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At the land's end: Marine resources and the importance of fluctuations in the coastline in the prehistoric hunter–gatherer economy of Portugal

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ABSTRACT

This paper focuses on the importance of aquatic resources in economy and subsistence strategies during the Middle and Upper Palaeolithic of Portugal. Modern theoretical biases in archaeology have led to a marginalization of marine resources and a dismissal of their use by Palaeolithic hunter–gatherers. Geological and archaeological data show that changes in the position of the coastline had a direct impact on the visibility of marine resources in the archaeological record. Marine regressions and transgressions have significantly altered the record of Pleistocene coastal settlement. Using recent studies on changes in upwelling intensity during the Last Glacial we offer a new perspective on Palaeolithic hunter–gatherer economy that emphasizes the importance of the coast as a focus of subsistence and settlement.

1. Introduction

The rarity of Pleistocene hunter–gatherer sites along the coasts of Western Europe led to a virtual consensus among archaeologists in the late 20th century that Palaeolithic people largely ignored this type of environment. Aquatic animals, especially molluscs, were perceived as fallback resources that people relied on to avoid starvation in times of terrestrial resource scarcity. Marine and estuarine economies, well-known from the Early Holocene, were seen as the result of technological "revolutions" and/or demographic pressure. The postglacial expansion of diet breadth visible in the archaeological record after global sea level rise was thought to suggest a new subsistence adaptation in human societies.

This 'Tardiglacial Paradigm' (Morales et al., 1998; Haws and Bicho, 2006), however, has begun to crumble in the face of new (and not so new) data, both archaeological (Stiner et al., 1999, 2000; Bailey and Milner, 2002; Stiner, 2003; Bicho et al., 2004) and ethnographical (Pálsson, 1988, 1991; Erlandson, 2001). Recently, Erlandson (2001) and Bailey and Milner (2002), among others, have demonstrated that the archaeological record may be strongly biassed against early coastal sites. In a few places, older Pleistocene sites exist in areas of steep bathymetry or uplifted continental margins. Where the older coastal deposits are visible, marine resources are frequently present in the subsistence of hunter–gatherers, complex or not (see also Bailey and Flemming, 2008; Erlandson et al., 2008). This reality has transformed the perspectives of many hunter–gatherer researchers (Parkington, 2001; Bailey and Milner, 2002; Bailey and Craighead, 2003; Bailey, 2004a,b; Parkington et al., 2004).

In this paper, we will focus on the importance of marine coastal resources in the Pleistocene economy and subsistence strategies of Portugal. We will also examine certain features related to the presence or absence of marine and estuarine resources in Portugal, namely the evolution of the coastline and the effects of upwelling, and their importance in understanding and predicting site location and subsistence economies during the Palaeolithic. Finally, we will present a new model of prehistoric coastal hunter–gatherer economies in Portugal.

2. Archaeological perspectives on marine resource use by Late Pleistocene hunter–gatherers

Binford (1968) noted that a diverse and complex set of changes took place in human societies at the end of the Pleistocene: human diet appeared to show a significant increase in the number of food resources, including aquatic resources; and the introduction or development of new techniques of hunting, food storage and processing allowed a more intensive use of plants and animals. Both changes led to new patterns of mobility, settlement systems and land use generally. Flannery (1969) labelled this dietary shift as the Broad Spectrum Revolution (BSR) (see Stiner, 2001, for an historical review). The beginning of agriculture in Southwest Asia was likewise seen as resulting from a set of conditions that included diversification of dietary resources and human population increase just prior to the Pleistocene–Holocene transition. This ecological

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disequilibrium was believed to be a consequence of climatic instability at the end of the Pleistocene compounded by population pressure (Cohen, 1977; Keeley, 1988).

With the adoption of a behavioural ecology focus by archaeologists (Winterhalder, 1981, 1986; Hill et al., 1987; Jochim, 1988; Kelly, 1995), marine animals, especially shellfish, came to be seen as marginal resources. These items typically rank lowest in economic models used to grade the importance of dietary resources because they provide a lower net energy return than terrestrial animals (or plants). In these energy-based foraging models borrowed from ecology, human foragers were not expected to harvest such low ranked items, regardless of their abundance, unless post-encounter return rates of higher-ranked ones decreased. This population–resource imbalance would occur either as a result of over-harvesting or reduced availability due to habitat loss. Alternatively, hunter–gatherers might exploit shellfish as a means of risk-avoidance (Winterhalder, 1986; Kelly, 1995).

After the postglacial sea level rise, the appearance of coastal shell middens in many places around the world suggested a new subsistence strategy. These highly visible remains provide a stark contrast to the Pleistocene archaeological record, which is apparently devoid of such features. While recognizing the obvious fact that the postglacial transgression had inundated substantial portions of the continental shelf, many dismissed the likelihood of significant Pleistocene coastal settlement (see Bailey and Parkington, 1988). One reason for this was that the Pleistocene oceans were thought to be less productive due to lower global CO_2 levels. Deep waters off the exposed continental shelves were also thought to have limited coastal productivity (Perlman, 1980), and the instability of Pleistocene climate to have resulted in abrupt changes in sea level that might have precluded the development of lagoons, estuaries and tidal flats providing habitats for large shellfish communities (Schubel and Hirschberg, 1978).

