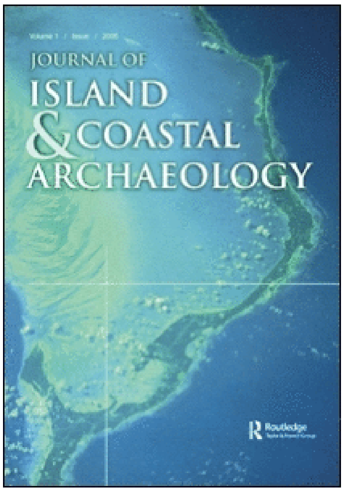

The Journal of Island and Coastal Archaeology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t716100767

The Emergence of Muge Mesolithic Shell Middens in Central Portugal and the 8200 cal yr BP Cold Event

Nuno Bicho[a,b]; Cláudia Umbelino[c]; Cleia Detry[b]; Telmo Pereira[a]
[a] FCHS, Universidade do Algarve, Campus de Gambelas, Faro, Portugal [b] Uniarq, Faculdade de Letras, Universidade de Lisboa, Lisboa, Portugal [c] CIAS, Departamento de Antropologia, Faculdade de Ciências e Tecnologia, Universidade de Coimbra, Coimbra, Portugal

Online publication date: 09 April 2010

To cite this Article Bicho, Nuno , Umbelino, Cláudia , Detry, Cleia and Pereira, Telmo(2010) 'The Emergence of Muge Mesolithic Shell Middens in Central Portugal and the 8200 cal yr BP Cold Event', The Journal of Island and Coastal Archaeology, 5: 1, 86 — 104

To link to this Article: DOI: 10.1080/15564891003638184
URL: http://dx.doi.org/10.1080/15564891003638184

Journal of Island & Coastal Archaeology, 5:86–104, 2010

ISSN: 1556-4894 print / 1556-1828 online
DOI: 10.1080/15564891003638184

SHORT REPORTS

The Emergence of Muge Mesolithic Shell Middens in Central Portugal and the 8200 cal yr BP Cold Event

Nuno Bicho,[1, 3] Cláudia Umbelino,[2] Cleia Detry,[3] and Telmo Pereira[1]

[1]*FCHS, Universidade do Algarve, Campus de Gambelas, Faro, Portugal*

[2]*CIAS, Departamento de Antropologia, Faculdade de Ciências e Tecnologia, Universidade de Coimbra, Coimbra, Portugal*

[3]*Uniarq, Faculdade de Letras, Universidade de Lisboa, Lisboa, Portugal*

ABSTRACT

The emergence of Portugal's Muge Mesolithic, with its characteristic shell middens and human burials, is widely seen as a response to the formation of a highly diverse terrestrial and aquatic ecotone in the Tagus basin by the Flandrian transgression. Recently, some have suggested that this was an adaptive response to the 8200 cal yr BP event. Using the available radiocarbon data for the shell middens, paleoclimatic data, and paleoceanographic data we present a new model for the appearance of the Muge Mesolithic shell middens and changes in settlement between the Boreal and Atlantic phases for central Portugal. Coastal ecosystems were altered due to diminution in upwelling and the occurrence of the 8.2 kyr cold event, with declining availability of marine resources, rapid sea level rise, and changes in coastal morphology. The result was that the previous coastal setting was no longer suitable for the hunter-gatherer-fishers causing a settlement shift to the new, large, and stable estuary of the Tagus Valley.

Keywords coastal settlement, Early Holocene, upwelling, Iberia

Received 11 May 2008; accepted 28 August 2009.
Address correspondence to Nuno Bicho, FCHS, Universidade do Algarve, Campus de Gambelas, Faro 8005-139, Portugal. E-mail: nbicho@ualg.pt

INTRODUCTION

Archaeologists have long viewed the development of shell middens along European shorelines as a post-Pleistocene phenomenon, but there is now a much deeper history of shellfish and other marine resource use in the Atlantic and Mediterranean coasts, since probably Middle Paleolithic times especially on the Iberian Peninsula (Bicho and Haws 2008). This does not change the fact that large shell middens first become a prominent part of coastal landscapes in the area during the Mesolithic, which may have seen an intensification of coastal settlement and subsistence.

The history of research on the Mesolithic shell middens of Muge, central Portugal, started 150 years ago, in the mid nineteenth century (Arias and Alvárez-Fernández 2004; Cardoso and Rolão 1999–2000; Clark 2000, 2004; Mendes Corrêa 1933; Newell et al. 1979; Ribeiro 1884; Roche 1954, 1972; Rolão 1999; Rolão et al. 2006), though the results have not been widely disseminated. Despite this problem, research on the Portuguese Mesolithic continues to generate considerable interest. Work has focused in recent years on two areas of interest: the Neolithic transition at the end of the period; and diet, health, and subsistence practices during the period. This effort materialized with at least three doctoral dissertations from the universities of Algarve, Lisbon, and Porto on the transition from the Mesolithic to the Neolithic (Carvalho 2007; Diniz 2004; Rodrigues 2008) as well as many papers focusing on this topic (e.g., Arnaud 1989; Carvalho 2003; Jackes 1988; Lubell et al. 1994; Soares and Silva 2003; Zilhão 1993, 2001). Research on diet, health, subsistence practices and to a lesser degree, settlement systems, was also widely published in the last decades (Araújo 2009; Arnaud 1989; Bicho 1994; Cunha et al. 2003; Cunha and Umbelino 2001; Detry 2007; Jackes and Meiklejohn 2004; Lentacker 1986; Umbelino 2006; Zilhão 1993).

Dietary reconstructions based on stable isotope analyses have been especially fruitful. Work by David Lubell and Mary Jackes (e.g., Jackes 1988; Lubell et al. 1994) was recently complemented by Umbelino (2006). Her trace element and isotopic analyses corroborated the earlier results of a marine and terrestrial animal diet but also showed that plants were an important dietary component. The results from isotopic analyses of the human skeletons indicate a wide diversity of resources in the diet within the same site, with marine proteins making up between 70% and 25% of the diet (Martins et al. 2008; Umbelino 2006; Umbelino et al. 2007). These results clearly contradict previous models on the land use and settlement patterns during the Mesolithic of the Muge and Sado valleys (e.g., Arnaud 1987, 1989; Roche 1972, 1989).

Despite the long-lasting archaeological research in Muge, no specific study has focused on the transition from the Epipaleolithic to the Mesolithic in the region. The aim of this paper is to offer an explanatory model for the change in settlement dynamics and technological systems that took place after the Boreal period (9000–8000 cal BP), from coastal settlements to inland estuarine locations where large Muge shell middens are located beginning around 8200 cal BP (Figure 1). Our argument synthesizes data from radiocarbon (^{14}C) dates (corrected and calibrated), the Early Holocene coastal upwelling regime and coastal morphology, archaeology, and the occurrence of the 8200 yr cal BP cold event.

EPIPALEOLITHIC AND MESOLITHIC SUBSISTENCE AND SETTLEMENT PATTERNS

More than 250 sites dated to the Early Holocene have been found in Estremadura and Alentejo (e.g., Araújo 2009; Araújo and Almeida 2006; Arnaud 1989, 1993; Bicho 1994; Carvalho 2007; Silva and Soares 1981; Valente 2008). Data suggest a highly diverse pattern of types and locations of sites, chronologies, technology, and subsistence. Unlike previous authors such as Roche or Arnaud who saw the Mesolithic as a single prehistoric phase, Bicho (1994) argued for a two-phase Holocene adaptive evolution in Central Portugal. The first is an Epipaleolithic phase, starting around 12,500 cal BP (Table 1),

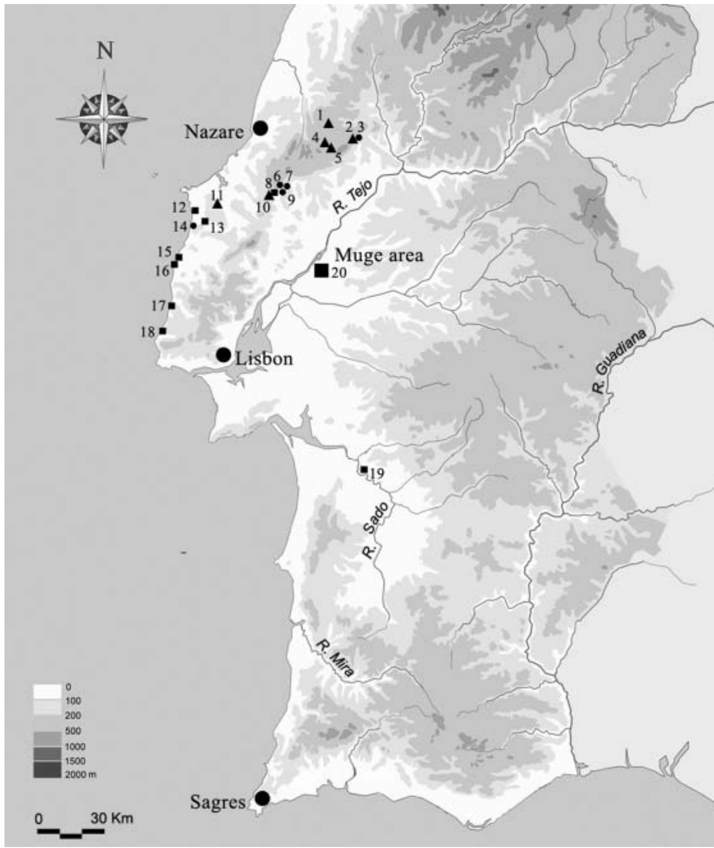

Figure 1. *Map of Epipaleolithic and Mesolithic sites in Central Portugal. 1. Casal Papagaio; 2. Pena d'Àgua; 3. Costa do Pereiro; 4. Pena de Mira; 5. Picareiro; 6. Cabeço do Porto Marinho; 7. Carneira; 8. Forno da Telha; 9. Areeiro III and Fonte Pinheiro; 10. Bocas; 11. Suão; 12. Vale Frade; 13. Toledo; 14. Ponta da Vigia; 15. Cabeço do Curral Velho; 16. Pinhal da Fonte; 17. S. Julião; 18. Magoito; 19. Sado shellmiddens (Arapouco, Poças de S. Bento, Várzea da Mó, Amoreiras, Vale de Romeiras, and cabeço do Pez); 20. Muge shell middens (Vale de Fonte da Moça I and II, Flor da Beira, Fonte de Padre Pedro, Cabeço da Arruda, Moita do Sebastião, Cabeço da Amoreira, Ribeira de Magos, Cova da Onça, Monte dos Ossos, Magos de Cima, Cabeço da Barragem, Cabeço dos Morros, and Magos de Baixo).*

resulting from an increase in population, with many similarities in technology and dietary characteristics to the long cultural tradition of the Final Upper Paleolithic (Magdalenian), but marked by an intensification of landscape use.

