Palaeodiets of Humans and Fauna at the Spanish Mesolithic Site of El Collado

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The first human stable isotope results from the Spanish Levant, from the Mesolithic (ca. 7500 BP, Mesolithic IIIA phase) site of El Collado (near Oliva, Valencia) provide evidence for the consumption of marine protein by humans, estimated at approximately 25% of the dietary protein for some individuals. Isotopic analysis of human remains from other coastal Mesolithic sites in Europe, particularly along the Atlantic coast, also shows significant consumption of marine foods, but the amount of marine food consumed by the El Collado humans was much less than at those sites. This may be because of a different dietary adaptation or because the Mediterranean is much less productive than the Atlantic.

Some of the most successful applications of stable isotope analysis as a method for reconstructing past human diets have focused on the European Mesolithic. This is because carbon ($\delta^{13}$C) and nitrogen ($\delta^{15}$N) bone collagen isotope ratios are particularly effective in detecting the consumption of marine protein (Schoeninger, De Nirola, and Tauber 1983; Chisholm, Nelson, and Schwarcz 1982), and marine foods were an important dietary source for coastal Mesolithic humans. Among the earliest published applications of bone collagen carbon isotope ratios in archaeology was that of Tauber (1981), which showed a great reliance on marine foods by late Mesolithic humans in Denmark. Subsequent isotopic studies of other Mesolithic humans in Denmark (Tauber 1983, 1986; Richards, Price, and Koch 2003) in other areas of Atlantic Europe such as the UK (Richards and Mellars 1998; Schulting and Richards 2002a, 2002b), Portugal (Lubell et al. 1994), and France (Schulting and Richards 2001), and in the Baltic (Lidén 1995) also found significant use of marine foods by coastal Late Mesolithic peoples. Most of these studies have focused on northern Europe, perhaps because there are very few Mesolithic human remains from southern Europe and collagen preservation is generally poor in the warmer southern regions of Europe. There are, however, isotopic values for Neolithic humans from southern Europe, including mainland Greece (Papathanasiou 2001; Papathanasiou, Larsen, and Norr 2000), Crete (Richards and Hedges n.d.), and Malta (Richards et al. 2001), and these indicate that despite the location of these sites on the Mediterranean, Neolithic humans there had a mainly terrestrial diet. Interestingly, this same pattern is observed in studies of the isotopic values of Neolithic humans in northern Europe, especially on the Atlantic coast (Tauber 1981; Richards and Hedges 1999a). It has been argued that this difference is related to a significant dietary shift at the Mesolithic-Neolithic transition (Richards, Schulting, and Hedges 2003; Richards 2003). However, up to this point it has been impossible to explore any such dietary shift at the Mesolithic-Neolithic transition in the Mediterranean area because isotopic data for Mesolithic humans are lacking. Since the Mediterranean is much less productive than the Atlantic, we may not expect to see the same level of marine food consumption as in northern Europe, which in some regions approaches 100%. However, we might predict that if Mesolithic peoples along the Mediterranean coast were following the same hunter-gatherer subsistence adaptation as Mesolithic people in northern Europe, then marine food should have played a significant role in their diets.

In this paper we present the first Mesolithic isotopic data from the Spanish Levant, from the shell midden site of El Collado, and discuss the data in the larger context of European Mesolithic dietary adaptations.

The El Collado Site

Mesolithic human remains are scarce and fragmentary in Spain (table 1 and fig. 1). With a total of 15 human burials, the site of El Collado contains the largest Mesolithic sample in the country. The site lies near the city of Oliva, Valencia, about 3 km from the eastern coast of the Iberian Peninsula. The region has a rich and varied ecosystem, with sea coast, inland rivers and lakes, plains, and mountains. There is evidence of settlement continuity in the area from the Middle Palaeolithic onwards (e.g., at Cova Foradà [Aparicio 1992, 79]), including human remains from the Mesolithic, Neolithic, and later periods.

El Collado is a large open-air shell midden site that was excavated by Aparicio between 1987 and 1989. It yielded a rich Mesolithic industry, faunal remains, and Mesolithic graves (Aparicio 1988, 1989, 1992). The stratigraphy as described by the excavator (Aparicio 1992) consisted of three main units that can be summarized as follows:

Layer 1 (depth ca. 0–1.5 m) was characterized by its black soil and had been greatly disturbed by centuries of agricultural activity. It contained mollusk remains and lithic material dominated by trapezoids and microburins with some notched blades. Aparicio (1992, 85) ascribed this material to destroyed
upper portions of Layer 2 and, possibly, to an obliterated horizon from the Mesolithic IIIA–IIIB transition. Layer 2 (depth ca. 1.5–2.8 m) consisted of a fine, compact, dark brown clayey matrix that became lighter at its base. It was intact and contained a homogeneous Mesolithic IIIA flint industry dominated by flakes and core tools with some scrapers and burins and very few geometric pieces. Mollusk shells were numerous in this layer, with a large proportion from marine species. All of the human burials were found in this layer, and with the exception of burial number 10 the grave cuts extended into Layer 3. There is no mention of any associated grave goods in the excavation report.

