UNIVERSITY OF ALBERTA

MOLLUSCS AND ARCHAEOLOGY: SETTLEMENT AND SEASONALITY IN THE PORTUGUESE MESOLITHIC

BY

RICHARD JOHN LELLO ©

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Mr. Richard Lello
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Dear Richard,

You have my permission to use my original drawings of the Pandeiro site map and section as Figs. 3 and 4 in your M.A. thesis ("Molluscs and Archaeology: Settlement and Seasonality in the Portuguese Mesolithic").

Yours sincerely,

Dr. David Lubell
Professor and Chair

UNIVERSITY OF ALBERTA

RELEASE FORM

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The undersigned certify that they have read, and recommend to the FACULTY OF GRADUATE STUDIES AND RESEARCH for acceptance, a thesis entitled MOLLUSCS AND ARCHAEOLOGY: SETTLEMENT AND SEASONALITY IN THE PORTUGUESE MESOLITHIC submitted by RICHARD JOHN LELLO in partial fulfillment of the requirements for the degree of MASTER OF ARTS.

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ABSTRACT

The excavation and analysis of mesolithic sites in southern Portugal during the past one hundred years or so has yielded considerable evidence in terms of lithic technology and resource base. However, other major aspects of the mesolithic economy of this region, particularly resource scheduling strategies and settlement systems, are not well understood. In the past, researchers have tended to concentrate on the study of lithic material and stratigraphy. More recently, however, problem-oriented research has been initiated in this area, and attempts have been made to determine seasons of resource exploitation and site occupation, based largely on the analysis of faunal remains.

In this study, the mesolithic archaeology and ecology of southern Portugal is discussed, and a settlement model is proposed using current theoretical perspectives. Present indications of seasonality are examined, and are found to be generally quite limited in terms of both resource exploitation and site occupation. However, the potential value of molluscs as seasonal indicators is noted.

The recent excavation and analysis of the Pandeiro shell midden is described. Evidence of environmental change during the Holocene is observed, and the role of the site within its regional setting is discussed. Seasonality determinations are undertaken based on the analysis of shell growth increments in the intertidal bivalve *Cerastoderma edule* Linnaeus, and are applied to the limited testing of hypotheses of seasonal or more permanent occupation at Pandeiro.

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CHAPTER ONE

INTRODUCTION

The concept and the definition of the Mesolithic in European prehistory has been the subject of considerable debate since Allen Brown first applied the term in 1893 to flint assemblages intermediate in age between the Palaeolithic and the Neolithic periods (Clark 1980:3; see also Czarnik 1976, Price 1987, Rowley-Conwy 1986). In 1936, Grahame Clark noted certain broad similarities between the adaptations of later Palaeolithic societies and those of the early Holocene in terms of economic strategies, which were based on hunting, fishing, fowling, and collecting; and also in terms of technology, pointing to the continued use of certain stone tool types. He observed that in consequence some researchers classify early Holocene societies as Epi-palaeolithic. While recognising such economic and technological similarities, Clark preferred to discuss these societies in terms of the Mesolithic, choosing a chronological definition and emphasising that, "In employing this term nothing more is implied than that the Mesolithic flourished in the main between the Palaeolithic and Neolithic civilizations in point of time". He added the rider, "it may be emphasised that it is not intended to suggest an evolutionary stage." (Clark 1936:xiv). In 1976, David Clarke observed that in southern Europe, "The same continuity is witnessed in many of the flint industries and it is a matter of preferences whether we label the regional complexes of c. 10,000-5,000 B.C. Mesolithic, Epipalaeolithic or Protoneolithic. They are all of these things taxonomically, but about their subsistence status we are less clear" (Clarke 1976:470). More recently, Price has proposed succinctly that, "The Mesolithic is simply that period of the Postglacial prior to the introduction of agriculture" (Price 1983:763; but cf. Rozoy's [1989] preference for the term Epipalaeolithic).

Studies of hunter-gatherer adaptations have, in the past, been influenced by two general assumptions: 1) small group size; and 2) high mobility (Lee and DeVore 1968, Price and Brown 1985a). However, many researchers recognise a wide and more complex range of adaptations, including larger aggregations (at least seasonally), and permanently occupied settlements (e.g., Jochim 1976, Kristiansen and Paludan-Müller 1979, Yesner 1980, Clark 1983, Rowley-Conwy 1983, Rowley-Conwy *et al.* 1987, Price 1987, Price and Brown 1985b). The concept of complex hunter-gatherers (discussed by Marquardt 1985, Price 1985, Rowley-Conwy 1983, Zvelebil 1986a) is integral to a number of recent theoretical perspectives which address questions of economic strategy, subsistence activity, settlement systems, and social relations (e.g., Carlson 1979; Ingold 1980, 1984; Woodburn 1980, 1982; Johnson 1982; Testart 1982; Bender 1985; McKay 1988). Zvelebil (1986b:112) further proposes that "the complex foraging adaptation ought to serve as the defining characteristic of the Mesolithic period".

Molluscs and Archaeology

A prominent feature of the mesolithic[1] landscape of western Europe is the shell midden (Bailey 1978, Bailey and Parkington 1988, Clark 1980); and shell midden analysis has contributed significantly to archaeological research in Europe, as in many other areas of the world (Meighan 1969, Waselkov 1987). Examples of such research in Europe include the work of Brinch-Petersen (1973) in Denmark; Coles (1971), Deith (1983a, 1986), Mellars (1978), and Mellars and Payne (1971) in Scotland; Bailey (1983), Clark (1983), Deith (1983b), and Strauss and Clark (1986) in Spain; Arnaud (1985, 1989), Lentacker (1986a), Lubell and Jackes (1987), and Lubell *et al.* (1989) in Portugal; Shackleton (1988), and Shackleton and van Andel (1980, 1986) in Greece. Although the economic importance of molluscs may have been exaggerated in the past (Bailey 1978, Jarman *et al.* 1982), molluscs are presently recognised by researchers as a significant supplemental resource, and as an emergency buffer when other resources are scarce (Clark 1975, Clark 1983, Yesner 1980, Waselkov 1987).

[1] The term is capitalised here only when used as a proper noun; i.e., Mesolithic period, but not when used as an adjective.

Settlement and Seasonality

A growing archaeological interest has developed in the study of seasonality, in terms of both resource exploitation and site occupation (Ham and Irvine 1975, Shackleton 1988). Bailey and Parkington (1988:9) point out that determinations of seasonality can provide evidence of resource scheduling: the ways in which hunter-gatherers combine the exploitation of various resources available at different times and places (see also Ames 1985). Deith (1983a:423) further argues that the season of occupation of a hunter-gatherer site is determined by the function of the site within the wider context of a settlement system; therefore determinations of seasonality may lead to a better understanding of the site itself, and also of the system of which it was part.

Seasonality determinations have been made on molluscs recovered from archaeological deposits by a number of researchers. In most cases, determinations have been based on either oxygen isotope analysis of shell carbonate (cf. Shackleton 1969, 1970, 1973; Killingley 1981; Deith 1983b, 1986; Deith and Shackleton 1986, 1988), or on the analysis of shell growth increments (cf. Coutts 1970, 1975; Coutts and Higham 1971; Koike 1975, 1979; Deith 1983a; Cerrato 1987; Lightfoot and Cerrato 1988). Seasonal determinations have also been based on the linear measurement of recent shell growth as a percentage of previous years' growth (cf. Ham 1976, Custer 1987).

This study will address questions of settlement and seasonality during the Mesolithic in southern Portugal. At present, the mesolithic settlement of this area is poorly understood; and evidence for the season of site occupation and resource exploitation is generally quite limited. A seasonality study based on oxygen isotope analyses on molluscs from midden deposits in the Sado Valley of southern Portugal has recently been undertaken by M. R. Deith (n.d.); however, shell growth increment analysis has so far proven unsuccessful in this area due to the difficulty in identifying a datable point on the annual growth sequence to which subsequent growth increments can be related (cf. Rhoads and Pannella 1970:153; Deith n.d., A. Lentacker *in litt.* 18.1.89).

In the present study a settlement model will be proposed using current theoretical perspectives, and based on the available archaeological and ecological data. Seasonality determinations will be attempted by means of the analysis of tidal growth increments observed on specimens of the intertidal bivalve *Cerastoderma edule* Linnaeus, recovered during preliminary investigations at the Pandeiro shell midden (Zilhão and Lubell 1986a), in an effort to resolve problems experienced by other researchers. The results of the analysis will be applied to the limited testing of hypotheses of seasonal or more permanent occupation of the site.

CHAPTER TWO

THE PORTUGUESE MESOLITHIC

Traditionally, three aspects of the Portuguese Mesolithic are recognised, viz., the Azilian of the Lisbon Peninsula (Estremadura); the Languedocian of the lower Tagus valley and the coast of Lower Alentejo and Algarve; and the Mugian of the Tagus and Sado estuaries (Figure 1)(Arnaud 1986, Ferreira and Leitão 1985). The Portuguese Azilian is characterized by small scrapers of various types made on blades. The Languedocian, characterized by large pebble tools and flakes on quartz and greywacke, is known from surface scatters of knapping debris; and is also associated with coastal shell middens that contain Early Neolithic pottery in their upper levels (Ferreira and Leitão 1985:109, nos. 2-8, 116). (A similar industry, termed the Portuguese Asturian, is described by Maury [1977] in northern Portugal and Galicia [Spain].) A regional variant, the Mirian, is found along the Lower Alentejo littoral; and is associated with a large flaked pebble tool termed the Mirian axe (Arnaud 1986).

The Portuguese Mesolithic is best known, however, as the result of excavations carried out since 1865 on the Muge shell middens of the upper Tagus estuary (Figure 1), particularly those excavations undertaken by J. Roche during the 1960s (Roche 1965, 1972, 1977, 1989; Arnaud 1985; Ferreira and Leitão 1985). The lithic assemblage consists of a microlithic component on flint, particularly triangles and trapezes (Ferreira and Leitão 1985:110, nos. 1-21, 112); and a macrolithic component on quartzite. Bone and antler tools are also present. Roche's excavations revealed evidence of living structures, hearths, storage pits, and human burials (Roche 1972, 1977, 1989).

More recently, two major research projects have been initiated in southern Portugal. The re-excavation of a number of shell middens on the upper Sado estuary is currently being undertaken by J. Arnaud (Arnaud 1985, 1986, 1989); and the excavation of several inland and coastal sites in Lower Alentejo has been undertaken by Arnaud, D. Lubell, C.T. de Silva, and others (Lubell 1984; Lubell and Jackes 1987, 1988; Lubell *et al.* 1989; Silva *et al.* 1985),

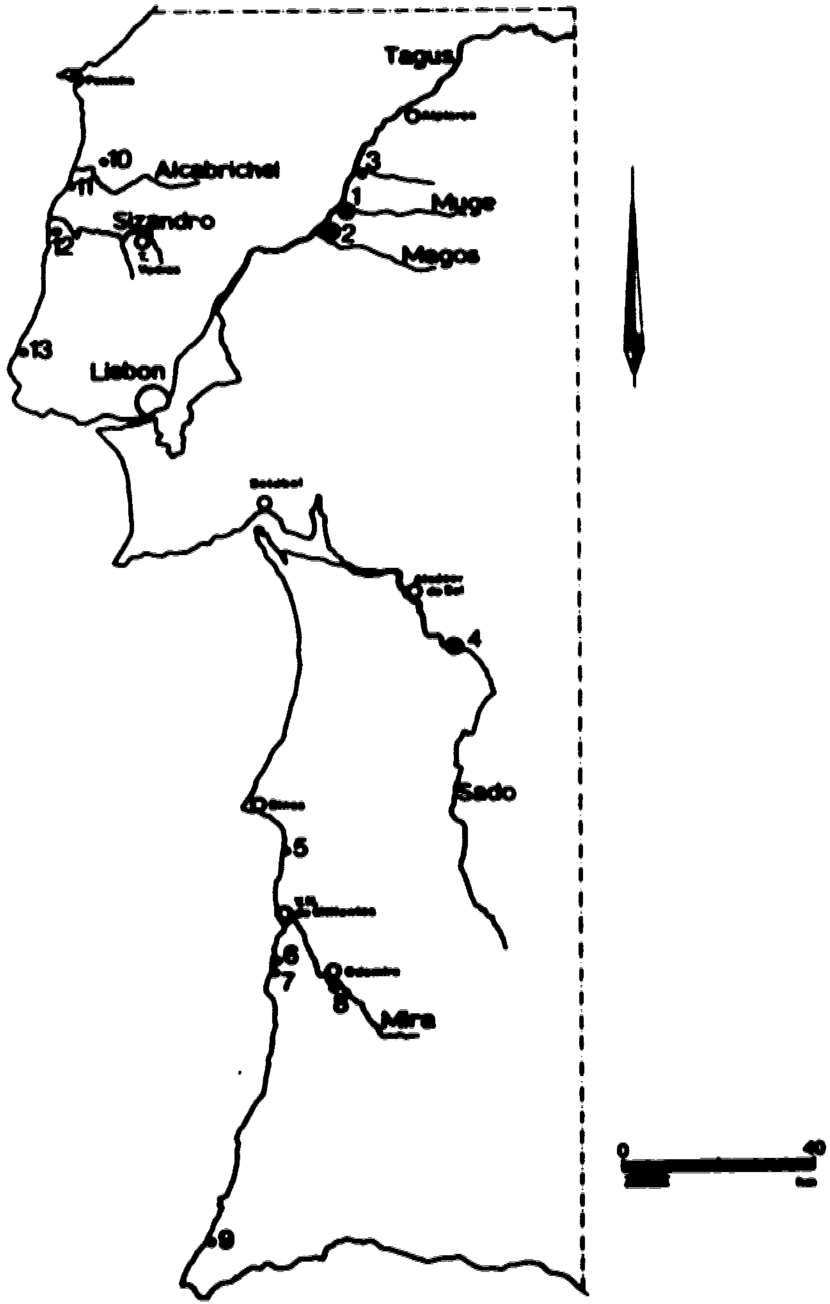

Figure 1. Mesolithic sites in southern Portugal (see Table 1 for key).

Table 1. Site index and radiocarbon dates.

Map Ref.	Site	Date bp	Lab. No.	Source
1	Moita do Sebastião	7240 ± 70	TO-131	1
		7200 ± 70	TO-133	1
		7180 ± 70	TO-132	1
		7160 ± 80	TO-134	1
		6810 ± 70	TO-135	1
1	Cabeço da Amoreira	7030 ± 350	Sa-195	2
		6050 ± 300	Sa-194	2
1	Cabeço da Arruda	6990 ± 110	TO-360	1
		6970 ± 60	TO-354	1
		6960 ± 70	TO-359	1
		6780 ± 80	TO-355	1
		6430 ± 300	Sa-197	2
		6360 ± 80	TO-356	1
		5150 ± 300	Sa-196	2
1	Flor da Beira			
1	Fonte do Padre Pedro			
2	Cova da Onça			
2	Cabeço dos Ossos			
2	Arneiro do Roquete			
3	Fonte do Moça			
4	Arapouca	7420 ± 65	Q-2492	3
4	Poças de S. Bento	7040 ± 70	Q-2493	3
		6850 ± 70	Q-2495	3
		6780 ± 65	Q-2494	3
4	Cabeço do Pez	6730 ± 75	Q-2497	3
		6430 ± 65	Q-2496	3
		5535 ± 130	Q-2499	3
4	Amoreiras			
4	Vale de Romeiras			
4	Cabeço do Rebolador			
5	Samouqueira	6370 ± 70	TO-130	1
		5080 ± 130	Beta-11722	1
5	Vidigal	6640 ± 90	Ly-4695	4
		6030 ± 80	Gx-14557	4
6	Medo Tojeiro	6570 ± 120	BM-2275	1
		5420 ± 160	Beta-11723	1
7	Palheirões do Alegre			
8	Fiais	7010 ± 70	TO-806	5
		6840 ± 70	TO-705	5
		6980 ± 80	TO-706	5
9	Castelejo	8040 ± 100	BM-2276	1
		7450 ± 90	Beta-2908	1
10	Pandeiro	7880 ± 110	TO-707	5
11	Ponta da Vigia	8730 ± 110	ICEN-51	6
12	Pinhal da Fonte			
13	Magoito	9580 ± 100	GrN-11229	7

Sources: 1. Lubell and Jackes 1988; 2. Roche 1972; 3. Arnaud 1989; 4. Straus and Vierra 1989; 5. Lubell pers. comm.; 6. Zilhão *et al.* 1987; 7. Arnaud 1986.

and in Estremadura by Lubell and J. Zilhão (Zilhão and Lubell 1986a, 1986b; Zilhão *et al.* 1987).

<u>Chronology</u>

The Lower Tagus and Sado Valleys

The Muge *concheiros* of Moita do Sebastião, Cabeço da Amoreira, and Cabeço da Arruda, located on the River Muge near its confluence with the Tagus, were occupied during the Atlantic phase and are dated between the late seventh and the early fifth millennia bc. Moita do Sebastião (7240 ± 70 bp to 6810 ± 70 bp[1]) is located 22 m above present sea level (asl) on an exposed spur of the 10 m to 20 m terrace on the south side of the Muge, 15 m above the flood plain (Roche 1972, Figure 18 and 19). Cabeço da Amoreira (7030 ± 350 bp, 6050 ± 300 bp) is also located 22 m asl on the 10 m to 20 m terrace about 1 km east of Moita do Sebastião (Roche 1972, Figure 18, 20). Cabeço da Arruda (6990 ± 110 bp to 5150 ± 300 bp) is located 8 m asl on a sandy promontory on the north side of the Muge, 3 m above the river (Roche 1972, Figures 18 and 20)(Figure 1, Table 1).

Roche reports that in 1952 the Moita do Sebastião shell midden was elliptical in shape, 60 m long, 50 m wide, and approximately 2.5 m thick. Two lithic industries are represented at this site, a microlithic industry based on flint, and a macrolithic industry on quartzite river cobbles. The flint component includes denticulates, geometric microliths (predominantly trapezes, but including triangles), utilized blades, retouched flakes and bladelets, microburins (a by-product of the manufacture of geometric microliths):, cores, and a small number of backed blades, scrapers, and burins. Quartzite tools include hammerstones, denticulates, and choppers. A large number of bone and antler tools were recovered, including polished splinters of bovid ribs, and antler axes and handles; and also a small number of ornamental items, including perforated pebbles, slate plaques, and pierced shells

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1 All dates are uncalibrated, conventionally indicated by lower case (cf. Renfrew 1973).

(*Neritina fluviatilis, Cypraea europaea, Nassa reticulata* and *Cerastoderma edule*)(Roche 1972).

Roche excavated Moita do Sebastião by surface stripping, and he recognises two sequences of occupation at this site. The earlier, dated between 7350 ± 350 bp and 7080 ± 130 bp, consists of a 7 m to 8 m diameter semi-circular structure with 61 postholes, identified by Roche as a hut. Associated features include a large number of deep and shallow pits, including hearths, cooking pits, rubbish pits, and storage pits containing clams (*Scrobicularia plana*); and also thirty four graves, twenty six containing the remains of about fifty nine adults, and eight containing children. The later occupation, superimposed on the former, consists of a rectangular 11.9 m x 3.2 m pit paved with a floor of pebbles and partly surrounded by a low pebble wall (Roche 1972, 1989).

