# Marine Resource Consumption in Ancient California

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### Abstract

Stable carbon and nitrogen isotope ratios were analyzed from a small sample of human skeletal remains dating from La Jollan (Archaic) through historic periods to assess the relative contribution of marine resource consumption in southern California and Baja California economies. Dietary variability is contrasted in the Santa Barbara Channel region through time with evidence for greater diet breadth and regional variability in Baja California. Based on stable isotope analysis of human bone collagen, marine resources were substantial contributors to the diets of most individuals despite the disparity in the development of social complexity and resource intensification between regions.


### Introduction

It is well established that stable carbon and nitrogen isotope ratios of an individual's bone, hair and soft tissue reflect the relative intake of particular food groups, including foods derived from marine sources (Tauber 1981; Chisholm et al. 1982; Schoeninger et al. 1983; Hobson and Collier 1984; Sealey and van der Merwe 1985; Ambrose 1986; Walker and DeNiro 1986; Newsome et al. 2004; Bartelink 2009). These data are complementary to archaeological evidence of dietary practices, including animal and plant remains recovered from archaeological sites, and present the advantage of reporting dietary data for individuals that may be compared by age, sex, or rank in society.

Investigations of stable carbon and nitrogen isotope signatures of bone collagen from small samples of human skeletal populations have proven useful in exploring marine resource consumption in southern California (Walker and DeNiro 1986; Goldberg 1993; Harrison and Katzenberg 2003; Rick et al. 2011) where a substantial modern database of terrestrial and marine fish, birds, and mammals show virtually discrete ranges of stable nitrogen and carbon isotope ratios (DeNiro and Epstein 1978, 1981; Schoeninger and DeNiro 1984; DeNiro 1985; Keegan and DeNiro 1988). This natural variation in dietary isotopic composition is incorporated into body tissues of consumers[1] including bone collagen that preferentially reflects dietary protein (Ambrose and Norr 1993). The stable isotope results from all studies demonstrate increased consumption of marine resources in the Channel Islands as compared to the coastal mainland, while individuals from the mainland interior demonstrate the least marine contribution to diet (Figure 1). Bone collagen nitrogen isotope values are most enriched from three sites on San Nicholas Island (Harrison and Katzenberg 2003) and indicate the increased contribution of higher trophic level marine mammals to the diet compared to mixed marine mammal and shellfish diets. Consumption of marine resources also increased through time on the mainland (Walker and DeNiro 1986), although the pattern on the southern Channel Islands demonstrates either consistently high marine resource exploitation in all time periods (Harrison and Katzenberg 2003) or a decrease through time relative to terrestrial products hypothesized as increased trade with the mainland (Goldberg 1993).

Molto and Kennedy (1991) explored the use of stable isotope analysis among the late prehistoric Las Palmas Culture of the Cape Region of the Baja California