The second phase, starting around 8200 cal BP with the beginning of the Atlantic phase was characterized by a clear break in the settlement and subsistence patterns as well as technological aspects seen before. The Muge and Sado regions likely had some kind of semi-complex social and economic system, very different from the hunter-gatherers of the earliest Holocene.

Epipaleolithic

During the Epipaleolithic phase, corresponding to the Preboreal and Boreal pollen stages, human occupation in central Portugal

Table 1. Radiocarbon dates from the Epipaleolithic and Mesolithic of Central Portugal.[1]

Site	Provenience	Lab code	Material	Date BP	ΔR[3]	cal BP 2σ
Magoito	Level 1B C	ICEN-82	charcoal	9910 ± 100		11170–11770
Casal Papagaio	Base	ICEN-369	Bones	9710 ± 70		10790–11250
Casal Papagaio	Middle	ICEN-372	Charcoal	9650 ± 90		10740–11220
Bocas	Camada 2	ICEN-903	Shell	10260 ± 70	380 ± 30	10590–11070
Magoito	Level 1 B	ICEN-52	Charcoal	9490 ± 60		10580–11080
Magoito	Level 1B M	ICEN-80	Shell	9970 ± 70	160 ± 60	10510–11050
Magoito	Level 1Cm	ICEN-577	Shell	9880 ± 80	160 ± 60	10320–10940
Magoito	Level 1B P	ICEN-81	Shell	9790 ± 120	160 ± 60	10190–10880
Cabeço do Porto Marinho	IIISW/top	SMU-2666	Charcoal	9270 ± 170		9960–11100
Magoito	Level 1A	GrN-11229	Shell	9580 ± 100	160 ± 60	9960–10540
Cabeço do Porto Marinho	area V/lower	ICEN-688	Charcoal	9100 ± 160		9740–10680
Areeiro III	Hearth 2	ICEN-494	Charcoal	8850 ± 50		9740–10170
Bocas	Camada 0+	ICEN-900	Shell	9880 ± 220	380 ± 30	9720–11000
Areeiro III	area 2	ICEN-547	Charcoal	8860 ± 80		9680–10200
Ponte da Vigia	Paleosoil	Sac-1747	Charcoal	8850 ± 90		9630–10200
Ponte da Vigia	Hearth	ICEN-51	Charcoal	8730 ± 110		9530–10150
Ponte da Vigia	Paleosoil	Sac-1741	Charcoal	8670 ± 80		9500–9910
Vale de Frade	Levels 5–6	Sac-1586	Shell	9810 ± 65	940 ± 50	9400–9730
Toledo	B12 (T45–13)	Sac-1529	Shell	9200 ± 70	380 ± 30	9310–9660
Areeiro III	Hearth 1	ICEN-546	Charcoal	8570 ± 130		9270–10120
Vale de Frade	Level 2b (base)	Gif-1438	Charcoal	8500 ± 110		9140–9740
Areeiro III	area 2	ICEN-548	Charcoal	8380 ± 90		9140–9530
S. Julião B	—	ICEN-108	Shell	8400 ± 50		
S. Julião B	—	ICEN-109	Shell	8550 ± 70	−70 ± 40	9060–9460
Lapa do Picareiro	Level D	Wk-6676	Charcoal	8310 ± 130		9010–9530
S. Julião C	Level 2C	Sac-1723	Shell	8470 ± 70	−70 ± 40	8990–9390
Fonte Pinheiro	Level 2	ICEN-973	Charcoal	8450 ± 190		8990–10130
Casal Papagaio	—	Hv-1351	Shell	8870 ± 100	380 ± 30	8810–9410
S. Julião B	—	ICEN-152	Shell	8430 ± 60		
S. Julião B	—	ICEN-153	Shell	8340 ± 45	−70 ± 40	8800–9230
S. Julião B	—	ICEN-179	Charcoal	8120 ± 100		8660–9400
Pinhal da Fonte	—	Sac-1671	Shell	8740 ± 70	380 ± 30	8660–9170
Toledo	D21 (T45–56)	Sac-1533	Shell	9120 ± 80	940 ± 50	8450–8970
S. Julião A	—	ICEN-76	Charcoal	7810 ± 90		8420–8980
S. Julião A	—	ICEN-78	Charcoal	7810 ± 90		8420–8980
Vale de Frade	Levels 5–6	Sac-1577	Shell	9090 ± 75	940 ± 50	8420–8930

(Continued on next page)

Table 1. **Radiocarbon dates from the Epipaleolithic and Mesolithic of Central Portugal.[1] *(Continued)***

Site	Provenience	Lab code	Material	Date BP	ΔR[3]	cal BP 2σ
Toledo	Pandeiro 1	TO-707	Bones	7800 ± 110		8410–8980
S. Julião A	—	ICEN-83	Shell	9090 ± 60		
S. Julião A	—	ICEN-84	Shell	9060 ± 50	940 ± 50	8410–8840
Toledo	Level 2	Sac-1587	Shell	9000 ± 60	940 ± 50	8360–8750
Cabeço do Curral Velho	Shell midden	ICEN-270	Shell	8400 ± 60	380 ± 30	8350–8630
Cabeço do Curral Velho	Shell midden	ICEN-269	Shell	8410 ± 90	380 ± 30	8300–8770
S.Julião A	—	ICEN-106	Shell	8060 ± 50		
S. Julião A	—	ICEN-107	Shell	8130 ± 50	170 ± 50	8290–8580
S. Julião A	—	ICEN-73	Charcoal	7610 ± 80		8210–8580
S. Julião A	—	ICEN-77	Charcoal	7580 ± 70		8210–8540
Costa do Pereiro	Level 1b	Wk-17026	Bones	7327 ± 42		8020–8280
Pena de Mira	breccia	ICEN-966	Charcoal	7810 ± 120		7980–8440
Pena d'Água	Level F	Wk-9213	Charcoal	7310 ± 110		7950–8360
S.Julião A	—	ICEN-151	Shell	7940 ± 140	170 ± 50	7930–8530
S.Julião C	Level 2B	Sac-1723	Shell	8470 ± 70		
S. Julião C	Level 2C	Sac-1724	Shell	7630 ± 60	170 ± 50	7760–8090
S. Julião C	Level 2C	Sac-1721	Shell	7650 ± 80	170 ± 50	7740–8150
S. Julião B	A2	ICEN-154	Shell	7390 ± 90	−70 ± 40	7710–8140
S. Julião C	Level 2A	Sac-1795	Shell	6820 ± 60		
S. Julião C	Level 2A	Sac-1796	Shell	7520 ± 70	170 ± 50	7640–7980
S. Julião C	Level 2C	Sac-1800	Shell	7170 ± 90		
S. Julião C	Level 2C	Sac-1801	Shell	7460 ± 60	170 ± 50	7610–7920
Forno da Telha	Level 2	Wk-18356	Bones	6764 ± 35		7570–7670
Bocas	Level 1	ICEN-899	Shell	7490 ± 110	380 ± 30	7400–7820
S. Julião C	Level 2G	Sac-1802	Shell	6390 ± 90		
S. Julião C	Level 2G	Sac-1803	Shell	7200 ± 90	170 ± 50	7320–7700
Forno da Telha	Shell midden	ICEN-416	Shell	7320 ± 60	380 ± 30	7320–7560
Forno da Telha	Shell midden	ICEN-417	Shell	7360 ± 90	380 ± 30	7310–7650
S. Julião C	Level 2A	Sac-1720	Shell	5700 ± 60	380 ± 30	5570–5860

[1]Dates BP in Valente (2008) and Soares and Dias (2006) (secondary data sources); % marine diet from Martins et al. (2008). Calibration curves are IntCal04 (Reimer et al. 2004) and Marine04 (Hughen et al. 2004).

[2]Second date from a pair from the same shell, corresponding to the internal and intermediate fractions (the third fraction was removed and destroyed with acid to remove possible contaminants). The first date is shaded and no calibration was carried out.

[3]ΔR values from Soares and Dias (2006). If there is no specific ΔR value known for the site or nearby site then the value is the standard value of 380 ± 30.