A rather circular argument emerged from the perspectives outlined above: marine resources are marginal; if humans exploit them there must be population pressure on resources; few coastal Pleistocene sites exist; oceans did not become productive until the Holocene; sea level stabilized in the Holocene; many coastal sites appear in the Holocene; therefore coastal adaptations began in the Holocene as a result of population pressure on resources.

3. Exceptions to the rule

In a thorough review of aquatic adaptations, Erlandson (2001) concluded that the few coastal Pleistocene sites with evidence of marine resource exploitation share one feature: they are all located in areas of steep offshore bathymetry. This also seems true in Iberia: several places along the coast are marked by a steep bathymetry: Asturias and Cantabria, Eastern Andalucia and Gibraltar, and in Portugal the Western Algarve and the waters off Sesimbra and Nazaré. The Gibraltar Caves have yielded shellfish in Middle Palaeolithic occupations (Barton, 2000; Fa, 2008). Two Upper Palaeolithic sites, La Riera in Asturias and Nerja in Andalucia have evidence for marine resource exploitation (Jordá, 1986; Ortea, 1986), and in Portugal, the faunal assemblage from Figueira Brava includes shellfish, shore birds and marine mammals (Antunes, 2000a,b).

Although some of the shells and bones of marine mammals that occur in Middle Palaeolithic Iberian sites could have been accumulated by natural processes, the Upper Palaeolithic evidence appears to indicate human agency. The question that must be addressed is the degree of marine resource harvesting by Pleistocene people. If marine resources were exploited, how intensive was this effort and how important were they to overall subsistence? The limited evidence suggests a gradual increase in the importance of marine resources between the Middle Palaeolithic and the end of the Pleistocene. One site in particular, La Riera, has been used to address this issue.

Clark and Straus (1986) explained the Late Pleistocene use of marine resources in Late Upper Palaeolithic sites in Cantabria in Northern Spain as a result of subsistence intensification and diversification due to population pressure. Based on the archaeological record of La Riera, as well as other Cantabrian sites, they saw a clear record of increasing intensification over time, through diversification and specialization (Clark and Straus, 1986, p. 359). This process started in Early Solutrean times, some 20,000 years ago, with evidence of the following changes:

- The use of shellfish, mostly large estuarine limpets (*Patella vulgata*) in large quantities.
- Evidence of catastrophic red deer (and occasionally ibex) mortality profiles, suggesting hunting of large numbers of animals in a single event, probably resulting from new hunting techniques such as collective drives, surrounds or ambushes. This hypothesis was confirmed by the seasonality results, indicating that most animals were hunted in the same season.
- The presence of heavily fragmented ungulate bones, including phalanges, indicating intensive use of carcasses, probably with grease rendering techniques.

By the Late Solutrean and Magdalenian new indicators appeared:

- A broadening of the use of shellfish species to include both estuarine and exposed Atlantic shorelines (including *Patella intermedia*, *Littorina littorea*, and *Monodonta lineata*), increasing steadily up to Holocene times with the Asturian occupation, when a true shell midden was formed.
- The use of sea urchin and crab began in the latest Pleistocene with a rapid increase in their representation in the Holocene.
- Addition of new types of marine fish (sea bream and sole).
- Significant bird exploitation.

Clark and Straus saw these dietary changes as the result of stress on the resource base due to population expansion in the Cantabrian Region. The reduction in limpet (*P. vulgata*) size was thought to result from overexploitation thus confirming the idea of human population pressure (but see Bailey and Craighead, 2003, for an alternative view). The idea was explicitly based on Cohen's (1977) population pressure model, which expanded on the earlier work of Boserup (1965). Though the La Riera record did not meet all Cohen's criteria for the presence of "subsistence saturation" leading to the development of agriculture in Early Holocene times, it seemed clear to Clark and Straus that the Northern Spanish archaeological record was a perfect example of the BSR.

Two aspects should be noted from the publication. First, their view, though not explicitly stated, was that a human demographic expansion took place near the end of the Pleistocene, sometime in Magdalenian or Azilian times. However, as suggested by the number of sites per millennium (Clark and Straus, 1986, p. 362, Table 20.1), and by the earliest evidence of use of shellfish and salmonids, changes implying population growth took place much earlier, at the beginning of the Solutrean. Similar patterns have been found in other regions, such as the Pyrenees (Straus, 1991, 1992) and Mediterranean Spain (Aura et al., 1998; Morales et al., 1998; Cortés-Sánchez et al., 2008).

