas constituyen una minoría de los mariscos recolectados, la recolección de almejas se llevó a cabo entre enero y agosto, con un marcado pico a mediados de invierno (febrero). No hay evidencia de cosecha de otoño, lo que sugiere que las personas no vivían en CA-ALA-11 durante este tiempo o se concentraron en adquirir otros alimentos disponibles estacionalmente. Comparamos estos resultados con los datos publicados anteriormente sobre la estacionalidad de la recolección de almejas en otros cinco sitios del área de la Bahía de San Francisco.

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KEYWORDS San Francisco Bay Area; ancestral Ohlone; clam harvesting; oxygen isotopes; seasonality; Early Period; *Macoma nasuta*; estuarine resources

The San Francisco Bay Area is well known for its precontact period shellmounds, built by the ancestors of modern-day Ohlone people. Although the shellmounds contain a wide range of materials, including sediment, pit hearths, artifacts, faunal/floral remains, and human interments, the dominant component is shell. While shellfish were an important resource among precontact coastal and bayshore Indigenous populations throughout California, shells are especially prominent in the mounds around San Francisco Bay (Culleton, Kennett, and Jones 2009; Eerkens et al. 2013; 2014; Eubanks 2018; Luby, Drescher, and Lightfoot 2006; Whitaker 2008).

Studies of shellfish clearly provide important information about ancient human diets. However, as living organisms that draw resources from their aquatic environment, shells record information about their ancient water environment, including paleotemperature and paleosalinity (Andrus 2011; Claassen 1998; Culleton, Kennett, and Jones 2009; Eerkens et al. 2013; 2014; 2016; Harold, Byrd, and Eubanks 2019; Ingram, Ingle, and Conrad 1996a; 1996b; Jazwa et al. 2020; Jones et al. 2008). Further, because shells grow in layers, estimating environmental conditions during the last-forming shell allows archaeologists to estimate the season of harvest for an individual shell, providing additional context for understanding human harvesting strategies, changes in diet across the year, and site seasonality (Codding, Whitaker, and Bird 2014; Hardy 2017; Hausmann and Meredith-Williams 2017; Jones and Richman 1995; Whitaker 2008).

Despite providing a relatively low number of calories per hour spent collecting, shellfish are an attractive resource when other high-ranked food items are unavailable, and, unlike larger prey, most community members can harvest them. Most shellfish are sessile and spatially predictable in their availability. In higher latitude regions, this may make them particularly attractive in the winter months when many plants are dormant and migratory animals have left for warmer environments.

Seasonality and Harvesting Practices in the San Francisco Bay Area

In the San Francisco Bay Area, shellfish began appearing in significant quantities around the end of the Middle Holocene (4,950–3,950 cal BP), coinciding with the stabilization of global sea levels and the development of an estuarine environment (Luby, Drescher, and Lightfoot 2006). Today, the area is the largest estuarine environment in California, supporting shellfish and other marine and brackish resources in large quantities (Luby, Drescher, and Lightfoot 2006).

This study focuses on clamming during the Early, Early-Middle Transition, Middle 1 and Middle 2 periods (2,950–1,400 cal BP). We provide new information on season of harvest for bent-nose clams (*Macoma nasuta*) at the ancestral Ohlone site of CA-ALA-11 (Figure 1), located on the bayshore in the modern-day city of Alameda. CA-ALA-11 faces an estuary with extensive mudflats that were likely shallow during the time of site occupation (2,000–3,000 years ago) and the presence of small fish and rays further supports this idea. Radiocarbon dates indicate that the site was occupied sometime between 4,600 cal BP and 1,250 cal BP, and it appears to have been occupied most intensely between 2,650 and 2,100 cal BP. These ages are supported by two additional direct accelerator mass spectrometry (AMS) dates on clams included in this study, calibrated assuming 50% marine carbon and a reservoir correction of 365 ± 50 as recommended by Ingram and Southon (1996; see Table 1).

Mitigation for a housing project prompted excavation of the site in 2020 and 2021. This included the grading of 6,200 cubic meters of soil in and around the northern part of the site. During this work, 182 burials, over 200 prehistoric thermal features, and more than 20,000 artifacts (including 18,000 shell beads) were recovered. Ethnographic and archaeological evidence suggest that beads were an important form of currency, such that this site could have been used as a trading hub (Gamble 2020; Luby, Drescher, and Lightfoot 2006). All recovered shells included in this study come from test units/grids with the densest shells by volume. While bay mussel (*Mytilus* cf. *trossulus*) and Olympia oyster (*Ostrea lurida*) were also recovered in high quantities, this study focuses only on bent-nosed clam (*Macoma nasuta*). In the future, we plan to report on seasonality of mussels and oysters.

