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Short Paper

Climate change, patch choice, and intensification at Pont d'Ambon (Dordogne, France) during the Younger Dryas

Emily Lena Jones *

Department of Sociology, Social Work, and Anthropology, Utah State University, Logan, UT 84322-0730, USA

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ABSTRACT

This paper considers the impact of the Younger Dryas on the prehistoric inhabitants of Pont d'Ambon, a site in the Dordogne region of southwestern France, through an examination of the zooarchaeological remains from this site. An investigation of patch choice indicates that patch choice evenness declines during the Younger Dryas due to increasing local dominance of the grassland patch. Analyses of demographic composition, cutmark frequency, and marrow processing in the wild European rabbit (*Oryctolagus cuniculus*) assemblage suggest intensified rabbit use during this period. This study thus supports the hypothesis that changing climate had significant impacts on the prehistoric inhabitants of Pont d'Ambon. However, the traditional climate hypothesis—that changing climate negatively impacted the availability of larger fauna, forcing a switch to smaller, lower-ranked prey items—is not supported here. The inhabitants of Pont d'Ambon seem to have adapted to changing climate by efficiently exploiting the new species available to them, and possibly, during the Younger Dryas, by intensifying their use of one of these new species, the European rabbit.

Introduction

Research on the relationship between the Younger Dryas climate change and contemporary human populations across the globe has flourished in recent years, with investigations on everything from megafaunal extinctions in the Americas (Firestone et al., 2007; Newby et al., 2005) to landscape use in northern Africa (Bouzouggar et al., 2008) to the development of maritime activity in the Mediterranean (Broodbank, 2006). In the Dordogne region of southwestern France (Fig. 1), where the Younger Dryas is known to have triggered a return to glacial conditions (Magny, 1997), analyses of the impact of the Younger Dryas on human populations are relatively rare. Instead, archaeologists have traditionally focused on the impacts of the longer-term warming that occurred at the end of the Pleistocene, commonly portrayed as a traumatic event for prehistoric peoples. During this time period in the Dordogne, diets dependent on large ungulates, principally reindeer (*Rangifer tarandus*), were replaced by those dependent on smaller species, and in particular on the wild European rabbit (*Oryctolagus cuniculus*) (Jones, 2006). Both previously published faunal data (Cochard, 2004; Delpech, 1992, 1999; Straus, 1999) and site location analyses (Demars, 2000, 2002; Jones, 2007) suggest that diets broadened to include a greater variety of species in the Dordogne during the Pleistocene-Holocene transition; the broadening began with the Allerød and continued through the Azilian (~9000 ^{14}C yr BP) and early Holocene.

As this change in diet coincides with a major warming period, the assumption that it has something to do with climate change seems logical. What increasing diet breadth means in terms of subsistence stress, however, is hotly debated (Broughton, 1999; Hockett and Haws, 2003; Stiner and Munro, 2002). In the Dordogne case, some researchers have concluded that climate change negatively impacted large mammal populations, thus forcing people to begin incorporating smaller and/or swifter species into their diets (e.g., Straus, 1996). If a straightforward causal relationship between climate and decreasing availability of large game is driving the increase in small prey in human diets in the late Pleistocene Dordogne, however, we would expect a return to the large game-dominated diets characteristic of the last glacial maximum with the return of glacial conditions precipitated by the Younger Dryas.

Unfortunately, fine-grained analyses of the impacts of the Younger Dryas on the archaeological populations of the Dordogne are rare. In this paper, I use data from the zooarchaeological assemblage at Pont d'Ambon, a site in the Dordogne region with deposits that span the Pleistocene-Holocene transition, to examine how climate change impacted human hunting choices at this site during the Younger Dryas and beyond.

Pont d'Ambon

Pont d'Ambon, a small rockshelter, is located on the banks of the Dronne River, in the northwest part of the Dordogne (Fig. 1). This site, excavated during the 1970s and 1980s by Guy Célérier, was used extensively by Magdalenian and Azilian people and has been relatively undisturbed by non-anthropogenic processes (e.g., Célérier

* Fax: +1 435 797 3943.
E-mail address: Emily.Jones@usu.edu.