In Portugal, Bicho (1994, 1998) applied the Clark and Straus framework to the Late Pleistocene record. Using the available data, he argued for increasing intensification, through diversification and specialization across the Pleistocene–Holocene transition. The presence of aurochs at Bocas rockshelter (Fig. 1) and red deer

Fig. 1. Map with sites referred to in the text. 1. Mira Nascente; 2. Lapedo (Lagar Velho); 3. Picareiro and Coelhos Cave; 4. Caldeirão Cave; 5. Foz do Enxarrique; 6. Suão Cave; 7. Figueira Brava Cave; 8. Vale Boi; and 9. Ibn Ammar Cave.

hunting at Picareiro Cave suggested specialized hunting of certain animal species (Bicho, 1993). The existence of sites with shell middens containing shellfish, marine and estuarine fish and crustaceans evidenced dietary diversification (Bicho, 1998). Both aspects were present just prior to the onset of the Holocene. Bicho (1994) concluded that there was a demographic expansion of human population that occurred in two phases: one around 10,000 years ago, and a second pulse 2500 years later with the appearance of the Mesolithic populations of the Tagus (in the Muge) and Sado Basins (Bicho, 1994).

Alternatively, according to Araújo (2003), the increased marine focus in the very Late Tardiglacial and the increase in the number of site types and areas occupied (including coastal ones) was the result of a decrease in human populations resulting from a reduction in exploitable territory as well as a reduction in the biomass of large and medium terrestrial fauna in Central and Southern Portugal due to an increase in forest density. This dwindling of terrestrial biomass at the very beginning of the Holocene (or perhaps at the end of the Pleistocene) forced humans to add marine and estuarine resources to their diet.

Recently, we have argued for an earlier use of coastal resources in Portugal based on new data emerging from archaeological survey and excavation (Hockett and Haws, 2002; Haws, 2003; Bicho, 2004a; Haws and Bicho, 2006). This suggests that previous models of demographic pressure on resources forcing a dietary shift to include marine resources are untenable. The new model rests on four points:

1. Using the Nutritional Ecology approach outlined by Hockett and Haws (2002, 2003, 2005), shellfish and other marine resources should rank much higher than in traditional models (Akazawa, 1988). Shellfish are typically marginalized as poor resources because they provide little energetic value. In fact, many shellfish are excellent sources of protein and their protein and fat content are similar to terrestrial resources, albeit in smaller package sizes (Wing and Brown, 1979; Erlandson, 1988). Shellfish even have some carbohydrates, absent in terrestrial animal resources. They are also easily harvested and thus represent a low-risk resource, especially for women and children (Meehan, 1982). Many subsistence decisions seek to minimize risk rather than maximize energy intake (Winterhalder and Smith, 1981; Bettinger, 1991; Kelly, 1995).
2. Ethnographic research among hunter–gatherers suggests daily subsistence needs are not met by medium to large game hunting but by more easily gathered resources such as plants and small game, often met by the gathering efforts of women, children and elderly members of society (Hawkes et al., 1991, 2001). We should expect that this has been the case for much of human history. Marine resources may therefore have been important from an early period of the Palaeolithic.
3. Intensified upwelling conditions off the Portuguese coast would have created a rich environment for human subsistence while at the same time reducing terrestrial biomass. Thus, Palaeolithic settlement may have been focused more on the coast than the interior.
4. Postglacial sea level rise has inundated the coastal land platform and destroyed most of the archaeological record. In those regions with steep offshore bathymetry, such as Southwest Algarve, Sesimbra and Nazaré, Palaeolithic sites with evidence of coastal and marine exploitation should still be present above modern sea level.

4. Upwelling off the Portuguese coast

Perlman (1980) has observed that hunter–gatherer coastal adaptations most often appear along shallow continental shelves and upwelling zones where marine and estuarine ecosystems are most productive. Upwelling is the upward movement of deep, cold waters to the surface, to replace surface waters moved away from coastlines as a combined result of surface winds and the Earth's rotation. These deep waters bring nutrients from the seabed to the surface resulting in very productive conditions for marine life (Margalef, 1978). We argue that since Western Iberia lies next to a coastal upwelling zone, Pleistocene hunter–gatherers would have had access to a very rich marine resource base, and we should therefore expect to find evidence of Pleistocene coastal settlement.

The modern Portuguese coast is well-known for its rich marine fisheries. The characteristic upwelling dynamics of the Southwestern Iberian Atlantic coast create a highly productive marine ecosystem (mainly South of Nazaré) (Fiuza, 1982, 1983; Abrantes and Moita, 1999; Loureiro et al., 2005). Upwelling tends to occur seasonally, when winds blow North along the West Coast (Loureiro et al., 2005) and West off the South Coast (Fig. 2), most intensively in the spring and summer months (Fiuza, 1982, 1983; Sousa and Bricaud, 1992; Loureiro et al., 2005), though it may be present during other periods of the year. In the Sagres area, the climate is one of mild summers and foggy days with sporadic winter rains, resulting in a semi-arid plant cover on land. In other areas, such as the Lisbon Peninsula, winter rains are more frequent and help to increase the drainage of nutrients from land to sea, enhancing the biological productivity of coastal marine resources during those times when upwelling does not occur. When there are peaks in upwelling on the West Coast, these can merge with the local upwelled waters from the Southern Coast of the Algarve, connecting to the runoff from the Guadiana River (Sousa and Bricaud, 1992). Frequently, these currents also reach the Gibraltar Strait, even in the winter months, though with lesser intensity (Foulkard et al., 1997). On the West Coast, upwelled waters frequently present plume-like features extending offshore by more than 200 km in such locations as the Nazaré Canyon, the Tagus Estuary, and the Capes of Sines and São Vicente, respectively in Estremadura, Southern Alentejo and Algarve (Fiuza, 1983; Sousa and Fiuza, 1989). Along both the Southern and Western Portuguese coasts, the zone of upwelling extends between 20 and 50 km seaward.

