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# Stable isotope reconstructions of shellfish harvesting seasonality in an estuarine environment: implications for Late Holocene San Francisco Bay settlement patterns

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ABSTRACT

Seasonality estimates based on stable isotope analyses of shellfish remains has been an important thrust of settlement pattern reconstruction, allowing researchers to place people on the landscape at points in space at different times of the year. In exposed coastal settings seasonality reconstructions are typically dependent on annual changes in water temperature. This paper has two goals. First, we continue development of a method for determining shellfish harvest seasonality in estuarine environments where annual salinity changes, not temperature, drive isotopic variation. Second, we contribute to settlement pattern studies by showing how small and large sites can be linked into a single system by examining different site types and shellfish species. Our case study focuses on the Late Prehistoric period of the San Francisco Peninsula, includes a large shellmound (CA-SMA-6) and an ephemeral camp (CA-SFR-171), and examines clam (*Macoma* spp.) and mussel (*Mytilus* spp.) harvesting. In this case, data support a fission-fusion settlement pattern, with periods of dispersal during late winter through early summer and aggregation in late summer through early winter.



## 1. Introduction

Understanding landscape use by past societies requires linking habitation, processing, and other sites and debris into a single settlement system, and continues to be an important theme in archaeological research (e.g., Anschuetz et al., 2001; Contreras, 2010; Walker, 2012), especially in hunter–gatherer archaeology (e.g., Bird et al., 2002; Fitzhugh and Habu, 2002; Jochim, 1998; Ugan et al., 2012; Winterhalder et al., 2010). Large-scale archaeological surveys (e.g., Kennett, 2005; Thomas, 1971), examinations of the ethnographic literature (e.g., Kelly, 1995), and ethnoarchaeological research (e.g., Binford, 1980; Bird and Bliege Bird, 1997; Meehan, 1982) have shown that people employ a range of settlement patterns to extract resources from local landscapes, ranging from highly residentially mobile patterns to more residentially sedentary and logistically mobile ones. In turn, the structure of settlement patterns has been shown to interact with a range of other aspects of ancient economies, technologies, and the like (Kelly, 1991, 1992; Marshall, 2006).

Archaeologists have developed and/or applied a range of analytical techniques to help reconstruct settlement patterns in ancient contexts. Determination of site seasonality has been an important development in this direction (Monks, 1981; Rocek and Bar-Yosef, 1998), allowing archaeologists to place foragers on various parts of the landscape at different points in time. In coastal regions, shellfish are typically an important component of the diet (Bird and Bliege Bird, 1997, 2000; Erlandson, 1988; Thomas, 2002), even in the distant human past (Jerardino and Marean, 2010; Steele and Klein, 2008). Irrespective of their role in diets, shell-forming organisms have been of tremendous interest to archaeologists (as well as geologists and paleontologists) because the calcite and aragonite minerals they secrete record a range of information about the water conditions they grew in, including temperature and salinity (Andrus, 2011). In determining seasonality, this is significant because water temperature in many exposed coastal regions of the world fluctuates seasonally in a predictable manner, while salinity is relatively constant. Because shells stop growing when the organisms in them die, we can often estimate water temperature at the point a shell was harvested, and from that, estimate the season

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of death (Harding et al., 2010). In this regard, oxygen and carbon isotope analysis of shells, in particular, have been extremely important in site seasonality and settlement pattern reconstruction, and this approach has a long history in California archaeology (Killingley, 1981).

Comparatively less attention has been given to estuarine environments where annual temperatures may not fluctuate as dramatically, but where changes in salinity are more extreme. Salinity is known to have an effect on the isotopic composition of shell carbonates, but it is not always clear if this factor varies enough to allow seasonality estimation. The case is particularly complex when both temperature and salinity are simultaneously changing throughout the year. Kennett and Voorhies (1995, 1996) were among the first to recognize that seasonality could still be estimated even under such conditions. Two recent studies, each employing a slightly different approach, suggest that season of harvest estimates for individual shells are also possible in the large San Francisco Bay estuary (Culleton et al., 2009; Schweikhardt et al., 2011). One of the goals of the current study is to further evaluate and build on these initial studies for San Francisco Bay through additional isotopic modeling using modern seawater data. In the process, we demonstrate that modeling seasonality in estuarine environments is possible, provided seasonal fluctuations in salinity are both relatively predictable from year to year and that the degree of change in salinity is large enough to counter-balance the effects of temperature on oxygen isotopes.

If a particular aquatic environment has predictable effects on calcium carbonate oxygen and carbon isotopes, we can then generate season-of-harvest estimates on a shell-by-shell basis. In aggregate, samples of shells with intact growing edges from particular archaeological contexts provide an overall estimate of the seasons in which shells were harvested. These estimates allow us to place groups of foragers at particular points in space, and at particular seasonal windows. Importantly, sampling from different sites, site types (e.g., ephemeral shell scatters vs. large dense shellmounds), or different archaeological contexts within a site (e.g., shell dumps, houses, stratigraphic levels) makes it possible to link the use of different places on the landscape to one another within an annual context.