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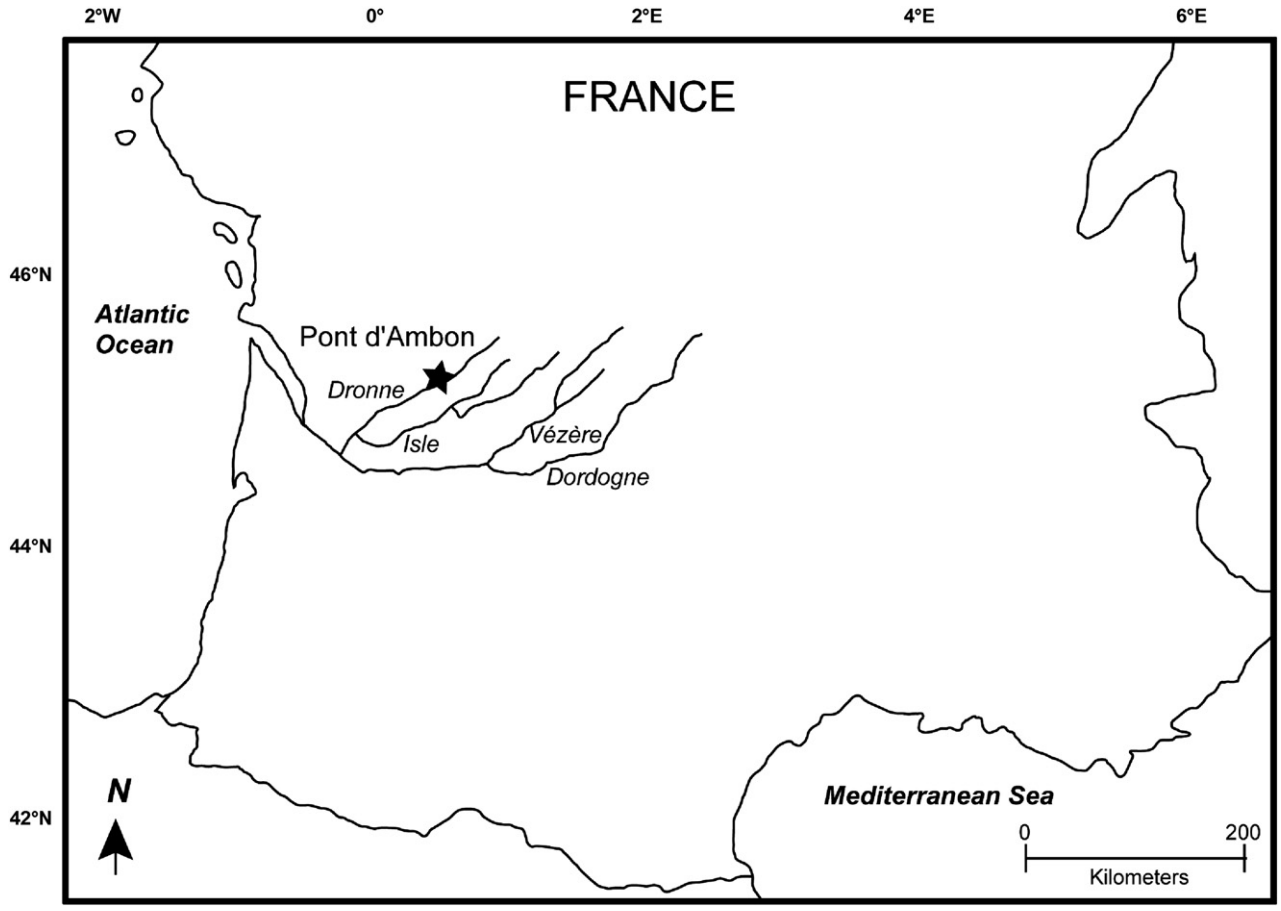

Figure 1. Location of Pont d'Ambon (Latitude 45°19.12′N, longitude 0°36′E) within the Dordogne River Valley.

and Kervazo, 1994). The deposits (extensively dated by Célérier; see Célérier, 1998) date between 13,000 and 9500 ^{14}C yr BP, including the Younger Dryas (Table 1).