[4]Estimated ΔR values based on proximity of space and time with the obtained values by Soares and Dias (2006).

is mainly along the modern coast, between Lisbon and Peniche, and on the highlands of the Serra dos Candeeiros and d'Aires. The sites are open air on the coastal stretch, while inland there are both open air (mostly in the Rio Maior area on the eastern base of the mountain range), and caves and rock shelters both on the lowlands and highlands of the "Serras." These sites tend to be fairly small (between 100 and 200 m^2) and represent single occupations.

Technological traits are marked by the production of miniature weaponry with both backing (Microgravette, Istres and Sauveterre, and la Malaurie points) and marginal retouch (Dufour bladelets or Ouchtata bladelets or points) as well as geometrics (triangles, crescents and trapezes; the latter are the most common, but all are made with the microburin technique) all using Upper Paleolithic type bladelets (Bicho 1998, 2002). In addition, there is also an important core-flake macrolithic technology with an intensive use of local non-flint raw materials.

Acquisition of stone tool materials, mostly flint, apparently took place more in the Rio Maior area, although some of the lithic raw materials may have been gathered near the coastal of Torres Vedras (Shockler 2006). Subsistence was based on both terrestrial resources (such as red deer, roe deer, wild boar, aurochs, horse, and rabbit) and marine resources (fish and shellfish, with *Cerastoderma edule*, *Venerupis decussata*, *Scrobicularia plana*, and *Mytillus* sp. as the more frequent species—Valente 2008), present more commonly in the coastal sites, but also in some of the inland rock shelters and caves (Bicho and Haws 2008).

Mesolithic

By Atlantic times, technology and settlement dynamics changed and the full Mesolithic mode was installed (Bicho 1994). Backed and marginal retouched weaponry disappeared and geometrics produced with microburin technique was fully established; Mesolithic bladelets were regular and standardized, longer than before, and probably made with soft hammer or even by indirect percussion (Marchand 2005). The settlement system is completely different, with most sites located in the lower Tagus Valley, around Muge, where the large majority of the sites are shell middens. There are still a few sites near the base of Serra dos Candeeiros and d'Aires, probably related to raw material acquisition. The only exception seems to be the coastal site of S. Julião that was used from ca. 9500 to 7300 cal BP, although most human occupations seem to have been prior to 8200 cal BP, apart from one locus (S. Julião C) that was occupied intermittently between 8000 and 7300 cal BP (Soares and Sousa 2004).

In the Muge area (Figure 2), the shell middens are large sites (>2500 m^2) with long and complex stratigraphy, and occupation layers as much as 5 m thick. At the base of the Moita do Sebastião shell midden several habitation features were found: 69 post-holes, two possible huts, one surrounded by river cobbles, more than 20 different types of pits, some filled with shells, and several hearths (Roche 1972, 1989). Above the features, as many as 59 adult and 12 child burials were found. Many other burials were excavated at other sites resulting in a total of more than 300 individuals found at the Muge sites. While the skeletons tend to appear isolated or in small groups without rare material offerings, it appears that there was a tendency to separate adults from children. There are many perforated marine and riverine shells (mostly *Trivia monacha* and *Theodoxus fluviatilis*—Arnaud 1987; Roche 1972; Rolão 1999), but it is not clear if they were used for pre- or post-mortem body adornment.

These sites were thought to be large living sites or base-camps due to their size, length of occupation (a couple of thousand years each), diversity of material culture, and the existence of burial grounds (Arnaud 1987; Jackes and Meiklejohn 2004; Roche 1972, 1989). Rolão (1999) suggested that two types of sites were represented, residential and logistical, based on differences in their size and length of occupation: Moita do Sebastião, Cabeço da Amoreira, and Cabeço da Arruda were large residential, semi-permanent sites, for instance; and much smaller sites (both in area and volume) with fewer lithic materials, faunal remains, and human burials, represented shorter occupations of a seasonal or logistical nature. Recently, Marchand (2005) studied the typological and technological characteristics of the lithic assemblages, suggesting that Moita do Sebastião, Cabeço da Amoreira, and Cabeço da Arruda shell middens were perhaps large residential sites used sequentially in time and representing a single stylistic (ethnic) group, different from that of the Sado region. Using other elements (site structure and location, burial characteristics, and subsistence), the same idea was defended by Arnaud (1987, 1989) some 20 years before.

Paleobiological analyses by Jackes et al. (1997) suggest that an increase in fertility may have happened during the Mesolithic (not only after the transition to the Neolithic), showing that there were changes in the life-ways of these populations. According to Jackes and Meiklejohn (2004) increased sedentism and earlier weaning may have caused a higher fertility rate. Dietary data published by Umbelino (2006; Umbelino et al. 2007) and Martins et al. (2008) show interesting results that do not fit with the idea of a single ethnic group or with seasonal occupation of the Mesolithic sites in Muge. The intra- and inter-site diversity in the animal (terrestrial and marine) and plant diets seen in Muge suggest that: 1) people had different diets at different sites; and 2) different people at the same site may have had very different diets. The implications are that the Mesolithic people from Muge, while characterized by the same general material culture and economy, do not belong to the same stylistic or ethnic group (which might help explain the lithic typological differences among sites). Finally, although the sites have different sizes and occupation lengths, it seems clear that, after the first occupations, they were not primarily residential, but used as burial grounds. This seems to be confirmed by the presence of a series of loci surrounding Cabeço da Amoreira, found during fieldwork in 2008.

Although the technological and settlement systems are very different when compared to the previous phase, subsistence seems to have been similar (Table 2), at least in the use of terrestrial and marine prey species: red deer, roe deer, wild boar, aurochs, horse, rabbit, cockles, clams (both *Venerupis decussata*, *Scrobicularia plana*), and fish (mostly *Sparidae*). The exceptions seem to be the rarer mussels and ibex that disappeared from the Atlantic phase sites. This fact is likely the result not of the change of subsistence but of settlement, since mussels are found in rocky shoreline habitats and ibex in the higher and rugged topographic environments, neither of which are found around Muge.

THE EVOLUTION OF UPWELLING ON THE PORTUGUESE COAST AND THE IMPACT OF THE 8200 CAL BP EVENT

Today, the Portuguese Coast from Vila Real de St° António (eastern extreme of Algarve) to Nazaré (~150 km north of Lisbon) is well known for its marine resources, both fish and shellfish. The main reason for the high levels of fish and shellfish production along the Portuguese shores is the upwelling dynamics of the Southwestern Iberian Atlantic Coast (Abrantes and Moita 1999; Fiuza 1982, 1983; Loureiro et al. 2005). The upwelling phenomenon is an upward movement of deep (100–200 m), cold waters to the surface induced by north wind circulation. These waters are extremely rich in nutrients and plankton production (Margalef 1978), fueling higher biomass productivity similar to the coasts of Peru, California, and Namibia. This is also the case of Portugal, particularly between the Nazaré and Sagres promontory, where the band of upwelling is between 20 and 50 km seaward, though there are commonly plume-like offshore extensions, with more than 200 km in the Nazaré Canyon, the Tagus Estuary, and the S. Vicente Cape (Fiuza 1983; Sousa and Fiuza 1989).

Today, upwelling along the Portuguese Coast tends to occur in the summer months, though it may be present during other periods of the year (Fiuza 1982, 1983; Loureiro et al. 2005; Sousa and Bricaud 1992). In addition, around the Lisbon Peninsula, winter rains increase the runoff of land nutrients to the ocean, enhancing the biological productivity of the marine and estuarine resources

Table 2. **Main food resources from Epipaleolithic and Mesolithic sites in Central Portugal.**[1]

	Preboreal			Boreal								Atlantic									
	Bocas	**Casal Papagaio**	**Magoito**	**Curral Velho**	**Pena de Mira**	**Picareiro**	**Pinhal da Fonte**	**S. Julião A**	**S. Julião B**	**Toledo**	**Vale Frade**	**Costa do Pereiro**	**S. Julião C**	**Pena d'Água**	**Bocas**	**Formo da Telha**	**Moita do Sebatião**	**Cabeço da Amoreira**	**Cabeço da Arruda**	**Cabeço dos Morros**
Cervus elaphus	√	√				√				√	√	√		?	√	√	√	√	√	√
Capreolus capreolus										√		√				?	√	√	√	√
Sus scropha	√					√				√	√	√			?	√	√	√	√	
Bos primigenius	√					√				√		?			√	?	√	√	√	√
Equus caballos	√														√	?		√	√	√
Oryctolagos cuniculus		√				√	√			√	√	?		√		?	√	√	√	
Lepus sp.		?					?			√	√	?					√	√	√	
Cerastoderma edule	√	√	√√	√√	√	√	√√	√√	√√	√√			√√		√√	√√		√√	√√	?
Venerupis decussata			?	√		√		?		√	√√		√			√		√	√	?
Scrobicularia plana		√	?	√						√	√		√					√√	√√	?
Solen sp.				√			√			√	√		√					√	√	?
Patella sp.	?		√							√	√		√			√				
Mytillus sp.		√	√			√				√	√		√√			√			√	
Ostreidae								√√	√√	√			√					√	√	?
Fish						√				√√	√√							√√	√√	
Sparidae										√√	√√							√√	√√	

[1]Adapted from Valente (2008:614, 618, and 619). √ present, √√ present in abundance in the case of fish and shellfish, ? presence not confirmed. It should be noted that the information presented here for most sites is not available in numeric form (NISP or MNI).

during those times when upwelling does not occur.

