Isotope evidence for the use of marine resources in the Eastern Iberian Mesolithic

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1. Introduction

The central Iberian Mediterranean region is centered around the coastal area of Valencia. To the north, west and south of this alluvial plain are the Iberic and Betic mountain ranges, with layered valleys and mountain peaks that reach up to 1500 m in altitude. This region has a long tradition of research on the Epipaleolithic and Mesolithic periods (Fortea, 1973; Martí et al., 2009) with recent published syntheses on environmental (Badal and Carrión, 2001), funerary (Aura, 2009; Olária et al., 2010; García Puchol et al., 2012), palaeoeconomy (Aura et al., 2005, 2009) and chronological (Aura et al., 2011) questions.

The archaeological regional sequence of the last foragers in this region is organized into two major periods (Aura, 2001; Aura et al., 2011): the Epi-Magdalenian (13,200–10,500 calBP) and the Mesolithic (10,100–7600 calBP). The Epi-Magdalenian has a tradition of blade lithic production (end-scrapers, retouched blades, notches, etc.) with bladelet projectile components that incorporate micro-liths from the Younger Dryas (12,900–11,500 calBP) onwards (small triangles and segments, double points, Sauveterre points, etc.), and a few bone and antler points. The Mesolithic is divided into two stages: an initial Mesolithic with notches and denticulates, characterized by flake production and knapping of local raw materials (Alday, 2006), and a later Geometric Mesolithic with laminar production used as support for the elaboration of geometric tools (triangles, trapezes, segments). The sites studied here correspond to both Mesolithic stages (Aura, 2009).

The palaeoeconomy data shows the use of resources from the coastal, inner valley, and middle-mountain areas. The most common mammal species found at Mesolithic sites are Cervus elaphus and Capra pyrenaica. Sus scrofa, Rupicapra rupicapra, and Capreolus capreolus also present in lower frequencies and Equus sp. and Bos sp. appear rarely. The most common carnivores are Vulpes vulpes, Felis sylvestris, Lynx pardina and Canis lupus. Small-game (Oryctolagus cuniculus and birds) are abundant but appear in lower frequencies than during the Late Magdalenian (Aura et al., 2009).

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The archaeological evidence points to a regional settlement model that has links between coastal and high altitude inland sites. Data come exclusively from rock shelters and caves, since there is a lack of knowledge about open-air sites in the region for this period. In this context, and acknowledging the presence of marine remains at the inland site of Santa Maira (Aura et al., 2009), direct dietary evidence obtained from carbon and nitrogen stable isotope analysis would help to establish if there was the regular consumption of marine resources at these inland sites, and if so, help us better understand the regional settlement, contact between inland and coastal sites, and the use of the landscape in the Mesolithic of this area.

2. The study sites

2.1. Coves de Santa Maira

The site of Coves de Santa Maira is a cave located in the Valencian town of Castell de Castells (Fig. 1 and Fig. 2a) and was discovered during the 1980s. It occupies a rocky promontory 600 m above sea level, close to the river Gorgos in the Barranc de Famorca, in an area known for its Neolithic rock art shelters (Hernández et al., 1988). Five units have been described at the west hall trench (Aura et al., 2008): Unit 5 (Late Magdalenian), Unit 4 (Epimagdalenian and Epipaleolithic with Sauveterrian elements), Unit 3 (Mesolithic), Unit 2 (Neolithic), Unit 1 (more recent periods). Radiocarbon dates for the Mesolithic sequence can be found in Table 1.

Although excavation and analysis is still ongoing, the initial anthropological study (De Miguel, 2009) of the human remains from the Mesolithic levels gives an MNI (Minimum Number of Individuals) of three: 2 adults and 1 child (Table 2). Palaeoenvironmental reconstruction shows an expansion of the Holocene forest (Aura et al., 2005, 2006; Badal and Carrión, 2001). Geoarchaeological and micromorphology studies show temperate conditions during the Mesolithic (Aura et al., 2006; Verdasco, 1999). Lithic and bone industry studies show successive episodes of Mesolithic occupations in relation to the exploitation of the middle-mountain region (Aura, 2001; Aura et al., 2006; Miret, 2007). Faunal and palaeoeconomical research suggests that the site was used for specialised goat hunting, although the number of forest animal remains at the site (Cervus elaphus, Rupicapra rupicapra and Sus scrofa) increased through the Holocene. The use of small-game (rabbits, hedgehogs, foxes), plants and marine resources (fish, molluscs) has also been documented (Aura et al., 2005, 2006, 2009; Pérez-Ripoll, 1992).