The fauna of Pont d'Ambon is of particular interest to those interested in the Pleistocene–Holocene transition in the Dordogne because it is extraordinarily rich in smaller prey species (Delpech, 1983; LeGall, 1993). Despite the fact that the site has been securely dated to the interval between 13,000 and 9500 ^{14}C yr BP, the fauna contains no reindeer (Table 2; Célérier, 1994; Delpech, 1983). Larger prey species in the Pont d'Ambon fauna include red deer (*Cervus elaphus*), aurochs (*Bos primigenius*), and horse (*Equus caballus*). However, the mammalian fauna at Pont d'Ambon are consistently dominated by lagomorphs, rather than large game. European rabbit (*Oryctolagus cuniculus)* remains comprise approximately 90% of the mammalian fauna throughout the Pont d'Ambon sequence (Fig. 2). There is a significant presence of other small prey types at Pont d'Ambon as well, including both fish and birds (Table 2).

Previous seasonality studies suggest year-round occupation of the site (LeGall and Pannoux, 1994; Pike-Tay, 1991). The *Oryctolagus* assemblage at Pont d'Ambon has undergone a detailed demographic analysis (Jones, 2006), which has provided information about both seasonality and hunting technique. The demographic data indicate that throughout the sequence, rabbits of a variety of ages were being taken (Jones, 2004a), providing further support for the hypothesis that Pont d'Ambon was occupied throughout the year.

In addition, the demographic data suggest that at least some warren-based harvest, a mass collecting technique that would boost the energetic return of rabbits, was ongoing at Pont d'Ambon (Jones, 2006). In warren-based harvesting, the hunter focuses his attention on rabbit warrens, large, complex burrows used by this species for reproduction and protection from aerial predators. Because the warrens are easily visible, rabbits can be trapped in and taken directly from them, *en masse*, thus raising the rate of energetic return for this prey species. As warrens contain primarily adult female and juvenile rabbits, this technique can be identified through demographic analyses. Though the Pont d'Ambon rabbits most likely represent a palimpsest of hunting techniques, the sex profiles indicate that warren-based harvest was probably the dominant method throughout the sequence (Jones, 2006).

Table 1
Culture history and ^{14}C dates from Pont d'Ambon (Célérier et al., 1994).

Stratigraphic layer	Industry represented	^{14}C yr 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

Patch choice at Pont d'Ambon

Environmental reconstruction for southwestern France suggests that local environments during the Pleistocene–Holocene transition would have been characterized by extreme patchiness (Huntley, 1990). The patch choice model of optimal foraging theory (Nagaoka, 2002) as well as more general patch-based analyses (i.e., Delpech, 1999) are often employed by zooarchaeologists in such situations. Patch-based analyses are difficult to operationalize in archaeological contexts due to the difficulty of fully reconstructing past patches (Lupo, 2007; Ritchie, 1998). As prehistoric patches have to be inferred from zooarchaeological remains, in most situations only very general patch types, such as “marine” and “forest” can be inferred. Despite the

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Table 2
The Pont d'Ambon fauna (after Delpech, 1983; LeGall and Pannoux, 1994).

Species	Couche 4	Couche 3b	Couche 3a	Couche 3	Couche 2
Mammals					
Cervus elaphus	90	59	147	137	66
Capreolus capreolus	14	13	27	37	7
Bos primigenius	5	5	5	33	116
Sus scrofa	3	10	31	38	7
Rupicapra rupicapra	0	0	0	0	1
Equus caballus	2	6	14	54	90
Oryctolagus cuniculus	1233	3832	4827	7148	2473
Castor fiber	12	12	46	26	12
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
Esocidae	85	209	240	259	55
Anguillidae	641	1848	1233	696	53

coarse-grained nature of such analyses, however, they have provided insights about prehistoric environments and human foraging (for example, see Cannon and Meltzer, 2008).