Diatom records from Atlantic deep-sea cores have been used to reconstruct changes in upwelling conditions and biological productivity off the coast of Portugal (Abrantes, 1988, 2000; Lebreiro et al., 1997; Abrantes et al., 1998). Two cores, located off Northern Portugal (KS11 – Abrantes, 1990) and off Southern Morocco (M12392 – Abrantes, 1991), give a general scenario for the Portuguese coast for the last 100 ka. The highest productivity occurred during OIS 6, OIS 4, and the Last Glacial Maximum, based on cores near the Canary Islands. In the Southern extreme of Iberia, the upwelling intensity was likely much higher than today during OIS 4. In Northern Portugal, off the Douro Estuary, the OIS 3 deposits had diatom abundances similar to today. During Tardiglacial times (Termination I), upwelling decreased, and the least intensive upwelling conditions occurred during the Early Holocene, when productivity decreased to a level similar to or even lower than today. The possible exception is the 8.2 ka cold event (Grafenstein et al., 1998; Barber et al., 1999; McDermott et al., 2001), which allowed a freshwater cold pulse to reach the coast of Portugal (Soares, 2005), including the Guadiana Estuary in Southeastern Portugal (Boski et al., 2004). During the Mid-Holocene the upwelling virtually shut down. The pattern of high intensity upwelled conditions during cold phases and decreasing marine productivity during warm phases has been confirmed by records of phytoplankton, $CaCO_3$, barium and carbon alkenones (Thomson et al., 2000; Pailler and Bard, 2002).

In summary, the data unequivocally confirm that during colder phases in the Upper Pleistocene, upwelling intensity was far greater than the present-day. This was likely the result of intensification of the Trade Winds and their impact on the Eastern Boundary Currents. In the case of the Canary system there was a northward extension of South Atlantic Currents (Abrantes, 2000, p. 14), increasing upwelling intensity and nutrient levels in Portuguese coastal waters during the LGM. The decline in upwelling at the end of the Tardiglacial, and during the Pleistocene–Holocene transition occurred at exactly the moment when, according to the traditional historical perspective, marine resources are supposed to have become important economically for the hunter–gatherers of Central and Southern Portugal.

5. The impact of coastline changes on the Palaeolithic archaeological record

5.1. Sea level and climate

As in other areas of the North Atlantic, sea level dropped to -120 m off the coast of Portugal during the LGM, rose steadily up to -40 m just prior to the Dryas III cold snap, <11 kyr, dropped