2.2. Penya del Comptador

Penya del Comptador is a rock shelter located close to the Valencian town of Alcoi, at 850 m above sea level (Figs. 1 and 2b). This site has only a sparse archaeological record, although two different time periods can be identified: an Early Neolithic occupation with cardial pottery fragments in the surface, and a Mesolithic burial at the bottom with a few flakes, blades, cores, and retouched tools (backed bladelets, endscrapers, notches). Its archaeological materials come from a deposit that has been completely destroyed except for one part attached to the wall (Aura et al., 2006). The most important findings are the adult human remains (Table 3), which have been dated to the Mesolithic (Aura et al., 2006; De Miguel, 2009). As can be seen in Table 1, the dates are quite similar to the ones from Coves de Santa Maira. Both sites are very close to each other, only 20 km apart.

2.3. Cingle del Mas Nou

Cingle del Mas Nou is an open-air site close to a rock shelter situated in the town of Ares del Maestre, in the northern part of the Valencian Country. It is on the southern side of Serra d’En Seller, close to the valleys of Cirerals and Molero, at 940 m above sea level (Figs. 1 and 2c). The site was discovered in 1975, and excavations ran from 1986 to 1999. The stratigraphic sequence of the site is divided into five levels, grouped in two occupation phases: Levels I and II are associated with the Early Neolithic, Levels III and IV to the Geometric Mesolithic, and Level V is sterile (Olària, 2007). The analysis of the excavated remains is ongoing. Nine human individuals dating to the Mesolithic have been described (Table 4): 2 adults and 7 children of different ages (Olària et al., 2010).

3. Stable isotopes and palaeodietary reconstruction

Carbon and nitrogen stable isotope analysis is a commonly used method for the reconstruction of past human and animal diets. This technique is based on the principle that the isotopic composition of the food eaten by both animals and humans is recorded on their...
body tissues after a predictable isotope fractionation (Schoeller, 1999, and see reviews by Ambrose, 1993; Katzenberg, 2000; Lee-Thorp, 2008; Sealy, 2001).

The $\delta^{13}C$ stable isotope ratio distinguishes the consumption of terrestrial ($^{13}C$ depleted) and marine ($^{13}C$ enriched) foods (Chisholm et al., 1982). It helps as well to define the input on the diet of C$_3$ ($^{13}C$ depleted) from C$_4$ resources ($^{13}C$ enriched) (Van der Merwe and Vogel, 1978). Since there are no edible C$_4$ plants reported in Europe during the Mesolithic time period (Sage et al., 1999), the main use of carbon isotopes is for estimating the consumption of marine protein. In an ecosystem devoid of C$_4$ plants, a $\delta^{13}C$ value around $-20_{\%}$ would indicate a total terrestrial diet, and one about $-10$ to $-12_{\%}$ would indicate that almost all ingested protein was marine. The $\delta^{15}N$ stable isotope ratio increases by 3–5$\%$ up the food-chain with each trophic level, meaning that the consumer has higher values than the consumed protein (De Niro and Epstein, 1981; Schoeninger and De Niro, 1984). This makes nitrogen stable isotopes useful for detecting the presence of high trophic level marine and freshwater foods on the diet (Schoeninger et al., 1983). However, the distinction of animal-rich diets from plant-rich diets using $\delta^{15}N$ values (Minagawa and Wada, 1984) is less straightforward than previously thought (i.e. Hedges and Reynard, 2007; Warinner et al., 2013).

Bone and tooth collagen are the preferred substrate for carbon and nitrogen stable isotope analysis. Quality indicators are used to determine the preservation quality of the extracted collagen (De Niro, 1985; Van Klinken, 1999). Because of slow collagen turnover, collagen stable isotope values reflect an average diet representative of the last 10–15 years of life (Hedges et al., 2007). In addition, they mainly reflect the isotopic signals of the main dietary protein sources rather than that of a diet as a whole, especially for nitrogen (Ambrose and Norr, 1993) since carbon may be derived from other dietary macronutrients like sugars and fats (Howland et al., 2003; Jim et al., 2006).

