An Iberian perspective on Upper Paleolithic plant consumption

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Plant use by prehistoric Mediterranean hunter-gatherers

David Clarke, in his essay "*Mesolithic Europe: The Economic Basis*" (1976), challenged the "meat fixation" of archaeologists and highlighted the potential for intensive plant use in Europe prior to the introduction of agriculture. He argued that plants likely made up 60-80% of the diet of prehistoric hunter-gatherers in Europe. Indeed, ethnographically known hunter-gatherers in temperate regions incorporate such percentages of plants in their diet (Kelly, 1995). The only area where meat completely dominates is the Arctic, where the lack of edible plants during much of the year leaves little choice. Even in this extreme, people are known to eat the contents of reindeer stomachs and exchange meat for seaweed with coastal peoples (Clark, 1952). Even still, this may only reflect a seasonal aspect of subsistence. The notion that meat would comprise 90% of the diet during the Upper Paleolithic or Mesolithic seems unfounded given these facts about modern hunter-gatherers and the nutritional problems associated with excess protein consumption (Noli and Avery, 1988; Speth and Spielmann, 1983). Recent stable isotope analyses suggest such a meat-focused diet in Britain during the LGM (Richards *et al.*, 2000), although one could argue that this is merely analogous to the Arctic case and is not the "rule" for all of Europe during this period.

Much of Iberia, especially Mediterranean Spain and Portugal, never experienced dramatically cold extremes except in mountain zones. Therefore, it seems reasonable to assume a high degree of plant exploitation in this part of Europe at least as far back as the LGM and likely farther. Even at the Cantabrian Magdalenian site El Juyo, where climatic and environmental conditions were cooler and less vegetated, Freeman *et al.* (1988) reported plant macrofossil remains from 21 families and 51 genera. These included acorn and hazelnut fragments, berry pits, grass seeds and aquatic plants. During this same period, prehistoric Mediterranean hunter-gatherers would have had access to a wide variety of plants including oak acorns, hazelnuts, wild tree fruits, berries, edible bulbs, grass seeds, and legumes.

Interestingly, the potential for plant exploitation during the Upper Paleolithic has never received due attention (Mason *et al.*, 1994). The focus has always been on the animal remains from archaeological sites. Most authors discussing Paleolithic subsistence either do not mention plants or suggest they would have been eaten when available and then dismiss the significance of their contribution to prehistoric diet and subsistence economies. Many researchers have argued that plants were not regularly exploited because the Late Pleistocene environments of Europe were too extreme to permit stable plant communities. Richerson *et al.* (2001) recently suggested that low global CO_2 levels during the Late Pleistocene kept plant productivity suppressed thus making plants unattractive to human foragers. They further argued that plant-based diets would have taken a long time to develop and that frequent climatic oscillations made long-term adaptations to plant resources unlikely. Stiner and Kuhn (2001) have also argued that intensive plant exploitation is only visible archaeologically at the end of the Pleistocene when stone-processing technology appears, namely grinding stones. This echoes Hayden's (1981) earlier claims.

Clarke's (1976) model for the Mesolithic might have been more acceptable to archaeologists working in that period because the Early Holocene was precisely the time that the Broad Spectrum Revolution was said to have occurred. For the Upper Paleolithic, the "meat fixation" was unchallenged. The main obstacles are the acceptance of energy as the appropriate currency to measure human subsistence choices and the invisibility of plants and the technology used to process them in the archaeological record. Kelly (1995) and others have argued that animal resources are usually better sources of energy than plants. In general, plants are viewed as low-ranked resources because they often have high percentages of inedible cellulose and/or toxins that must be removed prior to human consumption. The high processing costs outweigh their ease of collection and natural abundance when caloric value is relatively low. Since most foraging models consider all foragers equal, plants usually rank low. Some argue that any nutrient value will be greatly diminished or lost entirely during processing. However, as Stahl (1989) has pointed out, processing plants does not necessarily mean there will be nutrient loss. In many cases, toxins must be removed, thus increasing the nutritional value. Cooking may increase certain nutrient values in plants (Wandsnider, 1997; Wrangham *et al.*, 1999). In some cases, the processing costs may be offset by the benefits of nutrient increase although there is only qualitative data to support this because foraging modelers equate processing with nutrient loss (Stahl, 1989).

Many authors have assumed that extensive and intensive plant exploitation began, with the appearance of grinding stone technology widely used to process seeds and nuts (Hayden, 1981; Kuhn and Stiner, 2001). However, recent work shows that chimpanzees in Africa use unaltered stone tools to crack open nuts (Mercader *et al.*, 2002). The Lower Paleolithic site of Gesher Benot Ya'aqov has nut-cracking stones associated with several species of nuts (Goren-Inbar *et al.*, 2002). Thus, simple stone tools that require minimal labor input have been used to process plants for a considerable time. Grinding stones should not be considered a requisite for intensive plant exploitation (de Beaune, 1993). The fact is that many recent hunter-gatherers used perishable wooden implements to pound seeds and nuts (Lee, 1979; Stahl, 1989). Even stone sickle blades are not necessary to harvest wild grains, as pointed out by Madella *et al.* (2002) in their study of plant exploitation at the Middle Paleolithic site of Amud in Israel.

The lack of preservation obscures the archaeological visibility of plant use. Mason *et al.* (1994) have called for greater attention to recovering plant remains from Paleolithic sites. The main problem is that most plant foods would leave little trace in many sites. Preserved plant food remains have never been found in Upper Paleolithic sites in Portugal, but they have been recovered in archaeological sites around the Mediterranean. Albert *et al.* (2000) mention acorns, pistachios and legumes from Middle Paleolithic levels at Kebara Cave in Israel. Numerous charred pine nut cones and shells were found in Middle Paleolithic hearths at Vanguard and Gorham's Caves in Gibraltar (Gale and Carruthers, 2000) and throughout the Upper Paleolithic sequence at Cueva de Nerja (Badal, 1998, 2001). Magdalenian and Epipaleolithic levels of Nerja also contained acorns and wild olive pits (Aura *et al.*, 1998). Also in Spain, Freeman (1981) reported charred grass and vetch seeds from Abric Agut, which has now been radiometrically dated to the Pleistocene-Holocene transition (Vaquero *et al.*, 2002). In Greece, Koumouzelis *et al.* (2002) found evidence for seed-bearing grasses including Chenopodium and Polygonum, *Silene* and other typical Mediterranean plants in the Aurignacian site, Klisoura Cave. Plant foods were recovered from Upper Paleolithic levels at Franchti Cave (Hansen, 1978). At Ohalo II in Israel, Kislev *et al.* (1992) reported acorns and several other plants dated to 19,000 bp.

Evidence for the consumption of hazelnut, wild fruit and several legumes in the Early Holocene has been found at Balma Arbeurador in France, dated to 8,740 bp (Vaquer *et al.*, 1986). In Catalunya at Cingle Vermell (dated 9,760 bp) numerous remains of hazelnuts, acorns, pine nuts, chestnuts and wild fruits have been recovered (Vila i Mitja, 1985). Nearby, at Roc del Migdia (7,000-9,000 bp), Holden *et al.* (1995) have identified hazel shell, sloe and parenchymatous tissue of roots, tubers and edible aquatic plants. In the Basque country of Spain, Peña (2000) has reported on Mesolithic and Neolithic wild plant gathering. In several sites hazelnuts, acorns and wild tree fruits were common in both periods. Olària *et al.* (1988) reported pine nuts, acorns and chestnuts at Cova Fosca (9,460 bp). At the Mesolithic site, Grotta dell'Uzzo, in Sicily wild peas, acorns and arbutus fruits were recovered (Costantini, 1989). These examples illustrate the widespread prehistoric use and richness of edible plant resources in the Mediterranean region. The rest of this paper focuses on the Iberian Peninsula with primary emphasis on Portuguese Estremadura.

Plant resources in Iberia

Present-day climate and vegetation in Portugal

Several forces determine the climate of Portugal and create its Mediterranean-type environment. In the winter, the Polar Jet descends into the North Atlantic and brings storms across the ocean to Iberia. In the summer, the Azores High pressure cell keeps moisture from penetrating southward, thus creating the summer dry season. Annual rainfall varies from 1000-2000 mm in northern Portugal to 300 mm in the south. The central coastal regions average about 600-700 mm annually. In most of the country, the majority of the precipitation falls between October and March. Average winter temperatures range from 8-12°C on the northern coast to about 16°C in the south. The interior north and montane areas temperatures often fall below freezing in winter. Summer temperatures range from average highs of 25-28°C near the coast to as high as 40°C in the interior. In Estremadura, winters are cool and wet while summers are warm and dry.

On the Iberian Peninsula, the Euro-Siberian vegetation typical of temperate Europe occurs along the northern strip from the Basque country in the northeast to northern tip of Portugal in the west. The rest of the peninsula is covered by Mediterranean-type vegetation. Rivas-Martinez (1982) divided the Mediterranean vegetation into *étages* or levels based on altitudinal zonation. Most of Portugal falls within the meso-Mediterranean zone, which in its natural state is characterized by evergreen oak forest. The typical species are listed in Table 1. In central Portugal, meso-Mediterranean tree and shrub communities are found in varying proportions depending on exposure, soils and altitude. Agriculture, intentional planting and timber harvesting over several millennia have dramatically altered the natural vegetation communities. No truly wild places exist any longer. Some areas have been protected for several centuries and their composition provides the best model for the natural distribution of trees and shrubs. In these places, the evergreen oaks, Stone pine, privet, wild strawberry, wild olive, myrtle and Mediterranean buckthorn prefer the sunny, exposed areas. The Portuguese oak, Montpellier maple, laurel and Maritime pine are found in shadier areas. Along streams other trees and shrubs include alder, elm, poplar, willow and elderberry. The deciduous oak, *Quercus faginea*, is often seen as a transitional species occurring in the north and south (Vieira *et al.*, 2000). In the north and in the mountains, the vegetation is predominately supra-Mediterranean. Arboreal vegetation includes the deciduous oaks, chestnut, pine, birch, ash, elm, willow, and wild fruit trees. Shrubs include juniper, yew, hazel, holly and heather.

