Broad spectrum diets and the European rabbit (*Oryctolagus cuniculus*): Dietary change during the Pleistocene-Holocene transition in the Dordogne, Southwestern France

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Abstract

Broad spectrum diets and the European rabbit (*Oryctolagus cuniculus*): Dietary change during the Pleistocene-Holocene transition in the Dordogne, Southwestern France

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In the Dordogne region of southwestern France, a broadening of the diet is known to have occurred toward the end of the Pleistocene, with diets heavily dependent on large ungulates being replaced by those heavily dependent on smaller species, and in particular on the European rabbit (*Oryctolagus cuniculus*). There are two main hypotheses explaining this phenomenon: first, that climate change negatively impacted large mammal populations, thus forcing humans to begin incorporating smaller vertebrate species into their diets; and second, that humans themselves negatively impacted large mammal populations, which in turn forced humans to add smaller species to their diets. In this region, however, these hypotheses are complicated by the biogeographical history of *Oryctolagus cuniculus*. Since this species was present in only very small numbers in the Périgord prior to about 13,000 years ago, its increasing presence in archaeological faunas after this time may merely reflect its abundance on the landscape.

In the research presented here, I use data from two sites in the Périgord—Moulin du Roc (Detrain et al. 1996) and Pont d'Ambon (Célérier 1998; Célérier et al. 1993, 1994)—to explore questions of how and why diets broadened at this time and in this place. I explore the two dominant hypotheses, but also consider two others: first, that the European Rabbit was not, in fact, a lower-ranked prey type; and second, that the Magdalenian was not (as is popularly believed) an "age of plenty."

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Chapter 1:

The Pleistocene-Holocene transition in the Périgord

For many, the Périgord region of southwestern France is synonymous with Upper Paleolithic archaeological sites. The abundance of large, rich, well-excavated sites Paleolithic sites in this region has led many researchers (e.g., Gordon 1988; Jochim et al. 1999; Mellars 1994; Straus 1999, 2000; Straus et al. 2000) to suggest that the Dordogne area was a refuge during climatically harsh portions of the later Pleistocene, during which hunter-gatherers developed a complex culture based on specialized reindeer hunting, and perhaps salmon fishing as well. About 13,000 radiocarbon years ago[1], however, several significant changes took place in the Périgord.

The final stages of the Pleistocene began, signaled by a 2,000 year warming period. Simultaneously, prehistoric Périgordians, who had previously focused their diets on larger prey, began adding smaller prey items—birds, fish, and most notably, rabbits—to their diets in large numbers (Altuna et al. 1991; Aura et al. 1998; Clark and Straus 1983; Straus 1991, 1992b, 1995a, 1999, 2000).

The research presented here considers the meaning of the addition of small prey—specifically, the wild European rabbit (*Oryctolagus cuniculus*)—to the diets of late Paleolithic Périgordian hunter-gatherers. Did hunters begin pursuing the European rabbit

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[1] All dates given in this work are, unless otherwise noted, in radiocarbon years before present. I have chosen to present them this way because of the difficulties in calibrating dates from the Pleistocene-Holocene transition period.

because they were living in an environment degraded by climate change? Perhaps they added this prey type to their diets because they were interested in high-quality sources of protein or other nutrients (Hockett and Haws 2002; Kornfeld 1996)? Or was rabbit-hunting the most energy-efficient hunting strategy in this particular case? I address these questions by investigating dietary change and adaptation among the Périgordian people of the Pleistocene-Holocene transition. In doing so, I attempt to reconcile the diverse views of Epipaleolithic and early Mesolithic Périgordians that have persisted since the 19th century.

Historical background: cultural deterioration at the end of the Pleistocene?

Questions about cultural adaptation at the Pleistocene-Holocene transition are not new to this century. The origins of this debate are in the late 19th and early 20th century argument about the existence and significance of a "Mesolithic," which, in Western Europe, roughly correlates with the terminal Pleistocene and the onset of the Holocene (see Table 1.1).

Today, archaeologists use the term "Mesolithic" to indicate a cultural period in the Holocene (usually just after the period of Paleolithic hunters of the Pleistocene) in which foragers adapted to changing climate by adjusting their subsistence and mobility patterns. Mesolithic subsistence is generally portrayed as incorporating smaller mammals, fish, and plant foods, as opposed to the large game focus of the European

Table 1.1. Current definitions of the stages of European prehistory (Foley 1987; Price and Feinman 2001).

Geological Era	**Cultural Period**	**Dates***	**Definition**
Pleistocene	Paleolithic	800,000-11,000 BP	begins with the first evidence for stone tools; closes at the end of the Pleistocene
Terminal Pleistocene-Holocene	Mesolithic	11,000-6,000 BP	transitional period characterized by broad-spectrum foraging and the beginnings of agriculture
Holocene	Neolithic	6,000-4,000 BP	period of first agriculturalists; continues through the beginnings of metallurgy (the Bronze age)

Paleolithic. Today, although definitions of the term vary slightly in different regions, the term "Mesolithic," and its sister term, "Epipaleolithic" (which today usually refers to the transition between the final Paleolithic and early Mesolithic) are widely used in Europe and attract little attention.

In the past, however, both the presence of hunter-gatherers in the European Holocene prior to the Neolithic spread of agriculture, and (if there were any) their overall significance in European prehistory were hotly debated. In the late 19th century, many archaeologists believed that there were no people in Europe between the end of the Pleistocene and the introduction of agriculture, and scorned the term Mesolithic on these grounds (see discussion in Clark 1980; Daniel 1950; also see Dawkins 1874; de Mortillet 1877). Later archaeologists, confronted with undeniable evidence that hunter-gatherers had occupied Europe during the early Holocene, also recognized that all the domesticates used by the Neolithic peoples of Europe originated in the Near East. They concluded that early Holocene foragers were the insignificant remnants of Paleolithic hunters (Childe 1925, 1939, 1947; Obermaier 1924), soon exterminated by Asian agriculturalists. Such archaeologists often chose to use the term "Epi-paleolithic" to describe these peoples, to emphasize their connection to Paleolithic peoples and their dissimilarity to Neolithic ones. Other archaeologists looked at the early European Holocene differently, characterizing it as a "transitional" period, wherein hunter-gatherers both adapted to post-glacial environmental change and paved the way for later Neolithic economies (Brown 1893; Burkitt 1925; Clark 1932, 1936, 1939). These researchers preferred the term

"Mesolithic," emphasizing the significance of such foragers to the course of European prehistory.

The debate began in 1865. Sir John Lubbock considered the burgeoning archaeological data from prehistoric Europe, and undertook the task of dividing it into reasonable categories. He defined "four great epochs" of prehistoric archaeology: the Paleolithic (Old Stone Age), when humans co-existed with a suite of now-extinct species; the Neolithic (New Stone Age), characterized by "beautiful weapons and instruments made of flint" and contemporary with extant plants and animals; the Bronze Age, when bronze was the primary material used in the manufacture of tools; and the Iron Age, when iron replaced bronze as the preferred material for tools and weapons (Lubbock 1865: pp. 2-3). For Lubbock, the development of tools reflected the natural evolutionary progression of cultures. Tools in the Paleolithic were crude flakes, replaced by more sophisticated stone tools in the Neolithic, replaced by the superior bronze tools, which were in turn superseded by tools of iron (Lubbock 1865).

He noted, however, that "cultural evolution" was not steady through each of these periods. In particular, Lubbock was fascinated by the sharp contrast between Paleolithic cave deposits from the Dordogne, and the megaliths from northern Europe and archaeological deposits from Swiss lakes. The difference between these, he contended, was that of cultures at two different phases of development: the first, in a barbarous phase; and the second, having progressed to a less savage state (Lubbock 1865). Although he did allow for some transition—a possible earlier phase of the Neolithic, represented in the archaeological record by Danish shell middens—Lubbock drew a sharp line between these two phases.

Lubbock's decision to exclude a "middle stone age" from his prehistoric epochs reflects the knowledge of the archaeological record of the time. No post-glacial hunter-gatherer assemblages had yet been recovered from Europe; thus, the hiatus that Lubbock observed between the Paleolithic and the Neolithic was a fairly accurate reflection of the data available to him. Such a "jump" from crude tools to agriculture was rapid "progress"—this could potentially have been difficult for Lubbock to reconcile with his cultural evolutionary theoretical standpoint. However, even with the opportunity to create a "middle" period (the Danish shell middens), he chose to keep only a "new" and an "old" stone age.

Westropp (1872) was less comfortable with a "jump" in progress; he dealt with this problem by adding a "middle stone age," or Mesolithic. Westropp's Mesolithic was a period intermediate between the completely savage Paleolithic and the more civilized Neolithic (Table 1.2). He introduced this concept to account for the assemblages that even Lubbock acknowledged as problematic (i.e., the Danish shell mounds). By 1872, such shell mounds had been found in England and Ireland as well, and were associated with wild animals that were not extinct. Like Lubbock, Westropp was a 19th century evolutionist, a firm believer in cultural progress; to fit into his theoretical paradigm, any Mesolithic period would have to be "more civilized" (i.e., more similar to 19th century

Table 1.2. Westropp's stages of the development of humans (1872).

Stage of cultural development	Stage of tool development	Types of tools	Contemporaneous fauna
Barbarous	Paleolithic	Rough flints	Mammoth Rhinoceros Cave Bear Hyena Reindeer
Hunting	Mesolithic	Flint flakes Flints chipped into shape	Red deer Wild boar Wild ox
Pastoral	Neolithic	Stone implements ground at edge Stone tools ground and polished	Sheep Ox Goat

England) than the Paleolithic, and "less civilized" than the Neolithic. Westropp thus subdivided the Stone Age into three categories: 1) the Paleolithic, encompassing the cave deposits of the Dordogne, and represented by "rough flints"; 2) the Mesolithic, when people lived by hunting extant fauna, and represented by flint flakes and chipped flint; and 3) the Neolithic, when people lived by pastoral economies and utilized ground and polished stone implements.

Although Westropp was the first to use the term Mesolithic, his definition of this period was not equivalent to today's. He accounted for sites that were clearly the remains of post-glacial foragers, containing unimpressive tools, by constructing an evolutionary scheme that defined the Paleolithic period as one of sub-human barbarism. Lubbock may have agreed that Paleolithic peoples were barbarous, but he did grant them the ability to hunt; Westropp's description of Paleolithic peoples is hardly representative of even the knowledge of that time (i.e., Lubbock 1865).

Westropp's term was not widely adopted by his colleagues (Clark 1980), but debate about the interval between the Paleolithic and the Neolithic continued. Many scholars of the late 19th century continued to consider the early Holocene to be a "hiatus" in occupation, for there was little data pertaining to this period; the assemblages that troubled Westropp could be dealt with by placing them in an "early Neolithic" or "seasonal Neolithic" category (reviews in Clark 1980; Daniel 1950; Lubbock 1865; also see de Mortillet 1877). As more and more sites were excavated, however, more assemblages intermediate in age between the Paleolithic and Neolithic, such as those excavated by Piette at Mas d'Azil (1895; 1904), were recovered. This caused problems for researchers who did not wish to challenge the status quo but needed to classify their findings. Scholars such as Piette and de Mortillet (de Mortillet 1897; Piette 1895, 1904), rather than contesting the established terminology, simply placed their assemblages in either the late Paleolithic or early Neolithic. They did, however, argue against the existence of a “hiatus” (see review in Daniel 1950; also see de Mortillet 1897; Piette 1895; Salmon 1891). Salmon (1891) even argued that Lubbock’s entire scheme should be abandoned, while Brown (1893) suggested widespread adoption of Westropp’s term “Mesolithic.”

As more and more intermediate assemblages were discovered, the term “Mesolithic” came to be used more widely. The question on which 19th century archaeologists had focused (“were there hunter-gatherers in Holocene Europe?”) was resolved, and attention moved towards the question of whether these foragers were a true “transition” between Paleolithic and Neolithic periods. The ways in which different researchers used the term Mesolithic reflected their view on this question. Obermaier, who did not support a transition period, used the term Mesolithic only to describe assemblages which "properly speaking, are post-Paleolithic and pre-Neolithic" (1924). Others felt that use of the term Mesolithic indicated a transitional cultural phase rather than a mere period of time (Brown 1893; Burkitt 1925). Many scholars interested in European prehistory still embraced an evolutionary framework based on the notion of “progress”; for these individuals, the notion of a transitional Mesolithic was difficult.

The assemblages of stone trapezes characteristic of the Mesolithic, when compared with the polished tool types and dramatic cave art of the late Paleolithic, could hardly be seen as anything but degenerate in a Victorian evolutionist framework (Childe 1925, 1939, 1947; Obermaier 1924; Price 2000a). The period between the dramatic cave art of the Paleolithic and Neolithic pastoralists was widely described as one in which people regressed, undergoing a "dark age" (see discussion in Clark 1980).

Many scholars began to abandon the Victorian evolutionary paradigms during this period; despite this, the "transition" concept of the Mesolithic was not widely embraced. Instead, new approaches to the archaeological record revised and updated the "dark age" concept of the Mesolithic. The most famous of these new approaches was the "Neolithic revolution" of V. Gordon Childe (1925; 1939; 1947).

As others had before him, Childe noted that all the domestic species used by European Neolithic agriculturalists originated in southwest Asia; this led him to argue that the Mesolithic hunter-gatherers were mere remnants of a Paleolithic way of life, soon wiped out by Neolithic bearers of civilization, who migrated from the east (Childe 1925, 1939, 1947). Mesolithic people, Childe argued, were few in number and had no real significance in European prehistory (Childe 1925). He felt so strongly that Mesolithic hunters were the degraded remnants of Paleolithic peoples that he initially refused to use the term Mesolithic, relying instead on "epipaleolithic" to emphasize the relationship of these peoples to Paleolithic hunters.

> The conclusion...then is that, though the epipaleolithic cultures do fill a gap of time and prove the continuous occupation of parts of Europe from

> the old stone age, they do not in any real sense constitute points of transition from the palaeolithic to the neolithic culture. Rather does the advent of the latter point away from northern and Western Europe just as clearly as it did in the days of the hiatus. And so really do the epipaleolithic cultures themselves. Is it not curious that, in regions such as the Danube Valley and Thessaly, where the neolithic civilization began early and where a rich continuous series of successive cultures reaching without a break to the iron age is illustrated by plentiful finds, epipaleolithic remains are non-existent? (Childe 1925: 20)

This quotation, from the first edition of Childe's *The Dawn of European Civilization*, indicates the degree to which Childe's hypotheses were influenced by lack of information; the Danube valley today is known as the home of an extraordinarily large number of Mesolithic sites (Jochim 1998). The "Neolithic revolution" hypothesis was, in part at least, a reaction to the lack of Mesolithic data available.

By the time of the writing of the third edition of *The Dawn of European Civilization*, Childe had bowed to the increasing data from the Mesolithic and adopted the term, though he qualifies: "Their remains constitute cultures that are termed mesolithic, because in time—but only in time—they occupy a place between the latest paleolithic and the oldest neolithic cultures" (Childe 1939). He did not, however, alter his fundamental hypothesis:

> In general the mesolithic cultures just described fill gaps in time and prove the occupation of parts of Europe from the glorious days of mammoth hunting. None illustrates in any sense a transition from the old food-gathering economy to a new food-producing one....Whatever part

> mesolithic folk may have formed in neolithic populations, the flocks of sheep and the seeds of grain on which the new economy was based were not carried by wind or intertribal barter, but brought by actual immigrant shepherds and cultivators. (Childe 1939: 13)

Childe's hypothesis was contested from the beginning (Burkitt 1925; Clark 1932, 1936), most notably by Grahame Clark. Clark saw the Mesolithic as an important transition period, in which people became more mobile, adapting to new climatic conditions by exploiting new aspects of their environment and also engaging in massive land clearance. He focused on human adaptation to changing environment, and, as such, he emphasized environmental factors.

> In employing this term [Mesolithic] nothing more is implied than that the Mesolithic flourished in the main between the Palaeolithic and Neolithic civilisations in point of time; it may be emphasized that it is not intended to suggest an evolutionary stage between the two. The origins of Mesolithic civilisation may be traced to the changes of environment associated with the close of the Pleistocene period, the contraction of ice-sheets and the replacement of tundra and steppe by forests in Northern Europe.... (Clark 1936: xiv)

Childe had asserted that Mesolithic people were an insignificant part of European prehistory. Clark argued the opposite: not only were Mesolithic people complex foragers, their adaptations to climatic changes lay the ground for the later process of Neolithization (Clark 1932, 1936).

In the early years of Clark's research, there was little data to support his ideas; the Mesolithic was not very well known, certainly not in comparison to either the Paleolithic or the Neolithic. Most of the available data was typological in nature; since Clark's adaptation hypothesis relied on environmental factors, he needed paleoenvironmental and subsistence data as well. Testing the hypothesis that, contra Childe, there was a significant, populous transitional period between the Paleolithic and Neolithic thus required excavation with a focus on recovering environmental data. Although his initial work (1932) had been typologically focused, Clark's belief that adaptation to changing environments caused the Mesolithic led him to ask economically-based questions (Clark 1939, 1980; Trigger 1989). With this goal in mind, Clark established the Fenland Research Committee at Cambridge, including specialists from botany, geology, geomorphology, historical geology as well as archaeology (Mithen 1999). In 1948, this group was transformed into the Sub-department of Quaternary Research at Cambridge, and set out (with Clark in the lead) to excavate the site of Star Carr (Clark 1954, 1972; Mithen 1999).

Clark and his interdisciplinary environmental team excavated the waterlogged early Mesolithic site of Star Carr from 1949 to 1951 (1954). Other waterlogged Mesolithic sites in northern Europe had been found to have extraordinary preservation of organic materials; Clark hoped that by excavating the site with an emphasis on recovering environmental data, he would obtain details on the ways in which Mesolithic foragers adapted to their changing environments that had previously been obscured by the then-standard typological approach.

The results—a report with a significant paleoenvironmental reconstruction aspect along with an interpretation of the subsistence and mobility of the Mesolithic inhabitants of Star Carr (Clark 1954; Fraser and King 1954; Walker and Goodwin 1954)—were groundbreaking for Mesolithic archaeology, and set a standard to which many modern Mesolithic archaeologists still aspire (Dincauze 2000; Mithen 1999). Clark's discoveries at Star Carr were aided by the newly-available technique of radiocarbon dating; the Star Carr monograph contains one of the first published radiocarbon dates, at 7538 ± 350 BC (9488 BP).

Star Carr demonstrated that Mesolithic peoples of northern Europe had developed sophisticated adaptive strategies to cope with changing environment. A seasonal round and participation in widespread forest clearance were, Clark argued, adaptations to the temperate forests that had closed in over this region (Clark 1954, 1972, 1980; Mellars and Dark 1998). At the same time, forest clearance paved the way for the adoption of agriculture in the Neolithic (Clark 1980).

> Bioarchaeological studies have revealed how effectively [Mesolithic people] in fact adapted to environmental change, developed complex systems of food-procurement and devised material equipment admirably suited to their needs. In a word they fully earned the right to be termed Mesolithic, culturally as well as temporally, even in this territory remote from the main focus of innovation at this time in south-west Asia. (1980: 40.)

Thus, the excavations at Star Carr both provided a major advance in empirical knowledge about the early Mesolithic (i.e., the sophisticated adaptive strategies of the site's inhabitants, dated "absolutely"), and represented a sharp turn in approaches to Epipaleolithic and Mesolithic prehistory, moving from typological analyses to ecological ones.

Clark's research at Star Carr inspired an abundance of research on Mesolithic lifeways in northern Europe, all with a strong focus on changing environments and the ways in which Mesolithic foragers adapted to them (for example, Clark 1972; Clarke 1978; Mellars and Dark 1998; Mithen 1999; Price 2000a; Rowley-Conwy 1986; Trigger 1989). While few excavations have had the funds to employ the massive multi-disciplinary teams that Clark favored (Dincauze 2000), from the time of Clark through the present Mesolithic research in northwestern Europe has been actively pursued (Mithen 1999). Much of this work, however, has been descriptive in nature, rather than problem-oriented. While the research focus of Clark, ways in which people adapted to changing environments, has been broadened to include ways in which people impacted their environments, work in the early and middle Mesolithic of this region has primarily focused on describing what Price terms "dynamic groups of complex foragers" (2000).

Southwestern Europe, and particularly France, has been marked by a dramatically less impressive record of research in the Mesolithic (see review in Clark 2000). This can be seen in the collections of papers from Mesolithic symposia: of 62 papers from the 1985 symposium, a scant 9 are from this region, and none are from France (Bonsall

1989). The 1995 symposium has more (14 out of 69 concern southwestern Europe), and many papers from northern France, but this is not surprising given that the symposium was held in France. It is instead surprising that southwestern Europe is not better represented (Thévenin 1999).

Why this discrepancy between northern and southern Europe? The preservation of Mesolithic organic material in northern Europe's massive shell middens and waterlogged sites such as Star Carr has provided bases for research among Mesolithic archaeologists; in southwestern Europe, the focus has been instead on the dramatic sites of the Paleolithic (Clark 2000; Straus 1996; Thévenin 1999). Although some of the first sites recognized as intermediate in age between the Paleolithic and the Neolithic were identified in southwestern Europe (Piette 1895), relatively little is known about or published on the Epipaleolithic and Mesolithic of southwest France and Iberia, and that which is tends to be focused on the later Mesolithic period (Clark 1999).

Clark (1980) attributed the differences in archaeological knowledge of the post-glacial period in northern and southwestern Europe to the differences in scale of climate change that the post-glacial inhabitants of these regions underwent as well as to differences in preservation. Because northern Mesolithic people had to cope with a more radical change in environment, he implied, their adaptations were bound to be more remarkable than those of southern peoples. Given that comparatively little work has been done in the Mesolithic of southwestern Europe, however, this is difficult to ascertain. In many ways, the situation in southwestern Europe is similar to that in northern Europe in the early 20th century. One example of the persistent avoidance of a "Mesolithic" in this region can be seen in period names: although Mediterranean Spain has a strong tradition of Mesolithic study (Bernabeu Auban et al. 2001; Clark 1999), the preferred term for this period remains "Epi-paleolithic" (Table 1.3).

Table 1.3. Pleistocene-Holocene transition culture historical periods in southwestern Europe (Straus 1996).

Aquitaine	**Vasco-Cantabria**	**Levant**	**Portugal**
Sauveterrian 9,000-6,500 BP	Asturian/Geometric Epi-Paleolithic 9,000-6,500 BP	Geometric Epi-Paleolithic 8,000-7,000 BP	Mesolithic 8,500-6,000 BP
Azilian 11,000-9,000 BP	Azilian 10,500-9,000 BP	Microlaminar Epi-Paleolithic 10,500-8,000 BP	Final Magdalenian/ Epi-Paleolithic 10,5000-8,500 BP
Upper Magdalenian 13,000-11,000 BP	Upper Magdalenian 13,000-10,500 BP	Upper Magdalenian 13,000-10,500 BP	Late Magdalenian 12,500-10,500 BP

The question of the significance of the Mesolithic in southwestern Europe is clearly not yet resolved. Some are content to infer significance from activity in northern Europe (Binder 2000; Price 2000b; Thévenin 1999); others argue that the Mesolithic was relatively insignificant (Zilhão 2000, 2001). What work has been done is either in need of re-evaluation, due to current challenges (Geddes 1983, 1985; Guilaine et al. 1993), or applies to a limited area (Bernabeu Auban et al. 2001). More regional work on the Mesolithic—both early and late—is needed to understand what occurred in southwestern

Europe during this time. Were foragers scarce, eking a living out of less-plentiful, less-predictable post-Pleistocene herbivores (Binder 2000)? Or were they relatively populous, complex foragers, who transformed the landscape in such a way as to make the Neolithic inevitable (Bernabeu Auban et al. 2001; Marinval 1988; Price 2000b)? Without more investigation into the details of the Epipaleolithic and early Mesolithic in southwestern Europe, we will never know.

Rabbits versus Reindeer: the situation in the Périgord

I attempt to clarify at least some aspects of this question by focusing on one aspect of this problem: the addition of small prey to the diet of hunter-gatherers in the Dordogne Valley region of southwestern France (Figure 1.1). I take a behavioral ecology approach, specifically making use of the body of models known as optimal foraging theory (Stephens and Krebs 1986), as described further below.

One of the components of the classic definitions of the Mesolithic is diet (Table 1.1). In many parts of the Old World, human diets allegedly underwent a radical transformation during the transition from the Pleistocene to the Holocene (Aura et al. 1998; Binford 1968; Flannery 1969; Simek and Snyder 1988; Straus 1995a, b). Diets that previously focused on a small number of large, high-return mammal species broadened to include a wider variety of smaller prey items, including fish, rabbits, and plants, though both the specific species involved and timing of the change varied from region to region.

Flannery (1969) labeled this transition the "broad spectrum revolution," and hypothesized that such dietary diversification should accompany population growth.

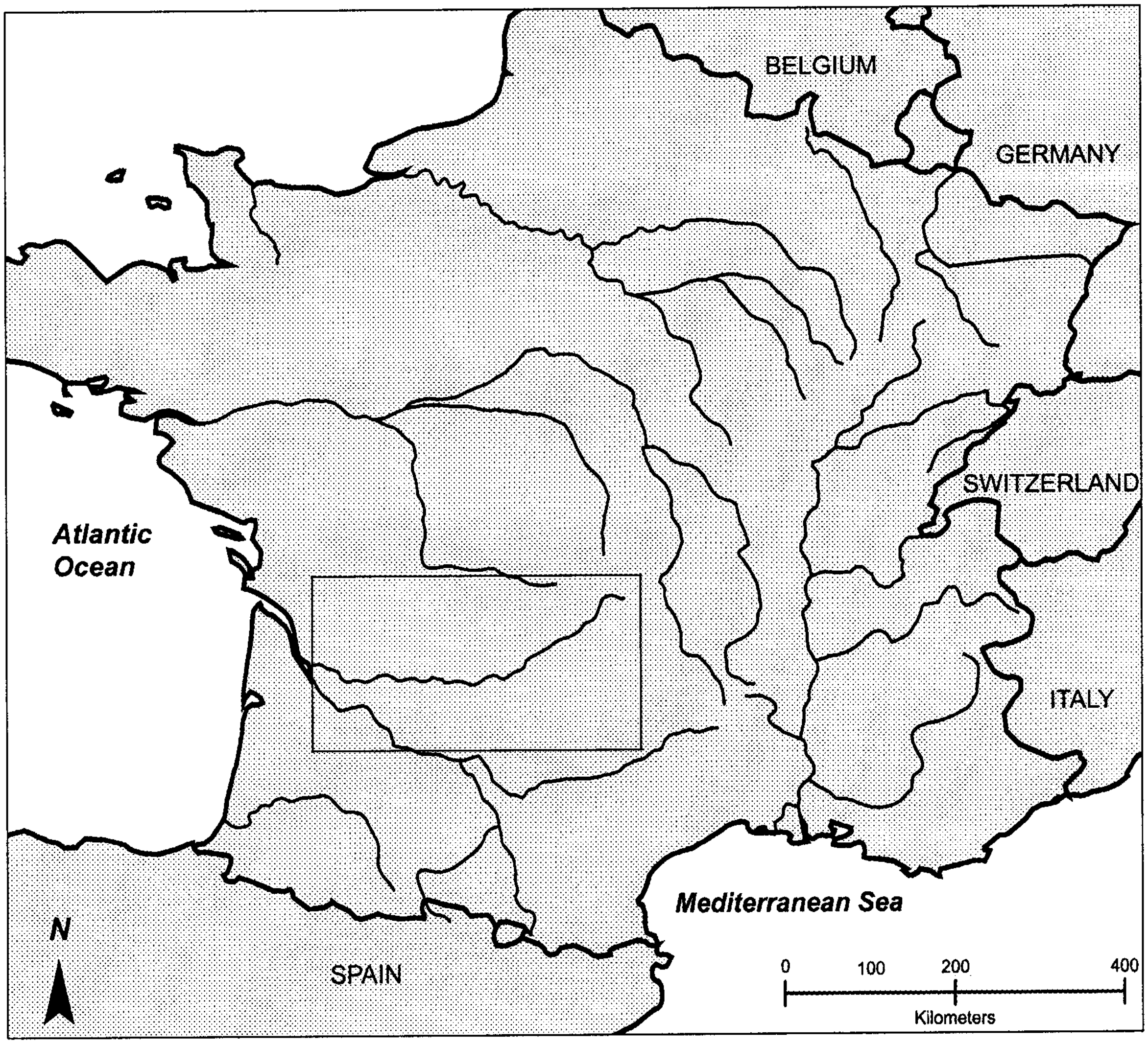


Figure 1.1. Location of the research area.

Others have argued that climate change was responsible for this shift (Altuna et al. 1991; Aura et al. 1998; Edwards 1989; Henry 1985; Horwitz 1996; Neely and Clark 1993; Simek and Snyder 1988; Straus 1991, 1995a, b, 1996, 1999; Straus and Clark 1986). Although additional causative variables have been invoked—for instance, rising sea levels (Binford 1968)—human population increase and climate change are the two most commonly implicated causes.

In the Dordogne region of southwestern France (Figure 1.1), changes similar to those detected elsewhere are known to have occurred toward the end of the Pleistocene, with diets heavily dependent on large ungulates being replaced by those heavily dependent on smaller species, and in particular on the European rabbit (*Oryctolagus cuniculus*). The two main hypotheses mentioned above—that climate change negatively impacted large mammal populations, thus forcing people to begin incorporating smaller vertebrate species into their diets; or that people themselves negatively impacted large mammal populations, which in turn forced people to add smaller species to their diets—are dominant in this region as well, but are complicated by the biogeographical history of *Oryctolagus cuniculus*. Since this species was present in only very small numbers in the Périgord during most of the Upper Paleolithic (Callou 2000; Cochard 2004; Donard 1982; el Guennouni 2001; Rogers et al. 1994), its increasing presence after this time may merely reflect its abundance on the landscape.

This species is also a well-known target of mass collection efforts (Biadi and Le Gall 1993; Rogers et al. 1994); what mass collecting means to human diets is currently under debate, as I will discuss in Chapter 5 (Lupo and Schmitt 2002; Madsen and Schmitt 1998; Ugan in prep). If prehistoric Périgordians were collecting *Oryctolagus en masse*, this may further complicate the dominant hypotheses.

Finally, what was the significance of the addition of this small, abundant, reliable species to the diet of Epipaleolithic and early Mesolithic people of the Dordogne? It has been argued that the addition of an such a species may cause human populations to increase markedly (Winterhalder and Lu 1997), thus exerting additional pressure on higher-ranked species in the diet. This prediction, generated from foraging theory and population ecology, is in accord with Flannery's Broad Spectrum Revolution (1969), which saw the addition of smaller prey as instigating a feedback loop that would result in the addition of ever lower-return resources.

In the research presented here, I use data from two sites in the Périgord—Moulin du Roc (Detrain et al. 1996) and Pont d'Ambon (Célérier 1998; Célérier et al. 1993, 1994)—to explore questions of the significance of the addition of rabbits to the diet. I also review data from a number of other Périgordian sites dating to the Pleistocene-Holocene transition to provide a regional context for the changes that occurred during this time.

Organization of this volume

This work can roughly be divided in to two parts: the first provides archaeological, theoretical, and methodological context, while the second presents data and interpretation of the fauna from Moulin du Roc and Pont d'Ambon, and synthesizes these data with other regional data to address the questions described above.

Chapter 2 provides background on the situation in the Périgord, reviewing the history of climate change across the Pleistocene-Holocene transition, the regional archaeological context in southwestern Europe, and the biogeographic history of *Oryctolagus cuniculus*. Chapter 3 discusses changing human settlement patterns in the Périgord across the Pleistocene-Holocene transition.

Chapter 4 reviews the relevant theory, including the history of the Broad Spectrum Revolution hypothesis, the logic of optimal foraging theory and its previous application to broad spectrum diet issues, recent considerations of how mass collecting might affect optimal foraging theory predictions, and risk management and the harvest of lower-return items. I then use these theories to derive testable hypotheses about the abundance of *Oryctolagus cuniculus* in zooarchaeological assemblages from the Dordogne.

Chapter 5 presents the methodology used in this analysis, including criteria for the identification of mass collecting and its potential significance, methods for identifying sex and age of *Oryctolagus cuniculus*, and the protocol for identifying resource depression in this case.

Chapter 6 presents a thorough analysis of the data from Moulin du Roc, while Chapter 7 does the same for Pont d'Ambon. Finally, Chapter 8 considers the applicability of these results to the rest of the Périgord and concludes the volume with some recommendations for future research.

Chapter 2:

Changing climate and broadening diets

As the historical review in the previous chapter shows, it has long been asserted that, in many parts of the Old World, diets broadened at the Pleistocene-Holocene transition. In the 1960s, this perception was articulated to the wider archaeological community by Binford (1968). Subsequent research (see Chapter 4) has shown that the hypothesis of broadening diets at the Pleistocene-Holocene transition is in many cases incorrect and overly simplistic for many other regions (e.g., Aura et al. 2002; Bernabeu Auban et al. 2001; Stiner 2001; Stiner et al. 2000; Straus 1992a; Villaverde et al. 1996). In the Périgord, however, this perception has been widely accepted but not much investigated (Enloe 1998; Pike-Tay 1991; Simek and Snyder 1988; Straus 1996, 1999).

In this chapter, I review the available climate data, the biogeography of some key prey types, and both faunal and site location archaeological data as a context for better understanding what changes did occur during the Pleistocene-Holocene transition in the Périgord. While it is clear that many changes were occurring, they are not necessarily the ones currently accepted.

Climate data: a matter of scale

A wide variety of proxy measures for climate are available: data from ice cores, deep-sea cores, and pollen cores, in particular, have all been used to reconstruct terminal Pleistocene and early Holocene climates. These methods represent climate at different scales: ice core and deep-sea core data tend to reflect global or ocean-basin (in this case, Atlantic) scale climate, while pollen presents a more regional picture. Together, these two scales can often provide a remarkably clear picture of how climate changed for a particular group of people.

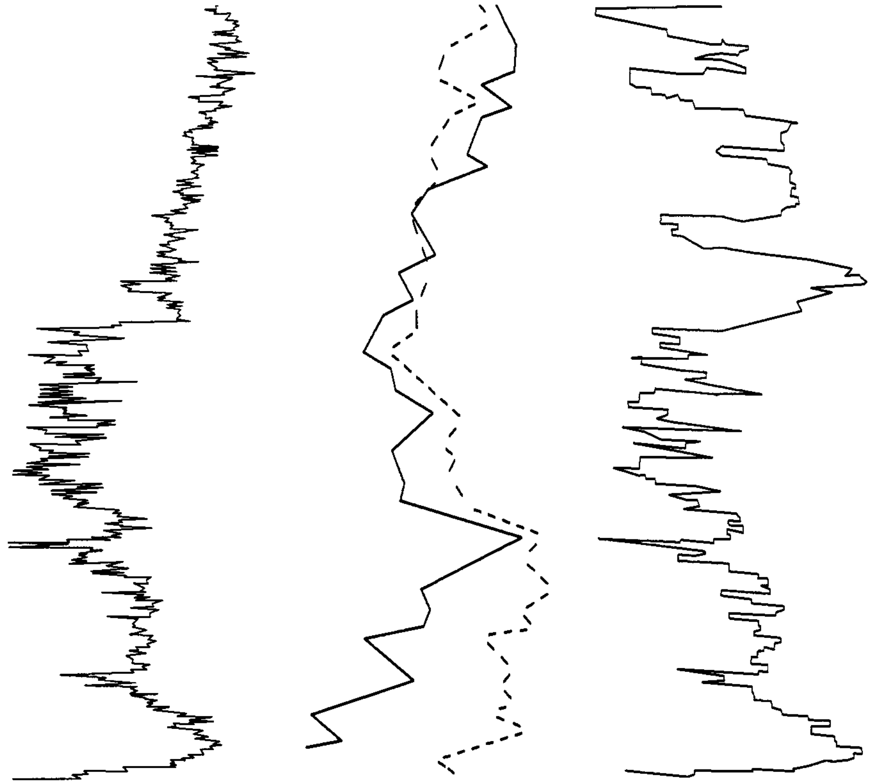
Unfortunately, due to the lack of lakes with deep, stratified deposits extending back into the Pleistocene, we lack a regional pollen record for the Périgord. Although numerous studies of pollen derived from cave deposits excavated for archaeological purposes are available (Célérier 1994), these studies have been heavily criticized (Turner and Hanson 1988). Pollen is not deposited continuously in stratified cave deposits, and thus it provides a variable and not necessarily reliable record; in addition, some of the pollen deposited in archaeological caves in southwestern France has been found to be intrusive from later time periods (Turner and Hanson 1988).

Other researchers have extracted regional climate data from the microfaunal records of archaeological sites (Marquet 1989), from large mammal histories in the region (Delpech 1999), from pollen cores in nearby regions (Grayson et al. 2001). None of these solutions is ideal: very few microfaunal analyses in the Périgord have been fully analyzed, and thus the data that is available tends to be very local rather than regional; large mammals often respond more slowly to climate change, and thus provide a more rough-grained signal than other methods; and the degree to which nearby regions' climate histories mirror that of the Périgord is debatable. However, all of these proxies (with the exception of microfaunal analysis) provide well-researched sources of data, and as long as their limitations are kept in mind, can prove useful in better understanding the climate history of the Périgord. Table 2.1 provides an overview of the relevant climate data from the GISP2 ice core, the pollen cores of La Grande Pile and Les Eschets in the Massif Central (Guiot 1990; Guiot et al. 1989), from the archaeological pollen stages of the Périgord, and from large mammal histories as reconstructed by Delpech (1983; 1992; 1999).

Several aspects of the data presented in Table 2.1 are relevant to this work. Although there are some notable differences in the climate sequences shown here, they all reflect a warming trend starting around 13,000 BP, followed by a relatively brief, strong cold period (the Younger Dryas cold event), and then a general amelioration of climatic conditions (the Preboreal). The details of how these large-scale events manifested, however, differ significantly depending on which line of evidence is used.

Some of these discrepancies are cause for discussion, most notably the difference between the faunal data and the GISP2 ice core and Massif Central pollen data. There are two potential explanations for this, in addition to the caveat listed above. First, much of the faunal data used to reconstruct climate comes from archaeological sites; therefore, the fauna involved provide a selection of the fauna available on the landscape. Second, the global changes at the Pleistocene-Holocene transition are well known to have, in some regions, created environments which have no modern analogue (Huntley 1990; Prentice et al. 1996).

Table 2.1. Climate reconstruction for the period 13 to 8 kyr BP.

kyr BP	Climate Stages(a)	GISP2 Ice core(b) colder ----------warmer	Pollen-based data(c) colder ----------warmer	Integrative data(d) colder ----------warmer	Large mammals(e)
8					Comparable to current distributions
	Boreal				
9					
	Preboreal				Instability/changes in distributions
10					
	Younger Dryas				
11					
12	Bølling/Alleröd				favorable to large/medium ungulates
13					

(a)climate stages based on archaeological pollen sequencing that are commonly used in Western Europe; (b)after Stuiver and Grootes (2000); (c)after Davis and colleagues (2003). The dashed line represents average summer temperatures, while the unbroken line indicates average winter temperatures; (d) curve based on data from Magny (1997); (e) after Delpech (1999).

It has been suggested that, during 13,000-11,000 BP, this was the case in the Périgord (Huntley 1988, 1990).

In addition, though faunal data suggest that there was a constant fluctuation between forested and grassy vegetation patterns in the Dordogne, it is important to keep in mind that the Périgord today is marked by dramatic landscape variability: it is dominated by a series of major, broad river valleys, which cut through limestone cliffs with plateaus on the top (Figure 2.1). Both the floral and faunal resources available in the region vary widely depending on whether one is in a river valley or on the plateaus; these could be considered different resource "patches," or areas in which different sets of resources are encountered. In this region, patchiness can extend beyond the distinction between valley and plateau environments; forested patches today are predominantly Atlantic deciduous forest, but contain pockets of more Mediterranean vegetation.

Because prehistoric environments were probably equally patchy, reconstruction of these environments is difficult. Broader patch types, however, have already been useful in regional archaeological analyses; the idea that the river valleys and plateaus constitute distinct resource "patches," and would have done so in the past, is central to many hypotheses about the behavior of humans in the Dordogne Valley region in prehistory (e.g., Bocquet-Appel and Demars 2000; Demars 1993, 1996, 2002; Lenoir 1992; Straus 1995b, 2000).

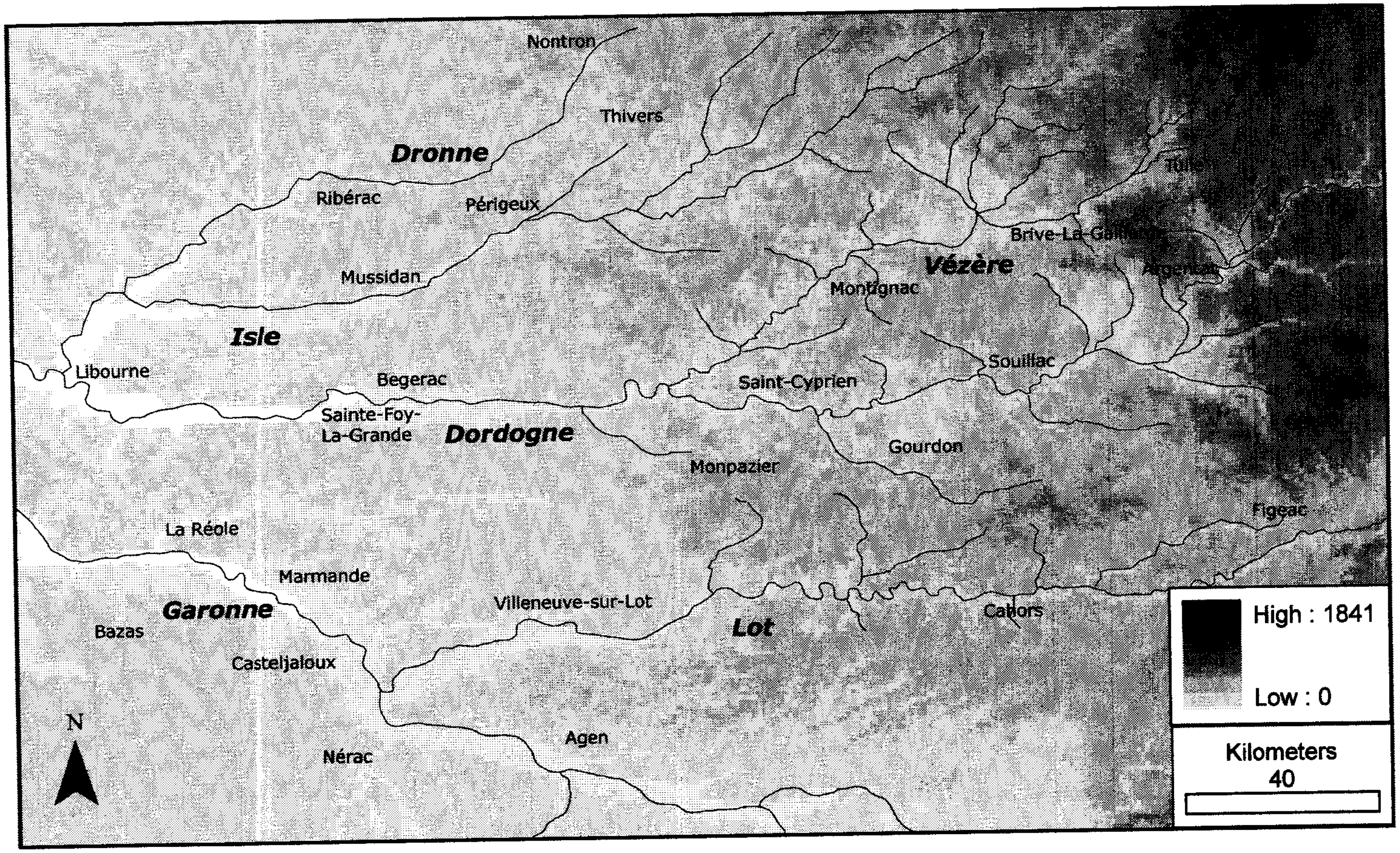


Figure 2.1. Relief map of the Dordogne Valley region.

Changing prey biogeography and the development of broad spectrum diets

The question of non-analogous environments at the Pleistocene-Holocene transition in the Périgord does pose some problems for reconstructing human dietary choice. However, both the zooarchaeological record (i.e., Delpech 1983) and the biogeography of many of the prey types used by humans (Delpech 1999) in the Périgord are well known. The Dordogne region has a carefully analyzed and well-dated archaeological sequence from the Upper Paleolithic (see Table 1.3 for the typical Upper Paleolithic/Mesolithic sequence from this region) in which small mammals that were part of the human diet are scarce prior to the final Paleolithic. As in the Cantabrian Alps, the changes in human diet breadth do not appear to occur until the tardiglacial (Aura et al. 1998; Hockett and Bicho 2000; Kuhn and Stiner 2001; Stiner 2001; Villaverde and Valle 1995). At the site of Le Flageolet I, for instance, fish, birds, and lagomorphs are minor parts of the Upper Paleolithic mammal assemblage (Delpech 1983). At Grotte XVI, which has an Upper Paleolithic sequence that begins with the Aurignacian and ends with the Magdalenian, there are only 215 leporid specimens for the entire Upper Paleolithic, and very few birds throughout (Table 2.2). When lagomorphs are found in early Upper Paleolithic deposits in this region, they are almost always *Lepus*; when *Oryctolagus* appears, it is invariably in very low numbers (Cochard 2004; Donard 1982).

Table 2.2. Faunal remains from the Upper Paleolithic layers of Grotte XVI (Grayson and Delpech 1998; Grayson et al. 2001).