4. Material and methods

4.1. Radiocarbon dating

Four human bone samples were selected from the three sites for AMS radiocarbon dating: one from Santa Maira, one from Penya del Comptador, and two from Cingle del Mas Nou (see “New dates” from Table 1). Bone was pre-treated for collagen extraction at the Department of Human Evolution of the Max Planck Institute for Evolutionary Anthropology (Leipzig, Germany) following the method described below. AMS radiocarbon analyses were performed at the Oxford laboratories. Calibration of radiocarbon dates was performed using IntCal09 and OxCal 4.2beta (Bronk Ramsey, 2009; Reimer et al., 2009).
2. Stable isotopic analysis

Prior to analysis, visible contaminants were removed with aluminium oxide powder abrasion. Collagen extraction proceeded following Richards and Hedges (1999), with the addition of an ultrafiltration step (Brown et al., 1988). To summarize, whole bone pieces of ca. 300 mg from each human and animal fragment were demineralized in 0.5 M HCl solution at 5°C over the course of one week, and were then rinsed three times with deionized water.

### Table 1
Radiocarbon dates from Coves de Santa Maira, Penya del Comptador and Cingle del Mas Nou.

<table>
<thead>
<tr>
<th>Site</th>
<th>Context</th>
<th>Material</th>
<th>Site</th>
<th>Sampled bone</th>
<th>Archaeological context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coves de Santa Maira</td>
<td>Mesolithic</td>
<td>Human bone</td>
<td>S-EVA 9051 OxA-V-2360-26</td>
<td>8283</td>
<td>37</td>
</tr>
<tr>
<td>Penya del Comptador</td>
<td>Mesolithic</td>
<td>Human bone</td>
<td>– Beta 244010</td>
<td>8690</td>
<td>50</td>
</tr>
<tr>
<td>Penya del Comptador</td>
<td>Mesolithic</td>
<td>Human bone</td>
<td>– Beta 156025</td>
<td>8570</td>
<td>40</td>
</tr>
<tr>
<td>Cingle del Mas Nou</td>
<td>Mesolithic</td>
<td>Human bone</td>
<td>S-EVA 9097 OxA-V-2360-30</td>
<td>8825</td>
<td>38</td>
</tr>
<tr>
<td>Cingle del Mas Nou</td>
<td>Mesolithic</td>
<td>Human bone</td>
<td>S-EVA 9089 OxA-V-2360-29</td>
<td>6925</td>
<td>35</td>
</tr>
<tr>
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<td>Mesolithic</td>
<td>Human bone</td>
<td>– Beta 170715</td>
<td>6820</td>
<td>40</td>
</tr>
</tbody>
</table>

### Table 2
Santa Maira δ13C and δ15N values, human sex and age, collagen control indicators (yield, %C, %N, C:N), S-EVA number, sampled bone and archaeological context [M?: probable male/F?: probable female].

<table>
<thead>
<tr>
<th>S-EVA</th>
<th>Species</th>
<th>δ13C (‰)</th>
<th>δ15N (‰)</th>
<th>Sex</th>
<th>Age</th>
<th>Yield (%)</th>
<th>%C</th>
<th>%N</th>
<th>C:N</th>
<th>Sampled bone</th>
<th>Archaeological context</th>
</tr>
</thead>
<tbody>
<tr>
<td>7691</td>
<td>Human</td>
<td>19.5</td>
<td>2.9</td>
<td>Male</td>
<td>29</td>
<td>43.6</td>
<td>16.8</td>
<td>3.6</td>
<td>3.2</td>
<td>Femur diaphysis</td>
<td>AB 6/1-3.18</td>
</tr>
<tr>
<td>7692</td>
<td>Human</td>
<td>19.4</td>
<td>3.0</td>
<td>Male</td>
<td>31</td>
<td>43.5</td>
<td>16.9</td>
<td>3.6</td>
<td>3.2</td>
<td>Femur diaphysis</td>
<td>AB 5/1-3.18</td>
</tr>
<tr>
<td>9031</td>
<td>Human</td>
<td>19.5</td>
<td>3.0</td>
<td>Male</td>
<td>31</td>
<td>43.5</td>
<td>16.9</td>
<td>3.6</td>
<td>3.2</td>
<td>Femur diaphysis</td>
<td>AB 5/1-3.18</td>
</tr>
<tr>
<td>7662</td>
<td>Cervus elaphus</td>
<td>19.4</td>
<td>3.0</td>
<td>Male</td>
<td>31</td>
<td>43.5</td>
<td>16.9</td>
<td>3.6</td>
<td>3.2</td>
<td>Femur diaphysis</td>
<td>AB 5/1-3.18</td>
</tr>
<tr>
<td>7685</td>
<td>Cervus elaphus</td>
<td>19.4</td>
<td>3.0</td>
<td>Male</td>
<td>31</td>
<td>43.5</td>
<td>16.9</td>
<td>3.6</td>
<td>3.2</td>
<td>Femur diaphysis</td>
<td>AB 5/1-3.18</td>
</tr>
<tr>
<td>7686</td>
<td>Cervus elaphus</td>
<td>19.4</td>
<td>3.0</td>
<td>Male</td>
<td>31</td>
<td>43.5</td>
<td>16.9</td>
<td>3.6</td>
<td>3.2</td>
<td>Femur diaphysis</td>
<td>AB 5/1-3.18</td>
</tr>
</tbody>
</table>