Shellfish were sorted taxonomically prior to sampling for isotopic analysis. We calculated the number of identified specimens (NISP), minimum number

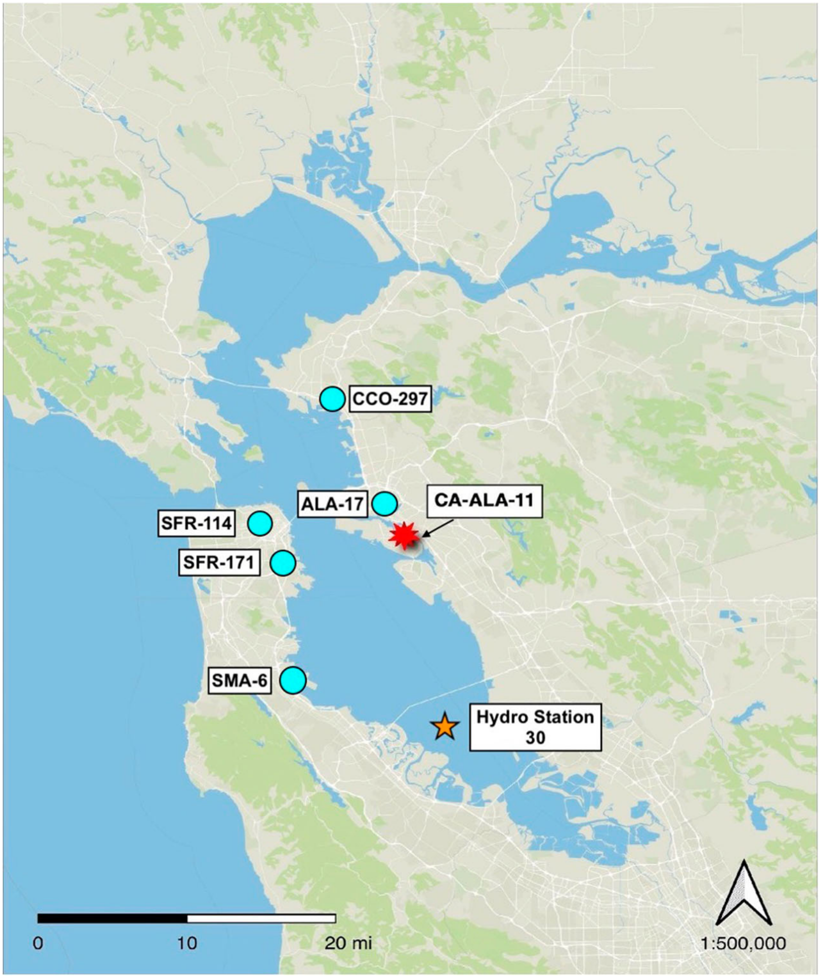

Figure 1. Map of study area showing the location of CA-ALA-11, Hydro Station 30, and other sites included for comparison in the San Francisco Bay Area, California.

of individuals (MNI, as determined by count of [umbo] hinges divided by two [bay mussel and clams] or the greatest number of left or right hinges [oysters]), and lastly the average and total weights of specimens by taxa. We then measured the size and took photographs of each shell selected for isotopic analysis ($n = 20$). Based on the quantification, bent-

Table 1. Radiocarbon Dates from CA-ALA-11.

UC Davis Archaeometry Lab No.	DirectAMS #	Radiocarbon Age BP	Radiocarbon Age 1σ error	2-σ Range, Marine-Reservoir Corrected
ALA-11: Clam #4	D-AMS 046368	2,641	25	2,105–2,343 cal BP
ALA-11: Clam #5	D-AMS 046369	2,427	28	1,823–2,104 cal BP

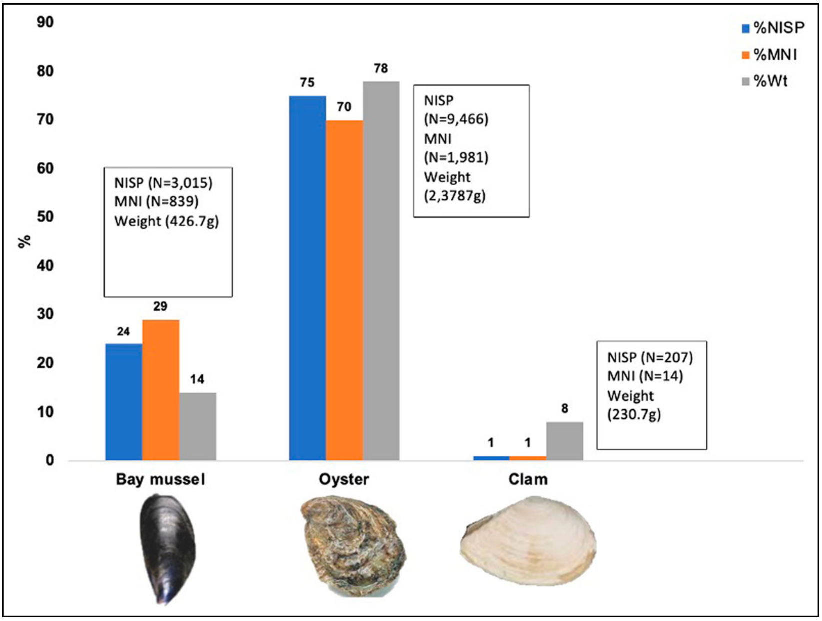

Figure 2. Histogram of major shellfish taxa by %NISP, %MNI, and %Weight for CA-ALA-11.

nose clam is the third most abundant species at CA-ALA-11, although it makes up only 8% of the sample by weight, and 1% MNI and NISP (see Figure 2). This finding is consistent with previous studies at sites predating 2,000 cal BP in the southern San Francisco Bay Area, where clams are less abundant than mussels and oysters (Culleton, Kennett, and Jones 2009).