In the last decade, Abrantes (1988, 2000) and colleagues (Abrantes et al. 1998; Lebreiro et al. 1997) have studied variability in the upwelling conditions and the biological productivity off the Portugal Coast. Data from two cores, located off northern Portugal (KS11; Abrantes 1990) and off southern Morocco (M12392; Abrantes 1991), show the upwelling oscillations for the Portuguese Coast for the last 200,000 years. Cores near the Canary Islands suggest that the highest productivity took place during the Last Glacial Maximum (LGM). By the end of the Pleistocene (Termination I), the upwelling intensity dropped to levels around 3 to 7 times the modern values. Parallel data on phytoplankton, CaCO3, barium and diatoms (Pailler and Bard 2002; Thomson et al. 2000) confirmed the pattern of intensive upwelling during cold phases and decreasing marine productivity during warm and dry atmospheric stages, such as the Atlantic phase.

Along the Portuguese Coast, Holocene upwelling strength decreased to levels similar to or lower than those of today (Abrantes 2000; Soares 2005; Soares and Dias 2006). Soares (2005; Soares and Dias 2006) used ^{14}C values as proxies for the presence of upwelling: these waters are depleted of ^{14}C compared to those from the sea surface (the oceanic water that is moved seaward due to the wind action) and, thus, the ^{14}C content of marine shells from these regions can be used as proxies for upwelling since the ocean reservoir is deficient in ^{14}C when compared to atmospheric values.

The difference between the marine and the atmospheric contents of ^{14}C varies regionally and temporally for several reasons; one of them is the upwelling phenomenon (Soares and Dias 2006:47). The difference between marine and atmospheric ^{14}C contents is the variable ΔR ("the difference between the reservoir age of the mixed layer of the regional ocean and the reservoir age of the mixed layer of the average world ocean," Soares and Dias 2006:47), and is determined by ^{14}C dating historical specimens of marine shells collected alive before 1950 (pre-atomic testing; Stuiver et al. 1986). Since the ΔR is regional and time-dependent, its value fluctuates through time. Presently, the ΔR for the Portuguese Coast is 250 $\pm$ 25 years (Soares 2005:160; Soares and Dias 2006:47). All ΔR values above this value correspond to a higher upwelling intensity than today and lower values to less intense upwelling in the region.

Research carried out by Soares (1993, 2005:166, 183; Soares and Dias 2006) on the evolution of ΔR along the Portuguese Coast through the Mesolithic, based on nine samples from seven archaeological sites (Magoito, S. Julião I and II, Castelejo, Fiais, Buraca Grande, and Alcalar) indicates that the upwelling intensity decreased continually between the Bond events 6 (9400 cal BP) and 5 (8200 cal BP)—from Preboreal to early Atlantic times—with weak upwelling intensities lower than today (Martins et al. 2008:76).

The only exception is a high ΔR value (940 $\pm$ 50) found in S. Julião II, dated to the Bond event 5, also known as 8.2 kyr cold event (Barber et al. 1999; Grafstein et al. 1998; Mcdermott et al. 2001) that occurred due to the collapse of the Hudson Ice Dome causing a huge freshwater cold pulse in the North Atlantic. The cold event, recorded in the GRIP core, was felt all over the northern hemisphere between 8300 and 8000 cal BP (Alley and Áugústdóttir 2005; Kleiven et al. 2008; Klitgaard-Kristensen et al. 1998; Rasmussen et al. 2007; Rensen et al. 2007), with a drop in sea surface temperature in the higher latitudes and drier atmospheric conditions further south (Rasmussen et al. 2006; Thomas et al. 2007; Vinther et al. 2006), GISP2 (Grootes et al. 1993; Meese et al. 1994). This global event is now documented in terrestrial records of North America (Spooner et al. 2002; Yu and Eicher 1998), in the Caribbean (Hughen et al. 2000), in Africa (Gasse 2000), in the sea surface temperature in the Alborán Sea (Cacho et al. 1999; Frigola et al. 2007), and other places of northern Europe (Grafenstein et al. 1998; Klitgarrd-Kristensen et al. 1998; Kofler et al. 2005; McDermott et al. 2001; Tinner and Lotter 2001). The high ΔR value seen in S. Julião II likely does not correspond to a moment of high intensity of upwelled waters off the coast of Portugal, but to the very rapid and catastrophic discharge of 100,000 km^3 icy freshwater to the Labrador Sea (Barber et al. 1999; Bauer et al. 2004), depleted of radiocarbon (Soares 2005:166–167 and 183).

In summary, the strongest upwelling conditions along the Portuguese Coast were during the LGM (proxy values for upwelling intensity of diatom accumulation rates are 8 to 9 times higher than today), with a continuous drop up to the end of the Pleistocene, still three times stronger than present conditions. During the early Holocene, these numbers are even lower, and the upwelling phenomenon was certainly at its lowest by the Bond 5 event (or 8.2 kyr cold event), with sea level continuously rising and altering the coastal morphology, and generally causing drier conditions than before (Bauer et al. 2004; Renssen et al. 2001, 2002). In the specific case of the Estremadura, the coastal ecosystem saw a strong decrease in marine productivity by 8200 cal BP, due to the continuous decrease in upwelling intensity, the impact of freshwater from the Hudson Bay, and drier atmospheric conditions that severely decreased riverine discharge of nutrients to the coast.

DATING THE FIRST MUGE MESOLITHIC OCCUPATIONS: RADIOCARBON DATA

Absolute dating of the Muge Mesolithic occupations has been a major concern for decades. The first ^{14}C date from a Muge sample was determined in 1957 from the basal levels of Moita do Sebastião (Sa-16) at the Laboratoire d'Electronique Physique du Centre d'Études Nucléaires in France. In the following decade, four more dates were obtained, for the basal and top levels of Cabeço da Arruda and Cabeço da Amoreira, bracketing the human occupation between ~8500 and 5300 cal BP, slightly after the beginning occupation of Moita, around 8000 cal BP (Table 3).

Presently, there are 38 uncorrected radiocarbon dates from Muge shell middens (Lubell et al. 1986; Martins et al. 2008; Rocksandic 2006; Rolão et al. 2006; Umbelino 2006), ranging from 7550 ± 100 to 5150 ± 300 cal BP and nine dates from 7668 ± 49 to 2220 ± 80 cal BP obtained from cores in the Muge Valley floor (van der Schriek et al. 2008). These dates cover a wide assortment of samples, from bulk sediment and plant/wood remains from the cores to charcoal, marine shells, and animal and human bones from the shell middens, making correction and calibration complex. There is the question of the old wood effect (see Zilhão 2001), for instance, which cannot be determined in some of these samples, since they were dated in the 1950s and 1960s). Human bones are less problematic, although isotopic data on the dietary mix of terrestrial and marine resources (Martins et al. 2008; Umbelino 2006) needs to be computed in the calibration. Thus, one needs to know what the ΔR value is for the time and region, so ^{14}C dates from human bones (and shell) can be calibrated. According to Martins et al. (2008:79), the ΔR value for the Muge Valley in the Tagus Estuary around 7000 cal BP is 140 ± 40 years.

Calibration of the Portuguese Mesolithic ^{14}C dates was carried out using two different curves, IntCal04 (Reimer et al. 2004) for terrestrial samples and Marine04 (Hughen et al. 2004) for marine and mixed samples. Samples were calibrated using CALIB 5.1.0beta (Stuiver et al. 2005) and the results are shown in 2δ (Table 3).

After calibration, all results from Muge range from 8680 and 5080 cal BP as extreme limits, including those dates from the valley bottom. Discarding those samples with large errors (>150 years), the two oldest dates are from the site of Cabeço da Arruda, from a skeleton and charcoal (Beta-127451 and TO-10215), corresponding to an interval between 8400 and 8030 cal BP. The second set of two samples (AA-48977 and AA-48978), between ~8300 and 8000 cal BP, dates the beginning of the influence of saltwater intrusion in the Muge Valley (van der Schriek et al. 2008:138). These four dates clearly fall in the time interval of the Bond 5 event dated between 8300 and 8000 cal BP (Thomas et al. 2007; Weninger et al. 2006). After that, most dates fall between 8000 and 7250 cal

