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The four seasons of reindeer: Non-migrating reindeer in the Dordogne region (France) between 30 and 18 k? Data from the Middle and Upper Magdalenian at La Madeleine and methods of seasonality determination

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ABSTRACT

This paper presents a study of the reindeer hunting seasons represented in Magdalenian occupations (levels 25 & 27) at the site of La Madeleine where this game comprises between 87 and 95% of the identified remains. The method of reindeer hunting season estimations based on the analysis of archaeological antlers, cheek teeth and fetal long-bone diaphyses underlines that the combined use of antlers, teeth, and fetal bones is indispensable for determining all four seasons. It also shows that summer and winter hunts are the most difficult to identify and may go unnoticed in small or poorly preserved samples, and those without fetal long-bone diaphyses (for winter). The hunting seasons identified, deducted from the minimum number of identified moments, are similar for levels 25 (Upper Magdalenian) and 27 (Middle Magdalenian), providing evidence of reindeer hunting throughout the year, during all four seasons. These results confirm those of four other sites, all of which are located in the same area at distances between 2 and 60 km from La Madeleine, while they strongly contrast those of every other currently well documented region (Paris Basin, Massif Central, Aude Basin). This suggests that if these data reflect the reality of non-migrating reindeer, rather than a high instability of seasonal ranges, at least between 30,000 and 15,000 cal BP, this phenomenon is related to a specific area, temporarily bordered by the Dronne and the Vézère valleys. The author discusses the assumption that this zone (still to be delineated), with an Atlantic climate in the Mammoth Steppe biome, at least during the Upper Pleniglacial and Oldest Dryas, was a zone of varied landscapes where the living conditions of reindeer would have limited their mobility, perhaps up to the close foothills of the Massif Central.

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1. Introduction

The economy of human populations in France between 26,000 and 14,700 cal BP, during the Upper Pleniglacial and the first part of the Late Glacial (Oldest Dryas), was largely based on reindeer. This cervid was regularly hunted in Western Europe since the beginning of the Upper Pleistocene (100,000 BP), and increasingly from the Lower Pleniglacial (70,000 BP), as seen in Mousterian sites. During the Upper Pleniglacial (30,000–20,000 BP), the last main cold period of the Pleistocene, reindeer became the dominant hunted game, especially in Solutrean occupations in France (Fontana, 2013, in press), and it was still the main animal resource for Magdalenian groups until the end of the Oldest Dryas, and even the Bölling in some areas (Lartet, 1861; Bouchud, 1966; Delpech, 1983; Fontana, 1999, 2012).

Since the end of the 19th century, one of the main topics addressed in studies of the hunting and consumption patterns of this resource has been the relationships between human mobility patterns and reindeer

migrations – related to the question of reindeer control or proto-domestication (Piette, 1891; Patte, 1958; Bouchud, 1959). Researchers have disagreed from very early on, some arguing that humans and reindeer were sedentary (Lartet and Christy, 1875), and others that they were migratory (Cartailhac and Breuil, 1906; de Saint-Périer, 1920). Studies in the early 1930s by German and Russian paleontologists and mammologists (Jacobi, 1931; Dubois and Stehlin, 1933; Gripp in Rust, 1937; Sokolov, 1937; Gripp, 1943), followed by those of Canadian and Swedish researchers in the 1950–1960s (Banfield, 1951; Bromée-Skuncke, 1952; Banfield, 1954; Kelsall, 1957; Banfield, 1961; Kelsall, 1968; Skoog, 1968; Bergerud, 1970), yielded a significant body of data on the biology and ethology of modern reindeer and caribou. This enabled Y. Guillion and J. Bouchud to develop a method to identify reindeer hunting seasons at Paleolithic sites based on tooth eruption and wear, and annual antler growth and shedding cycles. They first applied their method to the faunal assemblages of six sites in France (Badegoule, La Chaise, La Quina, Arcy-sur-Cure, Roc-en-Pail, Saint-Marcel) and identified year-round occupations (Bouchud et al., 1952; Bordes et al., 1953; Bouchud, 1953, 1954a; Bouchud and Guillion, 1953; Guillion, 1953). Through studies of other Paleolithic sites in