*In italics the samples that didn’t have good collagen quality indicators.
and ultra measured relative to the AIR scale (atmospheric N2), using the delta Evolutionary Anthropology (Leipzig, Germany). Stable carbon measured in duplicates using a Delta XP continuous- into tin capsules and loaded into the mass spectrometers.

The stable isotope results for the humans and animals from Cingle del Mas Nou are presented in Table 2 and Fig. 3. The stable isotope results for the humans and animals from Penya del Comptador are presented in Table 3 and Fig. 4. The stable isotope results for the humans and animals from Cingle del Mas Nou are presented in Table 4 and Fig. 5.

5. Results

The stable isotope results for the humans and animals from Santa Maira are presented in Table 2 and Fig. 3. The stable isotope
Bone samples from 3 humans and 27 animals were taken from the Mesolithic layers of Santa Maira, and from Penya del Comptador, bones of 3 humans and 3 unidentified medium-sized herbivores. All human remains and almost all terrestrial animal samples yielded enough collagen at the >30 kDa fraction for analysis in duplicate, and met published quality controls (Ambrose, 1993; Van Klinken, 1999). Only 2 of the 8 fish bones sampled had good quality collagen in the >30 kDa fraction enough for one measurement (the other samples yielded no collagen). Collagen extracted from one human bone from each site (S-EVA 9051 and 9097) was sent to the Radiocarbon Accelerator Unit of Oxford University for analysis. The human bone from each site (S-EVA 9051 and 9097) was sent to the Radiocarbon Accelerator Unit of Oxford University for analysis. The resulting dates (Table 1, Fig. 6) are compatible with the archaeological findings at the sites and the Mesolithic period at the region.

The herbivore δ¹³C values from Santa Maira (m = −20.3 ± 1.2 [1σ] %o, min: −21.7%o, max: −18.4%o) and Penya del Comptador (m = −19.5 ± 0.4 [1σ] %o, min: −19.9%o, max: −19.2%o) are typical values for a terrestrial C₃ European ecosystem (De Niro and Epstein, 1978; Schwarcz and Schoeninger, 1991). Most herbivores group between −20 and −18.5%o, and the presence of rabbits depleted in δ¹³C increases the standard deviation. The carnivore δ¹³C values (m = −19.1 ± 0.4 [1σ] %o, min: −19.4%o, max: −18.4%o) are consistent with the majority of herbivore values and a terrestrial C₃ food web. The herbivore δ¹⁵N values from Santa Maira (m = 3.7 ± 0.8 [1σ] %o, min: 2.6%o, max: 4.8%o) and Penya del Comptador (m = 4.4 ± 0.8 [1σ] %o, min: 3.6%o, max: 5.2%o) define the trophic baseline of the local mammalian food web. The carnivore δ¹⁵N mean value is 6.0 ± 0.9 (1σ) %o, which is almost 2.5%o more positive than the Santa Maira herbivore mean value (3.7%o), consistent with these species being a trophic level above the herbivores at the site (De Niro and Epstein, 1981; Minagawa and Wada, 1984). The fish (n = 2) δ¹³C mean value is −15.2%o and its δ¹⁵N mean value is 8.5%o, which is for low for purely marine fish (Chisholm et al., 1982; Schoeninger and De Niro, 1984) but could be result of the lifecycle of the species sampled, Sparidæ and Mugilidæ, which live for part of their life in rivers or estuaries.