Resource	**Stratum O** Magdalenian		**Stratum As** Solutrean		**Stratum Abc** Gravettian		**Stratum Abb** Aurignacian		**Stratum Aib** Aurignacian	
	NISP	% total	NISP	% total	NISP	% total	NISP	% total	NISP	% total
Ungulates	2139	93.5	384	76.0	1033	70.5	1059	57.7	239	46.0
Lagomorphs	47	2.1	48	9.5	164	11.2	222	12.1	45	8.7
Fish	17	0.7	4	0.8	26	1.8	35	1.9	15	2.9
Birds										
Total	**2288**		**505**		**1465**		**1834**		**520**	

Birds are found in significant numbers in some Upper Paleolithic sites in southwestern France. Laroulandie (2000), for instance, has shown significant human use of the Snowy Owl (*Nyctea scandiaca*) in the Solutrean deposits of Combe Saunière. However, there is little evidence that this resource had been part of the human diet; Laroulandie concluded that the Snowy Owl provided a non-dietary resource to the Solutrean hunters: its feathers. On the other hand, evidence from the final Magdalenian (at Bois-Ragot and La Vache) suggests that birds became dietarily important in the tardiglacial (Laroulandie 2000). Significant numbers of fish are sometimes found in Upper Paleolithic sites in southwestern France as well, and their absence from many sites may more reflect differences in excavation methodology than prehistoric differences in human diet (LeGall 1982, 1999). However, detailed studies of fish use during this time period suggest that there is an increase both in absolute frequency and in the number of species of fish taken beginning in the final Magdalenian (Cleyet-Merle 1990; LeGall 1982, 1999).

It seems that the faunal portion of Paleolithic diets was primarily composed of large, high-return mammals—often reindeer (*Rangifer tarandus*) during cold periods and red deer (*Cervus elaphus*) during warmer ones (Cleyet-Merle 1990; Delpech 1983, 1992; Gilbert 1984; Grayson and Delpech 1998; Grayson and Delpech 2002b; Grayson et al. 2001; Laroulandie 2000; LeGall 1982, 1999; Marinval 1988; Rowley-Conwy 2001; Straus 1995b, 1999; Straus and Clark 1986). In high-elevation sites in the French Pyrenees (and in adjacent high-elevation sites in Spain and Andorra), people continued this focus on large mammal species into the Mesolithic, concentrating on red deer (*Cervus elaphus*) and wild boar (*Sus scrofa*) as reindeer became locally extirpated (Straus 1991, 1992b, 1995b, 1999). This pattern extends well into the Holocene at such sites as Abri Dufaure, Duruthy, and Balma Margareida (Altuna et al. 1991; Arambourou 1978; Geddes et al. 1989; Straus 1995a, b, 1999). The change here appears to be straightforward: people are adapting to climate-induced changes in species availability by hunting species that had arrived or increased in abundance in response to warming (Geddes et al. 1989; Straus 1995b).

Similar changes are recorded in the lower-elevation sites of the Périgord, but with a difference. Although the switch from reindeer to red deer and wild boar occurs in this region as well, small prey also become common in archaeological assemblages around 13,000 years BP. *Oryctolagus cuniculus* begins to appear in significant numbers in sites where faunas had previously been dominated by reindeer, including Le Morin and La Gare du Couze (Delpech 1983; Gilbert 1984). Azilian low-altitude sites such as Pont d'Ambon (Célérier 1998; Delpech 1983; Donard 1982; Gilbert 1984), le Moulin du Roc (Detrain et al. 1996), la Faurélie II (Cochard 2004; Delpech 1983), and le Pégourie (Séronie-Vivien 1995) all contain faunas dominated by *Oryctolagus*. At the same time, the numbers of species and the numbers of individuals of birds and fish increase dramatically (Cleyet-Merle 1990; Delpech 1983; Laroulandie 2000; LeGall 1982, 1999; Pokines 2000). Plant materials and grinding stones became increasingly common in southwestern French sites as the Mesolithic progressed (Marinval 1988).

In the Périgord, then, the hypothesis of broadening diets around the Pleistocene-Holocene transition seems to hold. The question then becomes, did diets broaden at this time as a result of climate change? Table 2.3 presents some of the known histories of prey types used by Périgordians. As this table shows, there is little change in the presence of large ungulates in the Late Paleolithic (with the significant exception of reindeer, which becomes locally extinct); although the species vary in relative abundance, they are consistently available (Brugal et al. 2001; Delpech 1983, 1992, 1999; Gilbert 1984).

However, a number of smaller prey species, particularly fish species and the European rabbit, only become available at roughly the same time as diets broadened, around 13,000 BP (Callou 2000; Cleyet-Merle 1990; Donard 1982; LeGall 1988, 1999; Rogers et al. 1994). Birds, which also become relatively abundant in zooarchaeological faunas around 13,000 BP, are not represented in Table 2.3 as little historic information is available.

Table 2.3. Biogeographic information on selected prey types of the Late Pleistocene/Early Holocene in the Périgord.

Prey type	**Scientific name**	**Biogeographical data**	**Source**
Reindeer	*Rangifer tarandus*	Relatively abundant prior to 12,000 BP; patchy distribution 12,000-11,000 BP; extirpated post-10,000 BP	(Delpech 1983, 1992, 1999; Gilbert 1984)
Red deer	*Cervus elaphus*	Present throughout Pleistocene; ; increases dominance during warmer periods; increases post 13,000 BP	(Delpech 1983, 1992, 1999; Gilbert 1984)
Wild boar	*Sus scrofa*	Present throughout Pleistocene; increases dominance during warmer periods; increases post 13,000 BP	(Delpech 1983, 1992, 1999; Gilbert 1984)
Horse	*Equus* spp.	Present throughout Pleistocene and early Holocene.	(Brugal et al. 2001; Delpech 1983, 1992, 1999; Gilbert 1984)
Bovids	*Bos/Bison*	Present throughout Pleistocene and early Holocene.	(Delpech 1983, 1992, 1999; Gilbert 1984)
Hare	*Lepus* sp.	Available throughout the Pleistocene and early Holocene.	(Cochard 2004; Corbet 1986; Major 1898)
Rabbit	*Oryctolagus cuniculus*	Sporadically available prior to 13,000 BP, and primarily outside the Périgord; widely available after 13,000 BP.	(Branco et al. 2002; Callou 2000; Cochard 2004; el Guennouni 2001)
Freshwater fish	*Anguilla anguilla, Salmo trutta*, Cyprinidae	Only sparsely available before 13,000 BP; increasing in availability between 13,000 and 9,000 BP	(Cleyet-Merle 1990; LeGall 1988, 1993, 1994, 1999)

Changing biogeography of the European rabbit

Of particular to this study is another small prey type which is common Périgordian faunas dating to the Pleistocene-Holocene transition: the wild European rabbit (*Oryctolagus cuniculus*). As mentioned earlier, *Oryctolagus* is the dominant species in many archaeological sites dating to 13,000 to 9,000 years ago. Although it is adopted along with a suite of other small prey types (including birds and fish), *Oryctolagus* remains are consistently present in zooarchaeological assemblages and often comprise over 80 percent of the mammalian NISP (see Table 2.4). Before 13,000 years BP, however, this species is essentially absent from archaeological faunas in the Périgord.

Table 2.4. Frequency of Oryctolagus cuniculus *at selected Pleistocene-Holocene transition sites in southwestern France.*

Site	**^{14}C dates**	**%*Oryctolagus***	**Source**
La Faurélie II	No dates	78%	(Cochard 2004; Delpech 1983)
Pont d'Ambon	9640 ± 120 - 12840 ± 220	95%	(Delpech 1983; Gilbert 1984)
Le Morin	10,480 ± 2105	16%*	(Delpech 1983; Gilbert 1984)
Le Pégourie	11,290 ± 320 - 12,250 ± 350	98%	(Séronie-Vivien 1994, 1995)
Moulin du Roc	11,340 ± 170 - 12,890 ± 60	96%	(Detrain et al. 1996)

*This relatively low percentage may reflect the actual relative abundance of *Oryctolagus*, but it may merely reflect methods of analysis. This will be discussed further in Chapter 8; for this table, the point is only that *Oryctolagus* is consistently present in sites from this time period.

Traditionally, the lack of *Oryctolagus* elements in zooarchaeological assemblages prior to 13,000 years ago (and its abundance after this time) was seen as indicating human dietary choice: as a small, fast species, *Oryctolagus* would presumably be less desirable than larger and more easily hunted ungulates. However, it has recently been suggested that the European rabbit was only sporadically present in this region during the Upper Pleistocene prior to about 13,000 years BP (Callou 2000; Cochard 2004; Donard 1982; el Guennouni 2001; Rogers et al. 1994); thus its prevalence in Epipaleolithic faunas may merely be a matter of its abundance.

Although the European rabbit is remarkably environmentally tolerant, it is not well-adapted to cold, damp climates with thin soils, presumably because this restricts burrowing (Rogers 1981). Today, *Oryctolagus cuniculus* lives at altitudes below 1000 meters, preferring areas of mixed grassland and scrubby vegetation, though it can occupy areas with minimal plant cover as long as aerial predators are not abundant (Corbet 1994; Lombardi et al. 2003; Marchandeau et al. 2000; Rogers et al. 1994). *Oryctolagus*' ability to colonize new environments is impressive, in part because it can occupy a broad variety of habitats; its main requirement is soils of a depth suitable for burrowing. Largely as a result of translocations, this species is now established on every continent except Antarctica, but it does not inhabit areas where snow cover exceeds 140 days (Rogers et al. 1994). Studies of modern populations of *Oryctolagus* suggest that juvenile mortality rates are dramatically higher in cold and snowy climates. In addition, research suggests that *Oryctolagus*' abundance may be affected by competition with its close relative, the hare (*Lepus* spp.); in areas where soils are thin and not suitable for burrowing, *Lepus* seems to out-compete *Oryctolagus*, while *Oryctolagus* dominates in other areas (Corbet 1966; Flux 1994; Fraguglione 1960; Rogers et al. 1994).

These two factors may explain why *Oryctolagus* is rare in southwestern French faunas prior to the end of the Pleistocene. Even if it did manage to temporarily establish a breeding population in southwestern France at various times during the Pleistocene, *Oryctolagus*' abundance is restricted by the scarcity of soils sufficient for burrowing. In addition, harsh spring climatic conditions can have a detrimental effect on *Oryctolagus* populations (Angulo and Villafuerte 2004; Moreno and Villafuerte 1995; Villafuerte et al. 1997).

The European rabbit originated on the Iberian peninsula during the late Pliocene/ early Pleistocene (Corbet 1994), and seems to have colonized, become locally extinct, and re-established itself several times over in southwestern France prior to the Holocene (Corbet 1986; Flux 1994; Zeuner 1963). Although *Oryctolagus* is known from Pleistocene paleontological deposits in southeastern France (Cochard 2004; el Guennouni 2001), it seems to have been present in low numbers outside this region (Callou 2000; Donard 1982; Flux 1994), and absent north of the Seine (Callou 2000; Rogers et al. 1994). After 13,000 BP, however, *Oryctolagus* becomes very common in southern France, and begins to spread to the north and east (Rogers et al. 1994). This suggests that some factor or combination of factors—thin soils unsuitable for burrowing, or competition with *Lepus*, or heavy snow cover—restricted *Oryctolagus* populations to the

Iberian peninsula and to small populations in southern France during most of the Pleistocene, and this limiting factor was negated in the last stages of the Pleistocene (Callou 2000; Donard 1982; Rogers et al. 1994).

This, along with Table 2.2, suggests that while the increase in diet breadth seen in the Périgord at the Pleistocene-Holocene transition is certainly related to climate change, it may not be caused by climate variation in the way usually suggested. Rather, it suggests that diets in the Magdalenian may have been restricted by the lack of available smaller prey types, and that as soon as they became available, they were added to the diet. If this is in fact so, then broad diets should be seen earlier in the Iberian peninsula, where smaller prey types were available throughout the Paleolithic.

Although lagomorphs are present in abundance in Iberian Middle Paleolithic sites, taphonomic studies suggest that the presence of these small animals is generally the result of carnivore activity, not human hunting (Hockett 1999; Villaverde et al. 1996). In lowland Spain and Portugal, diet breadth expands significantly in the early Upper Paleolithic (Aura et al. 1998; Hockett and Bicho 2000; Villaverde and Valle 1995). These earlier Upper Paleolithic sites generally contain *Oryctolagus cuniculus* in abundance, as well as the more typically Upper Paleolithic suite of large mammals. For instance, the cave of l'Arbreda, a Paleolithic archaeological site in the Catalan region of northeastern Spain, is rabbit-dominated throughout the Solutrean levels (Table 2.5). Although the l'Arbreda fauna has not been completely published, it has been reported that the diets of humans living at l'Arbreda are rich in small vertebrates—specifically, fish and rabbits—from the Aurignacian levels on, here dated to about 37,000 B.P. (Bischoff et al. 1994; Carrion et al. 1999; Maroto et al. 1996; Munoz and Cadadevall 1997). The site of Cova Beneito, in southeastern Spain, shows a similar pattern (Villaverde and Valle 1995, also see Table 2.6), and Hockett and Bicho (2000) report rabbit-dominated human diets beginning in the Aurignacian at Picareiro Cave on the Portuguese Estremadura. Despite the widespread nature of rabbit and other small-game dominance in this region during the early Upper Paleolithic, this pattern does not extend to the entire Iberian Peninsula. In the Cantabrian Alps of northern Spain, diet breadth does not change significantly prior to the Pleistocene-Holocene transition (Altuna et al. 1991; Straus 1995a, b, 1996); as the climate in the higher elevations of this area would have posed some of the same barriers to smaller prey types as the climate in France did, this is not surprising.

The data from the Iberian peninsula thus support the hypothesis that diet breadth increased, not because climate negatively impacted large mammal populations, but because the climate restricted available diet options in the Magdalenian. When additional prey types became available in the final Magdalenian and early Azilian, they were immediately adopted.

Table 2.5. Faunal remains from the Solutrean of the Spanish Mediterranean site of l'Arbreda (Villaverde and Valle 1995).

	Stratum D		Stratum C		Stratum B	
Species	**NISP**	**% of total**	**NISP**	**% of total**	**NISP**	**% of total**
Cervus elaphus	76	11.78	13	5.37	5	2.08
Rangifer tarandus					1	0.42
Capra pyrenaica	2	0.31				
Rupicapra rupicapra	6	0.93				
Ovibos moschatus			1	0.41		
Bovinae	12	1.86	4	1.65	3	1.25
Equus caballus	148	22.95	36	14.88	18	7.50
Equus hydruntinus	4	0.62				
Sus scrofa	2	0.31				
Elephas sp.	1	0.16				
Vulpes vulpes	4	0.62	3	1.24	4	1.67
Lynx sp.			3	1.24		
Panthera pardus			1	0.41		
Oryctolagus cuniculus	390	60.47	180	74.38	208	86.67
Lepus capensis			1	0.41	1	0.42
Total	**645**		**242**		**240**	

Table 2.6. Faunal remains from the Solutrean of the Spanish Mediterranean site of Cova Beneito (Villaverde and Valle 1995).

	Stratum B6		Stratum B3/5		Stratum B1/2	
Species	**NISP**	**% of total**	**NISP**	**% of total**	**NISP**	**% of total**
Cervus elaphus	35	4.23	124	5.93	33	4.11
Capra pyrenaica	40	4.83	137	6.56	63	7.86
Equus caballus	5	0.60	38	1.82	14	1.75
Equus hydruntinus	5	0.60				
Canis lupus			2			
Vulpes vulpes			1	0.05		
Lynx sp.	7	0.85	12	0.57	8	1.00
Oryctolagus cuniculus	733	88.53	1765	84.45	684	85.29
Lepus capensis	3		10	0.48		
Erinaceus europaeus			1	0.05		
Total	**828**		**2090**		**802**	

Chapter 3:

Changing site elevation and subsistence strategy

The hypothesis that diet breadth increased not because climate negatively impacted large mammal populations, but because climate restricted available diet options in the Magdalenian can be further tested using settlement data, particularly information about site elevation. According to the traditional view in which the Magdalenian in the Périgord was resource-rich, Late Upper Paleolithic hunter-gatherers oriented their subsistence efforts toward the abundant resources of the river valleys (Laroulandie 2000; LeGall 1999; Pike-Tay 1991; White 1985). In this case, the hunters of the late Upper Paleolithic would have preferred as habitation sites the abundant caves and rockshelters that exist just above the river valleys of this region.

Hunter-gatherers of the Epipaleolithic and Mesolithic, however, are argued to have depended on a wider variety of resources, many of which (for instance, red deer) are typically found at higher elevations (Delpech 1983, 1999; Mellars 1994; Pike-Tay 1991; Straus 1995b). Likewise, as climate warmed, the few surviving reindeer would likely have been forced out of the river valleys and into higher elevations (Delpech 1983, 1999; Mellars 1994; Straus 1995b). The logical conclusion is that as climate warmed from the late Pleistocene to the Holocene, people should have moved consistently to higher elevations, and so later sites should occur at higher elevations than earlier ones (Demars

1993, 2000, 2002; Geddes et al. 1989; Guilaine et al. 1993; Straus 1995a, b, 1996, 1999; Straus et al. 2000; White 1985).

Although the change of focus from lower- to higher-elevation based resources from the late Paleolithic (Pleistocene) to the Mesolithic (early Holocene) is widely accepted, there is evidence suggesting that this hypothesized change may have little archaeological support (Delpech 1992, 1999; Enloe 1993; Grayson and Delpech 2002a; Grayson et al. 2001; Pike-Tay 1991, 1993). Many zooarchaeologists have demonstrated that Upper Paleolithic diets, while reindeer-rich, encompassed a variety of ungulate species, many of which are associated with different locations and elevations (Burke 1995; Grayson and Delpech 2002b; Pike-Tay 1991, 1993). The few archaeologists who focus on the archaeology of the early Holocene in this region have likewise established that Epipaleolithic and Mesolithic diets encompass both high- and low- elevation species (Séronie-Vivien 1995). Despite this inconsistency, however, there has been no systematic investigation of the elevation of archaeological sites in the Dordogne region across the Pleistocene-Holocene transition. The hypothesis that average site elevation should increase from the Magdalenian through the Sauveterrian is in need of testing.

Testing the elevation hypothesis

Elevation data for the Dordogne Valley region was obtained from the National Imagery and Mapping Association (http://www.nima.mil) Digital Terrain and Elevation Data maps (DTEDs). A coverage of the rivers in the region was acquired from ESRI's geography network (http://www.geographynetwork.com); locations of several of the major rivers in the region that were not included in this coverage were obtained from a variety of archaeological base maps. Following Demars (1996), I defined the "Dordogne Valley region" to encompass the Garonne, Dordogne, Vézère, Isle, and Dronne river valleys. By this definition, the Dordogne excludes both the low-lying Atlantic coastline (where sea-level rise may have obscured Paleolithic sites) and the higher-elevation Massif Central (which would have been uninhabitable during the Pleistocene); the entire region in this study would have been habitable in both the Pleistocene and the Holocene. By looking at patterns across a regional scale rather than a larger scale, I should be able to detect finer-scale variations in subsistence strategy.

Site location information was obtained from several published surveys (Bocquet-Appel and Demars 2000; Demars 1996; Lenoir 1979, 1992; Roussot-Larroque 1979; Rozoy 1978, 1999) as well as from unpublished site records available at the Institut de Préhistoire et Géologie du Quaternaire at the Université Bordeaux I in Talence, France. The analysis includes 125 individual site locations (a breakdown of the numbers of sites by cultural phase/technological period is available in Table 3.1), containing 181 discrete archaeological layers.

Table 3.1. Numbers of sites in this sample by cultural phase/technological period.

Cultural/Technological Period	**Number of sites**
Magdalenian	51
Final Magdalenian	51
Azilian	55
Sauveterrian	24

As dates are not available for the majority of recorded sites in the region, I used cultural phase/technological period to approximate time (e.g. Bordes et al. 1971; Bordes and de Sonneville Bordes 1979; Lenoir 1979, 1992; Roussot-Larroque 1979). Rough dates for each period are available in Table 1.3, and the number of continuities between layers of adjacent technological periods can be seen in Table 3.2.

One potential confounding factor in my approach involves the temporal interests of archaeologists working in different parts of the Dordogne region. Although some Epipaleolithic and Mesolithic sites have been recorded in the this area, known Paleolithic sites outnumber Mesolithic ones dramatically (Bordes and de Sonneville Bordes 1979; Lenoir 1976, 1979, 1989, 1992; Roussot-Larroque 1979). This may be a reflection of actual difference in numbers of sites, but it may also reflect that early archaeologists had no interest in Epipaleolithic and Mesolithic sites, and are known to have destroyed some archaeological deposits dating to these periods.

Table 3.2. Number of continuities in site layers. The continuities are not mutually exclusive.

Type of continuity	**Number of sites**
Magdalenian-Final Magdalenian	28
Magdalenian-Final Magdalenian-Azilian	14
Final Magdalenian-Azilian	23
Final Magdalenian-Azilian-Sauveterrian	2
Azilian-Sauveterrian	8

In addition, two of the most productive scholars interested in the Epipaleolithic and Mesolithic, Demars (1996) and Seronie-Vivien (1995), have worked in the eastern end of the Dordogne region, while Lenoir (1979), Bordes (1971), and Rigaud (1989) have published extensively on Paleolithic sites in the western Dordogne. It is unclear whether the concentration of published Paleolithic sites to the west and Mesolithic sites to the east reflects the actual distribution of sites, or the history of excavation in these areas.

Results

Maps of site location through time can be seen in Figures 3.1 (Magdalenian), 3.2 (Final Magdalenian), 3.3 (Azilian), and 3.4 (Sauveterrian). Two obvious changes across this time period can be observed from these maps. First, sites become less concentrated in the main river valleys through time. In the Magdalenian, sites are concentrated in the Dordogne, Vézère, Isle, and Dronne river valleys (Figure 3.1)—the four largest river valleys in the region. Although there are some Magdalenian sites in the higher elevation, higher slope, minor river valleys to the east and south, most are concentrated in the major valleys.

Figure 3.2, which shows the distribution of sites during the final Magdalenian (which occurred during a tardiglacial warming period), documents that while most sites are still concentrated in these major valleys, a few sites are located in the smaller, steeper river valleys. By the Azilian (Figure 3.3), sites are widespread within the minor river valleys; however, there are still a significant number of sites in the major river valleys. This is a far more dispersed settlement pattern than seen in the previous two periods. In the Sauveterrian, none of the sites in this sample are in the major valleys (Figure 3.4); they are all concentrated in the headwaters of the major rivers, at higher elevations. To quantify these changes through time, I used the geographic information system ArcGIS (Ormsby et al. 2001) to establish a 2-kilometer buffer around the major river systems. This buffer is a proxy for the river valleys; if the observations of changing site distribution above are correct, fewer sites should be located within the buffer (and more on the plateaus) through time.

The results of this analysis (Table 3.3) show that the number of sites located within the buffer (and therefore, the river valleys) does indeed decrease from the Magdalenian to the Sauveterrian, with just 13% of Magdalenian sites established on the plateaus, versus 34% of Final Magdalenian sites, 36% of Azilian sites, and 63% of Sauveterrian sites.

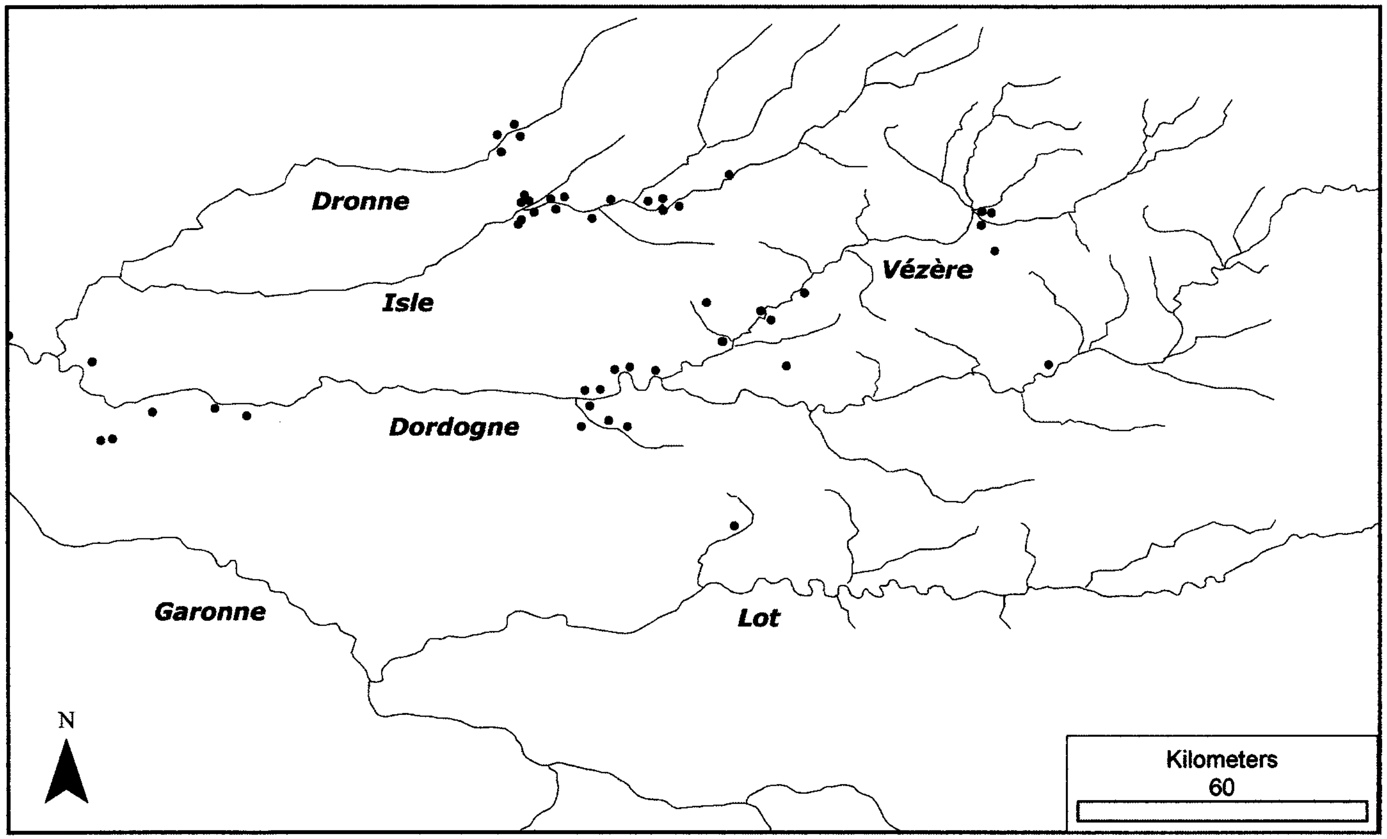


Figure 3.1. Site distribution in the Magdalenian.

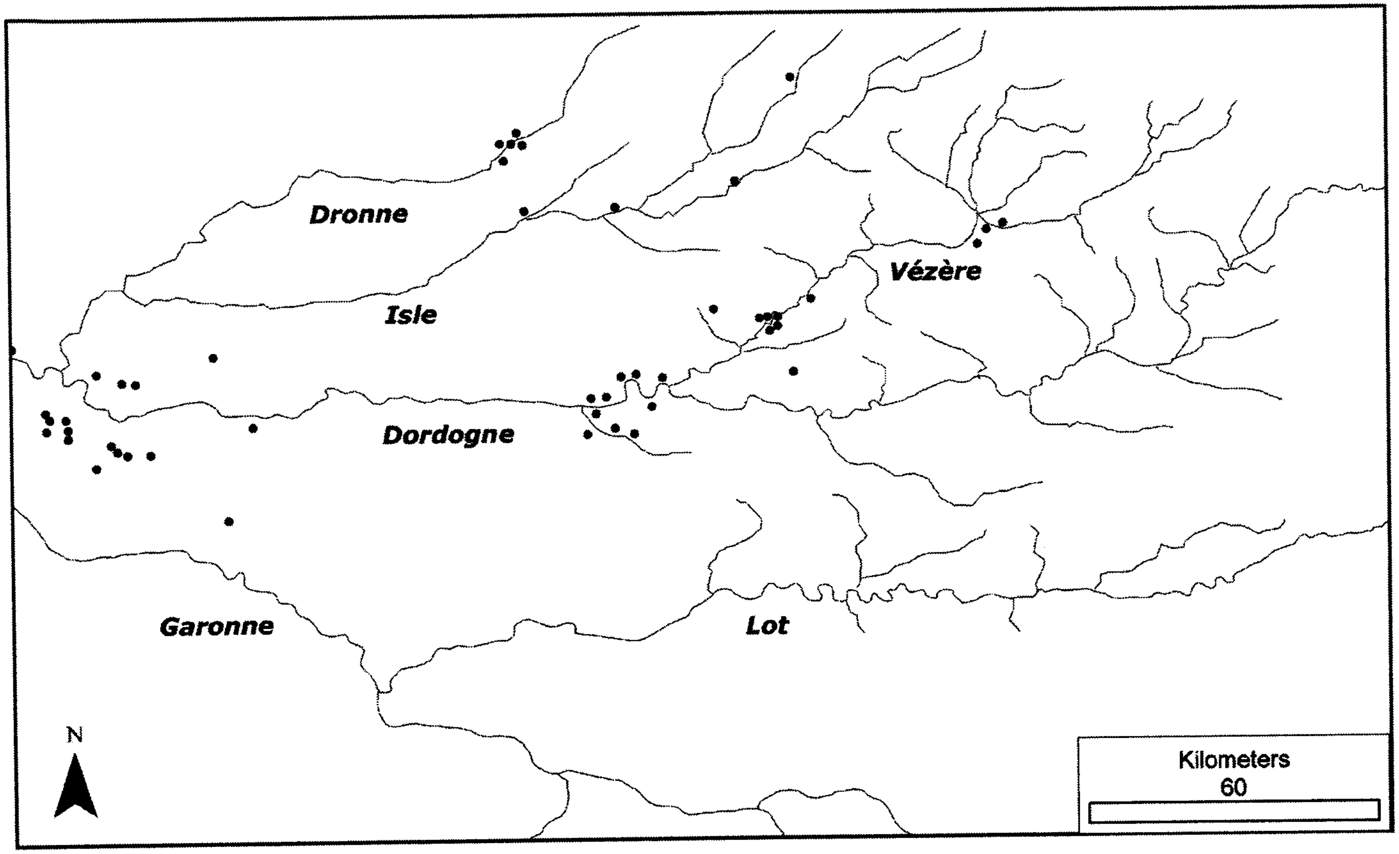


Figure 3.2. Site distribution in the Final Magdalenian.

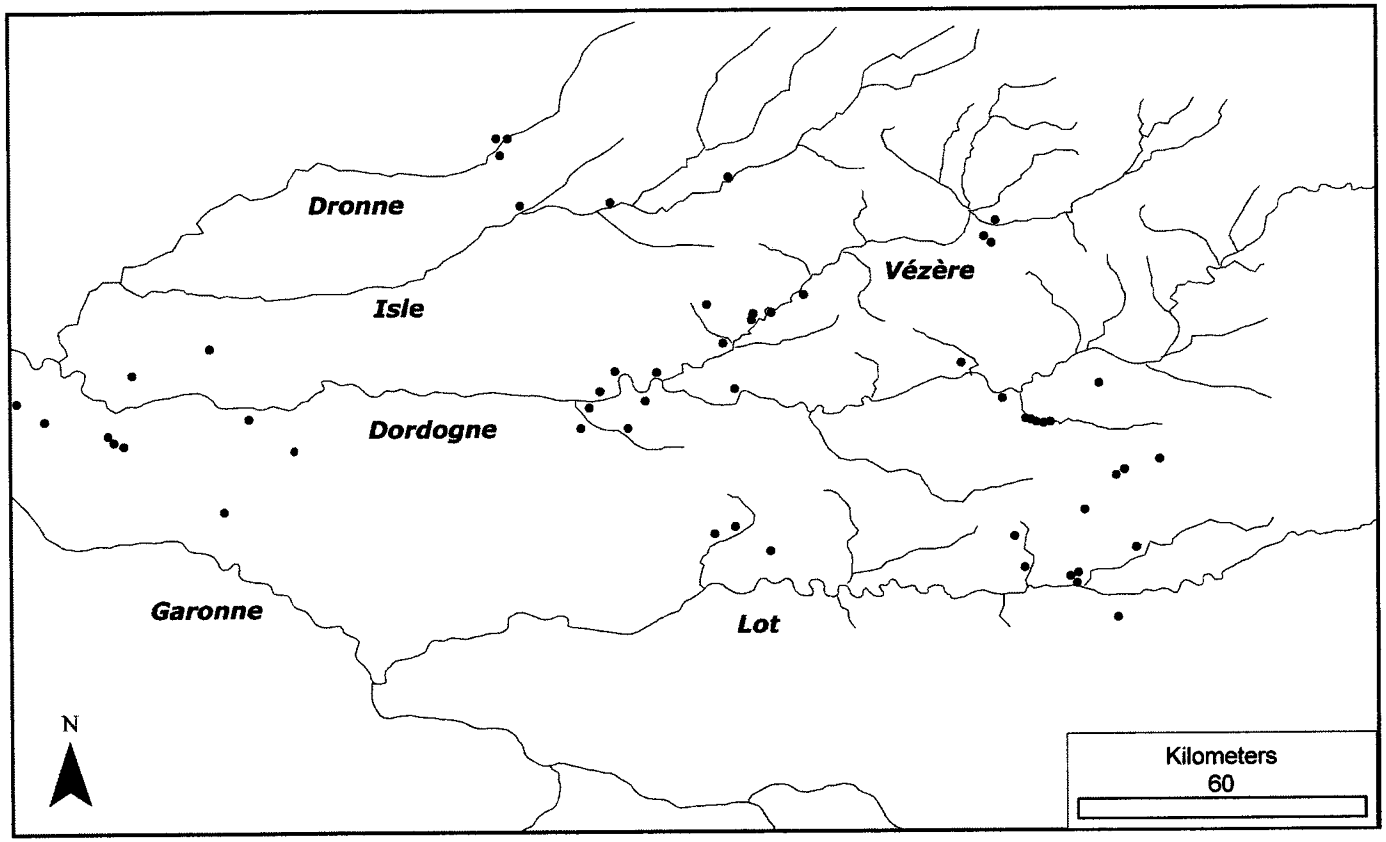


Figure 3.3. Site distribution in the Azilian.

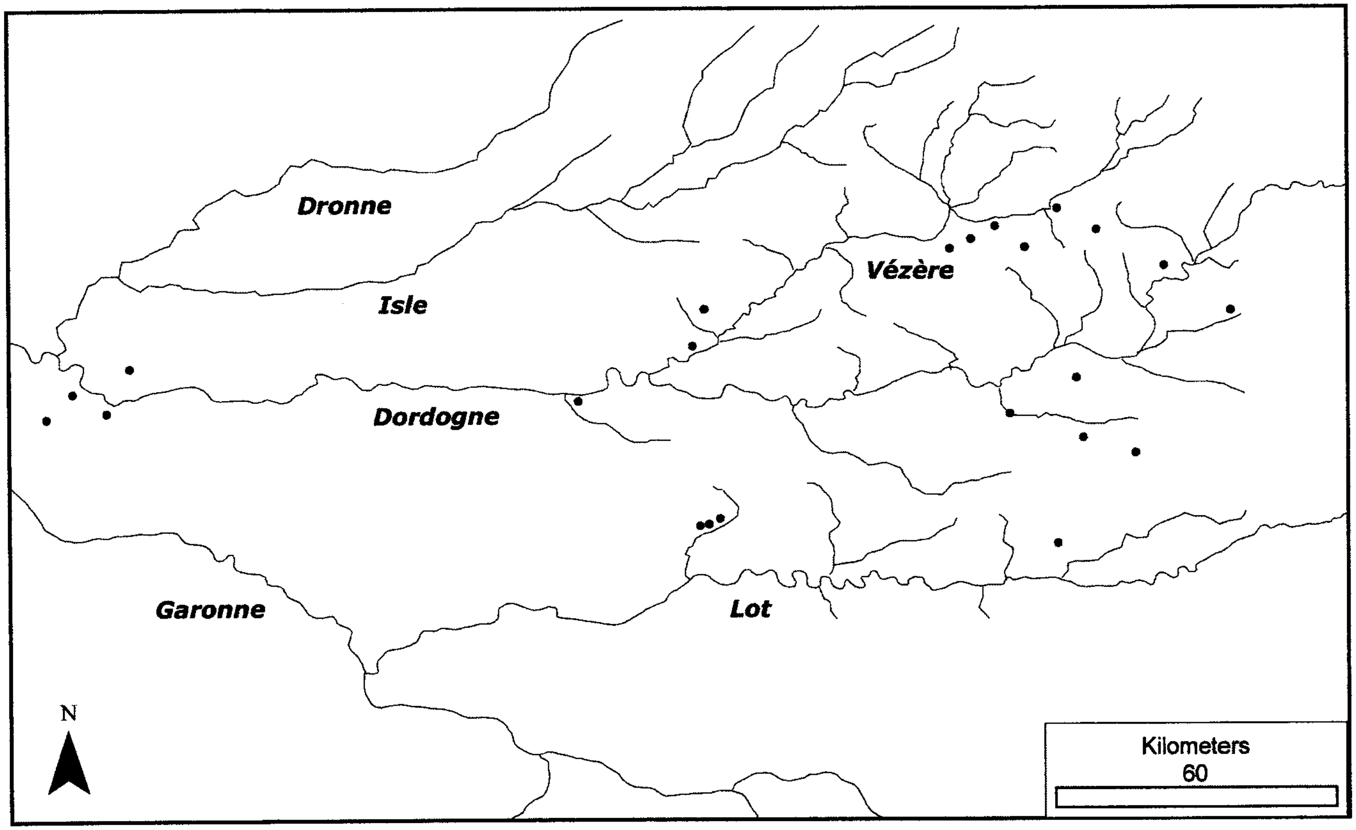


Figure 3.4. Site distribution in the Sauveterrian.

Table 3.3. Location of sites (in river valleys or on plateaus) in each time period.

Cultural/technological period	N of sites in valleys	N of sites on plateaus
Magdalenian	43	8
Final Magdalenian	33	18
Azilian	35	20
Sauveterrian	9	15

The other trend apparent in these maps is that sites tend to move farther east through time, though as discussed earlier this may reflect the chronological interests of different excavators. Another possibility, explored by Demars (2002), is that the amelioration of climate during this time period made the larger mountains to the east more attractive living environments.

The spatial analyst in ArcGIS was used to obtain the elevations for all the sites in each period from the DTEDs. A histogram (Figure 3.5) displays the distributions of elevations in each time period. Although there are some differences, the overall distributions are fairly similar. Descriptive statistics for the elevation data (Table 3.4) also demonstrate an overall similarity in the distributions of elevations. Mean elevation dips slightly in the final Magdalenian, but increases slightly through the Azilian and Sauveterrian. A regression and correlation analysis failed to find any significant correlation between mean elevation and number of sites ($r = +0.77$, $P = .233$).

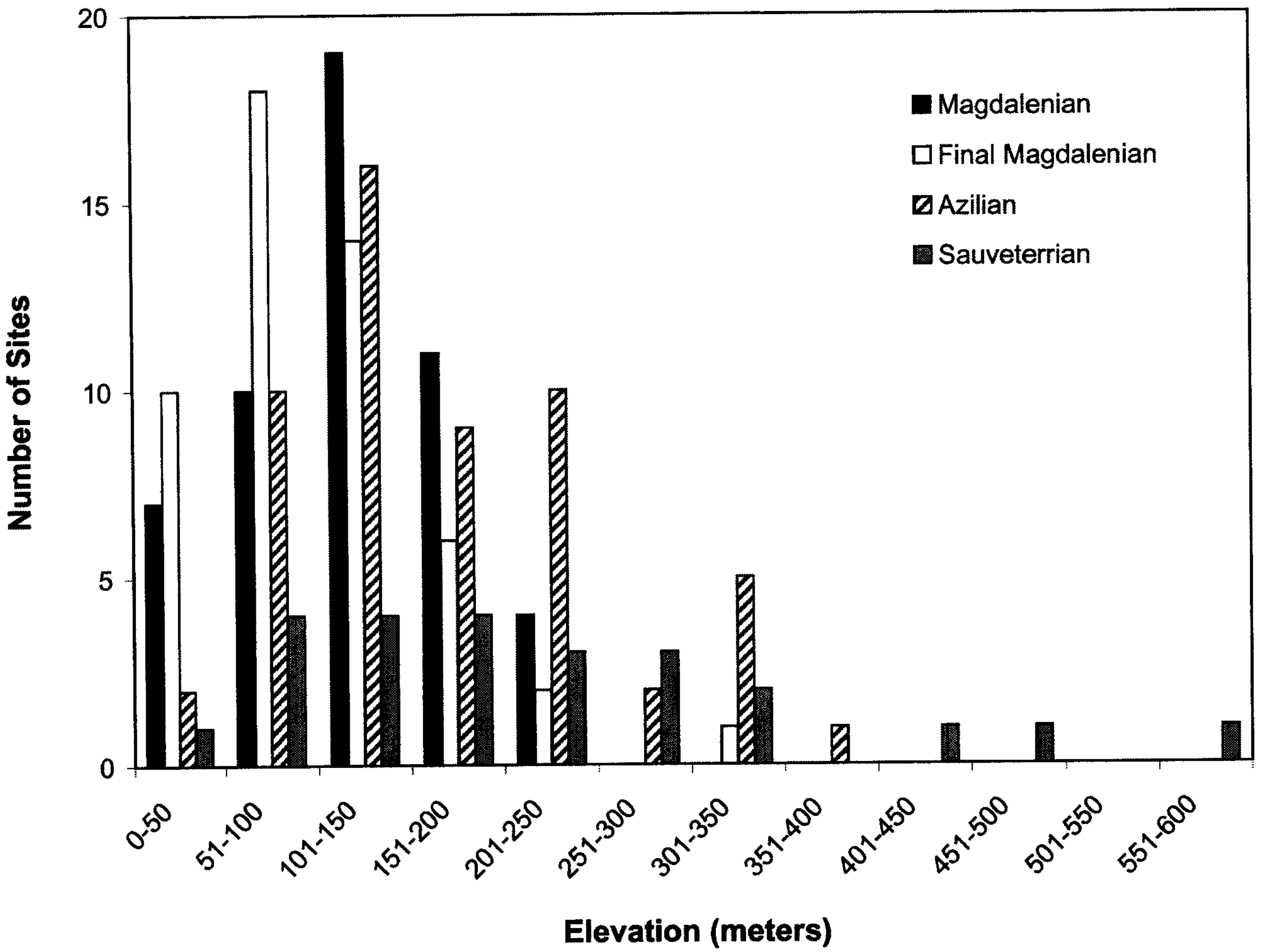


Figure 3.5. Distribution of site elevation by cultural phase/technological period.

Table 3.4. Elevation data for sites in this sample by cultural phase/technological period.

Cultural/technological period	No. of sites	Mean elevation	Std. deviation
Magdalenian	51	118.8	56.8
Final Magdalenian	51	101.3	62.2
Azilian	55	168.3	88.1
Sauveterrian	24	218.4	135.0

Using the elevation classes shown in Figure 3.5, I used an analysis of variance (ANOVA) to test the hypothesis that there is a difference in the distributions of elevations across these four periods. The ANOVA failed to identify any difference in the elevation distributions ($F = 1.481$, $p = 0.221$). When the smaller Sauveterrian sample was excluded, an ANOVA still failed to reject the hypothesis that the mean elevations are the same.

As these elevation data violate one of the underlying assumptions of ANOVA, that of equality of variances, I also compared the distributions using the χ^2-based Kruskal-Wallis test. Again, the test failed to reject the hypothesis that these four elevation distributions are equivalent ($\chi^2 = 7.141$, $p = 0.068$).

These tests suggest that, contrary to the suggestions of many authors writing about human settlement at the Pleistocene-Holocene transition, there is no significant change in site elevation at this time. Specifically, sites do not appear to be located at increasingly higher elevations from the Magdalenian through the Azilian and into the

Sauveterrian. However, other important changes in site location do appear to have taken place.

While there are no significant differences in elevation between these time periods, there are differences in site elevation variance, as Table 3.5 shows. I tested for homogeneity of variances using Bartlett's test (Zar 1999), with the null hypothesis that the variances are statistically equivalent tested against the hypothesis that site elevation variance increases through time. The test results confirmed that the variances for each period are significantly different from each other ($p < 0.001$).

Table 3.5. Variance data for sites in this sample by cultural phase/technological period.

Cultural/technological period	Range of elevation (m)	Variance of elevation
Magdalenian	0-236 (+237)	3221.35
Final Magdalenian	0-334 (+334)	3865.16
Azilian	15-399 (+384)	7761.61
Sauveterrian	24-560 (+536)	18230.90

We can thus conclude that, at least in this data set, site elevation variance increases significantly from the Magdalenian to the Sauveterrian (Figure 3.6).