In discussing southern Europe, Clarke (1976) wrote that the Mediterranean woodlands offered 200-350 edible wild plant species. He suggested numerous wild grass seeds, roots, bulbs, herbs and legumes were widely distributed and abundant on the Early

Holocene Mediterranean landscape. Examples of these native to the Iberian Peninsula are shown in Table 3. Combined with fruits, berries and nuts, hunter-gatherers would have maintained a diverse and nutritious diet when these plant foods were consumed with animal resources.

Pine nuts in Iberia

In particular, Clarke (1976) focused on the high protein, high yield seed of *Pinus pinea*, the Stone pine. Pine nuts are well known as a food source in Europe. The Greeks considered them (and acorns) "food of the gods" (Howes, 1948). Abundant remains are also known from Roman camps in northern Europe, outside the ecological range of the species. As noted above, their charred shells are found in Middle Paleolithic and Upper Paleolithic contexts. Yet, despite their early use, pine nuts (and most other mast resources) have been marginalized by archaeologists because they are considered an unpredictable and therefore unreliable resource.

In western North America, much has been written on the subject since *piñon* nuts were known in the subsistence of many Great Basin groups. Their widespread distribution and abundance made pine nuts an important, and probably high-ranked food item in the prehistoric diets of native peoples (Steward, 1938; Thomas, 1973). Simms (1987) calculated a relatively low kcal/hr return rate for pine nut processing in the Great Basin. However, among plants they ranked high and Simms predicted that they would be collected before most other resources. Because the masts occur every 3-5 years, hunter-gatherers would need to constantly monitor stands. Recently, Sullivan (1992), in challenging the maize-centered diet for the Western Anasazi of the Grand Canyon area, postulated that prehistoric hunter-gatherers with ample knowledge of the land in which they lived would have been able to predict mast years and/or move to areas where piñon harvests would have been abundant. He interpreted fire-cracked rock piles in a number of sites as evidence of piñon roasting, although paleobotanical remains were lacking. In a recent paper, Mithen *et al.* (2001) have interpreted similar features in Colonsay off Scotland as hazelnut roasting ovens. No substantial features such as these exist in the Mesolithic or Paleolithic archaeological record in Portugal, but these are not prerequisites as the charred shells from Gibraltar and Cueva de Nerja show.

Several species of pines are found naturally on the Iberian Peninsula today. These include *Pinus pinaster* and *P. pinea* in Portugal. In Spain these two exist along with *Pinus nigra*, *P. halepensis*, *P. uncinata* and *P. sylvestris*. Because of widespread intentional planting of *P. pinaster* and *P. pinea* for centuries and probably even millennia, it is virtually impossible to know their natural ranges. It is thought that both evolved on the Iberian Peninsula (LeMaitre, 1998). Because the seed of *P. pinea* is the commonly eaten one, the focus will be on this pine. However, this does not necessarily mean that *P. pinaster* seeds would not have been exploited. Rhode and Madsen (1998) noted that the much smaller limber pine seeds were utilized prior to piñon in the Great Basin.

Pinus pinea lives in sandy soils and podzols in sunny areas of Iberia up to 1,000 m asl. This species does not thrive in highly calcareous soils but can tolerate a limit of 50% limestone (Vieira *et al.*, 2000). It is generally found in thermo- and meso-Mediterranean regions and thrive in average annual temperatures 13-19°C. Their low temperature tolerance is about –5°C. They can withstand annual rainfall as low as 250-300 mm but prefer 400-1,000 mm. The stone pine masts every 3-4 or 5-6 years but some seeds are produced during non-mast years. In stands in southern Portugal, trees typically produce 250 cones per year, but often 1,000 and sometimes 2,000 (Vieira *et al.*, 2000). Seed production is generally more reliable in *P. pinea* than pines of western North America (LeMaitre, 1998). Peak production occurs in November and cones remain on the trees until January or February. Each cone averages about 100 pine nuts which is a tremendous contrast with *P. monophylla* of western North America that typically produces 6-16 nuts per cone (Barlow and Metcalfe, 1996; Badal, 1998). Similar yields were observed in natural stands of *P. pinaster* (Miguel Pérez *et al.*, 2002). Therefore, a single tree could produce 25,000-100,000 and even 200,000 pine nuts per year. In central Spain, where annual rainfall averages 450 mm, natural pine forests contain about 100 trees per hectare (Miguel Pérez *et al.*, 2002). Similar conditions in the past would have presented prehistoric hunter-gatherers with a bountiful harvest. Modern workers harvesting *P. pinea* with long pikes collect 400--600 cones per day on average. Cones are left exposed to the sun to dry and open so that seeds can be collected. One hundred kg of cones yields 15-22 kg of hulled seeds. For pine nuts in their hulls, 1 kg equals about 1,400 seeds. For hulled seeds, 6,300 pine nuts weigh about 1 kg (Badal, 1998). With minimal time and labor investment, prehistoric hunter-gatherers could have easily harvested and processed substantial amounts of pine nuts.

Table 4 shows the nutritional values for some of the varieties of pine nuts utilized for food around the world. There is considerable variability in pine nut nutrient composition between species. The most striking characteristic of *P. pinea* is the high percentage of protein. It also has high percent fat but low percent carbohydrate. In contrast, the values for *P. monophylla* in the Great Basin show it is poor in protein but high in carbohydrate. Considering Speth's (1991) argument that hunter-gatherers could have avoided problems associated with excessive protein intake by consuming carbohydrates, *P. monophylla* may have been a valuable "protein-sparing" resource in the Great Basin. However, in Iberia, pine nuts may have been more important as storable reserves of balanced protein and fat in order to mitigate the drought stress of summer. Table 5 shows nutrient values for *P. pinea* measured in grams/100g by three different laboratories. These results show that despite a high protein percentage, *P. pinea* seeds do constitute good sources of carbohydrate.

Seeds of *P. pinea* have a high fat content and therefore need to be dried or roasted to avoid spoilage. In controlled conditions, seeds dried at room temperature showed increases in soluble protein content that peaked after 6 months (Fernández-García de Castro and Martínez-Honduvilla, 1982). Under low heat (47°C) seeds showed an overall increase in protein and free amino acids but a slight decrease in lipid content (Martínez-Honduvilla *et al.*, 1974). Although no data were presented on changes in fat content in stored seeds it may be reasonable to assume that low-heat drying would result in better fat-retention. In addition, pine nuts can be eaten raw but their flavor and storability improves with light roasting.

Acorns in Iberia

For almost a century, anthropologists have realized the importance of acorns as human food (Merriam, 1918). Anthropologists long held that the incredible natural abundance of different acorns attracted human groups and led to their role as a dietary staple. Acorns seem to have supported very large human populations in late-prehistoric and early historic California. Until recently, acorns were viewed as a highly nutritious and productive resource that could be easily collected and utilized. Basgall (1987), using principles from optimal foraging theory, noted that acorns actually required significant labor investment to leach the tannins that made them too bitter for immediate consumption. He argued that the caloric return rates for acorns made them a low-ranked item because of the high processing costs relative to energy yield. Among North American archaeologists, acorns quickly became perceived as a marginal resource that only became economically important when other resources were exhausted (Basgall, 1987; Mason, 1995a&b; McCorriston, 1994). However, this model is based on the assumption that the appearance of grinding stones in California prehistory was correlated with acorn consumption (Basgall, 1987). Since acorns can be intensively processed using perishable materials such as wooden mortars and pestles, earlier acorn use might be archaeologically invisible. Additionally, evidence of leaching methods such as soaking in water either in special pits or in streams, boiling and roasting might not survive. Therefore, dismissal of significant prehistoric acorn consumption may be premature.

In his book, "*Prehistoric Europe: The Economic Basis*" (1952), Grahame Clark discussed prehistoric acorn consumption in the Mediterranean. Citing the geographer, Strabo, he noted the Lusitanians, in what is now Portugal, were observed to eat bread made of ground acorns for three-quarters of the year. Although in later times acorn flour was milled and made into "famine breads" when grains were scarce, many people appear to have subsisted off acorns for centuries (Jørgensen, 1977). Numerous citations from classical sources suggest acorns were viewed as the basis for all of civilization (Clark, 1952; Mason, 1995; Vencl, 1996; Sieso and Gómez, 2002). In fact, the genus name

"Quercus" is derived from two Celtic words meaning "beautiful tree" suggesting its importance in early times (Sánchez Arroyo, 1999). Vencl (1996) and Sieso and Gómez (2002) provide detailed summaries of the archaeological evidence for acorn use through time on the Iberian Peninsula. In Portugal, Afonso do Paço (1954) reported concentrations of acorns at the Copper Age site Vila Nova de São Pedro. Senna-Martínez (1994) reported carbonized acorns from the Neolithic site of Ameal in northern Portugal. Arnaud (1990), Bicho (1993) and Lubell and Jackes (1994) hypothesized that acorns were eaten during the Late Upper Paleolithic and Mesolithic though no direct evidence has been recovered to date. Acorn-eating, or balanophagy, survives today in Iberia where sweets are made from acorns. In Algarve, people eat raw acorns from the evergreen oaks. On Sardinia, local people still gather acorns and process them using traditional methods. Acorns are mixed with a special iron-rich clay and boiled to absorb the tannins (Johns, 1990). In the western Rif of Morocco, acorns are eaten raw, toasted, soaked in water or sun-dried (Peña, 2000).

Mason (1995b) detailed the widespread use across space and time in her review of the use of acorns as food in prehistoric Europe. She gave four reasons why acorns may have played an important role in Mesolithic diets which are also applicable to the Mediterranean Paleolithic and Epipaleolithic:

> 1) Oaks were an important element of vegetation... and would have been a commonly, and sometimes abundantly available, resource.
> 2) Acorns are, in nutritional terms, a potential energy staple – they are a bulk carbohydrate-provider and are very similar in nutritional terms to the cereals...
> 3) They are potentially storable for long periods, and can be a valuable overwintering resource.
> 4) Ethnographic and documentary evidence from wherever oak trees are found suggests that acorns have been an important (often dominant) plant-food resource for hunter-gatherers... (2000: 141).