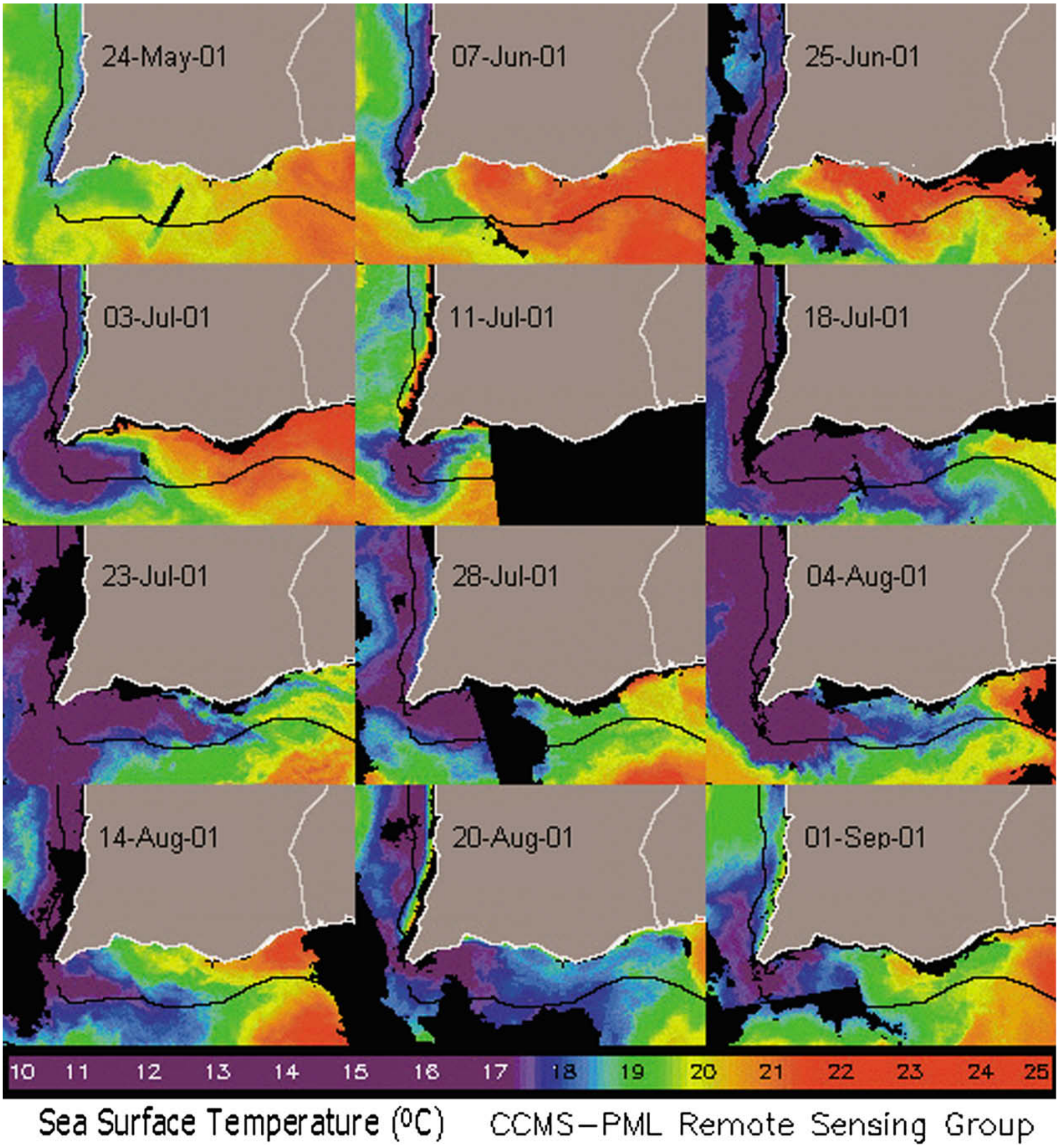

Fig. 2. Satellite image of SST (sea surface temperature) showing an upwelling event with a cold filament formation along the Southwest Coast of Portugal during the summer months (Loureiro et al., 2005).

again to −60 m in the Younger Dryas, then rose rapidly and continuously until about 8 kyr, reaching a slightly higher level than present between 5 and 3 kyr, subsequently stabilizing at its present level (Dias, 1985; Dias et al., 2000). During the LGM, an extensive, flat, land platform would have extended South and West of the present coastline.

For central Portugal, pollen and charcoal studies show that cold, arid *Artemisia* steppe characterized upland vegetation during the LGM. The now-submerged continental shelf is thought by some to have been mainly sandy dunes with little vegetation (Daveau, 1980; Zilhão, 1997), but it is also possible that this area was a refugium for arboreal and herbaceous Mediterranean species (Turner and Hannon, 1988). Deep-sea cores off SW Portugal show relatively high percentages of arboreal pollen in early OIS 3 followed by a gradual and sustained decrease (Roucoux et al., 2001). Sánchez-Goñi et al. (2002) noted correlations between Heinrich and Dansgaard–Oeschger events and vegetation, with low percentages of arboreal pollen during cold events and herb and shrub vegetation with steppe species dominating. Lowered temperatures and precipitation were also accompanied by intensified winds leading to increased upwelling. Diniz (2003) reported pollen along the coast South of Peniche, dated 35–45 kyr with low percentages of mixed Mediterranean and Euro-Siberian trees. Deciduous oak forest apparently characterizes the interstadials during this period (Mateus and Queiroz, 1993). Coastal vegetation was marked by humid heath with sheltered areas serving as refugia for oak-scrub taxa, based on the co-occurrence of hazel, birch, evergreen oak and olive (Diniz, 2003), with maritime pine, juniper, Ericaceae and

Calluna in the interfluves (Mateus and Queiroz, 1993). Two cold events in early OIS 2 led to the expansion of alpine *Pinus sylvestris* forests at 29–27 kyr and 25.4–24.5 kyr along the Northern Portuguese coast (Granja and de Carvalho, 1995).

Most of the research on the continental shelf has focused on the Northern Portuguese coast and interpretations of the Estremaduran coast are based on extrapolation (Dias et al., 2000). During the LGM, the continental shelf was much steeper and wave activity would have been strong. Deep submarine canyons devoid of recent sediment suggest that sediment loads, augmented by greater annual precipitation and spring ice and snow melt, were deposited offshore (Daveau, 1980; Dias et al., 2000). Sea levels were at least 100 m below present for thousands of years before and after the LGM, This stability is seen in the preservation of relict abrasion platforms, sea cliff remnants and offshore bars on the shelf (Dias et al., 2000), but the period of the maximum regression may have been too short for the extra land exposed at that time to undergo soil development and forest colonization.