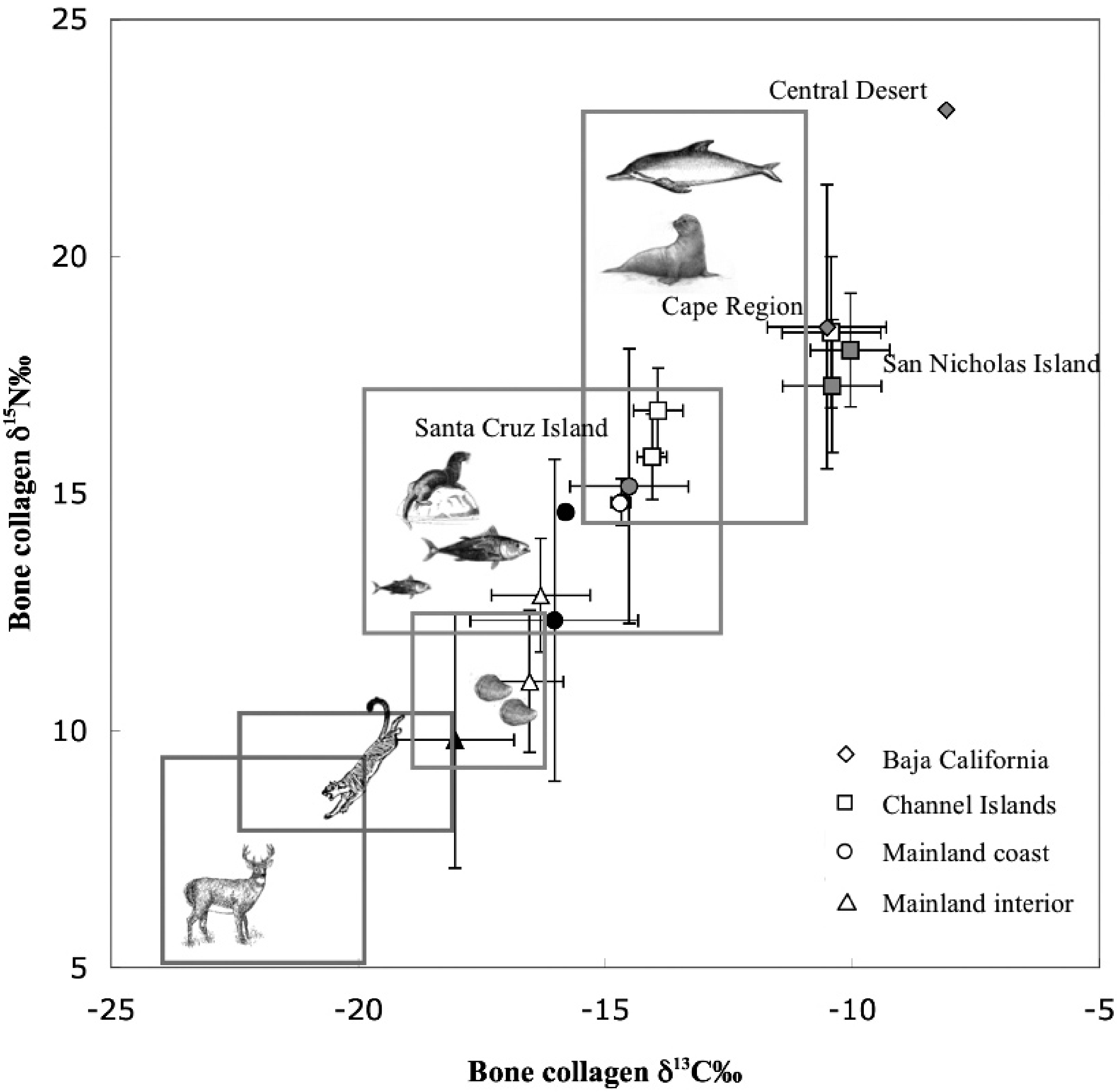


Figure 1. Isotopic composition of human bone collagen from select southern California and Baja California studies compared to isotopic composition of food resource categories from southern California. Temporal categories of early (>5,000 B.C. to 1,400 B.C.), middle (1,400 B.C. to A.D. 1150), and late (A.D. 1150 to A.D. 1804) are represented by black, grey, and hollow symbols, respectively for all studies after Walker and DeNiro (1986). Sites with less precise temporal associations are identified with the earlier temporal category.

Sources: Human: Interior and coastal southern California, Santa Cruz Island (Walker and DeNiro 1986); San Nicholas Island (Harrison and Katzenberg 2003); Baja California (Molto and Kennedy 1991). Animal: Schoeninger and DeNiro 1984; DeNiro 1985; Newsome et al. 2004. Animal bone collagen values are adjusted to represent isotopic composition of edible flesh (DeNiro and Epstein 1978, 1981; Keegan and DeNiro 1988).

Peninsula. Substantial marine resource contribution to the diet was indicated in the bone collagen carbon and nitrogen isotope values of six individuals analyzed, although corresponding dental pathology data from a larger sample suggested extensive use of plant resources similar to early southern California mainland and Channel Islands data where it is believed to represent consumption of cariogenic plant foods such as roots and tubers (Walker and Erlandson 1986). Interestingly, the stable isotope data from Baja California Sur demonstrate a level of marine resource consumption including higher trophic level marine mammals on par with San Nicholas Island (Figure 1). In addition, one Cochimí individual from Bahía de los Angeles in the arid Central Desert region (Molto and Kennedy 1991) demonstrated the most enriched nitrogen and carbon isotope ratios ever reported for the west coast of North America. King (1997) reported similar results for late Comondú period remains from nearby Bahía de las Animas in contrast to earlier remains from the Sierra de San Francisco. Isotope values from both studies are inconsistent with ethnohistorical evidence for resource extraction (see Aschmann 1967) and zooarchaeological data that demonstrate minor quantities of sea mammal remains, with the noted exception of a dolphin processing site at Las Tinas 3 in the Cape Region (Porcasi and Fujita 2000).

As elaborated by Moore (1999:18), many of the models proposed for the development of social hierarchy and economic specialization with concurrent sedentism, population density, and interregional exchange systems in southern California rely upon the natural abundance of marine resources in this region (e.g., Arnold 1987, 1992a, 1992b, 1995; Jones 1991, 1992; Glassow 1992, 1996; Raab 1992; Erlandson 1994; Raab et al. 1995). The absence of such development in northern Baja California, despite the similarity in resource composition, provides for an intriguing comparison of economic choices by individuals that can be partially addressed with stable isotope analysis.

The present research reports the stable isotope results of a small sample of individuals from the San Diego Museum of Man skeletal collection. The study sample includes 13 individuals from sites in southern California and 12 individuals from Baja California from La Jollan midden to historic cemetery contexts. With these data we test to what degree marine resource consumption varies across space and through time between similar environmental regions as a preliminary means to assess differential development of social complexity and to explore variables potentially contributing to the patterns observed.

## Materials and Methods

### *Sample Selection*

Twenty-five samples from the collections at the San Diego Museum of Man were analyzed for stable carbon and nitrogen isotope signatures from bone collagen. Details regarding sample location, temporal association, burial form, and demographic data are summarized in Table 1 and Figure 2.