Prior to the adoption of cereals, acorns may have been significant resources for prehistoric Mediterranean hunter-gatherers as is well-documented for Eastern and Western North America and Japan (Merriam, 1918; Lewthwaite, 1982; Mason, 1995a&b). In the Near East there is solid evidence that acorns were used as food as early as 19,000 bp at Ohalo II (Kislev *et al.*, 1992). At La Sarga, an Epipaleolithic site in València, a painted rock art scene shows several figures collecting acorns as they fall from the tree (Fortea and Aura, 1987). However, inadequate recovery techniques and/or preservation biases inhibit an understanding of the role acorns may have played in European hunter-gatherer subsistence. The absence of acorn parts is made difficult by taphonomic factors such as possible small mammal or wild boar feeding (Leiva and Fernández Alés, 2003). Processing methods may also disfavor preservation as most remains may never have been charred and thus preserved more easily (Mason, 1995). Field processing among stands near base camps may also eliminate those parts of the acorn (or pine nut) so that the evidence for use is discarded offsite. These processing locales would likely be archaeologically invisible since they would not require the use and retouching of stone tools which would leave behind a durable residue. If, however, processing included roasting and/or pounding with stones a durable record might be left. In this case it is doubtful, in the absence of lithic type fossils, that such scatters of unflaked, unretouched stones and charcoal would be reported as an Upper Paleolithic site.

Iberia is home to several species of evergreen and deciduous oaks. Typically, evergreen oaks are found in the thermo- and meso-Mediterranean vegetation zones. These include *Quercus ilex*, *Q. suber* and *Q. coccifera*. Deciduous oaks are found in the meso-Mediterranean zone but mainly in the supra-Mediterranean. These species include *Quercus faginea*, *Q. pyrenaica*, *Q. robur*. The species most commonly used as food in Iberia throughout the past is *Q. ilex*, but each can be consumed with some degree of processing. *Q. ilex* and *Q. suber* produce sweet acorns that require minimal processing time, usually light roasting. *Q. coccifera* has an astringent and bitter acorn and would require considerable leaching. The deciduous oaks are slightly bitter compared to *Q. ilex* and *Q. suber*, however, people consumed them in the past (Mason, 1995; Peña, 2000; Sieso and Gómez, 2002).

The Holm oak, *Quercus ilex*, today prefers calcareous soils and rainfall between 600-1000 mm. Holm oaks cannot maintain closed canopies with less than 400 mm precipitation (Terradas, 1999). Below that, Mediterranean shrubs will dominate. *Q. ilex* is more cold-resistant than other evergreen oaks in Portugal. Today it withstands temperatures as low as –15°C and can live through short periods as low as –20 to –25°C. Young trees may not survive below –10°C so that may be the low point for overall survival (Terradas, 1999). The Holm oak is a mast species in which high acorn production occurs every 4-6 years. Acorns mature and fall between November and January. Data on Holm oak productivity in Catalunya show considerably inter-annual variability in acorn production. Siscart *et al.* (1999) calculated ranges between 300 acorns per m^2 to $25/m^2$. In *dehesas*, individual trees produce an average of 12-18 kg of acorns per tree, but some may produce as much as 600 kg in a single year (Parsons, 1962).

Quercus suber, the cork oak, prefers siliceous soils and 600-800 m rainfall. It prefers the lower elevations of southern Spain and Portugal but it is found at elevations up to 800 m in northern Portugal. Cork oaks prefer mean annual temperatures of ~15°C but will tolerate temperatures as low as –5°C. Acorns mature in autumn and drop between October and March. Yields are slightly lower for cork oaks compared to the Holm oak.

The deciduous oaks are generally restricted to northern Portugal and upper elevations in the central part of the country. *Quercus faginea* prefers the 600-1200 m elevation zone but is still common in the lowlands. It will tolerate hot summers and temperatures as low as –12°C in winter. The acorns mature in September. *Q. pyrenaica* is mainly found between 400 and 1600 m asl, but can grow up to 2100 m asl. It prefers siliceous soils and annual rainfall above 600 m with a temperature range of –7°C in winter and 22°C in summer. The acorns mature in October and November. *Q. robur* is found between 0 and 1000 m asl, but as high as 3000 m in northern Portugal and Spain. It requires at least 600 m annual rainfall and is limited by winter lows of –15°C and summer highs of 25°C. Acorns mature in September and fall in October.

Table 6 shows the nutritional characteristics of *Q. ilex* and *Q. suber* acorns compared to the California oaks. In contrast to pine nuts, the acorns are poor in protein and fat, but much higher in carbohydrate. Fat and protein content are comparable to the California species but both are considerably lower on average in percent carbohydrate.

Recently, Harrison (1996) has brought attention to the highly productive and "sweet" acorn of the holm oak. This species is widespread in Iberia due to the *dehesa* (*montado* in Portugal) land-use system in which pigs are fattened on acorns prior to slaughter. The two primary oak species in the *dehesa / montado* are *Q. ilex* and *Q. suber*. For *Q. ilex*, 9 kg of acorns translates into 1 kg of pork (Joffre *et al.*, 1999). In some areas, pigs and cattle will eat the acorns from *Q. faginea*, the Portuguese oak, however its acorn is bitter compared to that of *Q. ilex* and *Q. suber*. The Pyrenean oak, *Q. pyrenaica*, is also incorporated into the *montados* north of the Tejo. Pollen studies in southwest Spain suggest the earliest physical record of such managed woodlands dates to about 6,000 bp (Stevenson and Harrison, 1992). While the *dehesa / montado* system is part of a pastoralist economy, it does not necessarily require domestic plants or animals. The system enhances productivity by encouraging oak groves as well as several other arboreal species in order to increase browse for pigs, goats and cattle. In addition, these human-created ecosystems are home to a wide diversity of wild animals including red deer, wild boar, rabbit, Iberian lynx and birds (Fernandes de Abreu *et al.*, 1993).

Hunter-gatherers incorporating simple forest management techniques such as pruning, burning or possibly intentional planting could have created improved foraging areas for wild boar, deer, chamois and even wild aurochs. Spring pruning in the *dehesa / montado* is the primary method for increasing acorn yields per tree however this would be difficult if not impossible to detect archaeologically. There is evidence of prehistoric fire management of European woodlands by people during the Mesolithic (Mellars, 1976; Mason, 2000). Much of this burning has been perceived as a means of encouraging new growth for browse to support deer and other ungulates. However, as Mason (2000) points out, burning can encourage the proliferation of desirable forest species for human subsistence.

In this case, fire may have been used as a tool to manage oaks or other fruit / nut-bearing vegetation. Fire may permit more light to reach the crown thus increasing acorn yield for individual trees (Mason, 2000). Comparisons between Holm oaks in managed stands and natural forests showed that unmanaged trees are generally shorter, found closer together and have smaller canopies (Pulido *et al.*, 2001).

Fire also benefits the cork oak which is used today to reforest fire-prone areas because of their thick protective bark (Carrión *et al.*, 2000). It also produces what is considered a "sweet" acorn, meaning that they are low in tannin. These sweet acorns of southern Iberia require minimal roasting time to make them palatable. It should be noted that the amount of tannin does not correlate well with perceptions of edibility. Some aboriginal groups in California preferred the most bitter acorns, possibly due to their higher fat content (Basgall, 1987; Mason, 1994, 1995).

Lewthwaite (1982) has raised the possibility that humans played a deliberate role in selecting sweet acorn varieties. This could have important consequences for lowering processing costs to remove tannins prior to human consumption. On the other hand, humans may have intentionally selected sweeter acorn varieties after observing that pigs prefer the sweeter ones (Parsons, 1962). Oak stands could have been managed to provide carbohydrate and fat for human diets or to create animal fat and protein, "porridge or pannage" to borrow from Grigson (1982).

The emphasis here on pine nuts and acorns serves to illustrate the productive yield of plants, their nutritional value and often minimal processing costs. Other productive and nutritionally valuable tree nuts may have been available such as chestnuts and hazelnuts. Table 4 also shows the nutritional values for each of these along with pine nuts and acorns.

Late Pleistocene / Early Holocene Portugal

The examples noted earlier provide evidence that plants were available and utilized by prehistoric people throughout the Late Pleistocene and Early Holocene in Iberia. Two key questions concern the timing of their availability and the antiquity of significant plant exploitation in central Portugal. There is a nearly complete absence of macrobotanical evidence of plant use during this period. Instead, inferences must be made based on paleoenvironmental studies, including pollen and charcoal, interpretations of stone tool technology, microscopic use-wear and recovery of starch grains. The last two are only beginning and no definitive results can be presented here. Thus, the discussion will focus on the potential plant availability from paleoecological studies, interpretations of stone tool technology and expectations derived from experimental and ethnographic studies of economic plant utility in other regions.

Climate change and paleoenvironment

Paleoenvironmental data for Tardiglacial and early Postglacial Portugal are extremely limited. Information comes from geomorphology, deep-sea cores, pollen, archaeofaunal and charcoal studies. Some of these data have been integrated into regional syntheses of the Portuguese Upper Paleolithic by Bicho (1993, 1994) and Zilhão (n.d., 1997, 1998). The standard interpretation was based on CLIMAP (1976), pollen diagrams from Lagoa Comprida in the Serra da Estrela and nearby ponds in northwest Spain (Janssen and Woldringh, 1981; Turner and Hannon, 1988; Mateus, 1993; van den Brink and van Leewarden, 1985, 1997), charcoal analysis from Cabeço de Porto Marinho (Figueiral, 1993), sedimentological and microfaunal evidence from Caldeirão Cave (Zilhão, 1992; Póvoas *et al.*, 1989), and geologic context of open-air sites (Marks *et al.*, 1994). New data published since these syntheses are considered here.

The general circulation model of CLIMAP (1976) showed the Polar Front as low as northern Portugal (42°N) during the Last Glacial Maximum (LGM), remaining there until approximately 12,000 bp (Ruddiman and McIntyre, 1981; COHMAP, 1988). The occurrence of cold temperatures below 42° was also attributed by Bard *et al.* (1987) to the southward movement of the Polar Front. However, summer sea surface temperatures (SST) were only a few degrees lower than present between 18-14,500 bp off southern Portugal (Duplessy *et al.*, 1992). The discrepancy between these studies is therefore explained by a steep thermal gradient caused by the southward position of the Polar Front and the movement of warm tropical waters northward. On the other hand, Fatela *et al.* (1994) used benthic foraminifera data to argue that this cooling was due to the influx of cold glacial meltwater into the North Atlantic during Termination IA of Oxygen Isotope Stage 2 deglaciation (Table 7). Furthermore, they argue that the Polar Front never penetrated south of 42°N during the LGM or deglaciation (Fatela *et al.*, 1994; Abrantes *et al.*, 1998). Zahn *et al.* (1997) estimated SST for the LGM (20-17k bp) of 18-23°C for winter and 22-26°C for summer due to oceanic circulation patterns that brought warm waters to the Portuguese margin. Termination 1A is also marked by the occurrence of a Heinrich event. These correspond to periods of iceberg flow from the Laurentide and Fenno-Scandinavian ice sheets into the North Atlantic between 40°N and 60°N where they melt and the dust that was locked in the ice accumulates on the ocean floor (Abrantes *et al.*, 1998; Baas *et al.*, 1998; Grousset *et al.*, 2000; Chapman *et al.*, 2000). The occurrence of such "ice-rafted detritus" (IRD) in cores off the coast of Portugal indicate the southernmost drift of icebergs during Heinrich events (Lebreiro *et al.*, 1996). Not surprisingly then, the deglaciation is marked by several fluctuations in temperature and salinity.