Excavations at Cabeço da Amoreira reveal similar lithic and bone industries; however, elongated triangles (apparently evolved from the trapeze) dominate the microlithic component, and segments (crescents) are also present (Roche 1972). This site, which was 90 m x 50 m and less than 2.5 m thick, was excavated by means of trenches which revealed a complex stratigraphy with evidence of three main periods of occupation (Roche 1972, Figure 21; 1989). At Cabeço da Arruda very few stone tools were recovered; however, a wide range of bone tools made from bovid, cervid, and avian remains was present. Trench excavations of the almost 5 m thick deposits revealed a complex stratigraphy with five main periods of occupation (Roche 1972, Figure 22; 1989). Roche observes evidence of levelling at Cabeço da Amoreira and Cabeço da Arruda, and suggests that the stratigraphy is indicative of repeated temporary occupations (Roche 1989).

Several other shell middens have been identified in the immediate area at Fonte do Padre Pedro and Flor da Beira; also a few kilometres to the south near the confluence of the Tagus and the River Magos at Cova da Onça, Cabeço dos Ossos, and Arneiro do Roquete; and 6 km to the north near Almeirim at Fonte do Moça (Figure 1). All, however, have been badly damaged by agricultural activities (Roche 1972; Arnaud 1985, 1986).

A group of eleven shell middens is located south of Alcaçer do Sal on the River Sado and its tributaries, and six of these middens have been excavated by Arnaud (Figure 1) (Arnaud 1985, 1989, Figure 2). Most of these *concheiros*, which are less than 1.5 m thick, are sited near the present 50 m contour overlooking the floodplain. Arapouca (7420 ± 65 bp), Cabeço do Rebolador, and Amoreiras are located between 40 km and 50 km inland on the south side of the river; and each occupies an area of about 1000 m^2. Cabeço do Pez (6730 ± 75 bp to 5535 ± 130 bp), a large shell midden of at least 4000 m^2, and the small Vale de Romeiros midden (60 m^2) are located several kilometres farther east on the north side of the river. Poças de S. Bento (7040 ± 70 bp to 6780 ± 75 bp), a large midden of 3570 m^2, lies 3 km south of the Sado on a small tributary at an elevation of 80 m asl (Figure 1, Table 1).

The lithic industry is represented by geometric microliths (trapezes predominate at Arapouca and Vale de Romeiras, and segments at Amoreiras and Poças de S. Bento; triangles are also present), and a few retouched bladelets and scrapers. Finished tools are scarce, however; and a large percentage of the lithic material recovered consists of waste, including microburins. The most common raw material is a poor quality flint, but quartz and quartzite were also utilised. Bone and antler tools were recovered at Cabeço do Pez in the form of a few bone spatulae and several worked antler tips. No evidence of a macrolithic industry has been recovered, however (Arnaud 1985, 1986, 1989).

Human burials are present at most of the Sado middens. Many are associated with beads of pierced fish vertebrae and shellfish (*Neritina fluvialis*, *Trivia* spp., and *Hinia reticulata*), and, in several cases, with geometric microliths (Arnaud 1985, 1989).

Lower Alentejo

Excavations were undertaken in 1984 on the coast of Lower Alentejo at Samouqueira and Medo Tojeiro by Lubell and Silva. In 1988, L.G. Straus excavated at Vidigal.

Samouqueira (6370 ± 70 bp, 5080 ± 130 bp), which has been disturbed by ploughing and slopewash, covers an area of at least 120 m x 140 m; and overlooks the Atlantic Ocean from a 10 m cliff (Lubell *et al.* 1989). Vidigal (6640 ± 90 bp, 6030 ± 180 bp) lies 6 km to the south. Located 2 km east of the present shoreline, the site covers an area of 5000 m^2 , and overlooks a small stream from an elevation of 45 m asl. The midden itself is about 10 cm to 15 cm thick, and occupies only the central area of the site. On the southwest edge, at the same level as the base of the midden, is a pavement area of sandstone, schist, and beach cobbles (Straus and Vierra 1989)(Figure 1, Table 1).

The lithic assemblages of both sites include a microlithic component on chert, flint, or other similar fine-grained rock; and a macrolithic component mainly on greywacke. Crystal quartz and fine-grained quartzite were also utilised, chert/flint and crystal quartz having been obtained from a non-local source (Sheppard 1985). Retouched artifacts form only a small percentage of the total assemblage; a small number of geometric microliths, including trapezes, triangles, and segments, and a large number of bladelets, probably intended as blanks for the manufacture of microlithic tools, were recovered. Other tools include retouched and backed bladelets, scrapers (Vidigal), and a burin (Samouqueira). A large number of greywacke flakes, several cores, and, at Samouqueira, a few pebble choppers were also present (Lubell *et al.* 1989, Table 5). In addition, a schist button or bead, four ceramic sherds, and three pieces of haematite were recovered at Vidigal (Straus and Vierra 1989, Tables 1 and 2). Straus and Vierra (1989:8) observe that the lithic assemblage at Vidigal is typical of the Mesolithic of south-central Portugal, and recognise similarities with the Sado collection.

A small remnant midden at Modo Tejeiro (6 m x 12 m, and 75 cm thick), underlain and overlain by dune sand, is located on top of a 30 m cliff overlooking the sea. It is dated to 6570 ± 120 bp and 5420 ± 100 bp. Several hearths and a surface scatter of lithic material are located 200 m inland on the deflated surface of a dune blowout (Modo Tejeiro II). Three kilometres to the south, at Palheirões do Alegre, a similar lithic scatter covering 1 ha was found on a raised beach 30 m asl (Figure 1, Table 1)(Lubell *et al.* 1989, Lubell and Jackes 1987, Zbyszewski and Penalva 1979).

The Medo Tojeiro midden produced only a small amount of lithic material; nevertheless, a macrolithic component on greywacke, represented by a chopper and a number of flakes, and a microlithic component on flint, represented by a small number of geometric microliths and bladelet fragments, were identified. Several ceramic sherds and a polished axe were also recovered. At Mejo Tojeiro II, a number of microliths and a greywacke flake were associated with several hearths (Lubell *et al.* 1989, Silva *et al.* 1985). Macrolithic artifacts found nearby, consisting mainly of chopper-like tools on greywacke or coarse-grained quartzite, are assigned by Zbyszewski and Penalva (1979) to the Languedocian, or Mirian. They cannot be associated chronologically with the hearths, however (Lubell *et al.* 1989). A similar surface scatter at Palheirões do Alegre consisted of an extensive layer of knapping debris, large stone anvils, a few Mirian axes, and tools in various stages of manufacture, including both macrolithic and microlithic components (Arnaud 1985, 1986; Museu Nacional de Arqueologia e Etnologia 1989).

One of the most southerly sites associated with the Languedocian is the shell midden of Castelejo, located on the right bank of a small stream on the west coast of Algarve near Vila do Bispo (Figure 1)(Devereux 1983). Artifacts are scarce, but include at least one greywacke chopper. The site is dated to 8040 ± 100 bp and 7450 ± 90 bp (Table 1)(Lubell and Jackes 1988).

In 1986 excavations were undertaken by Lubell and Arnaud at Fiais, a large shell midden of at least 1000 m^2, located 10 km inland near Odemira (Figure 1). The site, at an elevation of 100 m asl on the southern edge of the Serra do Cercal uplands, overlooks a small stream 2 km from the River Mira. The top of the midden lies 20 cm to 30 cm below ground surface (bs), extending to a maximum of ca. 75 cm bs. Preliminary excavations were commenced in two areas of the site. In the first area a hearth, located 30 cm to 50 cm bs, was dated to 7010 ± 70 bp. In the second area of the site, excavations were terminated for the season at 35 cm to 50 cm bs without reaching the bottom of the midden. Two dates were obtained from the second area, viz., 6840 ± 70 bp (45 cm to 50 cm bs) and 6260 ± 80 bp (30 cm to 35 cm bs)(Lubell and Jackes 1988).

Lithic material recovered at Fiais consists mainly of debitage, including microburins, exhausted cores, and a large number of bladelets. The majority of retouched tools are geometric microliths; triangles and trapezes occur in almost equal frequencies, and segments in lower frequency. A small number of retouched bladelets, including several endscrapers, was also recovered. The most common raw material is chert, utilized for all retouched tools, and comprising 75% of all debitage. Also utilized in low frequency were crystal quartz (bladelets) and coarse-grained quartz; and in very low frequency, quartzite and greywacke (flakes and shatter, including several utilized pieces)(Sheppard 1986).

Sheppard (1986) concludes that all core working carried out at Fiais was directed towards the production of bladelets. There is no evidence of a macrolithic component at this site.

Estremadura

Several earlier mesolithic sites, dated to the Boreal phase, are known in Estremadura to the northwest of Lisbon. In 1986 preliminary investigations were undertaken by Zilhão at the coastal site of Ponta da Vigia (Zilhão *et al.* 1987), and by Lubell at the inland shell middens of Pandeiro (Zilhão and Lubell 1986a) and Pinhal da Fonte (Zilhão and Lubell 1986b)(Figure 1).

Pinhal da Fonte is located 2 km inland at an elevation of 20 m asl on an ephemeral tributary of the River Sizandro. Discontinuous areas of midden were found at a depth of 80 cm below the ground surface, and a partially *in situ* hearth was exposed. The site was found to be badly disturbed, however, as the result of the uprooting of a plantation of pine trees (Zilhão and Lubell 1986b). Pandeiro (7800 ± 110 bp) is located 6 km inland on a small tributary of the River Alcabrichel. The small, non-diagnostic lithic assemblage recovered at this site awaits further analysis (Lubell pers. comm. 1989, Zilhão and Lubell 1986a).

Ponta da Vigia (8730 ± 110 bp) consists of several hearths and a small lithic scatter on the deflated surface of a dune blowout located on a 30 m cliff overlooking the palaeoestuary of the Alcabrichel. The lithic assemblage, which includes geometric microliths (several segments, trapezes, and a triangle), non-geometric points, and a few small scrapers and burins made on blades, is described by Zilhão *et al.* (1987) as typically Epipalaeolithic; and is placed chronologically between the late Upper Palaeolithic and the later Mesolithic of the Muge (Zilhão *et al.* 1987).

Magoito (9580 ± 100 bp), located on the Atlantic coast west of Lisbon, is the earliest known mesolithic site in Portugal (Figure 1, Table 1). Unfortunately, the shell midden contains only a very small amount of lithic material (Arnaud 1985, 1986; Zilhão *et al.* 1987). However, eight kilometres to the north lies the site of S. Julião, suggested by Arnaud (1986) to be contemporary with Magoito. S. Julião consists of a small, compact shell midden (ca. 100 m^2, and 1 m thick) and an adjoining shallow occupation layer. Lithic material collected at the site includes a finely retouched backed bladelet, and a few flint cores and bladelets, described by Arnaud as "indisputably mesolithic" (Arnaud 1986:3, Zilhão *et al.* 1987).

<u>Economy</u>

The Lower Tagus and Sado Valleys

At Moita do Sebastião, Cabeço da Amoreira, and Cabeço da Arruda, Roche reports the presence of mammals, molluscs, crustaceans, fish, and birds, many of which are extant in the area today. The presence of certain molluscs and crustaceans, moreover, gives some indication of environmental change (Roche 1972, 1977).

Extant mammals include wild pig (*Sus scrofa*), red fox (*Vulpes vulgaris*), badger (*Meles taxus*), otter (*Lutra vulgaris*), hedgehog (*Erinaceus europaeus*), and hare (*Lepus timidus*). Other mammals, which are not present in the area today as a result of human activities, include red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), the pardel lynx (*Felis pardina*), and the extinct aurochs (*Bos primigenius*) (Roche 1965, 1972, 1977). The small mammals may be found in a range of habitats; but the more specific habitat preferences of the larger mammals; i.e., red deer, wild pig, and aurochs, indicate a landscape of open and closed mixed woodland during the early Holocene (Lentacker 1986a).

The analyses of 19th and 20th century faunal collections from Cabeço de Amoreira and Cabeço da Arruda by Lentacker (1986a, 1986b) appears to confirm the economic importance of red deer and wild pig during the Mesolithic (cf. Davidson 1976, Guillaine *et al.* 1982, Straus and Clark 1986, Rowley-Conwy n.d.a; cf. Clarke 1979:451 for an alternative view), and also aurochs; and, to a lesser extent, roe deer. Mammalian collections from recent excavations include a large number of lagomorph remains, particularly rabbit (*Oryctolagus cunniculus*), suggestive of a relatively open landscape. Their economic importance in terms of food value, however, would be less than that of the larger mammals (Lentacker 1986a, Table 8; see also Davidson 1976). The optimal months for hunting red deer and wild pig are January to March, and November to March respectively; although all the identified mammals would have lived in the area year-round (Lentacker 1986a, Arnaud 1989).

The molluscan assemblages of the Muge *concheiros* are dominated by the common European cockle and the lagoon cockle (*Cerastoderma edule*, *C. glaucum*), followed by the peppery furrow clam (*Scrobicularia plana*)(Roche 1972, 1977). These species are infaunal; i.e., they burrow into the substrate of estuaries and sheltered beaches. *Cerastoderma* spp. favours sand or muddy sand, and *S. plana* favours soft estuarine mud. Both are euryhaline species (tolerant of low salinity); and are found in highest concentrations in the middle and upper reaches of estuaries, brackish marshes, and lagoons (McLusky 1971, Perkins 1974). Marine gastropods (*Neritina fluviatilis*, *Cypraea* spp.), razor clams (*Solen* or *Ensis* spp.), oyster (*Ostrea* spp.), scallops (*Pecten maximus*), and decussate venus (*Venerupis decussata*) are also present (Lentacker 1986a, Roche 1972). Roche observes that the presence of these molluscs is indicative of higher levels of salinity during the early Holocene in the River Muge than today. The presence in midden deposits of a crab, *Carcinus maenas*, now found only on the coast, supports this view. Also present is the crab *Gelasimus tangeri*, today found farther south in the warmer waters of Algarve and North Africa (Roche 1972, 1977). A similar assemblage of molluscs at Fonte de Moça on the Tagus 6 km to the north indicates that during the early Holocene tides penetrated farther inland than at present (Arnaud 1985).

Lentacker identifies at least seven species of marine fish at Cabeço da Amoreira and Cabeço da Arruda, the most common being eagle ray (*Myliobatis aquila*) and meagre (*Argyrosomus regius*), followed by sea bream (Sparidae), including gilthead (*Sparus aurata*) (Lentacker 1986a, Tables 2 and 5). Sparidae are usually found in shallow coastal waters, migrating to deeper waters during the winter. They are tolerant of brackish conditions, however; and enter estuaries to spawn between June and September (Lentacker 1986a, Arnaud 1989). Arnaud observes that meagre is today fished off-shore, but notes that at the turn of the century it is reported to have entered the Tagus and Sado estuaries between April and August to spawn (Arnaud 1989). Lentacker concludes, then, that fishing is likely to have been more productive during the spring and summer than at any other time of year (Lentacker 1986a).

A wide range of avian fauna is present, although in small numbers, particularly at Cabeço da Arruda (Lentacker 1986a, Tables 3 and 6). The majority of birds identified are waterfowl and marshland species, including curlew (*Numenius arquata*) and various Anseriformes, particularly mallard (*Anas platyrhynchos*) and Greylag goose (*Anser anser*); and most are present only during their winter migration. Permanent residents are also represented, particularly carrion crow (*Corvus corone*), and also woodcock (*Scolopax rusticola*), and woodpigeon (*Columba palumbus*), which favour wooded habitats (Lentacker 1986a).

The importance of plant foods during the Portuguese Mesolithic is unknown due to the scarcity of pollen and plant macrofossils in archaeological deposits. The analysis of charcoal from Cabeço da Amoreira and Cabeço da Arruda does, however, indicate the presence of stone pine (*Pinus pinea*), the kernels of which are of extremely high food value (Clarke 1976:458). Two other species of pine are also present, viz., Aleppo pine (*P.*

Halepensis) and maritime pine (*P. maritima* [=*pinaster*])(Roche 1972); all three species are common in southern Portugal today (Beckinsale and Beckinsale 1975).

Faunal evidence of economic activities during the Mesolithic at the Muge *concheiros* confirms the exploitation of a broad spectrum of food resources from a fairly wide range of environmental zones or micro-habitats within close proximity to the middens themselves. Furthermore, the evidence is suggestive of the seasonal scheduling of subsistence activities (Lentacker 1986a).

A similar assemblage of faunal remains is reported for the Sado middens (although birds are very scarce), and Arnaud proposes that here there is some evidence of seasonality. Estuarine molluscs, mammals, fish, and crustaceans are present at all the re-excavated sites; however, middens with abundant mammal remains contain little evidence of fish and crustaceans, and vice versa (Arnaud 1986, 1989).

The molluscan assemblages of all the Sado middens are dominated by *Cerastoderma edule* and *Scrobicularia plana* in a ratio of 2:1 (Arnaud 1986, 1989). The presence of these estuarine bivalves confirms the regular penetration of the tide more than 50 km inland during the early Holocene; today the tide does not generally penetrate beyond Alcaçer do Sal, a distance of 30 km from the sea (Admiralty 1942). Oyster (*Crassostrea angulata*) is present at several middens, particularly Cabeço do Rebolador, where it is relatively abundant; but razor clam (*Ensis* spp.) was recovered only at Arapouca. Also present is the marine gastropod *Cypraea pyrum*, now found only farther south in the warmer waters of Algarve (Arnaud 1989).

Mammal remains are well represented at the more inland sites of Cabeço do Pez (where a quantitative assessment was undertaken), Amoreiras, and Romeiras. Large mammals are dominated by red deer and, secondarily, wild pig. Aurochs, too, is of some economic relevance, but roe deer is scarce. Moreover, the presence is confirmed of wild horse (*Equus ferus*) and domesticated dog (*Canis familiaris*). The assemblage of small mammals is similar to that recovered at the Muge sites, and rabbit and hare are also plentiful. The presence of horse and the rarity of roe deer, moreover, may be indicative of a more open environment (Arnaud 1989, Rowley-Conwy n.d.a).

Fish and crustaceans are plentiful at Arapouca, the site closest to the sea; and are present in smaller quantities at Reboleder and Poças de S. Bento. Meagre, gilthead bream and other Sparidae, mullet (Mugilidae), ray (Rajidae), and shark (Lamnicae) are reported at these sites. The presence of cranial bones only in the case of meagre at Arapouca may indicate that these fish were processed at this site and consumed elsewhere (Rowley-Conwy and Zvelebil 1989:53). The small crab *Carcinus maenus*, also abundant at Arapouca, may have been used as bait (Arnaud 1989).

Lower Alentejo

Rowley-Conwy (n.d.b) reports that at Fiais the range of mammals present is broadly similar to the assemblages of Cabeço do Pez and the Muge middens. Among the larger mammals, red deer is the most common, followed by wild pig, roe deer, and aurochs; small mammal remains are dominated by rabbit. Roe deer, however, is more common than at Cabeço do Pez; and horse is absent, a fact which, Rowley-Conwy (n.d.b:2) suggests, may indicate a more wooded environment. The presence of main meat-bearing bones of large mammals, the rarity of mandibles, and the absence of crania leads Rowley-Conwy to conclude that this site functioned as a base camp (Rowley-Conwy n.d.b; cf. Binford 1978, Legge and Rowley-Conwy 1988).