The majority of samples included in this study are La Jollan burials excavated in the 1920s and 1930s from coastal terrace and midden contexts under the direction of Malcolm J. Rogers (S. L. Rogers 1963). Many of the remains, as detailed in Table 1, were eroding at the time of recovery, thereby reducing the associated data on site extent, temporal context, and other artifact associations. In addition, many of the excavations conducted by M. J. Rogers remain incompletely reported (see M. J. Rogers 1966).

Site designations presented follow the system from the San Diego Museum of Man in place for the 1930s, including the use of the prefix “W” for sites in western San Diego County and the use of “LC” (Lower California) to designate sites in northern Baja California. This includes the remains from sites W-5, W-9 (Scripps Estates), W-34 (Del Mar), LC-23A (Rio

Table 1. Location, Temporal Context, and Age and Sex Data for Samples Analyzed from the San Diego Museum of Man.

| **Sample No.** | **Site No.** | **Location** | **Temporal Context** | Sex | **Age** | **Description** | **Source** |
|---|---|---|---|---|---|---|---|
| **Southern California** | | | | | | | |
| 1973-42-1 | – | South Bay, San Diego County | La Jollan | M | A | Flexed fragmentary remains recovered near water from graded area in South Bay. | 1 |
| 16704 | W-34 | Del Mar | Probably La Jolla I or II | I | A | Remains partially eroded from sea cliff without associated artifacts. | 1,3 |
| 16705 | W-119 | Agua Hedionda | Luiseño (Late Prehistoric) | M | A | Flexed remains on right side with head to north recovered from a trench beside a sweat house covered in cobbles. | 1 |
| 17809 | G-1 | Pt. Sal | Chumash (A.D. 580-650) | M | A | Skeleton 17. Seated burial facing west | 1,5 |
| 17857 | G-1 | Pt. Sal | Chumash | M | A | Skeleton 21. Seated burial facing west. | 1 |
| 17868 | G-1 | Pt. Sal | Chumash | I | 12-15 yrs | Skeleton 35. Burial facing west. | 1 |
| 18131 | G-1 | Pt. Sal | Chumash | M | A | Skeleton 44. Remains in distorted position from Cemetery 2. Beads and hair ornaments recovered near skull. | 1 |
| 19229 | W-5 | La Jolla | Middle La Jolla II (3850 B.C.) | F | A | Flexed burial placed on left side with head to west under a deep trough-type metate near base of midden. | 1,3,4 |
| 19251 | W-9 | Scripps Estates | Early La Jolla II | I | 8-9 yrs | Flexed burial placed on left side with head to east under midden. | 1,3 |
| 19254 | W-9 | Scripps Estates | Middle La Jolla II | F | A | Flexed burial placed on left side with head to northwest under midden with broken trough-type metate. | 1,3 |
| 19255 | W-9 | Scripps Estates | Middle to Late La Jolla II | F | A | Disturbed burial underlain by midden. An inverted trough-type metate was placed over the skull. | 1,3 |
| **Channel Islands** | | | | | | | |
| 1971-78-1 | – | San Clemente Island | Prehistoric | F | A | Complete burial recovered from northwest end of island with shell necklace in association. | 1 |
| 2087 | SC-4 | San Clemente Island | Canaliño | F? | A | Complete burial from sand dune. | 1 |
| **Baja California** | | | | | | | |
| 1972-63-1 | LC-219 | Punta Minitas | La Jollan (1,150±300 B.C.) | F | A | Flexed burial placed on right side under a metate from shell midden. | 1,6 |
| 1972-63-3 | – | Carl Hubbs Temperature Station 9 | Prehistoric | I | A | Fragments of skull and mandible recovered from a shell midden 1.2 km south of Descanso. | 1 |
| 1972-64-1 | LC-218 | Arroyo San Jose | Comondú (Late Prehistoric) | M | A | Nearly complete extended burial on poles in sea cave. Material remains include basketry, digging stick, and palm fronds. | 1 |

Table 1. Continued.

| Sample No. | Site No. | Location | Temporal Context | Sex | Age | Description | Source |
|---|---|---|---|---|---|---|---|
| 2996 | – | Iron Springs, south of Jacumba | Late Prehistoric? | M | A | Burial with lower legs flexed underneath and head to the east with two metates and rocks in association. | 1,2 |
| 16694 | LC-31 | Megano Slough | La Jolla I or II | M | A | Flexed burial on right side with head to north eroded from shell midden. | 1,3 |
| 16696 | LC-31 | Megano Slough | La Jolla I or II | M | A | Burial recovered after eroded from original position in shell midden. | 1,3 |
| 16697 | LC-34 | Rosario River | Probably Historic | F | A | Extended burial under two upside down metates. Recovered in digging adobe with sherds located on surface. | 1,3 |
| 16759 | LC-34A | Rosario River | La Jolla II | F | A | Flexed burial with no associated offerings from midden. | 1,3 |
| 16842 | LC-60 | 18.7 km east of Descanso Mission | Historic | F | A | Burial with head to north and string of China beads around the neck. Cemetery located 18.7 km east of the Descanso Mission. | 1 |
| 16843 | LC-60 | 18.7 km east of Descanso Mission | Historic | F | A | Extended burial with head to north with fabric and leather recovered in neck region. Cemetery located 18.7 km east of the Descanso Mission. | 1 |
| 18077 | LC-23A | Rio Guadalupe | La Jolla II | F | A | Shell midden burial on left side, head to north, with half a metate possibly placed over head. Site is located on the north bank of the river, opposite the Mission. | 1 |
| none | LC-217 | Punta Negra | Prehistoric | F | A | Tightly flexed burial recovered from a crevice within a sea cave. | 1 |

Note: Sample data provided by 1) Rose Tyson, personal communication and San Diego Museum of Man catalog; 2) Tyson 1975; 3) S. L. Rogers 1963; 4) Ike et al. 1979:526; 5) Beta No. 159835; 6) La Jolla Natural Radiocarbon Lab sample LJ-5.