Duplessy *et al.* (1986) argued that continental deglaciation of northern Europe took place in two phases, the first (Termination 1A) occurred 16,000-13,000 bp and the second 10,000-8,000 bp (Termination 1B), with no apparent melting 13,000-10,000 bp. Other studies placed the initial deglaciation around 14,000 (Duplessy *et al*., 1986). Later studies of oxygen isotopes and planktonic foraminifera from deep sea cores off southern Portugal by Bard *et al*. (1987) show February sea surface temperatures (SST) as low as 4°C (15°C today) between 14,500-12,500 bp. Duplessy *et al*. (1996) show 11°C SST (21°C today) for summer. Both of these studies would appear to agree that conditions were much colder during the Termination 1A/H1/Dryas I in Portugal. The cause of the lowered SST and overall salinity has been attributed to meltwater influx from the continental ice sheets. After Dryas I, summer SST was as high as today during the Bølling / Allerød. In core SU 81-18 the Younger Dryas is characterized by a rapid drop in SST and salinity (Duplessy *et al*., 1992).

Geochemical analyses of sediment in Caldeirão Cave Layer Eb suggest strong humid (warm?) winds blowing across Estremadura some time after 16,000 bp and before 10,000 bp (Cruz, 1992). However, the lack of stratigraphic and chronological resolution makes it impossible to know when this occurred. It may correspond to the Lascaux or Bølling / Allerød interstadial. Zilhão's (1997) interpretation of the Caldeirão stratigraphy suggests the latter.

During the Last Glacial Maximum, sea levels were approximately 140 m below their current level (Dias, 1985; Dias *et al*., 1997; Rodrigues *et al*., 1991). In some places along the Estremaduran coast, the LGM shore was approximately 40 km east of its current position. By about 16,000 bp, sea level rose to about –100 m but large areas of land were still exposed, up to 30 km in much of Estremadura. According to Dias *et al*. (2000) sea levels remained steady until about 13,000 bp. Between 13,000 and 12,000 bp, sea levels rose to about 40 m below their current level, effectively shrinking the available land surface of Estremadura by about 25% during the Tardiglacial (Figure 2). This corresponds to the beginning of the Bølling / Allerød Late Glacial interstadial. During the Younger Dryas cold snap sea level lowered again to 60 m below present. Afterwards, between 10,000-8,000 bp sea level reached 30 m below present. This was followed by the Atlantic period transgression (7,500 bp) that created a large estuary in the lower Rio Tejo. By 3,500 bp sea level had stabilized at its present level. While seemingly dramatic by geologic time, human groups would probably not have faced crises in adaptation because the changes in sea level occurred over hundreds of human generations (Waselkov, 1987). However, the lag between the marine and terrestrial records of 180-350 radiocarbon years suggests more rapid shifts (Boessenkool *et al*., 2001). Whatever the case, the submergence of about 40 km of continental shelf has, in all likelihood, drastically affected the archaeological record for the Solutrean and Magdalenian in Portugal (Figure 2).

Information on vegetation in Portugal during the period 15,000-10,000 BP comes from pollen studies in the Serra da Estrela and charcoal analyses from Cabeço de Porto Marinho and Lapa do Suão (Van der Knapp and Janssen, 1991; Figueral, 1993; Haws and Valente, 2001). Pollen evidence from Charco da Candeeira, a pond located at 1400 m asl in the Serra da Estrela, shows a rapid succession of steppe grasses and composites to herb and Ericaceae near the pond in the early Bølling (Figure 3). The occurrence of pine, birch and oak forest pollen suggests an expansion of forest refugia at lower elevations during this interstadial, dated 12,600 bp (Van der Knaap and van Leeuwen, 1997). Prior to this, pollen was almost entirely absent possibly due to the outwash of montane glaciers. Unfortunately, no other pollen cores exist in Portugal earlier than 12,600 bp. In fact there are no low elevation pollen cores for the Late Pleistocene. After the interstadial forest expansion, the Charco da Candeeira core shows a climatic downturn corresponding to the Older Dryas (Dryas II) phase in northern Europe. This was followed by an amelioration correlated with the Allerød interstadial. In the nearby Covão do Boieiro deciduous and evergreen oaks increase approximately 10,000 bp (van der Knapp and van Leeuwen, 1997). An additional 60 cm of undated Late Glacial deposits shows a predominance of *Pinus sylvestris / pinaster* type pollen with a reduced but constant occurrence of oak and minor contributions of birch, alder, sycamore, ash, hazel, olive and yew. The authors place these deposits in the Allerød and Younger Dryas phases. Thus it appears that trees were widespread in the mountains by 11,500 bp. A number of shrubs are also evident including *Calluna*, *Erica*, *Genista*, and *Juniperus*. Their presence, along with grasses, suggests open woodland vegetation that reached a peak in density prior to the Younger Dryas. No radiocarbon dates have been made, but the Chafariz do Rei sequence (1770 m) shows *Pinus* and Artemisia at the base possibly corresponding to the Bølling (van der Knapp and van Leeuwen, 1997). Oak and birch appear during the late Bølling / Dryas II / Allerød sequence. At a slightly lower elevation (1150 m), the Lagoa de Marinho sequence dates to the Allerød phase. The arboreal pollen is dominated by deciduous oak with lesser amounts of evergreen oak, hazel, birch, chestnut, holly, ash, alder, poplar, willow and myrtle (Ramil Rego *et al.*, 1998).

From a regional perspective, additional pollen studies have been made in adjacent areas in Spain, namely Galicia and Andalucía. Galicia is important because it (and northern Portugal) marks a biogeographical boundary between the Euro-Siberian and Mediterranean zones (Muñoz Sobrino *et al.*, 1997). Cantabria is considered entirely within the Euro-Siberian belt. Andalucía is fully Mediterranean today. The only pollen sample in western Iberia dated to the Late Pleniglacial comes from Laguna Lucenza (1375 m asl) in Galicia (Muñoz Sobrino *et al.*, 2001). Cold loving and sun-loving plants dominate the period before 17,300 cal yr BP. Trees present include pine, birch and deciduous oak. Dryas I (here dated 17,300-15,300 cal yr BP) is marked by an increase in Artemisia indicating cool, dry steppe conditions. However, tree pollen in low percentages includes pine, juniper, birch, hazel and deciduous oak. Between 15,300 and 13,300 cal yr BP arboreal pollen expands to as high as 80%. Added to the previous types are evergreen oak, chestnut, alder and ash. On the coast at Mougás, tree pollen is low with dominance by humid-adapted heathers and grasses (Ramil Rego *et al.*, 1998). Additional pollen studies in the mountains of northwest Iberia show a Bølling / Allerød vegetation composed of 40-60% trees, mainly pine and birch with some deciduous oak, hazel and chestnut (Muñoz Sobrino *et al.*, 1997). Grasses and herbs made up the rest. The sequence from Brañas de Lamela (1280 m asl), a more south-facing, sheltered basin, contained the Mediterranean-type evergreen oak (*Quercus ilex*). It would appear therefore, that climate during this period was very similar to today.

In southern Spain, pollen cores dating to the Late Pleistocene have been published from El Asperillo (0-30 m) near Huelva, Padul (785 m asl) near Granada, San Rafael near Almería (Pantaléon-Cano *et al.*, 2003) and Navarrés (225 m asl) near Valencia (Stevenson, 1984; Pons and Reille, 1988; Carrión and van Geel, 1999). The El Asperillo sample is from a peat band dated to 13,000 bp. It shows a slightly cooler and wetter climate with a downward elevational shift in forest cover of about 100 m compared to today. Several studies have been conducted at Padul, the most recent supported by 21 radiocarbon dates (Pons and Reille, 1988). The LGM appears to be a time of widespread arid steppe vegetation with grasses and some pine trees. Oaks and Ericaceae are present but in very low percentages, indicating a nearby refugium of Mediterranean species. About 15,000 bp, pine pollen decreases sharply as steppe species increase, suggesting a possible climatic amelioration. Pons and Reille (1988) conclude that climatic amelioration did not take place until after 13,000 bp, when evergreen oak (*Quercus ilex*) pollen increases. The core from the Canal de Navarrés (Valencia) shows high aridity at 18,000 bp with a gradual replacement of Artemisia by pine sometime afterwards. The Dryas II is recorded at 12,000 bp by a return of Artemisia. Its occurrence in several peaks suggests rapidly fluctuating climatic conditions during the Tardiglacial (Carrión and Van Geel, 1999). At San Rafael, the Upper Pleniglacial vegetation is marked by a high arboreal pollen percentage (~75%) (Pantaléon-Cano *et al.*, 2003). The most abundant tree pollen comes from evergreen and deciduous oaks wild olive, with mastic also evident. Grasses are fairly well represented indicating perhaps open woodland.

Recently, marine pollen records from deep sea cores have been published (Hooghiemstra, 1988; Hooghiemstra *et al.*, 1992; Parra, 1994 – cited in Carrión *et al.*, 2000). Pollen diagrams from cores SU 8103 off SE Spain, SU 8113 off SW Spain and 8057B off SW Portugal show interesting correlations to the terrestrial cores. In all three, pine dominates the arboreal spectrum but other deciduous and evergreen trees are present from the LGM onwards. After 14,900 in core 8057B, *Pinus*, Artemisia and Chenopodiaceae decrease sharply at the expense of evergreen and deciduous oak (Hooghiemstra *et al.*, 1992). In the cores off Spain, there is a more gradual shift from the Artemisia and Chenopodiaceae to the evergreen oaks around 12,000 bp (Carrión, 2000). Sánchez Goñi *et al.* (1999, 2000, 2002), Boessenkool *et al.* (2001) and Roucoux *et al.* (2001) have correlated the terrestrial pollen records with the marine record from the Last Interglacial to present. Boessenkool *et al.* (2001) show the spread of deciduous oak slightly later, around 13,000 bp, than the record from core 8057B nearby. Turon *et al.* (2003) show the same pattern for core SU 81-18 to the west of 8057B. In core MD95-2039, a site 180 km offshore to the west of the mouths of the Douro and Mondego rivers, arboreal pollen reaches higher than present levels after Heinrich I (Roucoux *et al.*, 2001).