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France, along with new data concerning the ecology and ethology of reindeer populations, J. Bouchud confirmed that reindeer were hunted year-round in south-western France (Bouchud, 1966). He also confirmed his first conclusion that reindeer were not long-lived mobile animals in this area during the Middle and Upper Paleolithic. This particular point was criticized by F. Lacorre (Lacorre, 1953; Bouchud, 1954b) after the first publication in 1952 (Badegoule), but it was not until the 1970s that numerous studies attempted to prove or debate the existence of migrations (Sturdy, 1975; Bahn, 1977; Spiess, 1979; Gordon, 1988). These publications criticized Bouchud's work, arguing that, for many reasons, tooth wear and shed antlers cannot be used to identify age and season. Some critiques of these seasonality methods suggested that cementum increment analysis could be more reliable (especially Gordon, 1988) and constructed various scenarios of reindeer migration and human mobility patterns. Gordon's work has been harshly criticized (see Delpech, 1988; Clottes, 1988; White, 1989) due to the low number of samples, the unreliability of his methods and his erroneous analysis of archaeological data. Furthermore, not only Gordon's work, but nearly all of the studies arguing for reindeer migrations and suggesting their migration routes were carried out in a theoretical manner, rather than being based on data. Such studies, which led to the rejection of Bouchud's methodology, data and conclusions have never been expanded with the aim of testing, through a new methodology,¹ the possibility of obtaining precise information from the antler and teeth found in large Paleolithic faunal assemblages. The only constructive work in this domain, using osteometry to test reindeer migration models, is that of Weinstock (2000, 2002), who has compared the sizes of Upper Paleolithic reindeer through the use of VSI curves. He concluded that "(...) some of the proposed migration patterns of prehistoric reindeer can be ruled out completely using osteometric information".

Nevertheless, the hypothesis that Paleolithic reindeer populations did not migrate is still not discussed (neither is some form of control or proto-domestication): reindeer are still considered as a migratory species, though we know nothing about the range and frequency of their movements, and despite some studies and regional syntheses that suggest low mobility (Hahn, 1979; Weniger, 1982; Delpech, 1983; Weniger, 1987; Delpech, 1990; Pailhaugue, 1995; Straus, 1995; Pailhaugue, 1996; Sekhr, 1998; Cho, 1998; Fontana, 2000a, 2000b; Vannoorenberghe, 2004; Fontana, 2012). Similarly, regarding human mobility patterns, the only current debates are based on the locations of flint and shell sources. Such studies are used to draft maps of human territories and hypothetical reindeer migration routes, while data concerning hunting seasons are rare and unreliable in many cases, thus limiting the potential use of osteometric analyses (for example in Kuntz, 2011).

Currently, seasonality data (other than cementum increments) are "either unpublished or disputed" (Weinstock, 2000, p. 109) since previous publications (see above) have suggested that data from modern reindeer tooth eruption and antler cycles were not sufficiently precise (contra cementum increment analysis). Moreover, these same articles argue that the high fragmentation, frequent poor preservation and low numbers of teeth and antlers in Paleolithic sites make them unreliable for the collection of precise data on hunting seasons using this method. This idea is still prevalent since the methods of seasonal determination have still not been clarified. Modern references concerning the well-known annual cycles of reindeer and caribou, especially those related to antler cycles and tooth eruption (for example Miller, 1974), are of course now used by some zooarchaeologists. But even when this reliable modern data is used, determining hunting seasons based on the study of Paleolithic faunal assemblages entails particular problems and the methodology used for this very difficult task should therefore be clarified.

This was particularly true when I began my study of annual nomadic cycles in the Upper Paleolithic of south-western France, especially since my analysis of the Solutrean assemblages from Fourneau du Diable yielded the same results (year-round hunting) as those obtained by Bouchud, though I used different criteria.² It is for this reason that a new study of other major occupations in southwestern France is necessary in order to precisely identify the hunting-collecting seasons, with the aim of: 1) determining whether this large area was inhabited by non-migrating reindeer during a period to be defined, and; 2) understanding the relationship between this animal's behavior and the continuity of human occupation and annual cycles. To contribute to these two fundamental questions, the aim of the study presented here is to identify the reindeer hunting seasons represented in the Magdalenian occupation at the site of La Madeleine. I explain and discuss the proposed method of reindeer age estimation through the analysis of archaeological antlers, cheek teeth and fetal long-bone diaphyses. I then discuss the assumptions derived from my results in terms of reindeer mobility and the annual nomadic cycle of Upper Paleolithic populations in the Dordogne region.