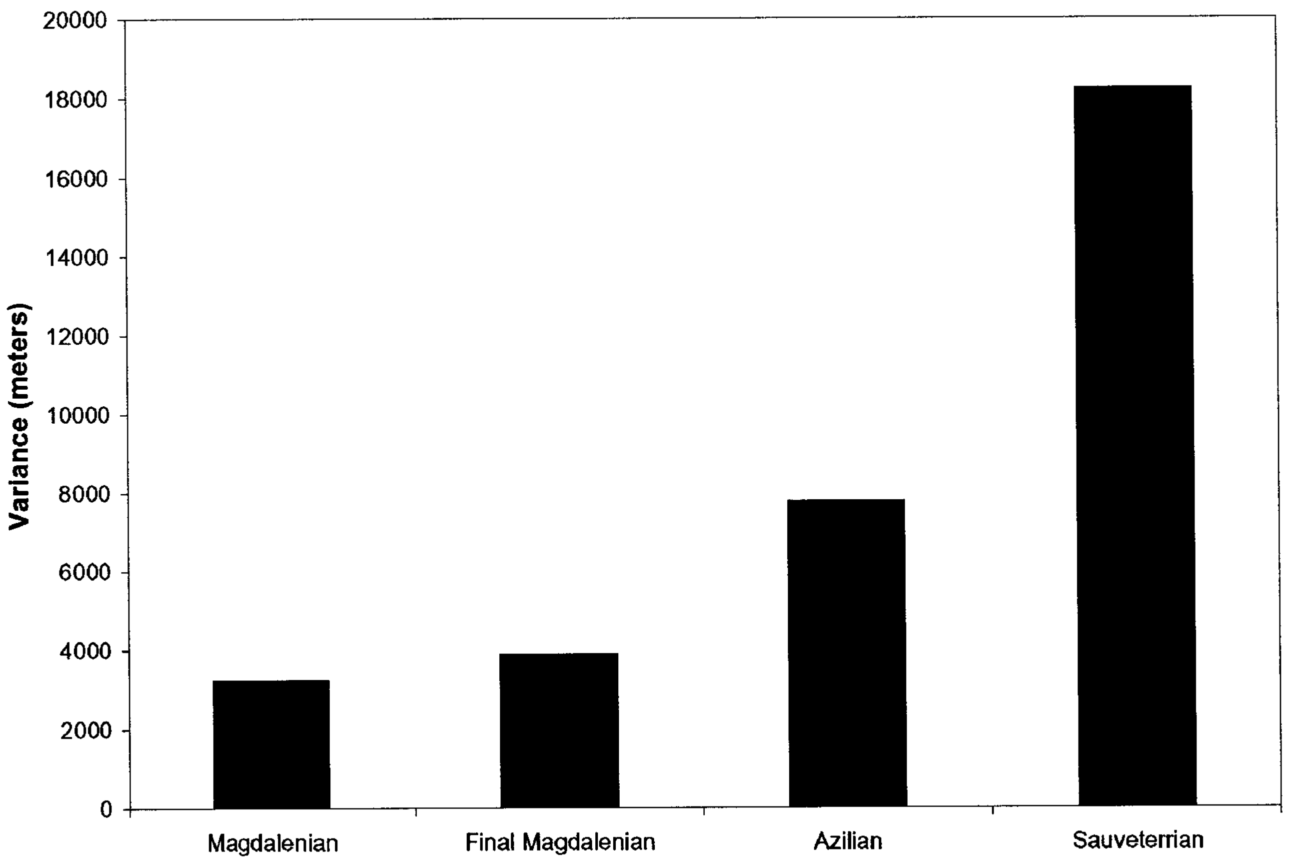


Figure 3.6. Histogram of site elevation variance by cultural phase/technological period.

Discussion

These results have a number of implications. First, the elevation hypothesis as articulated by Straus (1995b) and interpreted strictly is not supported by these data. Even when the smaller-sample Sauveterrian was excluded from the analysis, the hypothesis that later sites should on average be at higher elevations was not supported. This, along with the sample size regression analyses, suggests that there is no significant change in average site elevation across the Pleistocene-Holocene boundary in the Dordogne region.

This test of the elevation hypothesis did, however, identify a significant elevation-related trend in Dordogne sites across the Pleistocene-Holocene transition. While average site elevation did not increase significantly through this time period, site elevation variance did increase. In the late Pleistocene, most sites were at roughly the same elevation, while the transition period and the early Holocene saw the location of sites both in the valleys and on the plateaus.

Regional support for broadening diets

Both this chapter and Chapter 2 communicated regional data on change at the Pleistocene-Holocene transition in the Périgord. Three main conclusions can be drawn from this contextual information.

- Both the faunal data (e.g., Aura et al. 1998, 2002; Cleyet-Merle 1990; Laroulandie 2000; LeGall 1999; Simek and Snyder 1988; Straus 1995a, 1996, 1999; Villaverde et al. 1996, 1998; Villaverde and Valle 1995) and the elevation data support the hypothesis that diets broadened in the Périgord during the

Pleistocene-Holocene transition; the broadening began around 13,000 years BP and continued through the Azilian (~9,000 kyr BP).

- This increase in diet breadth is tied to climate to at least some degree, as the initial increase in diet breadth coincides with a major warming period; in addition, many of the small prey types that were added to the diet at this time were not available in the Périgord prior to the warming period (Biadi and Le Gall 1993; Callou 2000; Donard 1982; Rogers et al. 1994).
- However, the classic conception of how climate impacted human diets—that populations of larger fauna were negatively impacted by climate change, thus forcing increased diet breadth—is not supported by these data. All the main larger species (with the exception of reindeer) remain in the diet; in addition, faunal analyses show that the warming period at ~13000 kyr BP caused a substantial increase in the populations of ungulate species (Delpech 1983, 1992, 1999).

We have thus learned that diets did broaden, but not for the commonly accepted reasons. These data then leave us with the question of why diets broadened at this time. To answer this question, it is necessary to turn to theories of when and why people choose to include smaller prey in their diets.

Chapter 4:

Small prey exploitation, dietary expansion, and optimal foraging theory

Questions of why people might incorporate smaller prey into their diets are not new (i.e., Binford 1968; Boserup 1965; Childe 1952; Flannery 1969). Although many of these earlier works focus on the addition of plant resources to the diet, and specifically on the adoption of agriculture, they also touch on smaller prey items. Why are small prey and plants seen as similar? Central to all these works is the concept of energetic return: that prey can be valued based on the calories (or other value currency) they provide minus the energy spent in pursuing and processing them. By this reasoning, large mammals (such as, in the southwestern France case, reindeer or red deer) are seen as high-return, while smaller prey (such as lagomorphs, birds, or fish) are lower return, and plant resources generally (but not always) the lowest return of all. When looking at a suite of resources in this light, the obvious question becomes, why does anyone ever pursue lower-ranked resources?

The most common explanation relates to human population growth. Some researchers suggest that when lower-return items (which are often more reliable) are added to the diet, human population expands, thus creating a feedback loop that requires ever more intensification (Richerson et al. 2001). Others have argued that burgeoning human populations can cause people to deplete higher-return resources, thus forcing them to focus on lower-return ones, which in turn may cause increased population (Boserup 1965). Although human population does seem relevant to this issue, causation is a problem here: if population is at fault, what caused the population increase in the first place? And if expanding diet breadth is the culprit, what caused diet breadth to expand?

In this chapter I review the theories about resource depression and intensification most relevant to the question of small prey in the Périgord, taking a behavioral ecology perspective. I introduce models employed by foraging theorists and use them to derive testable hypotheses about the meaning of the increasing presence of *Oryctolagus cuniculus* in Epipaleolithic and early Mesolithic zooarchaeological assemblages.

Behavioral ecology and archaeology

In this work, I utilize a theoretical perspective drawn from human behavioral ecology to analyze human dietary decisions at the Pleistocene-Holocene transition. Behavioral ecology attempts to apply evolutionary theory to behavior and decision-making. Varying behavior is seen as a response to varying social and environmental conditions, with these responses assumed to be designed to be fitness-enhancing (Krebs and Davies 1993; Smith and Winterhalder 1992; Winterhalder and Smith 1981, 2000). Behavioral ecologists have created and tested a variety of models of predicted human behavior, many of which have been successfully applied to archaeology (e.g., Broughton 1994a, b, 1999; Broughton and Grayson 1993; Butler 2000, 2001; Cannon 2001; Grayson and Cannon 1999; Nagaoka 2001). The body of behavioral ecology work known as optimal foraging theory (Stephens and Krebs 1986) has been particularly widely used in prehistoric contexts.

In this work, I make use of two models drawn from optimal foraging theory, the prey choice and patch choice models; I will explain these in more detail later.

Binford, Flannery, and the "Broad Spectrum Revolution"

Binford (1968) was the first of the "New Archaeologists" to comment on the apparent expansion of diet breadth that appeared to take place at the Pleistocene-Holocene boundary. He suggested that increased population pressure at the end of the Pleistocene stemmed from rising sea levels, and this in turn induced people to turn to lower-return resources such as smaller prey and plants.

Flannery (1969) approached the same problem, but in a slightly different way, describing the increasing diet breadth at this time the "Broad Spectrum Revolution." Flannery felt that the expansion seen at this time was due to reductions in prey capture rates by foragers due to the foragers' own subsistence activities. Foragers broadened their diet in response, thus entering them into a feedback loop where human populations grew and ever more low-return items were added to the diet in response (Figure 4.1), eventually resulting in the adoption of agriculture.

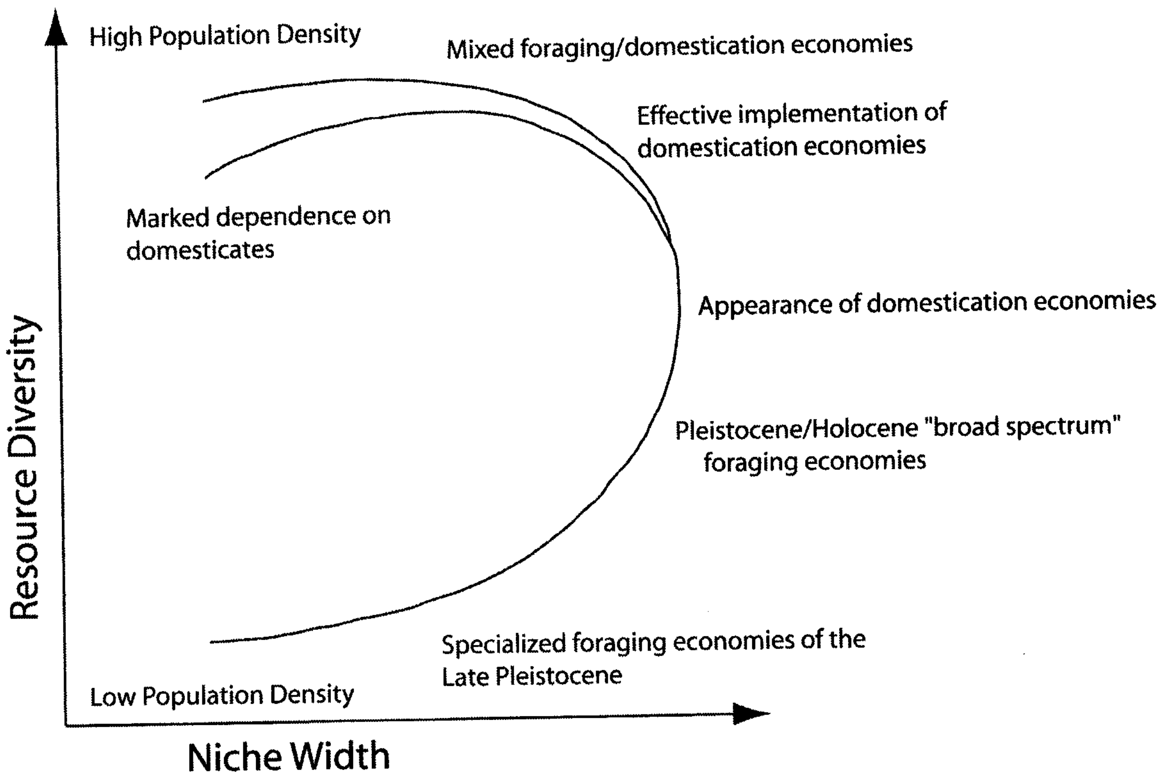


Figure 4.1. The broad spectrum revolution (after Clark 1999).

Flannery's broad spectrum revolution (BSR) hypothesis inspired a vast amount of research testing his arguments. Because his hypothesis was primarily targeted at western Asia, much of the initial BSR research focused on the Levant. Studies of plant use and grinding stones (Hillman et al. 1989; Keeley 1988; Miller 1992; Wright 1994) tended to support the BSR hypothesis, but work on archaeological faunas (Edwards 1989; Henry 1985; Horwitz 1996; Neely and Clark 1993; Stiner 1994; Stiner and Tchernov 1998; Tchernov 1992, 1994) produced mixed results. According to the BSR hypothesis, an increase in human population should force hunters to focus their efforts on smaller prey, such as birds, fish, and lagomorphs. Work on the faunas from the Levant, however, suggests that any change in human use of fauna during this period could be fully explained by concurrent climate change. Similar results have been obtained by researchers examining Pleistocene-Holocene dietary change in Western Europe (Altuna et al. 1991; Aura et al. 1998; Bicho 1993, 1994; Simek and Snyder 1988; Straus 1995a, 1996). Clark (1999) has suggested that changes in human population density, related to climate variability, might be responsible for dietary and technological variability in the Franco-Cantabrian region, but this suggestion has not been tested. All in all, while the paleobotanical data from the eastern Mediterranean tend to support the BSR, the faunal data—both in the Levant and elsewhere in the Old World—have been equivocal, with most suggesting that any changes in human faunal subsistence between 13,000 and 8,000 BP were climatically driven.

Optimal foraging theory: Prey choice

In recent articles, however, Stiner (2001) and colleagues (Stiner et al. 1999, 2000) have provided strong support for the BSR hypothesis using zooarchaeological data from Israel and Italy and a theoretical approach drawn from the prey choice model of optimal foraging theory (Charnov et al. 1976; Stephens and Krebs 1986). This model predicts the resources a forager will pursue once a resource has been encountered, given certain assumptions and parameter values (Grayson and Cannon 1999; Kelly 1995; Stephens and Krebs 1986; Winterhalder and Smith 2000). The prey choice model assumes that resources are encountered individually and randomly on the landscape. Potential prey types are placed in a rank-ordered set, with the ranking based on prey energy return rates—that is, how much energy (or other value currency) is returned from prey of a given type per unit pursuit and handling. The prey choice model thus suggests that a forager interested in maximizing foraging efficiency will pass up prey only if it has a sufficiently high probability of encountering higher-ranked prey. One clear conclusion of the prey choice model is that resources will be added to, or dropped from, a forager's optimal set according to efficiency rank order. It also follows that as encounter rates with high-ranked resources decline, a wider and wider array of increasingly lower-ranked prey types will be taken. Increasing numbers of lower-ranked prey types within a forager's diet can thus be seen as indicating a scarcity of higher-ranked resources.

The primary goal of most archaeological studies using the prey choice model has been to identify cases of prehistoric exploitation resource depression (Charnov et al. 1976), meaning reductions in prey capture rates by foragers due to the foragers' own subsistence activities, thus making this model an ideal tool for anyone interested in broad spectrum revolution research. Using a combination of the prey choice model and the observed correlation between prey size and return rate, most archaeological studies of resource depression have identified declines in archaeological faunas through time in the ratio of larger-bodied prey types to smaller ones (Broughton 1994a, b, 1995, 1997; Cannon 2000a; Grayson 1991; Janetski 1997; Szuter and Bayham 1989). In some situations, the body-size correlation seems to work well as a proxy for actual return rates.

In other situations, however, differences in ease of capture (Stiner et al. 1999, 2000), handling costs (Grayson and Cannon 1999), or method of capture (Grayson and Cannon 1999) may alter the rankings.

The prey choice model is thus merely a quantifiable approach to the concept of "return," which has been used by archaeologists investigating the broad spectrum revolution since Flannery first proposed it. Zooarchaeologists working with this approach (and using, essentially, the body-size proxy) were unable to identify a "broad spectrum revolution," as described earlier. Stiner, however, proposed that perhaps the reason no broad spectrum revolution was identified by these studies lay with the failings of the body-size proxy. By focusing on "work of capture" (that is, how much effort is required to capture prey) as a proxy return rate rather than prey body size, Stiner et al. (2000) have identified pulses in human population not only at the Pleistocene-Holocene boundary, but extending back as far as the Middle Paleolithic. Stiner (2001) concludes that the changes identified by Binford (1968) and Flannery (1969) were the last in a long series of periods of dietary expansion. Stiner's work suggests that the broad spectrum revolution hypothesis may be essentially correct; the inconsistencies encountered by previous researchers may have resulted from problems with the currency they used to rank faunal resources, rather than with the hypothesis itself. In addition, what Stiner sees as demographic expansions and associated increases in diet breadth may, in some regions at least, significantly pre-date the final Paleolithic.

Mass collecting and patch choice

The other commonly used optimal foraging model is the patch choice model. The patch choice model assumes that resources are distributed in patches, rather than homogenously on the landscape; that these patches are distributed and encountered randomly; and that travel time between the patches is non-productive. The longer foragers stay within a patch, the more resources are depleted and so the patch's return rate drops lower and lower. Under these conditions, foragers will maximize their overall foraging return rate (across all patches) if they leave a patch when its marginal return rate drops below the expected return from other patches, including the average cost of moving to these other patches. Once a patch is depleted, foragers may wait for it to be replenished before returning.

The patch choice model has not been widely tested in either ethnographic or archaeological contexts (but see Cannon 2001; Smith 1991; Zeanah 2000), as it is difficult to apply this model to particular situations. However, this model may be useful in situations where prey items are being taken *en masse*. Archaeological mass collecting may cause applications of the prey choice model to be problematic, because small prey taken *en masse* may cause a decreasing ratio of large to small prey even when encounter rates with larger prey types have remained constant (e.g., Cannon 2000a; Jones 2004; Madsen and Schmitt 1998). Mass collecting should not, however, disrupt patch choice-based analyses. The problem of mass collecting and its applicability to the Périgordian Pleistocene-Holocene transition situation will be discussed in depth in Chapter 5; here, I only note that in the case of any evidence of mass collecting, a patch choice analysis should be used rather than a prey choice one.

Resource predictability, risk management, and smaller prey

Evolutionary ecology-based approaches to risk management (e.g., Cashdan 1990; Layton et al. 1991; Smith 1991; Winterhalder 1986; Winterhalder and Goland 1997) may also be relevant here. All foragers face risk as part of their subsistence choices: while one may bring home a good meal one day, other days one may bring home nothing. Foragers have developed a number of strategies to cope with this problem, the most widely-documented being food sharing (Winterhalder 1986). If the foraging success of individual foragers is random and not synchronous, then food sharing should effectively mitigate individual variability in success by pooling their resources.

Another risk management option is shifts in residence, or the widely-observed seasonal round. The classic conception of the late Pleistocene in the Dordogne (i.e., Gordon 1988; Mellars 1994), suggests that foragers during this period focused their subsistence efforts on spatially and temporally predictable reindeer and salmon migrations; some have gone so far as to call Magdalenian hunter-gatherers specialized reindeer hunters. The focus on reindeer hunting allegedly determined many factors of Magdalenian life, from diet to settlement strategy (Enloe 1998; Gordon 1988; Mellars 1994; White 1985). In contrast, according to this view, the Holocene was marked by general unpredictability and an overall paucity of resources.

There are, however, serious problems with this argument. First of all, it has thus far not been supported by archaeological evidence; both studies of the relative abundance of large mammals in zooarchaeological assemblages and seasonality studies have demonstrated that Upper Paleolithic people were not specialized reindeer hunters (Burke 1995; Delpech 1992; Enloe 1993; Pike-Tay 1991, 1993). A diet focused on just one or two large mammal resources is improbable in any case, as large game hunting is not generally a reliable method of meeting daily caloric needs (see discussion in Chapter 5, also see Hunn 1981; Kornfeld 1996). Moreover, the temporal predictability of both reindeer and salmon migrations (the two resources most often suggested as the basis for late Pleistocene diets) is well-known to be negatively affected by climatic variability (Post and Stenseth 1999). Pleistocene climate may well have been variable enough to impact the temporal predictability of seasonal migrations.

In addition, it is possible that the broadening of diet that occurred during the very last phases of the Pleistocene and early Holocene may have resulted from *increased* predictability and seasonality of resources. It has been suggested that the extreme variability of Pleistocene environments made the availability of resources—both the large prey types that were allegedly the basis of the Upper Paleolithic diet and smaller prey types—both spatially and temporally unpredictable (Richerson et al. 2001). In such a situation, establishing a fixed seasonal round would have been inefficient. If resources were available only unpredictably (or perhaps not at all), it would be impossible to time one's stops on a seasonal round for maximal harvest of resources. A better strategy might have been to settle adjacent to a major river valley, which would be an enticement for many sorts of resources, and when possible intercept temporally unpredictable migrations of large mammals and fish. The advent of the Holocene, however, may have led to an increase in both spatial temporal predictability of resources, thus favoring the establishment of a seasonal round and settlement of previously unprofitable areas.

It is thus possible that the Magdalenian, contrary to popular perception, was not an "age of plenty" for Dordogne region hunter-gatherers (Grayson and Delpech 2002a). If the Magdalenian was relatively resource-poor, an increase in available resources around 13,000 years BP could explain both the broadening of diet and the change in site elevation variance described earlier.

Oryctolagus cuniculus *in the Périgord: hypotheses*

What does this mean when applied to the Périgord at the Pleistocene-Holocene transition? It is clear that there was a general widening of diet breadth in this region at the end of the Pleistocene (i.e., Table 2.4). According to the prey choice model, diet breadth may widen when the availability of higher-ranked resources drops below a certain threshold. In this case, higher-ranked resources may have decreased in relative abundance due to:

1) **Climate change effects on large mammals**, in which case we would expect a gradual addition of *Oryctolagus* and other smaller resources to the diet, correlated with climate change;

2) **Human-induced resource depression**, in which case we would expect a gradual addition of *Oryctolagus* and other smaller resources to the diet, not correlated with climate change, and also would expect signs of resource depression in the larger fauna;
3) **A resource-restricted Magdalenian**, in which case *Oryctolagus* should be present in archaeological faunas as soon as it was available in the region, and its abundance should fluctuate in response to climate changes known to have an effect on *Oryctolagus* abundance.

If, however, *Oryctolagus* was taken *en masse*, a prey choice-based analysis is likely inappropriate; this problem will be discussed in detail in Chapter 5. A patch choice-based analysis would be more appropriate, and would predict the following:

4) In the case of **climate change effects on large mammals** as a causative factor, people should gradually increase the number of patches exploited through time, and these increases should correlate with known climate changes.
5) In the case of **human-induced resource depression**, people should gradually increase the number of patches exploited through time; these increases should not correlate with known climate changes, and signs of resource depression should be visible among the larger fauna.
6) In the case of **a resource-restricted Magdalenian**, there should be a sudden increase in the number of patches exploited; in particular, there should be a

shift away from more distant, forested plateau-top patches towards more local, mixed-habitat river-valley patches.

Although there are other possibilities, these possibilities are the main contemporary hypotheses for understanding resource change in the Périgord across the Pleistocene-Holocene transition. Hypotheses and expectations are summarized in Table 4.1.

The first step, then, involves identifying whether or not *Oryctolagus cuniculus* was collected *en masse* in the Périgord, because this will determine the method for evaluating the reason and outcome of its inclusion. Chapter 5 will discuss mass collecting more broadly and outline a procedure for identifying it in zooarchaeological assemblages of *Oryctolagus cuniculus*.

Table 4.1. Summary of hypotheses and expectations.

	No mass collecting of *Oryctolagus*	**Mass collecting of *Oryctolagus***
Hypothesis #1: climate change effects on large mammals	• gradual addition of *Oryctolagus* and other smaller resources to the diet; • diet breadth correlated to climate change.	• gradual increase in the number of patches exploited through time; • increases should correlate with known climate changes
Hypothesis #2: human-induced resource depression	• gradual addition of *Oryctolagus* and other smaller resources to the diet; • diet breadth not correlated with climate change; • signs of resource depression in the larger fauna	• gradual increase in the number of patches exploited through time; • increases should not correlate with known climate changes; • signs of resource depression should be visible among the larger fauna
Hypothesis #3: resource-restricted Magdalenian	• *Oryctolagus* present in archaeological faunas as soon as available; • relative abundance fluctuates in response to landscape changes known to have an effect on *Oryctolagus* abundance	• sudden increase in the number of patches exploited; • shift towards more local, river-valley patches

Chapter 5

Identifying mass collecting in assemblages of *Oryctolagus cuniculus*

Evolutionary ecology and, specifically, optimal foraging theory were introduced in the previous chapter. In particular, I focused on explaining the prey and patch choice models of optimal foraging theory. The previous chapter also introduced the potential problem of mass collected items when constructing a ranked list for a prey choice analysis. Though the potential issue of mass collecting for archaeological prey choice analyses has been widely cited, only in a few cases has it been discussed at length (i.e., Madsen and Schmitt 1998). Here, I focus on explaining mass collecting, its potential implications for prey-choice based archaeological research, and the specific application of this issue to the Pleistocene-Holocene transition case. In particular, I present expectations should the wild European rabbit have been taken *en masse* in this instance, and provide methods for the identification and analysis mass-collected archaeological rabbit assemblages.

Mass harvest methods

Mass collecting is a widely-used technique among hunter-gatherers. The ethnographic record is replete with examples of mass harvest (see Table 5.1). As can be seen in Table 5.1, mass harvest techniques vary so widely that it is difficult to generalize about them. However, all require some sort of trap (this could be a net, weir, corral, or simply a large number of people); and many require a flushing agent (such as fire, water, or again, people). While some mass harvest techniques employ special technology, the strategy does not in and of itself require it—just a group size sufficient to trap and process the prey in question. There are numerous examples both of mass harvest techniques that require virtually no technology, and techniques that require complex and costly technology (Table 5.1).

One can loosely group different types of mass collecting into two groups: technique- or technology-focused approaches (i.e., you get whatever comes in the net) and taxon-focused, where the strategy depends strongly on the behavior and ecology of a particular prey type. In a technology-focused approach, the method of capture depends on some sort of tool that has been devised to withstand the constraints of a particular environment. For example, in the Congo Basin extraordinarily strong nets are devised to catch various strong, potentially dangerous forest prey which are flushed out of the bush (Lupo and Schmitt 2002). Among the Inujjuamiut (northern Canada) and other people of the American Arctic and Subarctic, ice-netting for a variety of fish species is a common technique (Nelson 1986; Smith 1980, 1991). In this case, nets are constructed to catch fish of an appropriate size and to withstand the strain of being set in the ice. While there are considerations of what particular species are desirable in the construction of both of these tools, they are both designed to accommodate variation in the catch, and to withstand the demands of the environment for which they are created (Nelson 1986). In

Table 5.1. A selection of different types of mass collecting.

Method	**Location**	**Target prey type(s)**	**Technology needed**	**Source**
Driving into pit	Great Basin	Grasshopper (*Anabrus simplex*)	Pit	Jones and Madsen (1991)
Driving into stream	Great Basin	Grasshopper (*Anabrus simplex*)	none	Jones and Madsen (1991)
Found in windrow	Great Basin	Grasshopper (*Anabrus simplex*)	none	Madsen and Kirkam (1988)
Ice netting	Arctic	Freshwater/anadromous fish	net	Nelson (1986); Smith (1991)
Fall netting	Arctic		net	Nelson (1986); Smith (1991)
Spring netting	Arctic		net	Nelson (1986); Smith (1991)
Net hunt	Central Congo	Mix of small mammals	net	Lupo and Schmitt (2002)
Net hunt	Australia	Mix of bird species	net	Satterthwait (1987)
Basket hunt	Great Basin	Mix of fish species	basket	Lindstrom (1996)
Rabbit drive	American West	Jackrabbit (*Lepus spp.*)	variable: corral, net, none	Schaffer and Gardiner (1995); Speck and Schaeffer (1950)
Eel traps	South Pacific	Eel (*Anguilla* spp.)	basket or net	Marshall (1987)
Salmon weir	PNW	Salmon (*Salmoninae*)	weir; gill net	Hunn (1990);

the end the "prey type" (i.e., whatever is caught in the net) is relatively diverse, encompassing a variety of species (Smith 1991).

This is unlike the taxon-focused approach, which is designed to exploit the behavior of a particular type of animal. An example of this sort of approach is the so-called rabbit drive of Western North America. In a rabbit drive, a group of hunters flushes out hares (*Lepus* spp.) and drives them into a net or corral (Schaffer and Gardiner 1995; Speck and Schaeffer 1950). This technique exploits the hare's instinctive reaction to a threat, which is to run for long distances (Cannon 2000b; Schmidt 1999). Cottontail rabbits (*Sylvilagus* spp.) and other leporids locally available were not targets of the rabbit drive, because they have not evolved the same response to threats.

Another example of a species-focused approach is salmon harvesting in the Pacific Northwest. In this region, people took advantage of the annual migration of salmon (or salmon "runs") in local streams as an opportunity for mass harvest. At the time of salmon runs, people would use gill nets or weirs to catch large numbers of salmon; they also collected dead spawned-out salmon (Hunn 1990). Ethnographic reports indicate that on a peak day, a fisherman might take several hundred fish (though this would only be possible for a few days each year). Like the rabbit drive, this approach takes advantage of a specific attribute of salmon—the annual migration—and makes it part of the technology used to gather large numbers of this prey at one time.

Gender and mass collecting

Gender is a potentially important aspect of this technique/taxon split in mass collecting techniques. Ethnographers have observed a nearly universal sexual division of labor: men generally focus on higher-return, less predictable resources (often large game), while women focus on the more reliable but lower return plants and smaller animals (Hurtado et al. 1985; Winterhalder and Smith 1981). In general, it seems that the costs (Hurtado et al. 1985) and benefits (Bliege Bird 1999) faced by men and women are different, and thus, in prey choice terms, their ranked lists differ substantially. In particular, the hunting of many large mammals is often more a question of male-male competition and prestige than one of caloric return (Hawkes and Bliege Bird 2002; Smith and Bliege Bird 2000).

Zooarchaeologists typically focus on the larger, more generally "male," high-return and high-prestige prey, thus avoiding the problem of trying to analyze two separate foraging strategies as one. Mass collecting, however, is often a group activity, including men, women, and sometimes children (Madsen and Schmitt 1998; Ugan in prep). If this is the case, then mass collecting may not be valued in the same way as larger, male-hunted, high-return, high-prestige mammals.

A particularly important aspect of this gender problem is how it plays into the difference in taxon vs. technology-focused mass collecting strategies. While taxon-focused approaches are almost always mixed-group strategies, the technology-focused ones are primarily male (though women often are responsible for or assist in the creation of the technology, as discussed in Lupo and Schmitt 2002).

Why does it matter?

As mentioned earlier, identifying mass collecting in archaeological situations is of crucial importance because prey choice methodology within archaeology relies so heavily on the body size proxy. It is well known that mass collecting may cause a discrepancy between prey body size and rank (Cannon 2000b; Grayson and Cannon 1999; Jones 2004; Madsen and Schmitt 1998). Table 5.2 compares prey rankings for Inujjuamiut foragers based on prey body size to ranks based on measured post-encounter energetic return. While there is some correlation, there are also some notable differences. In particular, the entries "ocean fish" and "ice netting" are of interest: the Inujjuamiut take fish in nets, both in ocean nets during the summer and in ice nets during freeze-up. The fact that these fish are taken *en masse* results in a difference in caloric return between the body-size ranking and the post-encounter energetic return rate.

One might ask if this is this truly important. There are those who argue that the increased handling costs as well as the start-up costs associated with mass harvest techniques will render small prey taken *en masse* lower ranked than larger package items despite their increased value (Lupo and Schmitt 2002; Ugan in prep). One could conceptualize this situation as a tradeoff: while *en masse* harvesting increases the value of the prey items in question, it also increases the costs. A famous example of this

Table 5.2. Prey ranking based on energetic return and on kcal/individual (Jones 2004; Smith 1991, pp. 181, 234).

Common name	**Post-encounter return rate (kcal/hr)**	**Rank**	**Kcal/individual (edible portion)**	**Rank**
Summer resources				
Bearded seal	25,680	1	68,020	3
Caribou (coastal)	25,370	2	149,810	2
Ringed seal	13,550	3	11,710	4
Beluga (encounter)	14,090	4	193,370	1
Ocean fish	8,900	5	2,120	6
Canada goose (canoe)	4,930	6	3,590	5
Eider	4,810	7	1,430	7
Fall resources				
Bearded seal	15,000	1	68,020	1
Ringed seal	13,010	2	20,210	2
Eider	5,160	3	1,430	3
Ptarmigan	3,450	4	510	5
Brook trout	2,280	5	810	4
Winter resources				
Caribou	25,370	1	149,810	1
Bearded seal	15,000	2	68,020	2
Ice netting	14,280	3	2,120	4
Ringed seal	13,010	4	20,210	3
Ptarmigan	2,670	5	510	5
Spring resources				
Bearded seal	15,000	1	68,020	1
Ringed seal	13,550	2	20,210	2
Canada goose (blind)	3,460	3	3,590	3
Eider (floe edge)	3,180	4	1,430	6
Ptarmigan	2,290	5	510	7
Canada goose (encounter)	1,720	6	3,590	3
Lake trout	1,110	7	3,060	5

situation involves the !Kung San harvest of the mongongo nut (Hawkes and O'Connell 1981, 1985; Lee 1979). Initial analyses of the Dobe !Kung use of the mongongo nut found this to be an extraordinarily productive resource, so much so that !Kung foragers allegedly spent much of their time in leisure activities (Lee 1979). In-depth analysis, however, showed that when the costs of processing the nut were taken into account, the mongongo nut (like plant resources in other parts of the world) fell into a very low-return category; in fact, much of the time allegedly spent in leisure in fact included processing activities (Hawkes and O'Connell 1981, 1985).

Likewise, the cost of producing the technology required for *en masse* hunting can be costly in terms of both time and resources. A recent study by Lupo and Schmitt (2002) demonstrated that the costs associated with *en masse* hunting in the Congo basin—both the creation of the nets used in this area and the risks involved with this kind of hunting—made the return associated with this technique lower than would be expected given the energetic return from a single hunting expedition. In the Congo basin example, game is flushed from the bush into sturdy nets. Making these nets is costly in terms of time and materials, and the actual hunting can be dangerous. The overall return, therefore, is relatively low.

The Congo net-hunting case is, however, an unusual one. The animals in this forest are often large and dangerous, and so both the need for strong nets and the risk involved in hunting are exceptionally high. In the Inujjuamiut case, the nets used are industrially manufactured ones, and so net creation and maintenance are relatively noncostly (there is no evidence for net use prior to European contact, see Smith 1980, 1991). The differences in rank between prey body size and energetic return are sufficient to disrupt the ordinal-scale ranking, and to render the standard relative abundance indices typically used by optimal foraging theory-inclined archaeologists completely useless (Jones 2004).

In the Congo net-hunting case, it is the variety of prey types that makes the strategy costly. The more taxon-specific the approach, the lower its overall risk and, often, the higher its potential return. Because the return is so high, the effect of processing costs is often less. In addition, in a mixed-group hunting strategy processing costs may have a more complex effect than in other situations. Ethnographic research shows that in many cases, processing is a task usually completed by women, and in these cases, the decision whether or not to pursue a resource may depend more on women's foraging strategies than on men's. For example, in the salmon run example described earlier, the costs of processing and drying the overall take for storage is offset by the large take. Although the processing costs would have some effect on overall return, in this example men do the actual fishing but not the processing (Hunn 1990)—while the women handled processing, men would be free to pursue other resources. This is true of many of the mixed-group mass capture activities whose return would be decreased by processing (Bliege Bird 1999; Hawkes and Bliege Bird 2002; Hurtado et al. 1985; Hurtado and Hill 1990).

Another example of this involves the capture of grasshoppers (*Anabrus simplex*) in the Great Basin. Ethnographically, many of the Paiute groups in the Great Basin collected and ate grasshoppers; methods included driving grasshoppers into trenches and streams, as well as collecting from windrows. This activity resulted in extraordinarily large returns—calculations place returns for this activity in between 41,598 kcal to 714,409 kcal (Jones and Madsen 1991; Madsen and Kirkman 1988). It has been argued that processing would significantly decrease the overall profitability of this strategy (i.e., Ugan in prep), but again, this is an example of a mixed-group harvest strategy where the processing was handled primarily by women (Steward 1933). Men were free to pursue other resources while women processed and prepared them for storage—leaving grasshoppers extremely high on men's ranked list of items.

In cases like these, all that is necessary for a mass-collected prey type to appear in the diet is that it is sufficiently high-ranked (including processing costs) for it to appear on the women's list of ranked resources. Thus the argument that processing costs will offset the high returns of mass capture strategies, thus leaving the body-size proxy intact, may not be valid in the case of a taxon-specific, mixed-group foraging strategy.

In sum, these mixed *en masse* harvest strategies take advantage of the biology and life history of specific prey types. To consider the salmon example yet again, if people had just stuck their nets in the water at random, this would have been both a less profitable and a riskier endeavor. The people involved need a strong knowledge of salmon behavior in order to make this strategy feasible. Likewise, zooarchaeologists interested in assessing prehistoric hunting strategies and efficiency need a knowledge of the behavior, life histories, and nutritional ecology of the species involved in order to both identify mass collecting situations and to assess how these strategies may have affected the prey type rankings of prehistoric hunter-gatherers.

Mass harvest of Oryctolagus cuniculus

Leporids have a long history of being collected *en masse*, but most discussion of leporid mass capture techniques has focused on the capture of hares (*Lepus* spp.) through what is commonly called a "rabbit drive" (Cannon 2001; Hockett and Haws 2002; Schaffer and Gardiner 1995; Schmidt 1999; Speck and Schaeffer 1950). Mass collecting of other leporids, however, has been recorded, in particular in reference to the wild European rabbit (*Oryctolagus cuniculus*). Unlike hares (but like *Sylvilagus* spp., the American cottontails), *Oryctolagus* is difficult to drive into nets, as they have evolved to hide when threatened rather than running long distances as hares do (Banks et al. 1999; Cannon 2000b; Kolb 1991). When their population is sufficient, however, *Oryctolagus* will build large, complex, easily visible warrens (Corbet 1966; Delibes and Hiraldo 1979; von Holst et al. 1999; Kolb 1994; Promislow and Harvey 1990). Rabbits generally breed in these warrens from January through August, with up to 60 rabbits per warren at any given time during this period (Delibes and Hiraldo 1979; Promislow and Harvey 1990). Because the warrens are easily visible, rabbits can be trapped in and taken directly from these warrens, thus raising the return rate from this resource.

This practice has been well-documented historically in Europe (Biadi and Le Gall 1993; Moreno and Villafuerte 1995; Rogers et al. 1994). The Romans are recorded as having taken this approach (Callou 2000); more direct evidence is available from medieval illustrations. Many of these (Callou 2000) show rabbit warrens enclosed by fences; noble ladies are also often present. Associated documents make it clear that in this period, wild rabbits could be considered semi-domesticates: people would enclose them with fences, and harvest as necessary (never clearing out the whole warren, as this would render such long-term investment as a fence useless).

This situation appeared to have persisted at least until the French Revolution, when the denial of "warren rights" to peasantry has been cited as one of the complaints that contributed to eventual rebellion (Callou 2000; Rogers et al. 1994). This is a particularly intriguing case, as the nobility wanted to hunt rabbits individually for sport, but rabbit warrens were an important source of food to peasants.

The mass harvest process was further refined in some areas with the use of dogs. These rabbit-hunting dogs were trained to enter the warrens and flush out the rabbits, thus eliminating the need for any other flushing agent (Biadi and Le Gall 1993).

This venerable history of *en masse* capture of *Oryctolagus* suggests that such a technique may have been used by the prehistoric inhabitants of Europe as well. Mass harvest of the European rabbit would be similar to the taxon-based, mixed-group approaches described earlier. Adult rabbits, on average, provide 5.3 kcal/gram, with individual rabbits ranging in size from 1 to 1.5 kg (http://www.rodentpro.com, also see

Anderson and Deskins 1995). Newborns generally weigh no more than 200 g when weaned, and provide 5.06 kcal/gram (Henderson and Bowen 1979; Kolb 1992; Robson 1993, http://www.rodentpro.com). Up to 60 individual rabbits may be present in a warren during breeding season; assuming that 4/5 of these are newborns, and using the lower weight, estimates the overall take from a full warren would be over 80,000 total kcal. Costs involved with capture are minimal, as while nets or fences can be useful in making a full capture they are not necessary (Biadi and Le Gall 1993; Schaffer and Gardiner 1995; Speck and Schaeffer 1950), and all that is needed to flush the warren is fire or water. Processing costs would be substantial, but again, ethnographically warren-based hunting was done by mixed groups, and presumably women would be responsible for processing (Biadi and Le Gall 1993). For men, who do not pay the processing costs, when ranking based on average kcal this resource would out-rank individual hunting of larger ungulates.

Hockett and Bicho (2000) have suggested that the presence of warrens made rabbits a higher-ranked prey item in Paleolithic Portugal, but this suggestion has not yet been tested. Certainly, the possibility that the Paleolithic inhabitants of Europe were mass harvesting *Oryctolagus*, and thus raising its energetic return value, should be investigated.

Demographic profiles

In the arid western United States, where rabbit drives raised the return rate from leporids, researchers have successfully distinguished assemblages of mass-captured leporids from ones taken singly using a variety of methods, but primarily relying on demographic profiles (Cannon 2000b; Klein 1982; Schmidt 1999). Demographic profiles attempt to reconstruct the demographic characteristics—usually age but sometimes sex as well—of the animals taken by prehistoric people.

Although demographic profiles can be an extraordinarily useful tool, their potential problems are well-reported (Lubinski 1997). As in most archaeological situations, time averaging—situations in which a deposit encompasses collections of fauna collected different ways—can be a problem (Bush et al. 2002; Lyman 2003). If an *Oryctolagus* assemblage contained both rabbits collected *en masse* and rabbits taken individually, over a series of years, the demographic profiles obtained from this assemblage would be affected. In addition, variation in the amount of time contained in the series of deposits undergoing analysis may affect results. It is thus critical that these issues be addressed in such an analysis.

Sample size is also a critical issue here. More significant, however, is that in a demographic profile, one will always get a pattern that could be interpreted. For a rigorous test, then, one must have clear expectations. Often people are looking for a "natural" profile, but for many species, the natural population demography is difficult to predict.

Fortunately, this is not a significant problem in the *Oryctolagus cuniculus* case. An assemblage of rabbits taken from a warren should present a distinct demographic signature. Warrens are almost exclusively inhabited by females of reproductive age and newborn rabbits, while rabbits taken on the landscape are predominantly adult (>2 years) males (von Holst et al. 1999; Promislow and Harvey 1990; Webb 1993). Thus, an age profile from a rabbit assemblage taken from warrens should be dominated by young (<1 month) individuals, while one from rabbits taken singly should be dominated by adults (>2 years). A sex profile of a warren-generated assemblage should be predominantly female, while one from landscape hunting should be predominantly male.

Another potential problem with demographic profiles in the *Oryctolagus* case concerns selection. Human predators sometimes avoid young rabbits and preferentially take adults, as adult rabbits provide a higher energetic return (Hockett and Bicho; Hockett and Haws 2002). A lack of juveniles in a demographic profile, then, is not a guarantee that no *en masse* harvest was occurring. Both juveniles and females should be under-represented in order to draw such a conclusion.

Finally, demographic profiles of *Oryctolagus cuniculus* can also be used to assess season of capture. As rabbits breed during a predictable cycle, the proportion of juveniles in a sample can be used to estimate when the rabbits were taken (Hockett and Bicho 2000). Generally, rabbits breed between January and August, though this varies based on climate (Bell and Webb 1991; Callou 2000; Lombardi et al. 2003; Villafuerte et al. 1993; Villafuerte et al. 1997). If the individuals were taken during the breeding period there should be a high proportion of sub-adult rabbits. If rabbits were taken in the autumn, however, there should be a low frequency of sub-adults.

Taxon and technology, revisited

It is, then, possible to identify mass collecting in some cases. However, doing so requires multifaceted, species-specific knowledge, essentially the same knowledge that the hunter-gatherers collecting these items would have had. In the *Oryctolagus cuniculus* case, several types of knowledge are necessary:

- an understanding of situations when rabbits will build warrens;
- paleoecological information from the area surrounding the site in question;
- understanding the biology and demography of a warren;
- sex and age data from the archaeological samples; and
- sufficient sample sizes to be able to draw conclusions from the demographic profiles.

Not all sites will provide such detailed information. In addition, the development of demographic expectations for other species which may have been targeted by mass collecting techniques is necessary in order to identify *en masse* hunting among these species. Work on mass collecting of *Lepus* spp. provides an example of this. Schmidt (1999) and Cannon (2001) have both identified indicators of mass collecting for hares hunted in rabbit drives; these differ substantially from expectations for mass-collected European rabbits. Most significantly, assemblages of hares taken in drives represent the demography of a complete living population. Assemblages of *Oryctolagus* taken from warrens represent a very specific segment of the living population: females of reproductive age and newborn rabbits.

It is clear, then, that techniques for identifying mass collecting will change from species to species, in relation to differences between the behaviors of the species in question. How similar the species are morphologically is irrelevant; *Lepus* and *Oryctolagus* are so similar in skeletal morphology that their skeletal elements can be very difficult to distinguish from one another (Callou 1997, 2000; Donard 1982). *Sylvilagus* spp., the American cottontails, have an appearance (both skeletally and with skin) and behavior quite similar to *Oryctolagus*, but are distant in terms of DNA (Branco et al. 2002; Callou 2000; Hibbard 1963; Monnerot et al. 1994), do not create warrens (Wilson and Ruff 1999) and there is no record that this species was ever a subject of a mass collection strategy (Cannon 2001). This serves as a caution: no matter how similar species may seem, it is the differences in behavior that count when it comes to identifying a mass collection strategy.

Related to this, the differences in the technology of mass collecting also will make a difference, both in how one can identify such a situation and also in the importance of the mass collection in determining the rank of the prey taken in it. The available technology will have a huge impact on whether mass collecting is possible or not (Lupo and Schmitt 2002); technology start-up costs may be low (as in the case of fish weirs, which require some time in creating the weirs and the possession of appropriate weaponry, or collecting *Oryctolagus* from warrens, which requires a net and access to water or fire with which rabbits can be drawn out of the warren), but in many instances they are not. In addition, an event like those in the Congo basin described by Lupo and Schmitt (2002) may be difficult to identify archaeologically. Such an activity would bring forth, not a particular sample of a species (which could then be identified by demographic profiles) but a sample of the prey types available in the bush. The only hope in such a situation might be size-related considerations, if certain items are too small to be caught in the net. However, since technology-based techniques are less likely to alter prey return-rate rankings, this is perhaps less important.

In the case of taxon-based approaches, though, identifying mass collecting is important. Although identifying mass collecting is labor-intensive, it is possible—and it is also necessary for any archaeologists interested in using prey choice. The possibility that any of the prey items in an archaeological sample may have been collected *en masse* must be considered before further analyses can take place. This requires knowledge of both the available technology and the biology and behavior of the species involved.

There are, of course, a number of problems. When integrating mass collecting analyses into prey choice-based studies, it can be difficult to quantify how the strategy affects energetic return. Short of actual return rates from specific collecting activities (such as those provided by Lupo and Schmitt 2002), it may be impossible to find an actual "rank" for mass-collected resources relative to non-mass-collected resources in the same set of prey items. However, since the way in which mass collecting affects the value of individual resources will vary depending on the species and the strategy involved, general rules for how to proceed are not appropriate.