Table 3. **Radiocarbon dates from the Muge Valley area.***

Site	Provenience	Lab code	Material	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	% marine diet	Date BP	cal BP 2σ
Cabeço da Arruda	Skeleton 6	Beta-127451	Homo	−19.0	—	24	7550 ± 100	8030–8400
Cabeço da Arruda	base	TO-10215	charcoal	—	—	—	7410 ± 70	8050–8380
Muge valley bottom	MUG-5	AA-48978	plant remains	—	—	—	7318 ± 44	8010–8280
Muge valley bottom	MUG-4	AA-48977	plant remains	—	—	—	7263 ± 56	7980–8180
Muge valley bottom	MUG-3	AA-49816	shell fragments	—	—	—	7668 ± 49	7860–8140
Cabeço da Amoreira	?	TO-11819-R	Homo	−16.3	—	50	7300 ± 80	7690–8010
Moita do Sebastião	Skeleton 22	TO-131	Homo	−16.1	12.2	51	7240 ± 70	7670–7950
Muge valley bottom	MUG-2	Beta-111011	sediment	—	—	—	7490 ± 180	7930–8680
Moita do Sebastião	Skeleton 29	TO-133	Homo	−16.9	10.4	44	7200 ± 70	7670–7940
Cova da Onça	?	Beta-127448	Homo	−17.2	—	41	7140 ± 40	7670–7860
Moita do Sebastião	Skeleton 24	TO-132	Homo	−16.8	11.9	45	7180 ± 70	7660–7940
Moita do Sebastião	Skeleton 16	Beta-127449	Homo	−16.8	—	45	7120 ± 40	6730–7830
Moita do Sebastião	Skeleton 41	TO-134	Homo	−16.7	11.2	46	7160 ± 80	7620–7930
Cabeço da Amoreira	?	Hv-1349	charcoal	—	—	—	7135 ± 65	7830–8160
Cabeço da Arruda	base	TO-10216	Homo	−17.9	10.6	34	7040 ± 60	7590–7830
Cabeço da Amoreira	Layer 4	TO-11862	mammal bones	−19.5	—	—	6990 ± 60	7690–7940
Cabeço da Arruda	Skeleton A	TO-354	Homo	−19.0	12.2	24	6970 ± 70	7570–7830
Moita do Sebastião	IIb	H-2119/1546	?	—	—	—	7080 ± 130	7670–8170
Cabeço da Arruda	Skeleton III	TO-360	Homo	−17.7	11.2	36	6990 ± 110	7460–7910
Cabeço da Amoreira	Skeleton 7	Beta-127450	Homo	−16.5	11.9	48	6850 ± 40	7430–7560
Moita do Sebastião	base breccia	Sa-16	charcoal	—	—	—	7350 ± 350	7520–9000
Moita do Sebastião	Skeleton CT	TO-135	Homo	−15.3	13.4	59	6810 ± 70	7260–7550
Vale Fonte Moça I	?	TO-11863	mammal bones	−22.2	—	—	6890 ± 140	7500–7980
Cabeço da Arruda	Skeleton D	TO-355	Homo	−18.9	10.3	25	6780 ± 80	7420–7660

Muge valley bottom	MUG-6	AA-48979	plant remains	—	—	—	6626 ± 44	7440–7570
Vale Fonte Moça I	?	TO-11864	mammal bones	−21.1	—	—	6650 ± 60	7430–7610
Cabeço da Amoreira	base	TO-10218	Homo	−17.1	—	42	6630 ± 60	7180–7430
Cabeço da Arruda	top	TO-10217	Homo	−18.1	10.5	32	6620 ± 60	7260–7470
Cabeço da Amoreira	Layers 2 and 3 (top)	TO-10225	Homo	−20.1	8.2	0	6550 ± 70	7320–7570
Cabeço da Amoreira	Level 39	Sa-195	charcoal	—	—	—	7030 ± 350	7180–8580
Cabeço da Arruda	Skeleton N	TO-356	Homo	−15.3	12.5	59	6360 ± 80	6720–7160
Cabeço da Arruda	Skeleton 42	TO-359a	Homo	−17.2	11.8	41	6960 ± 60	7480–7700
Cabeço da Arruda	first occupation	Sa-197	charcoal	—	—	—	6430 ± 300	6660–7920
Cabeço da Amoreira	Level 3	TO-11861	mammal bones	−19.6	—	—	5970 ± 70	6660–6990
Muge valley bottom	MUG-8	AA-48981	wood	—	—	—	5929 ± 52	6650–6890
Cabeço da Amoreira	recent occupation	Sa-194	charcoal	—	—	—	6050 ± 300	6290–7550
Cabeço da Amoreira	Level 2	TO-11860	mammal bones	−12.5	—	—	5710 ± 170	6130–6950
Muge valley bottom	MUG-7	AA-48980	sediment	—	—	—	4985 ± 73	5600–5900
Cabeço da Arruda	last occupation	Sa-196	charcoal	—	—	—	5150 ± 300	5980–6630
Cabeço da Amoreira	Camada 3 (top)	Sac-2023	shell	—	—	—	7260 ± 60	7460–7740
Ribeira de Magos	?	Beta-152956	dog	—	—	—	7070 ± 40	7800–7970
Cabeço da Amoreira	Camada 3 (top)	Sac-2080	shell	—	—	—	7080 ± 80	7270–7590
Cabeço da Amoreira	Camada 3 (top)	Sac-2079	shell	—	—	—	7050 ± 45	7300–7540
Cabeço da Amoreira	Camada 3 (top)	Sac-2102	fauna	—	—	—	6520 ± 120	7180–7610
Cabeço da Amoreira	Camada 3 (top)	Sac-2078	charcoal	—	—	—	5170 ± 40	5760–6000

*Dates BP in Detry (2007); Martins et al. (2008); Umbelino (2006).% marine diet from Martins et al. (2008). Calibration curves are IntCal04 (Stuiver et al. 2005) and Marine04 (Hughen et al. 2004). For marine and marine mixed samples the ΔR value is 140 ± 40.

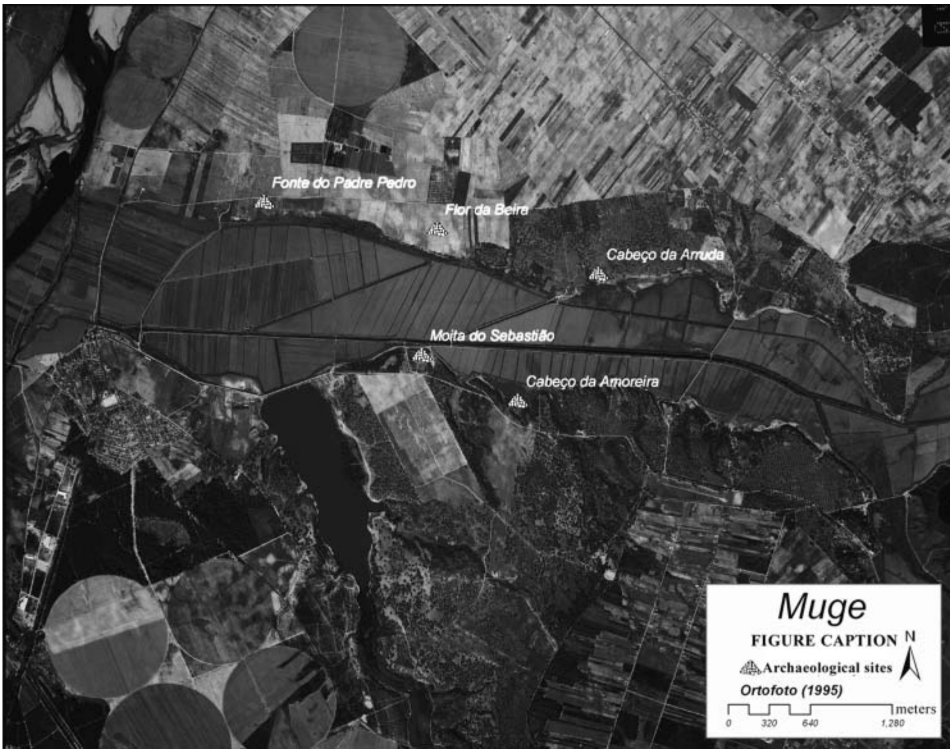

Figure 2. *Map of the Muge Valley with site locations.*

BP (coming from all dated shell middens, confirming that this was the main period of Mesolithic occupation in the region), with a small group of five dates after 7000 cal BP. Two of these are not archaeological and correspond to the end of the influence of the saltwater in the Muge Valley (AA-48980) and the beginning of soil formation in the valley bottom (AA-48981; van der Schriek et al. 2008:138).

Three other samples have large standard errors for which the distribution curve falls mostly after 7000 cal BP (Sa-194, Sa-196, and TO-11860). Thus, it seems that the complete Mesolithic desertion of the lower Tagus Valley was sometime around 7,000 years ago, although the abandonment of the area probably started a couple centuries earlier (corresponding to a phase of increased dryness and sedimentation of the valley), much earlier than the moment of the disappearance of salt water in the valley (between ~6900 and 6600 cal BP).

A NEW MODEL FOR THE EMERGENCE OF THE MUGE SHELL MIDDENS

The radiocarbon data strongly suggest that the first shell middens, probably Cabeço da Arruda, and the arrival of salt water took place around 8200 cal BP, and thus are coincidental with the Bond 5 (8.2 kyr cal BP) event (Figure 3). Because of the time concurrence between these episodes, Zilhão (2003) and Martins et al. (2008) see the 8.2 kyr event as the main trigger to the coastal-inland movement of Mesolithic people in central Portugal. The same event has been fundamental to explain other major cultural factors in Europe, such as the emergence