2. Material and methods

2.1. Identifying hunting seasons: methodology

Based on a study of the bones and teeth recovered at a single Paleolithic site, our aim is to identify the time of year during which reindeer, the main prey animal, was hunted. These archaeological remains provide evidence of skeletal and appendix development: in utero long-bone growth, tooth eruption and loss during the first two years, seasonal growth and antler shedding. This biological rhythm – in utero, in early life, or throughout life – is well known from studies of modern reindeer populations. It is therefore theoretically possible to identify reindeer hunting seasons at archaeological sites, especially since many Upper Paleolithic sites contain the three types of faunal remains that are useful from this perspective: antlers, cheek teeth, fetal long-bone diaphyses.

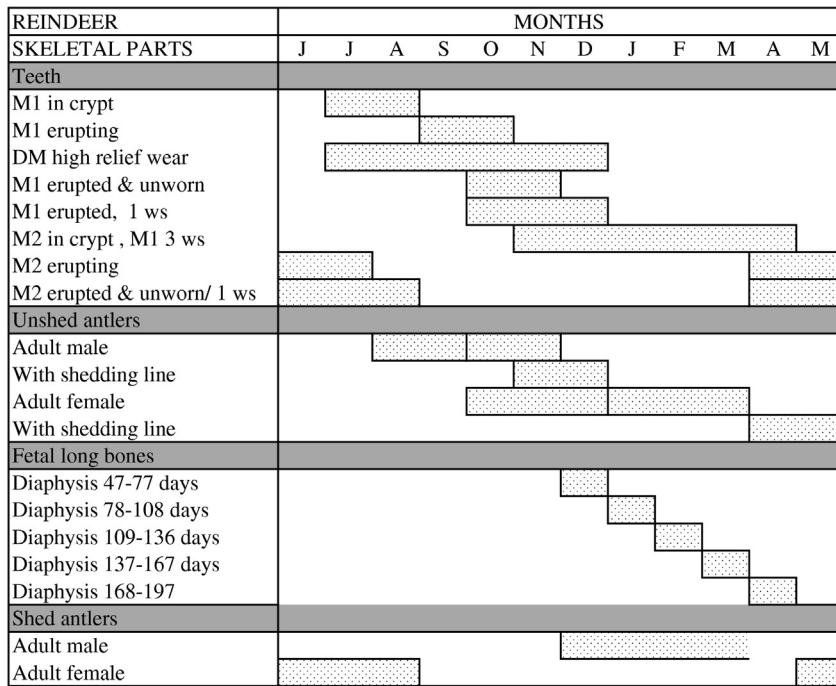
This task is nevertheless complicated by the low degree of precision associated with modern biological data, and the differential representation of archaeological remains. Firstly, the use of modern biological data is problematic since the timing of tooth eruption and loss, as well as antler growth and shedding can differ from one individual to the next within a long time range (more than three months), making the determination of archaeological remains imprecise. Secondly, studies must take into account the representativity of the sample analyzed, which can be influenced by numerous factors, which must be identified and considered for each type of archaeological remains. Finally, the identification of hunting seasons differs depending on the type of remains analyzed (teeth, antlers, fetal diaphyses), and the season concerned.

Fig. 1 presents the distinct stages of reindeer antler growth and shedding, tooth eruption, and fetal diaphysis length at the scale of an annual cycle, which can be used to identify the time of death, with calving at the end of May and mating in mid-October (based on the data in Bouchud, 1966; Parker, 1972; Miller, 1974; Spiess, 1979).

To determine the season(s) of death from teeth, it is necessary to precisely identify (within 2–3 months) the age of fawns. Since dental wear is highly variable (as illustrated by the photos in Miller, 1974), it was not used to determine the age of reindeer; it is possible to say only that unworn deciduous molars are associated with fawns that were killed at the start of summer, or before December if they are slightly worn. The time of death is calculated from the date of calving and is based on well-known times of molar eruption. Only the eruption dates of first and second molars can be used for this purpose since the first three deciduous molars are already erupted at birth, and the

¹ Since some of Bouchud's references and methodology were partly wrong (see Fontana, 2000a for details).