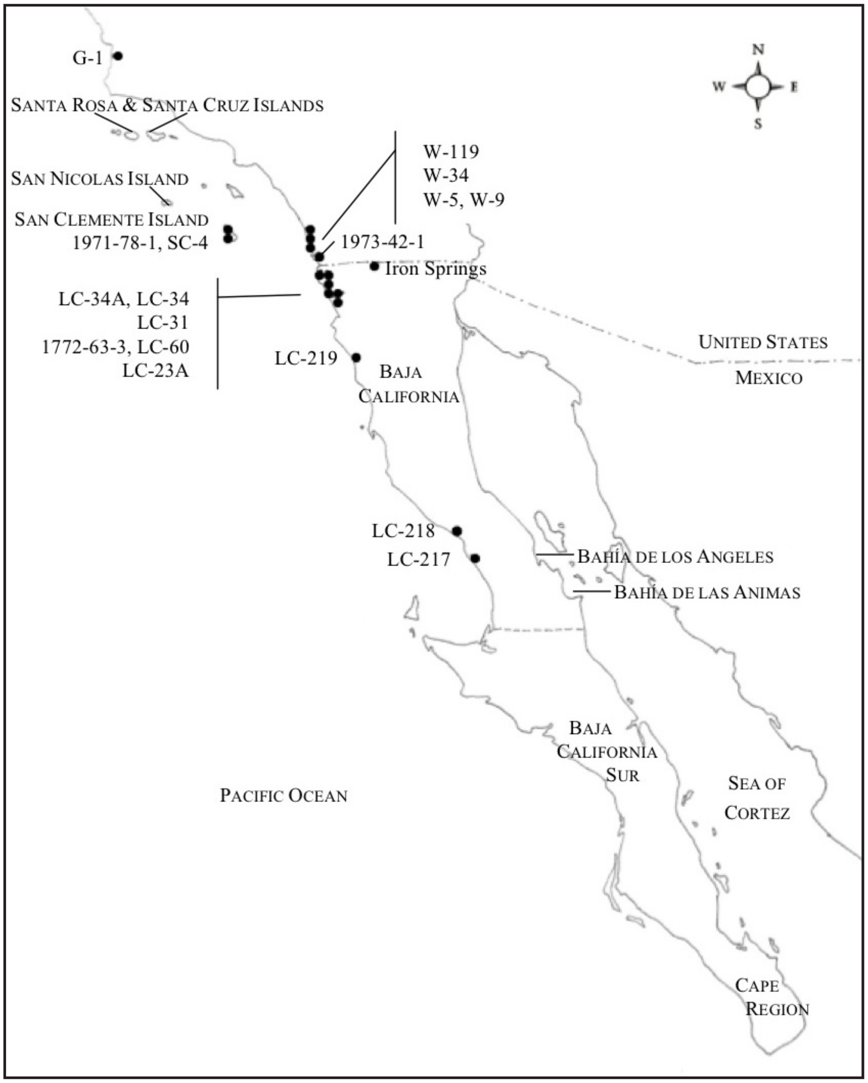


Figure 2. Map of southern California and Baja California skeletal samples analyzed for isotopic composition and other locations mentioned in the text. Site designations from San Diego Museum of Man catalogue.

Guadalupe), LC-31 (Megano Slough), and LC-34 and LC-34A (Rosario River).

Additional samples for this study were recovered as part of Carl Hubbs' paleoclimate project in the 1950s that focused on recovery of shell samples from archaeological middens for radiocarbon dating (Hubbs et al. 1965). Other samples were donated to the San Diego Museum of Man collections and likewise have limited information on site context (e.g., Iron Springs [Tyson 1975]). Despite the paucity of background data on each sample, temporal category assignments in Table 1 were provided by Rose Tyson based on a review of catalog and site form data at the San Diego Museum of Man. These data do allow for a comparison of protein diet change through time to the degree seen in previous isotope studies in this region, including comparisons of the "early" La Jollan Complex that falls within the Archaic Period (M. J. Rogers 1939; Moriarty 1966) and some middle Holocene and late prehistoric remains. Two graves excavated from a cemetery along the Guadalupe River (LC-60) by George Carter and F. S. Rogers in 1938 also permit limited comparison to post-Spanish impacts on indigenous diet.