In the *Oryctolagus cuniculus* case, identifying mass collecting is important. As a good candidate for mass collecting, and the ethnographic subject of a mixed-group strategy, if this species was taken *en masse* prehistorically, it is important for archaeologists to know it. It would not be appropriate to compare this resource, if taken *en masse*, to other resources typically taken individually and only by men, as it would be in a prey choice analysis. As discussed in the previous chapter, a patch choice-based analysis would be more appropriate. If, however, *Oryctolagus cuniculus* was not taken *en masse* but was taken individually, a prey choice analysis would be fully appropriate. Thus it is imperative to determine whether or not mass collecting occurred before proceeding with analysis.

Fortunately, as discussed earlier, the distinct demographic expectations for a warren-based collecting strategy make demographic profiles a strong tool. All that is needed are techniques for identifying age and sex from the osteological remains of this species.

Identification of age

Despite the plethora of work on determining the age of leporids (Hale 1949; Hockett 1999; Kolb 1992, 1994; Lechleitner 1959; Parer and Libke 1991; Robson 1993; Smith et al. 1995; Taylor 1959; Thomsen and Mortensen 1946), the majority of methods used by biologists are non-osteological, and thus not particularly useful for archaeologists (see Table 5.3). Some other methods, such as thin-sectioning the mandible, are destructive and therefore often not possible. In addition, most of this work has aimed at specifying the age of rabbits greater than 1 month old; relatively little attention has been paid to very young individuals. There are, fortunately, a number of other ways to determine age from *Oryctolagus cuniculus* skeletal elements.

Table 5.3. Other methods for the identifying the age and sex of Oryctolagus cuniculus.

Method
Eye-lens weight (Lord 1959)
Body weight (Dunnet 1956)
Supraorbital ridge morphology (Kolb 1992)
Thin-sectioning of mandible (Henderson and Bowen 1979)

Epiphyseal fusion is perhaps the most frequently used method for estimating age from mammalian skeletal elements. Details of the timing of fusion of elements for *Oryctolagus cuniculus* are not as well known as they are for many other mammals, but sufficient work has been done to make this a reliable method for determining age. Table 5.4 provides an overview of the timing of fusion for different skeletal elements.

Table 5.4. Fusion schedule of selected Oryctolagus cuniculus *elements (after Habermehl 1985; Hale 1949; Myers and Gilbert 1968; Taylor 1959; Thomsen and Mortensen 1946; Tyndale-Biscoe 1955; Watson and Tyndale-Biscoe 1953).*

Element	No fusion	Partial fusion	Full fusion
Proximal humerus	<8 months	8-9 months	>9 months
Distal humerus	<2 months	2-3 months	>3 months
Proximal femur (head)	<8 months	8-9 months	>9 months
Distal femur	<3 months	3-5 months	>5 months
Proximal tibia	<9 months	9-10 months	>10 months
Distal tibia	<3 months	3-5 months	>5 months

Another common method of age identification is tooth eruption schedules. As with epiphyseal fusion, however, less work has been done on this with *Oryctolagus cuniculus* than with many other mammals. Table 5.5 shows the approximate ages of eruption for permanent teeth in the European rabbit. Research has established that, by the time a rabbit leaves the nest, all its permanent teeth should be in place (Callou 2000; Dice and Dice 1941; Henderson and Bowen 1979; Kolb 1992; Watson and Tyndale-Biscoe 1953).

Table 5.5. Tooth eruption schedule for Oryctolagus cuniculus *(after Dice and Dice 1941).*

Tooth	**Age at eruption**	**Tooth**	**Age at eruption**
Lower incisor	1-2 weeks	Upper incisor	1-2 weeks
Lower P_3	~1 month	Upper P^3	~1 month
Lower P_4	~1 month	Upper P^4	3-4 weeks
Lower M_1	2-3 weeks	Upper M^1	2-3 weeks
Lower M_2	3-4 weeks	Upper M^2	2-3 weeks
Lower M_3	~1 month	Upper M^3	~1 month

Identification of mass harvest of the European rabbit through age profiles requires the identification of specimens that have not yet left the nest (that is, rabbits less than one month old). Only a few age indicators can provide this information (see Table 5.6). The most reliable of these is tooth eruption: if deciduous teeth are still present, then the individual is less than one month old. Thus the ratio of deciduous teeth/all teeth in the *Oryctolagus cuniculus* sample provides a good indication of the percent of individuals less than one month old in the sample.

Table 5.6. Methods used to determine % of samples less than one month old.

Method
Presence of any deciduous teeth/unerupted mature teeth
Unfused distal humerus
Unfused distal tibia

In addition, the timing of fusion of two elements can be used to assess the proportion of newborn rabbits present in an archaeological sample of *Oryctolagus cuniculus*. First, the distal humeral epiphysis fuses to the humerus at about one month old. Thus the percent of unfused distal diaphyses can help to identify the proportion of unweaned rabbits in the sample. Second, the distal tibia fuses at around three months. While the proportion of unfused distal tibiae to all tibiae will thus not give an accurate assessment of how many rabbits less than one month old there are in the sample, it will reflect the proportion of very young rabbits.

Potential confounding factors

There are a number of potential problems with the construction of age profiles for *Oryctolagus cuniculus* using the three indicators (deciduous teeth, unfused distal humeri, and unfused distal tibiae) described above. One such problem stems from the potential for differential destruction of juvenile specimens. It is often asserted that juvenile bones and teeth are more prone to density-mediated destruction issues (for example, Munson

2000; Munson and Garniewicz 2003; Pavao and Stahl 1999; Reitz and Wing 1999). This has not been quantified for *Oryctolagus cuniculus*; however, this issue cannot be ignored. It is possible that an adult-biased mortality profile of *Oryctolagus* might reflect, not an adult-biased hunting pattern, but rather differential destruction of juvenile elements.

In addition, times of fusion and eruption of teeth can, in mammals, be altered due to stress, in particular climate-related stress (Albert and Greene 1999; Gafni et al. 2001). This is a less important issue, as significant deviations from known fusion rates are rare; however, it is still a problem that should be taken into account.

How, then, is it possible to draw conclusions about *en masse* gathering of the European rabbit based on such age profiles? First, because of the potential for differential destruction of juveniles, even a small proportion of very young rabbits should be seen as significant. Since there is no place other than warrens to encounter rabbits less than one month old, the presence of such young individuals will indicate that at least some *en masse* hunting was occurring. By using as many measures of age as possible—for instance, all three of the proposed measures listed above—one can confirm this through multiple lines of evidence. Finally, even though it is unlikely that climatic factors could cause a significant problem, correlation of severe climatic changes with large proportions of juveniles should be viewed with skepticism.

Identification of sex

Although *Oryctolagus cuniculus* can be distinguished by differences in the cranium (Wallner et al. 2001; Zunino and Vivar 1983) and the innominate (Fernandez and Ceballos 1990), neither of these elements was frequent enough in the samples examined here to permit the creation of robust profiles. *Oryctolagus cuniculus* is, however, sexually dimorphic; and work with a number of comparative collections of known sex allowed the creation of three separate sexual dimorphism indices.

During a visit in March, 2003 to the comparative *Oryctolagus cuniculus* collections established by Cécile Callou at the Laboratoire d'Anatomie Comparée at the Muséum National d'Histoire Naturelle in Paris, I took measurements from 81 *Oryctolagus cuniculus* skeletons of known sex and age (Male=41, Female=40). Figure 5.1 shows the measurements taken. Previous research (Boag 1992; Callou 1997, 2000; Cerbon et al. 1996; Harant et al. 2001; Webb 1993) suggested that the most promising elements for sexual dimorphism were the maxilla (greatest breadth of the maxilla at the oral zygomatic and alveolus), the mandible (diastema), and the distal humerus. Thus, I focused my initial analysis on establishing sex indices for *Oryctolagus cuniculus* on these three elements.

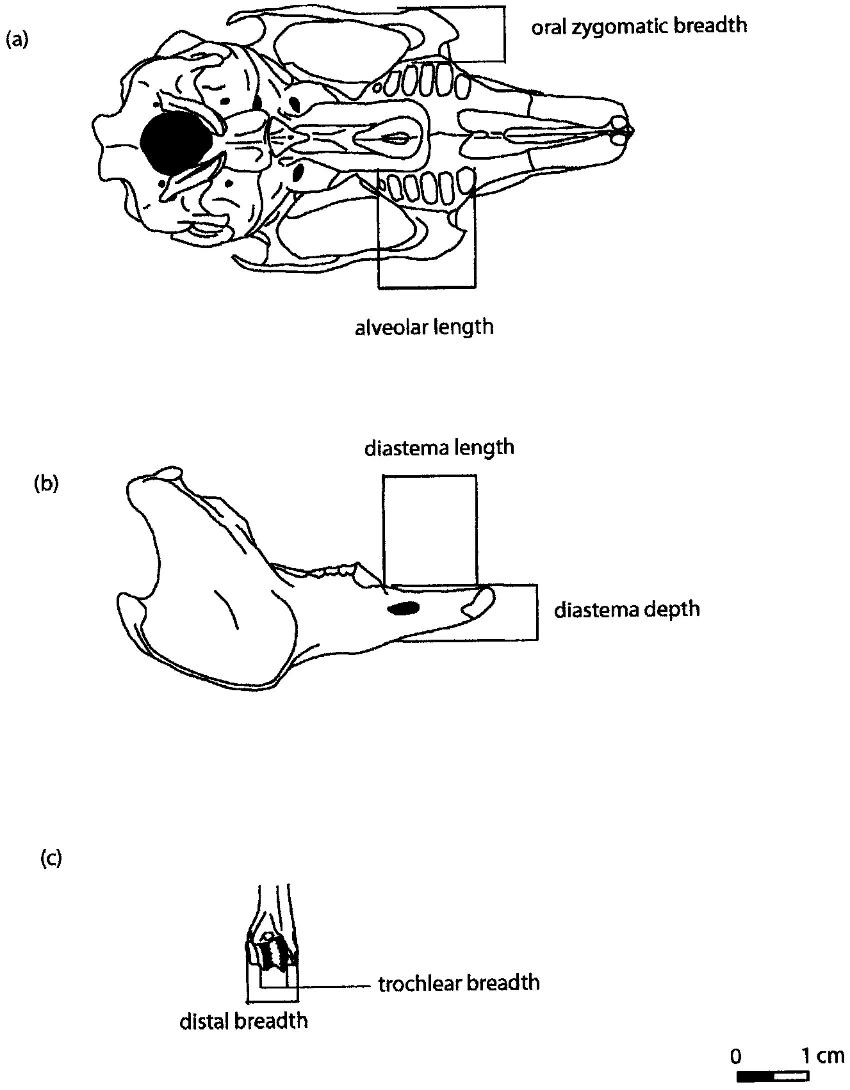


Figure 5.1. Measurements taken to create sexual dimorphism indices: (a) shows the measurements for the maxillary index; (b) shows the measurements for the mandibular index; and (c) shows the measurements for the humeral index (modified from Callou 1997).

Maxillary index

Previous research suggested that alveolar length and the breadth of the maxilla at the zygomatic process of the maxilla were the best candidates for a sexually dimorphic maxillary index (Callou 2000; von den Driesch 1976). I thus measured alveolar length and oral zygomatic breadth (greatest distance from the alveolus to the zygomatic process of the maxilla) on 40 female and 41 male *Oryctolagus cuniculus* specimens, and constructed a scatterplot of these two elements (Figure 5.2).

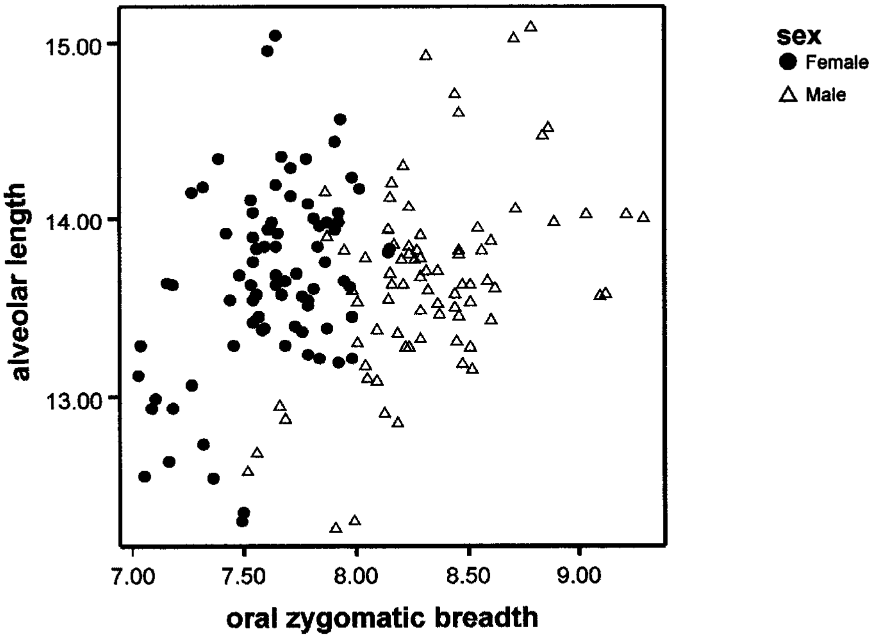


Figure 5.2. Results for the test of the maxillary index using measurements from comparative specimens from the Muséum National d'Histoire Naturelle.

As Figure 5.2 shows, there was a clear trend of sexual dimorphism; however, there was also considerable overlap between the male and female groups. While the maxillary index clearly can be used to identify sex in some instances, there is so much overlap in index values that I have not used it here.

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Mandibular index

In leporids, the diastema is often sexually dimorphic (von den Driesch 1976; Petrides 1951; Wallner et al. 2001). I thus measured diastema length and diastema depth on 40 female and 41 male specimens, and then plotted them (Figure 5.3). Regression and correlation analysis found two distinct and significant relationships (males: $r = +0.54$, $p < .01$; females: $r = +0.70$, $p < .01$), with two distinctly different relationships. This indicates that the mandibular index provides a valid method for separating male and female *Oryctolagus cuniculus* specimens.

Humeral index

The distal humerus is well-known to be sexually dimorphic for a number of species, including leporids (Callou 2000; von den Driesch 1976). I measured the distal breadth and trochlear breadth of 40 female and 41 male specimens and found that the plots produced two distinct clouds (Figure 5.4). Regression and correlation analysis showed two distinct and significant relationships (males: $r = +0.87$, $p < .01$; females: $r = +0.79$, $p < .01$), with two different relationships.

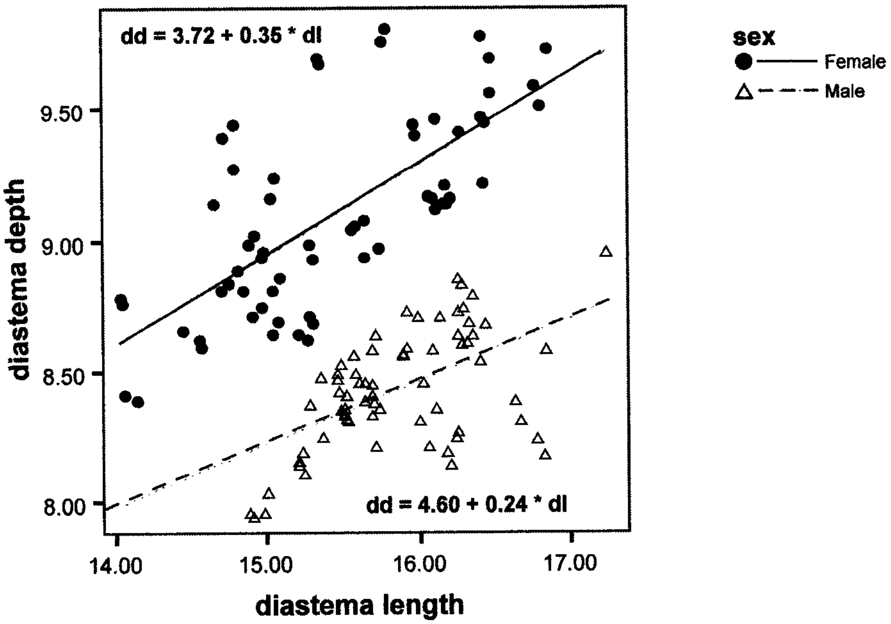

Figure 5.3. Results for the test of the mandibular index using measurements from comparative specimens from the Muséum National d'Histoire Naturelle.

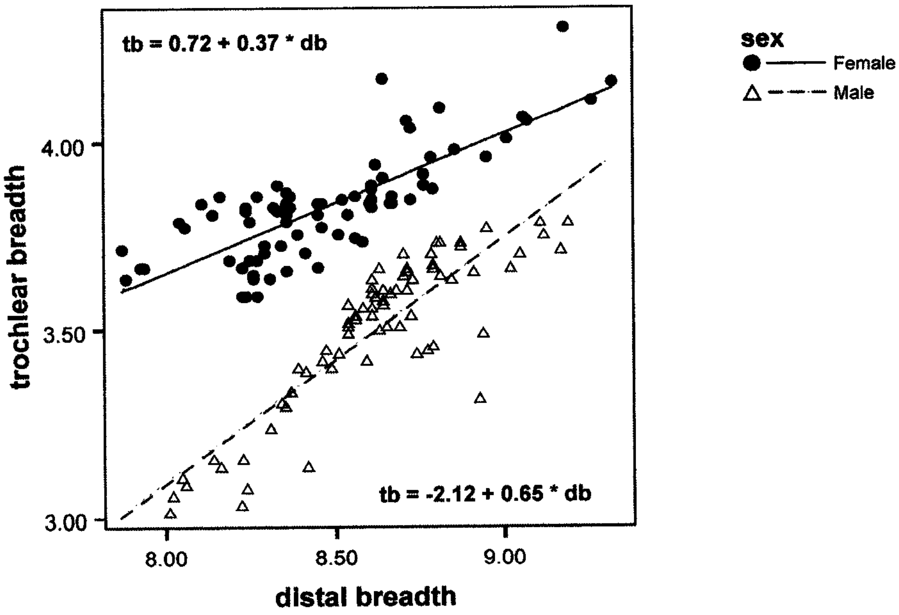

Figure 5.4. Results for the test of the humeral index using measurements from comparative specimens from the Muséum National d'Histoire Naturelle.

While the regression analysis is sufficient for this level of study, Figure 5.4 does raise some questions. In particular, although linear regression analysis does provide a good fit for the females, it is less accurate for the males. Since the male and female relationships are distinct from one another, this should not impact this study. Understanding how and why the relationships differ, however, would be an interesting subject for future research.

Results

Two of the three sexual dimorphism indices proved to be accurate methods of separating male from female for *Oryctolagus cuniculus*: both the mandibular index and the humeral index produced two distinct relationships for male and female groups. While the maxillary index does reflect some sexual dimorphism, it was a less accurate method than the other two indices. Given the problems with this index and the fact that there were few measurable maxilla specimens in the assemblages considered in this study, I chose not to pursue the maxillary index further.

The mandibular and humeral indices, however, can thus be used to distinguish the proportion of male and female specimens in archaeological samples of *Oryctolagus cuniculus* (Table 5.7). By taking the measurements on archaeological collections, and then using regression and discriminant function analysis to sort the samples into male and female groups, it is possible to create an accurate sex profile for this species.

Table 5.7. Methods used to determine % of sample that is female.

Method
Mandibular index: diastema depth/diastema length
Humeral index: distal breadth/trochlear breadth

Potential confounding factors

The most serious potential confounding factor for this method of determining sex is climate. *Oryctolagus cuniculus* varies in size in response to climate as well as with sex; indeed, work done on size, climate, and sex by other researchers (Callou 2000; Donard 1982) indicates that size differences due to sexual dimorphism in *Oryctolagus cuniculus* are often obscured by size differences due to climate change. Researchers looking for sexual dimorphism in collections of *Oryctolagus* specimens from different climatic regions have found size variation as a response to climatic differences, but no sexual dimorphism (Callou 2000). Thus, in very time-averaged assemblages that encompass periods of climate change, this method may fail to produce two distinct clouds.

Conclusions

This investigation shows that it is possible to use the simple tools of epiphyseal fusion schedules, tooth eruption schedules, and sexual dimorphism indices to establish accurate demographic profiles for archaeological assemblages of *Oryctolagus cuniculus*. Creation of such demographic profiles will not, however, be possible for all assemblages. As always with demographic profiles, large sample sizes will be necessary to obtain reliable results. In addition, the sexual dimorphism may be obfuscated in time-averaged archaeological sites that incorporate periods of climate change; in such cases, it will be impossible to create sex profiles.

Despite these potential problems, however, the methods described above can be powerful tools for identifying situations in which mass collection of *Oryctolagus cuniculus* took place. While these methods will not be appropriate in all settings, there are many instances in which they will allow researchers to distinguish mass-collected assemblages of *Oryctolagus* from ones created by episodes of individual hunting.

Chapter 6

Rabbit hunting at Moulin du Roc

Although the Périgord is better known for its Upper Paleolithic sites than for sites dating to the Pleistocene-Holocene transition, there is a suite of late Magdalenian and Azilian sites, rich in lagomorph faunas, that are well known and often cited as proof of broadening diets at this time (see chapter 2, also see Callou 2000; Donard 1982; Straus 1996). Moulin du Roc is much less well-known and rarely cited, but it shares many characteristics with this suite: it is rich in *Oryctolagus cuniculus*, has a mixed fauna that contains both forest and open landscape signals, and the stone tools present at this site are mixed Magdalenian and Azilian styles (Detrain et al. 1996).

I chose to include the fauna from Moulin du Roc in this analysis for two reasons. First, it is located in the heart of the Dordogne river valley (Figure 6.1), surrounded by rich Upper Paleolithic sites. If the Magdalenian was an "age of plenty," as is so often asserted, the effects of the disappearance of this golden age should be apparent at Moulin du Roc. Conversely, if the data from Moulin du Roc indicate that the Magdalenian was resource-poor, it would be hard to argue that this was merely a local phenomenon, since many of the classic Magdalenian sites are nearby. Second, the Magdalenian deposits at Moulin du Roc cover a period of time slightly earlier than the more typically cited rabbit-rich sites in the Dordogne. Moulin du Roc provides some of the earliest abundant specimens of *Oryctolagus* in the Périgord region, and thus the Moulin du Roc fauna should yield important information on how rabbits were first hunted.

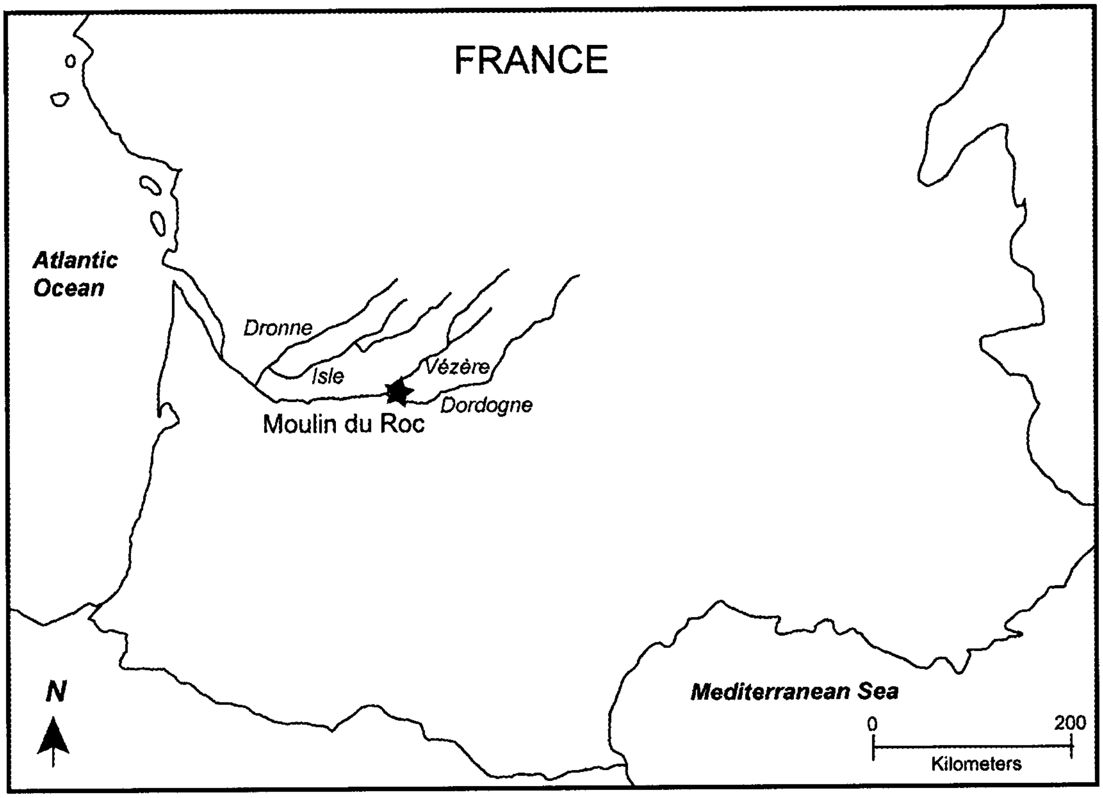

Figure 6.1. Location of Moulin du Roc.

Moulin du Roc is located in the community of Saint-Chamassy, on private land, about 1 km from the confluence of the Dordogne and Vézère Rivers (Figure 6.2). This cavesite is positioned at the junction of two valleys. The cliffs are steep and the area today is quite topographically diverse: while broad, grassy areas are present to the north, toward the Vézère, the immediate vicinity is marked by plateaus interspersed with steep cliffs and plunging valleys (Detrain et al. 1996). A topographic map showing the site location is shown in Figure 6.2.

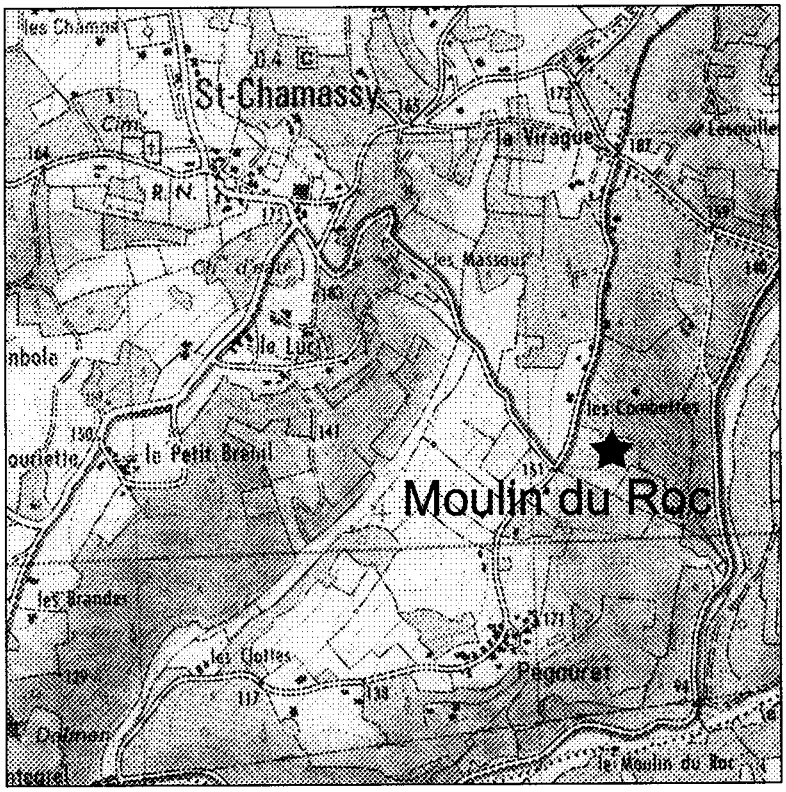

Figure 6.2. Topographic situation of Moulin du Roc (Institut Géographique National 2000).

Moulin du Roc was discovered and recorded by Peyrony (1949) in his survey of Périgordian archaeological sites in the 1940s. It was rediscovered by André Morala in December 1989; some parts of the site had been destroyed in the interim, but a significant portion of it was still intact (Detrain et al. 1996). Three data recovery expeditions followed Morala's rediscovery: two in 1990, and one in 1994.

In this chapter, I present background materials on Moulin du Roc, perform a full taphonomic analysis of the leporids in this assemblage, consider the demography of the *Oryctolagus* assemblage and then, using this information, assess the significance of

Oryctolagus in the diet of the prehistoric inhabitants of Moulin du Roc. I pay particular attention to why this resource was added to the diet at this time, and what such an addition means for current interpretations of prehistoric life during the Magdalenian.

Location and Excavation History

The stratigraphy of Moulin du Roc is complicated by construction-related disturbance activities that took place in the years between Peyrony's initial discovery and excavation. Most of the Magdalenian deposits were left intact, but the continuity of deposits along the rockshelter face was difficult to ascertain. Stratigraphy as recorded within the rockshelter can be seen in Figure 6.3, and is discussed in depth in Detrain et al. (1996). Couches Jaune, Brune, and Bigarée comprise the Magdalenian/Azilian deposits. In addition, there was a "Neolithic cap" present among the rockshelter deposits.

Some portions of the deposits were washed downslope into the valley below, including a small Sauveterrian layer (Detrain et al. 1996). While these deposits were excavated and material was recovered from them, these materials comprised only a small portion of the whole. I excluded this material from analysis because of its uncertain provenience.

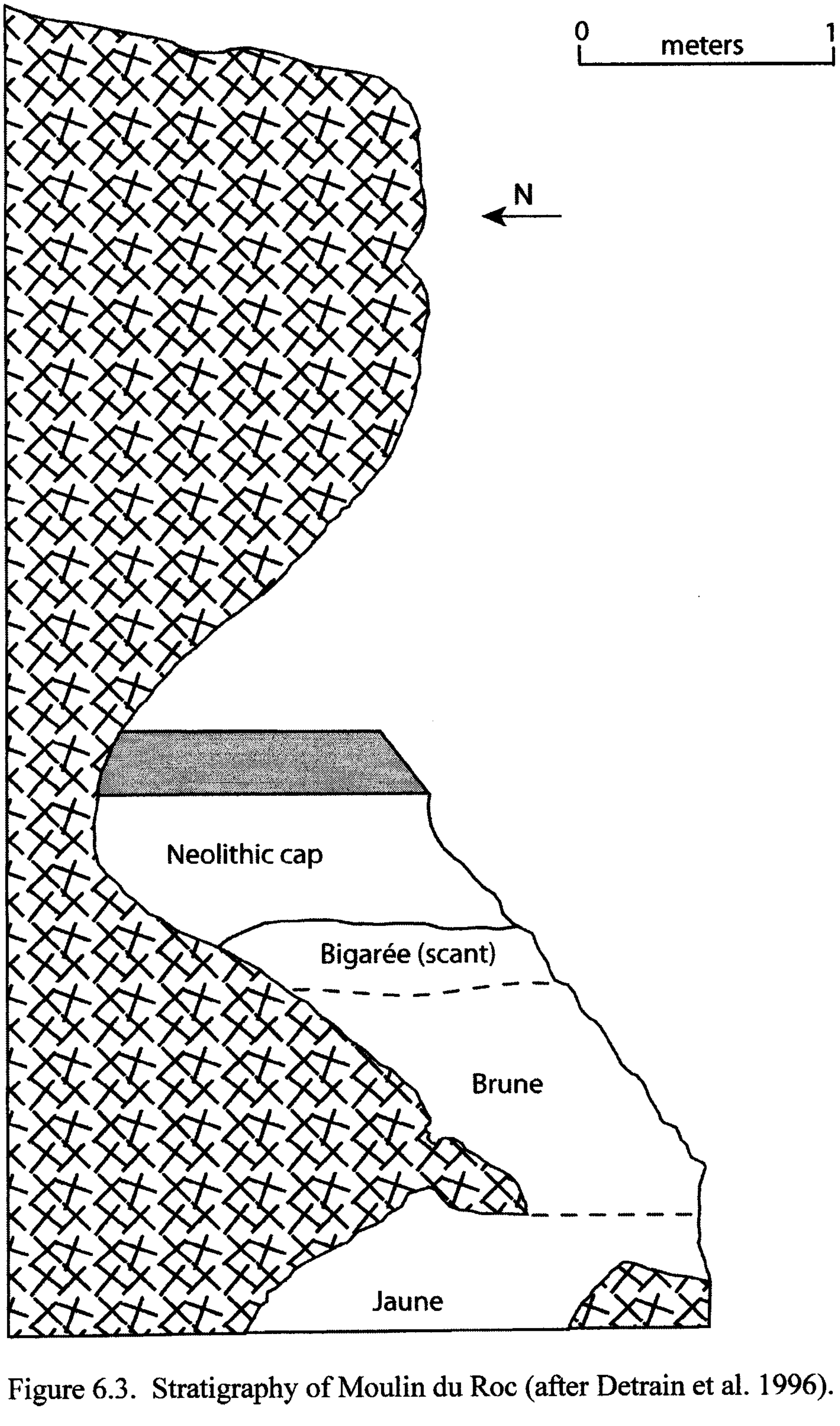

Figure 6.3. Stratigraphy of Moulin du Roc (after Detrain et al. 1996).

Moulin du Roc has been dated to the Pleistocene-Holocene transition based on stone tool industry analyses and on radiocarbon dates (Table 6.1). The date for Couche Jaune is unreliable; the error term is quite large and the Laboratoire de Radiocarbone, Centre de Datations et d'Analyses Isotopiques (which provided this date) commented that it should be used with caution. However, the stratigraphy from this portion of the site was intact, and the study of lithics places this deposit as earlier in the Magdalenian than Couche Brune or Couche Bigarée. While the actual date should be disregarded, the evidence (both stratigraphic and lithic) that this deposit is older than Couche Brune is robust, and it should be considered dating to the Late Magdalenian, from around 14,000 to 13,000 BP (Detrain et al. 1996). Dates and culture history for the entire site can be seen in Table 6.1.

Table 6.1. Culture history and ^{14}C dates from Moulin du Roc (after Detrain et al. 1996).

Stratigraphic layer	**Industry represented**	**^{14}C years BP**
Neolithic cap	Neolithic	4,050 ± 80 (AA 5526)
Couche Grise	Sauveterrian	n/a
Couche Bigarée	Final Magdalenian	11,340 ± 170 (Ly-5444)
Couche Brune	Magdalenian	12,700 ± 50 (Beta-180048); 12,890 ± 60 (Beta-180049)
Couche Jaune	Magdalenian	15,600 ± 1,200 (Ly-5445)

Of particular interest are the AMS dates for Couche Brune, which were taken from roe deer (*Capreolus capreolus*) and reindeer (*Rangifer tarandus*) bones, respectively. The statistical contemporaneity of these two bones (from different locations within Couche Brune) attests to the stratigraphic integrity of the site. In addition, such close dates have important implications for paleoclimatic interpretations of the larger fauna at Moulin du Roc.

In this work, I focused on the Magdalenian remains from inside the rockshelter, and disregarded the material from the valley. I also ignored both the Sauveterrian layer, as this deposit was not of a sufficient sample size for analysis (total NISP = 19), and the Neolithic cap, which was chronologically outside the area of interest in this study.

The mammalian fauna was analyzed by Stephane Madelaine (Detrain et al. 1996); for this research, I re-analyzed all the smaller mammals, though the lagomorphs were my primary interest. I relied on distinctions published by other researchers (Bensch 1967; Callou 1997; Cochard 2004; Lopez Martinez 1980) for identification of different genera and species of lagomorphs. Combined results can be seen in Table 6.2. One aspect of the Moulin du Roc fauna is that, other than *Oryctolagus* and a few *Lepus* specimens, it is completely lacking in smaller fauna, including a total absence of any fish or bird remains. One might argue that differential destruction or incomplete recovery is responsible for this paucity of smaller prey items, but the strong preservation of the lagomorph fauna argues against this hypothesis.

Table 6.2. Faunal remains from Moulin du Roc.

	Jaune		**Brune**		**Bigarée**	
Species	NISP	%	NISP	%	NISP	%
Rangifer tarandus	53	43.09	115	1.69	15	5.81
Cervus elaphus	0	0	34	0.5	5	1.94
Capreolus capreolus	0	0	17	0.25	7	2.71
Bos/Bison	0	0	3	0.04	0	0
Sus scrofa	0	0	23	0.34	0	0
Equus caballus	3	2.44	11	0.16	1	0.39
Oryctolagus cuniculus	64	52.03	6596	96.94	230	89.15
Lepus sp.	3	2.44	5	0.07	0	0
Total	123		6804		258	

An initial analysis of the paleontology (Detrain et al. 1996) suggested a simple climatic trend from Pleistocene tundra (Couche Jaune) to the more wooded, humid landscapes typical of the region today—much is as seen at other sites in the region, such as Le Morin and La Gare du Couze (Delpech 1983; Gilbert 1984). One issue that has repeatedly troubled analysts has been the distribution of reindeer versus animals more typical of a wooded landscape. Often, the differences in the large fauna between sites dated to the same age has caused researchers to question the dates involved, or to suggest stratigraphic problems (Gilbert 1984). It is also possible, however, that such differences might indicate a patchy landscape. I used the correlation feature in OxCal to determine whether the dates from the reindeer (tundra/grassland indicator) and roe deer (forest indicator) in Couche Brune differed significantly (Bronk Ramsey 1995, 2001). This analysis showed that the two dates were statistically identical, suggesting a patchy environment in which hunters had access to both forested and grassland environments at the same time.

Taphonomy

As can be seen from Table 6.2, lagomorphs—and particularly, *Oryctolagus cuniculus*—dominate the Moulin du Roc fauna, making this site a good candidate for the examination of rabbit hunting at the Pleistocene-Holocene transition. However, it is well known that a variety of non-human predators can introduce rabbits into cave deposits (i.e., Aura et al. 2002; Callou 2000; Hockett 1991, 1995, 1999; Hockett and Bicho 2000; Hockett and Haws 2002; Perez Ripoll 1993; Sanchis Serra 2000; Schmitt 1995, 2002; Schmitt and Juell 1994). If humans were not the accumulating agent at Moulin du Roc, then any zooarchaeological analysis would be futile.

I used information of the characteristics of raptor, carnivore, and human-accumulated rabbit assemblages from southwestern Europe and elsewhere (Cochard 2004; el Guennouni 2001; Hockett 1991, 1995, 1999; Hockett and Bicho 2000; Hockett and Haws 2002; Schmitt 1995, 2002; Schmitt and Juell 1994) to determine the origin of the Moulin du Roc assemblage. There are three main widely-accepted methods for this procedure: analysis of relative skeletal abundances; analysis of cutmarks, punctures, and other traces of different predators on the bones themselves; and, analysis of breakage patterns. I used all three to determine the primary agent of accumulation at Moulin du Roc.

Relative Skeletal Abundances

One common method of identifying the main accumulating agent of a rabbit assemblage is an analysis of relative skeletal abundances (Cochard 2004; el Guennouni 2001; Hockett 1991, 1995, 1999; Hockett and Bicho 2000; Hockett and Haws 2002; Laroulandie 2000; Schmitt 1995; Schmitt and Juell 1994). Human and non-human predators process prey differently, resulting in different relative frequencies of skeletal elements. By comparing the relative skeletal abundances of an assemblage of unknown origins to those of assemblages with known accumulating agents, one can determine which of the possible predators was the most likely accumulator.

The bone density of individual elements, however, can also affect relative skeletal abundances. If an assemblage has been subject to density-mediated destruction, then the relative skeletal abundances of that assemblage will merely reflect relative element density rather than predator behavior. Thus it is necessary to test for density-mediated destruction before proceeding with further analysis of relative skeletal abundances.

I calculated relative skeletal element abundance values using the number of anatomical specimens per anatomical part, normed by the number of times that part occurs in the *Oryctolagus* skeleton (Broughton 1999; Grayson 1988; Thomas and Mayer 1983). Although usually this measure of RSA is scaled to 100, I did not do so because my analyses are based on rank-order correlations and scaling the skeletal abundances does not change their relative ranks (Broughton 1999). Relative skeletal abundance values can be seen in Table 6.3.

Density values for *Oryctolagus cuniculus* have been published by Pavao and Stahl (1999); though these were taken from domestic rabbits, they should be sufficient for the purposes of this analysis. Density measures were taken from multiple scan sites on each element; since the individual elements here may represent any one or more of the scan sites measured, I calculated the mean density for the set of scan sites for each element. A Spearman's rank-order correlation between density and the *Oryctolagus* relative skeletal abundances by layer at Moulin du Roc revealed no correlations (see Table 6.4).

Table 6.3. Numbers of identified specimens (NISP) by skeletal element and relative skeletal abundances (RSAs) for the Moulin du Roc Oryctolagus *assemblage compared with* Oryctolagus *density values (Pavao and Stahl 1999) and non-human predator RSA data (Hockett and Haws 2002).*

	Couche Jaune		Couche Brune		Couche Bigarée			Non-human predator RSAs			
Element	NISP	RSA	NISP	RSA	NISP	RSA	Density	Golden eagle	Eagle owl	Barn owl	Small carnivore
Mandible	3	1.5	342	171.0	12	6.0	0.36	0.23	0.54	0.83	0.48
Maxilla	2	1.0	148	74.0	5	2.5	-	0.14	0.64	0.66	0.58
Scapula	2	1.0	314	157.0	16	8.0	0.18	0.06	0.59	0.57	0.19
Humerus	10	5.0	236	118.0	15	7.5	0.36	0.18	1	1	0.33
Radius	3	1.5	316	158.0	15	7.5	0.13	0.22	0.77	0.43	0.25
Ulna	2	1.0	323	161.5	11	5.5	0.17	0.19	0.91	0.88	0.31
Sacrum	0	0.0	0	0.0	0	0.0	0.43	0.41	0.53	0.13	0.19
Innominate	1	0.5	234	117.0	7	3.5	0.33	0.6	0.41	0.46	0.73
Femur	7	3.5	557	278.5	21	10.5	0.37	0.51	0.58	0.56	0.67
Tibia	4	2.0	430	215.0	22	11.0	0.37	1	0.57	0.51	1
Vertebra	0	0.0	166	6.4	9	0.3	0.35	2.3	—	5.9	5.7

Table 6.4. Spearman's correlation coefficients for Oryctolagus *RSAs and bone densities (Pavao and Stahl 1999) at Moulin du Roc.*

Couche	**Rho**	**P**
Couche Bigarée	+ 0.064	.860
Couche Brune	+ 0.049	.894
Couche Jaune	+ 0.157	.665

Skeletal element representation at Moulin du Roc, then, is not significantly influenced by element density. I therefore proceed with the analysis of skeletal element representation.

A plethora of information on how different predators affect relative skeletal abundances in archaeological sites is available (e.g., Hockett 1991, 1995, 1999; Hockett and Haws 2002; Sanchis Serra 2000; Schmitt 1995, 2002; Schmitt and Juell 1994). I used this information to assess whether the relative skeletal abundances at Moulin du Roc resembled those in assemblages created by non-human predators. Figure 6.4 shows a comparison between the relative skeletal abundances of the Moulin du Roc assemblage from Couche Brune, an assemblage created by a golden eagle, an assemblage created by a barn owl, one created by an eagle owl, and one created by a variety of small carnivores at a Portuguese cave site (Hockett and Haws 2002). As Table 6.5 shows, there are no significant correlations.

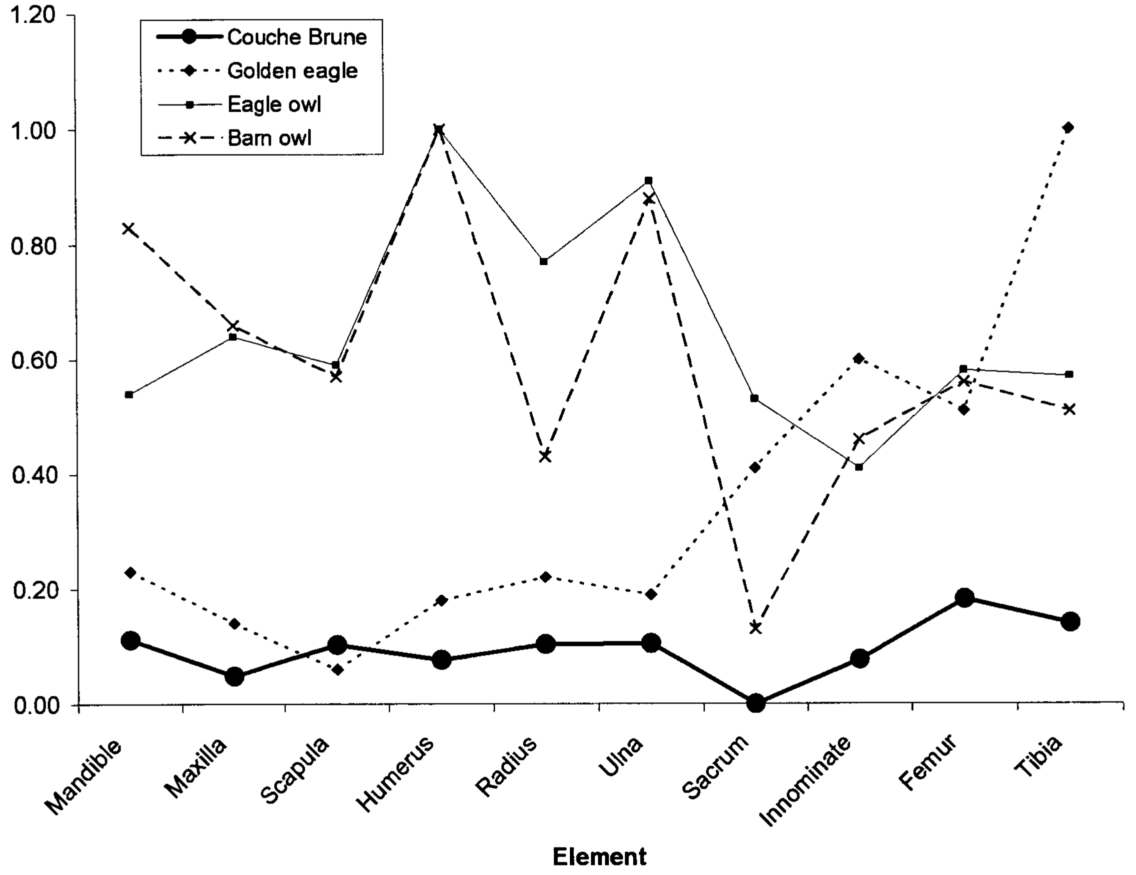

Figure 6.4. Comparison of skeletal element representation among the Moulin du Roc rabbits and expected values for a variety of non-human predators (non-human predator data from Hockett and Haws 2002).