All humans from Santa Maira have δ¹³C and δ¹⁵N mean values of −18.0 ± 0.2 (1σ) %o (min: −18.1%o, max: −17.8%o) and 9.3 ± 0.6 (1σ) %o (min: 9.0%o, max: 10.3%o) respectively. Their carbon values describe a diet where the protein was based mainly on terrestrial C₃ resources. Their nitrogen values clearly situate them in a higher trophic level than both the herbivores (almost 6%o higher) and the carnivores (3%o higher). Both δ¹³C and δ¹⁵N values together suggest that the diet included enough marine protein as to positively shift the carbon values almost 3%o from the herbivore mean value and the nitrogen values 3%o higher than the carnivores. There is no trace of freshwater protein consumption in the diet.

The δ¹³C mean value for the humans of Penya del Comptador is −18.5 ± 0.2 (1σ) %o (min: −18.7%o, max: −18.2%o), which is consistent with a diet based mainly on C₃ terrestrial resources. Their δ¹⁵N mean value is of 7.7 ± 0.1 (1σ) %o (min: 7.6%o, max: 7.8%o), which situates humans in a clear higher trophic position than the fauna (probably herbivores, 3%o higher). The combined δ¹³C and δ¹⁵N mean values also indicate that probably all the protein in the diet was from terrestrial C₃ animal sources.

The Santa Maira humans group tightly together, as observed in Fig. 3, showing no difference in protein input regardless of their expected sex or age. The terrestrial animals most likely consumed by the humans were the ibex, wild boar and red deer. There is no clear isotopic evidence of significant rabbit consumption by this population as suggested by zooarchaeological analyses on the Mesolithic levels of the site (Ara et al., 2006, 2009). Contrary to what is observed for Santa Maira, the humans from Penya del Comptador show no evidence for marine protein consumption and consume a largely homogeneous terrestrial C₃ diet (Fig. 4).

5.2. Cingle del Mas Nou isotope data

Samples from 9 humans (3 adults, 1 sub-adult, 3 infants, 2 perinatals) and 36 animals, of 7 different species, were taken from the Mesolithic contexts. All human and almost all terrestrial animal bones yielded enough collagen to run samples in duplicate. Collagen passed quality control criteria (Ambrose, 1993; Van Klinken, 1999), indicating good preservation in the >30 kDa fraction. Samples S-EVA 17066 and 17096 yielded enough collagen for only one run. Collagen extracted from the bones of two humans from Cingle del Mas Nou (S-EVA 9084 and S-EVA 9089) was also sent to the Radiocarbon Accelerator Unit of Oxford University for analysis. These two dates (Table 1, Fig. 6) are compatible with the archaeological findings and the Mesolithic period at the region.

The Cingle del Mas Nou herbivore δ¹³C values (m = −19.9 ± 0.6 (1σ) %o, min: −21.4%o, max: −18.8%o) are typical of a terrestrial C₃ European ecosystem (De Niro and Epstein, 1978; Schwarcz and Schoeninger, 1991). The tightly grouped herbivore δ¹⁵N values (m = 3.8 ± 0.5 (1σ) %o, min: 2.3%o, max: 4.7%o) set the ‘baseline’ for the local food chain and interpretation of human dietary values. Omnivores (Sus scrofa) present carbon and nitrogen values more positive than the herbivore ones: δ¹³C mean value of −19.8 ± 1.1 (1σ) %o and δ¹⁵N mean value of 6.6 ± 1.1 (1σ) %o. The carnivores have more positive δ¹³C values than the herbivores: −17.9 and
Fig. 6. Calibrated ages calculated using OxCal 4.2 and IntCal09 (Bronk Ramsey, 2009; Reimer et al., 2009) for the three Mesolithic sites. The OxA dates produced in this paper are in red. Beta results are in black. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

6. Discussion

The results from the three Eastern Iberian Mesolithic sites studied show that the diet of these populations was mainly a terrestrial C3 diet. There is no clear isotopic evidence for freshwater food intake on the diet at any of the sites, although it must be
considered that freshwater values are highly variable and that remains were unfortunately not available for analysis. There is no isotopic evidence of marine protein intake at Penya del Comptador, but evidence for some marine protein consumption at the sites of Santa Maira and Cingle del Mas Nou. At all three sites the majority of protein was from C3 animal sources.