5.2. *Active tectonics*

Tectonic factors also need to be incorporated into geomorphological reconstructions. Despite a general geological opinion that little activity took place in Portugal over the last 2 Ma, there is considerable evidence of localized neotectonic activity and faulting. A small fault runs through the centre of the Middle Palaeolithic site of Foz do Enxarrique, for example, probably following the line of the Tagus valley (Cunha and Martins, 2000; Cunha et al., 2005). The Eastern area of the archaeological deposit was uplifted by about a metre. Since the human occupation dates to about 33 ka (Raposo, 1995, 2000), fault movement took place sometime during OIS 2 or even more recently. Other examples of recent neotectonic activity have also been recorded on the coast, between Aveiro and Porto (Granja, 1999).

In the Algarve, there is a marked difference in the distribution of archaeological sites between the Western and Eastern Algarve, which cannot be explained by differential survey intensity or differential palaeoenvironments and potential economic productivity, but which instead reflects the differential visibility of archaeological sites resulting from the different geomorphological and tectonic histories of the two regions (Bicho, 2004a). In Eastern Algarve, there are fewer sites and they are all of Mesolithic and Neolithic date. In the West there are numerous Middle and Upper Palaeolithic and Mesolithic sites.

In the East, discovery of buried estuarine deposits and beaches in the region of the Guadiana River (Boski et al., 2002; González-Villa et al., 2003) shows that the region has undergone submergence and a higher rate of relative sea level rise compared to neighbouring Spain (Zazo et al., 1996; Dabrio et al., 1999; Moura et al., 2000, p. 208). This is the combined result of compaction of marshy deposits and fault movements on an East–West axis extending from Tavira to the Guadiana Estuary (Dias, 2001, Fig. 4. p. 128). The absence of archaeological sites earlier than Mesolithic in date is due to the fact that Late Pleistocene and Early Holocene land surfaces have been mostly covered by later sediments.

In the Western Algarve, the situation seems to be exactly the opposite – there is evidence for an uplift of the coastal shelf and the cutting of Pleistocene and Holocene terraces, and Mesolithic and Neolithic sites are rare, a notable exception being the sand dunes of the high cliffs of Sagres, where Mesolithic and Neolithic shell middens are frequently found (Bicho, 2004a; Carvalho and Valente, 2005). Tectonic faults seem to have been active during the Late Pleistocene, but mainly during the Early and Middle Holocene, causing a major uplift in the Southwestern coast of Algarve, at least as Far East as the Bensafrim Estuary, near Portimão. Moura (personal communication, 2004) found recent sandstone formations located in the cliffs, some 15 m above sea level. These were dated to the LGM and to the Atlantic period. The location and altitude of these sedimentary formations clearly indicate an uplift of the local limestone cliffs, already suggested by data from the Estuary of Alcantarilha River, some 50 km East of Sagres (Moura et al., 2002).

The impact of coastal uplift is a factor of major importance in evaluating the width of the coastal plain exposed during lowered sea level and the proximity of the shoreline to archaeological sites on or close to the present-day shoreline (Bailey and Flemming, 2008). The relatively steep offshore bathymetry in the Western Algarve, particularly offshore of the Sagres area, together with evidence of uplift, means that the coastline would have been displaced at most ca 10–15 km offshore from the present coastline, resulting in a relatively narrow and now-submerged land platform during OIS 2. Both before and after the LGM the coastline would have been even closer to the present, perhaps at certain times, such as the Gravettian, being almost in the same place as today. This increases the likelihood of finding Upper Palaeolithic sites with marine resources, in spite of the fact that there was severe erosion of sediments in the area. One such site is Vale Boi.

5.3. *Palaeolithic coastal sites with marine resources*

The site of Vale Boi contains a long sequence, covering all of the Portuguese Upper Palaeolithic, from Early Gravettian to Late Magdalenian (Bicho et al., 2003a,b). There is also an Early Neolithic level and traces of a Mesolithic occupation, now mostly eroded away. The marine resources are very diverse, with both marine mammals and shellfish (Table 1). The peak in their use was in the Gravettian, 24–22 kyr (Stiner, 2003; Manne et al., 2005), when there is a fairly compact shell layer with a wide diversity of species, including both edible and ornamental shells. The importance of the shells in the diet decreased through time, starting in the Solutrean,

Table 1
Dietary fauna from selected sites in Portugal dated to OIS 3 and 2

Sites	Medium and large herbivores	Lagomorphs	Tortoise	Marine mammals	Edible marine mollusks	Urchins	Crabs	Marine fish
Ibn Ammar	✓✓	✓✓	✓✓✓		✓			
Caldeirão	✓✓✓	✓✓	✓					✓
Figueira Brava	✓✓✓	✓✓	✓	✓	✓✓✓	✓	✓✓	
Columbeira	✓✓	✓✓	✓					
Salemas	✓✓	✓✓						
Furninha	✓	✓	✓		✓			
Suão	✓✓✓	✓✓						✓
Vale Boi	✓✓✓			✓	✓✓✓			
Picareiro	✓✓✓				✓			✓✓
Coelhos	✓✓✓	✓✓✓						✓✓
Lapedo	✓✓	✓✓	✓	✓				✓