I separated the Pont d'Ambon fauna into three main patches, based on the habitat preferences of the prey in the assemblage: river (represented by fish), grassy (represented by rabbits, horse, and bison) and forested (represented by red deer, wild boar, and roe deer). Placing rabbits in this scheme was difficult, as rabbits tend to prefer "edgy" grassland-scrub environments; increased grassland to forest edge, however, can result in an increase in large warren building (Corbet, 1994; Lombardi et al., 2003; Marchandeau et al., 2000; Rogers et al., 1994). Given the predominance of warren-based hunting at this site, I consider rabbits as a grassland indicator.

Change in patch use through time can be seen in Figure 3. 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. All three patches are in use, but the focus is on the two local patches rather than the presumably more distant one. These data also show 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 clear when we turn to 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 measured evenness using 1/D, the inverse of Simpson's Dominance index (Jones, 2004b; Magurran, 1988). Evenness declines steadily through time ($\chi^2 = 1946.74$, $p < 0.0001$), as patch choice is increasingly focused on the grassland patch. 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. There was no significant relationship ($r = -0.22$, $p = 0.683$). The steady decline in evenness is not due to changing sample size.

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 (Table 1). This suggests that climate change, and its corresponding impact on the surrounding landscape, may be the related to change in patch choice at Pont d'Ambon. I used pollen-based reconstructions of temperature and precipitation (Guiot, 1990) to approximate regional climate changes. While there was no significant relationship between changing patch evenness at Pont d'Ambon and changes in January/July temperatures (January: $r = +0.64$, $p = 0.12$; July: $r = -0.85$, $p = 0.06$) or January/July precipitation (January: $r = -0.25$, $p = 0.34$; July: $r = +0.23$, $p = 0.35$), there

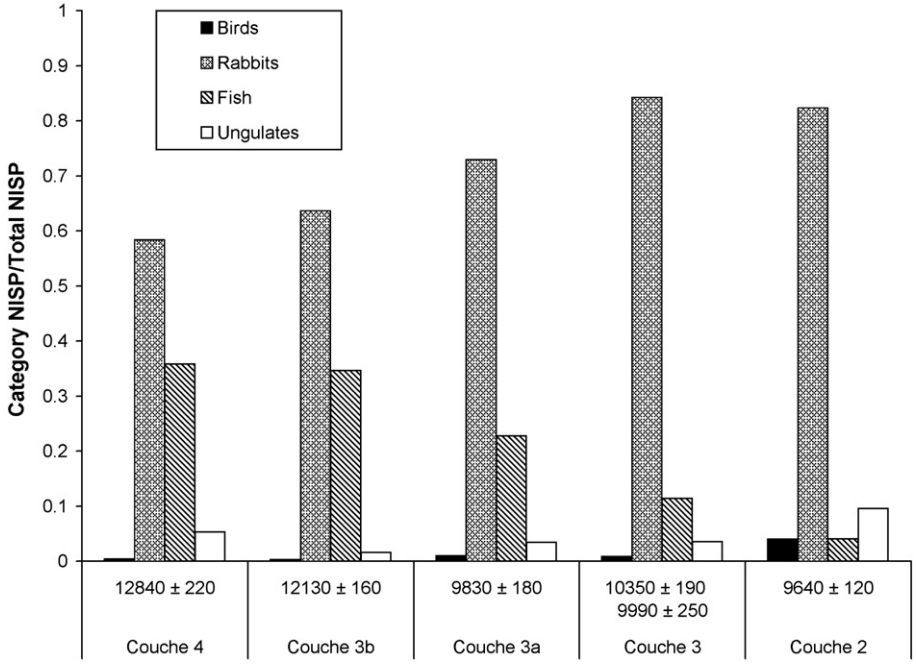

Figure 2. Changes in the relative abundance of birds (white bars), rabbits (black bars), fish (gray bars) and ungulates (hatched bars) at Pont d'Ambon through time. All dates are ^{14}C yr BP.