The analysis of molluscs and crustaceans collected at Fiais reveals significant differences when compared with the Muge and Sado assemblages. The most common species present are *Scrobicularia plana* (47.5% by weight[1]) and oyster cf. *Crassostrea angulata* (20.2%); the third most common species, *Cerastoderma* spp., comprises only 3.0% of the total assemblage. Other species present in lesser frequencies include acorn and stalked barnacles

[1] Frequency determinations of molluscs and crustaceans are based on the analysis of 1 litre bulk samples (>2 mm fraction) collected from each 5 cm spit of each 1 m^2 excavation unit.

(*Balanus* spp., *Lepas* spp.), limpet (*Patella* spp.), mussel (*Mytilus* spp.), whelk (cf. *Thais* spp.), decussate venus, and sea urchin (Echinoidea). A small number of fish teeth was also recovered. However, the material is very fragmentary; therefore identification to the level of species is difficult, and the fragile thin-shelled *S. plana* is probably underrepresented.

Today, tides penetrate the Mira to Odemira (Admiralty 1942, personal observation 1986); thus *S. plana* and *C. angulata* were probably available locally since both are euryhaline; i.e., tolerant of lower levels of salinity typical of the upper reaches of estuaries. Additionally, both species are found on muddy substrates; and are adapted to deal with turbid conditions and fine sediment in suspension (McLusky 1971, Orton 1936, Purchon 1977, Yonge 1960). Such muddy conditions would explain the low frequency of *Cerastoderma* spp., which favours sand or muddy sand (Farrow 1971, Figueras Montfort 1966). Barnacles, limpets, and mussels, however, could not have been obtained locally since they are typical of rocky shores, river mouths, or the lower reaches of estuaries where hard substrates are available (Barnes 1980, McLusky 1971). A suitable habitat is present today at the mouth of the Mira, a fact which would indicate that the exploitation territory of the mesolithic inhabitants of Fiais ranged from the uplands of the Serra do Cercal to the Lower Alentejo coast.

At the coastal middens of Medo Tojeiro and Samouqueira the shellfish assemblages are comprised of marine species, the most common being mussel, limpet, and whelk (*Thais haemastoma*). All are typical of this rocky littoral today (Lentacker n.d., Lubell *et al.* 1989, personal observation 1984). Other species represented are periwinkle (*Monodonta turbinata*), small marine gastropods (particulary *Gibbula* spp.), acorn and stalked barnacles, cockle, crab, and sea urchin. Lentacker observes that *Gibbula* lives on seaweed (*Laminaria*, *Zostera*), and suggests that its presence may indicate that seaweed was carried in to the site (Lentacker n.d.; cf. Bell 1981).

At Medo Tojeiro the faunal assemblage is made up entirely of molluscs and crustaceans, a fact which may be indicative of a single purpose site, used seasonally for short periods (Lentacker n.d., Lubell *et al.* 1987). At Samouqueira the faunal assemblage includes molluscs and crustaceans, fish (possibly gilthead bream), and terrestrial mammals. Rabbit bones are very abundant, while red deer and wild pig are the most important large mammals present. Aurochs, felid, wolf, red fox, and hare are also represented (Lentacker n.d.).

Lentacker (n.d.) notes that the faunal assemblage of Samouqueira is similar to those of the Muge middens. However, stable isotope analysis on human bone indicates a greater reliance on marine resources at this coastal site than further inland on the Muge (Lubell and Jackes 1988).

The analysis of charcoal from Samouqueira and Medo Tojeiro reveals the presence of stone pine, juniper (*Juniperus* spp.) and pistachio (*Pistacia* spp.). Their economic importance is not understood at present, however (Lubell and Jackes 1988).

A preliminary analysis of faunal material from the Vidigal shell midden suggests that a similar collection of marine molluscs and crustaceans is represented, and the assemblage is clearly do minated by limpets. Fish vertebrae and fragmentary mammal bones are also present. Mar nal remains associated with the pavement area are tentatively identified to aurochs and red deer. Much of the skeleton is represented, and the excavators suggest that the animals may have been killed nearby (Straus and Vierra 1989).

Estremadura

The coastal shell middens of Magoito and S. Julião reveal a wide range of littoral and estuarine molluscs, including mussel, limpet, periwinkle (*Littorina littorea*), cockle (*Cerastoderma edule*), oyster (*Ostrea edulis*), and decussate venus. However, estuarine species only were recovered on the thinner occupation area at S. Julião, dominated by *C. edule* (Arnaud 1986).

At Pinhal da Fonte the molluscan assemblage is also dominated by *C. edule*; additionally decussate venus, peppery furrow clam, and razor clam are present in low frequencies; and whelk, mussel, and limpet in extremely low frequencies (Zilhão and Lubell

1986a). Surface collections at Pandeiro indicate the presence of red deer, wild pig, and aurochs; fish, including gilthead bream and Rajidae; and molluscs, including cockle, decussate venus, and razor clam (Arnaud 1986).

Discussion

The later, or developed Mesolithic ("Mesolítico pleno" [Museu Nacional de Arqueologia e Etnologia 1989:27]) assemblages of the Tagus, Sado, and Mira estuaries and the Lower Alentejo coast that are dated between ca. 7500 bp and 5500 bp display a marked uniformity, in terms of both resource exploitation and technology. A broad range of resources is represented, including large and small mammals, fish, crustaceans, birds, and molluscs. Generally, red deer and wild pig appear to have been major food sources; and it is likely that plant foods also contributed to the diet (Clarke 1976, Museu Nacional de Arqueologia e Etnologia 1989).

The macrolithic Languedocian or Mirian industry, represented by pebble chopping tools, picks, discs, and Mirian axes, is present throughout the Mesolithic, occurring in association with microlithic assemblages in many *in situ* deposits. The widespread appearance of these large pebble tools on coastal sites may support a functional interpretation that they were used to remove molluscs from rocks (Arnaud 1986); it has also been proposed that they were used to dig up roots (Museu Nacional de Arqueologia e Etnologia 1989:25). A similar macrolithic industry, the Asturian, composed of quartzite pebble choppers and picks, and flake sidescrapers, notches, and denticulates, is found on the Boreal phase shell middens of the northern Spanish coast in association with a microlithic flint industry represented by bladelets and retouched bladelets (Clark 1983:106). In fact, macrolithic and microlithic industries occur together on many western European Mesolithic coastal sites, including southern Britain where flaked pebble tools have also been identified as axes, digging implements, and "limpet scoops" (Palmer 1977:20). An alternative interpretation of these heavy-duty assemblages is that they are expedient general purpose tools, quickly made when needed where appropriate raw materials (beach or river cobbles) were immediately available, and discarded after use. The absence of such tools at Fiais and in the Sado Valley may be explained by the lack of suitable raw material; and in fact a muddy, rather than a coarse-grained substrate has been suggested for the River Mira (see above).

Limited evidence available from sites near the present coastline of Estremadura dating to the earlier Mesolithic, or Epipalaeolithic ("Mesolítico de fácies arcaica ou Epipaleolítico" [Museu Nacional de Arqueologia e Etnologia 1989:26]), between ca. 9500 bp and 7800 bp suggests that economic strategies involving the exploitation of a wide range of coastal, estuarine, and terrestrial resources were already in place by the final Upper Palaeolithic (Zilhão *et al.* 1987; cf. Straus *et al.* 1981, Dennell 1983, Price 1987). The presence of small scrapers and burins on blades more typical of the later Magdalenian, recovered in an early Mesolithic context at Ponta da Vigia, demonstrates also a continuity in lithic technology (Museu Nacional de Arqueologia e Etnologia 1989:22; see also Clark 1936:xiv), correlating with Ferreira and Leitão's (1985) Portuguese Azilian tradition.

However, many coastal sites in this area were likely inundated between ca. 10,000 bp and 7500 bp during the Flandrian transgression when sea levels rose by 100 m to the present level (cf. Shackleton 1985). A coastal strip up to 60 km wide was lost (Arnaud 1986), and therefore the few known sites dated to this period may represent only the inland component of a more extensive economic system (cf. Clarke 1976:466). The Pandeiro shell midden, dated to 7800 ± 110 bp, is an exception to this generalization. The site was occupied at a time when the Flandrian transgression was approaching its maximum, and sea level was more or less the same as at present; furthermore, the occupation of this site overlapped the later Mesolithic occupations of the lower Tagus valley. Research at Pandeiro, then, may offer a better understanding of the earlier Mesolithic of Estremadura, and its relationship to the later Mesolithic represented by the Muge concheiros.

The excavation of mesolithic sites in southern Portugal has yielded considerable evidence in terms of technology and the resource base; yet other major aspects of mesolithic economy, including resource scheduling strategies and settlement systems, are not well understood. This problem will be addressed in subsequent chapters. A number of models of hunter-gatherer economic strategies and settlement systems have been advanced by researchers based on archaeological, ethnographic, ecological, and ethnoarchaeological data. Several of these models will be considered in the following chapter, and a settlement model for the Portuguese Mesolithic will be proposed. The question of seasonality of site occupation will be addressed in terms of alternative hypotheses, and evidence for seasonality presently available will be discussed.

CHAPTER THREE

HUNTER-GATHERER ECONOMICS, SETTLEMENT, AND SEASONALITY

Incongruencies in the spatial and temporal distribution of critical resources is a problem faced by hunter-gatherer societies (Ames 1985:157); and is an important factor in both the determination of site location, and in decisions of resource scheduling (see also Bailey and Parkington 1988). Jarman (1972) predicts that sites may be located close to the most static and most reliable resource. Jochim (1976) observes that the placement of base camps near secure resources is in fact a common response by hunter-gatherers, accompanied by the establishment of satellite extraction camps near other, mobile resources (Jochim 1976:63, see also Carlson 1979:131). Carlson and Mikkelson (1979) further note that a strategic response to seasonal variation of abundant resources is the relocation of the base camp in an area where these resources can be exploited more efficiently (Carlson 1979:133), characterized by group movements within an annual migration circuit (Mikkelsen 1979:79-80).

Vita Finzi and Higgs (1970:5) recognise that many occupation sites lie at the junction of two ecological zones, allowing for the integration of economically complementary resources. Mellars and Reinhardt (1978:280-281) also observe that the location of sites near the boundary of environmental zones gives access to a wider variety of habitats, and they further note that site location on waterways enables ease of transport and communication.

Mobile Hunter-Gatherers

Binford (1980) distinguishes between 'foraging' and 'collecting' systems. Foraging systems, or encounter strategies, are associated particularly with areas that are undifferentiated in terms of resources, such as equatorial forests, and also with areas in which resources occur seasonally in patches. Collecting, or logistical strategies, may be seen as an accommodation to a situation in which consumers are close to one critical resource, but far from another equally important resource (Binford 1980; see also Carlson 1979:112-133). Binford and

Carlson do point out, however, that foraging and collecting strategies should not be considered merely as two polar types of subsistence-settlement systems, but that a wide range of systems should be recognized in between (Binford 1980:17; Carlson 1979:215).

Foragers, e.g., the !Kung San of the Kalahari, gather food on a daily basis in relatively close proximity to the residential base. When the foraging area has been exhausted, the co-resident group moves on and a new residential camp is established. The residential base is the site of processing, manufacturing, and maintenance activities; extractive tasks are undertaken at locations within the foraging radius. The foraging mode is characterized by high residential mobility, and daily food procurement (Binford 1980:5-10, Figure 1).

Binford characterizes collecting systems by low residential mobility, the exploitation of specific distant resources by task groups, and food storage; e.g., the Nunamuit of Alaska. Seasonally-occupied base camps are complemented by smaller special-purpose sites, occupied on a short-term but often regular basis, which include field camps (functioning as temporary operational centres), stations (e.g., game observation points, hunting stands), and caches (field storage sites). Extractive tasks are undertaken at 'locations'; e.g., kill sites (Binford 1980:10-12, Figure 3). Binford further anticipates that as the degree of sedentism of a system increases, there will be an increasing repetition in the use of particular locales; and, further, the same activities will be undertaken more frequently in the same places (Binford 1982:20-21).

Woodburn (1980, 1982) classifies hunting and gathering societies in terms of immediate-return of labour or delayed-return of labour, and some parallels may be drawn with Binford's foraging and collecting systems. Immediate-return systems are characterised by the consumption of food soon after it has been obtained; it is neither stored nor elaborately processed. Woodburn further associates immediate-return systems with egalitarian societies; and offers several examples including the !Kung of Botswana and Namibia, and the Hadza of Tanzania. Delayed-return systems are characterised by rights held over valued assets which may represent a yield, or a return for labour applied over time. In hunting and gathering societies such valued assets may include processed and stored foods, technical facilities (e.g., boats and fishing gear, fish weirs, stockades, beehives), and wild products which have been improved or increased by human labour (e.g., selectively culled herds, wild plants which have been tended) (Woodburn 1982:432-433). Testart (1982) also distinguishes between economies based on the immediate consumption of food, and those based on large-scale seasonal food storage. Furthermore, he associates food storage with the development of sedentism (Testart 1982:523).

In a study of the Tulunaqmiut Nunamiut, Campbell (1968) recognises the occupation of a lake-side home base by all or most of the band during the warmer months of April, May, and August to October, followed by seasonal disbanding and the occupation of smaller settlements in sheltered valleys by two or more families during the colder months of November to January or April. He also recognises a number of special-purpose sites, including hunting and fishing camps and sites associated with non-food collecting activities, visiting and trading (Campbell 1968:15-17, Figure 2). A similar model of summer aggregation and winter dispersal is advocated by Jochim (1976) in his study of the Mesolithic of southwestern Germany. He suggests a four-season settlement strategy which includes a large summer lake-side or river-side base camp on the lower Danube; smaller, dispersed winter base camps in the sheltered Danube Valley; and intermediate spring and autumn occupations, probably on tributaries of the Danube (Jochim 1976:130-131, 171-174).

Bailey and Parkington (1988:8-9) observe that there are several ethnographic examples of sedentary hunter-gatherers, particularly in coastal areas. They further point out that whereas mobile hunter-gatherers exploit a succession of seasonal resources occurring in different places, sedentary economies may be based on the integration of a succession of seasonal resources which occur in the same place. A number of researchers in fact advocate a more sedentary way of life, at least in certain propitious areas, during the European Mesolithic (Dennell 1983, Zvelebil 1986a).

Sedentary Hunter-Gatherers

Matson (1985:246) defines a sedentary hunter-gatherer society as one in which a single settlement is occupied for a substantial portion of the year, and regularly reoccupied. He further states that "the notion of a sedentary settlement pattern as contrasted with a mobile one is another case of polar extremes existing definitionally and with human experience falling somewhere in between". Bailey and Parkington (1988:9) offer a similar definition: "most people stay in one settlement for most of the year". They also acknowledge a continuum between a fully sedentary economy and a fully mobile economy; and observe that in coastal areas an intermediate sedentary-*cum*-mobile economy appears to be common, in which the community is tied to a single fixed base, but groups move to various locations to obtain particular resources. A variant of this model is offered by Price (1985: 358) in a discussion of mesolithic communities in southern Scandinavia. He suggests that a series of related residences, rather than a single settlement, may be scattered around the margins of coastal bays and lagoons.

Mikkelsen (1979:79-80) proposes that permanently-occupied base camps may be established in rich ecological zones in which the economy is characterised by food storage for poor seasons (cf. Testart 1982), as on the northwest coast of North America; or at locations between different ecological zones in which two or more biotopes can be exploited by small task groups, as practised by the Ainu of Japan. Clarke (1976:469) observes that permanent base camps may be located where "a successive range of abundant fresh food could be gathered throughout the year". Matson (1985:247) further stipulates that to support a sedentary economy, resources must be predictable and reliable; must occur in sufficient concentration to be utilized efficiently; must be accessible from the home base; and must give abundant returns.

Coastal economies of the North American northwest were based on sea and river fishing, particularly the summer and autumn salmon harvests (Drucker 1963, Fladmark

1982). Great quantities of salmon, smelt, herring, and, in the north, olachen were caught by means of fish traps, dip nets, gill nets, leisters, and rakes as well as by angling; and were dried and stored for future consumption (Drucker 1963:35). Sea and land mammals, ducks, berries, and acorns also contributed to the diet; although the hunting of land mammals was rather limited (Drucker 1963:49). All resources, including tracts of land, fishing grounds, stretches of river, shell fish beds, and berry bushes were owned by extended families or lineages (Drucker 1939:59; 1963:121); and the economy supported dense populations residing in permanent winter villages of up to several hundred people (Fladmark 1982:136, Drucker 1963:112).

Ainu economy was based on spring and autumn salmon fishing, and deer hunting in the autumn and early winter. Extra food stores, especially salmon, were prepared as an insurance against possible low yields. Small, permanent villages were located on river terraces; and huts located at higher elevations were occupied by hunting parties during deer and bear hunting seasons (Watanabe 1968).

Watanabe (1968:73) proposes that a fundamental factor relevant to the residential stability of the Ainu may have been the distribution of ecological zones within the river valleys inhabited by them. He identifies four, or in some instances five, ecological zones exploited seasonally by the Ainu, viz., 1) the river and its tributaries: salmon fishing during the spring and autumn; 2) river banks: collecting wild plants between spring and autumn; 3) river terraces, the location of permanent villages: collecting wild plants between spring and autumn, deer hunting during the autumn; 4) hillsides along the valley, the location of hunting huts: deer hunting during early spring and early winter; 5) mountainous regions around the source of the rivers (not available to all groups), the location of hunting huts: bear hunting in spring and autumn, the collection of elm bark for clothing during the spring (Watanabe 1968:72).

As for the European Mesolithic, Rowley-Conwy (1983) proposes that permanent base camps and seasonal special-purpose camps were established during the Ertebølle period in eastern Denmark. Price (1985) also believes that year-round occupations were prevalent by the Ertebølle (ca. 6600 bp to 5200 bp) in Zealand (eastern Denmark) and Scania (southern Sweden); and Noe-Nygaard (1983) recognizes a more settled way of life in Denmark during the Late Ertebølle. Mikkelsen (1979) and Renouf (1988) suggest that permanently-occupied base camps were established in coastal areas of Norway during the Mesolithic. Mikkelsen (1979:80) proposes that settlements were located near the boundaries of different ecological zones, each zone having been exploited by task groups occupying temporary camps which were generally located further inland. Renouf (1988:114) observes that migratory resources can be exploited efficiently from a single, permanent coastal location, with secondary camps utilized to obtain other resources.

Rowley-Conwy (1983:118) proposes that certain areas of the western Baltic, in which migratory resources aggregate seasonally, were particularly favourable for the development of sedentary communities. He suggests that migratory species with differential seasonality were exploited in turn, and permanently-residing native species could be utilized together with stored foods when no migratory visitors were available. He identifies estuaries as favourable locations for permanent settlements, noting that they are areas of high primary biomass and the loci of migratory species. Additional benefits are the year-round presence of molluscs, available as an emergency resource; and convenience of travel and transportation by boat or on foot along river valleys. Paludan-Müller (1979:125) also recognises the importance of highly productive estuary ecosystems in the mesolithic economies of northwestern Zealand (Denmark). He observes that a variety of fish and birds frequent estuaries, both as perennial residents and seasonal visitors; and he too notes that molluscs, present in large numbers year-round, are available as an emergency food source during periods of scarcity.