### *Stable Isotope Methods*

Isolation of bone collagen followed methods described in detail by Ambrose (1990) whereby clean, ground bone (0.25-0.5 mm) was demineralized in 0.2 M HCl, followed by treatment with 0.125 M NaOH for 20 hours to remove humic and fulvic acid contaminants, solubilization by heating at 95°C in weak HCl for 10 hours, filtration through a glass frit filter and freeze-drying. Sample quality was acceptable when the ratio of carbon to nitrogen (C:N) in the collagen sample ranged from 2.9 to 3.6 (DeNiro 1985). Carbon and nitrogen isotope ratios were measured with a Finnigan-MAT DeltaPlus XL isotope mass spectrometer with a ConFlo III interface linked to a Costech ECS 4010 Elemental Combustion System (elemental analyzer).

Stable isotope ratios of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) are reported in delta ($\delta$) notation as difference in parts per thousand (per mil, or ‰) relative to the Pee Dee Belemnite (PBD) and atmospheric nitrogen (AIR) standards, respectively.

## Results and Discussion

Bone collagen $\delta^{13}C$, $\delta^{15}N$, and C:N data are provided for each of the 25 individuals analyzed for this study with the exception of the sample from the Del Mar site with poorly preserved collagen (Table 2). Stable isotope results are displayed graphically (Figure 3) with select, previously published results from these regions.

### *Southern California*

Although the human skeletal samples from different time periods and geographical contexts are small, a number of patterns of variation are evident. Among the 10 mainland coastal southern California samples analyzed, bone collagen $\delta^{13}C$ values range from –14.4 per mil to –17.5 per mil and $\delta^{15}N$ values range from +11.1 per mil to +16.5 per mil. These ranges are within those reported by Walker and DeNiro (1986) for human remains recovered from coastal sites. In contrast to previous studies, the La Jollan samples in the vicinity of the Scripps Estate (W-5, W-9) and the general South Bay Area have more enriched bone collagen $\delta^{15}N$ values than later Chumash (Pt. Sal) and Luiseño (Agua Hedionda) samples indicative of lower marine protein relative to terrestrial protein resource consumption in later periods. Specifically, three early adult samples from the Scripps Estate area have a mean $\delta^{13}C$ of -16.5 per mil and a mean $\delta^{15}N$ of +12.1 per mil compared to three Chumash adults from Pt. Sal that show $\delta^{13}C$ and $\delta^{15}N$ means of -16.3 per mil and +14.9 per mil, respectively.

The Pt. Sal Chumash sample isotope values may also indicate significant exploitation of marine shellfish which, although abundant in this region, contrasts with archaeological evidence for intensified fish and sea mammal exploitation (Glassow 1996). One burial from this sample has been dated to A.D. 580-650, which is earlier than the proposed transition to lower-ranked shellfish resources (Glassow and Gregory 2000) as a response to subsistence stress and/or social conflict towards the end of the middle period around A.D. 1100 (Arnold 1992a, 1992b; Arnold et al. 1997; Raab and Larson 1997). A distinction in protein resource consumption by sex may also be influencing the observed temporal change as all adult samples from the Scripps Estates are female, while those from Pt. Sal are male.

Two samples analyzed in this study from San Clemente Island reflect very different protein diet sources. Like the archaeological dietary data from Canaliño sites, the individual from SC-4 with a bone collagen $\delta^{13}C$ value of -13.5 per mil and $\delta^{15}N$ value of +16.8 per mil is consistent with data from Santa Cruz (Walker and DeNiro 1986) and Santa Rosa (Rick et al. 2011) Islands. In contrast, the second San Clemente Island individual analyzed that was recovered from the northwest end of the island displays a bone collagen $\delta^{13}C$ value of -17.0 per mil and $\delta^{15}N$ value of +11.5 per mil. These values are indicative of a diet derived

Table 2. Isotopic Composition of Bone Collagen for Individuals Analyzed in This Study.