Layer 3 was formed by a red clayey soil and was unevenly distributed throughout the site. This layer contained cardium and cockle shells and lithic material consisting of scrapers, burins, and backed blades and ascribed to the Mesolithic I stage (Aparicio 1992, 86).

On the basis of the lithic material, Aparicio (1992, 89) placed the Mesolithic occupation of El Collado between 10,000 and 6500 BC, with the phase of most intense utilization around 7500–6500 BC. Subsequently, two radiocarbon determinations made on human bone from burial 12 yielded the ages of 7,570 ± 160 BP and 7,640 ± 120 BP (Aparicio 1992; Pérez-Pérez et al. 1995), which calibrate to 6630–6250 BC (Stuiver and Reimer 1993; Stuiver, Reimer, and Reimer 2005). These dates agree with Aparicio’s estimate for the age of Layer 2 and the Mesolithic IIIA stage. Although the date was on burial 12, the fact that all graves originated in same layer suggests that they are all broadly contemporaneous and belong to the Mesolithic IIIA occupation.

Brug., *C. tuberculatum* L. *Spondylus gaederopus* L., *Pecten jacobaeus* L., *Arco novaee*. Mammal bones were rare and poorly preserved. The few identified specimens belonged to the Bovidae, Cervidae, Suidae, Rodentiae, and Leporidae families. There was no direct evidence for the contribution of plants to the Mesolithic diet at this site. In contrast to the mammal remains, the human bones were well preserved (fig. 2). The reasons for this difference may be taphonomic. Animal bones were likely deposited on the ground surface and remained exposed for some time, while the humans were buried in the highly basic shell midden. The human remains were studied under the direction of D. Campillo at the Archaeological Museum of Catalonia (Chimenos, Pérez-Pérez, and Lalueza 1991; Pérez-Pérez et al. 1995). Age estimation was based on the degree of mineralization and eruptive phases of teeth in individuals with deciduous or mixed dentitions (Ubelaker 1989) and on dental abrasion in individuals with permanent dentitions (Brothwell 1981; Perizonius 1983). Individuals were identified as one newborn, four subadults (age 12–17 years), and ten adults (age over 18 years), including two classified as mature (age 41–60 years). Sex determination was done on the basis of morphometric traits, especially those of the mandible (Martin and Saller 1957; Ferembach, Schwidetzky, and Stloukal 1979). Seven individuals were identified as males and four as females. Two subadults were probably males, and one adult and the newborn could not be sexed. Only individuals classified as adults were used in the stable isotope analyses (table 2).

### Stable Isotope Analysis for Palaeodietary Reconstruction

The stable carbon and nitrogen isotope ratios of animal tissues and, in particular, bone collagen, can be used to quantify the consumption of foods having different isotopic compositions (DeNiro and Epstein 1978, 1981; Schoeninger and DeNiro...
ponents of the diet. The value indicates the trophic level
be a measure of the marine versus the terrestrial protein com-
underlying bedrock. In these freshwater systems, the
values or can be more or less enriched, depending on local
In freshwater ecosystems the values can mimic terrestrial
such as seals values of 15‰ (Richards and Hedges 1999
piscivorous fish can have values of 12‰ and marine mammals
(Nelson, and Southon 1988). To summarize, 300 mg of ground
isolated through ultrasonication. Collagen extraction proce-
samples were taken from the diaphyses of long bones. In
Nine adult individuals were selected for stable isotope analysis,
in Europe, values in this context will only
top-level consumers than would be found in terrestrial
dietary extremes (e.g., cattle
and terrestrial protein sources (Schoeninger, DeNiro, and
1983). However, since edible C₄ plants are unknown
from Mesolithic Europe, δ¹³C values in this context will only
be a measure of the marine versus the terrestrial protein com-
ponent of the diet. The δ¹⁵N value indicates the trophic level
of the protein consumed, and mammal bone collagen values
are 2–4‰ higher than the average value of dietary protein
(Schoeninger and DeNiro 1984). In aquatic systems, in which
generally there are more steps in the food chain than in ter-
restrial ecosystems, the δ¹⁵N values of top-level consumers
are much higher than the values of their terrestrial counter-
parts. For example, for terrestrial carnivores such as wolves
in Europe, we might expect δ¹⁵N values of 10 ± 1‰, whereas
carnivorous fish can have values of 12‰ and marine mammals
such as seals values of 15‰ (Richards and Hedges 1999b).
In freshwater ecosystems the δ¹³C values can mimic terrestrial
values or can be more or less enriched, depending on local
circumstances such as the input of dissolved carbonates from
underlying bedrock. In these freshwater systems, the δ¹⁵N
values generally follow marine systems, with higher values for
top-level consumers than would be found in terrestrial
ecosystems.