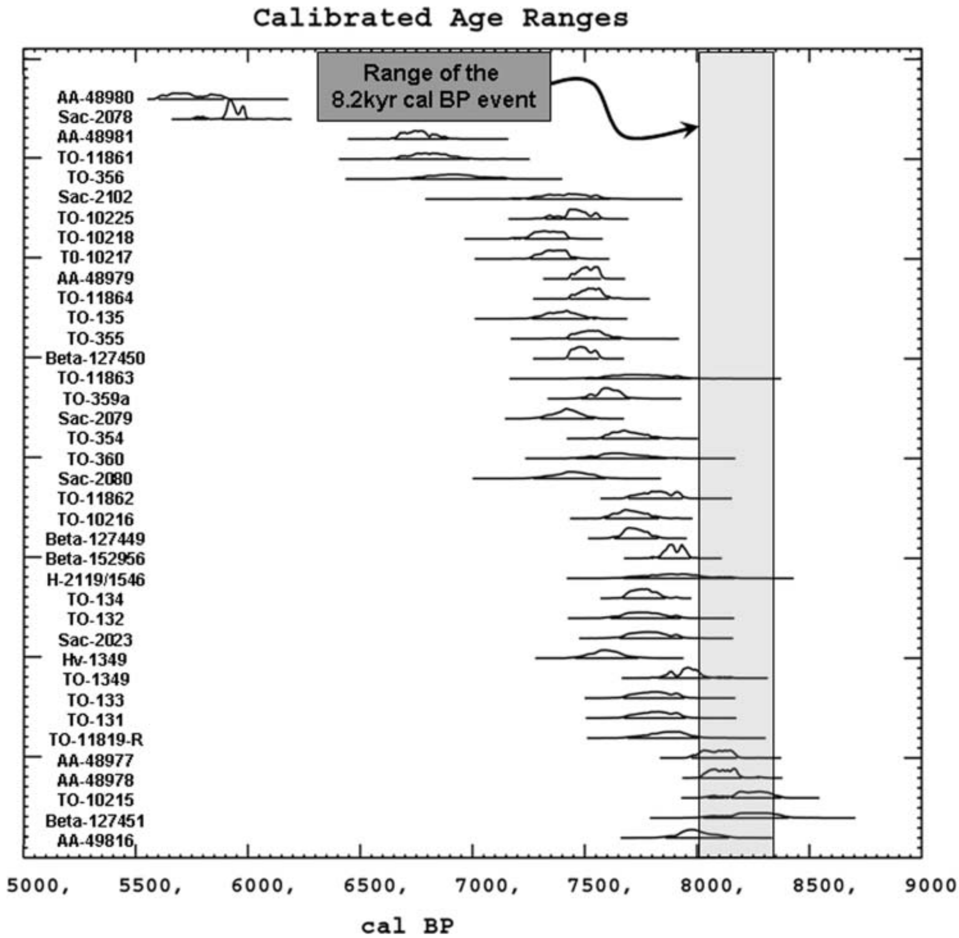

Figure 3. *Distribution of calibrated radiocarbon dates from Muge (cal BP). Calibration curves are IntCal04 (Reimer et al. 2004) and Marine04 (Hughen et al. 2004); for marine and marine mixed samples the* ΔR *value is* 140 ± 40.

of the Neolithic in the Eastern Europe and major disruptions of Neolithic cultures in the eastern Mediterranean (Weninger et al. 2006).

It is very unlikely, however, that the 8200 cal BP event by itself caused any major cultural impact in Portugal as Zilhão and Martins et al. have argued. Haws (2003:292–293) suggested that the decrease in upwelling may have been the key factor for the change in settlement system from the coastal Epipaleolithic to the estuarine Mesolithic in central Portugal. We argue here that the two factors are related and together are the basis for the change in the Mesolithic settlement system.

Bauer et al. (2004:11) argued that the freshwater volume (1.6×10^{14} m^3) from the collapse of the Hudson Dome (causing the 8.2 kyr cal BP event) led to a general sea level rise of 50 cm as well as abrupt flushing events, large gravity waves, and possible massive floods in coastal regions adjacent to the North Atlantic. If this model is correct, in the midst of the general sea level transgression of the early Holocene, the sea level rise caused by this event changed the coastal morphology through huge and fast-propagating surface waves. This lead to massive flooding in coastal areas adjacent to the North Atlantic, especially small estuaries (territories where clams, cockles, and shellfish species were gathered), causing the disappearance of many of them. In central Portugal it seems to have sped up the process of estuarine formation in the Lower Tagus Valley and overflowed permanently a littoral area of around 3,500 km^2.

The drop in upwelling intensity during Boreal and early Atlantic times caused a strong reduction in coastal marine nutrients and biomass productivity, and central Portugal saw a severe decrease in coastal resources such as fish and shellfish. This lack of nutrients was even more acute since coastal productivity in the area (augmented in the winter by the drainage of the land nutrients towards the ocean water due to the rain during Tardiglacial and Early Holocene times) severely decreased due to aridity resulting from the 8.2 kyr event. Thus, the resource availability known until around 8200 cal BP in the coastal areas of Central Portugal was strongly reduced (likely the lowest since 200,000 years ago), a change compounded by the fact that coastal morphology changed due to sea level rise.

Nonetheless, as we have said earlier, the resources were basically the same, possibly since before the LGM: terrestrial prey included red deer, roe deer, wild boar, aurochs, horse, and rabbit; marine resources included fish and shellfish (limpets and mussels in rocky environments and various types of clams and cockles in estuarine areas) and thus the subsistence was similar during the coastal Epipaleolithic and the inland estuarine Mesolithic.

Under conditions of rapid sea level rise, flooding, strong wave action, coastal morphology change, the disappearance of old estuaries, and decreasing resource availability, it is likely that the coastal setting was no longer suitable for the hunter-gatherer-fishers of Central Portugal, leading to a human settlement shift from the outer coast to the protected and stable inland lower Tagus Valley. Therefore, the key factor that caused the Mesolithic coastal-inland settlement shift may not have been simply the addition of a new setting but the decline in the availability of the marine resources in the coastal areas previously occupied. This settlement shift allowed the demographic expansion documented by the large burial grounds found in the Muge shell middens. Together with the settlement change, there seem to have been changes in technology and social structure, with the emergence of a new and more complex hunter-gatherer-fisher group based on the rich estuarine setting of the Lower Tagus Valley.

ACKNOWLEDGEMENTS

We thank Alice Newton, Delminda Moura, Jonathan Haws, Óscar Ferreira, and Fiona Petchey for help with the technical aspects of, respectively, the upwelling system, geomorphology of the Tagus Valley, revision of the paper, and radiocarbon dating. We are also indebted to the editors and anonymous reviewers for help in the review and revision of this paper. Naturally, all mistakes are ours alone. This paper is a result of the research project. The Last Hunter-gatherers in the Tagus Valley—The Muge Shellmiddens *(PTDC/HAH/64185/2006) funded by Fundação para a Ciência e Tecnologia, Portugal.*

REFERENCES

Abrantes, F. 1988. Diatom assemblages as upwelling indicators in surface sediments off Portugal. *Marine Geology* 85:15–39.

Abrantes, F. 1990. Increased upwelling off Portugal during the last deglaciation: diatom evidence. *Marine Micropaleontology* 17:285–310.

Abrantes, F. 1991. Variability of upwelling off NW Africa during the latest Quaternary evidence. *Paleoceanography* 6:431–460.

Abrantes, F. 2000. 200,000 yr diatom records from Atlantic upwelling sites reveal maximum productivity during LGM and a shift in phytoplankton community structure at 185,000 yr. *Earth and Planetary Science Letter* 176:7–16.

Abrantes, F., J. Baas, H. Hajlidason, T. Rasmussen, D. Klitgaard, N. Loncaric, and L. Gaspar. 1998.

Sediment fluxes along the northeastern European Margin: Inferring hydrological changes between 20 and 8 kyr. *Marine Geology* 152:7–23.

Abrantes, F. and T. Moita. 1999. Water column and recent sediment data on diatoms and coccolithophorids, off Portugal confirm sediment record as memory of upwelling events. *Oceanologica Acta* 22:319–336.

Alley, R. and A. Áugústdóttir. 2005. The 8k event: Cause and consequences of a major Holocene abrupt climate change. *Quaternary Science Review* 24;1123–1149.

Araújo, A. 2009. Hunter-gatherer adaptations during the Pleistocene/Holocene transition in Portugal: Data and explanatory models. In *Mesolithic Horizons* (S. McCartan et al., eds.):533–540. Oxford: Oxbow Books.

Araújo, A. and F. Almeida. 2006. Inland insights into the Macrolithic puzzle: The case of Barca do Xerez de Baixo. In *Papers in Honor of Anthony Marks* (N. Bicho, ed.):185–208. Faro: Universidade do Algarve.

Arias, P. and E. Alvarez-Fernández. 2004. Iberian foragers and funerary ritual—A review of Paleolithic and Mesolithic evidence on the Península. In *The Mesolithic of the Atlantic façade: Proceedings of the Santander Symposium* (M. Gonzalez and G. Clark, eds.):225–248. Anthropological Research Papers 55. Tempe: Arizona State University.

Arnaud, J. 1987. Os concheiros mesolíticos dos vales do Tejo e do Sado: Semelhanças e diferenças. *Arqueologia* 15:53–64.

Arnaud, J. 1989. The Mesolithic communities of the Sado valley, Portugal, in their ecological setting. In *The Mesolithic in Europe. Third International Symposium* (C. Bonsall, ed.):614–631. Edinburgh: John Donald.

Arnaud, J. 1993. O Mesolítico e a neolitização. Balanço e perspectivas. In *O Quaternário em Portugal: Balanços e perspectivas* (G. S. Carvalho, A. B. Ferreira, and J. C. Senna-Martinez, eds.):173–184. Lisbon: Edições Colibri.

Barber, D., A. Dyke, A. Hillaire-Marcel, A. Jennings, J. Andrews, M. Kerwin, G. Bilodeau, G. McNeeley, J. Southon, M. Morehead, and J.-M. Gagnon. 1999. Forcing of the cold event of 8,200 years ago by catastrophic drainage of Laurentide lakes. *Nature* 400:344–348.

Bauer, E., A. Ganopolski, and A. Montoya. 2004. Simulation of the cold climate event 8200 years ago by meltwater outburst from Lake Agassiz. *Paleoceanography* 19/3, PA3014, doi:10.1029/2004PA001030.

Bicho, N. 1994. The end of the Paleolithic and the Mesolithic in Portugal. *Current Anthropology* 35:664–674.