| Sample No. | Site No. | Location | Temporal Context | Sex | Age | C:N | δ13C | δ15N |
|---|---|---|---|---|---|---|---|---|
| **Southern California** | | | | | | | | |
| 1973-42-1 | – | South Bay, San Diego County | La Jollan | M | A | 3.3 | -14.4 | 15.4 |
| 16704 | W-34 | Del Mar | Probably La Jolla I or II | I | A | 0.7 | – | – |
| 16705 | W-119 | Agua Hedionda | Luiseño (Late Prehistoric) | M | A | 3.3 | -15.6 | 12.6 |
| 17809 | G-1 | Pt. Sal | Chumash (A.D. 580-650) | M | A | 3.3 | -15.8 | 13.1 |
| 17857 | G-1 | Pt. Sal | Chumash | M | A | 3.3 | -16.5 | 12.0 |
| 17868 | G-1 | Pt. Sal | Chumash | I | 12-15 yrs | 3.3 | -17.5 | 11.4 |
| 18131 | G-1 | Pt. Sal | Chumash | M | A | 3.3 | -17.2 | 11.1 |
| 19229 | W-5 | La Jolla | Middle La Jolla II 5,800 B.P. | F | A | 3.4 | -16.2 | 15.2 |
| 19251 | W-9 | Scripps Estates | Early La Jolla II | I | 8-9 yrs | 3.4 | -15.7 | 16.0 |
| 19254 | W-9 | Scripps Estates | Middle La Jolla II | F | A | 3.3 | -15.9 | 16.5 |
| 19255 | W-9 | Scripps Estates | Mid to Late La Jolla II | F | A | 3.3 | -16.9 | 13.1 |
| **Channel Islands** | | | | | | | | |
| 1971-78-1 | – | San Clemente Island | Prehistoric | F | A | 3.3 | -17.0 | 11.5 |
| 2087 | SC-4 | San Clemente Island | Canaliño | F? | A | 3.3 | -13.5 | 16.8 |
| **Baja California** | | | | | | | | |
| 1972-63-1 | LC-219 | Punta Minitas | La Jollan (1,150±300 B.C.) | F | A | 3.3 | -12.0 | 18.1 |
| 1972-63-3 | – | Carl Hubbs Temperature Station 9 | Prehistoric | I | A | 3.3 | -12.5 | 17.8 |
| 1972-64-1 | LC-218 | Arroyo San Jose | Comondú (Late Prehistoric) | M | A | 3.3 | -10.2 | 18.1 |
| 2996 | – | Iron Springs, south of Jacumba | Late Prehistoric? | M | A | 3.3 | -12.3 | 12.4 |
| 16694 | LC-31 | Megano Slough | La Jolla I or II | M | A | 3.3 | -13.6 | 15.4 |
| 16696 | LC-31 | Megano Slough | La Jolla I or II | M | A | 3.3 | -13.6 | 15.4 |
| 16697 | LC-34 | Rosario River | Probably Historic | F | A | 3.3 | -14.9 | 14.5 |
| 16759 | LC-34A | Rosario River | La Jolla II | F | A | 3.4 | -17.7 | 9.0 |
| 16842 | LC-60 | 18.7 km east of Descanso Mission | Historic | F | A | 3.3 | -16.1 | 11.1 |
| 16843 | LC-60 | 18.7 km east of Descanso Mission | Historic | F | A | 3.4 | -15.0 | 11.1 |
| 18077 | LC-23A | Rio Guadalupe | La Jolla II | F | A | 3.3 | -16.1 | 14.0 |
| none | LC-217 | Punta Negra | Prehistoric | F | A | 3.3 | -9.9 | 15.0 |