Methods

Nine adult individuals were selected for stable isotope analysis,
and samples were taken from the diaphyses of long bones. In
addition, five bovid bones from the site were sampled for
isotopic analysis.

Prior to the analysis, all visible contaminants were removed
from the bones with a scalpel, and the bones were then further
cleaned through ultrasonication. Collagen extraction proce-
dures followed those outlined in Richards and Hedges
(1999b), with the addition of an ultrafiltration step (Brown,
Nelson, and Southon 1988). To summarize, 300 mg of ground
bone from each sample was demineralized in 0.5 M HCl
solution for two to three days and then rinsed three times
with deionized water until the pH returned to neutral. Coll-
lagen was solubilized by heating the sample to 70°C in water
at pH 3. It was then filtered, ultrafiltered (30 kd), frozen,
and lyophilized. Isotopic measurements (δ¹³C and δ¹⁵N) of col-
gen extracts were determined through CF–IRMS (Thermo-
Finnigan Delta Plus XL coupled with a Carlo Erba elemental
analyzer). Stable isotope ratios were expressed relative to the
vPDB standard for carbon and atmospheric N₂ (AIR) for
nitrogen, using the delta (δ) notation in parts per thousand
(‰). Each sample was run in duplicate, and an internal stan-
dard was measured with each set of ten samples. All samples
discussed here had atomic carbon-to-nitrogen ratios in the
range of 3.2–3.5 and therefore retained their in vivo isotopic
signatures, according to the criterion proposed by DeNiro
(1985) (tables 2 and 3). The data obtained through the chem-
ical investigation were subjected to statistical analyses (SPSS
2001).

Results

The isotopic data obtained from the El Collado material are
given in tables 2 and 3 and presented graphically in figure 3.
Average values for humans and herbivores can be seen in
table 4.

The δ¹³C values for the human remains of El Collado range
from −17.6 to −19.5‰ (with an average of −18.3 ± 0.7‰),
and the δ¹⁵N values range from 8.9 to 12.8‰ (with an average
of 10.3 ± 1.2‰). To interpret the human δ¹³C and δ¹⁵N
values we need to determine theoretical end points, defining
δ¹³C values that correspond to 100% terrestrial and 100%
marine protein diets. For northern temperate Europe, a value
of −20 ± 1‰ is a good approximation of the terrestrial end
point, whereas −12 ± 1‰ defines the marine end point.
These values are largely derived from δ¹³C measurements of
mammals that have these two dietary extremes (e.g., cattle
versus seals) and from isotopic measurements of humans
whose diets can be inferred with some confidence (i.e., 100%
terrestrial diets for individuals from agricultural societies bur-
ied far inland). There is a temperature effect on the values
range of 3.2–3.5 and therefore retained their in vivo isotopic
signatures, according to the criterion proposed by DeNiro
(1985) (tables 2 and 3). The data obtained through the chem-
ic investigation were subjected to statistical analyses (SPSS
2001).

Table 3. Stable Carbon and Nitrogen Isotope Values of Bos
Bone Collagen

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>δ¹³C(‰)</th>
<th>δ¹⁵N(‰)</th>
<th>C:N</th>
<th>% C</th>
<th>% N</th>
</tr>
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<tbody>
<tr>
<td>COLL 101</td>
<td>−19.2</td>
<td>6.0</td>
<td>3.3</td>
<td>12.7</td>
<td>4.4</td>
</tr>
<tr>
<td>COLL 102</td>
<td>−19.3</td>
<td>5.2</td>
<td>3.6</td>
<td>7.7</td>
<td>2.5</td>
</tr>
<tr>
<td>COLL 124</td>
<td>−19.0</td>
<td>5.3</td>
<td>3.4</td>
<td>14.3</td>
<td>4.9</td>
</tr>
<tr>
<td>COLL 125</td>
<td>−19.1</td>
<td>5.8</td>
<td>3.3</td>
<td>12.0</td>
<td>4.3</td>
</tr>
<tr>
<td>COLL 127</td>
<td>−18.5</td>
<td>6.0</td>
<td>3.5</td>
<td>25.1</td>
<td>8.9</td>
</tr>
</tbody>
</table>
To determine terrestrial end points for mammal values (van Klinken 1997; van Klinken, Richards, and Hedges 2000). The marine end point is the same.