Bicho, N. 1998. Pleistocene-Holocene Transition in Portuguese Prehistory: A technological perspective. In *The Organization of Lithic Technology in Late Glacial and Early Postglacial Europe* (Sarah Milliken, ed.):39–62. BAR, International Series. Oxford: Archaeopress.

Bicho, N. 2002. Lithic raw material economy and hunter-gatherer mobility in the Late Glacial and Early Post Glacial Portuguese Prehistory. In *Lithic Raw Material Economies in Late Glacial and Early Postglacial Europe* (Lynn E. Fisher and Berit Valentin Eriksen, eds.):161–179. BAR, International Series. Oxford: Archaeopress.

Bicho, N. and J. Haws. 2008. At the land's end: Marine resources and the importance of fluctuations in the coast line in the prehistoric hunter-gatherer economy of Portugal. *Quaternary Science Review* 27:2166–2175.

Cacho, I., J. O. Grimalt, C. Pelejero, M. Canals, F. Sierro, J. Flores, and N. Shackleton. 1999. Dansgaard–Oeschger and Heinrich event imprints in the Alboran Sea paleotemperatures. *Paleoceanography* 14(6):698–705.

Cardoso, J. and J. Rolão. 1999/2000. Prospecções e escavações nos concheiros mesolíticos de Muge e Magos (Salvaterra de Magos): Contribuição para a história dos trabalhos arqueológicos efectuados. *Estudos Arqueológicos de Oeiras* 8:83–240.

Carvalho, A. 2003. A emergência do neolítico no actual território português: Pressupostos teóricos, modelos interpretativos e a evidência empírica. *O Arqueólogo Português* Série 4, 21:65–150.

Carvalho, A. 2007. *A Neolitização do Portugal Meridional: Os Exemplos do Maciço Calcário Estremenho e do Algarve Ocidental*. Ph.D. Dissertation. Faro: Universidade do Algarve.

Clark, G. 2000. Thirty years of Mesolithic research in Atlantic coastal Iberia (1970–2000). *Journal of Anthropological Research* 56(1):17–38.

Clark, G. 2004. The Iberian Mesolithic in the European context. In *The Mesolithic of the Atlantic façade: Proceedings of the Santander Symposium* (M. Gonzalez and G. Clark, eds.):205–224. Anthropological Research Papers 55. Tempe: Arizona State University.

Cunha, E., F. Cardoso, and C. Umbelino. 2003. Inferences about mesolithic life style on the basis of Anthropological data. The case of the Portuguese shell middens. In *Mesolithic on the move* (L. Larsson, H. Kindgren, K. Knutsson, D. Leoffler, and A. Akerlund, eds.):184–188. Oxford: Oxbow Books.

Cunha, E. and C. Umbelino. 2001. Mesolithic people from Portugal: An approach to Sado osteological series. *Anthropologie* 39:125–132.

Detry, C. 2007. *Paleoecologia e Paleoeconomia do Baixo Vale do Tejo no Mesolítico Final: O Contributo dos Mamíferos dos Concheiros de Muge*. Ph.D. Dissertation. Lisbon: Universidade Autónoma de Lisboa and Universidade de Salamanca.

Diniz, M. 2004. *O Sítio da Valada do Mato (Évora). Aspectos da Neolitização no Interior Sul de Portugal*. Ph.D. Dissertation. Lisbon: Universidade de Lisboa.

Fiuza, A. 1982. The Portuguese coastal upwelling system. In *Actual Problems of Oceanography in Portugal*:45–71. Lisbon: Junta Nacional Científica e Tecnológica.

Fiuza, A. 1983. Upwelling patterns off Portugal. In *Coastal Upwelling: Its Sedimentary Record* (E. Suess and J. Thiede, eds.): 85–98. New York: Plenum.

Frigola, J., A. Moreno, I. Cacho, M. Canals, F. Sierro, J. Flores, J. Grimalt, D. Hodell, and J. Curtis. 2007. Holocene climate variability in the western Mediterranean region from a deepwater sediment record. *Paleoceanography* 22:PA2209, doi:10.1029/2006PA001307.

Gasse, F. 2000. Hydrological changes in the African tropics since the last glacial maximum. *Quarternary Science Reviews* 19:189–212.

Grafenstein, U. von, H. Erlenkeuser, J. Müller, J. Jouzel, and S. Johnsen. 1998. The cold event 8200 years ago documented in oxygen isotope records of precipitation in Europe and Greenland. *Climate Dynamics* 14:73–81.

Grootes, P., M. Stuiver, J. White, S. Johnsen, and J. Jouzel. 1993. Comparison of oxygen isotope records from the GISP2 and GRIP Greenland ice core. *Nature* 366:552–554.

Haws, J. 2003. *An Investigation of Late Upper Paleolithic and Epipaleolithic Subsistence and Settlement Patterns in Central Portugal*. Ph.D. dissertation. Madison: University of Wisconsin-Madison.

Hughen, K., M. Baillie, E. Bard, J. Beck, C. Bertrand, P. Blackwell, C. Buck, et al. 2004. Marine04 marine radiocarbon age calibration, 0–26 cal kyr BP. *Radiocarbon* 46:1059–1086.

Hughen, K., J. Southon, S. Lehman, and J. Overpeck. 2000. Synchronous radiocarbon and climate shift during the last deglaciation. *Science* 290(5498):1951–1954.

Jackes, M. 1988. Demographic change at the Mesolithic-Neolithic transition: Evidence from Portugal. *Rivista di Antropologia* 66:141–158.

Jackes, M., D. Lubell, and C. Meiklejohn. 1997. Healthy but mortal: Human biology and the first farmers of Western Europe. *Antiquity* 71:639–658.

Jackes, M. and C. Meiklejohn. 2004. Building a method for the transition of the Mesolithic-Neolithic transition in Portugal. *Documenta Praehistorica* 31:89–111.

Kleiven, H., C. Kissel, C. Laj, U. Ninnemann, T. Richter, and E. Cortijo. 2008. Reduced North Atlantic dep water coeval with the glacial Lake Agassiz freshwater outburst. *Science* 319:60–64.

Klitgaard-Kristensen, D., H. Sejrup, H. Haflidason, S. Johnsen, and M. Spurk. 1998. A regional 8200 cal. yr BP cooling event in northwest Europe, induced by final stages of the Laurentide ice-sheet deglaciation? *Journal of Quaternary Science* 13:165–169.

Kofler, W., V. Krapf, W. Oberhuber, and S. Bortenschlager. 2005. Vegetation responses to the 8200 cal. BP cold event and to long-term climatic changes in the Eastern Alps: Possible influence of solar activity and North Atlantic freshwater pulses. *The Holocene* 15:779–788.

Lebreiro, S., J. Moreno, F. Abrantes, and U. Pflaumann. 1997. Productivity and Paleoceanographic implications op the Tore Seamount (Iberian Margin) during the last 225 Kyrs foranimiferal evidence. *Paleoceanography* 12:718–727.

Lentacker, A. 1986. Preliminary results of the fauna of cabeço da Amoreira and Cabeço da Arruda (Muge, Portugal). *Trabalhos de Antropologia e Etnologia* 26(1–4):9–26.

Loureiro, S., A. Newton, and J. Icely. 2005. Microplankton composition, production and upwelling dynamics in Sagres (SW Portugal) during the summer of 2001. *Scientia Marina* 69:323–341.

Lubell, D., M. Jackes, H. Schwarcz, and C. Meiklejohn. 1986. New radiocarbon dates for Moita do Sebastião. *Arqueologia* 14:34–36.

Lubell, D., M. Jackes, H. Schwarcz, M. Knyf, and C. Meiklejohn. 1994. The Mesolithic-Neolithic transition in Portugal: Isotopic and dental evidence of diet. *Journal of Archaeological Science* 21:201–216.

Marchand, G. 2005. Interpretar as mudanças dos sistemas técnicos do Mesolítico final em Portugal. *O Arqueólogo Português* Série IV 23:171–195.

Margalef, R. 1978. Life-forms of phytoplankton as survival alternatives in an unstable environment. *Oceanologica. Acta* 1:493–509.

Martins, J., A. Carvalho, and A. Soares. 2008. A calibração das datas de radiocarbono dos esqueletos de Muge. *Promontoria* 6:73–93.

McDermott, F., D. Mattey, and C. Hawkesworth. 2001. Centennial-scale holocene climate variability revealed by a high-resolution speleothem δ^{18}O record from SW Ireland. *Science* 294;1328.

Meese D., R. Alley, T. Gow, P. Grootes, P. Mayewski, M. Ram, K. Taylor, E. Waddington, and G. Zielinski. 1994. *Preliminary Depth-Age Scale of the GISP2 Ice Core*. CRREL Special Report 94–1. Hanover, NH: Cold Regions Research and Engineering Laboratory.

Mendes Corrêa, A. 1933. Les nouvelles fouilles à Muge (Portugal). In *XV^{e} Congrès International d'Anthropologie et d'Archaéologie Préhistorique, Paris, 1931*:1–16. Paris: Librairie E. Nourry.

Newell, R., T. Constandse-Westermann, and C. Meiklejohn. 1979. The skeletal remains of mesolithic Man in Western Europe: An evaluative catalogue. *Journal of Human Evolution* 8:29–154.

Pailler, D. and E. Bard. 2002. High frequency palaeoceanographic changes during the past 140 000 yr recorded by the organic matter in sediments of the Iberian Margin. *Palaeogeography, Palaeoclimatology, Palaeoecology* 181:431–452.