This dietary pattern is similar to the stable isotope results from other Mediterranean Mesolithic sites studied, but differs from other European Mesolithic populations. Few datasets for Mesolithic Western and Central Mediterranean populations have been published so far, so this described pattern could change with new isotopic studies. In Atlantic (i.e. Richards and Hedges, 1999; Richards et al., 2003; Schulting et al., 2008; Schulting and Richards, 2002) and Baltic (i.e. Eriksson, 2003; Lidén et al., 2004) Mesolithic sites there exists a considerable consumption of aquatic resources, while in the Mediterranean populations it is almost absent. In Mesolithic sites from Italy (Francalacci, 1988; Mannino et al., 2011), Croatia (Lightfoot et al., 2011) and Corsica (Vigne, 2004) there is no isotopic evidence of significant levels of marine food consumption.

Isotope results from two Mesolithic Eastern Iberian sites have also been published: the shell midden of El Collado (García-Guixé et al., 2006) and the Late Mesolithic site of La Corona (Salazar-García et al., 2013). All δ13C and δ15N values from these Mediterranean Iberian sites are plotted in Fig. 7, together with the sites from this study. Humans from Penya del Comptador, La Corona and some from Cingle de Mas Nou and El Collado clearly present a completely terrestrial diet that shows no isotopic evidence for aquatic resource consumption (the individual from La Corona with a highest carbon and nitrogen value is an infant whose values are positively shifted due to the breastfeeding influence). The humans from Santa Maira and some from Cingle del Mas Nou and El Collado show a significant marine protein input in the diet, up to about 25% for the two individuals with the highest δ13C values (García-Guixé et al., 2006).

All of this shows both an inter- and an intra-heterogeneity of the diet of the last hunter-gatherer societies of Eastern Iberia. The geographic location is sometimes the best predictor of the diet of these populations (Fig. 1). It is expected that populations that lie far away from the coast, such as La Corona or Penya del Comptador, show no isotopic evidence for marine food in the diet, or that populations like El Collado, which lie on the coast, consumed some marine protein. There are some sites like Santa Maira or Cingle del Mas Nou that lie in the mid-mountain area, far from the coast, where the population had enough of a marine signal in their collagen to likely imply an inland-coastal population mobility or an existence of a wide exchange network that connects these sites with other populations living on the coast. This was suggested in a published model of settlement population dynamics for the region that proposes the existence of fifteen Mesolithic groups occupying 700–1200 km² of land with a diameter of 25–35 km from the littoral up to the upper-mountain area (Aura, 2001; Martí et al., 2009). Furthermore, the development of the first necropolis in this region at 9500 calBP is consistent with the presence of contemporary shelters, caves and open-air sites in the same region, suggesting the integration of different human groups in a same territory and probably also indicating an increase in sedentism (Aura, 2009).

For Penya del Comptador and La Corona the preliminary zooarchaeological finds are compatible with the isotope evidence of a mainly terrestrial diet. At Penya del Comptador the faunal remains are few and poorly preserved, exhibiting a lack of fish and shellfish, although that may be due to post-depositional processes not preserving the fish and shellfish remains (Aura et al., 2006). For La Corona only terrestrial animals have been found in the Mesolithic levels, except for some marine shellfish (Columbella rustica) used as parts of body ornaments and never attributed to being the products of food consumption (Salazar-García et al., 2013). The same cannot be said for Cingle del Mas Nou, where the faunal study shows that red deer and goat were the most abundant species and there are no freshwater or marine remains (Ollària et al., 2005), while the isotopic study suggests marine consumption in the diets of some of the humans from the site.