The general picture for the Last Glacial Maximum climate in Iberia is of aridity with slightly cooler temperatures followed by instability between 17-14,500 bp. After a cold event triggered by meltwater and iceberg rafting around 14,500 bp, temperatures and precipitation increased by 13,000 bp, allowing forests to return to the uplands. The lack of low elevation pollen records for much of Iberia precludes a definitive paleoenvironmental reconstruction. In all cases, except El Asperillo, Mougás and San Rafael, pollen cores come from lakes, ponds or peat deposits in mountain zones. Most have no record of the initial deglaciation or at best imply cool arid steppe vegetation prior to the last glacial--interglacial transition. In spite of this problem, warm adapted Mediterranean trees are evident in these cores albeit in very low frequency. This likely reflects a regional pollen input and that low elevation zones must have been refugia for these plants (Carrión, 2002). The enhanced aridity evident from pollen cores during the Heinrich events was likely caused by shifts in atmospheric circulation patterns. The present-day Mediterranean climate regime is characterized by hot dry summers and mild wet winters. During the LGM and Termination 1A / Heinrich 1 / Dryas I the winter precipitation decreased because of increased stability in high-pressure due to the lack of southward movement of polar highs (Combourieu Nebout *et al.*, 2002). Conversely, during millennial-scale oscillations of interstadial conditions known as Dansgaard-Oeschger events higher winter precipitation and summer temperatures permitted forest expansion (Combourieu Nebout *et al.*, 2002; Sánchez Goñi *et al.*, 2000, 2002). The slow rate of expansion of oak forests and the long lag between the marine pollen and SST records suggest that warming began much earlier than 13,000 bp (Boessenkool *et al.*, 2001; Chapman *et al.*, 2000).

Charcoal analyses at the Upper Paleolithic site of Cabeço de Porto Marinho provide the only low elevation Tardiglacial paleobotanical data for Portugal. Figueral (1993) identified components of a mixed Atlantic / Mediterranean community of pine (*Pinus pinaster / pinea*), evergreen and deciduous oak, birch (*Betula pubescens*), olive (*Olea europaea* var. *sylvestris*), ash (*Fraxinus angustifolia*), wild strawberry (*Arbutus enedo*), tree heath (*Erica arborea*) and Leguminosae in CPM levels dated 11,200 bp, corresponding to the Allerød. Charcoal analyses from the Magdalenian levels of Lapa do Suão shows a similar composition. Species identified include deciduous oak, pine, wild fruit (members of the Rosaceae family) and olive. Radiocarbon inversions preclude a high-resolution chronology of plant succession. Lapa do Picareiro has abundant charcoal in levels dated between 8,310-12,300 bp but it has not been fully analyzed. Preliminary analysis points to a similar vegetation comprised of deciduous oak, pine, wild olive, willow, ash and Leguminosae typical of Mediterranean garrigues. The majority of oak in the Late Magdalenian levels is a deciduous oak, possibly *Q. faginea*. The dominance of this species in the Magdalenian levels indicates warm, humid conditions as its highest densities in Iberia today occur along the Estremaduran coast down to southern Portugal.

In Spain, charcoal analyses have been done on numerous sites in Cantabria, the Pyrenees and the Mediterranean region. Late Glacial assemblages from Cova de les Cendres, Cova de Santa Maira, Ratlla del Bubo, Tossal de la Roca, Cova Bolumini and Cueva de Nerja in the Mediterranean region show a much greater abundance of trees during the Dryas I phase 15,000-12,500 bp than pollen diagrams. This is likely due to elevational differences between the montane ponds and lakes where the pollen cores were taken and the archaeological sites. At Ratlla del Bubo, dated to the Solutreo-Gravettian, juniper dominates but several other trees are present in low frequency. These include turpentine tree and mastic (*Pistacia terebinthus* and *P. lentiscus*), wild olive (*Olea europaea* var. *sylvestris*), fig (*Ficus*) and ash (*Fraxinus oxyphylla*) (Badal and Carrión, 2001). Charcoal from the preceding Solutrean levels at Cendres was predominately black pine (*Pinus nigra*), with woody Leguminosae, juniper and small percentages of the evergreen oaks, *Quercus ilex* and *Q. coccifera* (Villaverde *et al.*, 1999). Herbs and shrubs were also identified. During the initial warming, pine decreased as juniper, Leguminosae and evergreen oak increased. Also identified during this period are *Prunus* sp., deciduous oak, heather (*Erica multiflora*) and *Ephedra*. The Dryas I cold phase is marked by a sharp increase in juniper at the expense of pine and Leguminosae. The evergreen oaks decrease but are still present. In the Upper Magdalenian levels corresponding to the Bølling / Allerød interstadials pine comprises over 50% of the assemblage with juniper, Leguminosae and evergreen oak in low percentages. At the end of the occupation deciduous oak, poplar and *Pinus halepensis* appear. Villaverde *et al.* (1999) note that the environment surrounding the shelter was probably as dry as today but slightly cooler due to the co-occurrence of black pine and evergreen oak. At Tossal de la Roca the early occupation level, dated 15,360 bp, had charcoal from pine (*Pinus nigra*), with low percentages of juniper and deciduous oak (*Quercus faginea*), and box (*Buxus sempervirens*) (Cacho *et al.*, 1995). This suggests a similar vegetation to Cendres for the same period. In the Final Magdalenian level dated after 12,500 bp pine still dominates but deciduous oak increases from 1% to 18%. Montpellier maple (*Acer monspessulanum*) and rockcherry (*Prunus mahaleb*) appear in low frequencies. In the Microlaminar Epipaleolithic level (10,500) pine drops to a low percentage while oak and juniper dominate. In the Exterior section, the dated to the Geometric Epipaleolithic, here dated 9,000-7,000 bp, there is a higher diversity of trees represented in the charcoal assemblage. Evergreen and deciduous oaks comprise about

80% of the assemblage followed by *Prunus mahaleb*, *Sorbus* sp. (another wild fruit tree), maple and pine (Cacho *et al.*, 1995). The Santa Maira charcoal assemblage shows a steady decline in juniper from about 60% in the Upper Magdalenian levels to less than 10% by the Geometric Epipaleolithic (Badal and Carrión, 2001). During this time evergreen and deciduous oaks comprise about 50% followed by low percentages of *Prunus*, maple and poplar. Other Mediterranean types include ivy (*Hedera helix*), Cistacae, *Erica* sp., *Fraxinus* sp., *Buxus sempervirens* and *Pinus pinea*. The vegetation represented is similar to that identified at CPM in Portugal during the same period with the exception of juniper. This may simply be due to elevational differences between the two sites. At Bolumini, the brief Late Magdalenian levels show the oak expansion during the Bølling / / Allerød interstadial.

Microfaunal analyses are also useful in accurate paleoenvironmental reconstruction. Together with pollen and charcoal studies, these data can help balance the biases in regional pollen inputs and human selection of wood fuel. In Portugal, Póvoas *et al.* (1992) argue for a shift to a Mediterranean climate during the formation of Level Eb at Caldeirão, dated 14,450-10,700 bp. This interpretation is based on the increase in percentages of the Mediterranean pine vole *Terricola duodecimcostatus* and decrease in the ratio of the voles, *Microtus arvalis* to *M. agrestis*. Unfortunately the rodents are mixed in with ceramics and sheep bones dated directly to 6,200 bp making it impossible to recognize climatic fluctuations seen in the deep-sea record. At Picareiro, during the Upper Paleolithic sequence, Markova (n.d.) notes high percentages of *Terricola duodecimcostatus* together with *Apodemus sylvaticus* (field mouse) and *Eliomys quercinus* (garden dormouse) indicative of Mediterranean forested environments and rocky habitats in Level J. This trio dominates the entire sequence with subtle changes observed in Level I where the snow vole, *Chionomys nivalis*, appears, as well as Level F where *Microtus agrestis* occurs. Level I could date to either the LGM, Upper Pleniglacial or Dryas I which would have been times of cooler and relatively dry conditions. This is supported by the deposition of *éboulis sec* in the cave. Level F dates almost entirely to the Dryas II climate phase which was likely more moderate (wetter) than today as indicated by the presence of *Microtus agrestis* (Markova, n.d.). Indeed, Dryas II barely registers in the deep sea core (SU81-18) off the coast of southern Portugal and is absent in many regional pollen cores (Bard *et al.*, 1987; Peñalba *et al.*, 1997; van der Knapp and van Leeuwen, 1997; Carrión and Van Geel, 1999). The presence of the water vole, *Arvicola terrestris*, in E Lower is not surprising given the radiocarbon overlap between this level and Level F. In the Magdalenian levels of Lapa do Suão, dated to roughly 15,000-10,000 bp, Haws and Valente (2001) identified *Eliomys quercinus*, *Arvicola terrestris* and *Microtus agrestis*. The composition matches that of Caldeirão Eb and Picareiro E and F.

Pleistocene paleoenvironmental reconstructions also rely on macrofaunal remains from archaeological sites (Bicho, 1993, 1994; Cardoso, 1993a&b; Zilhão, 1995). At Caldeirão, the disappearance of ibex (*Capra pyrenaica*) and chamois (*Rupricapra rupicapra*) and subsequent replacement by red deer, roe deer, wild boar and beaver has been argued to indicate a change from cold, dry steppe to warm, humid forest conditions. Explicit in this argument is the idea that the former animals are cold-adapted because of their presence in alpine areas of Iberia today. However, researchers in Mediterranean Spain use chamois as an indicator of warm, humid forest conditions in the early Holocene. Although chamois today is usually found in higher elevations across Europe, Tosi *et al.* (1987) show it living at 300 m elevation in Italy. These facts support the idea that chamois have a much-restricted range than in the past. Indeed, Miracle and Sturdy (1991) presented evidence from the Balkans that habitat alteration and human hunting pressures in the recent past have forced chamois out of low-elevation karst zones. Therefore, the disappearance of chamois from the Caldeirão assemblage likely represents a change in human selection of this prey, not simply a change in climate. Its occurrence in Allerød levels at Picareiro provides further support (Haws, 1998).