Table 6.5. Spearman's correlation coefficients for Moulin du Roc Oryctolagus *RSAs and those in predator-created assemblages (non-human predator data from Hockett and Haws 2002).*

	Couche Jaune	**Couche Brune**	**Couche Bigarée**
Golden eagle	Rho = -0.198, p = .559	Rho = +0.127, p = .709	Rho = +0.009, p = .979
Small carnivore	Rho = +0.044, p = .898	Rho = +0.159, p = .640	Rho = +0.091, p = .989
Eagle owl	Rho = +0.468, p = .173	Rho = +0.091, p = .803	Rho = +0.213, p = .555
Barn owl	Rho = +0.111, p = .746	Rho = +0.027, p = .937	Rho = +0.027, p = .936

The relative skeletal abundances of the rabbits at Moulin du Roc do not correspond to those of assemblages created by predators common in tardiglacial southwestern Europe. This suggests that non-human predators were not responsible for the accumulation of the Moulin du Roc assemblage, and that the Moulin du Roc *Oryctolagus* fauna were accumulated by humans.

Surface modifications

Another typical method of identification of non-human accumulated assemblages involves quantification of the occurrence of different bone surface modifications left by carnivore, raptor, and human activity. Different predators modify bones differently and thus leave different traces. These traces can be used to identify the predator primarily responsible for the assemblage.

Carnivore activity can typically be identified by digestive traces and the particular fashion in which carnivore digestion weathers the bone (Hockett 1999). Bones modified by the red fox, *Vulpes vulpes*, generally lose any protuberances during digestion; thus they can be identified by the digestive weathering on the ends. In addition, carnivores usually leave puncture marks from their canines. Such puncture marks usually come in groups of two, on only one side of the bone (Hockett 1999). Gnawing may also be present, although this is more typical of rodent activity (Hockett 1999).

Assemblages accumulated by raptors are harder to identify by surface modifications. Some raptors do typically leave puncture marks, but it is usually only one. Typical marks left by digestion are mostly gastric etching (Hockett 1991, 1995), although the ends may be modified by digestive processes (Sanchis Serra 2000).

Human-accumulated assemblages can also be difficult to identify. Cutmarks are the most frequently used index of human activity, but on small prey items the frequency of cutmarks is often low (Hockett and Bicho 2000). Some researchers, however, have identified high percentages of cutmarks on *Oryctolagus* assemblages (Aura et al. 2002; Cochard 2004), so this is a possibility. Another method of identifying human-accumulated assemblages is the frequency and patterning of burnt items in the assemblages (i.e., Hockett and Bicho 2000).

As part of the analysis of the Moulin du Roc lagomorph fauna, all skeletal elements (except teeth) were examined for puncture marks, gnawing, digestive traces, cutmarks, and/or burning (the number of identified specimens of each element can be seen in Table 6.3). Frequencies of these surface modifications can be seen in Table 6.6. As this table shows, there are no puncture marks, gnawing, or digestive traces on the bones in the Moulin du Roc rabbit assemblage, but there are traces of human activity: burning and cutmarks. Thus the surface modifications of the bones themselves suggest a human accumulated assemblage.

Table 6.6. Frequencies of puncture marks, gnawing, digestive traces, cutmarks and burning in the Moulin du Roc rabbits.

	Couche Jaune	**Couche Brune**	**Couche Bigarée**
Puncture marks	0	0	0
Gnawing	0	0	0
Digestive traces	0	0	0
Cutmarks	8 (12%)	666 (10%)	27 (22%)
Burning	18 (28%)	1284 (19%)	32 (26%)

Breakage patterns

Patterns of breakage and fragmentation can also be used to identify the primary accumulating agent of leporid assemblages; the breakage patterns in assemblages created by different predators are well understood (Hockett 1999; Hockett and Bicho 2000; Schmitt 1990, 2002). Small carnivores generally leave a high percentage of complete limb elements (Hockett and Bicho 2000). The proportion of complete limb elements in the Moulin du Roc fauna is 0% in Couche Jaune, .6% in Couche Brune, and 1.2% in Couche Bigarée. It is thus unlikely that small carnivores are responsible for the Moulin du Roc assemblage.

Human-created assemblages are characterized by a different pattern in limb elements: the frequency of "rabbit cylinders," or midshaft portions of rabbit long bones. This has been observed in a wide variety of human-created lagomorph assemblages (Cochard 2004; Hockett 1991; Hockett and Bicho 2000; Perez Ripoll 1993; Schmitt 1990). Research suggests that these cylinders are the result of snapping off the ends of the bones to obtain marrow; this practice has been widely observed in ethnographic contexts (Hockett and Bicho 2000). At Moulin du Roc, a high frequency (over 50%) of the limb bone elements are midshaft fragments (Table 6.7). In addition, the assemblage contains a large collection of rabbit cylinders. Figure 6.5 shows the relative frequency of rabbit cylinders in the Moulin du Roc fauna through time; examples of rabbit cylinders from the Moulin du Roc assemblage can be seen in Figure 6.6. These frequencies are comparable to those found by other researchers in human-accumulated assemblages.

Table 6.7. Rabbit limb bone portions recovered from Moulin du Roc.

	Midshaft	Proximal	Distal	Complete	Total
Couche Bigarée					
Femur	9	8	4	0	21
Tibia	13	3	6	0	22
Humerus	6	1	8	0	15
Radius	10	1	4	0	15
Ulna	1	9	0	1	11
Couche Brune					
Femur	236	225	96	0	557
Tibia	242	60	127	1	430
Humerus	95	56	200	3	354
Radius	113	138	60	5	316
Ulna	71	209	41	2	323
Couche Jaune					
Femur	2	3	2	0	7
Tibia	2	0	2	0	4
Humerus	1	4	5	0	10
Radius	0	2	1	0	3
Ulna	0	2	0	0	2

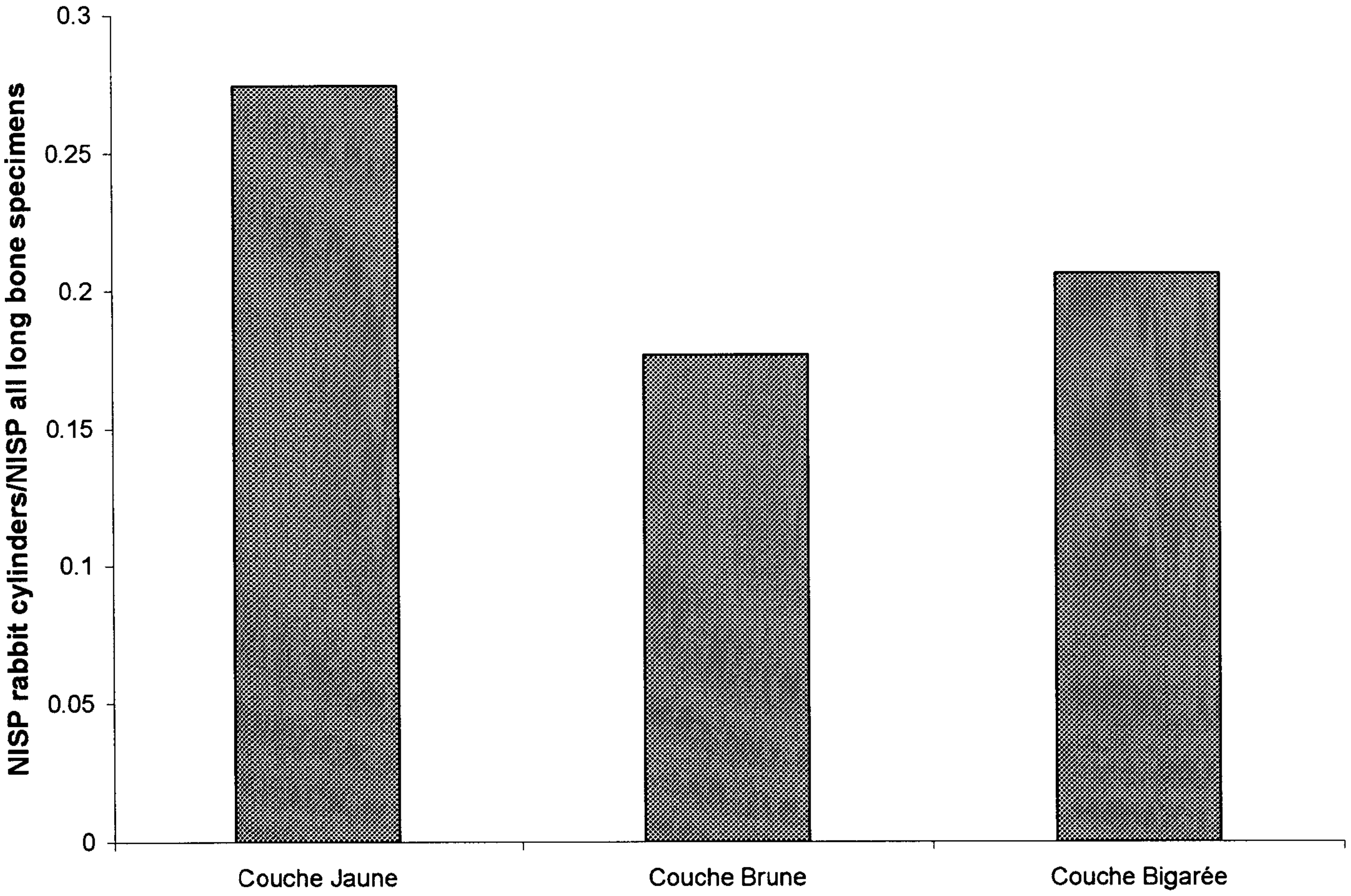

Figure 6.5. Frequency of "rabbit cylinders" in the Moulin du Roc fauna.

Figure 6.6. “Rabbit cylinders” from Moulin du Roc, Couche Brune.

Summary

All three analyses presented here—relative skeletal abundances, frequencies of raptor marks on bones, and presence of rabbit cylinders—suggest that humans, rather than other predators, were the primary accumulating agent of the lagomorph fauna at Moulin du Roc.

Rabbit demography

As I discussed in Chapter 5, I will use aspects of the demography of the archaeological *Oryctolagus cuniculus* collections to determine whether these animals were collected individually or *en masse*. To reconstruct the age and sex profiles of the Moulin du Roc rabbits, I used the methods presented in Chapter 5. However, the Moulin du Roc assemblage presented several challenges in the construction of dependable age and sex profiles. First, the assemblage was extremely fragmented. This meant that many specimens of the mandible and humerus were not sufficiently intact for accurate measurements. The sample sizes on which these profiles are based, therefore, are fairly small. Attention to the possible effects of sample sizes is therefore important; I discuss this further in the analyses below.

I first present the age data, and then turn to the sex profiles.

Age

I used the three age indicators presented in Table 5.6 to assess the frequency of very young rabbits in the Moulin du Roc assemblage. Sample sizes for the elements used in this analysis can be seen in Table 6.8.

Table 6.8. NISP for elements used to construct age profiles.

Element	**Couche Jaune**	**Couche Brune**	**Couche Bigarée**
Mandible	19	187	98
Distal humerus	8	200	15
Distal tibia	9	127	11

All three age profiles can be seen in Figure 6.7. As described in Chapter 5, the presence/absence of deciduous teeth is the most accurate method for the identification of rabbits less than one month old. As can be seen, there is a very small number of juveniles in Couche Brune (less than .1 %), and none in the other two layers. As discussed earlier, however, this difference in presence between the three couches may be merely one of sample size. Indeed, the correlation between this pattern and sample size is significant ($r = +0.99$, $p = .015$). Since, however, the inter-couche pattern of presence/absence is not the main point of interest in this study, this correlation does not affect the overall conclusion: very young juveniles are exceedingly rare in this sequence. This is in accord with the prediction (see Chapter 5) for individually hunted assemblages.

As discussed in Chapter 5, however, juveniles may be underrepresented in archaeological faunas due to density-mediated destruction (Munson 2000; Munson and Garniewicz 2003). The distal humerus and the distal tibia are not such strong indicators of youth as unerupted teeth (see Chapter 5); however, if the proportions are much higher than those when deciduous teeth are used, then the profile based on this indicator may indicate that the lack of juveniles reflects differential destruction rather than a true demographic trend. As Figure 6.7 shows, however, this is not the case. As in the profile based on the presence/absence of deciduous teeth, there are no juveniles at all in either Couche Jaune or Couche Bigarée, and the proportions of juveniles in Couche Brune remain extremely low (1% based on fusion of the distal humerus, and 3% based on fusion of the distal tibia). Again, the difference between couches is probably an artifact of

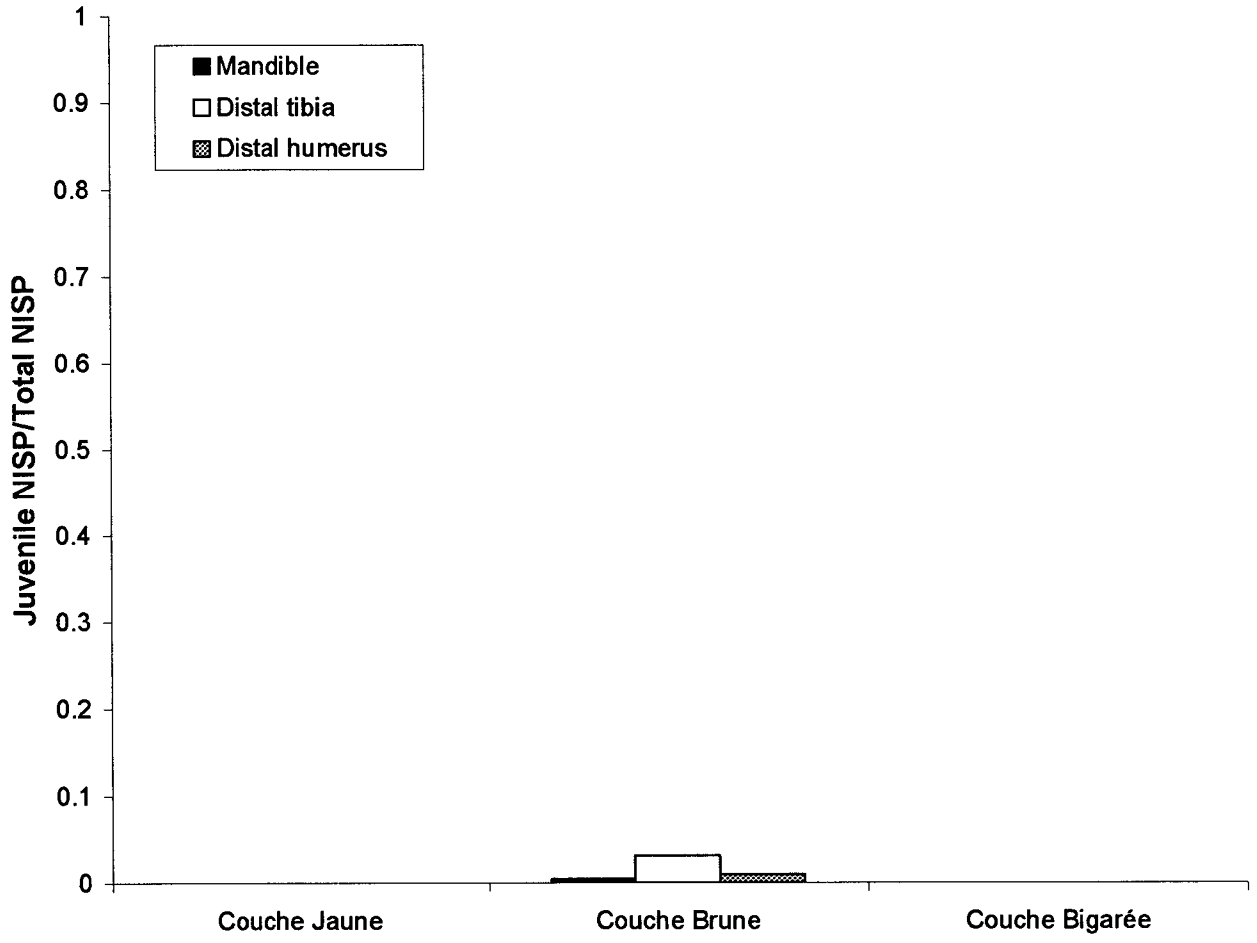

Figure 6.7. Proportion of very young rabbits in the Moulin du Roc *Oryctolagus* assemblage.

sample size, but the overall conclusion—that there are virtually no young rabbits throughout this sample—is straightforward, and should be unaffected by sample size.

I also considered the overall proportion of juveniles in the sample (Figure 6.8). This would not be a valid test for establishing warren-based hunting, because of the differences in the timing of fusion of different elements; I merely use it here to confirm that the pattern seen in Figure 6.7 is not an artifact of small sample sizes of individual elements. Figure 6.8 shows that the overall proportion of juveniles is less than 5% throughout the entire sample. Again, the pattern correlates with sample size ($r = +0.99$, $P = .048$), but even in Couche Brune the number of juveniles is very low ($n = 130$). The correspondence between all these measures suggests that the samples presented here, though small, are representative. There appear to be very few juveniles in the Moulin du Roc sample as a whole, and that the proportion of unweaned rabbits at this site is negligible.

These data suggest that the Moulin du Roc rabbits were not taken directly from a warren, but were hunted individually. As discussed in Chapter 5, however, juveniles may be underrepresented in rabbit assemblages even when collected *en masse* due to human selection preferences (see Chapter 5, also see Hockett and Bicho 2000; Hockett and Haws 2002). Sex profiles are necessary to confirm the pattern seen here.

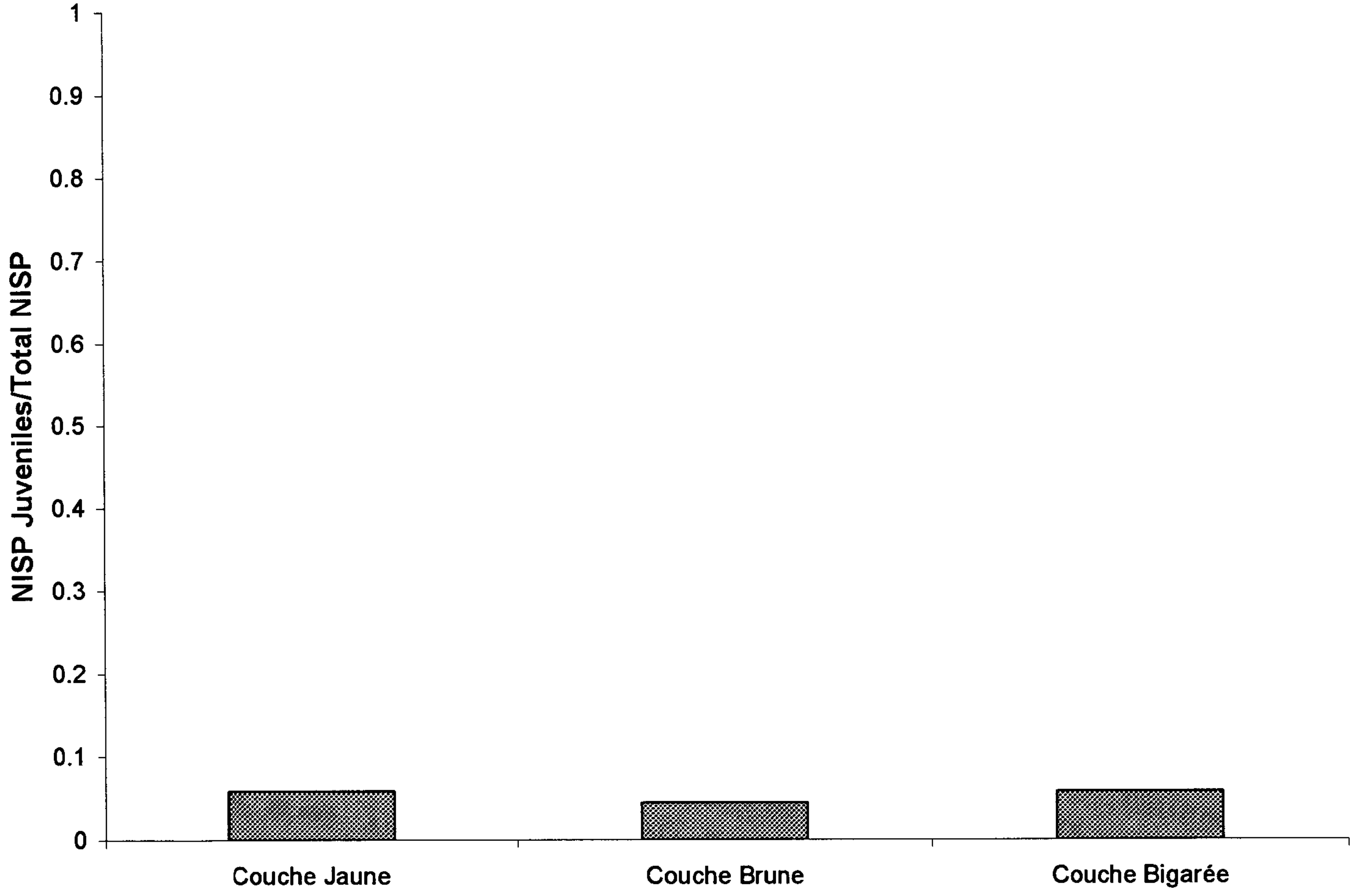

Figure 6.8. Proportion of unfused elements in the Moulin du Roc *Oryctolagus* assemblage.

Sex

Sample sizes were even more problematic in the construction of sex profiles for the Moulin du Roc assemblage than they were for age profiles. In the end, I was unable to create a sex profile using the mandibular index, as the sample sizes for mandibles in Couche Bigarée were extremely low (see Table 6.9). I was, however, able to create a sex profile based on sexual dimorphism in the distal humerus. Figures 6.9, 6.10, and 6.11 plot the distal breadth versus trochlear breadth for each stratum alongside the measurements from the modern specimens.

Table 6.9. NISP for elements used to construct sex profiles.

Element	**Couche Jaune**	**Couche Brune**	**Couche Bigarée**
Distal humerus	26	166	15
Mandible/diastema	16	109	4

As can be seen in these figures, each scatterplot showed two distinct clouds: a larger group and a smaller group. I identified the larger group in each layer as the females and the smaller as the males, and used these numbers to determine the overall percentage of females in the group.

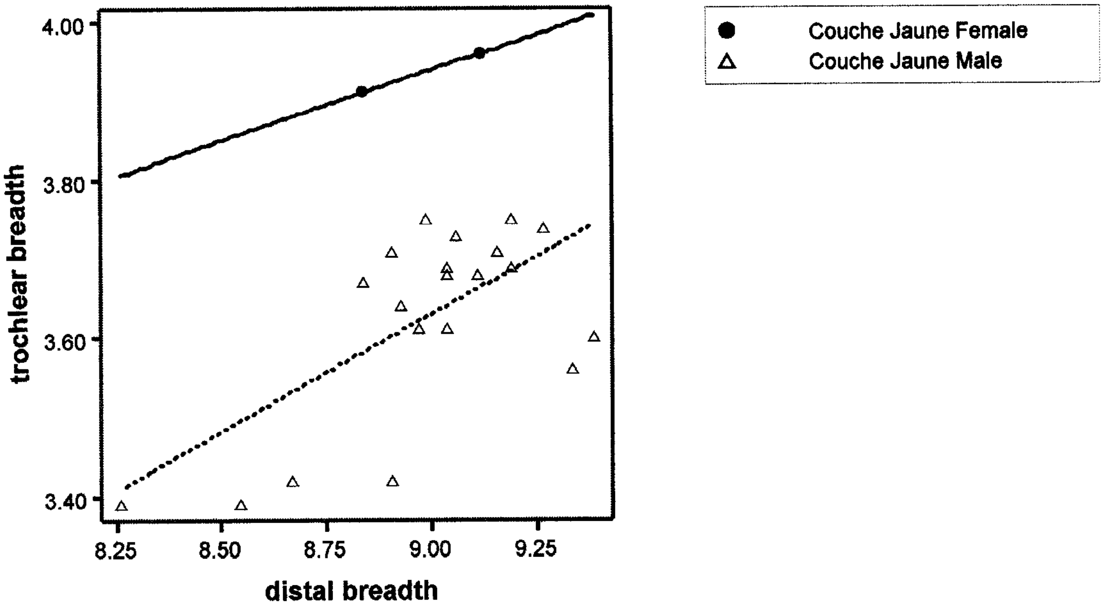

Figure 6.9. Scatterplot of distal humerus measurements from Couche Jaune.

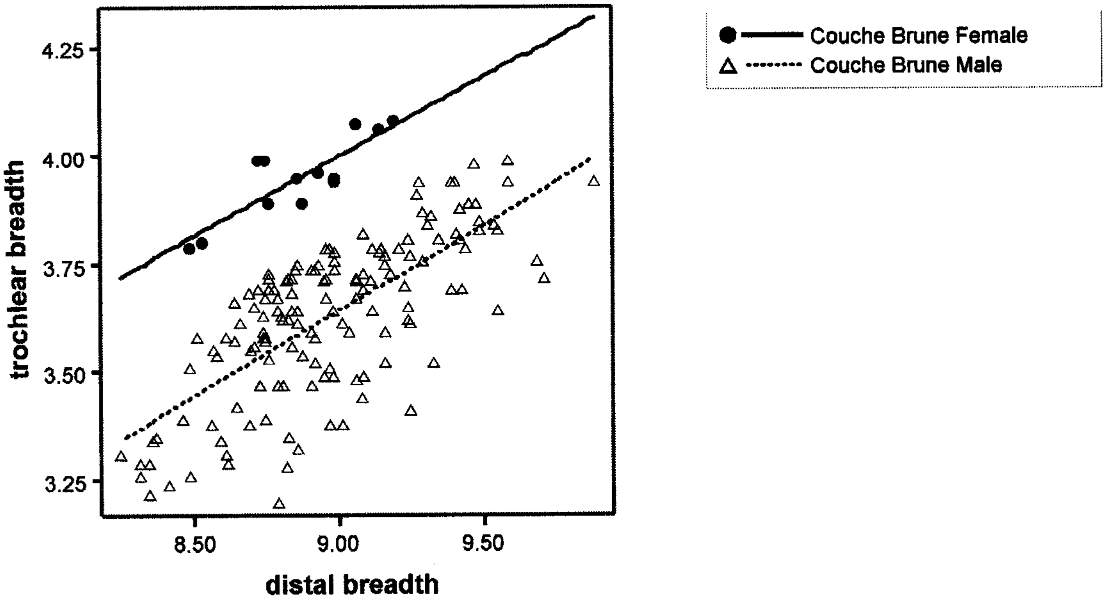

Figure 6.10. Scatterplot of distal humerus measurements from Couche Brune.

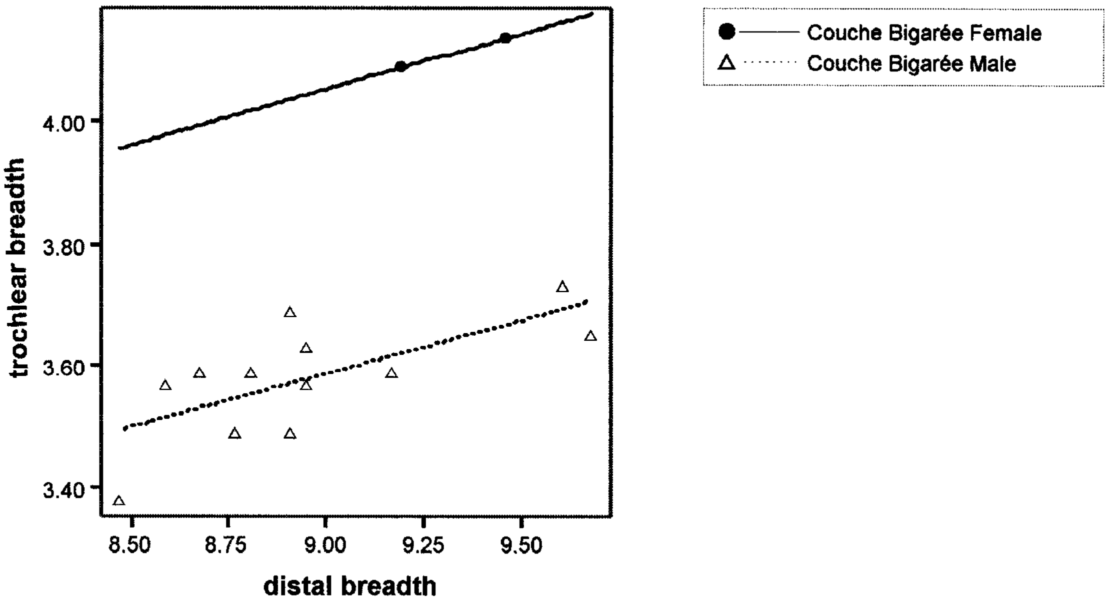

Figure 6.11. Scatterplot of distal humerus measurements from Couche Bigarée.

As Figure 6.12 shows, the percentage of females fluctuates mildly through time but remains low throughout the Moulin du Roc assemblage. Only 8.7% in Couche Jaune, 14.3% in Couche Brune, and 8.1% in Couche Bigarée were identified as female. These values correspond with the frequencies suggested for rabbits taken individually (see Chapter 5). The sex profile thus suggests that the rabbits at Moulin du Roc were being hunted as individuals rather than gathered *en masse*.

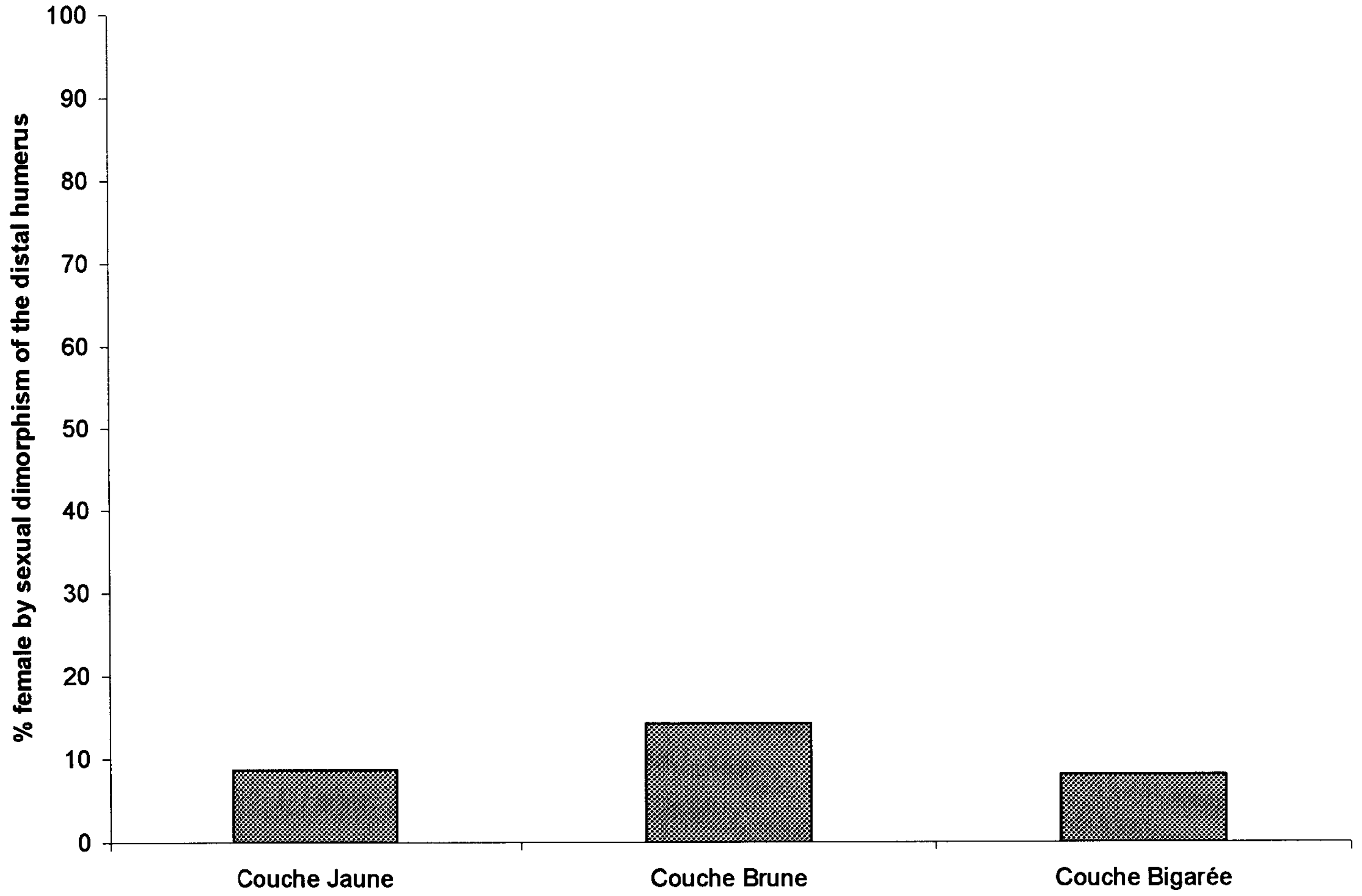

Figure 6.12. Proportion of females in the Moulin du Roc *Oryctolagus* assemblage based on size differences in the distal humerus.

Summary

Both the age profiles and the sex profile suggest that the rabbits at Moulin du Roc were taken singly on the landscape, rather than *en masse* from warrens. There are certainly problems with the individual profiles presented here: all were constructed with less than optimal sample sizes, and more than one profile for sex would be preferable. Taken as a group, however, these profiles are strong evidence that rabbits were hunted singly at Moulin du Roc. All of the five profiles presented here (Figures 6.7 and 6.12) point to the same conclusion. If sample size were causing these patterns, we would not expect to see the same results from the profile constructed from deciduous teeth (where the Couche Jaune sample was extremely small) and that constructed from the distal tibia (where the small sample was from Couche Bigarée). In addition, the consistently low proportion of juveniles in the Moulin du Roc assemblage overall (Figure 6.8), supports the position that the profiles are accurate. Given the consistent message from these multiple lines of evidence, the conclusion that the Moulin du Roc rabbits were taken individually, rather than *en masse*, is warranted.

Seasonality

As discussed in Chapter 5, demographic profiles can also be used to assess site seasonality. At Moulin du Roc, virtually all the individuals in the sample are adults. This suggests that the rabbits of Moulin du Roc were captured in the fall; during any other season, there should be a significant proportion of sub-adult rabbits. The overall lack of young rabbits suggests a fall season of capture. This may indicate that Moulin du Roc was inhabited in the fall only. It is also possible, however, that rabbits were only in the diet in the fall season. Data from other seasonality indicators is necessary to distinguish between these possibilities. Either way, since fall is the one season in which rabbits are generally not in warrens (Angulo and Villafuerte 2004; Boyd and Myhill 1987; Daly 1980), this may be the reason why they were not taken *en masse*.

Changing prey choice at Moulin du Roc

Since the rabbits at Moulin du Roc were taken as individuals, rather than as a group, a standard prey choice analysis with individuals treated as prey items should be valid. In Chapter 4, I presented three different expectations for Périgordian Pleistocene-Holocene transition zooarchaeological assemblages. If the abundance of larger fauna decreased due to climate change, we would expect a gradual addition of *Oryctolagus* and other smaller resources to the diet, correlated to climate change. If human-induced resource depression was the cause, we would expect a gradual addition of *Oryctolagus* and other smaller resources to the diet, not correlated to climate change, and also would expect signs of resource depression in the larger fauna. Finally, if the Magdalenian was a resource-poor period, *Oryctolagus* should be present in archaeological faunas as soon as it was available in the region, and its abundance should fluctuate in response to climate changes known to have an effect on *Oryctolagus* abundance (i.e., Lombardi et al. 2003; Moreno and Villafuerte 1995; Villafuerte et al. 1993).

Figure 6.13 shows the ratio of the *Oryctolagus* NISP to the NISP of ungulates plus *Oryctolagus* through time at Moulin du Roc. The proportion of *Oryctolagus* begins at around .53, and then increases to .97 and .89, respectively, in Couches Brune and Bigarée. Without an accurate date for either Couche Jaune or the increased availability of rabbits in this region, it is impossible to definitively state that the Moulin du Roc *Oryctolagus* fauna meets the prediction for the resource-poor Magdalenian hypotheses, that *Oryctolagus* should be present in archaeological faunas as soon as it was available in the region. Figure 6.13, however, does suggest that the rabbit was being taken at Moulin du Roc soon after it because widely available. It is unlikely that *Oryctolagus* was widely available in the Périgord prior to 13,000 BP, and it is similarly unlikely (Detrain et al. 1996) that Couche Jaune post-dates Couche Brune.

The changing pattern of *Oryctolagus* relative abundance apparent in Figure 6.13 is intriguing: this species starts as a substantial portion of the fauna, but increases dramatically in Couche Brune. A test for sample size effects showed no significant correlation ($r = +0.66$, $p = .544$), and a Cochran's test of linear trend confirms that the increase is statistically significant ($\chi_t^2 = 89.617$, $p < .001$). We can therefore conclude that the pattern shown in Figure 6.13—that of increasing representation of *Oryctolagus* through time at Moulin du Roc—is not an artifact of sample size.

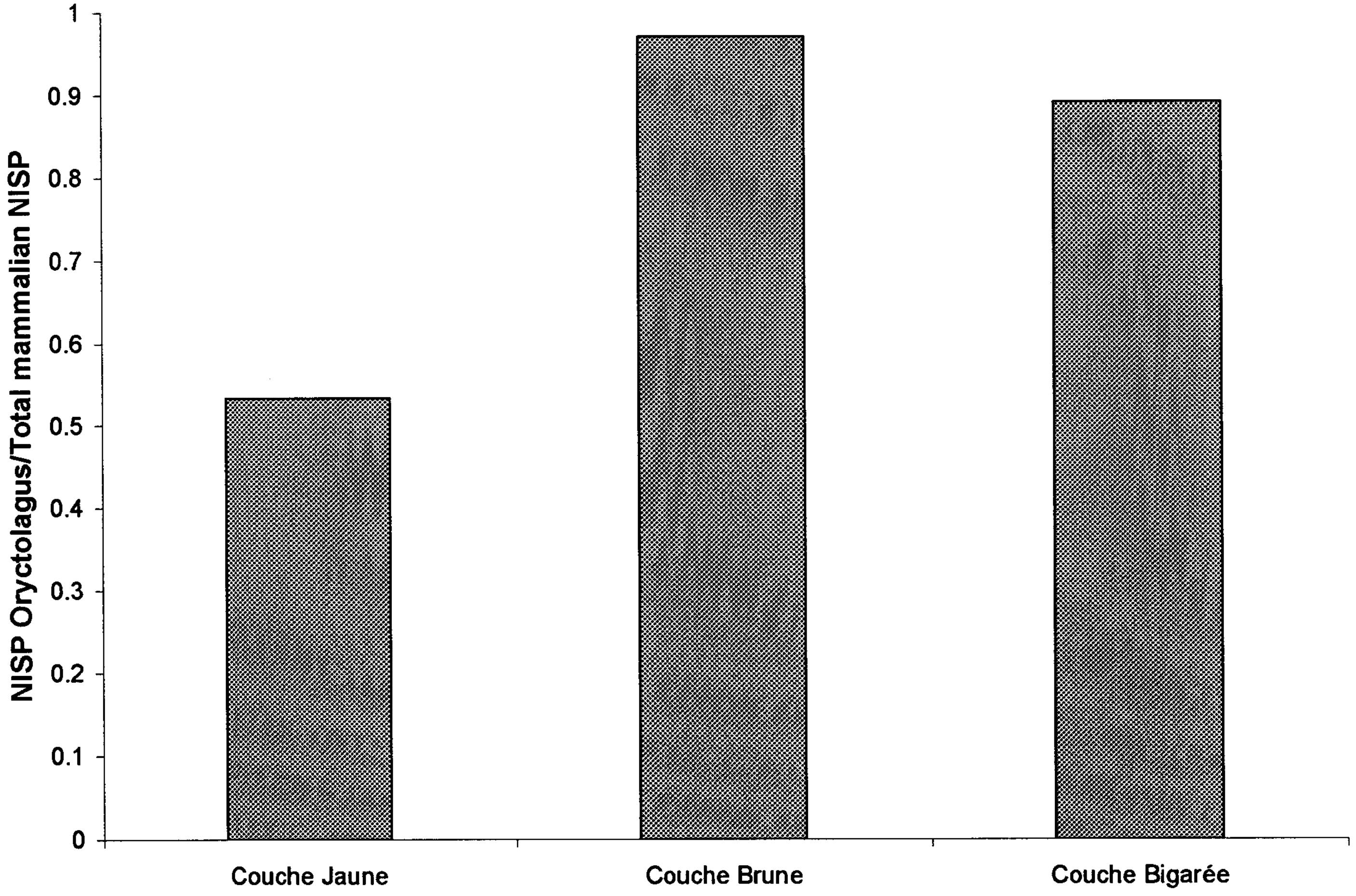

Figure 6.13. The relative abundance of rabbits in the Moulin du Roc fauna through time.

Climate

All the hypotheses set forth in Chapter 4 (see Table 4.1) contain a prediction concerning climate. Unfortunately, given the radiocarbon plateau at this time, the relatively low sample sizes for Couches Jaune and Bigarée, and the lack of a reliable date for Couche Jaune, the relationship of climate change to the relative abundance of different species in the Moulin du Roc fauna is difficult to asses. Although reconstructions of temperature anomalies for this period are available (Guiot 1990), the dating problems make a rigorous comparison between Guiot's data and the Moulin du Roc fauna impossible.

A few general conclusions, however, are possible. A comparison of the data compiled in Table 2.1 and the Moulin du Roc fauna indicates that the increase in rabbits at Moulin du Roc does correspond to an increase in average temperature; the period between 14 kyr and 12 kyr was, no matter which proxy climate data are used, a period of general warming. Although a statistical comparison is impossible, it is clear that changing climate is to some degree related to the changes in rabbit relative abundance. Therefore, based on the predictions set forth in Chapter 4 (see Table 4.1), the hypothesis of human-induced resource depression does not seem to be supported by these data.

However, the changing relative abundance of rabbits at Moulin du Roc is also closely tied to the changing relative abundance of reindeer; regression shows a strong, significant, negative correlation (Figure 6.14). The relative abundance of *Oryctolagus* in the Moulin du Roc fauna could be a result of increasing abundance of rabbits on the landscape, but given this correlation it could also be a result of decreasing availability of reindeer. Distinguishing between climatic effects on reindeer and climatic effects on rabbits (i.e., between hypotheses 1 and 3; see Table 4.1) with these data is thus impossible. It is therefore necessary to turn to other approaches to determine whether increasing rabbit abundance or decreasing reindeer abundance is the cause of changing prey choice at Moulin du Roc.

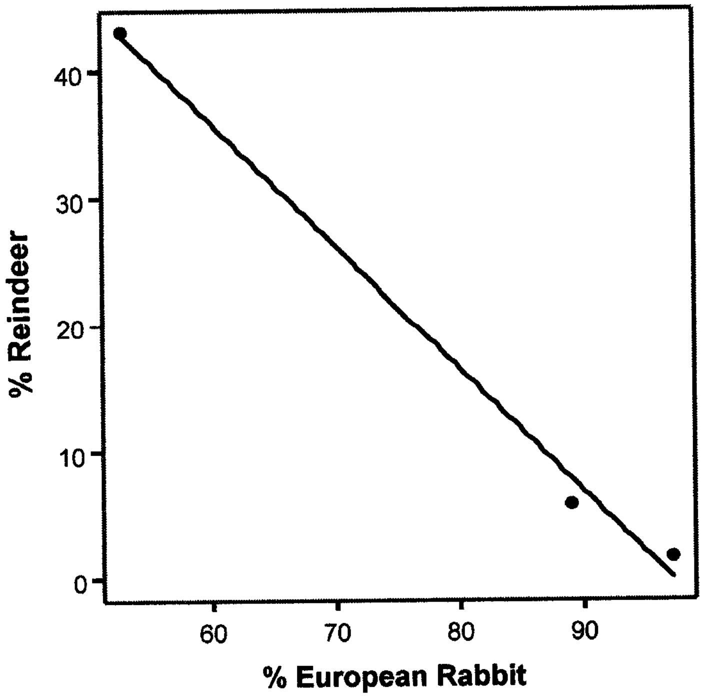

Figure 6.14. Relationship of reindeer and rabbit relative abundance at Moulin du Roc (r = +0.99, P = .026).

Landscape changes

As well as distinct climatic preferences, reindeer and rabbits have specific landscape preferences. I therefore used data on landscape change and habitat preferences to determine whether rabbit or reindeer abundance was driving changes in prey choice at Pont d'Ambon. Rabbit abundance is known to be highest in habitats with a high frequency of edges (Lombardi et al. 2003)—that is, on the border of woodland (where there is abundant cover from predators) and grassland (where rabbits' preferred food can be found). Patchy environments thus favor rabbit abundance, and so a correlation between landscape patchiness and rabbit abundance at Moulin du Roc would demonstrate that landscape rabbit abundance is responsible for the changing dietary contribution of rabbits at Moulin du Roc.

There is a good deal of descriptive information in reconstructing landscape change at this time in this area available. Pollen data from the Vienne and Massif Central areas—both of which are adjacent to the Dordogne—indicate that the period from 15,000 to 13,000 BP was dominated by a "cold steppe" biome, while the period from 13,000 to 11,000 BP was characterized by a mix between taiga, deciduous forest, and cold steppe biomes (Fauquette et al. 1999). Continental-scale analysis by Huntley (1988; 1990) concurs with this concept of a patchy Périgord.