For Cantabria, northern Spain, Clark (1983) proposes the establishment of base camps occupied by at least a portion of the local group on a perennial basis during the Boreal phase (9650 bp to 6900 bp). Coastal shell middens in this area, often located in the mouths of caves, are identified as large rubbish heaps associated with open-air living sites. The middens are composed of sediment, bone fragments, and intertidal molluscs (particularly limpet [*Patella* spp.] and topshell [*Trochocochlea crassa* or *Monodonta lineata*]). Clark identifies red deer as the major food source; and suggests that plant foods including acorns, beechnuts, hazelnuts, juniper, and cereal grasses were also utilised (Clark 1983:98-100). Shellfish may have provided either a permanent dietary supplement, or an "insurance resource" exploited intensively when other staples were unavailable or of diminished productivity (Clark 1983:102).

Clark advocates that base camps would have been strategically located along estuaries near the coast; and in valleys of the coastal hills to take advantage of a range of ecological zones, including the lowland forest and forest margin habitats of red deer and roe deer, the coastal plain grassland and parkland habitats of the horse and aurochs, the alpine zone in which chamois and ibex were available on a seasonal basis, and estuaries in which molluscs were available throughout the year. He also suggests that distant resources may have been exploited by task groups sent out on a periodic basis, and that travel would have been facilitated by the north-south-trending river valleys (Clark 1983:108, Figure 9.4).

Portuguese Ecology and Mesolithic Settlement

Clarke (1976) predicts high levels of human occupation during the Mesolithic in Portugal in view of this region's high potential primary productivity, which is the result of a unique combination of Mediterranean climate, a mixed ecology, and the very productive Atlantic-shelf littoral (Clarke 1976:468). He notes particularly the high primary and edible productivity of major estuaries and associated marshes and lagoons (Clarke 1976:464, Tables 1 & 2).

Estuary ecosystems support a lesser number of permanently-residing estuary-adapted species than adjacent marine and fluvial environments, but actual population densities are higher. Furthermore, the edible proportion of net productivity is high; and it includes some species which are available in all seasons, and others which are limited to bulk occurrence in certain seasons only (McLusky 1971, 1981, Table 1.6; Walne 1972; Barnes & Green 1972). Intertidal molluscs, an easily collectible, highly concentrated protein source rich in salts, glycogen, and vitamin A, are present throughout the year in great numbers (Clarke 1976:466, Erlandson 1988:106, Paludan-Muller 1979:125, Yesner 1980:729). Fish, ducks, and waterfowl frequent the estuaries and associated lagoons and marshes in large numbers, both as perennial residents and seasonal visitors (Paludan-Muller 1979, McLusky 1981); and a wide range of edible water-related and terrestrial plants is also available (Clarke 1976:466). The high resource potential of the Portuguese estuaries is complemented by that of adjacent terrestrial environments. A range of very productive habitats, including marshlands, grasslands, and forests, is rich in waterfowl, game birds, and mammals; and a wide variety of herbaceous plants, root tubers, and rhizomes, and trees and bushes that bear edible fruits, nuts, and berries (Clarke 1976:458, Roche 1972; see also Dimbleby 1978, Yesner 1980:729). Clarke predicts that plant foods may have in fact provided 60% to 80% by weight of the diet of mesolithic hunter-gatherers in Temperate and Mediterranean Europe between the latitudes of 35° and 55° North, including Portugal (Clarke 1976:450).

The Settlement Model

The archaeological and ecological evidence currently available supports a model which identifies the Portuguese estuaries as centres of human population during the Mesolithic, and loci of the home bases of local co-resident groups. The rivers would have facilitated travel by boat or on foot along the river valleys; and the transportion of resources, or people, between extraction sites and home bases, or between neighbouring communities (Yesner 1980:730). Specific resources located at some distance from the home base, or seasonal resources not available locally, may have been exploited by task groups using smaller, temporary or short-term field camps and special-purpose sites; and it is likely that such task groups would have taken advantage of local food resources to satisfy their immediate nutritional needs (Binford 1982:8). At the upland cave of Balma El Gai (Catalonia, Spain), which is identified by Guilaine *et al*. (1982) as a kill site associated with the exploitation of deer, wild pig, ibex, and aurochs, there is evidence of the on-site consumption of small mammals (especially lagomorphs) and plants. In Scotland, at a coastal location near Morton (Fife) identified by Deith (1983a, 1986) as a regular source of raw material for the manufacture of stone tools, there is also evidence of the local consumption of fish, birds, and molluscs.

Arnaud (1989) proposes a settlement model based on Binford's concept of logistical strategy for the Sado valley during the Mesolithic. He advocates a two-season settlement pattern involving greater emphasis on fishing during the spring and summer, associated with a base camp located at Poças de S. Bento; and on hunting large mammals during the autumn and winter, associated with a base camp located farther inland at Cabeço do Pez. He further proposes that the smaller Sado middens may have functioned as special-purpose sites utilized by task groups. Deith (n.d.) suggests that the winter collection of molluscs at a number of sites on the Sado may indicate the dispersal of the local population along the river valley during difficult times between winter hunting and summer fishing, when other resources were unavailable or in short supply.

The settlement model proposed here can be be summarised briefly as follows:

1) Estuaries were centres of human population during the Portuguese Mesolithic.

2) Home bases, located on estuaries or their tributaries, were occupied by all or part of the local group, either seasonally or on a more permanent basis.

3) Distant resources, or seasonal resources not available locally, were exploited by task groups using smaller temporary camps.

The question of seasonally-occupied base camps or more permanent settlements may be addressed in terms of alternative hypotheses, viz.,

a) Two or more seasonal base camps were occupied by all or most of the local group for part of the year, each site reflecting a greater emphasis on specific, seasonally-available resources (cf. Arnaud 1989).

b) One or more permanent settlements were occupied throughout the year by at least a portion of the local group, or a co-resident segment of the local population, who exploited in turn migratory resources and native resources with differential seasonality.

The second hypothesis allows for the establishment of several permanent settlements on the same estuary, representing the scattered homesteads of co-resident segments of the local population. Furthermore, evidence of greater emphasis on specific resources at certain sites may be indicative of occupational specialization by co-resident groups (cf. Price 1985:358; see also Watanabe's [1983] discussion of hunting-oriented and fishing-oriented families among the Ainu).

Present Indications of Seasonality

Research by Roche on the Muge *concheiros* has tended to concentrate on the study of lithic material and stratigraphy (Arnaud 1986). Recent analysis of faunal material from Cabeço de Amoreira and Cabeço da Arruda by Lentacker (1986a) does indicate the use of seasonally-available resources, but more detailed information on resource scheduling is not available. Roche concludes, based on the wide range of resources present, that the occupants of the Muge sites were "semi-sedentary" (Roche 1972:353), or "plus ou moins sédentaires" (Roche 1977:357). He further interprets the evidence of structures and features, and of site levelling, as an indication that the sites were occupied repeatedly by a small number of people, perhaps a family group (Roche 1989).

Deith (n.d.) has undertaken oxygen isotope analyses on cockles from several of the Sado middens in order to determine the season of exploitation. She recognizes an autumn-winter collection at Arapouco, autumn-winter or early spring at Amoreiras, and winter at Rebolador and Cabeço do Pez.

The faunal assemblage of Cabeço do Pez includes a wide range of mammals dominated by red deer and wild pig; large quantities of molluscs are also present, but fish and crustaceans appear only in very low frequencies (Arnaud 1986, 1989). Arnaud suggests that this site may have functioned as a winter base camp, observing that the optimal hunting periods for red deer and wild pig are January to March, and November to March respectively; while marine fish are available only during the spring and summer when they enter the estuary to spawn. Similar assemblages are present at the nearby sites of Amoreiras and Vale de Romeiras; and Arnaud suggests that they too may have been occupied during the winter, or during a transitional period between winter and spring (Arnaud 1989).

Rowley-Conwy (n.d.a:3) has analysed tooth eruption on five immature pig jaws from Cabeço do Pez; and determined that the animals were killed between September and January, based on spring births. However, it should be noted that the birth season of pigs in southern Europe is not restricted to spring as it is in the north (Rowley-Conwy n.d.b:3). Deith reports the winter collection of molluscs at Cabeço do Pez, and autumn-winter or early spring at Amoreiras, which lends support to Arnaud's model. There is, however, some evidence of diagenetic change on specimens from the former site (Deith n.d.). Such change involves the dissolution and reprecipitation of shell material, with isotopic exchange between shell carbonate and ground water (Deith 1985b:119); as a result seasonal determinations on molluscs from Cabeço do Pez are questionable.

Sites located farther downstream on or near the Sado contain lower frequencies of mammal remains, but fish and crustaceans are better represented (Arnaud 1986, 1989). Arnaud suggests that Poças de S. Bento may have functioned as a spring and summer base camp. The site is located farther from the estuary, which was likely to be unhealthy during the summer because of stagnant water; and close to natural springs. Abundant remains of marine fish were recovered at Arapouco, including meagre and Sparidae which are known to have visited the estuary to spawn between April and August, and between June and September respectively. Arnaud (1989) suggests that this site may have functioned as a spring and summer fishing camp. The presence of the cranial bones only of meagre may indicate that fish were processed at this site and consumed elsewhere. Rowley-Conwy and Zvelebil (1989) further suggest that fish may have been stored for later consumption.

Evidence for the autumn-winter collection of molluscs at Arapouca (Deith n.d.) indicates that this site was occupied outside the season predicted by Arnaud (1985, 1989). However, the presence of 'winter' resources at a 'summer' site does not necessarily invalidate Arnaud's interpretation: Binford (1982:15-16) predicts that sites may be utilized differentially throughout the year. Moreover, the low frequency of fish remains at Cabeço do Pez does not preclude a more permanent occupation of this site since large and small mammals would have been present in the area throughout the year, and molluscs were also available year-round (Arnaud 1989). A wide range of plant foods would have been available, not only between spring and autumn, but also during the winter in the case of roots, bulbs, and acorns. The availability of plant foods could also have been extended through storage (Arnaud 1989, Clarke 1976).

At Fiais, Rowley-Conwy (n.d.b:3-5) bases determinations of seasonality on tooth eruption in immature mammals, and epiphyseal fusion in rabbit longbones. Two red deer mandibles are from animals probably killed in late spring; one aurochs mandible may represent a summer kill; two pig maxillae may represent late summer kills, and two additional pig maxillae may represent winter kills. However, the birth season and tooth eruption ages of the aurochs are not well understood; and the variable birth season of pigs in southern Europe has already been noted. A significant proportion of rabbit longbones exhibit unfused epiphyses; which would indicate the summer-autumn death of individuals born in spring or early summer. Seasonality determinations are very tenuous; nevertheless, Rowley-Conwy (n.d.b:4) suggests that the limited evidence available does indicate an occupation during the warmer part of the year, while winter occupation cannot be demonstrated.

At present, evidence of seasonality in terms of both resource exploitation and site occupation is generally quite limited, particularly since seasonal determinations based on tooth eruption in immature mammals are less reliable in southern Europe than in the north (Rowley-Conwy n.d.b:3). Deith (n.d.), however, has demonstrated the potential value of molluscs as seasonal indicators, especially when considered in conjunction with other evidence (cf. Deith 1989:77, Bailey and Parkington 1988).

CHAPTER FOUR

EXCAVATIONS AT PANDEIRO, TOLEDO (LOURINHA)

In the spring of 1986 preliminary investigations were conducted at the mesolithic shell midden of Pandeiro by D. Lubell, in collaboration with J. Zilhão (Zilhão and Lubell 1986a). The quantitative analyses of midden deposits were undertaken, and evidence of environmental change was observed.

Environmental Setting

The Pandeiro midden lies on the the southwest side of the village of Toledo, in the rural municipality of Lourinha, about 50 km northwest of Lisbon (Figure 2). The open-air site is located 4 km inland at an elevation of 30 m above present sea level in the small valley of the Ribeira de Toledo, a southwest-flowing tributary of the River Alcabrichel (grid reference 736377, *Carta Militar de Portugal*, Series M888, Sheet 361, 1970). The present channel of the *ribeira* runs approximately 200 m to the south of the midden, at an elevation of 20 m asl. To the north of the site the sides of the valley rise gradually to a maximum elevation of 138 m asl at the crest of the interfluve; to the south, the valley rises more steeply to just 69 m asl. The alluvial deposits of the sheltered valley floor are presently utilized for market gardening; the south-facing slopes are covered with vineyards and orchards, while the steeper north-facing slopes are given over to pasture and *Eucalyptus* plantations. The shell midden is located just above the flood plain, at a point where the vegetable gardens give way to the vineyards and orchards of the limestone slopes.

The confluence of the Ribeira de Toledo and the River Alcabrichel lies 1.5 km to the southwest of Pandeiro near the small town of Vimeiro. The Alcabrichel itself enters the Atlantic Ocean 3 km west of Vimeiro at Porto Novo, where the river mouth is now blocked by sand (personal observation 1986). Inshore currents are responsible for the formation of sandbars and lagoons along much of the Portuguese coastline, and for the silting up of

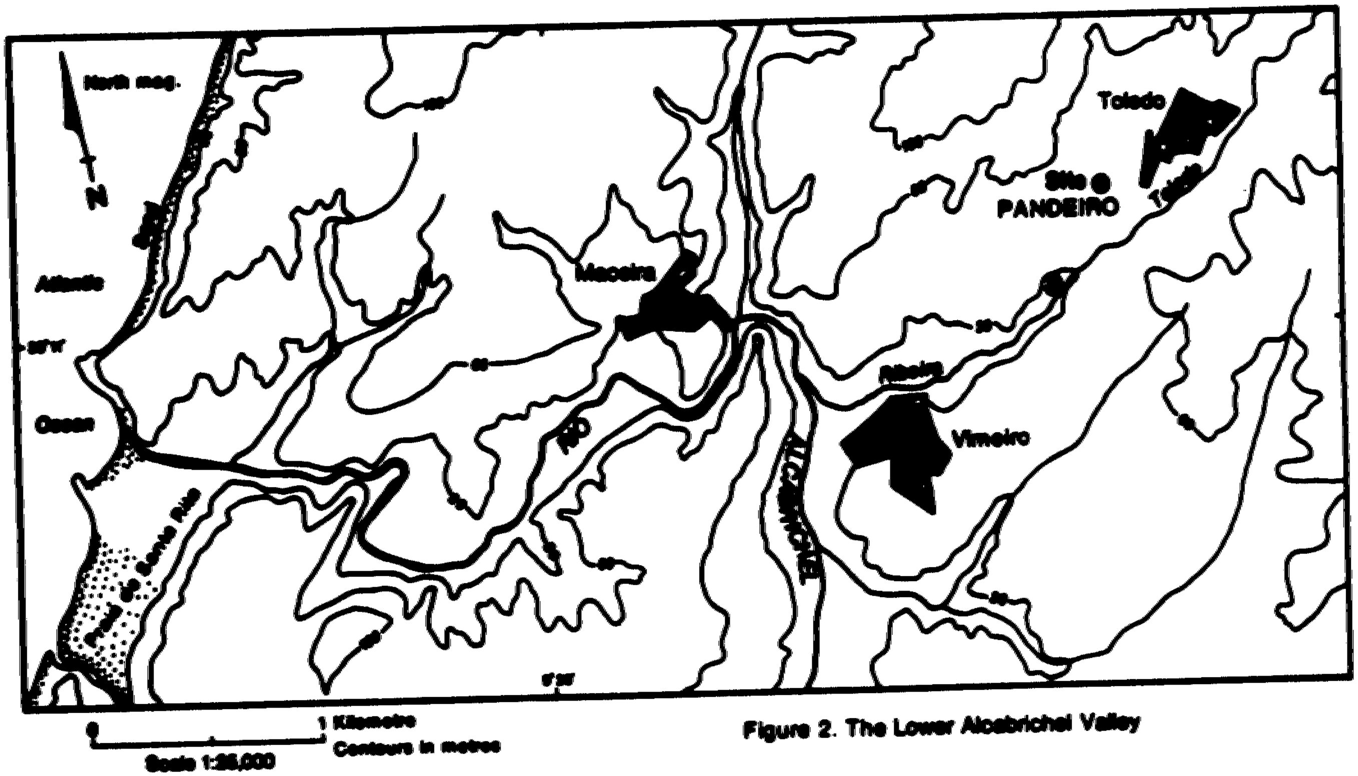

Figure 2. The Lower Alcabrichel Valley

river mouths; ports and fishing harbours are kept open only by frequent dredging (Admiralty 1942, Ferreira 1982). The more extensive palaeoestuary of the Alcabrichel lies to the south of Porto Novo, now a sandy beach known as the Praia de Santa Rita (Zilhão *et al.* 1987). Tidal penetration is severely restricted, especially during the drier spring and summer months; and, in fact, intertidal shellfish are not collected on the river today (J. Zilhão, pers. comm. 1988), due in part to the sand berm at the mouth of the river, and also to a decrease in stream volume as a result of the widespread drilling of wells for domestic and agricultural purposes (*Carta Militar de Portugal*, Series M888, Sheet 361, 1970).

The alluvial deposits of the flood plain of the Alcabrichel presently support the cultivation of cereals, fruit, and vines. These deposits are of Recent origin; and are the result of the rise in sea level during the Flandrian transgression, and, more recently, an increase in erosion brought about by the intensification of agricultural activities (Ferreira 1982, Beckinsale and Beckinsale 1975; cf. Vita Finzi 1969).

Limited palynological evidence suggests that during the 8th millenium bp southern Portugal supported widespread deciduous oak forests and coastal pine woods. A pollen core taken from an ancient coastal lagoon near the Sado estuary, dated between ca. 7500 bp and 6500 bp, reveals a predominance of arboreal pollen from humid Mediterranean deciduous species (particularly oak, *Quercus* spp.), true Mediterranean sclerophyllous species (such as olive, *Olea* spp.), and littoral Mediterranean pines (*Pinus* spp.)(Mateus 1985). Pine appears to have been abundant on the littoral during the Boreal phase of the Holocene, but declined sharply by the beginning of the Atlantic. Also present in the inner areas of fluvial basins was alder (*Alnus* spp.), ash (*Fraxinus* spp.), and elm (*Ulmus* spp.)(Arnaud 1986).

The abundance of oak and the decline of pine is also indicated in the Serra da Estrela of north-central Portugal, where two pollen cores have been obtained at Lagoa Comprida, located at an elevation of 1600 m asl. Van den Brink and Janssen (1985) recognise seven pollen zones in a sequence dated from the 10th millenium bp to less than 1000 years ago; two of these zones are of interest here.

Zone SDE-3, the base of which is dated to 9080 ± 200 bp, is dominated by oak, followed by pine which decreases in frequency throughout the zone. Birch (*Betula* spp.) is present in low frequency; juniper (*Juniperus* spp.) and alder are present in very low frequency; and olive is present sporadically. Non-arboreal pollen, also occurring in low frequency, includes dock (*Rumex* spp.), sage (*Artemisia* spp.), aster (*Asteraceae liguliflorae*), and grasses (Cerealia). A date of 8310 ± 160 bp has been determined near the top of SDE-3, just below the base of zone SDE-4. The transition zone coincides with the transition of the Boreal and Atlantic phases, and approximately the time at which Pandeiro was occupied. During the transition oak remains dominant, but decreasingly so through the lower half of SDE-4. Birch increases significantly, overtaking pine which declines sharply. Willow (*Salix* spp.) and hazel (*Corylus* spp.) appear at this time, and also bracken (*Pteridium* spp.)(Van den Brink and Janssen 1985:205-206, Figure 4).