Methods

The ratio of ^{18}O to ^{16}O in shell carbonate is related to both temperature and salinity (Andrus 2011). Because temperature and salinity fluctuate in a predictable fashion throughout the year in San Francisco Bay, and shellfish grow in distinctive layers (or rings), measuring $\delta^{18}O$ in the final growth layer of a shell informs on water conditions at the time of death. This has been used in previous studies in California to determine shellfish harvesting practices (e.g., Eerkens et al. 2013; Jew et al. 2013).

For this study, samples of calcium carbonate from the terminal growth edges, as well as three serial samples that formed at regular intervals prior to the terminal growth, were gathered from a sample ($n = 20$) of individual clam shells. This series of samples provided information on whether temperature and/or salinity were increasing or decreasing at the time of harvest. Since CA-ALA-11 is an estuarine site, salinity will be key in determining seasonality. Furthermore, we used a chi-squared statistical test to assess the differences in shellfish seasonality across the different sites. The chi-squared test allowed us to test the null hypothesis that seasonal patterns of shell counts do not differ by site.

An Annual Model for CA-ALA-11

In San Francisco Bay, significant input of freshwater runoff has a marked effect on estuarine salinity and $\delta^{18}O_{water}$, which in turn affects the $\delta^{18}O_{carbonate}$ of a mollusk shell. Although $\delta^{18}O_{carbonate}$ is affected by both temperature and $\delta^{18}O_{water}$, in fact, the effects of these changes in salinity overwhelm any influence from annual changes in water temperature (Eerkens et al. 2013). Because there is enough predictability in the timing of annual runoff into the bay, we can estimate the season of death for shellfish harvested from these waters. Because of this, our focus was only on seasonal salinity changes in subsequent interpretations.

Weather in cismontane California follows a marked seasonal pattern with about 80 percent of annual precipitation falling between November and March, and nearly no rain in the summer. Approximately 40% of all runoff in California flows through the California Delta and into northern San Francisco Bay (California Department of Water Resources 1995). There is a slight lag between the timing of precipitation and runoff into the bay (ca. 0.5–1 month). Early in the rainy season, upstream soils are dry and absorb much of the water, and later in the year snow continues to melt and run off even after precipitation has largely ceased.

Salinity in San Francisco Bay is highest during late summer and early fall, after runoff has dropped, averaging 32‰ practical salinity units (psu) which is close to open Pacific Ocean salinities. Salinity drops during the late fall and winter as runoff increases, with the annual minimum averaging 15 psu. Salinity generally reaches a minimum at the end of winter or early spring, and then slowly increases again as runoff into the bay wanes. The timing of seasonal salinity shifts between full marine and estuarine values can vary by ±1 month year to year (see below). This value provides an approximate degree of precision to our month-of-harvest estimates (i.e., ±1 month).

For mollusks that secrete mainly aragonite, such as bent-nose clams, we can predict $\delta^{18}O_{aragonite}$ if we can estimate $\delta^{18}O_{water}$ and water temperature. In San Francisco Bay, $\delta^{18}O_{water}$ is strongly correlated to water salinity (Ingram, Ingle, and Conrad 1996a; 1996b); thus, salinity serves as a proxy for $\delta^{18}O_{water}$ using the following equation:

$$\delta^{18}O_{water} = 0.34S - 11.6 \tag{1}$$

where S is water salinity measured in psu and $\delta^{18}O_{water}$ is in ‰ units relative to the VSMOW (Vienna Standard Mean Ocean Water) standard. Using

Equation (1) for $\delta^{18}O_{water}$ and substituting into an equation for predicting $\delta^{18}O_{aragonite}$ (Rosenheim, Swart, and Willenz 2009), and rearranging terms, we use Equation (2) to estimate $\delta^{18}O_{aragonite}$ for the CA-ALA-11 shells (see Eerkens et al. [2013] for additional details):

$$\delta^{18}O_{aragonite} = 0.34S - 0.154T - 9.25 \tag{2}$$

where S is water salinity, T is water temperature (°C), and $\delta^{18}O_{aragonite}$ is in ‰ units relative to the Vienna Pee Dee Belemnite (VPDB) standard.

Sample Processing

Flotation samples (4,500 mL of soil) from several stratigraphic contexts from the densest part of the midden deposits at CA-ALA-11 were processed in December/January of 2020–2021. From these samples, we selected 20 whole shells or shell fragments of bent-nose clam with a clearly intact terminal growing edge. Prior to drilling, shells were brushed delicately with deionized water to remove any adhering soil or other material. Using a hand-held drill with a 0.5-mm drill bit attached, powdered samples were removed from the surface of the shell in shallow grooves (about 0.3 mm deep) running parallel to the growth lines.

Serial samples begin at the outermost shell edge (0 mm or sample A), which aligns with the most recent growth at the time of harvest. From there, an additional three samples were taken from the growing edge at 1, 2.5, and 4 mm intervals (labeled samples B, C, and D, respectively). All sampling locations were bracketed by black dots plotted on the shell (Figures 3 and 4). Each sample comprises about 85–120 µg of powdered carbonate. Lastly, one shell (Clam #17) was sampled more intensively ($n = 20$ samples; sections A-T, Figure 4) at 1-mm intervals to provide a longer overview of the cyclical patterning of isotope data from the winter/spring months (low salinity) and summer/fall months (high salinity).