As discussed in Chapter 2, however, pollen data is regional, rather than local, and local conditions, rather than regional or continental ones, would determine the abundance of rabbits. It is possible, however, to evaluate landscape change using data on the relative abundance of large ungulates, since there is a large body of work reconstructing prehistoric habitats from zooarchaeological and paleontological faunal assemblages in the Périgord (Delpech 1983, 1992, 1999). Most of this work reconstructs regional, rather than local, landscape trends; however, the large ungulates at a particular site are a local signal, rather than a regional one. Thus the large mammal fauna at Moulin du Roc can be used to reconstruct prehistoric landscape change. Habitat preferences of the large mammals commonly represented in Périgordian assemblages are fairly well known, thanks to this extensive paleoenvironmental research, and so dividing them into patches based on these preferences is possible. The degree of landscape patchiness can be assessed using measures of evenness, or the degree to which the patches in the set are equally represented. The more even the distribution of patches, the more patchy the landscape.

I separated the Moulin du Roc large fauna (see Table 6.2) into two patches, following other researchers (Delpech 1993; Gilbert 1984): grassy (represented by reindeer, horse, and bovids) and forested (represented by red deer, wild boar, and roe deer). I used 1/D, or the inverse of Simpson's Dominance index, to evaluate evenness of patch distribution (Magurran 1988). I then calculated the relative evenness of patch representation for Moulin du Roc (Figure 6.15).

Evenness measures are prone to sample size effects (Grayson et al. 2001; Magurran 1988), so I tested for a relationship between sample size and patch use evenness, to be sure that sample size was not causing the pattern seen in Figure 6.15.

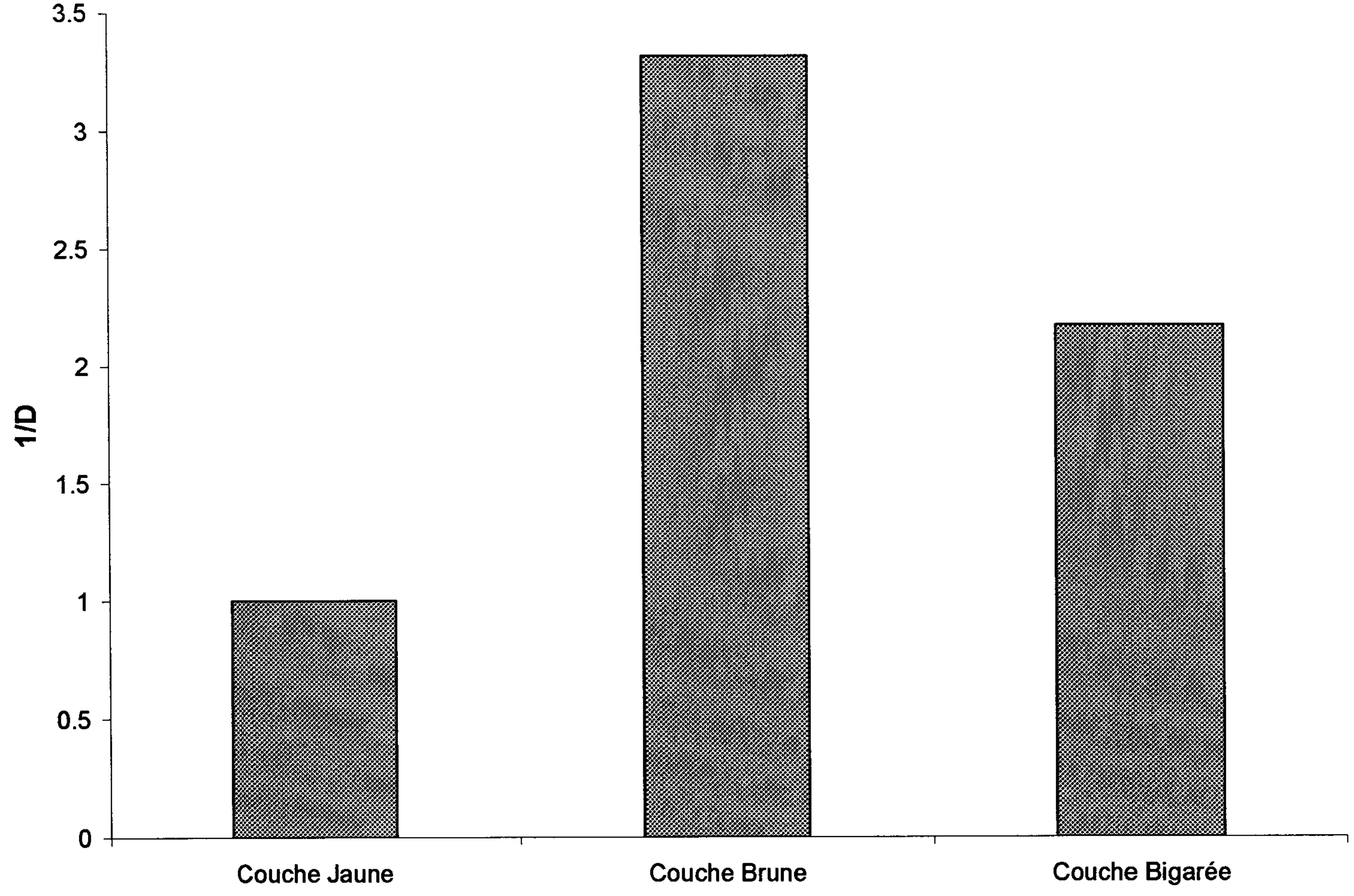

Figure 6.15. Evenness of patch representation among the Moulin du Roc large mammal fauna.

There was no significant relationship (r = +0.74, p = .467). The pattern in evenness seen here are not a result of changing sample size.

I then compared the evenness values to the proportion of *Oryctolagus* through time at Moulin du Roc. The result is a strong, significant correlation (r = +0.94, p < .01; Figure 6.16). The more that the large ungulates at Moulin du Roc represent a patchy landscape, the higher the relative abundance of *Oryctolagus*. These data support the hypothesis *Oryctolagus* abundance in the Moulin du Roc fauna is driven by *Oryctolagus* abundance on the landscape.

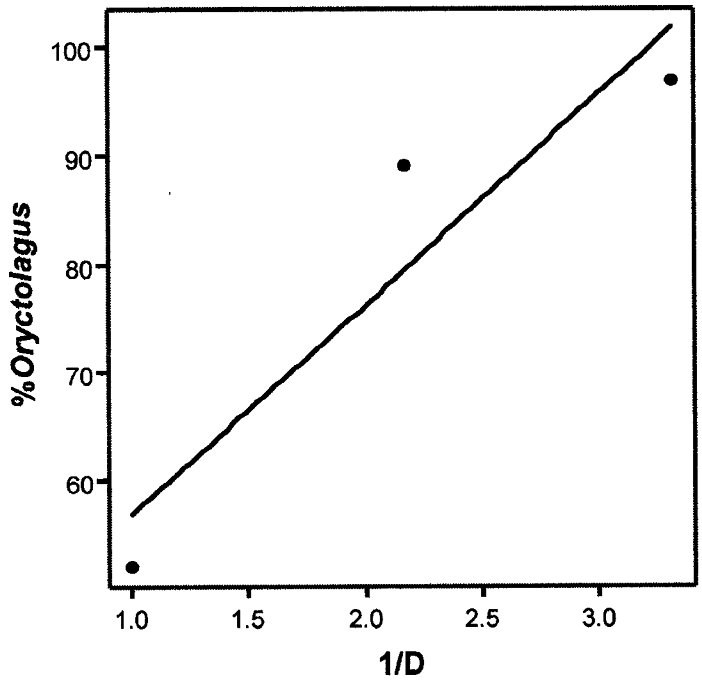

Figure 6.16. Relationship between patch evenness and the relative abundance of *Oryctolagus* at Moulin du Roc.

Summary of findings

The evidence presented here, summarized in Table 6.10, suggests several conclusions. First, rabbits appear to have been taken singly, rather than from warrens, in the Moulin du Roc sample. Despite this, however, they seem to be present (in significant numbers) relatively soon after they became locally available. This supports the hypothesis set forth in earlier parts of this work, that (contrary to popular opinion) the Magdalenian was not resource-rich; instead, it was resource poor, and so as soon as additional prey items were available, they were taken.

Table 6.10. Summary of findings at Moulin du Roc.

Rabbits were taken singly, rather than directly from warrens, at Moulin du Roc.
Climate and landscape changes correspond to changing prey choice at Moulin du Roc.
Landscape changes are more strongly related to relative rabbit abundance than to relative large mammal abundance.
The Moulin du Roc fauna support the hypothesis of a resource-poor Magdalenian.
Moulin du Roc was probably a seasonal (fall) habitation, rather than a year-round camp. Further work should be done with ungulate fauna to confirm this.

Although comparing faunal relative abundance patterns at Moulin du Roc to climate data is difficult due to dating issues, changing prey choice does seem to correspond to climate changes, as it would not if human-caused resource depression was the cause of the increasing relative abundance of *Oryctolagus*. Distinguishing between climate effects on reindeer and climate effects on the European rabbit, however, proved to be impossible.

The landscape data, on the other hand, support the hypothesis that, as rabbits increased locally due to increased landscape patchiness, the relative abundance of rabbits in the diets of the prehistoric inhabitants of Moulin du Roc increased as well. Using the logic of optimal foraging theory, this would indicate that *Oryctolagus cuniculus* was already in the optimal diet set at the onset of its availability. Magdalenian diets were narrow, not because resources were plentiful, but because there were so few prey types to choose from. Changing prey biogeography at the end of the Pleistocene increased the number of available prey types, thereby allowing the broadening of diets.

A final conclusion from this work concerns seasonality at Moulin du Roc. The demography of the rabbits taken at Moulin du Roc suggests that this site was a seasonal one, rather than a year-round habitation. Additional research on the season of capture of other fauna at the site is needed to confirm this.

In conclusion, the Moulin du Roc fauna suggest that *Oryctolagus* was added to the diet neither because climate negatively impacted the availability of larger fauna (Simek and Snyder 1988; Straus 1996, 1999), nor due to human-induced resource depression (Kuhn and Stiner 2001; Stiner 2001). Rather, the addition of *Oryctolagus* at Moulin du Roc seems to indicate that resources were scarce prior to the end of the Magdalenian, and that the smaller prey that became increasingly available at this time was a welcome addition to a diet that had been restricted by scant resources.

Chapter 7

Mass harvest at Pont d'Ambon

While Moulin du Roc is one of the least-known Pleistocene-Holocene transition sites in the Périgord, the best-known rabbit-rich site in the Périgord is almost certainly Pont d'Ambon (Straus 1996). Pont d'Ambon is a small rockshelter site in the Dronne River valley (Célérier 1998; Célérier et al. 1993, 1994). Several aspects of this site combine to make it of particular interest. First, it contains the remains of a domestic dog (*Canis familiaris*) that dates to the Azilian (9,640 ± 120 BP, see Célérier and Delpech 1978). Second, despite the fact that it has been securely dated to the interval between 13,000 and 8,000 years ago, the fauna contains no reindeer, even though sites of a similar age usually do (Célérier 1994; Delpech 1983; Gilbert 1984). Finally, it is extraordinarily rich in both rabbit and fish remains (Delpech 1983; Gilbert 1984; LeGall 1982, 1993). The research presented in this chapter focuses on understanding these last two aspects of Pont d'Ambon.

Pont d'Ambon is located to the north of Moulin du Roc, in the Périgord Vert (Figure 7.1). Unlike the situation at Moulin du Roc, the topography surrounding the site is relatively gentle (Figure 7.2). Although there is a cliff face directly behind the site, it is not particularly steep or high, and the alluvial floodplain of the Dronne stretches out directly in front of the site (Célérier and Kervazo 1994; Duchaedeau-Kervazo 1982, 1994). Although the "front" of the site (that part closest to the river) has been heavily modified by flood activities, the portion within the rockshelter itself was used extensively by Magdalenian and Azilian people and has been relatively undisturbed by non-anthropogenic processes (Célérier and Kervazo 1994; Célérier et al. 1993).

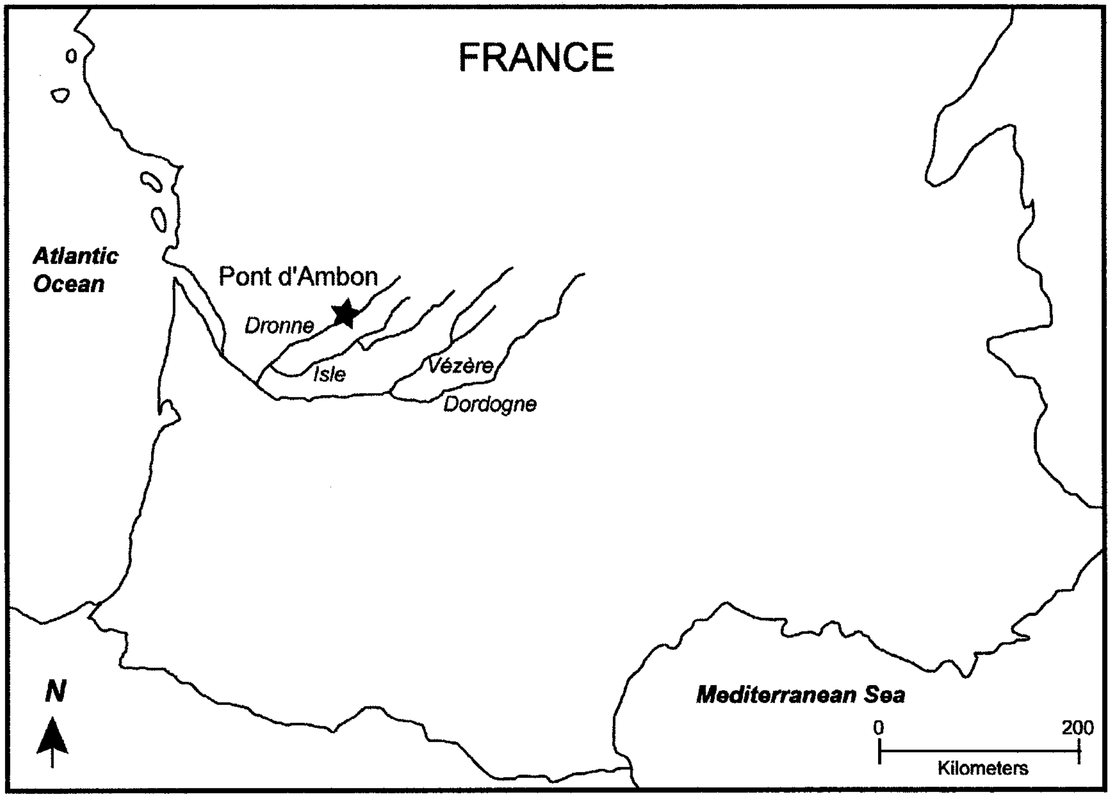

Figure 7.1. Location of Pont d'Ambon.

Pont d'Ambon was first recorded during a survey of sites in the Dronne River Valley conducted from 1968-1969 (Célérier 1976; Célérier et al. 1993, 1994; Duchaedeau-Kervazo 1982). From 1970-1987, Célérier directed excavations at

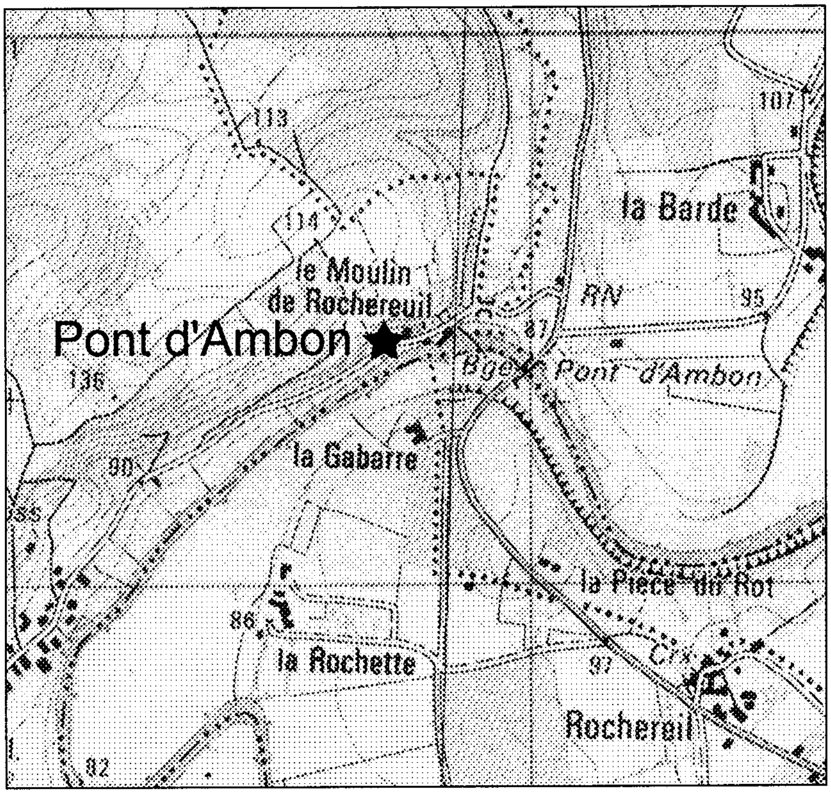

Figure 7.2. Topographic situation of Pont d'Ambon (Institut Géographique National 1984).

Pont d'Ambon; these long-term excavations resulted in an extraordinarily rich collection of information about the Epipaleolithic in this area (Célérier 1998; Célérier et al. 1993, 1994). These collections have been used in a wide variety of studies on the Epipaleolithic in the Dordogne. Thus Pont d'Ambon has become the type site for the Pleistocene-Holocene transition in the Périgord despite the fact that it is anomalous in numerous ways (Straus 1996). Its differences from the norm, however, make it a valuable location in which to investigate the meaning of *Oryctolagus*-rich diets during this period.

Summary of Previous Analyses

Table 7.1 lists some of the previous work that has been undertaken with material from Pont d'Ambon. In addition to the standard stratigraphic, lithic, and faunal analyses, the ground stone material from the site has been studied, seasonality analyses have been done, the microfauna has been analyzed, and analysis of stable carbon isotopes from ungulate bone are available. Paleoclimatic indicators are well understood, as are site formation processes. This wealth of information means that a detailed analysis of prey choice can be conducted with these data.

Pont d'Ambon has been thoroughly dated and the stratigraphy is well-understood. Célérier and Kervazo divided the deposits into three groups: the base deposits, Couches 7 to 4; the middle deposits, Couches 3B and 3A; and the upper deposits, couches 3 and 2. Couches 5 and 6 contain earlier Magdalenian occupations; unfortunately, the bottom portion of the site is inundated with water from the Dronne, and though attempts were made to excavate these strata, they were not successful (Célérier 1998). I thus excluded Couches 5 and 6 from this analysis. Table 7.2 displays the dates and cultural/stratigraphic information available for Pont d'Ambon. A detailed view of the stratigraphy is available in Figure 7.3.

Table 7.1. Previous analyses at Pont d'Ambon.

Description	**Citation**
Monograph	(Célérier 1998; Célérier et al. 1993, 1994)
Geology/Sedimentology/Geomorphology	(Célérier 1982, 1998; Célérier and Kervazo 1994; Duchaedeau-Kervazo 1982, 1994; Guérin 1994)
Lithics	(Célérier 1993a, b; Nisole 1993)
Ground stone	(de Beaune 1993)
Seasonality	(Pike-Tay 1991)
Botanical	(Célérier 1994; Thiébault 1994)
Faunal	(Célérier 1994; Delpech 1983; Donard 1982; Gilbert 1984; LeGall and Pannoux 1994; Limondin 1994; Marquet 1989; Robert 1983)
Isotopic	(Drucker and Célérier 2001)

Table 7.2. Culture history and ^{14}C dates from Pont d'Ambon.

Stratigraphic layer	**Industry represented**	**^{14}C years BP**
Couche 2	Azilian	9640 ± 120
Couche 3	Azilian	10350 ± 190 and 9990 ± 250
Couche 3a	Azilian	9830 ± 130
Couche 3b	Transitional Azilian	12130 ± 160
Couche 4	Final Magdalenian	12840 ± 220

The Pont d'Ambon fauna were analyzed by a number of individuals; although most of the focus has been on the mammalian fauna, studies of fish, birds, insectivores, and shellfish have also been completed (Célérier 1994; Delpech 1983; Gilbert 1984; LeGall and Pannoux 1994; Limondin 1994; Robert 1983). As part of my analysis of Pont d'Ambon, I re-analyzed the lagomorph fauna. The mammalian fauna are presented in Table 7.3. Not included in this table are the small rodents (Marquet 1989). While these comprise a substantial portion of the fauna recovered from Pont d'Ambon (Delpech 1983), they were not a dietary resource and so I do not consider them in this work.

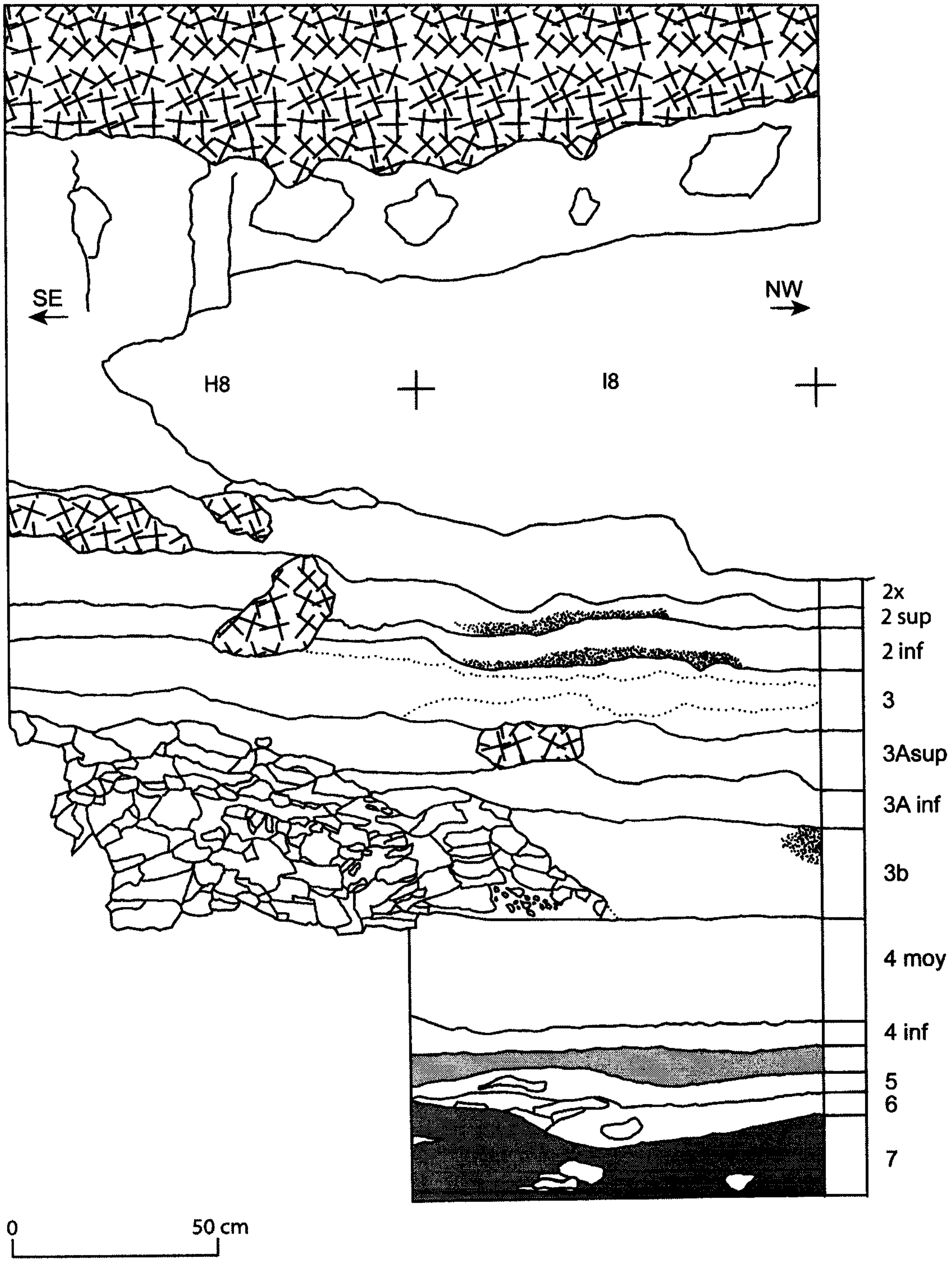

Figure 7.3. Stratigraphy at Pont d'Ambon (after Célérier and Kervazo 1994).

Table 7.3. Mammalian faunal remains from Pont d'Ambon.

	Couche 4		**Couche 3b**		**Couche 3a**		**Couche 3**		**Couche 2**	
Species	**NISP**	**%**	**NISP**	**%**	**NISP**	**%**	**NISP**	**%**	**NISP**	**%**
Cervus elaphus	90	6.62	59	1.5	147	2.88	137	1.83	66	2.38
Capreolus capreolus	14	1.03	13	0.33	27	0.53	37	0.5	7	0.25
Bos primigenius	5	0.37	5	0.13	5	0.1	33	0.44	116	4.18
Sus scrofa	3	0.22	10	0.25	31	0.61	38	0.51	7	0.25
Rupicapra rupicapra	0	0	0	0	0	0	0	0	1	0.04
Equus caballus	2	0.15	6	0.15	14	0.27	54	0.72	90	3.25
Oryctolagus cuniculus	1233	90.73	3832	97.33	4827	94.7	7148	95.65	2473	89.21
Castor fiber	12	0.88	12	0.3	46	0.9	26	0.35	12	0.43
Total	**1359**		**3937**		**5097**		**7473**		**2772**	

Even more than at Moulin du Roc, the mammalian fauna at Pont d'Ambon are consistently dominated by lagomorphs. *Oryctolagus* remains comprise approximately 90% of the mammalian fauna throughout the Pont d'Ambon sequence. Unlike the situation at Moulin du Roc, however, there is a significant presence of other small prey types at Pont d'Ambon, both mammalian and amphibian. Fish are a consistently strong presence in the fauna; birds are also present, though less abundant (Table 7.4).

Table 7.4. Bird and fish fauna from Pont d'Ambon (after Delpech 1983; LeGall and Pannoux 1994).

Species	**Couche 4**	**Couche 3b**	**Couche 3a**	**Couche 3**	**Couche 2**
Birds					
Coelus monedula			1	5	
Purrhula pyrrhula				1	
Alauda arvensis				3	
Turdus sp.					1
Otus scops				1	
Aquila chrysaetos			2	1	
Falco tinnunculus					1
Nyroca fuligula					1
Anas platyrhyncus				2	
Oidemia fusca			5		
Numenius sp.				1	
Porsana porzana			1		
Crex crex				1	
Perdix perdix	1		9	14	2
Caccabis rufa				1	
Coturnix coturnix	2		16	16	5
Fish					
Salmonidae	30	30	33	12	9
Cyprinidae	1288	2716	5029	7713	446
Esocidae	85	209	240	259	55
Anguillidae	641	1848	1233	696	53

The fish fauna is primarily composed of members of the Cyprinidae family, or minnows; particular species represented include *Leuciscus leuciscus, Leuciscus cepahlus,* and *Alburnus alburnus* (LeGall and Pannoux 1994). Both *Leuciscus leuciscus* and *Alburnus alburnus* are widely used as bait today; in addition, all three species are preyed upon by raptors (Berg 1964; Kottelat 1997; Muus and Dahlström 1968). While Le Gall and Pannoux (1994) do not consider the possibility that these remains were deposited by non-human agents, I believe this hypothesis, along with the hypothesis that they were collected by humans, but for non-food purposes, must be considered. Therefore it is necessary to treat the fish data with some caution.

The faunal analyses thus far carried out at Pont d'Ambon have focused on paleoclimatic issues (Célérier 1994; Delpech 1983; Donard 1982; Drucker and Célérier 2001; LeGall and Pannoux 1994). A summary of the paleoclimatic data derived from this site can be seen in Table 7.5. As mentioned earlier, Pont d'Ambon has been of considerable interest because it is an example of early onset of the Azilian. The faunal data—specifically, the lack of reindeer—have led several researchers to question the radiocarbon dates at this site (Delpech 1983; Gilbert 1984). The suite of ungulates present throughout the Pont d'Ambon assemblage more closely resembles sites dating 11,000-10,000 years BP, than ones dating to 12,800 BP (as Couche 4 does). A comparison between the faunal composition of Couche Brune at Moulin du Roc (see p. 110) and Couche 4 at Pont d'Ambon illustrates this problem nicely: whereas the large fauna at Moulin du Roc during this time period are dominated by reindeer, there are no reindeer at all in the Pont d'Ambon sample, and diet breadth at Pont d'Ambon, even if one only considers the mammalian fauna, is much broader than at Moulin du Roc.

The dates at Pont d'Ambon are, however, remarkably consistent. It is possible that environments in the Dronne river valley were different from those elsewhere in the Dordogne region (Duchaedeau-Kervazo 1982). The consistency of the dates throughout the Pont d'Ambon sequence suggests that this may have been the case. Given the overall patchiness of the region today, it would not be surprising that the inhabitants of the Dronne valley were facing different environmental conditions than their neighbors to the south.

Pont d'Ambon differs from Moulin du Roc and other nearby sites in another way as well. In Chapter 6, I made an argument that Moulin du Roc was occupied seasonally, in the fall. Similar arguments have been made for other Dordogne Pleistocene-Holocene transition sites (Straus 1996). The numerous seasonality studies based on the Pont d'Ambon fauna, however, all point to the same conclusion: Pont d'Ambon was utilized year-round, rather than only seasonally (LeGall and Pannoux 1994; Pike-Tay 1991).

Table 7.5. Summary of paleoclimatic information for Pont d'Ambon (Célérier 1994; Drucker and Célérier 2001; Limondin 1994).

	Couche 4	**Couche 3b**	**Couche 3a**	**Couche 3**	**Couche 2**
Culture	Final Magdalenian	Early Azilian	Azilian	Azilian	Final Azilian/Laborian
Geology	cold and rigorous	temperate	temperate	cold	cold
Large mammals	temperate period	temperate	temperate	colder	temperate and grassy
Microfauna	cold and dry	temperate forest	cold and dry	cold and dry	temperate and grassy
Shellfish	cold	cold	cold	temperate and forested	temperate and forested
Fish	cool and dry	cool and dry	temperate and humid	temperate and humid	cooler and drier
Climatic stage	Bølling/Alleröd	Bølling/Alleröd	Younger Dryas	Younger Dryas	Preboreal period

Taphonomy

As with the Moulin du Roc fauna, the first stage in my consideration of the Pont d'Ambon fauna was a taphonomic analysis. And, as with the Moulin du Roc fauna, I relied on the work of many others to determine the accumulating agent for the Pont d'Ambon assemblage (Cochard 2004; el Guennouni 2001; Hockett 1991, 1995, 1999; Hockett and Bicho 2000; Hockett and Haws 2002; Schmitt 1995, 2002; Schmitt and Juell 1994). I analyze the same aspects of the fauna here as I did in Chapter 6: relative skeletal abundances, cutmarks, punctures, and other traces of different predators on the bones themselves, and analysis of breakage patterns.

Relative skeletal abundances

Before addressing whether the relative skeletal abundances at Pont d'Ambon correspond with any patterns of skeletal element abundances known to be produced by non-human predators, I first considered whether density-driven destruction could be responsible for the relative skeletal abundances at Pont d'Ambon. As at Moulin du Roc, I calculated relative skeletal element abundance values using the number of anatomical specimens per anatomical part, normed by the number of times that part occurs in the *Oryctolagus* skeleton (Broughton 1999; Grayson 1988; Thomas and Mayer 1983). Relative skeletal abundance values can be seen in Table 7.6.

Table 7.6. NISP by skeletal element and RSAs for the Pont d'Ambon Oryctolagus *assemblage compared with Oryctolagus density values (Pavao and Stahl 1999) and non-human predator RSA data (Hockett and Haws 2002).*

	Couche 4		Couche 3b		Couche 3a		Couche 3		Couche 2			Non-human predator data			
Element	NISP	RSA	NISP	RSA	NISP	RSA	NISP	RSA	NISP	RSA	Density	Golden eagle	Eagle owl	Barn owl	Small carnivore
Mandible	66	33.0	176	88.0	102	51.0	149	74.5	48	24.0	0.36	0.23	0.54	0.83	0.48
Maxilla	26	13.0	126	63.0	73	36.5	120	60.0	43	21.5	-	0.14	0.64	0.66	0.58
Scapula	45	22.5	119	59.5	104	52.0	124	62.0	39	19.5	0.18	0.06	0.59	0.57	0.19
Humerus	42	21.0	185	92.5	200	100.0	228	114.0	85	42.5	0.36	0.18	1	1	0.33
Radius	61	30.5	152	76.0	158	79.0	120	60.0	37	18.5	0.13	0.22	0.77	0.43	0.25
Ulna	47	23.5	128	64.0	148	74.0	177	88.5	45	22.5	0.17	0.19	0.91	0.88	0.31
Sacrum	3	3.0	1	1.0	5	5.0	21	21.0	6	6.0	0.43	0.41	0.53	0.13	0.19
Innominate	48	24.0	176	88.0	146	73.0	280	140.0	88	44.0	0.33	0.6	0.41	0.46	0.73
Femur	59	29.5	278	139.0	236	118.0	362	181.0	144	72.0	0.37	0.51	0.58	0.56	0.67
Tibia	51	25.5	219	109.5	210	105.0	330	165.0	114	57.0	0.37	1	0.57	0.51	1
Vertebra	17	0.7	59	2.3	69	2.7	277	10.7	67	2.6	0.35	2.3	—	5.9	5.7

Density values for *Oryctolagus cuniculus* have been published by Pavao and Stahl (1999). Density measures were taken from multiple scan sites on each element; since the individual elements here may represent any one or more of the scan sites measured, I calculated the mean density for the set of scan sites for each element. A Spearman's rank-order correlation between density and the *Oryctolagus* relative skeletal abundances by layer at Pont d'Ambon revealed no significant correlations (Table 7.7).

Table 7.7. Spearman's correlation coefficients for Oryctolagus *RSAs and bone densities (Pavao and Stahl 1999) from Pont d'Ambon.*

Couche	**Rho**	**P**
2	+0.341	.334
3	+0.287	.422
3a	+0.018	.960
3b	+0.260	.468
4	-0.189	.601

It thus appears that density is not responsible for the skeletal abundance patterns at Pont d'Ambon.

I then turned to a comparison of Pont d'Ambon's relative skeletal abundance patterns to patterns characteristic of non-human predators. Figure 7.4 shows the relative skeletal abundance of different elements in Couche 4 of Pont d'Ambon, compared to assemblages created by a barn owl, an eagle owl, and a variety of small carnivores (Hockett 1991, 1995, 1999; Hockett and Haws 2002; Schmitt 1995, 2002; Schmitt and Juell 1994). A Spearman's rank-order correlation demonstrates that there are no significant similarities in patterns of relative skeletal abundance between the deposits at Pont d'Ambon and between the deposits created by these non-human predators, not just in Couche 4 but for all layers under consideration here. The statistical data are compiled in Table 7.8.

Table 7.8. Spearman's correlation coefficients for Pont d'Ambon Oryctolagus *RSAs and those in predator-created assemblages (non-human predator data from Hockett and Haws 2002).*

Couche	**Barn owl**	**Small carnivore**	**Eagle owl**	**Golden eagle**
2	Rho=+0.25, p =.47	Rho=+0.21, p =.53	Rho=-0.14, p=.70	Rho=+0.53, p =.10
3	Rho=+0.23, p =.49	Rho=+0.36, p =.27	Rho=-0.07, p=.84	Rho=+0.59, p=.10
3a	Rho=-0.07, p =.83	Rho=+0.17, p =.66	Rho=+0.33, p=.35	Rho=+0.05, p=.89
3b	Rho=-0.02, p =.95	Rho=+0.40, p =.23	Rho=+0.01, p=.99	Rho=+0.20, p=.56
4	Rho=-0.20, p =.56	Rho=+0.10, p =.77	Rho=-0.14, p=.70	Rho=+0.10, p =.77

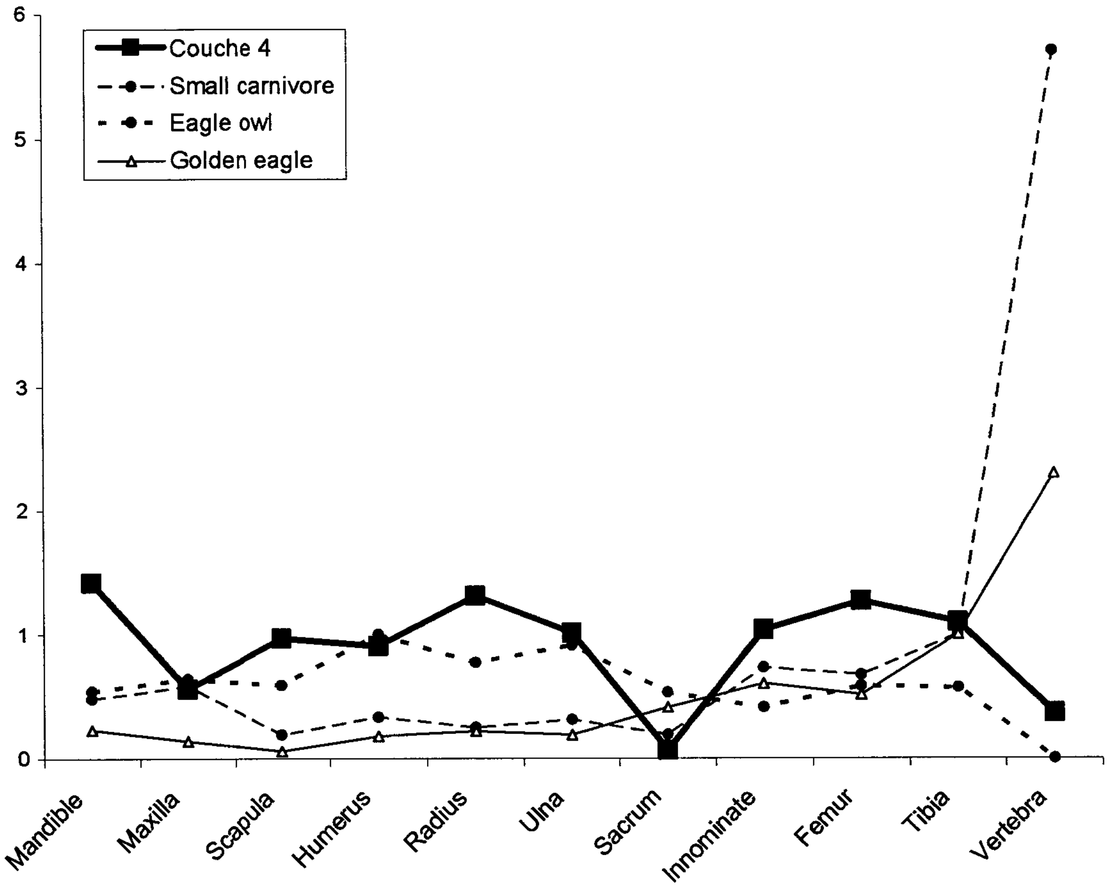

Figure 7.4. Comparison of skeletal element representation among the Pont d'Ambon rabbits and expected values for a variety of non-human predators (Hockett and Haws 2002).

The relative skeletal abundance data support the hypothesis that the Pont d'Ambon lagomorph fauna was primarily deposited by human activity, rather than by non-human predators.

Surface modifications

As part of the Pont d'Ambon analysis, all *Oryctolagus* skeletal elements except teeth were examined for puncture marks, gnawing, digestive traces, cutmarks, and burning. Frequencies of these surface modifications can be seen in Table 7.9.

Table 7.9. Frequencies of puncture marks, gnawing, digestive traces, cutmarks and burning in the Pont d'Ambon rabbits.

	Couche 4	**Couche 3b**	**Couche 3a**	**Couche 3**	**Couche 2**
Puncture marks	2 (.08%)	3 (.08%)	3 (.06%)	5 (.07%)	2 (.08%)
Gnawing	0	0	0	0	0
Digestive traces	5 (.40%)	14 (.36%)	14 (.29%)	64 (0.90%)	7 (.27%)
Cutmarks	154 (12%)	537 (14%)	757 (16%)	1075 (15%)	451 (18%)
Burning	169 (14%)	1558 (41%)	1136 (24%)	707 (10%)	223 (9%)

Although there were a few specimens containing puncture marks and/or digestive traces in the Pont d'Ambon assemblage, their numbers were uniformly low, at less than 1% of the entire assemblage. These numbers are comparable to those found by Hockett and Bicho in the human-accumulated lagomorph assemblage at Picareiro Cave in Portugal

(Hockett and Bicho 2000). These results also suggest that non-human predators were not responsible for the accumulation of *Oryctolagus* at Pont d'Ambon.

In addition, there were traces of human activity—burning and cutmarks—which suggest that humans did accumulate this assemblage. The analysis of surface modifications, like the relative skeletal abundance analysis, thus suggests that the Pont d'Ambon rabbit assemblage was created by human activity, rather than by non-human predators.

Breakage patterns

As at Moulin du Roc, the Pont d'Ambon rabbit fauna contained very few complete limb elements (unlike faunas typically collected by small carnivores of southwestern Europe). A breakdown of limb bone fragmentation can be seen in Table 7.10. Evidence from the breakage patterns thus does not support the hypothesis of an assemblage created by small carnivores.

The breakage patterns do suggest a human-accumulated assemblage. The Pont d'Ambon rabbit fauna evidenced a significant frequency of "rabbit cylinders," or long bones with the ends snapped off (Hockett and Bicho 2000; Perez Ripoll 1993; Schmitt 1990, 2002). A high frequency of the limb bone elements are midshaft fragments (Table 7.10). In addition, the overall frequency of "rabbit cylinders" ranged from between 11% and 27% of the entire limb bone assemblage (Figure 7.5). Examples of specimens identified as rabbit cylinders can be seen in Figure 7.6.

Table 7.10. Rabbit limb bone portions recovered from Pont d'Ambon.

	Midshaft	Proximal	Distal	Complete	Total
Couche 2					
Femur	71	35	37	2	145
Tibia	70	23	20	1	114
Humerus	45	3	23	7	78
Radius	30	3	0	4	37
Ulna	11	32	2	3	48
Couche 3					
Femur	87	129	103	1	320
Tibia	104	86	140	0	330
Humerus	32	40	147	2	221
Radius	9	77	28	4	118
Ulna	34	127	14	1	176
Couche 3a					
Femur	47	138	50	1	236
Tibia	65	33	110	1	209
Humerus	21	35	140	2	198
Radius	20	113	23	2	158
Ulna	47	89	6	1	143

Table 7.10 con't. Rabbit limb bone portions recovered from Pont d'Ambon.

	Midshaft	Proximal	Distal	Complete	Total
Couche 3b					
Femur	100	117	60	1	278
Tibia	100	43	75	1	219
Humerus	33	31	120	1	185
Radius	43	88	20	1	152
Ulna	38	81	9	0	128
Couche 4					
Femur	22	31	6	0	59
Tibia	23	10	18	0	51
Humerus	6	9	24	1	40
Radius	13	36	9	3	61
Ulna	7	31	9	0	47

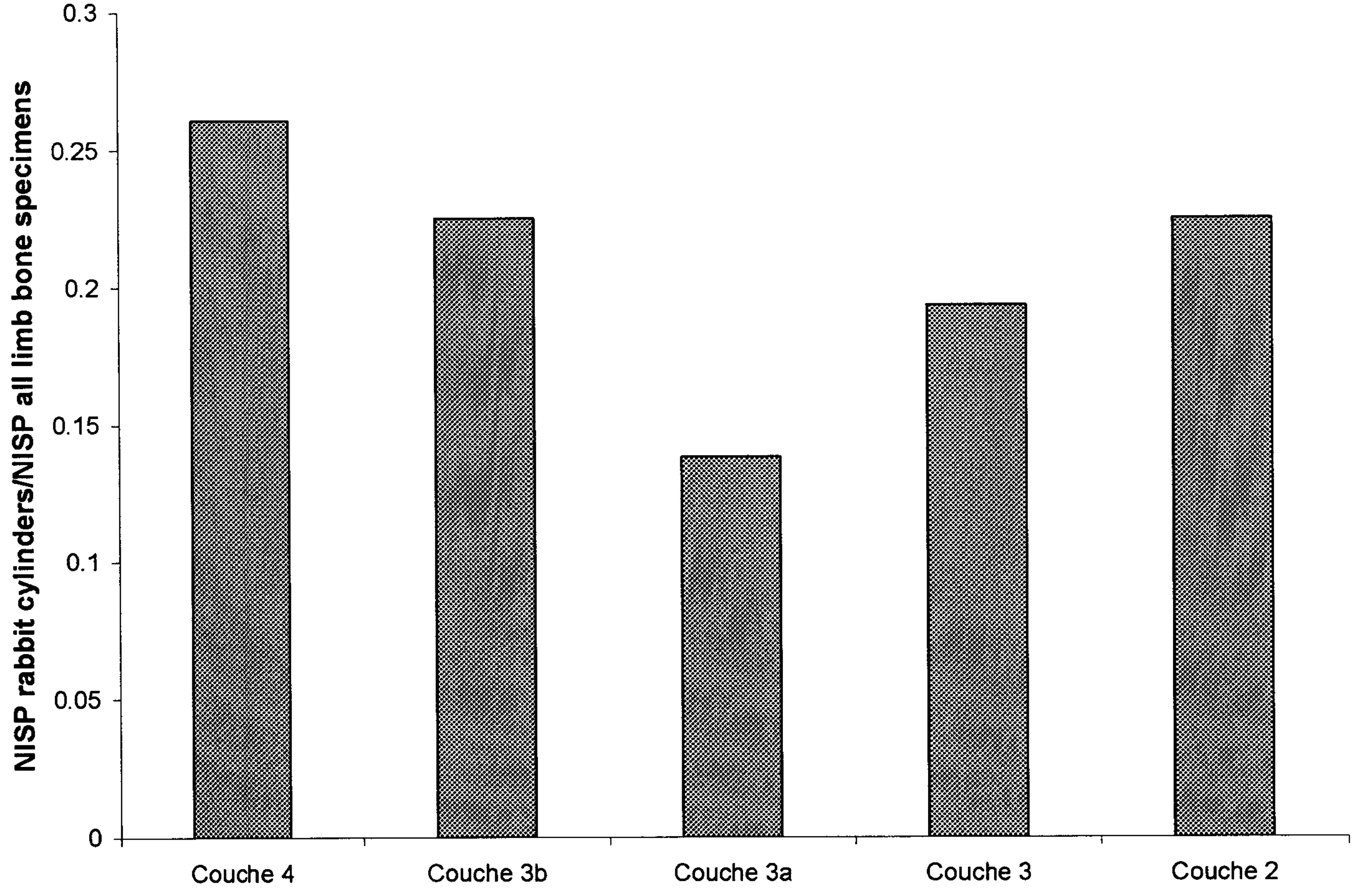

Figure 7.5. Frequency of "rabbit cylinders" in the Pont d'Ambon fauna.