✓✓✓, Very common; ✓✓, present; and ✓, rare.

when the coastline was the furthest away from the site. The same species of shells, however, were still used for adornments but in a limited manner. The importance of fishing is suggested by the presence of a large number of bone points throughout the sequence, which could have been used as fishing implements (cf Yellen, 1998), including one found in one of the Gravettian levels and dated to 24,500 BP, and Aura and Pérez Herrero (1998) have made a similar suggestion for the Cave of Nerja, East of Malaga (see also Cortés-Sánchez et al., 2008).

Is Vale Boi an isolated occurrence, or a special case due to its location in the Sagres Region? Large amounts of shellfish were found in the Solutrean levels of Nerja, mentioned above (Jordá, 1986; Cortés-Sánchez et al., 2008). The same pattern was also found in Parpalló, near Alicante (Pericot García, 1942). Further South, in the Strait of Gibraltar, Gorham's and Vanguard Caves show the use of marine mammals as well as shellfish during the Mousterian occupation (Barton, 2000; Finlayson, personal communication, 2005; Fa, 2008). All these three areas in Mediterranean Iberia are marked by fairly steep underwater platforms.

In central Portugal, the only coastal site with faunal remains is the Mousterian Cave of Figueira Brava, near Sesimbra, some 30 km South of Lisbon. The site is dated to ca 30 kyr (radiocarbon years) and the fauna is composed of a wide variety of terrestrial mammals (including ungulates and carnivores) as well as shellfish (which gave the radiocarbon dates for the occupation) and a few species of marine mammals (Antunes, 1990–1991, 2000a,b). It should be noted that the shore where the Cave Site is located is marked by an accentuated drop of 10–15 m against the base of the cliff. Thus, the marine fauna, some of which has cut marks, is probably the result of human prey activities and was not accumulated by natural processes.

Breuil et al. (1942) recorded Mousterian assemblages on raised beaches along the coast near Peniche dated between the Sicilian and Tyrrhenian, roughly equivalent to OIS 5 and OIS 2 respectively. Differences in technology between the coastal assemblages and the interior ones led to the suggestion that shellfish collection may have been the primary subsistence focus.

Ongoing archaeological survey along the coast near Nazaré has demonstrated the presence of numerous open-air Palaeolithic sites on aeolian dunes (Haws et al., 2006). These would have been near the prehistoric shoreline given their proximity to the steep shelf off Nazaré. One site in particular, Mira Nascente, is a Middle Palaeolithic occupation on a foredune near a coastal lagoon (Benedetti et al., 2006; Haws et al., 2006). This site is located 35 m asl today, which suggests an uplift rate of about 3.5 mm per year. Several fault blocks exist along this stretch of coast and research is currently underway to understand the impact of tectonic uplift on the archaeological record of Pleistocene settlement.

The present coast near Nazaré has both sandy and rocky shores, thus shellfish taxonomic diversity is high in the area. Fish are highly productive near the so-called Nazaré Canyon where the submarine morphology creates one of the most intensive upwelling zones along the Portuguese coast. In the Pleistocene, this zone would have been even more productive. At São Pedro de Muel, approximately 10 km North of Nazaré, Firtion and de Carvalho (1952) reported a series of raised marine clays, and assigned a Late Glacial age based largely on pollen identifications of birch and other Euro-Siberian vegetation types. Haws et al. (2006) obtained an AMS radiocarbon date of 27,080 $\pm$ 230 BP on organic sediment from the lowest level. The dates and the geology of these deposits imply a diverse range of palaeocoastal landforms from medium-high energy beaches to protected low-energy tidal flats during OIS 2 and 3, features likely to have been conducive to abundant and accessible marine food resources.

At about the same latitude, but only ca 20 km from the modern coastline, a number of shell pendants were found in the Gravettian levels of Lagar Velho, including the Lapedo child burial (Vanhaeren and D'Errico, 2002). Also, a single cetacean bone was recovered (Moreno-Garcia et al., 2003).

During the Late Upper Palaeolithic, marine fish and shellfish were found in the Magdalenian occupation of Lapa do Suão, dated at 16–10 ka (Haws and Valente, 2001; Haws, 2003). This site is only a few kilometres from the modern coastline. Further North, in the Serra d'Aire, some 100 km Northeast of Lisbon and 50 km from the Nazaré coast, the Cave Sites of Picareiro (Bicho et al., 2000, 2004) and Coelhos (Almeida et al., 2004) each have a series of Magdalenian occupations with newly discovered older Gravettian levels. In both cases there is unequivocal evidence for marine fishing and shellfishing from Gravettian times onward. Further inland, near the town of Tomar, fish were recovered from Magdalenian levels in the Cave Site of Caldeirão (Zilhão, 1997). Marine shells were used as adornments as early as the Solutrean (Callapez, 2003; Chauviere, 2002).