We used existing water temperature and salinity data from Hydro Station 30 (see Figure 1) to plot predicted $\delta^{18}O_{aragonite}$ in shells at CA-ALA-11 throughout the year (Figure 5). We fitted a polynomial regression over the distribution of points to create a predicted annual curve of changing $\delta^{18}O_{aragonite}$. As expected, lows, or periods of lowest salinity, represent late winter-early spring when runoff should be high, while highs represent highest salinity and correlate with late summer through fall. We recognize that there are differences between the spatial location of Hydro Station 30 (in the center of San Francisco Bay) and the location where CA-ALA-11 clams grew (on the bayshore), which is likely to affect water salinity values. As well, we acknowledge possible changes in water temperature and salinity 3,000 years ago versus today. To account for these differences, we adjusted (i.e., stretched) the amplitude of the annual temperature

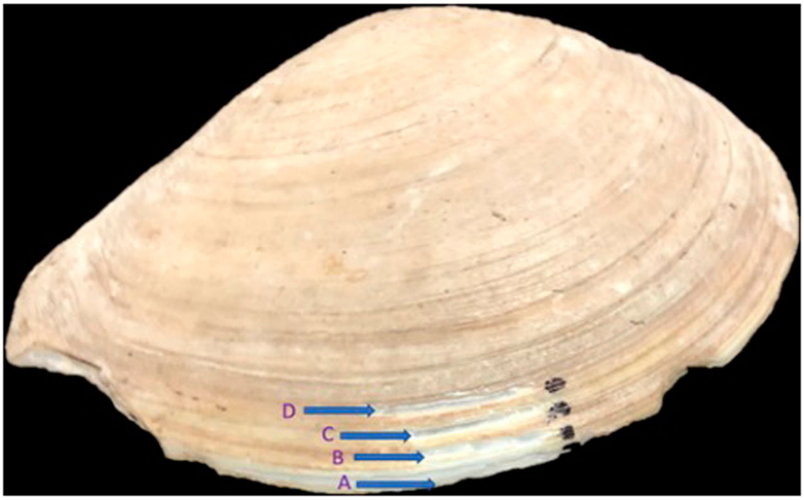

Figure 3. Bent-nose clam (*Macoma nasuta*) shell from CA-ALA-11 showing sample locations A–D for all shells (except Clam #17 where sampling continued through sample T, or between 0 and 19 mm).

curve based on the range of empirical $\delta^{18}O_{aragonite}$ data from archaeological shells. For example, while the curve predicts a maximum annual $\delta^{18}O_{aragonite}$ at 0‰ and a minimum at −3.8‰, our empirical range is between −0.5‰ and −4.4‰.

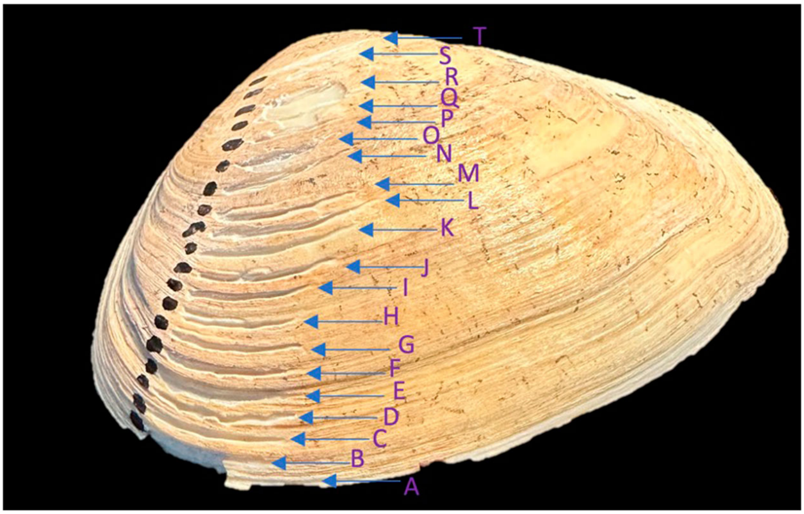

Figure 4. Clam #17 (*Macoma nasuta*) which was serial sampled from A-T in 1 mm increments. (Note some portions of the shell broke after drilling was complete).

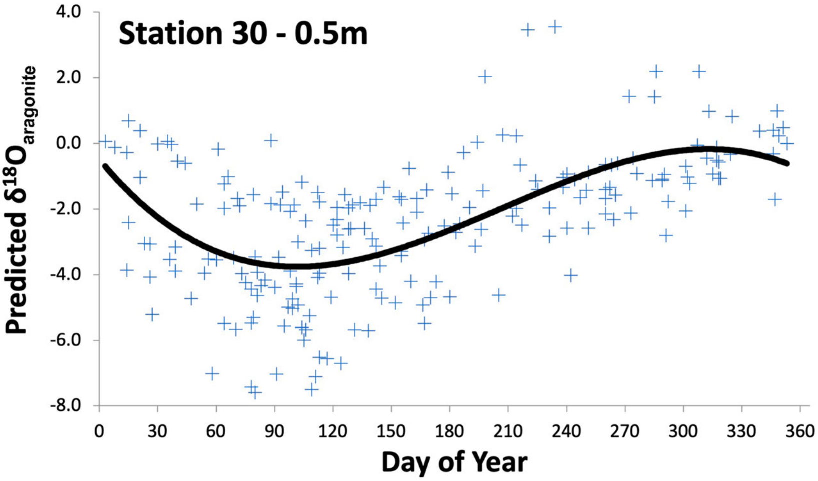

Figure 5. Scatterplot showing predicted annual variation in $\delta^{18}O_{aragonite}$ for shells growing near Hydro Station 30.