Rasmussen, S. O., K. Andersen, A. Svensson, J. Steffensen, C. Vinther, B. Clausen, M.-L. Siggaard-Andersen, et al. 2006. A new Greenland ice core chronology for the last glacial termination. *Journal of Geophysical Research* 111, D06102, doi:10.1029/2005JD006079.

Rasmussen, S. O., C. Vinther, B. Clausen, and K. Andersen. 2007. Early Holocene climate oscillations recorded in three Greenland ice cores. *Quaternary Science Review* 26;1907–1914.

Reimer, P. J., M. Baillie, E. Bard, A. Bayliss, J. Beck, C. Bertrand, P. Blackwell, et al. 2004. IntCal04 terrestrial radiocarbon age calibration, 0–26 cal kyr BP. *Radiocarbon* 46:1029–1058.

Renssen, H., H. Goosse, and T. Fichefet. 2002. Modeling the effect of freshwater pulses on the early Holocene climate: The influence of high-frequency climate variability. *Paleoceanography* 17(2): 1020, doi:10.1029/2001PA000649.

Renssen, H., H. Goosse, and T. Fichefet. 2007. Simulation of Holocene cooling events in a coupled climate model. *Quaternary Science Review* 26;2019–2029.

Renssen, H., H. Goosse, T. Fichefet, and J.-M. Campin. 2001. The 8.2 kyr BP event simulated by a global atmosphere-sea-ice-ocean model, *Geophysical Research Letters* 28:1567–1570.

Ribeiro, C. 1884. Les kioekkenmoedings de la Vallée du Tage. In *Compte Rendu de la IX^{ème} Session du Congrès International dÁnthropologie et d'Archéologie Préhistoriques, Lisbonne 1880*:279–290. Lisbon: Typographie de l'Académie des Sciences.

Roche, J. 1954. Resultats des dernières campagnes de fouilles exécutées a Moita do Sebastião (Muge). *Revista da Faculdade de Ciências* IV:179–186.

Roche, J. 1972. *Le gisement Mésolithique de Moita do Sebastião. Muge, Portugal*. Lisbon: Instituto de Alta Cultura.

Roche, J. 1989. Spatial organization in the Mesolithic sites of Muge, Portugal. In *The Mesolithic in Europe. Third International Symposium* (C. Bonsall, ed.):607–613. Edinburgh: John Donald.

Rocksandic, M. 2006. Analysis of burials from the new excavations of the sites Cabeço da Amoreira and Cabeço da Arruda (Muge, Portugal). In *Do Epipaleolítico ao Calcolítico na Península Ibérica. Actas do IV Congresso de Arqueologia Peninsular* (N. Bicho and H. Veríssimo, eds.):43–54. Faro: Universidade do Algarve.

Rodrigues, S. 2008. *Pensar o Neolítico Antigo. Contributo para o Estudo do Norte de Portugal entre o VII e o V Milénios B.C.* Ph.D. Dissertation. Porto: University of Porto.

Rolão, J. 1999. *Del Wurm Final al Holocénico en el Bajo Valle del Tajo (Complejo Arqueológico Mesolítico de Muge)*. Ph.D. Dissertation. Salamanca: Universidad de Salamanca.

Rolão, J., A. Joaquinito, and M. Gonzaga. 2006. O complexo mesolítico de Muge: Novos resultados sobre a ocupação do Cabeço da Amoreira. *Do Epipaleolítico ao Calcolítico na Península Ibérica. Actas do IV Congresso de Arqueologia Peninsular* (N. Bicho and H. Veríssimo, eds.):27–42. Faro: Universidade do Algarve.

Shockler, J. 2006. Hunter-gatherer movement in the Portuguese Upper Paleolithic: Archaeological results of a Regional Lithic Sourcing Project. In *Papers in Honor of Anthony Marks* (N. Bicho, ed.):141–162. Faro: Universidade do Algarve.

Silva, C. and J. Soares. 1981. *Pré-história da Área de Sines*. Lisbon: Gabinete da Área de Sines.

Soares, A. 1993. The ^{14}C content of marine shells: Evidence for variability in coastal upwelling off Portugal during the Holocene. In *Isotope Techniques in the Study of Past and Current Environmental Changes in the Hydrosphere and the Atmosphere*: 471–485. Viena: International Atomic Energy Agency.

Soares, A. 2005. *Variabilidade do "upwelling" costeiro durante o holocénico nas margens atlânticas ocidental e meridional da*

Península Ibérica. Ph.D. Dissertation. Faro: Universidade do Algarve.

Soares, A. and A. Dias. 2006. Coastal upwelling and radiocarbon—evidence for temporal fluctuations in ocean reservoir effect off Portugal during the Holocene. *Radiocarbon* 48(1): 46–60.

Soares, J. and C. Silva. 2003. A transição para o Neolítico na costa sudoeste portuguesa. In *Muita gente, poucas antas? Origens, espaços e contextos do Megalitismo* (V. Gonçalves, ed.):45–56. Lisbon: IPA.

Soares, A. and A. Sousa. 2004. Cronologia Absoluta. In *São Julião. Núcleo C do concheiro pré-histórico*:75–82. Mafra: Câmara Municipal de Mafra.

Sousa, F. and A. Bricaud. 1992. Satellite-derived phytoplankton pigment structures in the Portuguese Upwelling area. *Journal of Geophysical Research* 97:11343–11356.

Sousa, F. and A. Fiuza. 1989. Recurrence of upwelling filaments off northern Portugal as revealed by satellite imagery. In *Proceedings of the 4th AVHRR Data Users' Meeting, EUMEYSAT*:219–223. Darmstad.

Spooner, I., M. Douglas, and L. Terrusi. 2002. Multiproxy evidence of an early Holocene (8.2 kyr) climate oscillation in central Nova Scotia, Canada. *Journal Quaternary Science* 17:639–645.

Stuiver, M., P. Reimer, and R. Reimer. 2005. *CALIB 5.0.* http://calib.qub.ac.uk/calib/

Stuiver. M, G. Person, and T. Braziunas. 1986. Radiocarbon age calibration of marine samples back to 9000 cal yr BP. *Radiocarbon* 28(2B):980–1021.

Thomas, E., E. W. Wolff, R. Mulvaney, J. P. Steffensen, S. J. Johnsen, C. Arrowsmith, J. W. C. White, B. Vaughn, and T. Popp. 2007. The 8.2 ka event from Greenland ice cores. *Quaternary Science Review* 26:70–81.

Thomson, J., S. Nixon, C. Summerhayes, E. Rohling, J. Schönfeld, R. Zahn, P. Grootes, F. Abrantes, L. Gaspar, and S. Vaqueiro. 2000. Enhanced productivity on the Iberian Margin during glacial/ interglacial transitions revealed by barium and diatoms. *Journal of the Geological Society* 157:667–677.

Tinner, W. and A. Lotter. 2001. Central European vegetation response to abrupt climate change at 8.2 ka. *Geology* 29:551–554.

Umbelino, C. 2006. *Outros sabores do passado. As análises de oligoelementos e de isótopos estáveis na reconstrução da dieta das comunidades humanas do Mesolítico Final e do Neolítico/Calcolítico do território português*. Ph.D. Dissertation. Coimbra: Universidade de Coimbra.

Umbelino, C., A. Pérez-Pérez, E. Cunha, C. Hipólito, M. Freitas, and J. Cabral. 2007. Outros sabores do passado: Um novo olhar sobre as comunidades humanas mesolíticas de Muge e do Sado através de análises químicas dos ossos. *Promontoria* 5:45–90.

Valente, J. 2008. *As Últimas Sociedades de Caçadores-Recolectores no Centro e Sul de Portugal (10.000–6.000 anos BP): Aproveitamento dos Recursos Animais*. Ph.D. Dissertation. Faro: Universidade do Algarve.

Van Der Schriek, T., D. Passmore, F. Mugica, A. Stevenson, I. Boomer, and J. Rolão. 2008. Holocene palaeoecology and floodplain evolution of the Muge tributary, Lower Tagus basin, Portugal. *Quaternary International* 189:135–151.

Vinther, B. M., H. Clausen, S. Johnsen, S. Rasmussen, K. Andersen, S. Buchardt, D. Dahl-Jensen, et al. 2006. A synchronized dating of three greenland ice cores throughout the Holocene. *Journal Geophysical Research* doi:10.1029/2005JD006921.

Weninger, B., E. Alram-Stern, E. Bauer, L. Clare, U. Danzeglocke, O. Jöris, C. Kubatzki, G. Rollefson, H. Todorova, and T. van Andel. 2006. Climate forcing due to the 8200 cal yr BP event observed at Early neolithic sites in the eastern Mediterranean. *Quaternary Research* 66: 401–420.

Yu, Z. and U. Eicher. 1998. Abrupt climate oscillations during the last deglaciation in central North America. *Science* 282:2235–2238.

Zilhão, J. 1993. The spread of agro-pastoral economies across Mediterranean Europe: A view from the Far West. *Journal of Mediterranean Archaeology* 6(1):5–63.

Zilhão, J. 2001. Radiocarbon evidence for maritime pioneer colonization at the origins of farming in west Mediterranean Europe. *PNAS* 98:14180–14185.

Zilhão, J. 2003. Algumas observações acerca do Mesolítico do interior peninsular e do modelo de passagem ao Neolítico através de colonização pioneira por via marítima. Comentário a Carvalho, 2007. *O Arqueólogo Português* 4 Série, 21:108–118.