Though the data are scarce, certain patterns seem to emerge. Marine resources were in use by at least 30 kyr. Coastal sites are known in areas where the shore is marked by steep bathymetry. It is clear that the use of marine resources and, thus, of a broader diet, thought to be a characteristic of the Pleistocene–Holocene transition, is present much earlier in Portugal, much as in other regions of the Mediterranean Basin. Therefore, a new model (or in this case, perhaps, a paradigm) is needed to understand the adaptations of Palaeolithic hunter–gatherers in Southwestern Iberia.

6. Conclusion

The traditional model in which marine resources become an important factor in human diet only in the very Late Tardiglacial or even in the Early Holocene, together with a general intensification of resources through diversification and specialization, seems now to be completely obsolete. It is clear that not only marine resources, including marine mammals, fish and shellfish, are present since at least 30 kyr. These were also complemented by a diversity of types of food that greatly improved the diet of those hunter–gatherers. Small terrestrial mammals, such as rabbits, and birds are known in most Portuguese sites mentioned above, and tortoise remains are present at the Mousterian Cave of Ibn Ammar, near the city of Portimão in Algarve (Bicho, 2004b). Resource intensification is apparent from the new technological innovations that began as early as 25 kyr. Bone grease rendering in Gravettian levels at Vale Boi (Stiner, 2003; Manne et al., 2005) demonstrates the intensive exploitation of fat, proteins and minerals present in the marrow and spongy areas of bone of terrestrial mammals. Rabbits were intensively processed in many Upper Palaeolithic sites (Hockett and Bicho, 2000; Hockett and Haws, 2002). The diet was probably supplemented by fruits, roots, and tubers throughout the Upper Palaeolithic (Haws, 2003). Thus, the so-called lower rank resources, that is plants and small aquatic and terrestrial animals, were utilized when available from an early period (Kislev et al., 1992; Mason et al., 1994; Richards et al., 2000; Erlandson, 2001; Stiner, 2001).

Maritime resources were utilized in Portugal by at least 30 ka, although taphonomic work is needed in some cases before human agency can be confirmed. Marine mammals are present in Middle and Early Upper Palaeolithic sites. Shellfish is present from the Late Middle Palaeolithic onwards and throughout the entire period of the Upper Palaeolithic. Fish are known from Picareiro, Suão and Lapa dos Coelhos. At Vale Boi bone tools possibly used for fishing are dated to the Gravettian.

It seems obvious that shellfishing was a constant in the habits of the Palaeolithic hunter–gatherers of Portugal independently of the energetic value of shellfish, thought frequently to be a lower rank resource (Osborn, 1977; Yesner, 1984, 1987) (but see opposite perspectives in Meehan, 1977, 1982; Erlandson, 1988). Whether this was a consequence of dietary needs or due to other reasons is difficult to assess, but like fish and marine mammals, shellfish seem to have been available in large quantities. This may be explained by the upwelling situation described above: the sea biomass productivity is very high today, mostly in the summer, but during OIS 4, 3 and 2, it was even higher than today by a factor of 3–10. The coast would have been an extremely rich environment with abundant low-risk food resources. The resilience of the shellfish population would have been sufficient to avoid overexploitation (Stiner et al., 1999; Fa, 2008). In all likelihood, the human population was too small to cause serious overexploitation of the shellfish population of any given area. In the event of localized overexploitation, people could have moved to the next bay or beach.

The lack of more sites with marine resources is probably due to two very different reasons. The first is the fact that most Palaeolithic coastal sites are now-submerged. Those few sites with maritime resources are either in locations where the steep bathymetry places the LGM shore very near the present coastline, or locations where upwelling was very high, like the case of the Nazaré Canyon. The second major reason is the lack of archaeological research, specifically survey, in key areas. Also, the number of recently excavated Palaeolithic sites with faunal preservation is very low, though in most cases marine resources are present at these sites.

In conclusion, the model proposed here (still to be confirmed with new data) encompasses a series of elements that were not previously taken into account: upwelling intensity was much higher than today off the coast of Portugal; the productivity of marine resources would have been much higher, and these resources would have been available to the human populations that lived in the coastal regions extending from the Algarve to at least as far as the Mondego Estuary; these resources were frequently used, making up an important part of a subsistence intensification process that may have started at least as early as 30 kyr with the last Neanderthal communities of Iberia.

This process of resource intensification included not only a broadening of the dietary spectrum (large and small terrestrial animals, fish, shellfish, marine mammals, birds, plants and fruits), but an increase in the amount of fat and other essential nutrients obtained from the marrow of medium-sized ungulates and the long bones of rabbits. All in all, it seems that the Portuguese Palaeolithic hunter–gatherers would have had a very nutritious and diverse diet, well adapted to the environment and to the available resources, including those from the Atlantic sea.

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