Figure 7.6. "Rabbit cylinders" from Pont d'Ambon, Couche 3b.

Like the relative skeletal abundance data and the surface modification data, the breakage patterns from the rabbit assemblages at Pont d'Ambon do not support the hypothesis that these assemblages were created by non-human predators. Instead, they suggest that humans were the primary accumulating agent of *Oryctolagus* at Pont d'Ambon.

Summary

All three taphonomic lines of evidence here—relative skeletal abundances, surface modifications, and breakage patterns—suggest that humans, rather than other predators, were the primary accumulating agent of rabbits at Pont d'Ambon. The Pont d'Ambon rabbits are a zooarchaeological assemblage rather than a paleontological one.

Rabbit demography

As at Moulin du Roc, I used a variety of methods to assess the age and sex of the rabbit populations represented at Pont d'Ambon. Unlike Moulin du Roc, however, there were no obvious sample size issues with the Pont d'Ambon assemblage. With sample sizes ranging from a low of 1,233 *Oryctolagus* specimens in Couche 2 to a high of 7,148 in Couche 3, there were ample individual elements to create both sex and age profiles. This allowed me to consider changing patterns of *Oryctolagus* demography through time in addition to simply assessing whether they were being taken *en masse* or not.

Age

Age profiles were assembled using the three age indicators presented in Table 5.6. Sample sizes for each of the elements used to construct age profiles are available in Table 7.11.

Table 7.11. NISP for elements used to construct age profiles.

Element	**Couche 4**	**Couche 3b**	**Couche 3a**	**Couche 3**	**Couche 2**
Mandible	458	1325	1225	1430	398
Distal humerus	24	99	134	144	50
Distal tibia	18	75	110	140	46

All three age profiles can be seen in Figure 7.7. In the profile based on the presence or absence of deciduous teeth, the proportion of juveniles is low, but rabbits less than one month old are demonstrably present throughout the sequence, ranging in frequency from 1% in Couche 4 to 13% in Couche 2. This consistent presence suggests that rabbits less than 1 month old were being taken by the prehistoric inhabitants of Pont d'Ambon. Cochran's test of linear trend confirms that the trend of increasing representation of juveniles through time is statistically significant ($\chi_t^2 = 25.501$, $p < .0001$).

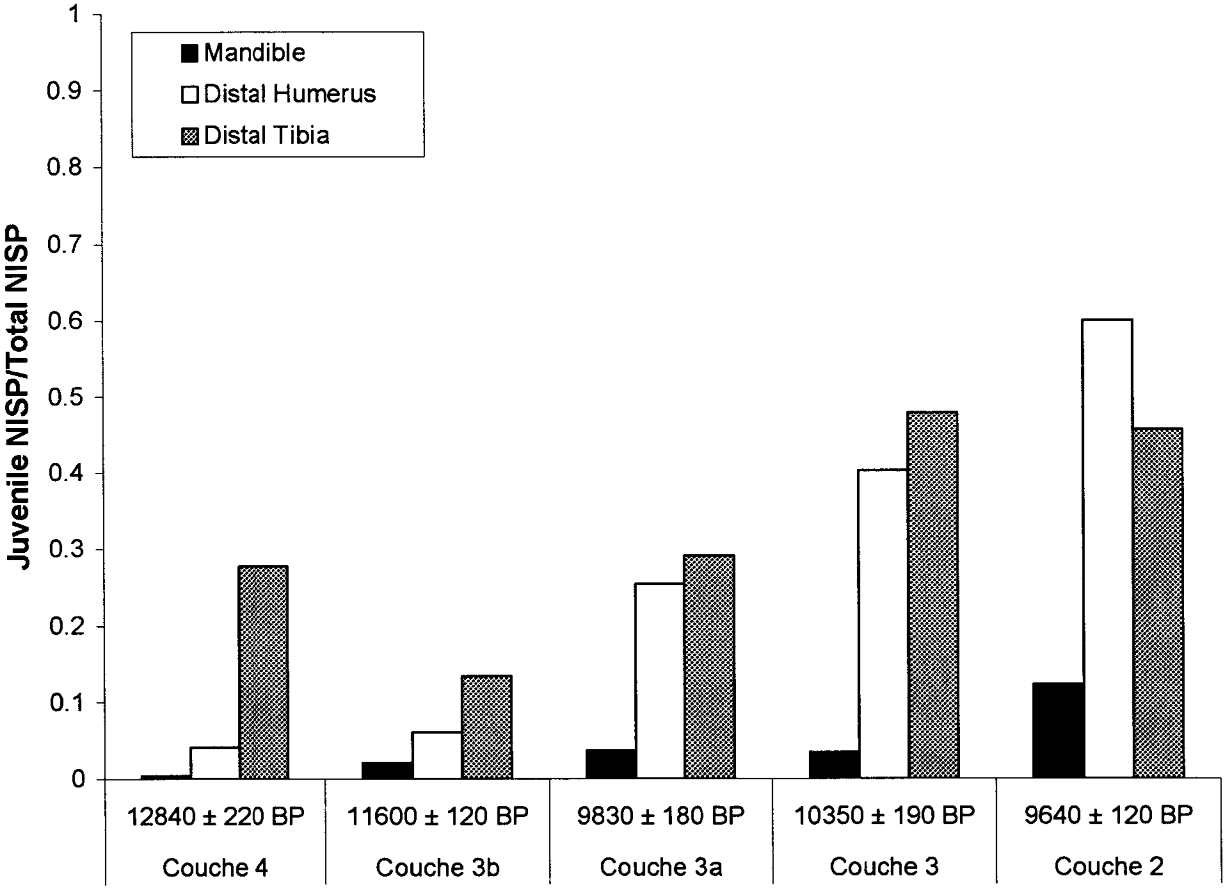

Figure 7.7. Proportion of very young rabbits in the Pont d'Ambon *Oryctolagus* assemblage.

The age profile based on fusion of the distal humerus reveals the same pattern. Just as with the age profile based on deciduous teeth, very young individuals are always present (ranging from 4% to 60% of the total sample), and their proportion also steadily increases through time. Cochran's test of linear trend confirms that the trend of increasing representation of juveniles through time is statistically significant ($\chi_l^2 = 19.631$, $p < .0001$).

The pattern derived from fusion of the distal tibia is slightly more complex. In this case, Couche 4 in composed of almost 28% very young individuals. In Couche 3b, the percentage drops to 13%, and then slowly increases again (overall range is from 13% to 48%). There is still a significant trend of increase through time (Cochran's test of linear trend, $\chi_l^2 = 6.347156$, $p < .05$), but it is less marked than in the other two profiles. A Kruskal-Wallis analysis of variance shows a significant difference in distribution from the other two profiles ($H = 8.34$, $p < .01$). Why this difference? As mentioned in Chapter 5, the distal tibia fuses at around 2-3 months of age, which is later than the target age. The difference in ratio of rabbits less than one month and over two months suggests that at least some juveniles were being taken on the landscape.

If this hypothesis is correct, then the same difference should be apparent when one looks at the overall proportion of unfused elements. The overall frequency of subadults in the Pont d'Ambon assemblage (Figure 7.8) is relatively high, and a Kruskal-Wallis analysis of variance confirms that this distribution differs significantly from the profiles based on fusion of the distal tibia and on deciduous teeth ($H = 7.76$, $p < .05$)

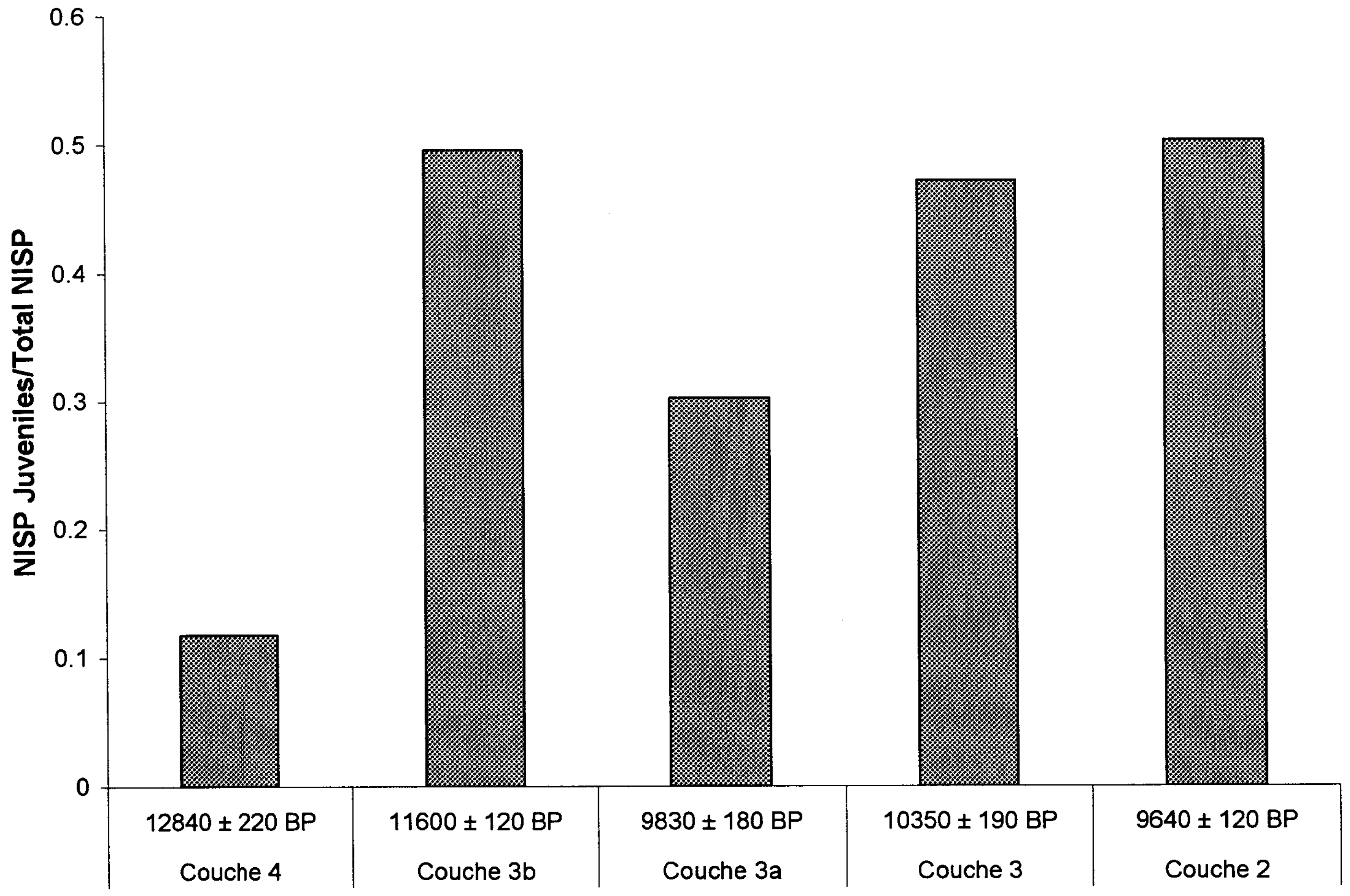

Figure 7.8. Proportion of unfused elements in the Pont d'Ambon *Oryctolagus* assemblage.

The age profiles suggest a palimpsest of rabbit hunting methods at Pont d'Ambon. Although it does appear that at least some of the Pont d'Ambon rabbits were being taken individually, these profiles make a strong argument for the collection of at least some individuals from warrens. Additionally, all three profiles show a significant trend towards increasing representation of juveniles through time. There was no significant relationship between sample size and any of the age indicators (Table 7.12), so this increase cannot be attributed to sample size.

Table 7.12. Regression values for the relationship between sample size and relative abundance of juveniles based on each age indicator.

Age indicator	**r**	**P**
Presence/absence of deciduous teeth	+0.42	.471
Fusion of the distal humerus	+0.14	.834
Fusion of the distal tibia	+0.27	.654

The increase in frequency of juveniles through time suggests that either warren harvesting itself increased through time, or that people increasingly harvested very young individuals from the warren. In the first case, the sex profiles should show a similar trend, with increasing representation of females through time. In the second case, the proportion of females should be strong throughout the sequence, with no apparent trend.

Sex

Sample sizes at Pont d'Ambon were robust enough to construct sex profiles based on both the distal humerus and the mandible (Figure 7.19). There was a paucity of both measurable distal humeri (n = 11) and measurable mandibles (n = 15) in Couche 2, but the sample sizes from other layers, both for the mandible and humerus, were sufficient (Table 7.13).

Table 7.13. NISP for elements used to construct sex profiles.

	Couche 4	Couche 3b	Couche 3a	Couche 3	Couche 2
Humerus	25	80	75	72	11
Mandible	24	47	37	60	15

For the humeral index, I plotted distal breadth versus trochlear breadth for each stratum, to verify that the individuals were dimorphic enough to render this course of analysis valid. Each scatterplot showed two distinct clouds, representing larger and smaller specimens (Figures 7.9. 7.10, 7.11, 7.12, and 7.13). I identified the larger individuals in each layer as the females and the smaller as the males, and used these numbers to determine the overall percentage of females in each couche. I then repeated this process using diastema length and diastema depth on the mandible (Figures 7.14, 7.15, 7.16., 7.17, and 7.18).

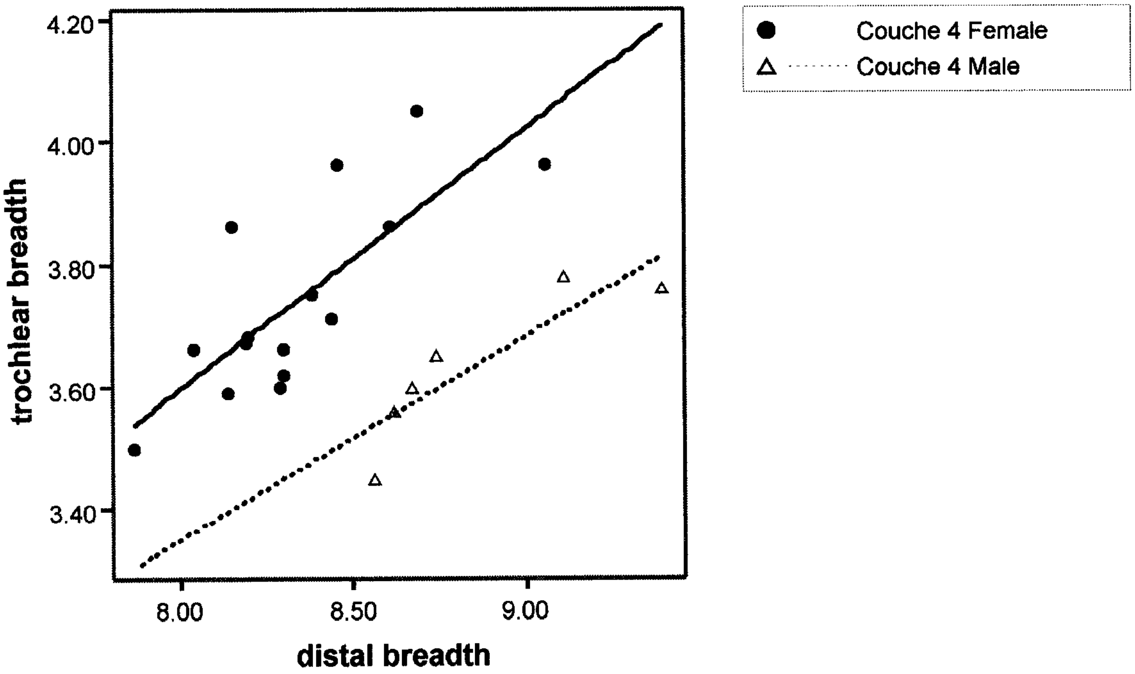

Figure 7.9. Scatterplot of distal humerus measurements from Couche 4.

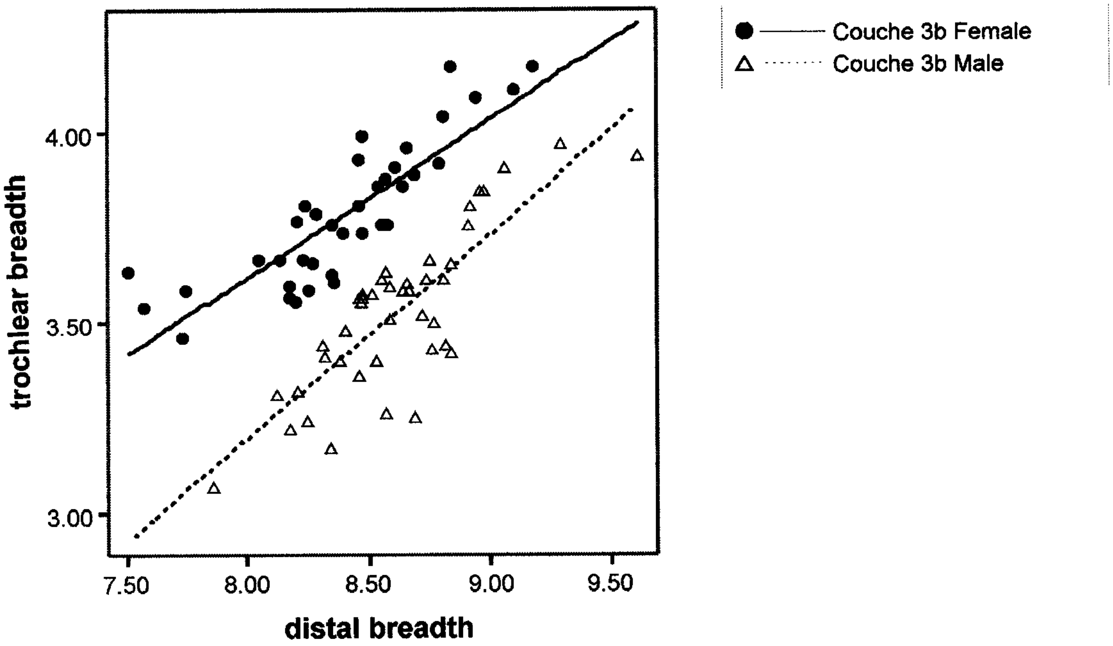

Figure 7.10. Scatterplot of distal humerus measurements from Couche 3b.

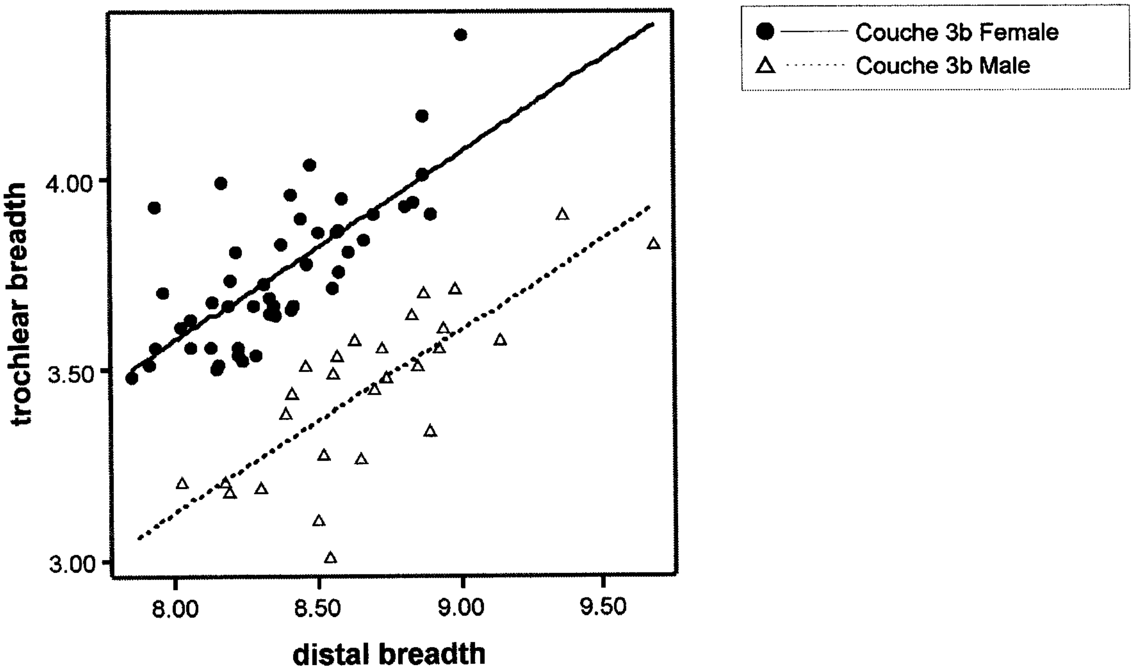

Figure 7.11. Scatterplot of distal humerus measurements from Couche 3a

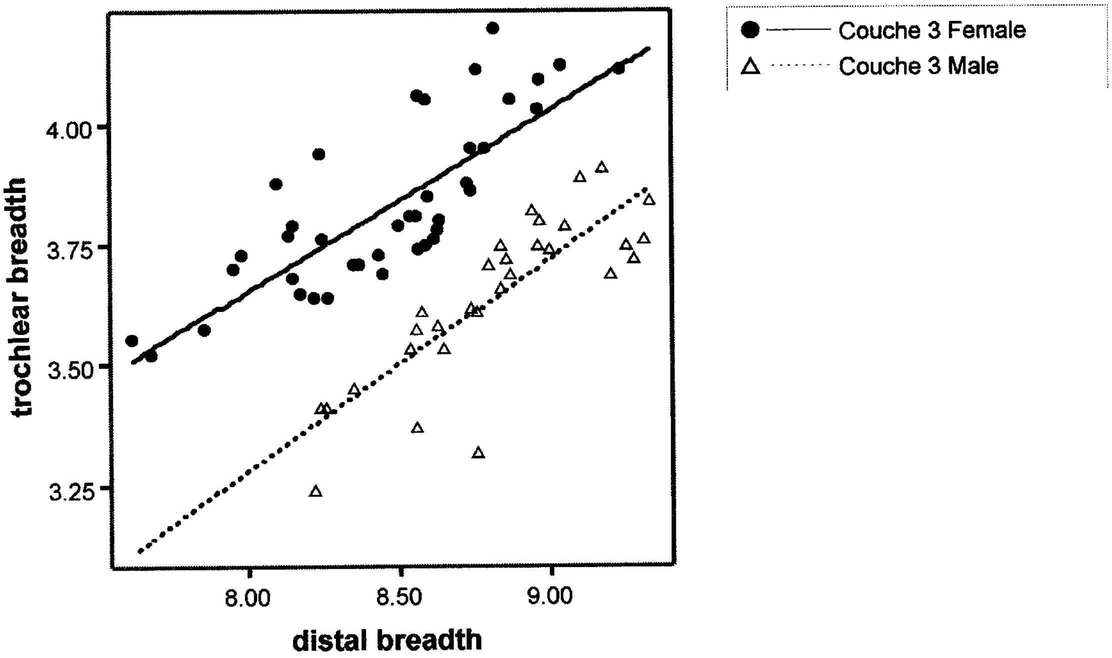

Figure 7.12. Scatterplot of distal humerus measurements from Couche 3.

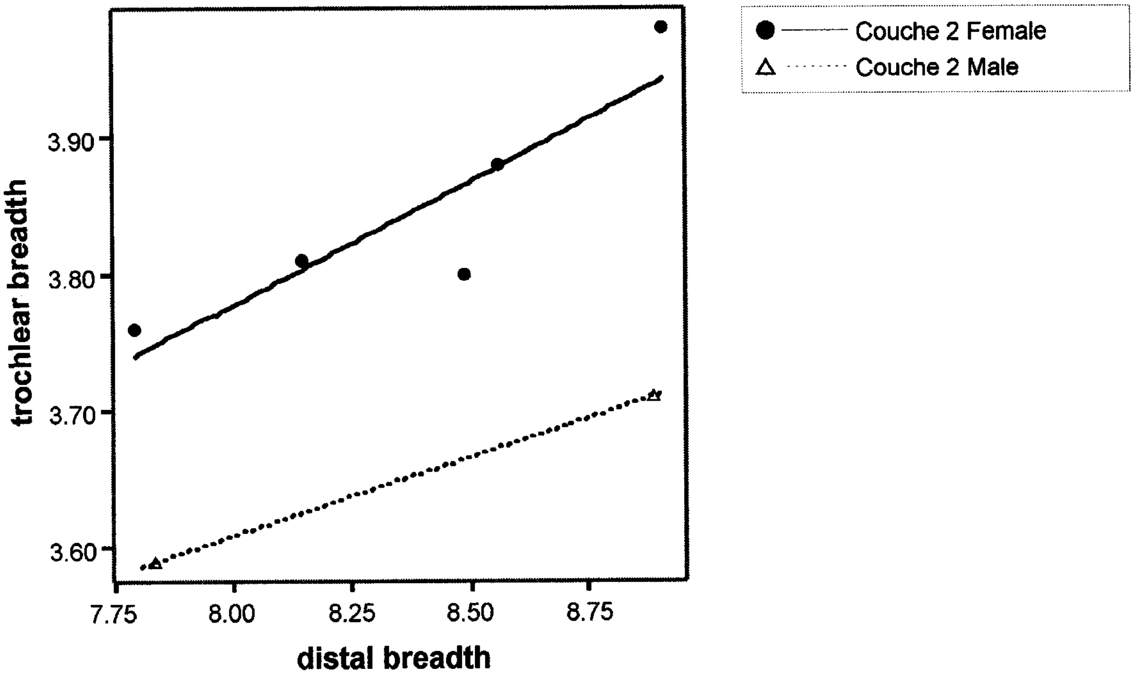

Figure 7.13. Scatterplot of distal humerus measurements from Couche 2.

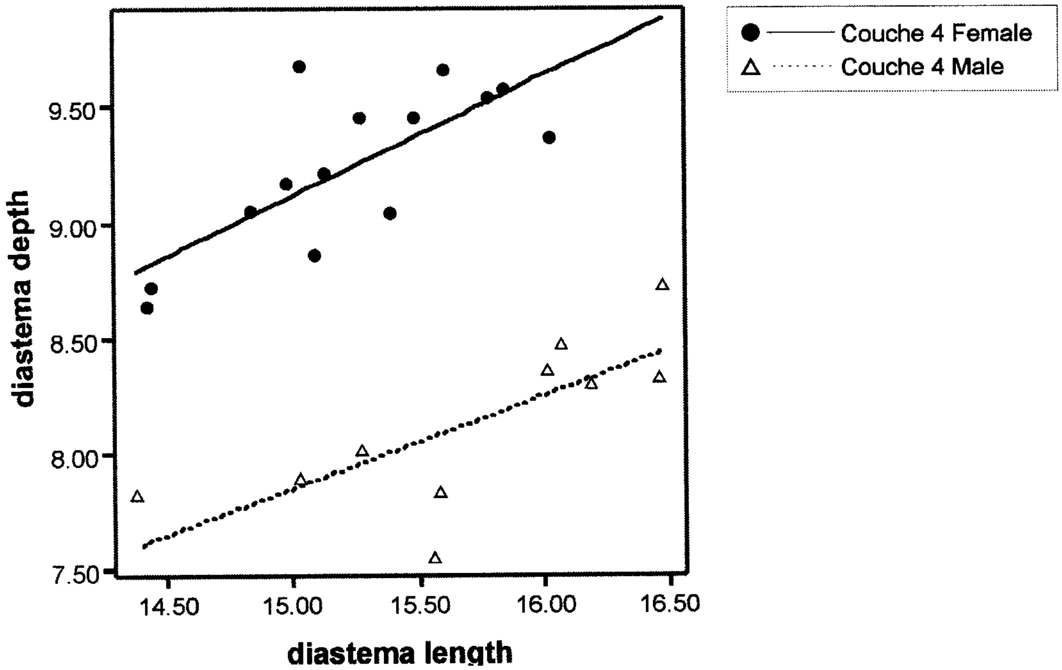

Figure 7.14. Scatterplot of mandible measurements from Couche 4.

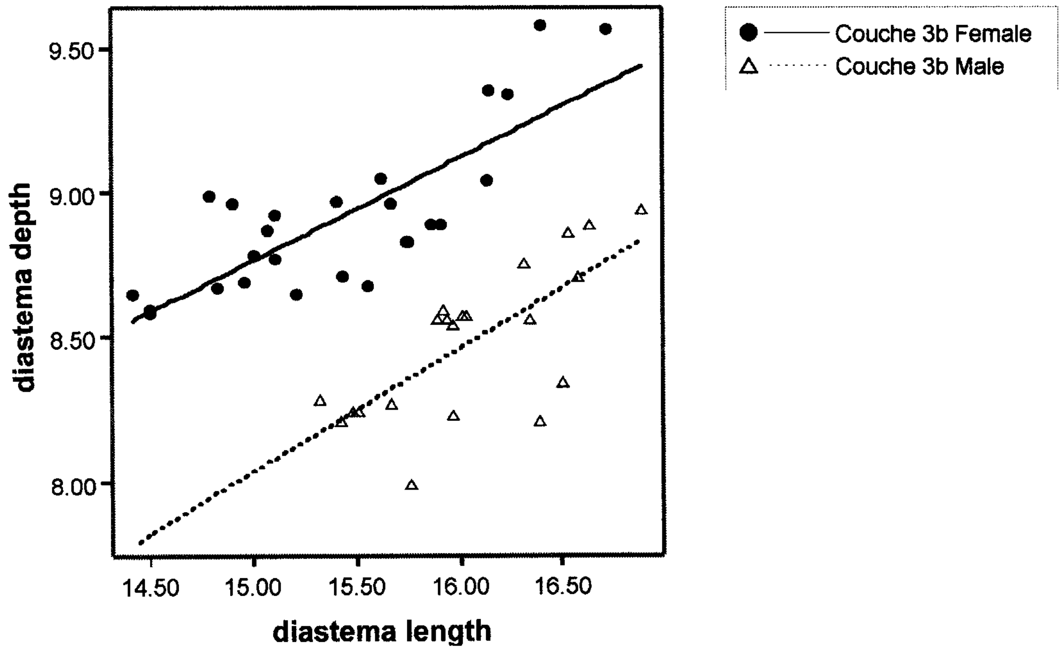

Figure 7.15. Scatterplot of mandible measurements from Couche 3b.

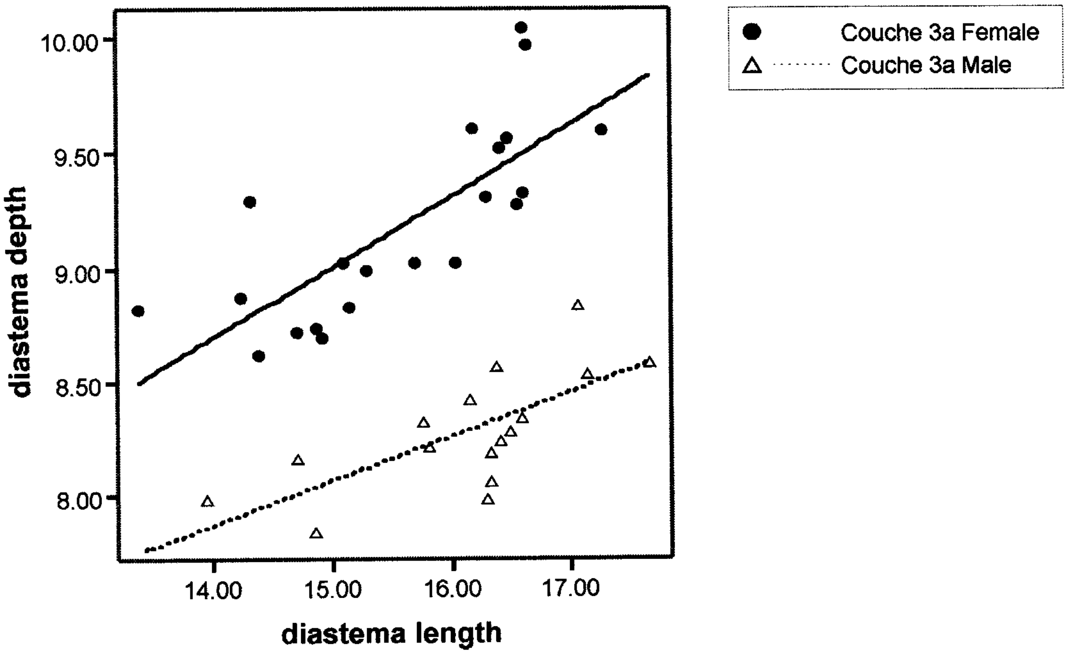

Figure 7.16. Scatterplot of mandible measurements from Couche 3a.

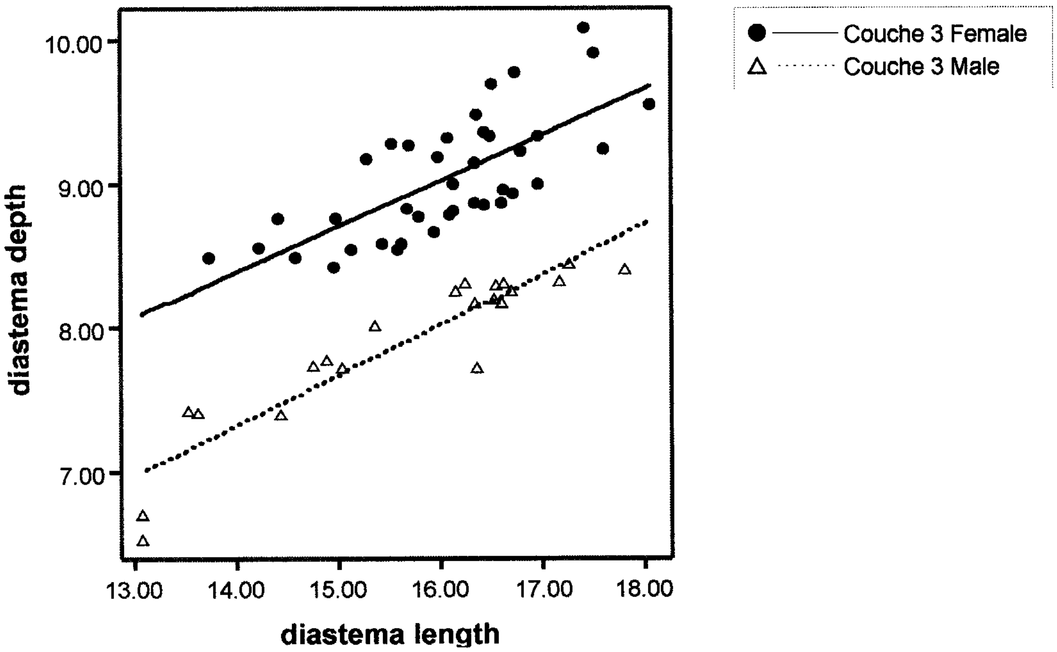

Figure 7.17. Scatterplot of mandible measurements from Couche 3.

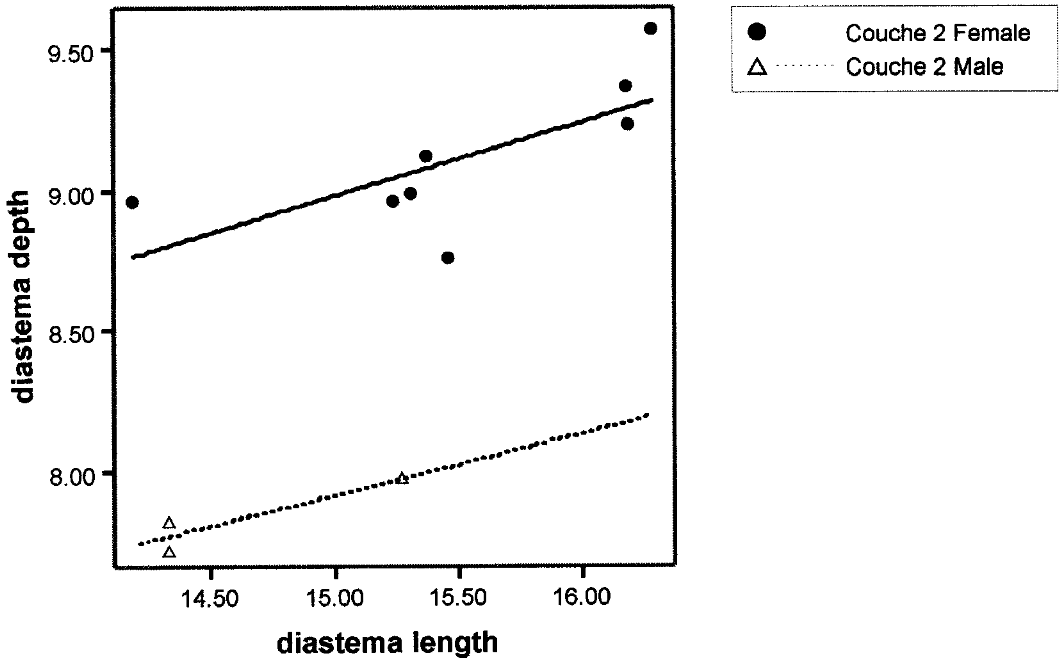

Figure 7.18. Scatterplot of mandible measurements from Couche 2.

The resulting sex profiles can be seen in Figure 7.19. Both sex indicators produced profiles in which females dominate throughout the sequence. Using the humeral index, percentages ranged from a low of 53.8% to a high of 85.7%; based on the mandibular index, the range was from 44.7% to 78.6%. This strong, consistent presence suggests that warren hunting was the dominant method at Pont d'Ambon. However, while there is a weak diachronic trend in the proportion of female rabbits in the profile based on the humeral index, and a slightly stronger one in the profile based on the mandibular index, neither of these trends is statistically significant ($\chi_t^2 = 4.462$, $p > .25$ for the humeral index; $\chi_t^2 = 8.259$, $p > .05$ for the mandibular index). The pattern of increase seen in the age profiles is not present in the sex profiles. This suggests that of the possibilities presented to account for the increase in juveniles through time (that either warren harvesting increased through time, or that people increasingly took very young individuals from the warren), the second is more likely.

As with the age profiles, I tested to be sure that sample size effects were not influencing the sex profiles. Since these profiles show no clear trend through time, this test was less critical; however, there was no significant correlation between sample size and the frequency of females in the Pont d'Ambon sample. Results can be seen in Table 7.14. Sample size is not responsible for the sexual demographics of the Pont d'Ambon *Oryctolagus* assemblage.

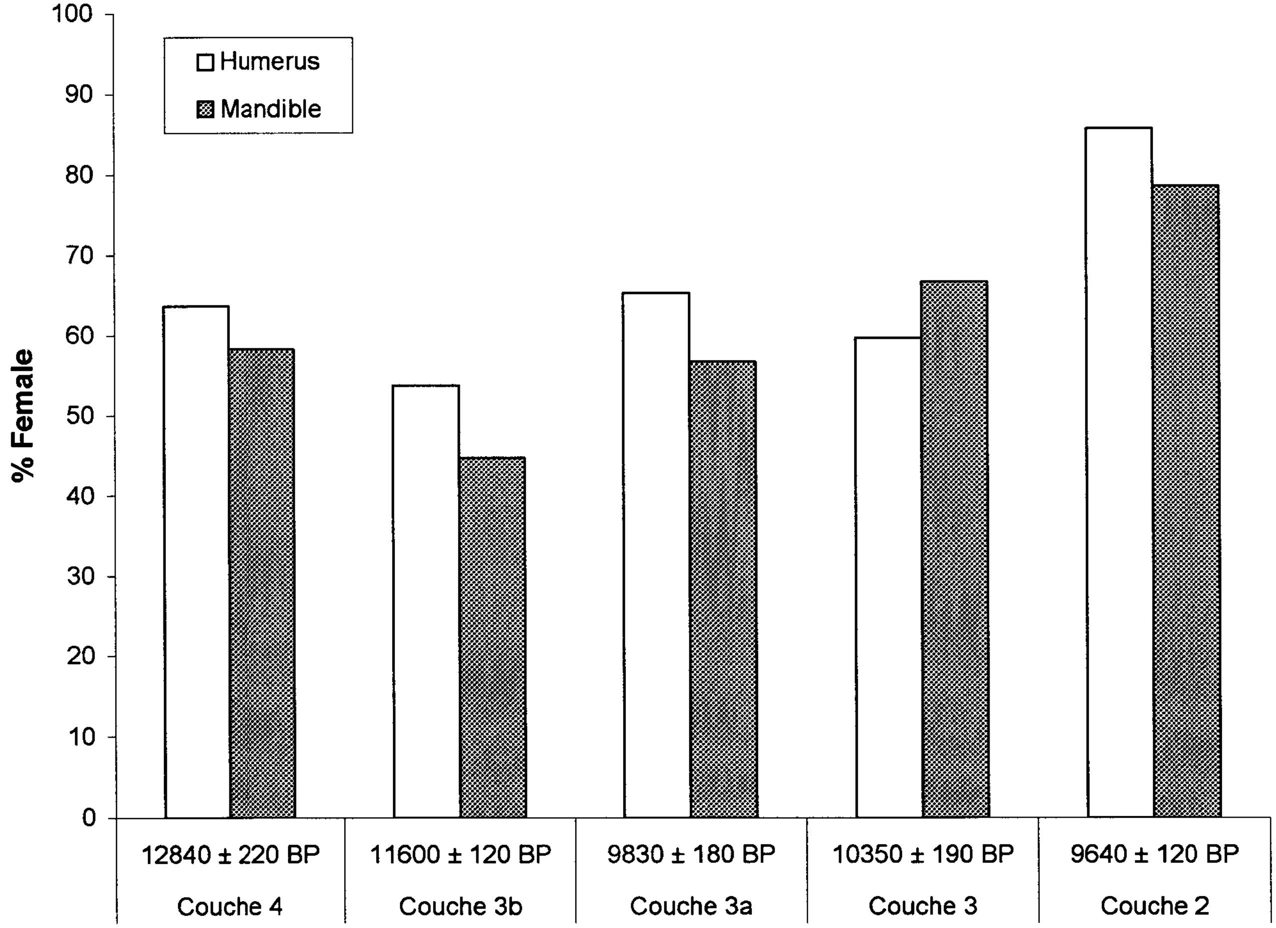

Figure 7.19. Proportion of females in the Pont d'Ambon *Oryctolagus* assemblage based on size differences in the mandible and in the distal humerus.

Table 7.14. Regression values for the relationship between sample size and relative abundance of females based on each sex indicator.

Sex indicator	**r**	**P**
Sexual dimorphism in the distal humerus	+0.67	.213
Sexual dimorphism in the diastema	+0.44	.459

Summary

Two main conclusions can be drawn from the changing demography of the Pont d'Ambon rabbit fauna. First, the inhabitants of Pont d'Ambon took at least some (but not all) of the rabbits they harvested directly from warrens. This suggests that they were harvesting rabbits *en masse*, which would likely change the relative value of rabbits versus other fauna in the diet. In addition, the *Oryctolagus* assemblage at Pont d'Ambon is complicated by the fact that it represents a palimpsest of methods; while some rabbits were being harvested *en masse*, the representation of a variety of different age classes in the rabbits at Pont d'Ambon indicates that some were also being taken individually. A standard archaeological prey choice analysis (Broughton 1999; Grayson and Cannon 1999) would not be appropriate in this instance, as the rabbits at Pont d'Ambon represent at least two separate prey types, and possibly more. Other techniques are needed to ascertain why and how the prehistoric inhabitants of Pont d'Ambon used this resource.

Second, the prehistoric inhabitants of Pont d'Ambon increasingly harvested very young individuals through time. Juveniles, whether taken *en masse* or not, would be a less efficient resource to pursue than adult rabbits. They are of smaller size and they provide a lower caloric return per unit weight (Chapter 5). Their increasing presence in the Pont d'Ambon fauna may indicate resource intensification. I will consider this possibility further in later stages of this analysis.

Seasonality

In Chapter 6, I made an argument that the rabbits at Moulin du Roc were hunted seasonally, in the fall. At Pont d'Ambon, the differences between the age profile based on fusion of the distal tibia and the other two profiles suggest the opposite: people were hunting rabbits throughout the winter, spring and summer, and possibly in the autumn as well. The distribution of the overall frequency of juveniles in the sample (Figure 7.8) confirms this variability. The proportion of juveniles starts low, at 11% in Couche 4, then jumps to 50%, dips back down to 30%, and then hovers around 50% in Couches 3 and 2. The differences in proportion of juveniles through time depending on how one measures age show that rabbits of a variety of ages were being taken. This confirms the year-round seasonality results found in other research (LeGall and Pannoux 1994; Pike-Tay 1991).

Patch choice

In Chapter 4, I made predictions about what changes in patch choice might be expected in different scenarios of rabbit exploitation. In the case of climate change as a causative factor, people should gradually increase the number of patches exploited through time, and these increases should correlate with known climate changes. In the case of human-induced resource depression, people should gradually increase the number of patches exploited through time. These increases should not correlate with known climate changes, and signs of resource depression should be visible among the larger fauna. Finally, in the case of a resource-restricted Magdalenian, there may be a sudden increase in the number of patches exploited, since as new patches become available they should immediately be added. At the same time, however, there should be a shift away from more distant, plateau-top patches—which, as forested enivoronments, would be less attractive to rabbits—towards more local, mixed-habitat river-valley patches.