<u>Climate</u>

Portugal presently enjoys a maritime variant of the Mediterranean climate, with warm, dry summers and mild, wet winters (Beckinsale and Beckinsale 1975:148). The coolest months are generally mid-December to February; and the lowest temperatures usually occur in January, although they may occur either in December or February. Highest temperatures occur during July and August (Lines Escardo 1970). In the Lisbon area average temperatures range between 10.3°C in January and 22.1°C in August (Table 2). Rainfall occurs mainly in the autumn and winter, with in excess of 60% of the total precipitation falling at this time (Lines Escardo 1970). Drought conditions (i.e. less than 30 mm of rain per month) occur during June, July, and August (Beckinsale and Beckinsale 1975). The mean maximum monthly precipitation of 116 mm occurs in November, and the mean minimum precipitation of 5 mm per month in July and August (Table 2).

The rivers of southern Portugal fall to very low water during the hottest and driest months; and in the Lisbon area many small streams, including the Ribeira de Toledo,

Table 2. Climatic statistics for the Lisbon area: mean monthly temperatures (°C), and mean monthly precipitation (mm) (based on Beckinsale and Beckinsale 1975).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
°C	10.3	11.3	12.6	14.2	16.6	19.3	21.4	22.1	20.3	16.9	13.7	10.5
mm	89	88	87	75	50	22	5	5	37	75	116	98

Table 3. Sea surface temperatures (°C) (based on US Naval Oceanographic Office 1967).

	Lisbon Coast		Algarve	
Month	Min.	Max.	Min.	Max.
Jan	11.1	16.7	12.2	17.8
Feb	11.1	16.7	12.2	17.8
Mar	11.1	16.7	12.2	17.8
Apr	11.1	17.8	12.2	18.9
May	12.2	18.9	13.3	20.0
Jun	13.3	20.0	14.4	22.2
Jul	14.4	21.1	15.6	23.3
Aug	15.6	21.1	16.7	25.6
Sep	14.4	22.2	16.7	24.4
Oct	14.4	20.0	15.6	22.2
Nov	13.3	20.0	13.3	20.0
Dec	12.2	17.8	12.2	18.9

may cease to flow completely. However, with the onset of the autumn and winter rains, flooding often occurs despite the regularization of rivers (cf. Arnaud 1989). Flood control and irrigation schemes are, in fact, necessary for the regularization of all Portuguese rivers; and the Alcabrichel itself has been extensively regularized (Beckinsale and Beckinsale 1975, personal observations 1986).

The late Boreal-early Atlantic phase is associated generally in western Europe with higher temperatures and precipitation than at present (Goudie 1977), and limited faunal and palynological evidence from Portugal does tend to indicate warmer conditions at that time. In the Sado valley, Arnaud (1989) reports the presence in archaeological deposits of the marine gastropod *Cypraea pyrum*, presently found further south in the warmer waters of Algarve (Table 3). Oxygen isotope analysis of cockles from the Sado middens by Deith (n.d.) shows that the range of delta O^{18} values is lighter than that for modern shells from the Sado estuary, a fact which may also be an indicator of warmer conditions. Further evidence of higher temperatures during the early Holocene comes from the Muge middens, where Roche (1972, 1977) reports the presence of a crab, *Gelasimus tangeri*, found today in Algarve and North African waters.

Palynological evidence from the Lagoa Comprida indicates that olive was present sporadically between ca. 9060 ± 200 bp and 8310 ± 160 bp, becoming continuously present by 4340 ± 90 bp. Today, *Olea europaea* does not grow above 750 m in the *serra*; and the presence of olive at higher altitudes during the early Holocene may be indicative of higher temperatures at that time (Van Den Brink & Jansen 1985:208-209). Summer temperatures across Europe 6000 years ago have been reconstructed from palynological data by Huntley and Prentice (1988), who suggest that July mean temperatures for Portugal north of the Sado estuary were in fact 2°C higher than at present.

Excavation

The Pandeiro shell midden lies beneath 0.60 m to 1.20 m of colluvial overburden. It is exposed for approximately 100 m on its southern flank where it has been damaged by a roadcutting; however, test excavations revealed that at least part of the midden remains intact. Lithic material and faunal remains, including molluscs, were recovered during the excavations; and a radiocarbon date of 7800 ± 110 bp was later obtained, based on a sample of bone (Lubell pers. comm. 1989).

Preliminary investigations included the excavation of three one-by-one metre test units, and the clearing of a one metre-wide section of the roadcutting. Two adjacent units (F6 and F7) were sited one metre north of the roadcutting section (F10) near the centre of the exposed midden deposits, and a single unit (T1) was sited 20 m southwest of the other test units (Figure 3). Each unit was excavated in 5 cm or 10 cm artificial levels using trowel and brush, and all fill was screened through 5 mm mesh. Finds were stored in level bags (lithics, bone, shellfish), and a one-litre bulk sample was collected in each 5 cm spit of F7 for quantitative analyses of the midden deposits. Field identification of mammal bones was undertaken by M. Jackes.

In test unit F7 (Figure 4), concentrated midden deposits 40 cm to 60 cm thick were overlain by 120 cm of grey/brown colluvium containing scattered bone and shell fragments, lithic waste, and modern potsherds; moreover, no evidence of soil profile zonation was observed (cf. Shackley 1975:3). The colluvial overburden had been disturbed by ploughing which also appears to have damaged the upper part of the original midden, resulting in the reworking of midden deposits. Animal burrowing has further contributed to the reworking of deposits. The midden is underlain by brown sandy deposits at ca. 160 cm bs, replaced by clean yellow sand between 180 cm and 200 cm bs. The upper section of *in situ* midden deposits was composed of a high concentration of shells, rock, and ash within a black sandy matrix. In the lower part of the midden shell and ash occurred in lower concentration; and

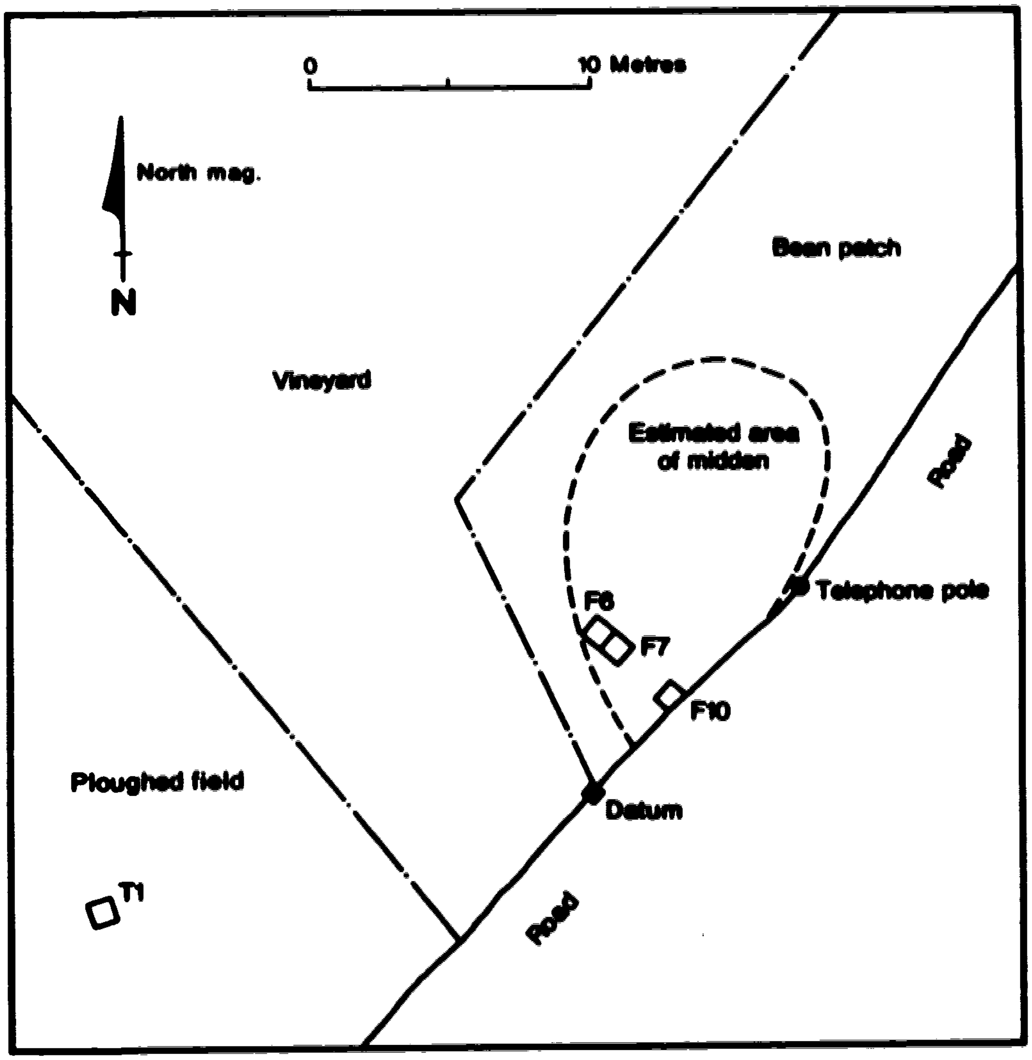

Figure 3. Pandeiro site plan (reproduced with the permission of D. Lubell).

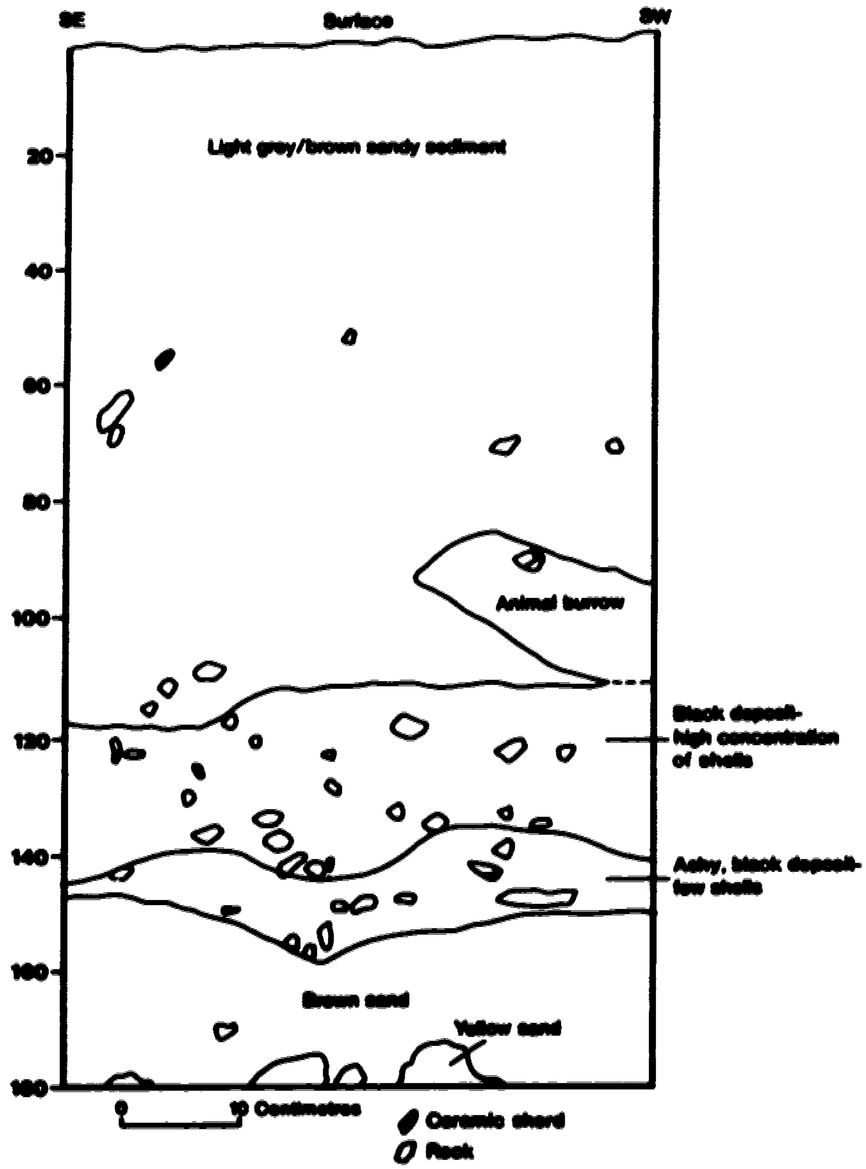

Figure 4. Pandeiro test unit F7: profile of south wall (reproduced with the permission of D. Lubell).

the matrix became lighter in colour. Sedimentological analysis confirmed the predominately sandy composition of the matrix (Table 4)(Mayne 1987).[1]

Artifacts, which were rare in this unit, consist of flakes and other debitage on reddish-coloured flint. Twenty lithic pieces were recovered in the midden deposits between 120 cm and 160 cm bs (level bags and bulk samples combined), generally occurring in frequencies of one or two pieces per 5 cm level. However, six pieces were recovered in level 145 cm to 150 cm bs, and four pieces in level 150 cm to 155 cm bs (Tables 5 and 7). Similar lithic material was recovered in the plough zone above the midden and in the sand below to a depth of 185 cm bs, the limit of excavation.

A total of thirty nine mammal bones and bone fragments were recovered from the midden deposits (not including bulk samples), most of which are of lagomorph. The highest frequency of mammal bone occurred in level 145 cm to 150 cm bs (Table 5), from which fifteen bones or bone fragments were recovered, including the remains of deer and pig, and also fish vertebrae. Other bone fragments were recovered above and below the midden proper, again mainly of lagomorph but including bird, and possibly rodent, reptile, and sheep or goat.

Shellfish valves collected during excavation and screening consist mainly of cockle (*Cerastoderma edule*). Peppery furrow clam (*Scrobicularia plana*), mussel (*Mytilus edulis*), razor clam (Solenidae), deccussate venus (*Venerupis deccussata*), and oyster (*Ostrea* spp.) were collected in lower frequencies. Also recovered were marine gastropod fragments (Gastropoda), including the syphons of whelk-sized species, acorn barnacles (*Balanus* spp.), crab or lobster remains (Pleocyemata), and land snails (Table 5).

Test unit T1 was excavated to a depth of 140 cm bs. Bone, shell, ceramic, and lithic material was scattered throughout the unit, apparently not *in situ* (Zilhão and Lubell 1986).

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1 Sedimentological analysis was undertaken on 50 g sub-samples of the <2 mm fraction of bulk samples collected in each 5 cm level of F7.

Table 4. Pandeiro test unit F7: sedimentological analysis, <2 mm fraction of 50 g samples of 1 litre bulk samples (% weight by level) (based on Mayne 1987).

Level	Shell[1]	Matrix		
		Sand[2]	Silt[2]	Clay[2]
120	15.7	89.0	11.0	0
125	22.7	96.1	3.9	0
130	31.2	92.0	8.0	0
135	27.7	95.0	5.0	0
140	20.9	91.5	8.5	0
145	19.4	90.5	9.5	0
150	18.2	97.2	2.8	0
155	16.7	91.1	8.9	0
Mean	21.6	92.8	7.2	
SD	5.1	2.7	2.7	

Note: Level number indicates top of level in cm below surface (bs).

[1] Percentage of total sample

[2] Percentage of matrix only

Table 5. Pandeiro test unit F7: level bag contents (NISP).

Lev	Cer	Scr	Myt	Sol	Ven	Ost	Pro	Bal	Ple	Pis	Mam	Pul	Lit
120	106	1	1	4			1	2	1		3	2	2
125	160	5	3	15	4	1		2			4	5	1
130	112	5	11	2	3		4	19			4	2	2
135	37	10	6	7	2		5	3	2		2	5	1
140	25	1	4	4			5	5			6	2	2
145	175	11	30	11	2		3	20	3	3	15	19	6
150	48	6	5	9	1		2	5	3		3	5	2
155	27	4	12	3			3		2		2	2	1
All	690	43	72	55	12	1	23	56	11	3	39	42	17

Table 6. Pandeiro test unit T1: level bag contents (NISP).

Lev	Cer	Scr	Myt	Sol	Ven	Ost	Pro	Bal	Ple	Pis	Mam	Pul	Lit
65	13	3	2	1		1	1	1			1		4
70	36	16	8	3	5	1	2				2	9	10
75	26	15	8	9	3		4	1			3	10	6
80	17	3	6	1			1				1	2	2
90	10	4		3				2			3	2	28
100	3	4	3	7	1							1	38
110	5	7	1	1			1					2	38
All	110	52	28	29	9	2	9	4	0	0	10	26	126

Note: Levels 80 to 110 are 10 cm spits.

Lev	Level (cm bs)	Pro	Prosobranchia (marine gastropod)
Cer	*C. edule*	Bal	*Balanus* spp.
Scr	*S. plana*	Ple	Pleocyemata (crab/lobster)
Myt	*M. edulis*	Pis	Pisces
Sol	Solenidae	Mam	Mammalia
Ven	*V. decussata*	Pul	Pulmonata (terrestrial gastropod)
Ost	*Ostrea* spp.	Lit	Lithics

Reworked midden deposits were located beneath approximately 65 cm of grey/brown colluvium, resting on brown sand at a depth of 110 cm to 120 cm bs. Identified bone recovered within the midden deposits consists entirely of lagomorph, but fish vertebrae were found near the surface. A similar collection of shellfish was recovered, with *C. edule* the most frequent species present. Lithic material, consisting of flakes and other waste on reddish-coloured flint, occurred in much higher frequencies than in F7, however; and one hundred and twenty six pieces were recovered between 65 cm and 120 cm bs (Table 6).

Similar faunal and lithic material was recovered in unit F6 and the roadcutting, F10. Identified mammal bone consists mainly of lagomorph; but pig, bird, and possibly bovid or deer are also represented.

<u>Quantitative Analysis of Bulk Samples</u>

One-litre bulk samples were collected from eight 5 cm artifical levels of unit F7 between 120 cm and 160 cm bs. Each bulk sample was screened through 2 mm mesh. The >2 mm fraction was sorted using a hand lens and dissecting microscope, and seventeen categories were recognized (Table 7). For each level all specimens in each category were counted and weighed. In the case of shellfish, identifications were sought at the level of species; however, identification was not possible for all specimens or all categories due to the very fragmentary nature of the material (cf. Shackleton 1988:9).

Lithic material consisted of three pieces of debitage on reddish-coloured flint, two of which were recovered in level 145 cm to 150 cm bs. Rock was present throughout the midden; and occurred in the highest frequency in levels 145 cm to 150 cm bs, and 150 cm to 155 cm bs, which together produced more than 63% of the total amount recovered. Charcoal appeared in two levels in very low frequency, one of these levels being 150 cm to 155 cm bs.

Mammal bone was present in low frequency throughout the midden. Fish (Pisces), and crab or lobster (Pleocyemata) appeared in very low frequency in only one and two levels respectively.

Table 7. Pandeiro test unit F7: >2 mm fraction of 1 litre bulk samples (weight in grams).