In the Atlantic (Jennings et al. 1997; Francalacci 1989; Richards and Hedges 1999), from the Mediterranean have δ13C values similar to those of species from the Atlantic (Jennings et al. 1997; Francalacci 1989; Richards and Hedges 1999b), and therefore the theoretical 100% marine end point is the same, −12 ± 1‰. We interpret the human δ13C values of the El Collado site as indicative of diets with 100% terrestrial protein for the individuals with values close to −19‰, with those individuals with δ13C values close to −17.5‰ having a marine-protein input into the diet of up to 25%.

It has been observed that the δ15N values of terrestrial herbivores in hot climates can be much higher than those in more temperate environments (e.g., in Egypt [Schwarz, Dupras, and Fairgrieve 1999] and Turkey [Richards et al. 2003]). However, the El Collado herbivore δ15N average value is 5.6 ± 0.4‰, which is very similar to that observed for herbivores in other areas of Holocene Europe (e.g., Polet and Katzenberg 2003; Herrscher et al. 2001; Richards 2000). Therefore, we can interpret the human δ15N values as indicators of the sources of terrestrial protein, with an end point of approximately 6‰ indicating a 100% plant protein diet and an end point of 10‰ indicating a 100% animal (herbivore) protein diet. Values that exceed the end point of 10‰ will therefore be indicative of the consumption of protein from an aquatic ecosystem. Therefore, both δ13C and δ15N values will change with increasing input of marine protein into a largely terrestrial diet, with the δ13C values approaching the end point of −12 ± 1‰ and the δ15N values increasing depending on the source of marine protein. For example, if the protein source is piscivorous fish, we would expect a δ15N end point similar to that for marine mammals, in the range of 15–18‰. Turning to the δ13C and δ15N human data from El Collado, we observe that there is no uniform diet at this site. Some individuals have a nearly 100% terrestrial protein diet, largely from animal sources. Other individuals, such as individuals 3 and 4, have clear marine input in their diets. The δ15N values of individuals with significant marine input vary, likely indicating different sources of marine protein. Individual 3, for example, has a δ15N value of 10.2‰, which probably reflects the consumption of lower-trophic-level foods such as marine shellfish, whereas individual 4, with a value of 12.8‰, likely consumed higher-trophic-level marine food such as fish.

What is clear from these data, however, is that despite the fact that the site is a shell midden, marine foods were not the dominant dietary protein sources at this site. The isotopic values are significantly less enriched than those of Late Mesolithic humans from Denmark and the UK but have affinities with the values from estuarine sites in Portugal (Lubell et al. 1994).

There are no discernible differences in isotope values between males and females at El Collado (U Mann-Whitney test, \(P = 0.39\) for δ13C and \(P = 0.25\) for δ15N). This is the usual tendency observed in Mesolithic populations in which there are enough individuals to make gender comparisons (e.g., Lillie and Richards 2000), although differences have been observed (Schulting and Richards 2001). However, it is possible to observe graphically a tendency toward lower δ15N values in the female subgroup (fig. 3), which may be related to a more terrestrial diet. We cannot forget that because of the limited size of the human sample, our data set is inadequate to demonstrate gender differences in access to food-stuffs.

Figure 3. Bone collagen δ13C and δ15N values of adult humans and Bos from El Collado.

Discussion

The El Collado isotopic data clearly show that marine foods were an important part of the diets of some individuals at this site but not the dominant dietary protein sources despite the site’s nature as a shell midden and its coastal location. Interestingly, contemporary earlier Mesolithic humans in both Denmark (e.g., Tybrind Vig, ca. 6,740 BP, \(δ^{13}C = −17.6‰, δ^{15}N = 8.5‰\) [Richards, Price, and Koch 2003]) and South Wales (e.g., Potter’s Cave 308, ca. 8,580 BP, \(δ^{13}C = −17.3‰, δ^{15}N = 13.1‰\) [Schulting and Richards 2002a]) also had isotopic values indicative of approximately 25% marine protein consumption, but this was more mixed. Perhaps the early Mesolithic data from these contexts, including El Collado, are contributing to a picture of early Mesolithic subsistence patterns that conforms to the generally accepted view of mobile hunter-gatherers using a range of seasonally available food resources, including marine foods. Only in the Mesolithic do we see isotopic values indicating large-scale reliance on marine foods. Another explanation for the relatively minor contribution of marine foods in the diets of humans from El Collado as opposed to those in northern Europe may be the less productive nature of the Mediterra-
nean versus the Atlantic. It may simply have been impossible to obtain enough marine foods to survive in the Mediterranean area and therefore diets had to be supplemented by terrestrial foods.