Although data are scanty it is likely that the Younger Dryas impacted central Portugal. Bard *et al.* (1987) and Duplessy *et al.* (1996) show cold waters of the coast of southern Portugal during the Younger Dryas. Magnetic susceptibility curves for Picareiro show a sudden drop between 11,700 and 10,070 bp likely corresponding to the Younger Dryas (Ellwood *et al.*, 2001). An abrupt decrease in oak pollen from marine cores suggests a rapid decline in temperatures on land. Pollen spectra from northern and southern Spain, however, show a return of steppe communities indicative of dry but not very cold conditions (Pons and Reille, 1988; Peñalba *et al.*, 1997; Carrión and Van Geel, 1999). Both evergreen and deciduous oaks remain present in Padul and Quintanar de la Sierra (1470 m asl) but in lesser frequency. In Catalunya, the Lake Banyoles record shows a drop in Pinus but other species remained constant (Pérez-Obiol and Julià, 1994). The molluscan evidence from Pedra do Patacho dated 10,400 bp have been argued to indicate cold waters off the southwestern Portuguese coast due to the presence of *Littorina littorea*. However, these limpets are found today on the Algarve coast casting doubt on their use as paleoclimatic indicators.

In the early Holocene, by 9,500 bp, a mix of Mediterranean and Atlantic species returned to Estremadura. Pollen diagrams from the Lagoa Comprida (1400 asl) show vegetation at 9,200 bp dominated by pine with Artemesia and Chenopods indicating an open forest (Jansen and Woldringh, 1981). Between 9,200-9,000 bp, there was a rapid transition from the open pine forest to a more closed one dominated by oak. Shortly before 8,300, birch pollen rises along with grasses. Between 8,300-2,600 bp, the pollen record shows several oscillations of oak and birch with small percentages of pine. Ash, willow, hazel, and alder are also present. On the coast, the earliest pollen record is dated 9,500 bp just south of Lisbon in the Lagoa do Golfo (Mateus and Queiroz, 1997). Since the base of the core was dominated by pine, Mateus and Queiroz (1993) argue for extensive Maritime pine (*Pinus pinaster*) stands on the coastal dunes. They extrapolate this hypothesis further back to the Late Glacial and suggest the entire coastal strip from Sines in Alentejo to Porto was covered by Maritime pine. Obviously, this requires data from offshore since the Late Glacial coast lay 10-40 km west of its present location.

Many researchers have attempted to correlate the climate changes documented in deep sea and ice cores with terrestrial records and subsequently argue for similarities between the changes in northern and southwestern Europe (de Beaulieu *et al.*, 1994; Lowe and NASP Members, 1995; Peñalba *et al.*, 1997; Zilhão, 1997; Roucoux *et al.*, 2001; Ellwood *et al.*, 2001). Indeed, there are agreements and disagreements between the different records. However, the evidence from Portugal shows a much more moderate climate (similar to today) during the last glacial-interglacial transition than in Northern Europe or even northern Spain. While the Polar Front may have been situated off the coast of Galicia during the Last Glacial Maximum and montane glaciers grew in the mountains of north and central Portugal, climate was never severe enough to permit colonization by cold, steppe-adapted mammoth and reindeer as in Cantabria. The plant and animal communities in Portugal were flexible enough to adapt with some altitudinal and latitudinal shifts resulting in localized changes in community composition, mainly the proportions of species represented. Thus, non-arboreal shrubs and sedges expanded their range in the mountains, but trees were still present. Mediterranean types shifted downward in elevation and possibly southward, while birch, pine and deciduous oak prevailed in montane valleys. Horse and wild aurochs likely had increased area of grassy plains to grow their populations. Ibex and chamois may have been more numerous to the detriment of red deer and wild boar populations. By 17,800 bp sea surface temperatures rebounded to those of the present day. Unfortunately, there is no solidly-dated terrestrial record in Portugal for the period between 18,000 and 12,500 years bp. One can only assume conditions on land also improved. The first indications from charcoal analysis show this to be true at least by 14,000 bp. The composite magnetic susceptibility reference section for southern Europe by Ellwood *et al.* (2001) shows the Lascaux interstadial followed by two warm oscillations prior to the Allerød. It is likely therefore that the warm ocean temperatures dated 17,800 bp correspond to the Lascaux interstadial. The second oscillation reflects the onset of the Bølling period. The Younger Dryas cold snap seems to have resulted in cooler and more arid conditions across much of Iberia.

Reconstructing plant availability for Late Pleistocene Portugal is also made difficult by the millennia of landscape alteration by people since the Neolithic. Recent planting of Maritime pine (*Pinus pinaster*) forest since the 12th century has led to an artificial abundance of this tree species in central Portugal (Vieira *et al.*, 2000). This species has great economic value for its resin and wood, which was used to build ships. *Pinus pinea* was also valued in ship building and it was more widespread in the historic past. During the Arab occupation, dense forests of *P. pinea* were cleared in order to export wood to North Africa and the Middle East (Vieira *et al.*, 2000). The planting of Stone pine plantations in the south has also led to the common idea that they are better adapted to warmer, sunnier climates while the former prefer slightly more temperate conditions. In protected natural places in Estremadura like the Tapada de Mafra (the former royal hunting grounds) both pines are present. In general, *P. pinea* outcompetes *P. pinaster* on the sunnier, south-facing slopes of hills while on the northern face the opposite is true. Identifying their occurrence in prehistoric archaeological sites can be problematic since ecologists consider them both part of the meso-Mediterranean (Barberó *et al.*, 1998). Charcoal studies are perhaps the most common method used. Figueiral (1995), Schweingruber (1990), Jacquiot (1955) and Greguss (1955) each give criteria for distinguishing the two types based on wood anatomy. Mateus and Queiroz (1997) identified *Pinus pinaster* charcoal from a single hearth at Ponte da Vigia and pollen cores from Fernão Ferro, leading them to extrapolate a Maritime pine forest on the Late Glacial coast of Estremadura. Given small sample size, single species dominance, and the fact that both date to the early Holocene one has to wonder about the accuracy of this reconstruction. Zilhão's (1997) hypothesis that the Late Glacial coast was covered by sand dunes is based on four lines of evidence: 1) the Solutrean site of Vale Almoinha, which today is located near the coast in eolian deposits; 2) sedimentary analyses of submerged landforms by Daveau (1980) that suggest desert-like condistions on the LGM coast; 3) the pollen / charcoal record from Fernão Ferro; and 4) the geochemical study of Caldeirão Eb showing elevated Na, argued by Zilhão to indicate the persistence of cold, salty winds blowing inland. Vale Almoinha is probably 40 km inland from the LGM coast and therefore should not be considered a "coastal" site. Therefore conclusions about the origin of the eolian deposits need to be reconsidered. The pollen record from Fernão Ferro is reported to have a high percentage *Pinus* pollen that is assumed to be *P. pinaster*. Caldeirão Eb is badly mixed and the two radiocarbon dates are on bulk bone samples. There is no reason to conclude from them that the deposit accumulated gradually over 5,000 years, nor that elevated Na in the deposit is due to salty winds blowing inland from the ocean, especially given that the cave is located in a sheltered valley 60 km inland. Furthermore, Turner and Hannon (1988) suggest that deciduous forest refugia during periglacial times were likely the maritime coasts of Spain and Portugal.

As evident in the pollen and charcoal data, southern Spain and central Portugal witnessed a much earlier expansion of warm, temperate and Mediterranean forests after the LGM than in northern Spain and Catalunya. The Dryas I phase saw a regression of forest species. In southern Spain and central Portugal the reappearance of mixed temperate and Mediterranean vegetation took place in the Bølling / Allerød phase whereas in northern Iberia it occurred in the Early Holocene. Rich plant communities were certainly available to Magdalenian hunter-gatherers in central Portugal. It is necessary to consider the potential utility of the available plants for Late Upper Paleolithic hunter-gatherers in central Portugal and the factors that condition their deposition and preservation in archaeological sites.

Modeling economic and nutritional utility of plants

Researchers using energy-based foraging models to understand plant exploitation among hunter-gatherers often implicitly ask the question, "what are the costs relative to the benefits of exploiting a given food item?" With regard to many plants, especially tannin-rich ones requiring high processing costs, the answer is usually that the costs often far exceed the energetic benefits and that their inclusion in the diet must be due to some sort of subsistence stress brought on by population-resource imbalance. However, an important question may be asked from a wider nutritional perspective: "what are the costs of not utilizing certain plant resources?" All resources are not equal and probably should not be measured by a single variable, energy, despite its appeal to simplicity (e.g., Jochim, 1998). Non-energetic nutritional needs can alter the perceived "value" of a food resource.

Most of the work on modeling prehistoric plant use has been done within a foraging theory framework. The majority of these studies are centered in western North America, mainly the Great Basin and California, though models also have been developed for eastern North America (Simms, 1987; Barlow and Metcalfe, 1996; Gardner, 1997; Gremillion, 2002). Basgall (1987) considered the role of acorns in prehistoric California subsistence economies. Simms (1987) experimentally derived energetic return rates for wild plant resources utilized by prehistoric Great Basin foragers. Note that Table 8 shows that plants and small game consistently rank lower than large game. For Europe, Rowley-Conwy (1984) has also estimated return rates for acorns and hazelnuts as well as other economic resources based on Perlman's (1980) figures for eastern North America (Table 9). However, neither Rowley-Conwy nor Perlman considered handling times in their return rate estimation. Additional studies focused on nutritional returns from wild plant collecting have been conducted in northern Mexico and northwest Patagonia (Laferrière, 1995; Ladio and Lozada, 2000). These studies show that energetic return rates are often not the primary factor determining plant food choice by hunter-gatherers. Emphasis is given here to studies in western North America and Europe that focus on acorns and pine nuts because these resources from different species of oaks and pines would have been present in the Late Pleistocene of central Portugal. In fact, they are evident from Late Pleistocene and Early Holocene sites in Mediterranean Spain.