Lev	Cer	Ser	Myt	Sol	Ven	Ost	Pro	Bal	Ech	Ple	usf	Pis	Mam	Pul	Cha	Roc	Lit
120	34.4	12.8	5.8	7.4	2.6		0.6	3.3			131.7						
125	28.7	31.4	11.8	7.5	6.0		2.7	2.5			251.8		0.6			185.8	
130	42.9	21.9	17.9	7.7	4.0	0.4	0.1	3.2	+		239.2		1.2	0.2	+	48.1	
135	50.1	22.8	12.7	6.4	7.8	1.2	3.0	2.7		0.3	290.7		0.8	0.8		91.3	1
140	45.2	15.8	12.8	2.3	6.7		8.2	3.4			175.8	0.1	4.0			51.6	
145	43.8	14.6	18.5	4.6	5.0		1.5	9.1	+		241.3		0.7	0.4		327.2	
150	24.3	15.9	11.7	6.9	7.3		0.1	11.8		0.1	208.6		0.1	0.5	0.1	385.5	2
155	17.3	9.8	9.8	8.4	4.1		0.9	0.9			163.7		0.4	2.5		34.1	
Mean	37.1	18.1	12.6	6.4	5.4		2.1	4.6			212.9		1.1	0.9		160.5	
SD	12.5	6.4	3.8	1.9	1.7		2.5	3.5			49.3		1.2	0.8		133.3	

Note: Lithics recorded as number of pieces.
+ = <0.1 g.

Lev	Level (cm bs)	Ost	*Ostrea* spp.	Pis	Pisces
Cer	*C. edule*	Pro	Prosobranchia (marine gastropod)	Mam	Mammalia
Ser	*S. plana*	Bal	*Balanus* spp.	Pul	Pulmonata (terrestrial gastropod)
Myt	*M. edulis*	Ech	Echinoidea (sea urchin)	Cha	Charcoal
Sol	Solenidae	Ple	Pleocyemata (crab/lobster)	Roc	Rock
Ven	*V. decussata*	usf	unidentifiable shell fragments	Lit	Lithics

Six families of bivalves were identified, four to the level of species and one to genus. Cockle, *Cerastoderma edule*, was the most common species present by weight (mean value for all levels: 37.1 ± 12.5 g); followed by peppery furrow clam, *Scrobicularia plana*, (18.1 ± 6.4 g); mussel, *Mytilus edulis*, (12.6 ± 3.8 g); razor clam, Solenidae, (6.4 ± 1.9 g); decussate venus, *Venerupis decussata*, (5.4 ± 1.7 g); and oyster, *Ostrea* spp. All species except oyster were present throughout the midden; oyster was present in two levels only in very low frequency. Shell and syphon fragments of marine gastropods (Prosobranchia), and acorn barnacles (*Balanus* spp.) of a wide range of sizes were present throughout the midden in low frequencies (means 2.1 ± 2.5 g and 4.6 ± 3.5 g respectively). Sea urchin (Echinoidea) was represented by two spine fragments only (Tables 7 and 8).

Of the shellfish present in the midden, *C. edule*, *S. plana*, *M. edulis*, Solenidae, and *V. decussata* appear to have been the more important food sources (Table 9). Furthermore, both *S. plana* and Solenidae are under-represented, since during analysis in most cases the hinges only of these bivalves were weighed and counted, the remainder of the valve being too fragmentary and lacking in diagnostic features for accurate identification. Marine gastropods and barnacles, although present in low frequencies, are likely to be overrepresented in terms of frequency determinations by weight. The shell and particularly the syphon fragments of the larger gastropods are thicker and heavier than most other shells, while many of the smaller barnacles were probably brought to the site attached to molluscs or rocks.

In Figure 5, the frequency by weight of the five major shellfish species is presented in the form of standard scores (Z score), with the curve representing the deviation from the mean in units of standard deviation (*cf.* Shennan 1988:105). Unidentified shell from both <2 mm and >2 mm fractions of bulk samples is also represented. In most cases, shell frequency decreases quite abruptly in the upper level (<125 cm bs) of *in situ* deposits. This fact, together with the reworking of midden deposits in the colluvial overburden, supports the view that the midden has been truncated as the result of ploughing (*cf.* Schiffer

Table 8. Pandeiro test unit F7: shellfish taxa, >2 mm fraction of 1 litre bulk samples.

PHYLUM/ Subphylum	Class	Suborder (-a)/ Family (-ae)	*Spp. et gen.*	(Key)
MOLLUSCA				
	Gastropoda		Spp. et gen. indet.	(Gas)
	Bivalvia			
		Mytilidae	*Mytilus edulis*	(Myt)
		Ostreidae	*Ostrea* spp.	(Ost)
		Cardiidae	*Cerastoderma edule*	(Cer)
		Veneridae	*Venerupis decussata*	(Ven)
		Semelidae	*Scrobicularia plana*	(Scr)
		Solenidae	Spp. et gen. indet.	(Sol)
Crustacea				
	Cirripedia			
		Balanidae	*Balanus* spp.	(Bal)
	Malacostra			
		Pleocyemata	Spp. et gen. indet.	(Ple)
ECHINODERMATA				
	Echinoidea		Spp. et gen. indet.	(Ech)

Table 9. Pandeiro test unit F7: identifiable shellfish, >2 mm fraction of 1 litre bulk samples (% weight by level).

Lev	Cer	Scr	Myt	Sol	Ven	Ost	Gas	Bal	Ech	Ple
120	51.4	19.1	8.7	11.1	3.9		0.9	4.9		
125	32.4	34.3	12.9	8.2	6.6		2.9	2.7		
130	43.8	22.3	18.2	7.8	4.1	0.4	0.1	3.3	+	
135	50.9	19.7	10.9	5.5	6.7	1.0	2.6	2.3		0.3
140	47.9	16.7	13.6	2.4	7.1		8.7	3.6		
145	45.1	15.0	19.1	4.7	5.1		1.5	9.4	+	
150	31.1	20.4	15.0	8.8	9.3		0.1	15.1		0.1
155	33.5	19.1	19.1	16.4	8.0		1.8	1.8		
Mean	42.1	20.8	14.7	8.1	6.4		2.3	5.4		
SD	7.9	5.5	3.6	4.0	1.8		2.6	4.3		

Note: See Table 8 for key to taxa.
+ = present.

Table 10. Pandeiro test unit F7: shellfish, <2 mm and >2 mm fractions of 1 litre bulk samples (weight in grams).

Level	Cer	Scr	Myt	Sol	Ven	Oth	U>2	U<2
110	11.5	3.2	2.0	2.0	1.6	0.6	85.7	4.0
115	18.4	6.7	2.1	2.3	1.5	2.3	107.3	4.8
120	34.4	12.8	5.8	7.4	2.6	3.9	131.7	7.6
125	29.7	31.4	11.8	7.5	6.0	5.2	251.8	11.1
130	42.9	21.9	17.9	7.7	4.0	3.8	239.2	14.8
135	50.1	22.8	12.7	6.4	7.8	6.9	290.7	12.4
140	45.2	15.8	12.8	2.3	6.7	11.6	175.8	9.9
145	43.8	14.6	18.5	4.6	5.0	10.6	241.3	9.3
150	24.3	15.9	11.7	6.9	7.3	11.9	208.6	8.7
155	17.3	9.8	9.8	8.4	4.1	1.8	163.7	8.2
160	9.7	5.0	4.9	2.0	1.3	1.7	48.1	4.7
165	13.5	5.2	6.7	3.8	1.0	0.7	126.5	7.4
175	2.6	1.4	0.4	0.3			9.8	3.6
Mean	27.1	12.8	9.0	4.7	4.1	5.1	160.0	8.2
SD	16.3	8.5	5.7	2.7	2.4	4.0	81.5	3.3

Note: See Table 8 for key to taxa.
Levels 165 and 175 are 10 cm spits.

Oth combined weight of other identifiable shellfish
U>2 unidentifiable shell fragments, >2 mm fraction
U<2 unidentifiable shell fragments, <2 mm fraction (50 g samples)

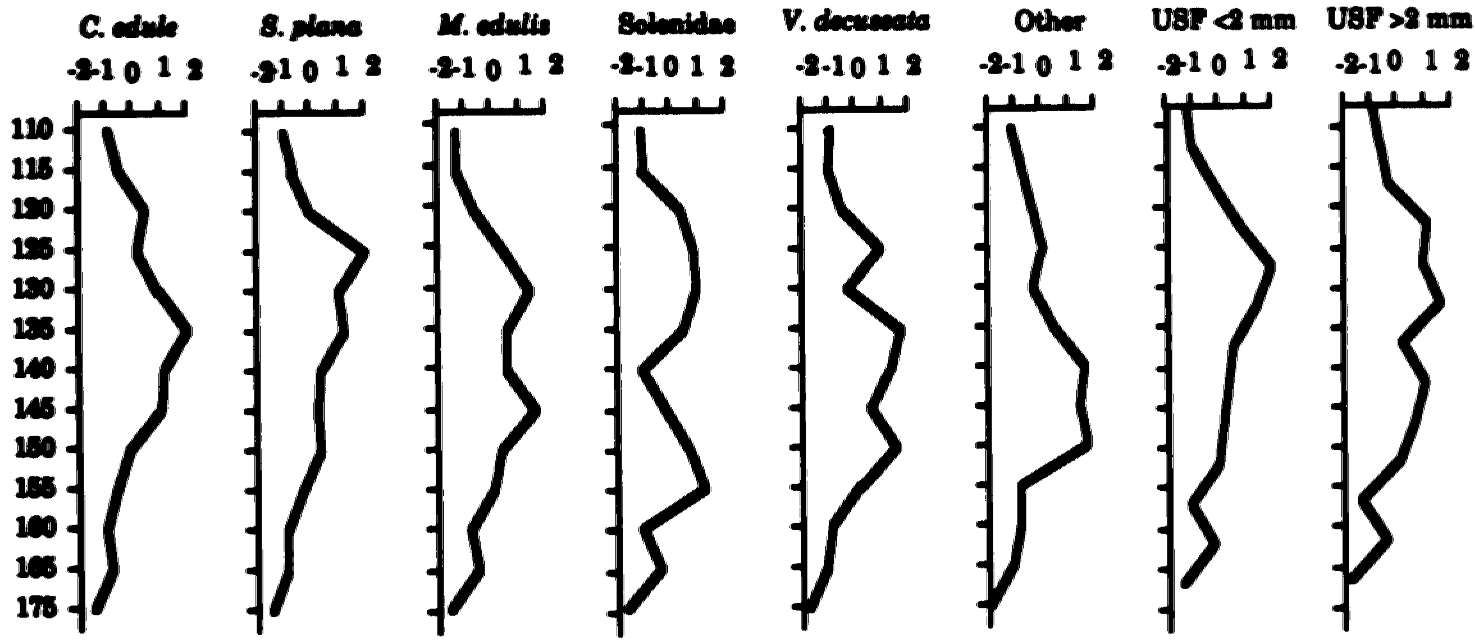

Figure 5. Pandeiro test unit F7: Z scores computed from Table 10 (*in situ* midden deposits lie between 120 cm and 155 cm bs).

1987:130). A general decrease in shell frequency is also observed in lower levels (>150 cm bs) where shell deterioration can be expected as a result of leaching (Waselkov 1987:158). Other variation in shell frequency may be attributable to the effects of taphonomic factors acting on shells of differing robustness, especially in the case of the thin-shelled razor clams (Solenidae). The curves representing unidentifiable shell fragments (<2 mm and >2 mm fractions) confirm that the most highly concentrated midden deposits lie between 125 cm and 145 cm bs. A chi-square test was employed to investigate variability in the frequency of the five major shellfish species. There was found to be no significant difference in frequency at the .05 level of significance (observed x^2 value: 39.44; degrees of freedom: 28; critical x^2 value at the .05 level of significance: 41.3371).

Discussion

A number of geomorphological changes have occurred in the Alcabrichel drainage basin during the Holocene, including the silting-up of the main channel, and of the river mouth. The presence of intertidal molluscs in the Pandeiro midden, particularly *C. edule, S. plana*, and *V. decussata* which frequently occur together as key components of sand and mudflat ecosystems (McLusky 1981:62), suggests that the tide regularly penetrated the Ribeira de Toledo during the early Holocene. This conclusion implies that the site was located on the palaeoestuary, facilitating access to a wide range of estuarine and terrestrial resources. Moreover, the presence of mussels and barnacles on the midden, which are typical of the coast and the river mouth where salinity levels are higher (McLusky 1971:52, 1981:66; Barnes 1974), indicates that more distant resources were also exploited; and these shellfish may have been brought back to Pandeiro during the course of other activities (cf. Deith 1986:75, Shackleton 1988:36).

The limited evidence presently available does indicate that a wide range of resources was exploited by the inhabitants of the site, including large and small mammals, fish, possibly birds, and certainly shellfish; resources which are, in fact, typical of the economy of the later Mesolithic in southern Portugal. No evidence for the use of plant foods has been recovered; but limited palaeoecological reconstructions based on palynological studies do suggest that acorns, pine kernels, hazelnuts, juniper berries, and bracken roots would have been available at the time the site was occupied.

In levels 145 cm to 150 cm bs, and 150 cm to 155 cm bs of unit F7, the high frequency of rock and bone, including deer, pig, and fish; and the presence of charcoal and a higher frequency of lithic waste may be indicative of an activity area, possibly a hearth or other processing location. This feature lies at the base of the midden, resting on brown sandy deposits; and it may represent the earliest occupation of the site, dated (level 145 cm to 150 cm bs) to 7800 ± 110 bp. Immediately above the feature lie the more highly concentrated shellfish remains, which decrease in frequency fairly abruptly at ca. 125 cm bs.

These observations point to the possiblity of a single episode of site occupation. Waselkov (1987:116) notes that long, low midden deposits running parallel to the river bank may be the result of repeated occupations in the same general area, particularly since shell middens may accumulate at a rapid rate (Waselkov 1987:143). However, it was also observed that the upper part of the Pandeiro midden has been truncated by ploughing, and it is not known just how representative are the remaining *in situ* deposits of the original midden. Furthermore, the high frequency of lithic waste recovered in unit T1 compared to that recovered in F7 may indicate that several different activities were undertaken on the site. Areal excavation at Pandeiro was extremely limited; and so neither a series of repeated occupations in close proximity along the estuary, nor a more continuous and more extensive occupation of the site can, at present, be ruled out.

Certain broad similarities exist between the later Mesolithic sites of Cabeço do Pez, Poças de S. Bento, and Fiais, and Pandeiro, in terms of site location, areal extent of deposits, and faunal remains. These similarities suggest that Pandeiro may have functioned as a base camp. However, this conclusion must be considered as very tentative, pending further excavation and analysis of faunal remains (cf. Binford 1978, Legge and Rowley-Conwy 1988).

CHAPTER FIVE

SEASONALITY DETERMINATIONS ON *CERASTODERMA EDULE* LINNAEUS

Analysis of shell growth was undertaken on a sample of cockles (*Cerastoderma edule* Linnaeus) from the Pandeiro midden in order to determine the season of death. Acetate-peel replicas of shell sections were prepared, and growth structures were examined using an optical microscope. Modern specimens obtained at Cascais, located near the mouth of the River Tagus west of Lisbon, were used for comparative purposes. Additional comparative data were obtained from two reports by Figueras Montfort (1966, 1967) on the ecology and shell growth of *C. edule* on the Mino and Vigo estuaries of western Spain near the Portuguese border.

Shell Growth and Tidal Influence

The bivalve shell consists primarily of a crystalline calcium carbonate ($CaCO_3$) structure, made up of sequentially deposited layers, embedded within an organic matrix (conchiolin). The outer surface of the shell is covered by an organic horny layer (the periostracum). Shell deposition and the secretion of conchiolin is the function of the mantle, the modified body wall of the organism (Pannella 1975). In the Cardiidae, growth increments are added around the growing edge of the shell (the axis of maximum growth) and along the inner surface as far as the pallial line (Figure 6; Deith 1983a:427, Fig 3b).

Shell growth occurs during tidal immersion when the valves gape for feeding purposes and the mantle is extended around their periphery (Evans 1975:121, Richardson *et al*. 1979:201). Each tidally-deposited layer consists of two parts: a growth increment, and a finer growth line or band (Panella 1975, Figure 2; Deith 1985a, Figure 2). The growth line marks the termination of shell growth upon emersion at ebb tide (Deith 1985a:579). The period of time represented by the growth increment can be calculated if the periodicity of the

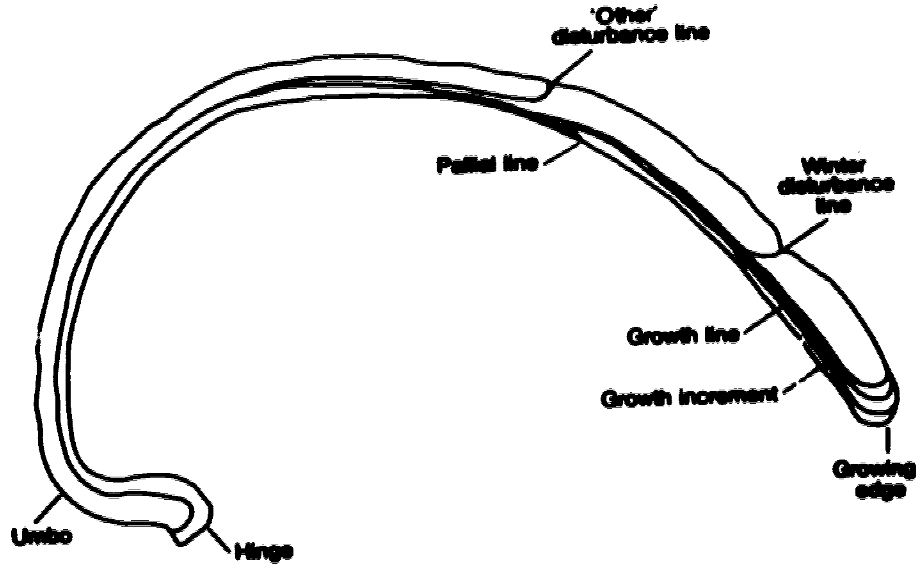

Figure 6. ***Cerastoderma edule:*** **section through axis of maximum growth (based on Deith 1983a, Figure 3b).**

local tidal establishment is known (cf. Figueras Montfort 1967:36, Deith 1985b:120), and may be presented in terms of solar days or lunar months.

The tidal establishment of the eastern Atlantic, including the Portuguese coast, is semidiurnal (U.S. Naval Oceanographic Office 1965, Clark II 1974). There are two high tides and two low tides each lunar day (24 hr 50 min), which may also be stated as one high tide per 12.42 hr period, or 1.93 high tides per 24 hr solar day. In any lunar month (28.51 lunar days, or 29.53 solar days) there are potentially fifty seven high tides (Clark II 1974, Perkins 1974, Pannella 1975). However, it should be noted that actual tidal records depart from predicted curves. Irregular oscillations occur due to air pressure changes, winds, and wave interference; and tides may also be affected locally by the bottom topography of sea shore or estuary (U.S. Naval Oceanographic Office 1965:1, Pannella 1975:274).