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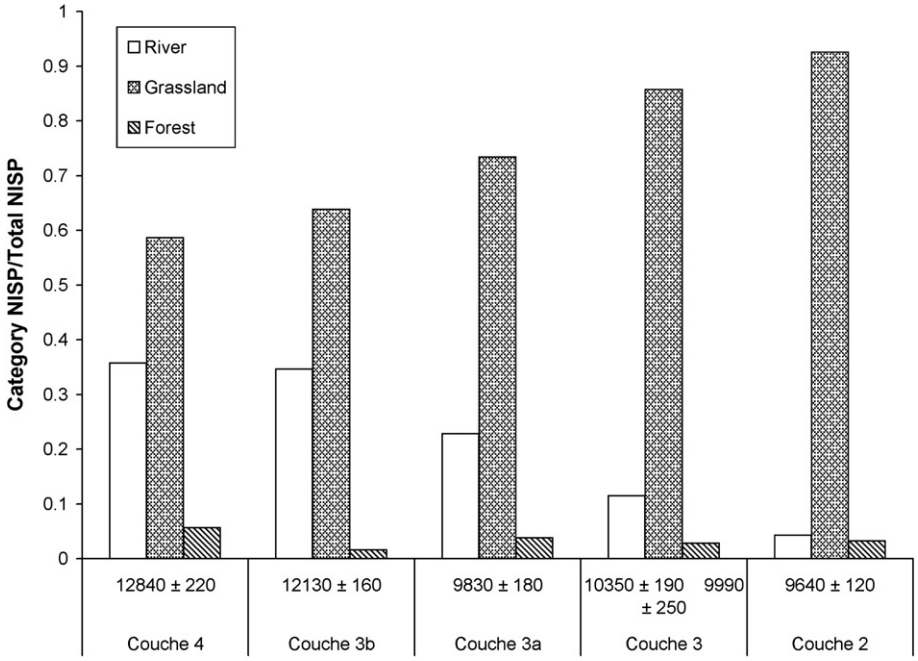

Figure 3. Changes in the relative abundance of the river (white bars), grassland (gray bars), and forest (hatched bars) patches as represented in the Pont d'Ambon fauna through time. All dates are ^{14}C yr BP.

was a significant relationship between changing patch evenness and both average annual precipitation ($r = +0.79$, $p = 0.05$) and average annual temperature ($r = +0.80$, $p = 0.05$). Patch evenness decreases with both decreased temperatures and decreased precipitation.

These data suggest that the dietary shifts were caused by climate-driven changes in local environments. The Younger Dryas had significant impacts on landscape and vegetation (Fauquette et al., 1999; Magny, 1997). French pollen data suggest this cold period corresponds with an increase in tundra-like conditions, and a decrease in the forested patches that had begun to spread across the region during the prior warming period (Huntley, 1988, 1990). The increase in representation of the grassland patch at Pont d'Ambon may relate to an increase in the local availability of this patch, although the continued presence of forest/grassland species (as well as the lack of reindeer) suggests that the environments of the Younger Dryas did not replicate those of the Last Glacial Maximum.

The environmental effects of the Younger Dryas event, then, may have caused patch choice evenness to narrow due to increasing local dominance of the grassland patch. The patchy, non-analogous environments that characterized southwestern France during the Allerød disappeared as a colder climate returned to the Dordogne; these cold conditions may have had a corresponding negative effect on river patch as well (LeGall, 1993).

Resource intensification?

Although the Younger Dryas did bring 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 did not revert to the large-game dominant zooarchaeological assemblage typical of the Dordogne Magdalenian (Table 2; Jones, 2006). Reindeer did not recolonize the area in the Younger Dryas; red deer decreased in relative abundance, while horse and bovids increased. In addition, while fish did decrease in relative abundance with the Younger Dryas, rabbits (and, to a lesser extent, birds) increased (Fig. 2). A Cochran's test of linear trend confirms that this increase is statistically significant ($\chi^2_t = 347.930$, $p < 0.0001$).

These changes suggest several conclusions. First, the Younger Dryas does not seem to have caused extirpation of the European rabbit in the Pont d'Ambon area, despite the fact that previous cold intervals are known to have extirpated *Oryctolagus* colonists in southern France (Donard, 1982; el Guennouni, 2001; Rogers et al., 1994). It is of course possible that the Pont d'Ambon sample has missed a relatively brief extirpation event; however, the continuous record of *Oryctolagus* in other Dordogne sites throughout this time span makes this improbable (Cochard, 2004). A comparison with Guiot's (1990) climate reconstruction may explain why the European rabbit seems to persist through this cold period. While the Younger Dryas resulted in severe decreases in annual temperature and precipitation, July temperatures seem to have been only slightly impacted (Guiot, 1990; Guiot et al., 1989). Indeed, Guiot's reconstructed July temperatures are strongly related to rabbit relative abundance at Pont d'Ambon ($r = +0.84$, $p = 0.037$).