Samples for isotopic analysis were processed in the stable isotope laboratory at UC Davis on a Micromass Optima isotope ratio mass spectrometer (IRMS). Prior to analysis on the IRMS, powdered aragonite samples were gently heated at 75°C in vacuo for 30 min to remove adsorbed water and subsequently reacted in 105% orthophosphoric acid at 90°C using an ISOCARB automated common acid bath system. The resulting CO_2 was then purified through a series of cryotraps and introduced into the IRMS through a dual inlet system. Both oxygen and carbon isotopes are measured and reported, although only oxygen is used in the interpretation of shell season of harvest. Isotopic data are expressed in standard delta (δ) notation, where:

$$\delta(^{18}\mathrm{O}\ \mathrm{or}\ ^{13}\mathrm{C}) = R_{\mathrm{sample}}/R_{\mathrm{standard}} - 1) \times 1000 \qquad (3)$$

and R_{sample} and $R_{standard}$ are the oxygen (or carbon) isotopic ratios ($^{18}O/^{16}O$ or $^{13}C/^{12}C$) of the sample and the VPDB (for aragonite) or VSMOW (for waters) standards, respectively, in ‰ or "per mil" values. External precision for $\delta^{18}O$ and $\delta^{13}C$ values is ±0.07‰ and ±0.04‰ (one standard deviation), respectively, based on multiple ($N = 177$) analyses of the calcite standards NBS-19 and UCD-SM92.

Results

Figure 6 plots $\delta^{18}O_{aragonite}$ for the 20 serial samples from Clam 17. As expected, samples follow a sinusoidal pattern, indicating changing salinity in San Francisco Bay over time. Based on the samples, we estimate the 20 serial samples represent three years of time, or approximately 6–8 mm of shell growth per year. Based on the terminal sample (Sample A), and matching of the sinusoidal isotopic patterns of whole shells with the average distance between samples, we estimate that this shell was harvested in April during a period of decreasing salinity in San Francisco Bay. Moreover, based on these values, we estimate that for most shells, the four serial samples should represent about 6–8 months of total growing time.

For the remaining 19 shells, we plotted the four serial samples onto the curve in Figure 5, matching and estimating the month of harvest based on the absolute value of the terminal sample A, and whether the preceding samples were increasing in $\delta^{18}O_{aragonite}$ (suggesting water was decreasing in salinity) or decreasing (suggesting water salinity was increasing). The results from all 20 clam shells sampled are plotted in Figure 7 (top pane). As well, the raw data for $\delta^{18}O_{aragonite}$ and $\delta^{13}C_{aragonite}$ for the first four serial samples for all shells are provided in Table 2, along with the archaeological context (unit and depth). The last column represents the estimated month of harvest. Table 3 provides the raw data for $\delta^{18}O_{aragonite}$ and $\delta^{13}C_{aragonite}$ for the 20 serial samples taken from Clam 17.

Figure 7 (top) reveals a strong pattern of seasonal harvesting of bent-nose clams. Harvesting seems to have been most intense during mid-winter (February), but it continues in lesser intensity through mid-summer (August). No harvesting of bent-nose clam seems to have taken place from late summer through fall.

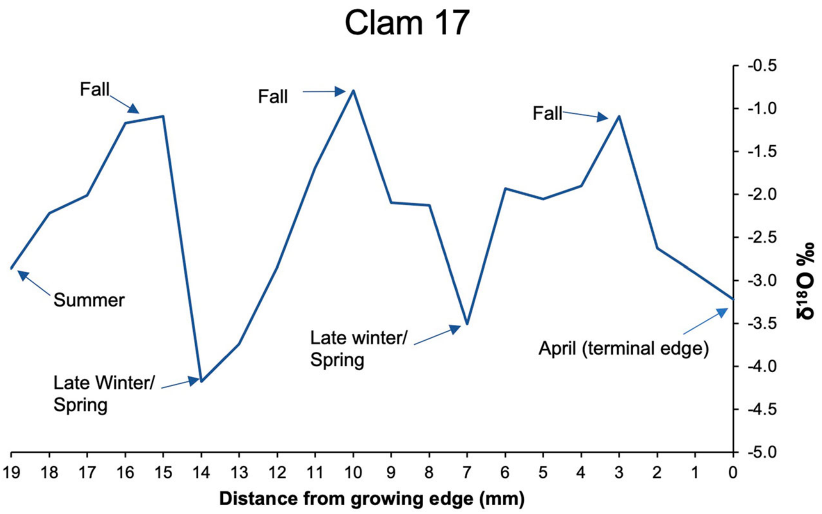

Figure 6. Line graph showing results of serial sampling Clam #17 from CA-ALA-11.

Table 2. δ^{18}O and δ^{13}C Data for Clam Shells (*Macoma nasuta*) from CA-ALA-11 and Corresponding Month of Harvest Estimates.