To explore the meaning of the El Collado isotopic data further we can compare our results with those for other early prehistoric (pre-Neolithic) humans from the Mediterranean (table 5). There are two published values for Palaeolithic humans, both from the site of Arene Candide in Ligura, Italy. Pettitt et al. (2003) found evidence of a marine contribution to the diet of the "Il Principe" Gravettian burial, with isotopic values remarkably similar to those reported here for individual 4. An earlier study of two Late Palaeolithic humans from Arene Candide (ca. 11,000 BP) and two Mesolithic humans from the site of Uzzo Cave, Sicily (ca. 9,000 BP), by Francalacci (1989) did not produce similar results; here the $^{15}N$ values indicated a largely animal-protein diet. There appears to have been a range of diets in the Upper Palaeolithic and early Mesolithic in coastal Spain and Italy, with some individuals obtaining their protein largely from terrestrial animal sources while others obtained up to 25% of their protein from the Mediterranean.

Summary and Conclusions

Most of the previous isotopic research on the European Mesolithic has been in northern Europe, where there is clear evidence for a marine adaptation, especially in the Late Mesolithic. There are few data from southern Europe as a whole, and the data presented here are similar to those presented elsewhere for early Mesolithic humans in northern Europe in pointing to a seasonal dietary adaptation with the use of marine foods during only certain periods of the year. As more data become available we will be better able to compare the Mesolithic dietary adaptations in northern and southern Europe and in Palaeolithic, Mesolithic, and Neolithic populations.

Acknowledgments

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References Cited


<table>
<thead>
<tr>
<th>Site</th>
<th>Species</th>
<th>$n$</th>
<th>$\delta^{13}C$ (Average)</th>
<th>$\delta^{15}N$ (Average)</th>
<th>Source</th>
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<tbody>
<tr>
<td>Arene Candide (ca. 11,000 BP)</td>
<td>Herbivore</td>
<td>9</td>
<td>−19.4</td>
<td>4.7</td>
<td>Francalacci (1989)</td>
</tr>
<tr>
<td></td>
<td>Human</td>
<td>2</td>
<td>−19.5</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>Arene Candide (ca. 23,500 BP)</td>
<td>Human</td>
<td>1</td>
<td>−17.6</td>
<td>12.4</td>
<td>Pettitt et al. (2003)</td>
</tr>
<tr>
<td>Uzzo Cave (ca. 9000 BP)</td>
<td>Herbivore</td>
<td>2</td>
<td>−20.9</td>
<td>6.2</td>
<td>Francalacci (1989)</td>
</tr>
<tr>
<td></td>
<td>Fish</td>
<td>3</td>
<td>−10.4</td>
<td>10.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cetacean</td>
<td>2</td>
<td>−17.1</td>
<td>11.8*</td>
<td></td>
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<tr>
<td></td>
<td>Carnivore</td>
<td>1</td>
<td>−18.8</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Human</td>
<td>2</td>
<td>−21.0</td>
<td>10.6</td>
<td></td>
</tr>
</tbody>
</table>

*Only one sample for $\delta^{15}N$. 

Table 4. Average and One Standard Deviation of Stable Carbon and Nitrogen Isotope Values of Human and Bos Bone Collagen

<table>
<thead>
<tr>
<th></th>
<th>$n$</th>
<th>$\delta^{13}C(‰)$</th>
<th>$\delta^{15}N(‰)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult males</td>
<td>5</td>
<td>−18.1 ± 0.6</td>
<td>10.8 ± 1.2</td>
</tr>
<tr>
<td>Adult females</td>
<td>3</td>
<td>−18.4 ± 0.6</td>
<td>9.4 ± 1.0</td>
</tr>
<tr>
<td>All humans</td>
<td>9</td>
<td>−18.3 ± 0.7</td>
<td>10.3 ± 1.2</td>
</tr>
<tr>
<td>Bos</td>
<td>5</td>
<td>−19.0 ± 0.3</td>
<td>5.6 ± 0.4</td>
</tr>
</tbody>
</table>

Table 5. Stable Carbon and Nitrogen Values from Two Italian Palaeolithic and Mesolithic Sites


Richards, M. P. 2000. Human consumption of plant foods in the British Neolithic: Direct evidence from bone stable iso-