Although sufficiently warm summers may have helped the European rabbit to avoid extirpation during the Younger Dryas, the decrease in patchiness and increase in openness would likely have caused its local availability to decline. European rabbit abundance is typically highest in environments that contain a large amount of forest/meadow edge habitat (Lombardi et al., 2003); the patchy environments common during the Allerød would have been ideal for this species. The decreasing patchiness that accompanied the Younger Dryas would most likely have caused rabbit abundance to decline, 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 the European rabbit. When broadening one's diet is not a possibility, one potential response is to make use of less desirable individuals and/or use less desirable parts of the prey item. In particular, we might see the following archaeological signals: increased relative frequency of very young individuals; increased processing, represented by increases in cutmarks; and increased use of marrow, represented by "rabbit cylinders."

Young rabbits are both smaller and provide a lower kcal return per gram than adults (Jones, 2006). Thus, the logic of optimal foraging theory suggests that an efficient forager would focus on full-grown individual rabbits, and avoid the juvenile ones (e.g., Broughton, 1994; Burger et al., 2005). As times become hard, however, the diet may broaden to include the younger individuals. If the prehistoric inhabitants of Pont d'Ambon were intensifying their use of the

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European rabbit, a foraging theorist might expect to see an increase in the relative abundance of very young individuals.

Demographic information about the Pont d'Ambon rabbits suggests that there was a significant increase in the number of juvenile rabbits through time at this site (Jones, 2006). Figure 4 provides one example of this process, the abundance of unfused distal humeri relative to all humeri. In the European rabbit, the distal humerus fuses at around 2 months of age; rabbits leave their nests in the rabbit warren at about 1 month, but are still significantly smaller than adult rabbits. The increase in juveniles suggested by Figure 4 is statistically significant ($\chi^2_t = 19.631$, $p < 0.0001$).

There are, of course, other possible explanations for the increase in juveniles through time. Changing season of occupation can influence demographic patterns; as discussed earlier in this paper, seasonality studies of the ungulates (Pike-Tay, 1991), fish (LeGall and Pannoux, 1994) and the rabbits themselves (Jones, 2004a) suggest year-round occupation throughout the late Pleistocene and early Holocene levels. However, a slight shift in season of occupation, undetectable at the gross level of seasonality studies, could be a contributing factor to the increasing number of juveniles. An increase in warren-based harvesting through time could also cause this pattern. Then again, from a foraging theory perspective, any change in exploitation that resulted in more juveniles could be seen as an indicator of intensification.

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 rabbit use. Intensified processing has been shown to often result in an increase in cut marks on the surface of the bones (Lyman, 2008). I thus considered the change in frequency of cut marks on the Pont d'Ambon rabbits through the sequence. Cuts do slowly but steadily and significantly increase in frequency on the Pont d'Ambon rabbit bones through time ($\chi^2 = 30.705$, $p < 0.0001$; Fig. 4), supporting the hypothesis that the inhabitants of Pont d'Ambon intensified their use of rabbits.

The final expectation is for increased fragmentation of long bones. The long bones of the European rabbit are rich in marrow, and humans routinely snap the long bones to extract this resource, creating a high proportion of long bone shafts, often referred to as "rabbit cylinders," in assemblages (Hockett and Bicho, 2000; Perez Ripoll, 1993; Schmitt, 1990). If the hunter-gatherers of Pont d'Ambon intensified their use of *Oryctolagus* in response to the Younger Dryas, then presumably extraction of marrow would become particularly important. Thus one would expect "rabbit cylinders," as artifacts of marrow processing, to increase in the case of intensified use of the European rabbit.