In the eastern Atlantic, spring tides of maximum vertical range occur with a periodicity of approximately 14.77 solar days, at new moon and full moon when sun, moon, and earth are in opposition. Neap tides of minimum vertical range occur with a similar periodicity at the first and third quarter of the moon when sun, moon, and earth are in quadrature (U.S. Naval Oceanographic Office 1965; Perkins 1974, Figure 3.5). Wide growth increments are deposited during maximum immersion at spring tide high water, while narrower increments may be deposited during a briefer period of immersion at neap tide high water. Some increments may be missed entirely on high-shore individuals located above the neap tide high water mark (HWNT) during neap tides when tidal oscillations are at a minimum. Therefore, regular growth increment patterning is more likely to occur on high-shore individuals than on those located on the lower shore below the neap tide high water mark. (Richardson *et al.* 1979). The location of the individual on the shore in relation to high tide levels is the determining factor of the growth pattern expressed on the shell, since the pattern itself is the product of a cycle of tidal immersion and emersion (Whyte 1975:183).

Growth Rate

A wide range of environmental factors influence molluscan shell growth, including the substrate type, salinity level, food supply, level of dissolved oxygen, turbidity, temperature, and population density (Lutz and Rhoads 1980:226). In the case of *C. edule* specifically, researchers have identified several major factors which affect the rate of growth. Extended periods of emersion, to which high-shore cockles are likely to be subjected during periods of minimum tidal range, result in growth stunting (Fiqueras Montfort 1967:368, Farrow 1972, Richardson *et al.* 1979). The nature of the substrate further influences the rate of shell growth (Fiqueras Montfort 1967:368). Farrow (1971:577) observed a 25% higher growth rate in sand than in mud on the Thames estuary in southeastern England. Seasonal differences in growth rates are also recognised (Craig and Hallam 1963:746). In temperate and northern zones, minimum growth, and ultimately growth stoppage, occurs during winter months; while maximum growth rates tend to occur during spring and early summer (Fiqueras Montfort 1967, Farrow 1971, Richardson *et al.* 1980). On the Vigo estuary, Fiqueras Montfort (1967) further observed that early spring spat grew rapidly, achieving a mean height of 31 mm in 6 to 8 months; while late summer spat exhibited a slower growth rate, reaching a mean height of 31 mm after 14 months. The age of the individual also affects the growth rate; faster growth occurs in earlier years, and slower growth during later life (Craig and Hallam 1963:746).

Growth Disturbance

A number of periodic or random events may interupt shell growth. Periodic events include winter growth stoppages due to lower temperatures, and equinoctial or solstitial disturbances due to lunar- or solar-influenced changes in tidal oscillations (Fiqueras Montfort 1967, Farrow 1971, Clark II 1974, Perkins 1974, Whyte 1975, Deith 1983a). Random events include storms, spawning, and attacks by predators (Barker 1964, House and Farrow 1968, Rhoads and Pannella 1970, Clark II 1974). Winter growth stoppage is marked by a heavy

Plate 1. Winter growth disturbance (x240).

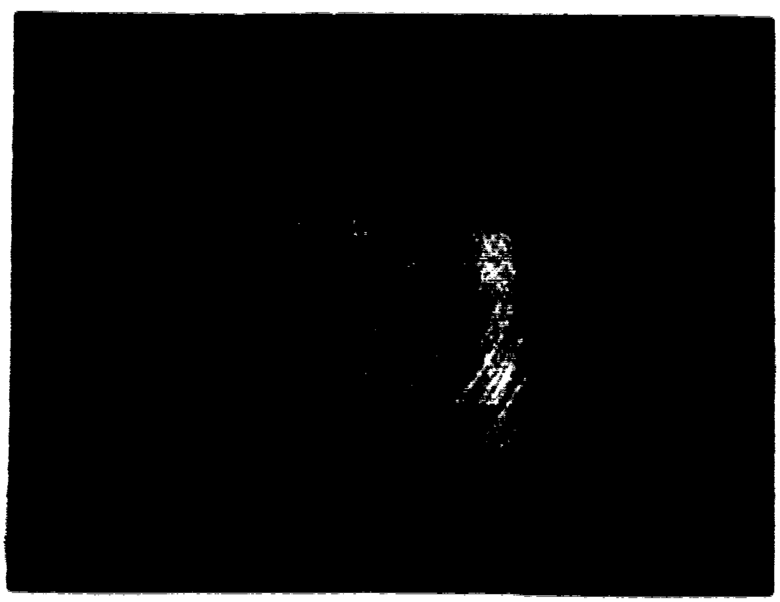

Plate 2. 'Other' growth disturbance (x240).

disturbance line extending back into the shell structure, and a groove on the outer surface of the shell; growth reduction before, and growth resumption after stoppage is gradual (Plate 1)(cf. Ham 1976:69, Cerrato 1987:176). Other disturbances are also marked by a distinctive line; but their more sudden appearance may result in a narrow groove on the shell surface, with regular growth increments on either side of the event (Plate 2; Farrow 1972, Plates 8, 9, 10).

It is difficult to differentiate between winter and 'other' growth disturbance when examining the surface sculpture of the shell, and any observed evidence of growth disturbance may be mistakenly attributed to winter growth stoppage (Pannella and MacClintock 1968:71). However, when a cross-section or acetate-peel replica of the shell is examined, the above-noted differences in growth prior to, and following the event can be observed; and winter or 'other' growth disturbance may be differentiated (cf. Rhoads and Panella 1970, Ham and Irvine 1975).

<u>Preparation of Acetate-Peel Replicas</u>

The preparation of acetate-peel replicas was adapted from methods described by Rhoads and Pannella (1970:146-7), Farrow (1971:573-4), Richardson *et al*. (1979:278), Kennish *et al*. (1980), Deith (1983a:428), and Cerrato (1987:176). Six procedural steps were undertaken involving cleaning, sectioning, embedding, grinding and polishing, etching, and replicating.

1) Cleaning. Archaeological specimens to which midden matrix and other debris adhered were placed in an ultrasonic cleaner with water and detergent for ten minutes, and were then cleaned with toothbrush and dental probe under running water. Comparative specimens were boiled in a 5% solution of hydrogen peroxide (H_2O_2) to remove soft tissue.

2) Sectioning. Valves were sectioned radially from umbo to growing edge near the line of the mid rib, the axis of maximum growth, using a Buelher Isomet 11-1180 low-speed saw and 4"

diamond wafering blade. Care was taken to avoid cutting obliquely to the direction of growth in order not to exaggerate the width of growth increments (cf. Farrow 1971:573, Plate 108[2]).

3) Embedding. One half-section of each valve was embedded in Cold Cure epoxy resin. The cut section was positioned near the surface to facilitate grinding and polishing.

4) Grinding and Polishing. Cut sections of valves were ground to the line of the mid rib in order to expose the axis of maximum growth, using lapidary wheels with the following sequence of grit sizes: 320, 400, 600. The sections were then polished on lapidary wheels using 6μ diamond powder, followed by 0.05μ alumina powder. Shell surfaces were thoroughly cleaned with soap and running water between each stage to avoid contamination by larger particles (cf. Kennish *et al.* 1980:599-600).

5) Etching. Valve sections were immersed in a weak solution of hydrochloric acid (HCl) in order to enhance details of growth increments (cf. Farrow 1971:574). A series of tests was undertaken to determine the optimum etching time (cf. Rhoads and Pannella 1970:146), which proved to be a one-minute immersion in 1% solution of HCl (one part concentrated [38%] HCl to one hundred parts distilled H_20). Each sample was then thoroughly rinsed in water to wash away the acid, and set aside to air-dry.

6) Replicating. Etched valve sections were flooded with acetone; and a piece of acetate film, backed by a glass slide, was firmly applied to the surface. A small weight was placed on top for ten minutes to ensure a firm contact until the acetone evaporated. The acetate-peel replica was then removed and mounted between two glass slides.

Acetate-peel replicas of comparative and archaeological specimens were examined by means of optical microscopy at magnifications of x60, x150, and x600. Tidal growth increments were counted, where possible, between growing edge (GE) and winter disturbance line (WDL), where present, or 'other' disturbance (ODL)(Figure 6). Specimens were measured using sliding calipers, and all measurements were converted to the nearest one-tenth of a millimetre.

Analysis of the Comparative Sample

A comparative sample of one dozen fresh cockles was obtained in Cascais on 10th June 1989. However, only seven specimens were available for analysis since edge damage was observed on the remainder. All seven specimens display one winter disturbance line (Table 11), indicating that death ocurred during the second year of growth. Three specimens also display one 'other' growth disturbance line during the first year of growth prior to winter growth stoppage.

Figueras Montfort (1967) observed up to three annual disturbance lines on specimens from the Vigo estuary. He noted that a heavy winter disturbance line was laid down in January-March as a result of growth stoppage caused by low temperatures. A light disturbance line may occur in June-July at the time of the summer solstice (ca. 21st June), when spring tides are at minimum oscillation, causing high-shore disturbance. A medium disturbance line may be laid down in September-October at the time of the autumnal equinox (ca. 21 September), when spring tides are at maximum oscillation, and are more likely to affect the growth of individuals on the lower shore (Figueras Montfort 1967:375-7, Figures 2 and 3; Farrow 1971:67-8; Perkins 1974:49-50; Clark II 1974).

Shell Height

The shell height of the comparative sample (Table 11), measured from the umbo to the growing edge, ranges from 21.2 mm to 25.5 mm, with a mean height of 23.4 ± 1.9 mm. The first year growth range (umbo to winter disturbance line) is 16.7 mm to 23.8 mm, with a mean of 21.1 ± 3.0 mm. Two size-groups are present: specimen nos. 1 to 5, with a first year growth range of 20.2 mm to 23.8 mm and a mean of 22.9 ± 1.4 mm; and specimen nos. 6 and

Table 11. Comparative sample: growth disturbance.

No.	Ht.	WDL	Wmm	WGI	WSD	ODL	Omm	OGI	OSD
1	25.5	1	23.7	180	93.3	1	22.2	80	41.5
2	25.1	1	23.8	198	102.6	1	19.3	113	58.5
3	25.0	1	23.6	204	105.7	1	21.2	83	43.0
4	24.2	1	23.1	200	103.6	0			
5	21.4	1	20.2	*87*	*45.1*	0			
6	21.2	1	16.7	176	91.2	0			
7	21.2	1	16.7	165	85.5	0			
Mean	23.4		21.1	187.2	97.0		20.9	92.0	47.7
SD	1.9		3.0	14.3	7.4		1.2	14.9	7.7

Note: Specimen no. 5 data are not included in the calculation of mean and standard deviation of WGI and WSD since this individual appears to be anomalous.

Ht. shell height (umbo-growing edge) in mm
WDL winter disturbance lines
Wmm umbo-WDL in mm
WGI growth increments WDL-GE
WSD solar days WDL-GE
ODL 'other' disturbance lines
Omm umbo-ODL in mm
OGI growth increments ODL-WDL
OSD solar days ODL-WDL

7, each of which attained a height of 16.7 mm during their first year. Figueras Montfort also recognizes two size-groups among the Vigo population, which he identifies as two separate spat-falls during the spawning season (April-May to September), one spat settlement occurring in the spring and the other in the autumn (Figueras Montfort 1967:370). Specimen nos. 1 to 5 may represent an earlier spat settlement during the 1988 spawning season, and specimen nos. 6 and 7 a later settlement during the same season.

Tidal Growth Increments

Tidal growth increments were counted between the growing edge and the winter disturbance line, which represents the period from the time of growth resumption in 1989 (following winter 1988-9 growth stoppage) to the time of death on 9th or 10th June. The number of increments ranges from 165 to 204, with a mean of 187.2 ± 14.3[1] (Table 11). Generally, tidal growth increments appear fairly uniform; and no grouping of increments was observed. This fact suggests that the specimens are from the lower shore, where they would have been immersed regularly at high water by both spring and neap tides (Farrow 1972, Plate 8[C]; Deith 1986:74). Specimen nos. 1 to 3 display one 'other' growth disturbance line prior to winter growth stoppage. The number of tidal growth increments between 'other' disturbance line and winter growth line ranges from 80 to 113, with a mean of 92.0 ± 14.9.

In Table 11, the number of tidal growth increments counted between growing edge and winter growth disturbance line has been converted to solar days (WSD) using the following formula:

$$\frac{\text{(no. of growth increments)}}{\text{(potential no. of high tides per solar day)}} \quad [1]$$

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[1] Specimen no. 5 is not included here since this individual appears to be anomalous.

Since there are potentially 1.93 high tides per solar day on the Portuguese coast; this calculation gives a range of 85.5 to 105.7 solar days, and a mean of 97.0 ± 7.4. Therefore, following winter stoppage, shell growth resumed between 24th February (specimen no. 3) and 16th March (specimen no. 7). The mean date of growth resumption is 5th March, and the statistical range represented by one standard deviation is 23th February to 13th March.

Alternatively, the number of tidal growth increments counted between growing edge and winter growth disturbance can be converted to lunar months using the following formula:

[II]

$$\frac{\text{(no. of growth increments)}}{\text{(potential no. of high tides per lunar month)}}$$

There are potentially fifty seven high tides per lunar month on the Portuguese coast; and so this calculation gives a range of 2.9 to 3.6 lunar months, with a mean of 3.3 ± 0.3. (Figure 7). Lunar months can be converted to solar days using the following formula:

[III]

(no. of lunar months)(no. of solar days per lunar month)

There are 29.53 solar days per lunar month; therefore this calculation gives a range of 85.6 to 106.3 solar days and a mean of 97.5 ± 7.5, indicating that shell growth resumed between 23rd February (specimen no. 3) and 16th March (specimen no. 7). The mean date of growth resumption is 4th March, and the statistical range represented by one standard deviation is 22rd February to 12th March. It can be seen that statistically identical results are obtained whether calculating directly from tidal growth increments to solar days, or indirectly through lunar months.

The above calculations indicate that following winter stoppage, the resumption of shell growth is predicted during a period of approximately three weeks between late February and mid-March. The resumption of shell growth coincides with the occurrence of warmer air temperatures in the Lisbon area. During December and January, mean monthly temperatures are 10.5°C and 10.3°C respectively; in February the mean rises to 11.3°C, and in March to 12.6°C (Table 2).

Winter Growth Stoppage

As noted above, three specimens displayed 'other' growth disturbance some time prior to winter growth stoppage. The number of growth increments observed between 'other' disturbance line and winter disturbance line can be converted to solar days (using formula [II]) giving a range of 41.5 to 58.5 solar days and a mean of 47.7 ± 7.7, or to lunar months (using formula [III]) giving a range of 1.4 to 2.0 lunar months and a mean of 1.6 ± 0.3 (Figure 7). Pre-winter growth is displaced, and appears more recent than it really is since tidal increments are lost during the period of winter growth stoppage (Richardson *et al*. 1980:986). In the Lisbon area, the mean monthly air temperature drops significantly between November and December from 13.7°C to 10.5°C (Table 2). It is likely that growth stoppage coincides with the lower December temperatures, since the rate of chemical reaction decreases with temperature, while the solubility of carbon dioxide (CO_2) increases (Whyte 1975:182), thus inhibiting the precipitation of calcium carbonate ($CaCO_3$) and the formation of shell. It has been observed (above) that the resumption of shell growth coincides with the warmer temperatures of February-March. If winter growth stoppage commences at the beginning of December, then the 'other' growth disturbance line observed on specimen nos. 1 to 3 would have been laid down in October; i.e., 47.7 ± 7.7 solar days prior to winter growth stoppage (Figure 8). This coincides with growth disturbance predicted for low-shore individuals at the time of the autumnal equinox (Figueras Montfort 1967:375-7, Farrow 1971:67-8).

<u>Analysis of the Archaeological Sample</u>

A sample of twenty undamaged valves from level 130 cm to 135 cm bs of unit F7 was used in the analysis. A limited number of specimens was available due to growing-edge damage on

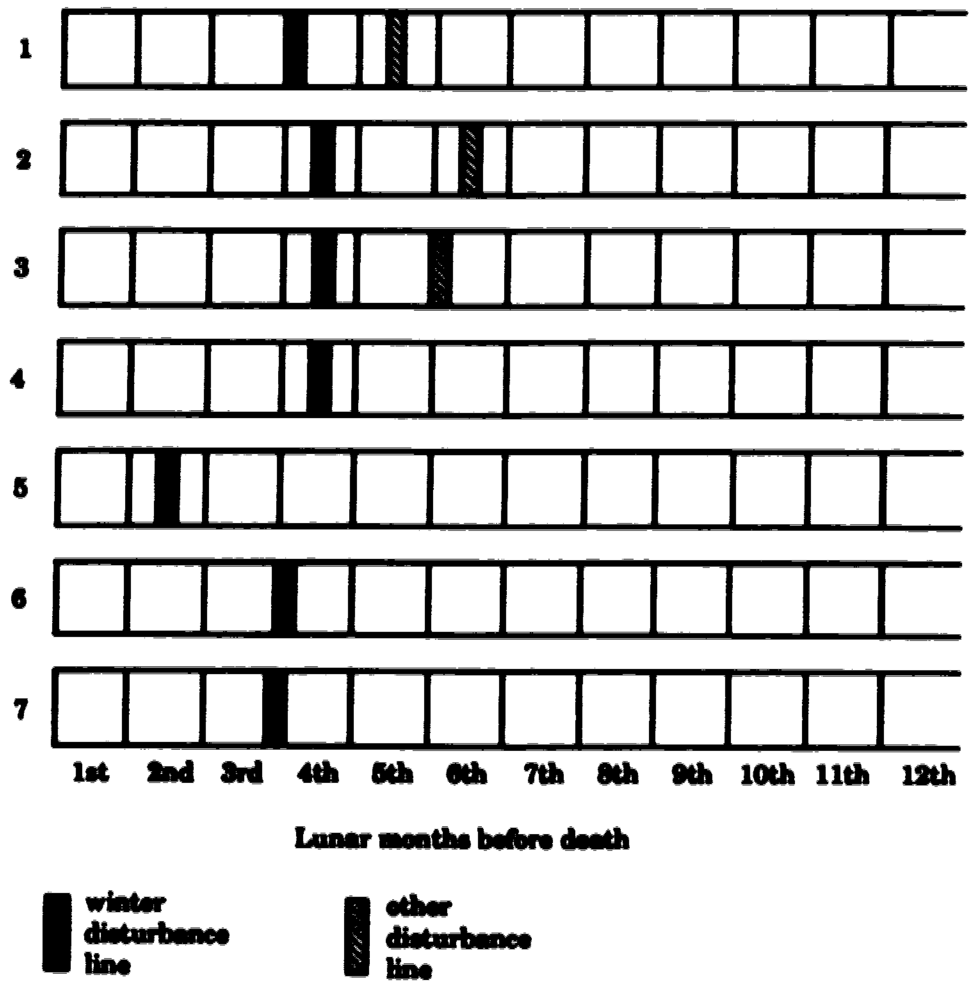

Figure 7. Comparative sample: growth disturbance (growing edge at left).