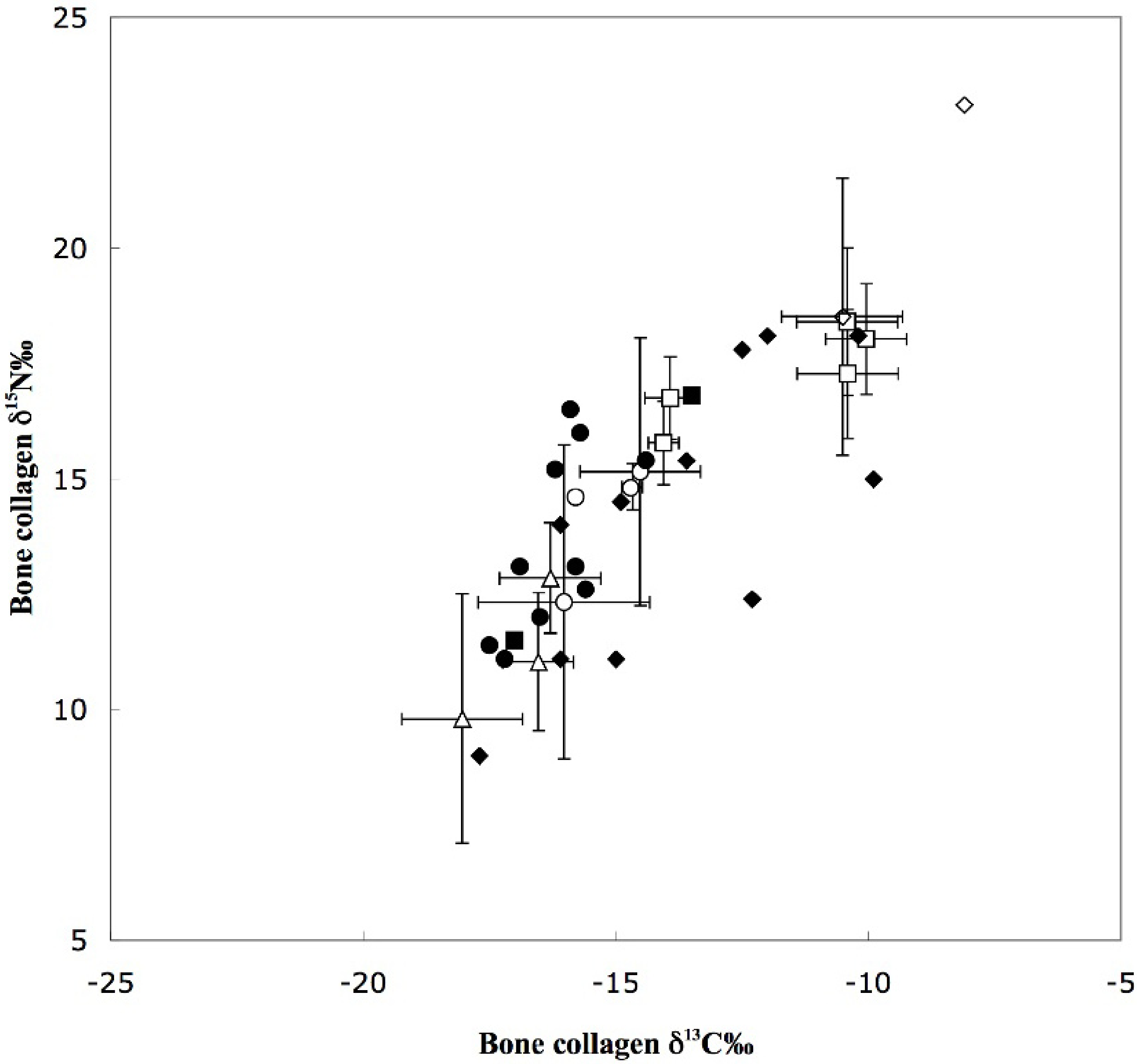


Figure 3. Isotopic composition of human bone collagen analyzed in the present study from the southern California mainland (circles), San Clemente Island (squares), and Baja California (diamonds) compared to data from select studies identified in Figure 1.

predominantly from terrestrial protein resources leading to the inference that this individual was nonlocal to the Channel Islands. In addition, previously published data for samples on the Channel Islands (Walker and DeNiro 1986; Harrison and Katzenberg 2003; Rick et al. 2011) show lower standard deviations relative to mainland samples (Figure 1) as dietary diversity is more limited in terms of terrestrial protein resources but with many marine mammal, bird, and fish resources available (Rick et al. 2005). Similar suggestion of nonlocality has been made for extremely enriched isotope values among individuals in coastal southern California where marriage exchanges with the Channel Islands (or less likely in this case, sexual division of labor) could influence the dietary patterns observed at one site (Walker and Erlandson 1986).

***Baja California***

The 12 individuals analyzed from Baja California demonstrate greater heterogeneity in consumption of dietary protein resources with bone collagen $\delta^{13}C$ values ranging from –9.9 per mil to –17.7 per mil and $\delta^{15}N$ values ranging from +9.0 per mil to +18.1 per mil. No clear temporal patterning exists, although the La Jollan samples represent the majority of the diversity in stable isotope values produced in this study. One individual from the mouth of the Rosario River (LC-34A) with a $\delta^{13}C$ value of -17.7 per mil and a $\delta^{15}N$ value of +9.0 per mil was almost exclusively a terrestrial protein resource consumer, while an individual recovered from Punta Minitas (LC-219) with a $\delta^{13}C$ value of -12.0 per mil and a $\delta^{15}N$ value of +18.1 per mil demonstrates higher trophic level marine resource consumption consistent with the Channel Islands. While either of these individuals may have been migrants to the northern Baja California coast, the overall range of sample values could also be reflective of situational resource extraction across larger seasonal rounds from the coast to interior mountain ranges in contrast to the nucleated villages with intensive resource collection strategies of the Santa Barbara Channel area (Laylander 1997). Greater fluidity in community membership as identified in ethnographic accounts of northern Baja California patrilocal bands (Owen 1965) could produce a similar effect where adult females from ecologically distinct resource areas relocate over long distances for marriage.

Only one individual from the Baja California sample was recovered from an interior site, that of Iron Springs located 4.8 km south of the international border near Jacumba. With a bone collagen $\delta^{15}N$ value of +12.4 per mil, this individual is within the range of interior southern California samples previously reported (Walker and DeNiro 1986). However, a $\delta^{13}C$ value of -12.3 per mil is more enriched than expected for a terrestrial protein resource base.

Two additional individuals from more southern coastal sites (LC-217, LC-218) display more enriched collagen $\delta^{15}N$ values of +15.0 per mil and +18.1 per mil with $\delta^{13}C$ values of -9.9 per mil and -10.2 per mil, respectively. The enriched carbon isotope ratios of bone collagen in these samples may indicate a mixed marine and Crassulacean Acid Metabolism (CAM) plant diet where shellfish and agaves, plus other cactus resources are the most predictable on the landscape (Moore 1999). However, this would require additional foodweb data to discern as the current database of stable isotope values for food resources in this area is largely derived from southern California and focused on animal protein (Schoeninger and DeNiro 1984).

It is worth mentioning that three samples from the present study (LC-218, LC-219, 1972-63-3) display bone collagen $\delta^{15}N$ values more enriched than individuals from Santa Cruz (Walker and DeNiro 1986) and the site SC-4 sample from San Clemente Island (this study). In contrast, faunal remains from Punta Minitas (LC-219) support seasonal mollusk collection (Killingley 1980; Shor 1980). While ethnohistoric accounts provide details of open water hook and line fishing from small seaworthy reed canoes in the area of Bahía de San Quintín (de la Ascención 1929; Vizcaíno 1992), the isotopic signatures of certain individuals suggest the consumption of higher tropic level marine mammals that is potentially a complication of aridity on the Baja California peninsula.