			δ^{13}C				δ^{18}O				
Clam No.	Unit	Depth (cm)	A	B	C	D	A	B	C	D	Month of Harvest Estimate
1	Unit 35	40–60	−0.08	0.25	−0.38	−0.04	−2.38	−2.31	−3.54	−2.91	June
2	Unit 36	40–60	−0.17	−0.42	−0.37	−0.92	−2.13	−3.15	−4.38	−4.12	July
3	Unit 34	60–80	−1.19	−0.16	−0.32	−0.17	−3.79	−4.08	−3.53	−3.76	April
4	Unit 34	20–40	−1.03	0.33	−0.04	−0.08	−4.30	−2.28	−2.37	−3.51	April
5	Unit 34	80–100	0.05	0.05	−0.67	0.44	−2.73	−2.83	−3.72	−3.02	May
6	Unit 34	80–100	0.89	1.19	0.82	1.12	−2.40	−2.13	−1.91	−2.50	June
7	Unit 34	80–100	−1.74	−2.39	−1.77	−0.31	−2.96	−4.40	−2.89	−1.03	February
8	Unit 34	80–100	−1.57	−1.19	−1.06	−0.61	−2.30	−1.27	−2.00	−1.45	February
9	Unit 33	0–20	−0.04	0.82	0.31	0.37	−3.74	−1.35	−3.56	−3.00	March
10	Unit 33	20–40	0.40	0.97	0.43	0.99	−2.23	−1.18	−2.11	−1.88	January
11	Unit 33	20–40	0.08	0.82	1.12	−0.69	−3.00	−2.53	−1.55	−4.20	May
12	Unit 33	20–40	0.17	−0.11	−0.57	−0.41	−2.29	−3.45	−4.06	−3.26	July
13	Unit 33	60–80	−2.43	−1.49	−0.98	−0.25	−3.03	−3.46	−1.30	−2.33	May
14	Unit 32	20–40	−0.36	−0.02	0.21	0.61	−3.28	−2.76	−2.56	−2.25	May
15	Unit 32	20–40	−1.52	−1.99	−1.55	−2.23	−2.21	−1.98	−3.93	−4.47	July
16	Grid A3	Burial 41 matrix	−1.07	−0.14	−1.41	−2.14	−3.28	−2.40	−3.99	−3.99	May
17	Grid A3	Burial 41 matrix	−0.91	−0.45	−0.12	0.13	−3.22	−2.91	−2.63	−1.09	April
18	C4	Burial matrix	−0.42	−0.88	−2.07	−1.46	−1.30	−2.37	−4.17	−1.85	August
19	C4	Burial matrix	−1.08	0.06	−0.27	−0.43	−3.38	−1.83	−2.72	−3.13	April
20	C4	Burial matrix	−0.53	−0.21	0.36	0.82	−3.57	−3.15	−1.23	−0.47	April

Table 3. $\delta^{18}O$ and $\delta^{13}C$ Data for Clam #17 at CA-ALA-11.

Sample	$\delta^{13}C$	$\delta^{18}O$
A	−0.9	−3.2
B	−0.5	−2.9
C	−0.1	−2.6
D	0.1	−1.1
E	0.2	−1.9
F	−0.2	−2.1
G	−0.2	−1.9
H	−0.4	−3.5
I	0.2	−2.1
J	0.6	−0.8
K	−0.5	−1.7
L	−0.5	−2.8
M	−0.9	−3.7
N	−1.5	−4.2
O	0.3	−1.1
P	0.2	−1.2
Q	0.2	−2.0
R	0.0	−2.2
S	−0.3	−2.9
T	0.0	−3.0

Note: From Unit 35, 40–60 cm.

Discussion

The data presented herein suggest a seasonal aspect to clamming during the Early and Early-Middle Transition periods. We suggest two possible interpretations. First, the pattern may suggest that people were seasonally mobile, leaving the site during the late summer through fall in search of other foods. In particular, the late summer and fall would have been the time when many plant foods would have ripened, especially acorns. While some plant foods may have been available near the bayshore, they may have been more abundant in more inland locations. Likewise, the density of ungulates (including deer, pronghorn, and elk) feeding on these plants may have been higher in these inland locations, making hunting more productive inland during the late summer and fall.

Second, people may have been living at CA-ALA-11 year-round, but they did not focus their efforts on clams during the late summer and fall. Clamming requires digging for individual animals on the mudflats, a labor-intensive activity. Other foods, including other shellfish species (e.g., mussels and oysters), may have provided higher returns during the late summer and fall. This may also explain the higher abundance of mussels and oysters within the site deposit. Clams may have been attractive as a backup food resource during spring and winter because they are predictable in their spatial location even during the lean season. Additional research on the relative abundance and seasonality of other potential foods, especially bay mussel and oyster, should help to address this issue.

To further contextualize clamming in the San Francisco Bay Area, we compare the data from CA-ALA-11 to previously published seasonality studies on bent-nose clam. Below are data from five other sites: three dating to the Late Period (690–200 cal BP; CA-CCO-297, CA-SFR-171, and CA-SMA-6; Eerkens et al. 2013; 2014) long after CA-ALA-11 was occupied; one that dates to the late Middle and Middle-Late Transition periods (1,370–685 cal BP; CA-SFR-114; Harold, Byrd, and Eubanks 2019); and one with a long occupation (4,000–1,500 cal BP; CA-ALA-17; Culleton, Kennett, and Jones 2009) that overlaps slightly with CA-ALA-11 (Figure 7). These studies were all conducted using the same stable isotope serial sampling strategy (some with fewer samples per shell), and hence are roughly comparable.