The faunal analysis from the upland site of Santa Maira is much more complete and identifies a diet based on terrestrial animals with the ibex as the main dietary element. It shows an increase in the relative presence of the minority taxa from the Late Upper Palaeolithic to the Mesolithic levels, namely forest species and small carnivores. Rabbit remains are still the most abundant and show cutmarks from whole animal processing (Aura et al., 2009). The stable isotope analysis shows that rabbit was not a main protein source in human diets at this site, perhaps because of the relatively low amount of meat on rabbits compared to larger herbivores. Although not present in great quantities, edible shellfish (Mytilus edulis, Cardium sp.) and fish remains (Anguilla anguilla, Sparus aurata, Diplodus vulgaris, Sparus sp., Mugil sp.) increase considerably in frequency in the Mesolithic levels of Santa Maira compared to previous periods (Aura et al., 2008, 2009), probably
related to the raised sea level and the possible subsequent increase in movement between these inland valley sites and the coastal plain, which matches the isotopic evidence for human consumption at the site.

What we call here the “fish paradox” should be assessed when addressing fish consumption by stable isotopes at Western Mediterranean sites such as Santa Maira and Cingle del Mas Nou. Typically, a marine human value of around −10 to −12‰ δ13C is considered to represent a 100% marine diet (Chisholm et al., 1982; Schoeninger and De Niro, 1984). However, the published prehistoric fish remains from the Western Mediterranean are more negative than expected, with highly ranging δ13C values from −8 to −16‰. In Fig. 8 all archaeological Mesolithic humans are plotted with the prehistoric fish published from the Western Mediterranean: Santa Maira (Mesolithic), Cova de l’Or (Early Neolithic, Salazar-García, 2012a), La Vital (Late Neolithic, Salazar-García, 2012b), Cova des Riuets (Bronze Age, García-Guixé et al., 2010) and Monte Leone (Mesolithic, published in Vigne, 2004). Sometimes the more negative than expected fish δ13C values may be caused simply because some fish (i.e. Sparidae and Mugilidae) are estuarine-marine, or because some whale remains are filter feeders that eat a large quantity of small low-trophic level organisms. The issue is that by consuming some marine foods with more negative isotopic values, it is possible that one of these sites a “marine diet” could actually result in a more negative human δ13C carbon isotope value than that usually expected. If so, we consider that the fish remains from Santa Maira are mainly from Sparidae and Mugilidae, it is possible that their contribution to human diets could have been significant, highlighting the importance of measuring fish remains from archaeological sites alongside the humans whenever possible in order to more accurately quantify the amount of aquatic protein consumed in the diet.

Although probably less evident than marine consumption through isotopic evidence, the archaeological Mesolithic Western Mediterranean sequence also shows the use of vegetable resources (Buxó, 1997; Holden et al., 1995; Zapata et al., 2002). Plenty of seed and fruit remains have been recovered at Eastern Iberian Mesolithic sites like Santa Maira, mainly from shrubs and trees (Crataegus sp., Juniperus sp., Olea europaea var. sylvestris, Pistacia sp., Quercus sp., Sorbus sp., Vitis vinifera var. sylvestris) and also from legumes (Lathyrus/Vicia) (Antolin et al., 2010; Aura et al., 2005). The significant consumption of these plants is not indicated by the isotope analysis, likely due to the relatively low amounts of protein in plants compared to herbivore meat. However, it could also indicate that plants were not regularly consumed, and could also be used for other purposes (preparing glues, as part of firewood, etc.).

7. Conclusions

There is no clear direct relationship between proximity to the coast and consumption of marine resources in the Eastern Iberian Mesolithic up to a certain distance from the coast. The type of site (open-air, rock shelter-cave) is also not related to the level of sea-food consumption. Therefore, the use of marine resources by the Mesolithic people in Eastern Iberia could probably be explained by demographic and social factors.

The observed pattern of different use of resources showing variability between sites suggests a constant high inland-coastal mobility amongst these populations. The northern inland site of Cingle del Mas Nou suggests a human consumption of some marine resources and thus a connection with the coast. From the southern sample, the results from the coastal site of El Collado and the inland site of Santa Maira (30 km from sea) suggest an unequal and low consumption of marine resources amongst individuals, while the data from Penya del Comptador and La Corona (>40 km from the coast) show no isotopic nor archaeozoological evidence for marine resource consumption. Future isotope studies focussing on mobility, such as strontium and sulphur, will help in interpreting the relationship between marine consumption and coastal-inland human mobility in this region.

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