Archaeological analyses of patch choice are not as common as analyses of prey choice (Kelly 1995) because precisely determining which patch different resources came from and patch distance from a base camp are extremely difficult in archaeological contexts. Those archaeological patch choice analyses that exist are necessarily basic, generally dividing fauna into just two or three patches (Broughton 1999; Cannon 2000a; Zeanah 2000).

Analyses of patch choice that rely on patch richness, or the number of patches in the set, will therefore probably not be very meaningful in archaeological analyses.

Evenness, another measure of diversity, might be more useful (Magurran 1988). Evenness, or the degree to which different individual groups in a set are equally represented, has been successfully used in a variety of zooarchaeological analyses (Grayson 1984; Grayson and Delpech 2002b; Grayson et al. 2001; Jones 2004; Nagaoka 2001; Stiner 2001), as I did in the Moulin du Roc analysis. I used patch choice evenness, or the degree to which all patches in the set are equally represented, as a measure of diversity of patch use. I measured evenness using 1/D, the inverse of Simpson's Dominance index (Jones 2004; Magurran 1988).

I separated the Pont d'Ambon fauna into three main patches: river (represented by fish), grassy (represented by rabbits, horse, and bison) and forested (represented by red deer, wild boar, and roe deer). Because I am unsure that the cyprinids were dietary resources, I excluded them from this analysis. The analyses can be seen in Figures 7.20 (change in patch use through time) and 7.21 (changing evenness through time).

Several things are apparent from these data. First, the river and meadow patches are both present in significant proportions in the earlier deposits at Pont d'Ambon; forest resources are consistently present, but at very low proportions. So, initially at least, patch choice at Pont d'Ambon seems to suggest a resource-restricted Magdalenian. All three patches are in use, but the focus is on the two local patches rather than the presumably more distant one.

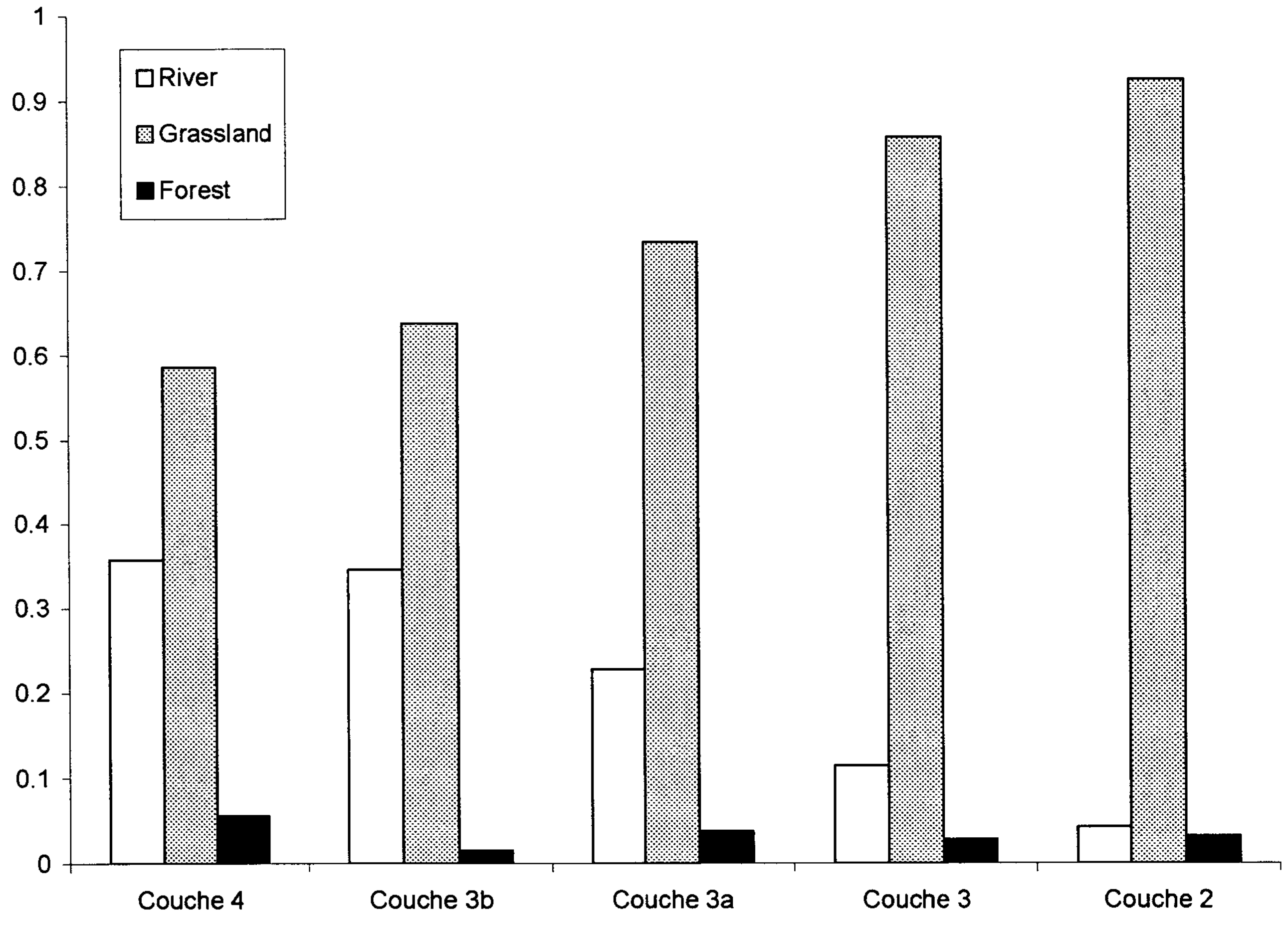

Figure 7.20. Changes in Pont d'Ambon patch choice, excluding Cyprinidae.

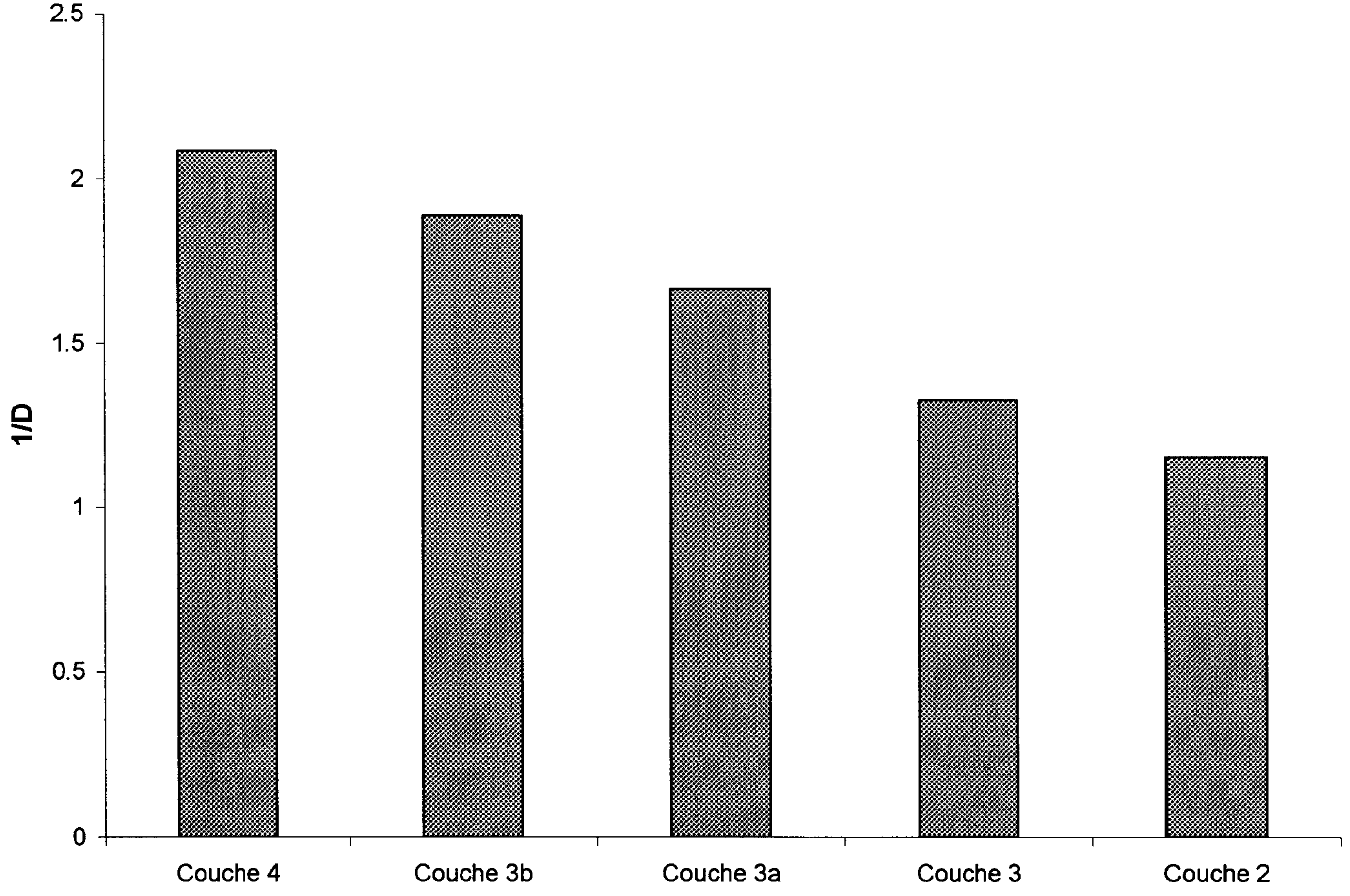

Figure 7.21. Changes in Pont d'Ambon patch use evenness, excluding Cyprinidae.

These data also show a significant trend of increasing dominance of the grassland patch through time. The use of the river patch declines, while forest patch use remains relatively constant and grassland patch use increases. The dramatic change in relative patch representation is shown when we turn to evenness (Figure 7.21). Evenness declines steadily through time ($\chi^2 = 1946.74$, $p < .0001$), as patch choice is increasingly focused on the grassland patch. At Moulin du Roc, patch evenness increased through time (Chapter 6). At Pont d'Ambon, the pattern is the opposite.

Evenness measures are prone to sample size effects (Grayson et al. 2001; Magurran 1988), so I tested for a relationship between sample size and patch use evenness, to be sure that sample size was not causing the pattern seen in Figure 7.21. There was no significant relationship ($r = -.22$, $p = .683$). The patterns in evenness seen here are not due to changing sample size.

Why should patch choice at Pont d'Ambon decrease in evenness through time? The decline in patch evenness (and the related increase in dominance of the grassland patch and decrease in use of the river patch) seems to correspond with the onset of the Younger Dryas cold period (see Table 7.5). This suggests that climate change, and its corresponding impact on the surrounding landscape, may be the causal factor for change in patch choice at Pont d'Ambon.

I used Guiot's (1990) pollen-based temperature and precipitation data to approximate climate changes in the Pont d'Ambon area. While neither the January nor the July seasonal changes in climate showed any relationship with changing patch evenness at Pont d'Ambon, there was a significant relationship between changing patch evenness and both average annual precipitation (r = +0.79, p = .008) and average annual temperature (r = +0.80, p = .009). Figures 7.22 and 7.23 show these two relationships. Patch evenness decreases with both decreased temperatures and decreased precipitation.

Why is this happening? The reasons are fairly straightforward. The Younger Dryas was a major cold event, with significant impacts on landscape and vegetation (Alley et al. 1993; Dansgaard et al. 1989; Fauquette et al. 1999; Magny 1997). In southwestern France, this cold period corresponds with a return to tundra-like conditions; forested patches that had begun to spread across the Dordogne region during the prior warming period disappeared (Fauquette et al. 1999; Huntley 1988, 1990). The increase in representation of the grassland patch represents an increase in the local availability of this patch.

The Younger Dryas event, then, caused patch choice evenness to narrow due to an increase in the local availability of the grassland patch. The patchy, non-analogous environments that characterized southwestern France during the warming period from 13,000 to 10,000 years BP disappeared as tundra environments returned to the Périgord. These cold conditions may have had a corresponding negative effect on river patch as well (LeGall 1993), thus causing river patch representation to decrease.

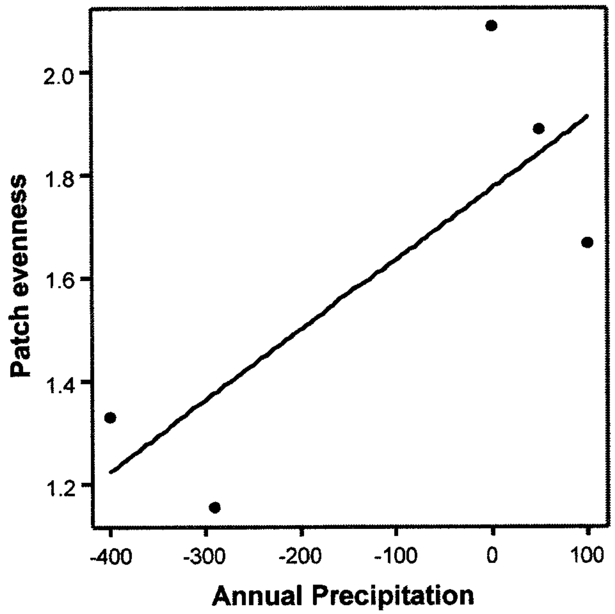

Figure 7.22. Relationship between patch evenness and annual precipitation anomalies (after Guiot 1990).

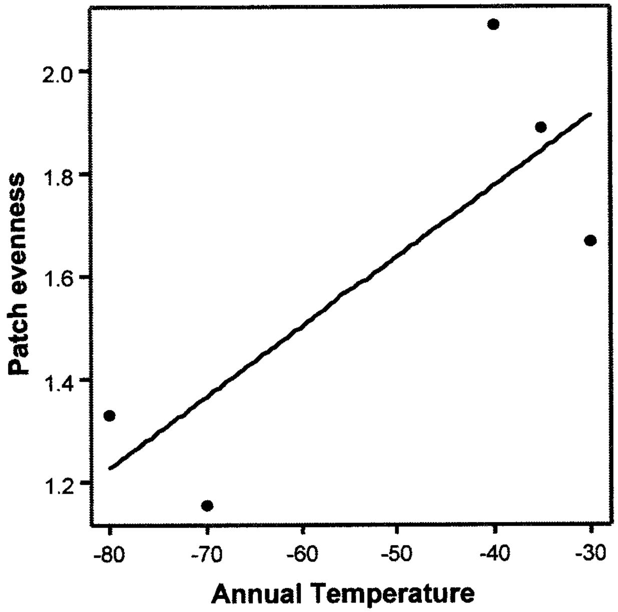

Figure 7.23. Relationship between patch evenness and annual temperature anomalies (after Guiot 1990).

Changing prey use at Pont d'Ambon

Although the Younger Dryas does seem to have brought a return of glacial environments to southwestern Europe, both at Pont d'Ambon and across the region (Straus 1999, 2000), the fauna at Pont d'Ambon does not revert to a typical Magdalenian zooarchaeological assemblage. An overview of changing faunal relative abundance at Pont d'Ambon can be seen in Figure 7.24. Reindeer do not recolonize this area in the Younger Dryas, despite the rigorous climatic conditions. Red deer decrease in relative abundance, while horse and bovids increase (Table 7.3).

In addition, while fish (Table 7.4) do decrease in relative abundance with the Younger Dryas, rabbits (and, to a lesser extent, birds) increase (Figure 7.24). A Cochran's test of linear trend confirms that this increase is statistically significant ($\chi_t^2 = 347.930$, $p < .0001$). The rabbit increases in relative dietary importance, even as the Younger Dryas impacts the use of other prey types.

Several conclusions can be drawn from this. First, the Younger Dryas did not cause extirpation of *Oryctolagus* in the Pont d'Ambon area. Although previous cold intervals are known to have extirpated *Oryctolagus* colonists in southern France (Cochard 2004; Donard 1982; el Guennouni 2001; Rogers et al. 1994), in this case the European rabbit survived. A comparison with Guiot's (1990) climate reconstruction may explain why this happened. While the Younger Dryas resulted in severe decreases in

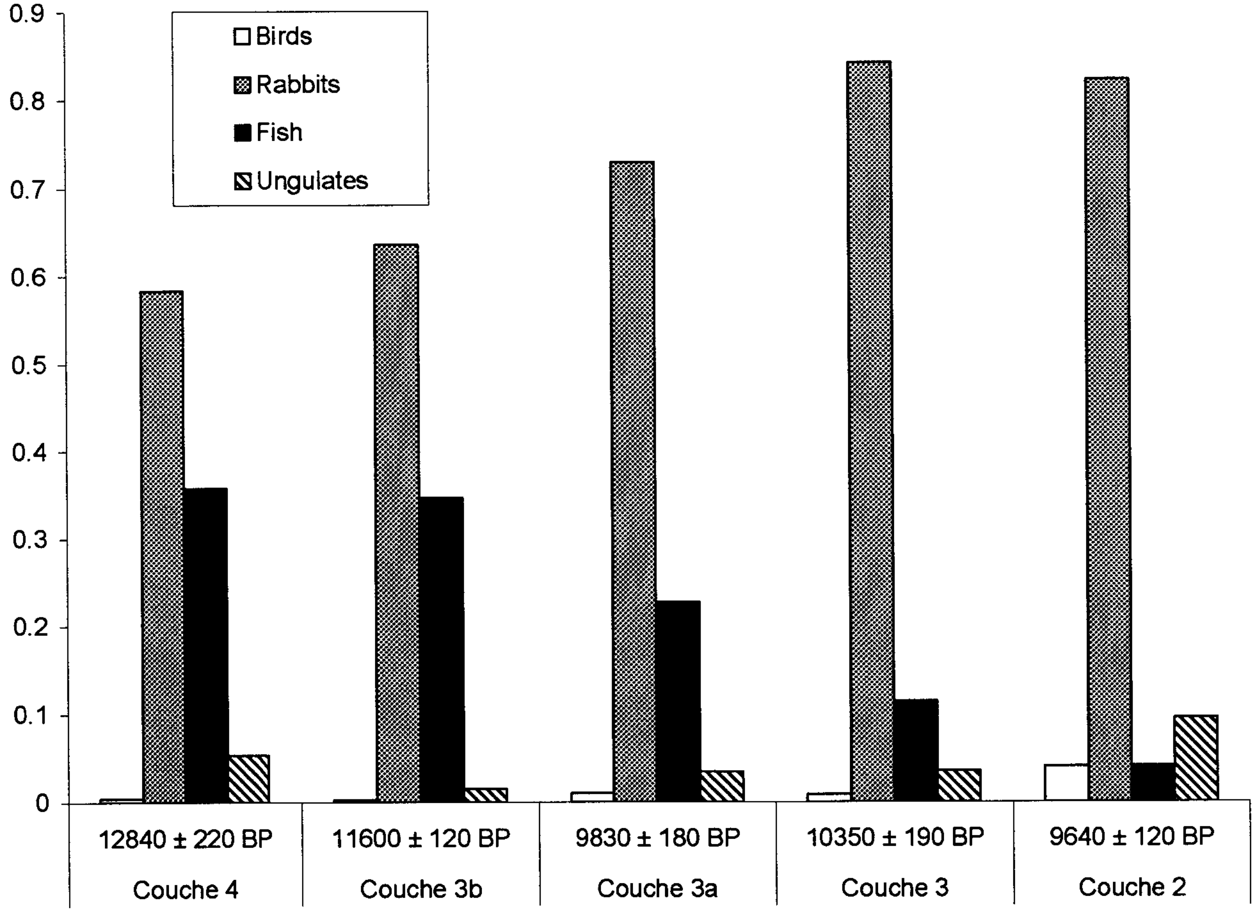

Figure 7.24. Changes in the relative abundance of different types of fauna at Pont d'Ambon.

annual temperature and precipitation, July temperatures were only slightly impacted (Guiot 1990; Guiot et al. 1989). Indeed, Guiot's reconstructed July temperatures are strongly related to *Oryctolagus* relative abundance at Pont d'Ambon (r = +0.84, p = .037; see Figure 7.25).

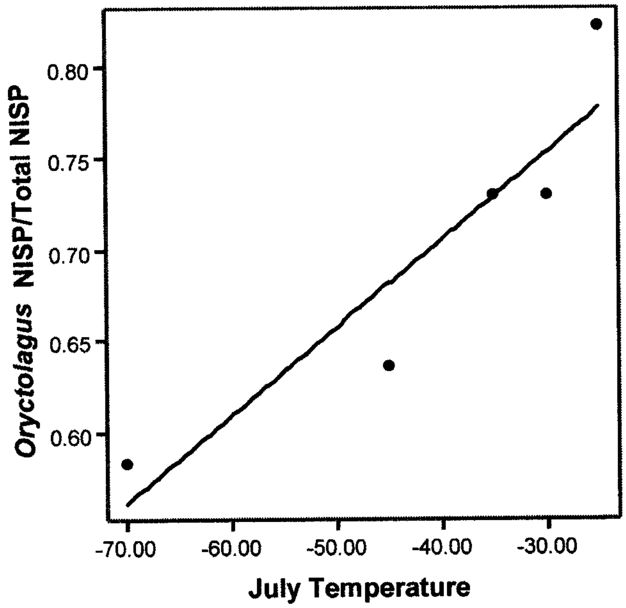

Figure 7.25. Relationship between *Oryctolagus* relative abundance and reconstructed July temperature anomalies (Guiot 1990).

Although sufficiently warm summers may have helped *Oryctolagus* to avoid extirpation during the Younger Dryas, the decrease in patchiness and increase in openness would almost certainly have caused its local availability to decline. As mentioned earlier, *Oryctolagus* abundance is typically highest in environments that contain a large amount of forest/meadow edge habitat (Lombardi et al. 2003); the patchy environments common between 13,000 and 11,000 BP would have been ideal for this species. The decreasing patchiness that accompanied the Younger Dryas would probably have caused *Oryctolagus* abundance to decline, though not dangerously so, just as other resources were becoming less available as well.

In such a situation, we might expect the prehistoric inhabitants of Pont d'Ambon to intensify their use of *Oryctolagus*; that is, to adapt their strategies so as to more efficiently use this prey resource. When broadening one's diet is not a possibility, one must make use of less desirable individuals and/or use less desirable parts of the prey item. Table 7.15 lists expectations for a situation in which intensification of *Oryctolagus* use was occurring.

One of the most widely used measures of resource intensification that is not listed in Table 7.15 involves relative skeletal abundances. A number of archaeologists have used skeletal element representation to infer resource depression and intensification, using the logic that, as resource depression occurs, body part selectivity should decrease, initially causing an increase in representation of lower-utility body parts. Likewise, as more distant patches are exploited, more field processing should occur, and fewer low-utility body parts should be present (Binford 1978; Broughton 1999; Metcalfe and Barlow 1992; O'Connell et al. 1988, 1990). Most of these hypotheses are based on ethnographic information on the hunting of large ungulates. As small prey, rabbits would have very low transport costs, and patterns of skeletal element representation would presumably be the result of a different decision-making process, and thus not an appropriate indicator of intensification in this context.

Table 7.15. Expectations for intensification of Oryctolagus *at Pont d'Ambon.*

Increased relative frequency of very young individuals
Increased processing, represented by increases in cutmarks
Increased fragmentation

The first item in Table 7.15 involves the increased use of very young rabbits. As mentioned both in Chapter 5 and earlier in this chapter, young rabbits are both smaller and provide a lower kcal return per gram than adults. Thus, an efficient forager would probably focus on full-grown individual rabbits, and avoid the less valuable juvenile ones. As times become hard, however, the diet may broaden to include those less valuable individuals. Thus, if the prehistoric inhabitants of Pont d'Ambon were intensifying their use of *Oryctolagus*, we would expect to see an increase in the relative abundance of very young individuals.

As shown in the age profiles presented earlier in this chapter (Figures 7.7 and 7.8), there is a significant increase in the relative frequency of very young rabbits through time at Pont d'Ambon. Thus the first expectation for rabbit intensification is met. However, it is important to note that it is possible that the increase in juveniles reflects an increase in warren-based harvesting; such an increase would not be surprising, as rabbits are more likely to build warrens in grassy environments. If this were the case, we would expect a corresponding increase in the representation of females. As discussed earlier in this chapter, while there was a significant increase in the representation of juveniles through time, there was no corresponding significant increase in the representation of females.

The second expectation is related to processing. Theoretically, in difficult times waste should be less tolerated than when resources are plentiful. Thus, one would expect increased processing as a corollary of intensified use of *Oryctolagus*. I made the assumption that intensified processing would likely result in an increase in cutmarks on the surface of the bones, and so considered the change in frequency of cutmarks through time. Figure 7.26 shows that cutmarks do slowly but steadily increase in frequency on the Pont d'Ambon rabbit bones through time. A χ^2 test confirms that this trend is significant ($\chi^2 = 30.705$, $p < .0001$). Thus, the second expectation for intensification of *Oryctolagus* use at Pont d'Ambon is also met.

The final expectation in Table 7.15 is for increased fragmentation of long bones. As has been discussed at length earlier in this work and elsewhere, *Oryctolagus* long bones are rich in marrow, and humans routinely snap the long bones to extract this resource (Hockett and Bicho 2000; Perez Ripoll 1993; Schmitt 1990). If the hunter-gatherers of Pont d'Ambon were forced to intensify use of *Oryctolagus*, then extraction of marrow would become particularly important. Thus one might expect rabbit cylinders, which are artifacts of processing for marrow, to increase in the case of intensified *Oryctolagus* use.

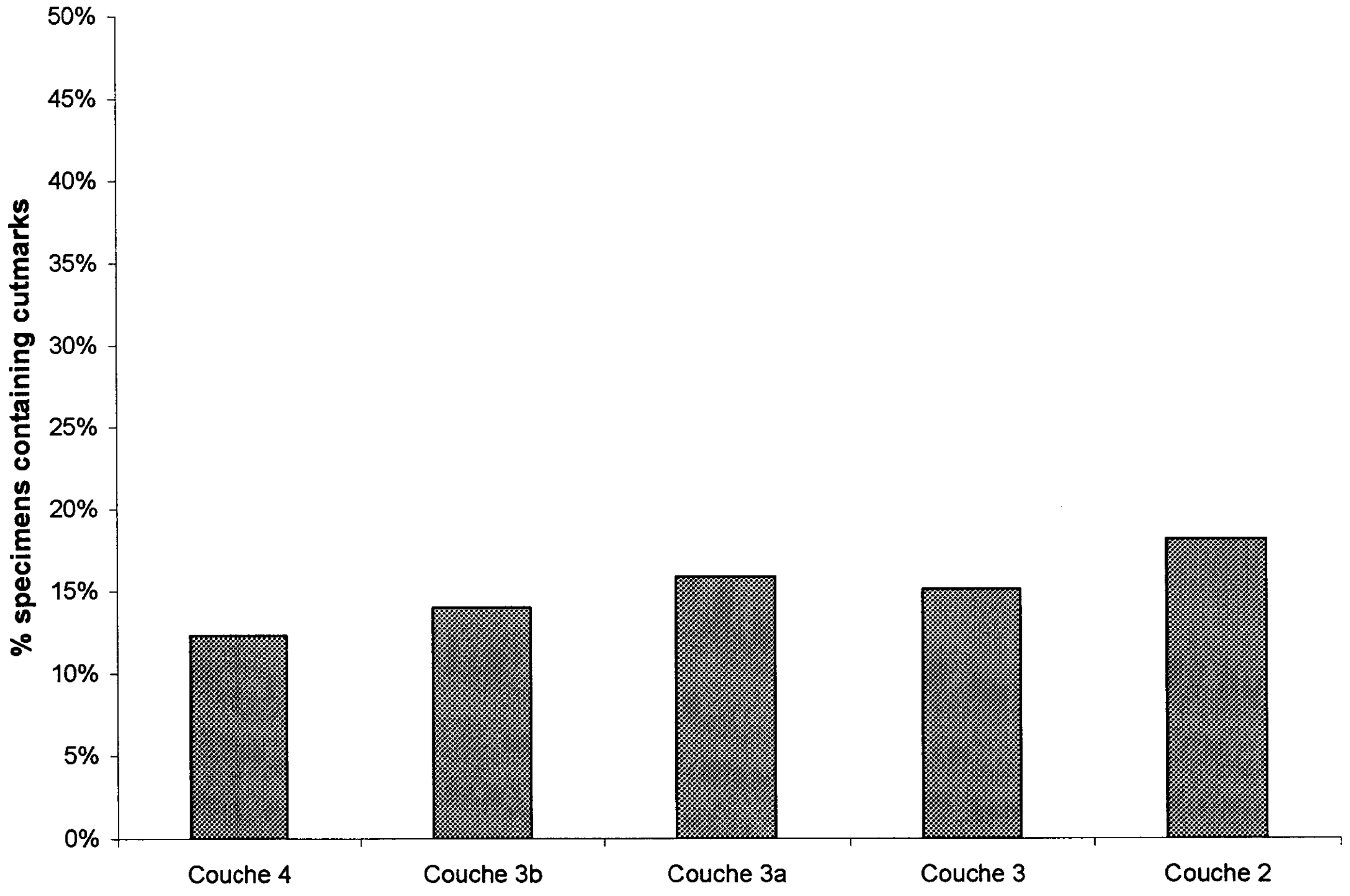

Figure 7.26. Frequency of cutmarks on *Oryctolagus* specimens in the Pont d'Ambon rabbits.

I quantified fragmentation by reconsidering the frequency of rabbit cylinders through time (Figure 7.5). The pattern derived from this measure is more complex than those produced in the other two measures of intensification. Rabbit cylinders are relatively frequent in couches 4 and 3b, drop to a low in couche 3a, and then slowly increase in frequency in couches 3 and 2. Thus the third expectation for intensification of *Oryctolagus* is not met.

Why was the fragmentation hypothesis not met? One plausible explanation is that processing for marrow is so integral to the value of *Oryctolagus* (and so low in cost) that it will usually be done, no matter what the need. The constant high rate of fragmentation supports this explanation. Given that the other two expectations laid forth in Table 7.15 were met, this suggests that some resource intensification was occurring. More data are needed to confirm this, however.

Summary of findings

The Pont d'Ambon rabbit data are an extraordinarily rich source of information about rabbit hunting and broad spectrum diets in the Périgord. A summary of the findings of this research is presented in Table 7.16. As at Moulin du Roc, the Pont d'Ambon rabbits were demonstrated to have been deposited by human activity. However, both the methods of hunting and patterns of changing exploitation through time varied considerably between the two sites.

Table 7.16. Summary of findings at Pont d'Ambon.

Rabbits were, at least in part, taken *en masse* at Pont d'Ambon
Changes in Pont d'Ambon patch choice are correlated to climate and landscape change; in particular, changes in patch choice evenness are closely related to the onset of the Younger Dryas cold period.
The prehistoric inhabitants of Pont d'Ambon may have intensified their use of rabbits in response to a narrowing of diet choices associated with the Younger Dryas
Overall, the data suggest that the broad-spectrum diet present at Pont d'Ambon is a response to a resource-restricted Magdalenian; decreased evenness of patch choice and intensification of rabbit use in the upper layers of the site may reflect the onset of the Younger Dryas

At Pont d'Ambon, at least some of the rabbits in the sample were gathered *en masse*, whereas at Moulin du Roc the rabbits were taken singly. Most likely, the Pont d'Ambon rabbits represent a palimpsest of hunting techniques, but the sex profiles indicate that warren-based harvest was the dominant method throughout the sequence.

Also in contrast to the situation at Moulin du Roc, at Pont d'Ambon rabbit use increased as the landscape became less patchy. These data support the hypothesis that the decrease in patchiness at Pont d'Ambon correlates with the onset of the Younger Dryas cold period, and that this cold period corresponded with a decrease in available resources. This may explain why rabbit use increased (rather than decreased) during this period. Intensified use of rabbits may be one symptom of this cold episode.

Despite the differences in the details of how and when rabbits were used, however, as at Moulin du Roc the Pont d'Ambon data support the hypotheses that the Magdalenian was not a resource-rich period, and that the broadening of diet observed at the Pleistocene-Holocene transition in this region reflects the increasing availability of additional resources. Neither the impacts of climate change on large mammals nor human-induced resource depression are supported as explanations for this phenomenon.

Chapter 8

Conclusions: patchiness and prey use in the Périgord

The research presented here examined both the nature and meaning of the addition of *Oryctolagus cuniculus* to the diets of the prehistoric residents at two sites in the Périgord. A summary of major findings is presented in Table 8.1. The data from both sites, despite profound differences in the ways in which their residents used *Oryctolagus cuniculus,* support the hypothesis of a resource-poor Magdalenian. This suggests new research directions that may lead to a new understanding of dietary choices in the Périgord at the Pleistocene-Holocene transition.

Table 8.1. Major conclusions of this research.

Rabbits were, at least in part, taken *en masse* at Pont d'Ambon; this indicates that at least some *en masse* harvest of *Oryctolagus* was occurring in the Epipaleolithic
Changes in diet breadth and rabbit use at both Moulin du Roc and Pont d'Ambon are closely related to climate and landscape change; in particular, changes in patch choice evenness are correlated with the onset of the Younger Dryas cold period.
The prehistoric inhabitants of Pont d'Ambon may have intensified their use of rabbits in response to a narrowing of diet choices associated with the Younger Dryas
The rabbit data at both Moulin du Roc and Pont d'Ambon, as well as the settlement analysis presented in chapter 2, support the hypothesis that the Magdalenian was resource-poor.

Although *Oryctolagus cuniculus* remains dominate the zooarchaeological fauna at both sites, the ways in which the prehistoric inhabitants of Moulin du Roc and Pont d'Ambon made use of this resource are strikingly different. At Moulin du Roc, rabbits were taken individually as soon as they were available. At Pont d'Ambon, they were part of a more generalized subsistence strategy, and were increasingly used through time. As shown in Chapters 6 and 7, these differences in rabbit use are related to differences in the surrounding environments and in the time periods represented at these two sites, and possibly also to differences in seasonality and site function.

A patchy Magdalenian?

Given that data from two such different sites support the same explanation for the addition of *Oryctolagus* to the diet, I now examine whether these conclusions can be generalized to the rest of the Dordogne region. As discussed earlier, Moulin du Roc and Pont d'Ambon are only two of a suite of rabbit-rich sites in the Périgord; La Faurélie II, La Gare de Couze, and Le Morin are some of the more well-known Pleistocene-Holocene transition sites that contain *Oryctolagus* (a map can be seen in Figure 8.1). Though a thorough comparison of these sites with Moulin du Roc and Pont d'Ambon is outside the main scope of the present work, the zooarchaeological assemblages at all these sites have been analyzed (Cochard 2004; Delpech 1983; Gilbert 1984; Gourichon 1994), allowing a rough comparison to the Pont d'Ambon and Moulin du Roc faunas.

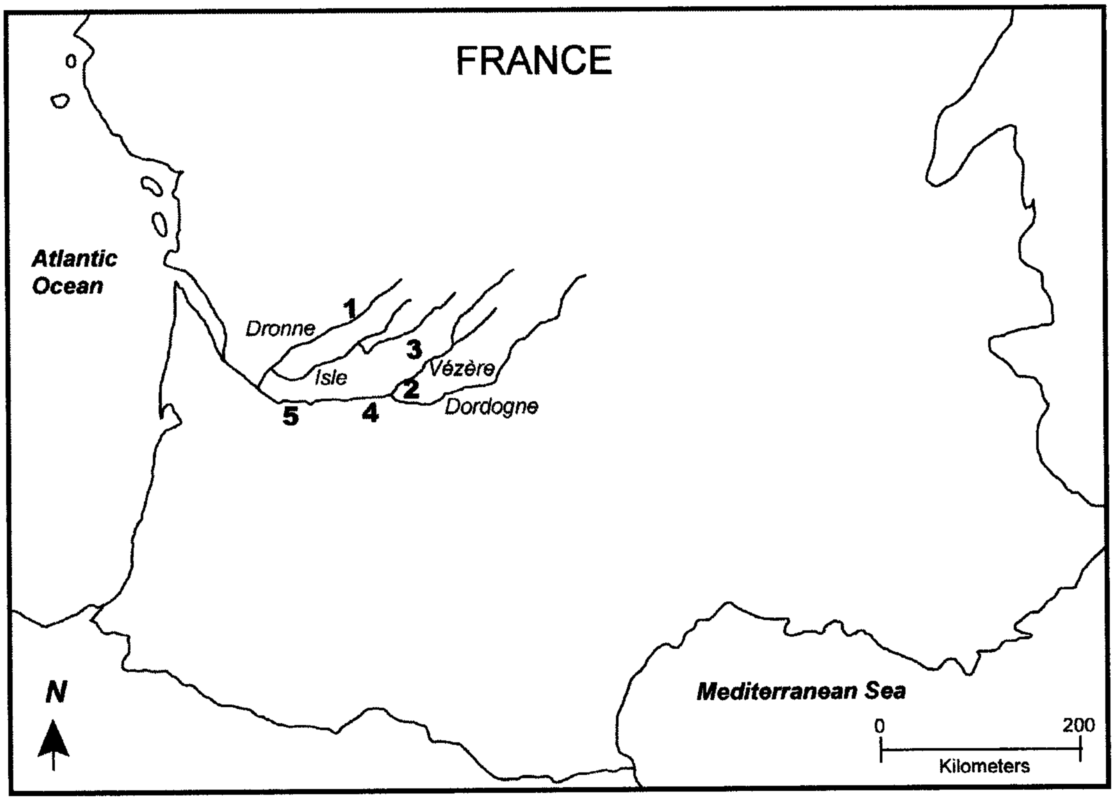

Figure 8.1. Location of sites discussed in this chapter: 1) Pont d'Ambon; 2) Moulin du Roc; 3) La Faurélie II; 4) La Gare de Couze; and 5) Le Morin.

Table 8.2 shows a rough chronological order of the available data from these sites. More radiocarbon dates are necessary to ensure the accuracy of this sequence, but these data are sufficient for establishing a rough assessment of how change in *Oryctolagus* frequency at these sites relates to the data presented in this work.

Table 8.2. Chronological order of site layers discussed in this chapter (Cochard 2004; Delpech 1983; Gilbert 1984).

Layer	**Cultural affiliation**	**C-14 dates**	**%*Oryctolagus***
La Faurélie II 2	Azilian		89.26
La Faurélie II 3	Azilian		70.74
Le Morin A	Final Magdalenian		14.63
La Gare de Couze B	Final Magdalenian	10,900 ± 230 BP	8.62
La Gare de Couze C	Final Magdalenian	11,750 ± 310 BP	9.13
La Gare de Couze D	Final Magdalenian		14.68
La Gare de Couze E	Final Magdalenian		13.73
La Gare de Couze F	Final Magdalenian		14.54
La Gare de Couze G	Final Magdalenian		15.73
La Gare de Couze G0	Final Magdalenian		4.36
La Gare de Couze G1	Final Magdalenian		0.61
Le Morin B	Magdalenian		1.05
La Gare de Couze H	Magdalenian	12,430 ± 320 BP	0.31

Table 8.2 also shows my calculation of the percent of *Oryctolagus* in each of these layers; this frequency is represented graphically in Figure 8.2. In general, *Oryctolagus* comprises a much smaller portion of the total recovered faunal specimens than at Pont d'Ambon and Moulin du Roc. The exception is the two layers from the site of La Faurélie II, one of the later sites in the sample. Perhaps significantly, this is also the only site in the sample that, like Pont d'Ambon and Moulin du Roc, has undergone a lagomorph-specific analysis (Cochard 2004).

There are at least two plausible explanations for the lower frequency of *Oryctolagus* in these sites. First, the difference in frequencies may reflect resource patchiness. One of the conclusions of both the Moulin du Roc and Pont d'Ambon analyses was that local resource patchiness directly affected the composition of diets at the different sites. Differences in local environments (or, perhaps, seasonality) at these sites might cause the lower frequencies of *Oryctolagus*; alternatively, the Magdalenian at Le Morin and La Gare de Couze (both of which are located in the western end of the Dordogne Valley) may have been much richer in available resources than it was at La Faurélie II, Moulin du Roc, or Pont d'Ambon (all of which are located farther to the east and/or north).

However, it is also possible that the lower frequency of *Oryctolagus* at Le Morin and La Gare de Couze reflects a difference in analysis. Until a lagomorph-specific study is conducted on these sites, we cannot know which of these explanations is most plausible.

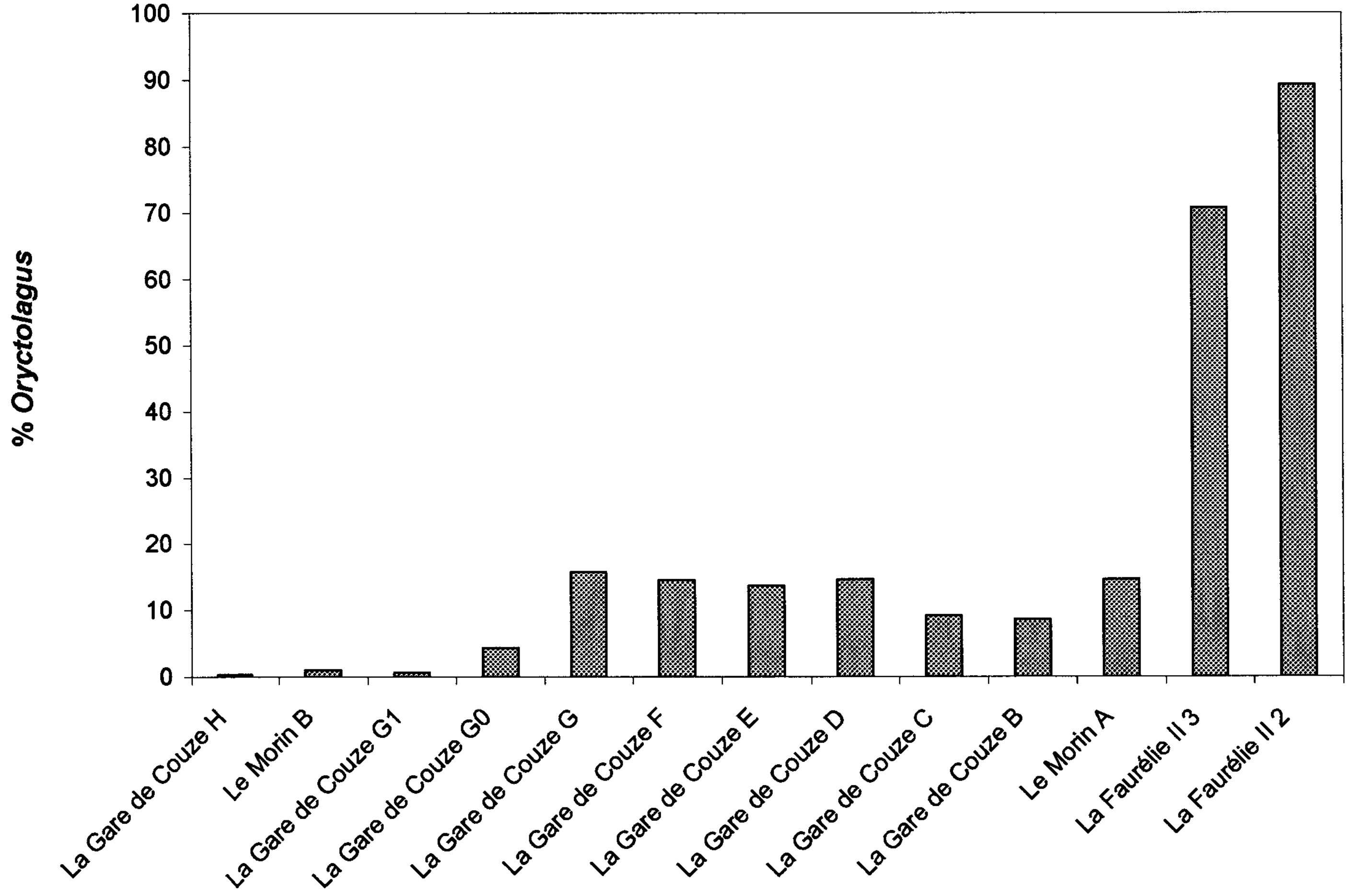

Figure 8.2. Change in the relative frequency of rabbits in Dordogne sites through time.

Conclusions

In the research presented here, I set forth to explain, at least in part, the development of broad-spectrum diets in the Périgord region in several ways. Although there is much work still to be done, this study has contributed to our understanding of dietary change at the Pleistocene-Holocene transition in southwestern France in several ways. First, I developed and presented a method for identifying *en masse* harvest of the European rabbit. I then demonstrated that there was variability in rabbit-hunting techniques during the Epipaleolithic. At least some of the rabbit specimens analyzed here were captured *en masse*, which means their overall energetic return rate is higher than might be expected based on individual size. Since we now know that there was variability during this time period, demographic analyses are critical in value-based analyses of *Oryctolagus* assemblages.

In addition, I demonstrated that the increase in use of the European rabbit seen in the Périgord at the Pleistocene-Holocene transition was a function of their increased abundance on the landscape. Although further work needs to be done to confirm this across the region, at both Moulin du Roc and Pont d'Ambon the addition of *Oryctolagus* to the diet seems to have been a response to increasing resource availability, rather than a decrease in high-ranked resources. All the analyses presented in this work support the idea that the Magdalenian period in the Périgord, far from being a "golden age," seems to have been a period where diets were restricted because only a few resource types were available.

Finally, this research makes it clear that the effects of climate change on Périgordian diets are more complex than has previously been suggested. Analyses of the fauna at Moulin du Roc and at Pont d'Ambon strongly support the hypothesis that changing climate had significant impacts on the prehistoric inhabitants of the Dordogne region. However, the traditional climate hypothesis—that changing climate negatively impacted the availability of larger fauna, thus forcing a switch to smaller, lower-ranked prey items—is not supported by this work.

The conclusions drawn from this work add to our knowledge of how one resource, *Oryctolagus cuniculus,* was used by the prehistoric inhabitants of the Périgord. Perhaps more importantly, they suggest a new understanding of the development of broad spectrum diets in the Périgord at the Pleistocene-Holocene transition. More research is needed to determine the extent to which we can generalize from the situations at Pont d'Ambon and Moulin du Roc; however, the results presented here suggest new directions for research on the broad spectrum revolution in the Dordogne region.

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Vita

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