All six sites are consistent in showing a peak in clam harvesting during winter, although at some sites the peak occurs in early winter (e.g., CA-CCO-297, CA-SMA-6, CA-SFR-114) while in others it occurs in later winter (CA-SFR-171, CA-ALA-17). This pattern aligns with what we found at CA-ALA-11, which also shows a late winter peak. These results suggest that winter clamming was a consistent activity for Ohlone ancestors along the bayshore for many millennia, perhaps as a backup food resource during the otherwise lean winter months. All six sites also show a secondary emphasis on clamming during the summer, suggesting that this too was a persistent activity for Ohlone ancestors.

While other resources may have been available in greater abundance during the summer, suggesting people should have devoted efforts to foraging pursuits that offered higher return rates, daylight hours are longer during this season as well. In this respect, it is possible that summer may have provided opportunities for gaining both riskier but high-return rate foods (e.g., fish, large game) as well as more predictable lower ranked foods (such as clams). The latter sessile but low-return foods may especially have been gathered by younger children who did not yet have the skills to pursue the former, or by more elderly individuals who no longer had the stamina or suffered from ailments such as osteoarthritis that limited their effectiveness in gaining the former. Assuming foods were shared, pursuing both risky high-return and predictable low-return foods in the same season would have ensured that families or the community had at least some consumables each day.

While there are general similarities to other sites in the seasonality of clamming, only one other site (CA-SFR-171) shows a gap in clamming during the fall, as seen at CA-ALA-11. CA-SFR-171 is an ephemeral camp occupied between 700 and 400 cal BP that seems to have been used by small family groups during short periods of settlement dispersion away from larger villages (Byrd and Kaijankoski 2011; Eerkens et al. 2013). All the other sites show some evidence for clamming during the fall, as

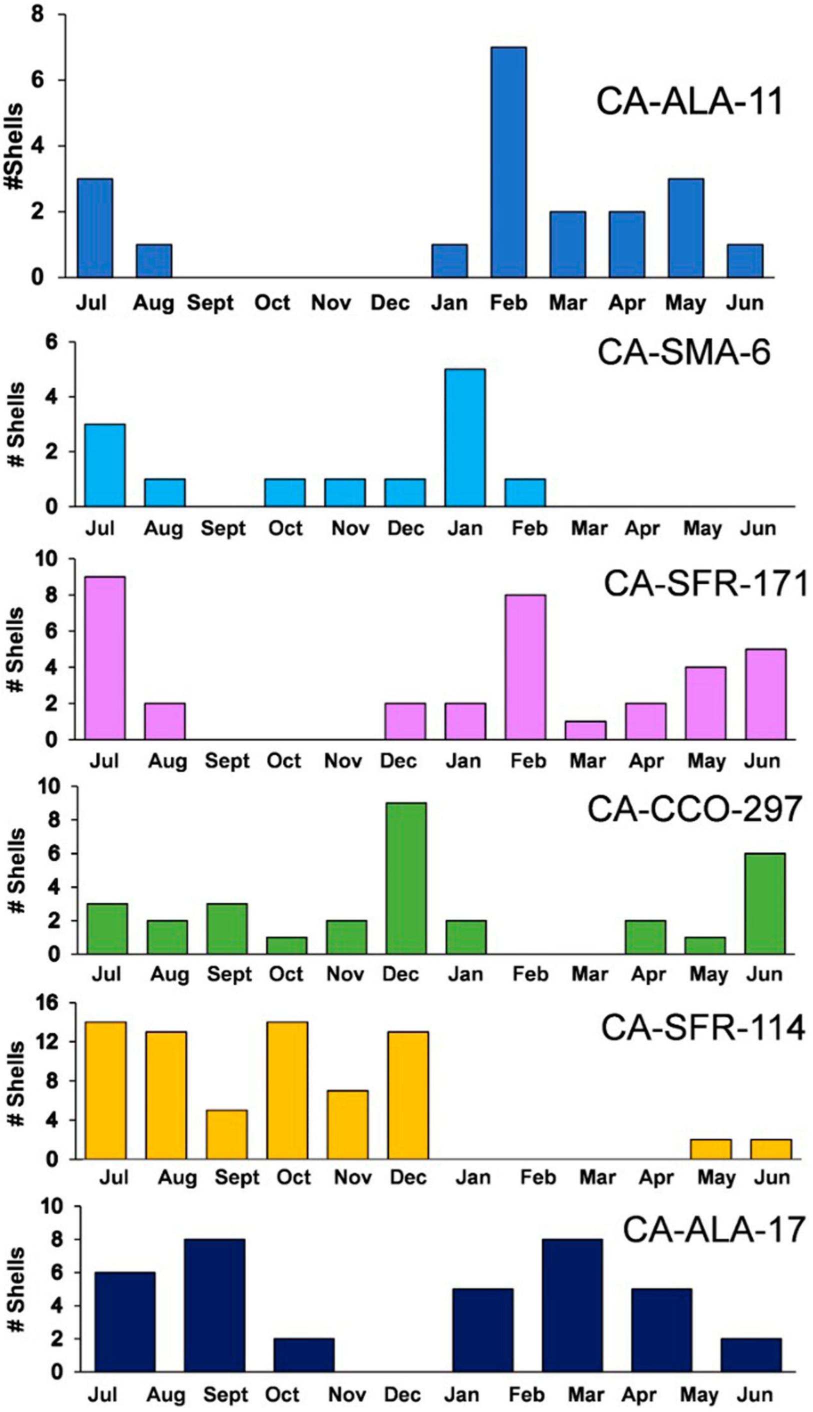

Figure 7. Seasonality of clam harvesting based on oxygen isotope analysis (CA-ALA-11 compared to other sites).

would be expected of sites that were occupied year-round. Furthermore, the pattern at CA-ALA-11 contrasts most strongly with that observed at CA-SFR-114. At the latter site, clamming was nearly absent in the winter and heaviest during the summer and fall, while at CA-ALA-11 clamming occurs from early winter through mid-summer and is absent in the fall.