For the Great Basin, Metcalfe and Barlow (1992) built a model for field processing and transport of pine nuts from *Pinus monophylla*. This pine is widespread in the Great Basin and was the most widely exploited variety in prehistoric and historic times (Rhode and Madsen, 1998). In the Metcalfe and Barlow model, field processing decisions are conditioned by the travel time to the resource, its utility (edible: inedible portion) and the time necessary to process it. Utility indices for pinyon pine nuts were then applied to a central place foraging model to "explore relationships between the costs and benefits of collecting, field processing and transporting loads... to base camps and the implications for overall efficiency while foraging" (Barlow and Metcalfe, 1996: 352). Bettinger *et al.* (1997) also used a central place foraging model to explore acorn and mussel use in central California. In each of these models, knowledge of distance and/or travel time to resource location and the time needed to process are critical elements. The results of these studies are used in this section to explore some of the factors that may have relevance to Late Pleistocene and Early Holocene plant exploitation.

Unfortunately, paleoenvironmental reconstructions are not fine-grained enough to know the locations of various resources in relation to an archaeological site. Often, site types (i.e., residential vs task sites) are not easily determined. Given these problems the central place foraging models cannot be fully utilized for most prehistoric cases. They do, however, provide some expectations concerning resource use that can be applied to Late Pleistocene Portugal. The Metcalfe and Barlow (1992) model predicts when resources should be processed in the field prior to transport. The feasibility of processing is dependent on the type of "package" the resource is found, or the inedible fraction that must be removed. Removing this portion increases the utility of a resource and allows more to be collected and transported back to camp. For plants, the greater the processing time required the less likely a resource will be field processed. Time and group composition also place important constraints on the decisions. If women and children are collecting, they are less likely to camp overnight than men, thus placing a time constraint on collecting. Weight is also an important variable because of thresholds in the amount that can be carried. Reducing or eliminating bulky, inedible parts lowers the weight and increases the overall utility of a resource.

In their experimental model for pine nut and pickleweed exploitation, Barlow and Metcalfe (1996) found that foragers could lower costs and raise return rates if they moved residence to the resource location. For pine nuts, the cones represent a significant, space-consuming fraction and should be removed to maximize the amount of edible nuts transported. The hulls require more processing and it is not economical to remove them prior to transport unless extremely long distances are involved (>100 km). Unless stands are within a very short distance pine nuts should be transported to base camps in their hulls. This means that cones should be rarely deposited in residential camps, but pine nut hulls may be deposited in large numbers. Since they do not require heating to be cracked open, these may rarely be charred and therefore not likely to preserve except in rare cases. Based on the central place model, if pine nuts were a significant resource then residential camps would not necessarily be expected in areas near stands because pine nuts can be transported fairly long distances before it becomes unprofitable.

In the Great Basin example, significant weight differences were found in the amounts of processed vs unprocessed pine nuts that could be carried using basket containers whose function as pine nut carriers is known ethnographically. Barlow and Metcalfe (1996) report that these baskets could be filled with 6 kg of unprocessed cones vs 18 kg of processed nuts. Of course, carrying such a large load over long distances would be physically demanding. Ethnographic data suggest women would carry 3-15 kg (Metcalfe and Barlow, 1992). Based on this alone it would seem doubtful that prehistoric foragers would have traveled long distances to carry heavy loads. However, Barlow and Metcalfe (1996) show that return rates are higher for larger load sizes regardless of processing time and distance to patches. This pattern appears to hold true in other regions such as northwest Patagonia where the Mapuche make overnight trips to the forest 50 km away to collect seeds of the *Araucaria araucana*. Ladio and Lozada (2000) do not report individual load size, numbers of carriers or whether cones were discarded prior to transport but observed that Mapuche families transport 100 kg of seeds per trip. Given the large size of the *Araucaria* cone, it was almost certainly discarded.

Pine nuts

For Portugal, the charcoal data are equivocal concerning the types of pine located near the archaeological sites of the Bølling / Allerød phase. Figuieral (1993, 1995) has developed some criteria to discern *Pinus pinaster* from *P. pinea*. Distinguishing these two is important because *P. pinaster* has a much smaller seed than the "pignolia" of *P. pinea*. Initial research led Figueiral (1993) to argue that both types were present in the charcoal assemblage from CPM. Subsequent SEM analyses may suggest that much of the pine charcoal from CPM was from *P. pinaster* but the assemblage was not systematically reanalyzed (Figueiral, 1995). The conclusion is based solely on impressions and the methodology itself is new and so far has not been replicated by others. More SEM analyses are needed in order to verify these criteria. Considerable variability and overlap in the criteria offered by Jacquiot, Schweingruber and Figueiral makes it difficult to accept that these pines can be reliably differentiated by their wood anatomy at present. In evolutionary terms, the wood is under the least amount of selection and thus inter-species variation is low. Most species within a given genus are only distinguishable by leaf structure and form, flower and seed morphology.

Considering the preferred habitats of these pines, the calcareous soils of the limestone uplands in Estremadura may have limited the spread of *P. pinea*. Thus, sites in Serras of Aire and Candeeiros, where most of the fauna-bearing caves are located, would not be expected to have evidence of pine nut consumption. As will be seen in the next chapter, these sites are specialized animal carcass processing locations, not residential sites (Bicho, 1996; Zilhão, 1995). On the other hand, the low plains and valleys of Estremadura are covered by Miocene sands and podzols which are well suited for *P. pinea*. The Rio Maior valley would have been prime habitat for *P. pinea*. Its occurrence during the Tardiglacial is confirmed by the charcoal record. Unfortunately, direct evidence of pine nut processing in open-air sites is missing. Organic preservation is extremely poor in the sediments of the area. The absence of charred nutshells does not necessarily mean that pine nuts were not utilized. Although heating aids seed removal and thus may result in charring, it is not required. Dried seeds could easily be cracked open to remove the seed from the hull. The technology does not necessitate large slab grinding stones, common for plant processing in later times. Small grinding stones have been found at CPM in the Rio Maior valley but no residue analyses have been made on them. Grinding stones were also found in open-air Gravettian sites in the Rio Maior valley and Vale Boi in southern Portugal (Thacker pers. com; Bicho *et al.*, 2000). Of course, the occurrence of grinding stones does not necessarily mean they were used in plant processing. They could have been used in pigment grinding or animal bone grease processing. Until residue analyses are made, interpretation of their use is open.

For Mediterranean Spain, Badal (1998, 2001) identified over 9,900 carbonized pieces of pine cones and seed hulls from *Pinus pinea* in the Cueva de Nerja. Though natural fires can ignite vegetation in caves, the association of these pieces with archaeological occupations provides a reasonable basis for considering them human food refuse. The majority was collected in three archaeological levels dated to the Solutrean, Upper Magdalenian and Microlaminar Epipaleolithic. In the Solutrean level 9, dated 18,420±530 bp to 17,940±200 bp (Jordá Pardo *et al.*, 1990), Badal (1998) reported 2580 fragments of cones and 196 hull pieces. The occurrence of *P. pinea* indicates warm, humid conditions near the cave suggesting an occupation during an interstadial following the LGM. Importantly, it demonstrates substantial human use of pine nuts as early as the Solutrean in the cave, although pine cones and hulls are found in the Early Upper Paleolithic levels too. Equal frequency of pine nuts occurs in the Upper Magdalenian level 7 dated 12,130±130 bp corresponding to the Bølling / Allerød interstadials. Large numbers of cone and hull fragments are also found in the subsequent Microlaminar Epipaleolithic level dated 10,860±160 bp. While this date falls within the Younger Dryas period, it overlaps the end of the warmer Allerød. Based on faunal analyses, the Younger Dryas at Nerja is characterized by cold-adapted birds and fish so it is unlikely that vegetation remained the same. Therefore, the pine nuts in the Epipaleolithic levels were likely deposited prior to the Younger Dryas.

In all levels containing evidence for pine nuts, the occurrence of cone fragments implies a short distance to pine stands. According to the Barlow and Metcalfe (1996) model, these would only be transported with pine nuts if round trip times to find and collect them were less than a couple of hours.

Acorns

According to pollen and charcoal analyses, both evergreen and deciduous oaks were present in Late Pleistocene Portugal. Generally, only broad categories may be discernible by wood anatomy. Oaks are divided by non-taxonomic categories, such as white oaks, black oaks red oaks, etc., by North American foresters. Identification through wood anatomy is more easily done for these categories than by species although there is apparent disagreement on this between North American and European specialists. Carrión *et al.* (2000) claim to have distinguished the pollen form of *Q. suber* from *Q. ilex*. Their criteria have not been applied to other regional pollen analyses so the best hope for determining which species was more prevalent during the Bølling / Allerød phase is the modern ecology and biogeography of the two species. Regardless of these problems, each of the species present today would have been present in the Late Pleistocene. Because Iberia was a refuge for many northern European plants, additional deciduous types may be present in the pollen and charcoal samples from northern Iberian sites (Bennett *et al.*, 1991).

During the cold periods of the LGM and Dryas I, *Q. ilex* was probably limited in its biogeographic range. While it may have been able to withstand the lower temperatures, the increased aridity would have precluded the formation of closed-canopy Holm oak forests that characterize much of the natural areas of lowland central and southern Portugal today. Charcoal analyses of LGM sites shows that *Q. suber* was present in Caldeirão, located in a sheltered valley, but not in the upper elevation site of Anecrial or the open, low-elevation site of CPM (Zilhão, 1997). Thus, acorns from these species would not have been available in large quantities to hunter-gatherers during cold, dry periods like the Solutrean and Middle (?) Magdalenian. They would likely have been present during the immediate post-LGM Early Magdalenian but more prevalent during the warm, humid Bølling / Allerød period corresponding to the Late Magdalenian. The evergreen oak charcoal from CPM attests to its presence in the Late Magdalenian. The occurrence of *Q. suber* in CPM and Caldeirão is likely due to their location near sandy Miocene sediments where cork oaks are found today.

At present there is no physical evidence of acorn use during the Upper Paleolithic or Epipaleolithic in central Portugal. In Spain, acorn parts were identified in the Upper Paleolithic levels of Cueva de Nerja and a few Epipaleolithic sites in Catalunya mentioned earlier. Considering the Bettinger *et al.* (1997) model for acorn processing and transport, unprocessed acorns should be transported from stands to residential sites. They found that cupule removal, cracking, winnowing and leaching or roasting are not economical in the field unless acorns are transported over 125 km. Since no groups were ever observed transporting acorns over such long distances it is assumed that this processing did not take place in the field. Drying to reduce load weight may be the only economical field processing but this is contingent on the amount of time spent in the field. Therefore, evidence of acorn use should occur predominately in residential camps, not in logistical task sites. Unfortunately, these are the sites in Portugal that lack organic preservation.