The pattern derived from this measure is more complex than those produced in the other two measures of intensification (Fig. 4). "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. There is no significant trend in the relative frequency of "rabbit cylinders" through time at Pont d'Ambon. One plausible explanation is that processing for marrow is so integral to the value of the European rabbit (and so low in cost) that it will usually be done, no matter what the need. The constant high rate of fragmentation of rabbit bones both at Pont d'Ambon (Jones, 2004a) and at other late Pleistocene and early Holocene sites in southwestern Europe (Cochard, 2004; Hockett and Bicho, 2000; Perez Ripoll, 1993) supports this explanation.

The increasing numbers of juveniles in the assemblage and the increasing frequency of cut marks on the Pont d'Ambon rabbits suggest some intensification. The frequency of "rabbit cylinders" does not conform to expectations for intensification, but this may reflect the nature of this prey type rather than indicating that intensification was not occurring.

Conclusions

These data support the hypothesis that at Pont d'Ambon a decrease in patchiness correlates with the onset of the Younger Dryas. Although the conventional wisdom, as applied to the Pleistocene–Holocene transition in the Dordogne, has been that cold periods caused an increase in larger mammals, the Pont d'Ambon fauna does not suggest a return to diets dominated by large game during the Younger Dryas.

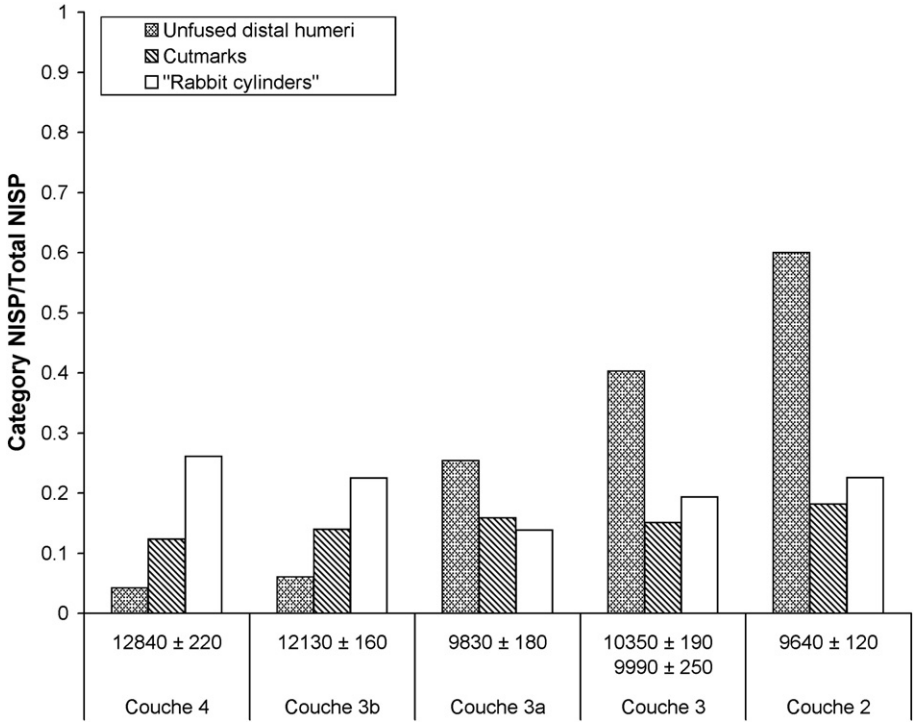

Figure 4. Changing frequency of juvenile rabbits (gray bars), cutmarks (hatched bars), and "rabbit cylinders," (white bars) in the Pont d'Ambon rabbits through time. All dates are ^{14}C yr BP.

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Rather, the Pont d'Ambon data provide some indicators of resource intensification and stress during this cold period.

Analysis of the fauna at Pont d'Ambon thus supports the hypothesis that changing climate had significant impacts on at least some prehistoric inhabitants of the Dordogne region. The traditional climate hypothesis—that changing climate negatively impacted the availability of larger fauna, forcing a switch to smaller, lower-ranked prey items—is not supported here. The inhabitants of Pont d'Ambon seem to have adapted to changing climate by efficiently exploiting the new species available to them, and possibly, during the Younger Dryas, by intensifying their use of one of these new species, the European rabbit.

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