This study examine the seasonality of two very different site types, using two different shellfish species that inhabit different ecological zones, the bay mussel (*Mytilus* sp.) and bent-nosed clam (*Macoma nasuta*). Although focused on San Francisco Bay, we show how such studies can suggest links between different site types as part of a larger settlement pattern. Based on the seasonality data, we propose testable hypotheses regarding ancient settlement systems in the region.

## 2. San Francisco shellmounds

Despite over a century of research on San Francisco shellmounds and shell middens (Nelson, 1909; Uhle, 1907), there is little consensus regarding the nature of prehistoric settlement patterns in this region. Even in the last 30 years, many scholars have studied Bay Area shell middens and put forward varying interpretations regarding their function and formation (Leventhal, 1993; Lightfoot, 1997; Lightfoot and Luby, 2002; Luby and Gruber, 1999), but few have explicitly addressed whether or not they represent sedentary or seasonal settlements. The literature indicates a great diversity of opinions. For example, King (1974) has argued for a sedentary pattern from ca. 2000 BP onwards, due mainly to population growth and social circumscription. Others (Banks and Orlins, 1981) argue for a regular settlement pattern, where inhabitants shifted periodically between two or three locations unrelated to the season. Still others have argued for a more residentially mobile settlement round between two or more locations (Bocek, 1991; Parkman, 1994), with the use of different sites and landscapes tied to specific seasons.

Under these various models, large and small sites play dramatically different roles in settlement patterns. Under the more sedentary models, large sites represent permanently occupied base camps of larger populations, while small sites represent either permanently occupied locations for smaller groups, or field processing locations for people living at the larger sites. Under the more mobile models, large sites represent either aggregation locations or productive places consistently and repeatedly visited, while smaller sites represent camps in less productive places that were less often used and/or occupied by smaller groups during periods of dispersal. Establishing the season of occupation of different site types would provide a new source of data in the evaluation of these competing settlement models.

## 3. CA-SFR-171 and CA-SMA-6

CA-SFR-171 and CA-SMA-6 are both Late Period 1 (700–400 cal BP) prehistoric sites on the San Francisco Peninsula (Milliken et al., 2007). They are situated along the western shore of San Francisco Bay some 15 km from each other (see Fig. 1). The climate is Mediterranean, with cool, wet winters, and warm, dry summers. The majority of rainfall occurs December through March. A series of water courses drains into the Bay from the San Francisco Peninsula, creating a mosaic landscape typified by mixed hardwood forest upland, and a lowland with a coastal prairie-scrub mosaic, riparian corridors and willow groves, estuaries, and coastal marshlands. Varied animal resources such as fish, shellfish, birds, terrestrial mammals, and marine mammals, as well as a range of plant resources, including nuts, such as acorns (*Quercus* spp.), and small seeds were available to local inhabitants.

CA-SFR-171 is a small ($\sim$600 m$^2$) prehistoric shell midden located just south of downtown San Francisco. The site lies near sea level along the south side of an extensive tidal marsh associated

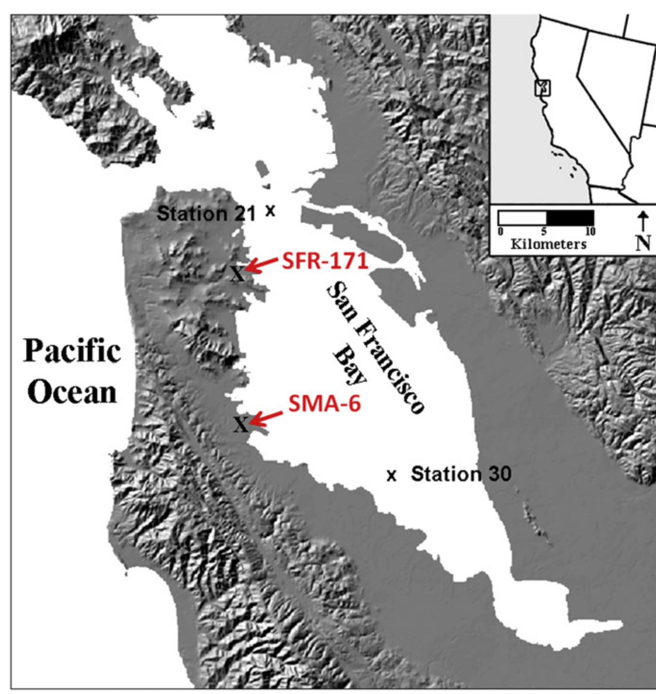


**Fig. 1.** Map of study area showing location of CA-SFR-171 and CA-SMA-6 on San Francisco Bay.