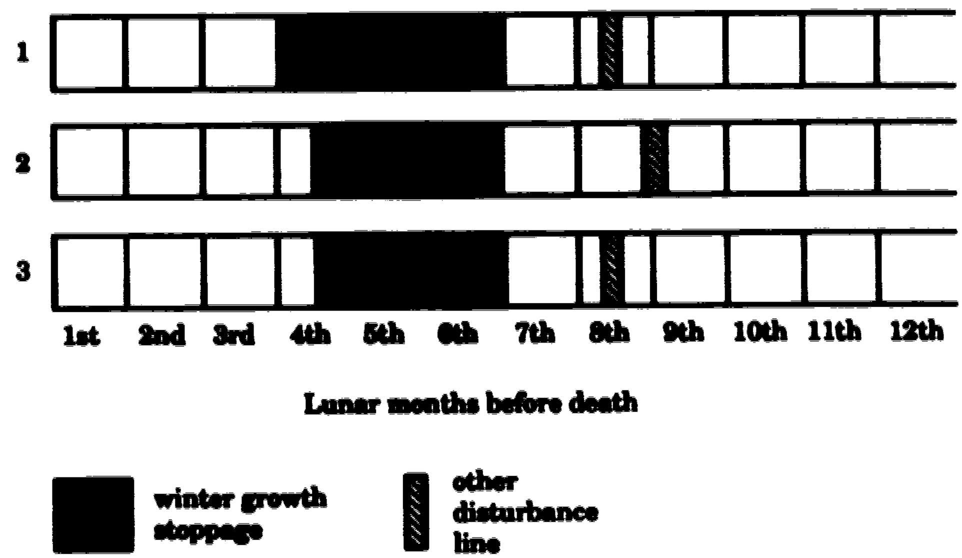

Figure 8. Adjusted comparative sample: growth disturbance (growing edge at left).

many otherwise-intact cockles, and to the fragmentary condition of much of the material. Evidence of winter growth disturbance was observed on four individuals only (Table 12). Specimen nos. 1 to 4 each exhibit one winter growth disturbance line, and specimen no. 1 displays one 'other' disturbance line between growing edge and winter disturbance line. Additionally, specimen nos. 5 to 9 each exhibit one 'other' growth disturbance line.

Shell Height

The shell height of the sample ranges from 18.0 mm to 23.4 mm, with a mean height of 20.5 ± 1.9 mm. The first year growth range of specimen nos. 1 to 4 is 8.4 mm to 16.4 mm, with a mean of 12.2 ± 3.0 mm. Clearly, first year growth in the archaeological sample is significantly less than that observed in the comparative sample (range 16.7 mm to 23.8 mm, mean 21.1 ± 3.0 mm). A number of factors which influence shell growth have been identified. It is suggested here that the archaeological sample represents a high-shore colony in which growth stunting has resulted from extended periods of emersion during high tides of minimum range, and this hypothesis will be discussed below.

Tidal Growth Increments

In specimen nos. 1 to 8, tidal growth increments form regular groups or patterns, each group consisting of a series of growth increments which become progressively wider, then progressively narrower. The groups are bracketed by distinctive growth lines, although the surface sculpture of the shell is not usually indented.

Tidal growth increments were counted between growing edge and winter disturbance line (where possible) in specimen nos. 1 to 4, and between growing edge and 'other' disturbance line in specimen nos. 5 to 9. In specimen nos. 1 to 3, growth increments immediately following the winter growth disturbance line are very narrow and could not be distinguished individually; however, it was observed that these growth increments also occur in groups bracketed by distinctive growth lines. The range of growth increments per group is

Table 12. Archaeological sample: growth disturbance.

No.	Ht.	WDL	Wmm	WGI	WLM	ODL	Omm	OGI	OLM
1	23.4	1	16.4	ic	8th	1	20.9	146	3rd
2	19.7	1	10.7	ic	7th	0			
3	18.1	1	8.4	ic	7th	0			
4	20.4	1	13.4	281	6th	0			
5	21.0	0				1	20.4	54	2nd
6	20.1	0				1	18.6	90	2nd
7	19.7	0				1	18.2	72	2nd
8	18.1	0				1	17.5	63	2nd
9	20.4	0				1	20.1	15	1st
10	24.9	0				0			
11	23.8	0				0			
12	22.8	0				0			
13	21.3	0				0			
14	20.7	0				0			
15	20.3	0				0			
16	19.8	0				0			
17	19.2	0				0			
18	18.8	0				0			
19	18.7	0				0			
20	18.0	0				0			
Mean	20.5		12.2				19.3	73.3	
SD	1.9		3.0				1.2	39.7	

Ht. shell height (umbo-growing edge) in mm
WDL winter disturbance lines
Wmm umbo-WDL in mm
WGI growth increments WDL-GE
WLM lunar month WDL-GE
ODL 'other' disturbance lines
Omm umbo-ODL in mm
OGI growth increments ODL-GE
OLM lunar month ODL-GE
ic incomplete count of indistinct growth increments

30 to 60, and the mean is 50.8 ± 8.5 (excluding group 1, the group closest to the growing edge, which may be incomplete) (Table 13).

Growth Increment Grouping

Growth increment patterns or groupings have been observed on a number of intertidal bivalve species (Berry and Barker 1975, Lutz and Rhoads 1980, Rhoads and Pannella 1970), including the Cardiidae, and are attributed to the changing tidal cycle that is regularly repeated each lunar month (Evans 1972, 1975; Farrow 1972; Richardson *et al.* 1979). In a study of the basket cockle, *Clinocardium nuttali*, from the Oregon coast of the United States, Evans (1972, Figure 1; 1975, Figure 1B) observed a fortnightly pattern of shell growth increments. The pattern is influenced by the peculiar nature of the mixed semidiurnal tides of the eastern Pacific, where the two high and two low tides each day are of unequal amplitude. The difference in amplitude of low waters, being greatest during periods of spring tides occurring every two weeks at the time of new and full moon, results in a regular pattern of wide (spring tide), and narrow (neap tide) growth increments (Evans 1972:417; Pannella 1974, Fig 3.5). Farrow (1972) also observed tidal patterning on specimens of *C. edule* from the Dyfed coast of South Wales, an area which is subject to the eastern Atlantic semidiurnal tidal regime. A fortnightly pattern resulted from the fact that cockles from higher shore levels would not be immersed at high water neap tides. The pattern produced is one of wider growth increments during spring tides, and narrower increments, or even brief periods of growth stoppage, during neap tides (Farrow 1972:67-68, Figures 6 and 7; see also Richardson *et al.* 1979). A similar fortnightly pattern of tidal growth increments was observed on cockles (*C. edule*) from high-shore levels on the Fife coast of eastern Scotland by Deith (1986:74, Figure 5).

Researchers also predict a monthly pattern of growth (Rhoads and Pannella 1970, Clark II 1974, Berry and Barker 1975, Lutz and Rhoads 1980). The actual alignments of sun, earth, and moon are different at each phase of the moon since these bodies have motions of

Table 13. Archaeological sample: growth increment groups.

No.	1	2	3	4	5	6	7	8	Mean	SD
1	38	60	48/D	56	40	ic	ic	ic/W	51.0	7.7
2	22	58	60	36	42	ic	ic/W		49.0	10.2
3	55	58	52	52	48	ic	ic/W		52.5	3.6
4	25	45	60	42	59	55/W			52.2	7.4
5	25	30/D								
6	14	58/D								
7	25	54/D								
8	10	53/D								
9	15/D									
All									50.8	8.5

Note: Group 1 growth may be incomplete and the data are not included in the calculation of mean and standard deviation.

/W winter disturbance line
/D 'other' disturbance line
ic incomplete count of indistinct growth increments

different periods, with the result that the tidal ellipsoid varies in shape (Perkins 1974, Figure 3.5). This pattern is further complicated by the rotation and inclination of the earth, and the shape and size of the oceans (Clark II 1974:81-83). The topography of sea shore and estuary (U.S. Naval Oceanographic Office 1965:1), and of river channel (Figueras Montfort 1966) will also contribute to local variations in the tidal establishment. Consequently, new moon and full moon spring tides, and first and third quarter neap tides are unlikely to be of completely equal range (Fiqueras Montfort 1966, Figure 2; Clark II 1974); and therefore certain high-shore cockles may not be immersed at high water during neap tides of minimum oscillation occurring once per lunar month.

The potential number of tides, and therefore tidal growth increments, per lunar month is fifty seven; however, since tidal increments may be missed during neap tides of minimum oscillation, the actual number of growth increments per monthly group is likely to vary. A chi-square test was employed to investigate variability in the frequencies of observed growth increment groups in specimen nos. 1 to 4 (Table 13; groups 2 to 5 were used in the test). At the .05 level of significance, there was found to be no significant difference between groups (observed x^2 value: 14.119; degrees of freedom: 9; critical x^2 value at the .05 level of significance: 16.9190). A second chi-square test was used to investigate variability between the mean number of growth increments observed in the same specimens (Table 13), and the potential number of high tides per lunar month (i.e., 57). There was found to be no significant difference at the .05 level of significance (observed x^2 value: 2.465; degrees of freedom: 3; critical x^2 value at the .05 level of significance: 7.81473).

The growth increment groupings observed on the archaeological sample are consistent with the lunar monthly pattern predicted for certain high-shore individuals, and the distinctive growth lines coincide with periods of minimum tidal oscillation when growth increments may be missed. Therefore, it is proposed that the period between winter growth stoppage and the death of the individual can be calculated by counting growth increment groups/lunar months, even though a complete count of tidal increments is not possible in all specimens (cf. Cerrato 1987:177)(Figure 9).

Season of Death

In the case of specimen no. 1, death occurred during the eighth lunar month following the resumption of shell growth after winter stoppage. Based on the comparative data discussed above, this fact would suggest that the individual died between mid-October and early November. Specimen nos. 2 and 3 died during the seventh month, and specimen no. 4 during the sixth month following growth resumption; i.e., mid-September to early October, and mid-August to early September respectively.

One 'other' disturbance line was observed on specimen no. 1, which occurred during the fifth lunar month following growth resumption; i.e., mid-July to early August. While this disturbance line does occur near the time of the summer solstice when growth disturbance is predicted for high-shore individuals (Figueras Montfort 1967:375-7, Perkins 1974:49-50), it may simply represent a random or individual event since no similar disturbance was observed on specimen nos. 2 to 4. However, specimen nos. 5 to 9 also exhibit one 'other' disturbance line occurring within one (specimen no. 9) or two (specimen nos. 5 to 8) lunar months of death (Figure 9). In the absence of winter growth lines it is not possible to determine with any certainty when the disturbance occurred; however, if death occurred during the same season as specimen nos. 1 to 4, then solstitial tides could be expected to disturb shell growth at this point.

The majority of specimens (nos. 10 to 20) revealed no evidence of winter or other growth disturbance; however, the grouping of tidal growth increments was observed[1]. This pattern may be indicative of a first year group which died during the late summer or autumn prior to winter growth cessation. However, hardy individuals (cf. Farrow 1971:576) may grow

[1] Deith (in press) also reports the lack of a complete annual cycle on many specimens from the Sado middens.

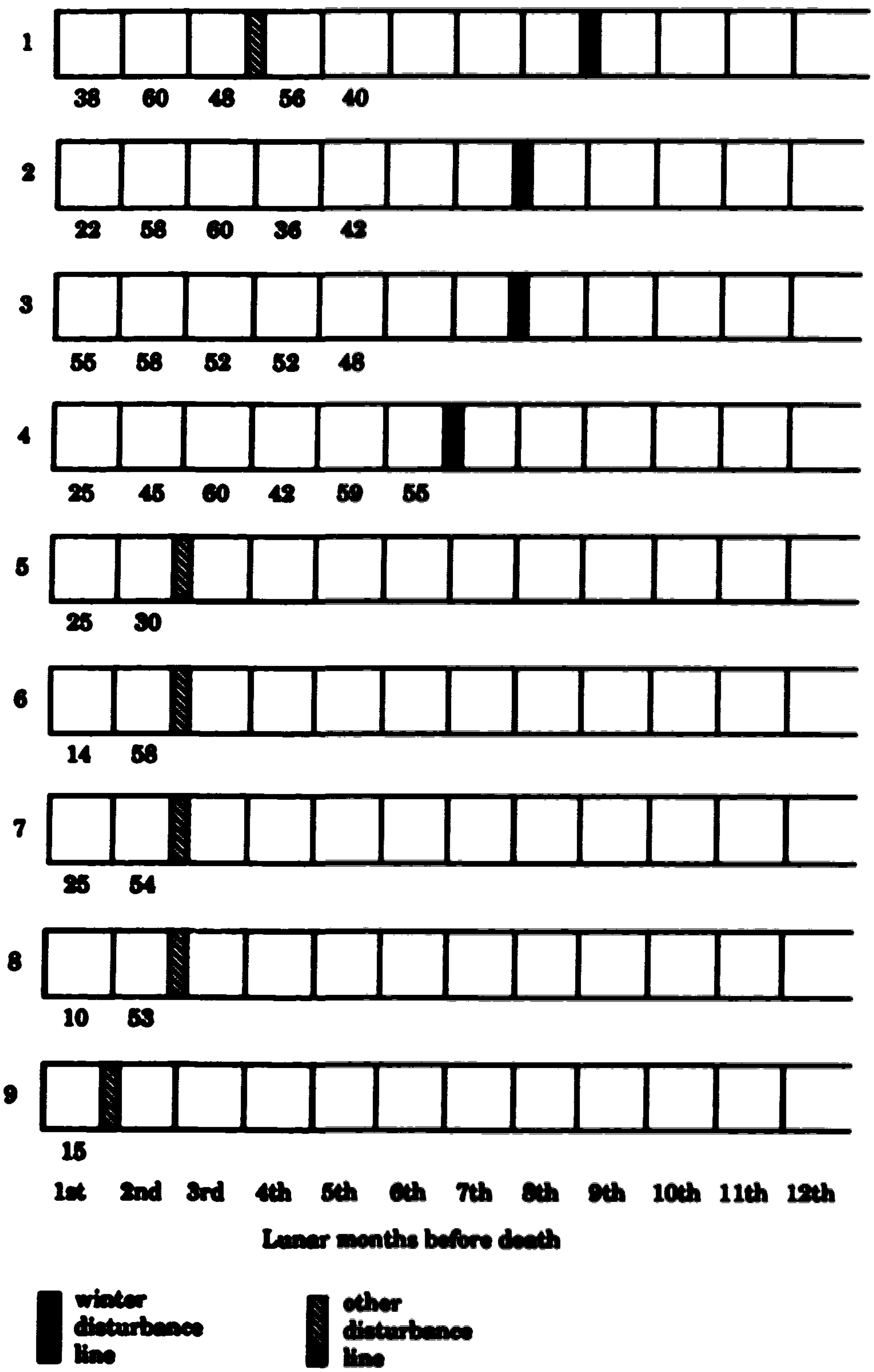

Figure 9. Archaeological sample: growth disturbance (growing edge at left).

continuously, especially during their first year, or in favourable environments; and it is not possible to determine the season of death in the absence of a recognisable point in the annual growth sequence (Deith 1985b:121).

Discussion

Deith identifies three fundamental requirements for seasonality determinations based on shell growth analysis: the lines between increments must be visible, they must have chronological significance, and there must be a seasonal marker from which to measure final growth (Deith 1985b:121). Previous attempts to determine seasonality based on the analysis of tidal growth increments in Portuguese cockles have proved unsuccessful due to the difficulty in differentiating between winter growth disturbance lines and other growth disturbance events, and the inability to identify a datable point in the annual growth sequence to which subsequent growth increments could be related (Deith n.d., Lentacker *in litt.* 18.i.89).

It has been demonstrated here that winter growth disturbance lines can, in fact, be identified on molluscs from Portuguese waters; and seasonality determinations based on growth analysis can be made. It has also been shown that seasonality determinations may be possible, based on the interpretation of cyclical patterns of growth and growth disturbance, even when individual tidal growth increments are not distinguishable. Moreover, seasonal determinations based on regular increment groups, where present, are more reliable than determinations made on counts of individual tidal increments, since individual increments may be missed, and thus the commencement of growth following winter stoppage is likely to appear more recent. Specimen no. 4 (Table 12) provides an illustration: a count of growth increment groups between growing edge and winter disturbance line indicates that the animal died during the sixth lunar month following growth resumption; however, a count of individual tidal increments (281) would indicate the fifth month (using formula [II]).

The analyses indicate that shellfish were collected at Pandeiro between mid-August and early October. However, this finding does not exclude shellfish collection or site occupation at other times of the year, and the question of seasonal or more permanent occupation cannot be resolved on the limited evidence presently available.

The analyses also indicate that young (first or second year) cockles were collected from high-shore levels only. Larger, more succulent individuals are usually found on the lower shore; and it might be expected that this area would be exploited preferentially, particularly during late summer-early autumn when equinoctial tides expose the lowest levels of the shore (Farrow 1972:64-66, Figures 3 and 4; Deith 1986:75). The fact that only smaller, high-shore individuals were present in the archaeological sample may be indicative of over-exploitation of the resource. Alternatively, this fact may be the result of adverse micro-ecological conditions which inhibited the colonization of the lower shore by cockles (cf. Figueras Montfort 1966;578-579). However, this conclusion may also be the result of small sample size.

CHAPTER SIX

CONCLUSIONS

Two major problems relating to the mesolithic economy of southern Portugal have been identified: the poor understanding of the settlement of this area during the early Holocene; and the limited evidence of seasonality in terms of resource exploitation and site occupation. A settlement model has been proposed which identifies the Portuguese estuaries as centres of human population during the Mesolithic, and the loci of the home bases of local groups. The question of seasonal or more permanent occupation of the home bases has been discussed in terms of alternative hypotheses. A further problem has been outlined, that of difficulties experienced by researchers in attempting seasonality determinations based on growth increment analysis of intertidal molluscs from Portuguese waters.

Evidence obtained during preliminary investigations at the mesolithic site of Pandeiro lends support to the settlement model. Indications of environmental change during the later Holocene, and the presence of estuarine species in the midden deposits demonstrate that the site was located on the palaeoestuary of the Alcabrichel drainage basin. A wide range of resources was utilised by the inhabitants of Pandeiro, whose exploitation territory encompassed terrestrial, estuarine, and coastal environments (*cf.* Zilhão *et al.* 1987).

A single episode of site occupation has been suggested, based on quantitative analyses of midden deposits and visual examination of site stratigraphy. However, it was also observed that the upper levels of the original midden have been disturbed by agricultural activities; and the *in situ* deposits may not be fully representative of site activities. Moreover, areal excavation of the site was very limited. Nevertheless, similarities observed between the Pandeiro midden and other Portuguese *concheiros*, in terms of site location and extent, and the wide range of seasonally-available resources present, suggest that Pandeiro may have functioned as a base camp.

It has been demonstrated that seasonality determinations can be undertaken by means of growth increment analysis on the intertidal bivalve *Cerastoderma edule*, which is present in large numbers on many Portuguese sites dating to the early Postglacial. The analysis of cockles from the Pandeiro midden indicates that the site was occupied in mid-summer to mid-autumn. However, the sample was taken from one location only of an extensive midden, and so shellfish collection and site occupation during other seasons cannot be ruled out. The collection of shellfish during the warmer part of the year when a wide range of resources would have been available does suggest that shellfish were utilised as a regular dietary supplement, and not merely as an emergency buffer when other resources were scarce.

Bailey and Parkington (1988:9) observe that while seasonality studies may demonstrate the presence of people at a site during a particular season, it is more difficult to prove their absence. They recognise that interpretations of seasonal or more permanent site occupations may rest on indirect evidence, including the nature of structures and the variability of artifacts. Clearly, further excavation is required at Pandeiro to resolve these problems.

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