Nutritional utility

The evolutionary ecological studies of tropical foragers have shown that reproductive fitness, not energy maximization, is the primary factor driving subsistence strategies (Hawkes *et al.*, 1991, 1997, 2001; O'Connell, 2000; Winterhalder and Smith, 2002). The nutritional ecology approach offers an additional perspective to dietary choice by considering the health and reproductive consequences.

Tables 10, 11, 12, 13 and 14 show the nutritional values of food types that were available to Late Pleistocene hunter-gatherers in central Portugal. Note that small game like rabbits offer the same proportions of protein, fat and micronutrients as large game if not higher. Birds are also high in protein and much higher in fat than terrestrial mammals. Fish are also comparable sources of protein. Shellfish contain lesser quantities of protein the proportions of various proteins are better suited to human metabolism (Wing and Brown, 1979; Nettleton, 1985; Erlandson, 1988). Plants on the other hand have a wide range of nutrient values but are the best source of carbohydrate. In the case of tree nuts, pine nuts and hazelnuts have high proportions of protein and fat and, consequently, immensely high caloric value compared to animals. Acorns and chestnuts are generally good sources of carbohydrate. Detailed nutritional analyses of other edible wild plants such as seeds, leaves, roots, bulbs and tubers are not available. However, some qualitative information is provided in Table 15. For the most part, these would have provided vitamins, minerals, fiber, essential oils and fatty acids. These types of plants would have been better sources of vitamins C & E than animal organ meat.

While post-encounter return rates for all the resources available to Upper Paleolithic people in Iberia are not feasible, the conclusion reached by many that large game will always outrank small game, aquatic resources, and plants in terms of caloric energy is a useful starting point for discussing foraging efficiency in energetic terms (Kelly, 1995; Broughton, 1995; Broughton and O'Connell, 1999; Ugan and Bright, 2001). Assuming the larger the animal, the higher the rank, horse and aurochs should be the highest ranking resource since they would arguably provide the greatest number of calories per animal unit even though they might not be encountered frequently. Medium ungulates like red deer, ibex, chamois and wild boar might be roughly equivalent in caloric value but much lower than large animals and encountered more often. Small game such as rabbits and birds would rank lower due to their smaller package size and despite their greater abundance and encounter frequency. Plants and shellfish, while highly productive, would rank lowest because they require higher labor investment for much lower caloric return as Bailey and others have argued.

However, resource rank does not often predict the relative contribution to the diet. If generalizations about modern hunter-gatherers can be extrapolated to the past, then perhaps large game hunting was driven more by male status-seeking than subsistence concerns (Hawkes *et al.*, 2001). In places like the temperate mid-latitudes and sub-humid Mediterranean where plants and small animals were always present, large game hunting might not have been as important to overall subsistence as in the polar region where there is little else to eat. Daily subsistence may therefore have been based on plant collection and small animal procurement by all segments of the population.

On the other hand, if Jochim's (1998) claim that hunter-gatherers will naturally choose a balanced diet is a result of our evolutionary heritage as primates then meat would not be the central focus of prehistoric diets given the problems discussed by numerous authors (Speth and Spielmann, 1983; Eaton *et al.*, 1997, 1998, 2002; Cordain *et al.*, 2000a&b, 2002). Hockett and Haws (2003) have argued that balanced essential nutrient intake through dietary diversity enabled Early Upper Paleolithic humans to grow their populations and replace archaic forms in Europe. In Iberia, diverse diets may have a greater antiquity due to greater availability of plants and small animals. Given this it is more plausible to assume that modern humans in Iberia were naturally acquiring a balanced diet during the Upper Paleolithic of Iberia through dietary diversification.

In nutritional terms, the values for the foods in Tables 10-14 show that plants and small animals like shellfish offer many nutrients in better proportion than ungulates. Hunter-gatherers would have achieved better overall health and greater reproductive success by exploiting a wider range of resources. Nutritionally, tree nuts may have been important substitutes for meat in lean seasons due to their storability. In the Mediterranean region, including Portugal, the lean season would have been the summer dry season. Pine nuts would have maintained their fat stores for several months enabling hunter-gatherers to offset and risk of protein poisoning if they were eating large amounts of meat in the absence of plants. They could also have complemented meat during seasons where both were plentiful. Stores of carbohydrates in the form of acorns and/or chestnuts would also benefit people through their protein-sparing action. The leafy greens with their essential vitamins and carotenoids would have been available for much of the year due to the mild, rainy winters.

Discussion

Where edible plants are found people will consume them. This is obvious from ethnographic observations and global surveys of hunter-gatherers. The appearance of edible portions of various plants in the Early Holocene sites of Catalunya, Andorra and southern France tracks the changes in the environment. In these regions climate was more rigorous during the Late Pleistocene as evident by charcoal analyses, pollen and deep sea cores in the northwest Mediterranean. As forests spread, so does evidence of the use of their products. In areas such as southern Spain and central Portugal where climate was less severe the pollen and charcoal record shows that the types of plants exploited in later times were present in the same proportion as today by 12,500 bp. If the hypothesis that humans will consume plants when they are available is true, then there should be evidence of their use during this period. Sites in southern Spain do contain evidence of plant exploitation before the Early Holocene. However, there is no such evidence of macrobotanical remains in central Portugal. This is largely due to excavation methods and the non-use of techniques suited to recovering plant remains. Most sites were excavated before modern techniques like flotation were developed. Research bias against the idea that plants were important components of Paleolithic diets also made attempts at recovery seem pointless to previous excavators.

Using the expectations derived from analogous species of pine nuts and acorns in the Great Basin and California, there would be little reason to expect either to have been processed in Lapa do Picareiro, Caldeirão, Lapa dos Coelhos, Bocas or Lapa do Suão. Neither require intensive field processing with the exception of removing pine seed hulls from their cones. These would likely have been deposited in locations within pine stands or in residential sites, not specialized animal carcass processing sites. Acorns would only be processed and inedible fractions discarded in residential sites as well. No features have been identified as leaching pits in the open-air Upper Paleolithic, Epipaleolithic or Mesolithic sites of central Portugal. Charred nutshells of either pine nuts or acorns have not been recovered. No site has been excavated using flotation or any other systematic method for recovering these items. Recently, wet-sieving has been done using bulk samples from a few sites but this has not been done for or by paleoethnobotanists. All charred material is treated as charcoal and only recently has identification of wood species occurred prior to sample destruction for radiocarbon dating (Figueiral, 1993). No report on charcoal remains has mentioned plant parts other than wood.

It can be demonstrated that central Portugal was a refugium for Mediterranean and temperate plant species during the Late Glacial (Bennett *et al.*, 1991; Figueiral and Terral, 2002; Turner and Hannon, 1988; Vogel *et al.*, 1999). This mixed community existed in low-lying plains and valleys until the Late Glacial interstadials allowed recolonization of upper elevations. However, the archaeological record is insufficient to know whether or not plants comprised a substantial portion of the diet during the Late Upper Paleolithic and Epipaleolithic. Current research projects in central and southern Portugal are utilizing methods to recover such evidence. Preliminary data indicate the use of plants as early as the Gravettian (Thacker pers. com.). Given these findings, it is likely that plant exploitation was a regular and probably significant portion of the human diet during the Late Upper Paleolithic. The implications from central place modeling drawn upon in this chapter should serve to guide future research expectations concerning the types of plant materials that could be expected occur in a given location.

Based on energy-considerations alone, the central place models applied to analogous resources shows that certain plants can be economically exploited over long distances. The Mapuche example cited above further illustrates the value of plants with regard to macronutrient content. The nutrient values for the tree nuts of the Mediterranean are comparable and/or complementary to those of animal resources. If people were under resource stress, the prime motivation for subsistence change in the Broad Spectrum Revolution model and diet breadth model, it is doubtful that people would have ignored such an abundant and easily processed resource such as pine nuts. The labor inputs and nutritional gains, whether energetic or marcronutrient, would have made pine nuts as highly ranked and probably higher than those from the Great Basin. Although late fall and winter would have been ideal collection times, immediate consumption would not have been necessary. Cones or seeds in hulls could be stored for several months, increasing their value for human diets.

Pine nut and acorns serve as examples of the types of plants that could have played important roles in Upper Paleolithic hunter-gatherer subsistence in Portugal. Whether or not they could have been staples is debatable. Additional nuts may not have been as abundant as pine nuts and acorns in Estremadura. Walnuts are thought to have been introduced to Portugal by the Romans. Chestnuts and hazelnuts occur naturally and were evident from Late Pleistocene pollen diagrams in northwest Iberia. However, neither has been identified in charcoal assemblages from Estremadura.

Certainly, a wide variety of plants besides tree nuts were available as food. Many of these, such as greens and tubers leave no durable remains. The pit of wild fruits and berries are virtually unknown in archaeological sites from this period. Only a few seeds from *Rubus*, probably blackberry, were recovered at Picareiro. Of the edible roots, tubers and bulbs mentioned by Clarke (1976), there is no specific evidence to date. However, the use-wear and starch grain analyses on Gravettian tools have produced some promising results (Thacker pers. com.). The availability of these plants is unknown because there are no pollen cores in low altitude locations in central Portugal that date to the Late Glacial. However, the pollen diagram from San Rafael in Spain shows that coastal marsh taxa were present as early as 16,000 bp. Even at Mougás, in Galicia, pollen from the Liliaceae and Umbelliferae, two important families with edible taxa, were present in the Bølling / / Allerød. Since many of the plants Clarke discussed inhabit this zone, they may have been available to Magdalenian people. The lack of human skeletal material on which stable isotope and trace element assays can be made precludes a better understanding of the sources of protein and calcium in the diet and the role of marine foods.

The discussion here was intended to evaluate some of the possibilities. Of course, the absence of evidence of plant exploitation does not equal evidence of absence. Paleolithic people almost certainly utilized plants for food. The nature of this utilization is an important lacuna in our understanding of Upper Paleolithic subsistence. Hopefully, future research will shed light on the problem of Upper Paleolithic plant exploitation in Portugal.

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