To further test this, we performed a chi-squared test of independence between monthly shell counts and sites. The null hypothesis is that the seasonal patterns of shell counts do not differ by site. In this case, the chi-square statistic is very large (195.71), and the *p*-value is very small (1e–04), so the null hypothesis fails. The seasonal patterns of shell counts do, in fact, differ by site. Tables 2 and 3 show the differences between the expected and observed values of shell seasonality per site.

While these two sites (CA-ALA-11 and CA-SFR-114) are not contemporaneous, it is possible that sites such as these are complementary components of a single settlement pattern during the Early and Middle periods, where people moved annually between two base camps. Alternatively, these differences could be related to environmental effects. For example, high freshwater run-off from the Sacramento River, moving along the peninsula and into the Pacific Ocean, may have made clamming more difficult in this region during winter, while the marshier mudflats near Alameda may have made clamming viable during all seasons. As well, relative seasonal availability of various foods in these different locations may have made clamming more attractive during different seasons. Future studies could seek to explore these patterns further.

One last important consideration is comparing sample sizes among the six sites, since this can affect our overall interpretations. At CA-ALA-11, based on the percent NISP, MNI, and % by weight, oysters by far dominate throughout the site at 75% NISP and 70% MNI followed by bay mussels as the second most abundant at 24% NISP and 29% MNI, and clams the least abundant overall at 1% NISP and MNI (Figure 2). Based on these percentages, it is worth noting that when comparing % by weight, there is a significant difference between oysters (78%) and bay mussel (14%) (Figure 2). This difference is due to oyster shells being thicker than the thinner shells that make up bay mussels. Overall, this demonstrates that NISP and MNI are by far more useful for determining relative abundance since weight differs by species. However, in this article, we focused only on patterns seen in clams. At CA-SMA-6, there are similar patterns where clam makes up 0.7% of the sample by weight (Eerkens et al. 2014). At CA-SFR-171 and CA-CCO-297, another pattern was observed where clam made up most of the sample at 82.5% and 80.2% by weight, respectively (Eerkens et al. 2013; 2014).

Similar to our approach, at CA-SFR-114, %MNI and %weight was calculated for all three species (Harold, Byrd, and Eubanks 2019). Specifically, clam made up 27% of the total sample by weight, including upper (33%) and lower (18%) middens, and falls right in the middle abundance overall. Comparing this to %MNI, clam makes up 5% of the total, including upper at 6% and lower at 4%, and the same pattern of abundance is observed (Harold, Byrd, and Eubanks 2019). Lastly, at CA-ALA-17, clam is the least abundant shellfish species and is dominated by oyster and bay mussel (Culleton, Kennett, and Jones 2009). Specific percentages were not given for each species.

Since we have information on the % by weight and %MNI of clams collected at all of the sites, we can examine whether relative abundance of bent-nose clams varies with harvest seasonality. Comparing CA-ALA-11 and CA-ALA-17, there are similarities observed in weight and harvesting. At these sites, clams are in the minority among shellfish species and show a peak of harvesting during the late winter months. Likewise, at CA-SMA-6, clams were least abundant at 0.7% by weight and were harvested during the early winter. Interestingly, at CA-SFR-114, bent-nose clam was the least abundant when noting their %MNI, which differs from their % by weight, possibly due to the thicker clam shells affecting the weight compared to other shellfish species. Similar patterns were also observed with a small abundance of shells collected during the early winter months. Unlike the other sites, CA-SFR-171 and CA-CCO-297 have abundant clams in terms of % by weight but differ in harvesting seasonality. Winter harvesting was observed at CA-SFR-171, while CA-CCO-297 focused on harvesting during the late winter.

Conclusion

CA-ALA-11 clamming seems to have focused on the winter through summer months, with no evidence for fall harvesting. The lacunae during fall could be due to an absence of people at the site during the fall or a focus on other food-gathering activities during this season. Future studies exploring seasonality profiles of mussels and oysters may help to address this issue.

Overall, our results reveal both similarities and differences in the seasonality of clamming at CA-ALA-11 compared to other San Francisco bayshore sites ($n = 5$) that have employed similar and comparable isotopic methods. All sites are consistent in showing a primary winter peak, along with a secondary summer peak. We suggest that the winter peak represents a focus on gathering a sessile and spatially predictable resource during a season when other resources are typically in short supply. The consistent summer peak is more challenging to explain, but may relate to longer daylight hours providing opportunities to focus on a wider range of foods, including clams. At the same time, the sites differ in the degree to which fall and spring harvesting is represented. While CA-ALA-11 lacks a fall harvesting signature, four of the five other sites show at least some fall clamming activity.

Determining the reasons for these differences will require more research. Compared to other sites, CA-ALA-11 is a relatively older site. Thus, differences may be due to changes in human behavior over archaeological time or differences in local bayshore environments at the sites (e.g., size of adjacent mudflats, density of shellfish and other resources). Future studies exploring the seasonality of clamming at other contemporaneous sites could help to address this question.

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