Arid environments pose certain challenges to interpretation of stable isotope data as succulent and cactus food sources have carbon isotopic signatures similar to marine resources, and a number of environmental factors including decreased vegetation cover (Mariotti et al. 1980; Karamanos et al. 1981), salinity (Karamanos et al. 1981), and potentially sea salt spray (Heaton 1987) may elevate soil and plant nitrogen values. Conditions of water and/or protein stress in animals can further complicate nitrogen isotope values due to urea and tissue recycling (Ambrose and DeNiro 1987;

Sealy et al. 1987; Ambrose 1991). To some degree, then, aridity may be enriching stable isotope values from the peninsula; this can be best addressed through the analysis of additional foodweb data.

Two post-Spanish (Yuman III – W. Diegueño) samples were analyzed from a cemetery 18.7 km east of the Descanso Mission (LC-60). Based on site notes from the San Diego Museum of Man, the female burials were recovered from graves marked by cairns and were accompanied by China beads and fabric/leather, respectively. Despite a coastal location, these samples demonstrate bone collagen carbon and nitrogen isotope ratios consistent with interior southern California samples.

While the temporal association of LC-60 and the Descanso Mission is unclear, an increased terrestrial orientation to diet among proximate, contemporaneous populations could be the result of the disruption of traditional transportation networks limiting access to coastal foraging areas or the receipt of provisions to encourage missionization, whereby the missions were located to make use of traditional resource and social networks (Aviles and Hoover 1997; Panich 2010). Cultivated crops at the northern Baja California missions included corn, wheat, barley, and beans as well as livestock (Meigs 1935). While all are terrestrial resources, this mix of crops is diverse in isotopic composition as maize (corn) is a tropical grass that uses the $C_4$ photosynthetic pathway. $C_4$ plants have $\delta^{15}N$ values within the range for other terrestrial plants, but $\delta^{13}C$ values range from -15 per mil to -7 per mil (Smith and Epstein 1971), comparable to carbon isotope values for marine resources (Figure 1). This added foodweb diversity and the complexity of interactions in the post-Spanish period would be difficult to tease out from bone collagen data alone.

**Conclusions**

The bone collagen stable isotope analysis conducted on 25 samples from the San Diego Museum of Man supports some results of previous research in this region and provides additional avenues for research. Within the samples from southern California, the range of isotope values is consistent with previously published data, particularly for "early" period remains.

However, the Chumash samples from Pt. Sal demonstrate a decrease in marine resource consumption compared to earlier periods. These stable isotope results may indicate greater site variation among the Chumash leading up to the transition to lower ranked resources posited to have occurred around A.D. 1100.

Stable isotope data has great potential for providing additional data to explore how and when a dietary transition occurred, by demonstrating whether sites showed consistent or variable shifts in resource extraction as responses to subsistence stress. This data set suggests the possibility of differences in diet among males and females, although a true comparison would require relatively large samples from more than one site within a given time period.

The La Jollan samples from northern Baja California analyzed in this study display significantly greater dietary heterogeneity than those from southern California. As stable isotope data from bone collagen reflect the accumulated diet of an individual over approximately 10 years, this diversity suggests resource extraction strategies and possibly the availability of different categories of resources were more varied. Fluidity in community structure and membership as reported ethnographically in the region (Owen 1965) could also influence the dietary signatures observed as individuals move between groups with relatively small differences in subsistence economy.

As with the samples from southern California, greater support for the patterns observed from stable isotope data would require the analysis of larger site samples from ecologically distinct regions, preferably where skeletal remains of both biological sexes are represented. In addition, further exploration of the isotopic signatures observed in human consumers on the Baja California peninsula must be supported by additional data on the isotopic composition of food resources. These data could supplement increasingly robust archaeological studies of mobility and resource orientation in a variety of regions along the Baja Peninsula (e.g., Laylander and Moore 2006).

Although southern California and northern Baja California are adjacent regions, differences in water temperature, rainfall, soil matrix, and other environmental variables may have affected the foodweb and the resultant isotope signatures in the human populations exploiting it. Without these additional background data, the accuracy of interpretation of higher trophic level marine mammal consumption in some La Jollan samples analyzed here and the Las Palmas and Cochimí samples from further south on the Baja California peninsula (Molto and Kennedy 1991) is in question.

As stated by Arnold (1995), the development of social complexity depends not just on marine resource abundance but also on the diversity of habitats to exploit and access to those resources, including sufficient technology and need. Coastal Baja California displays an abundance of marine resources. The stable isotope data presented here suggest at least some individuals were able to make use of the resources on par with Channel Island populations. However, greater diversity in resource extraction strategies among La Jollan samples suggests an early divergence from the pathway to marine resource intensification seen among the Chumash and other populations further north. While it is possible (and discernible with additional data) that environmental conditions limited subsistence strategies, such as the distribution of water resources or the inability to store predictable succulent resources such as agave in humid environments (Moore 1999, 2006), the reasons for divergence may also be primarily cultural and tied to politics surrounding the development of interregional trade relations that would both necessitate and drive resource intensification.

## Endnote

1. Nitrogen isotope values are biologically fractionated by 3-4 per mil at each successive trophic level (Minagawa and Wada 1984), while carbon isotopes show only a 1 per mil increase.

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