² Old excavations (Fontana, 2001) and current excavations (of M. Baumann, since 2015).



Based on end of may calving & mid october mating
ws : worn surface

Fig. 1. Cheek teeth, antlers and fetal long-bone diaphyses as indicators of season: data from modern reindeer (*Rangifer tarandus*).

eruption of the third molar and of the three premolars is highly variable between two and three years-old. The first molar is the most useful (two-month time span) and easily indicates the end of summer and/or the start of autumn. On the contrary, since the eruption date of the second molar varies from one to five months, it is not possible to identify the season of death from a M2 in crypt (autumn or winter) and erupted-erupting (spring or summer). Fig. 2 illustrates the different stages of fawn cheek teeth (at La Madeleine) mentioned in Fig. 1.

To identify the season of death from antler it is necessary to distinguish between shed and unshed antlers, male and female antlers, based on juvenile and adult antler bases. The modern data related to the annual antler cycle can be used but once again, antler wear occurs over a long time span, especially for females, who have antlers from autumn to spring. Since adult antlers are totally matured only from September for males, and from January for females, the difference between mature and immature antlers is not always easy to detect (see Bouchud, 1966). Fortunately, the shed line, which can be seen on antler bases just before casting (from one to three weeks), provides evidence of the month of death, and autumn and spring may therefore be easily determined (Fig. 3).

Finally, shed antlers found at archaeological sites should not be used to identify the season of human occupation because though the antler shedding period is well-known, it is impossible to know if the antlers were collected at that time. It is only possible to conclude that antlers were available from November (adult males) and May (adult females).

Fetal diaphyses provide evidence of the age (expressed in completed days) of the fetus, which enables a determination of the season of death of adult females, from the date of mating, actually from the start to the end of October. The age is given by the relationship between the length of the diaphysis and the length of the hind-foot, which is correlated with the age of the fetus (Fig. 4, data from Spiess, 1979). The fetal diaphysis is the only element that allows the hunting season to be determined at the scale of one month, and it is also the only one that can provide clear evidence of winter.

As explained above, the imprecision of dates related to biological rhythms differs for the three kinds of remains, making some seasons

difficult to identify. The second problem is the representativity of the archaeological sample and of the three kinds of remains involved in the season identification. As we know, archaeological remains are representative of: 1) the time of the excavation (old or recent) and the excavation methods, and 2) the location and size of the excavated area. Furthermore, the representativity of cheek teeth, antlers and long-bone diaphyses is different since their characteristics differ widely according to three types of features, as outlined in Fig. 5.

The first type consists of features that may influence representativity related to: A) the preservation-fragmentation of remains and sample size, and B) the selected part of the object. The second feature C) may reduce representativity since a part of the population sample is selected in terms of the age and sex of individuals; in fact, it is not really limiting because fawns live with other reindeer.

The last type of features is related to the informative value of the remains in terms of: D) the activity related to faunal exploitation and E) the visibility of the remains that may be present on-site (in an excavated part or not), outside of the site (at the kill site, at the preceding or following occupation, at the collection location - in part).

In summary, cheek teeth, antlers and fetal long-bone diaphyses do not yield the same kind of information: their preservation, fragmentation or quantity, differ and some of them are selected as portions of remains and as representing part of the population. Cheek teeth are usually numerous at Upper Paleolithic sites due to their very good preservation potential. While the deciduous molars are more breakable than permanent ones, they are often found complete. The first and second permanent molars are found either on broken or complete mandibles, or isolated (since mandibles are broken to extract the marrow), broken or not. Antlers are also most often very well-preserved but highly fractured since they are used to make bone tools, which reduces the number of determinable remains, as does their removal from the site. Fetal long-bone diaphyses are very rare since they are most often poorly preserved and difficult to identify, even though sieving and sorting.

In conclusion, cheek teeth, antlers and fetal long-bone diaphyses from Paleolithic sites have a real informative potential. The main problem is that a season lasts three months, while some of the remains

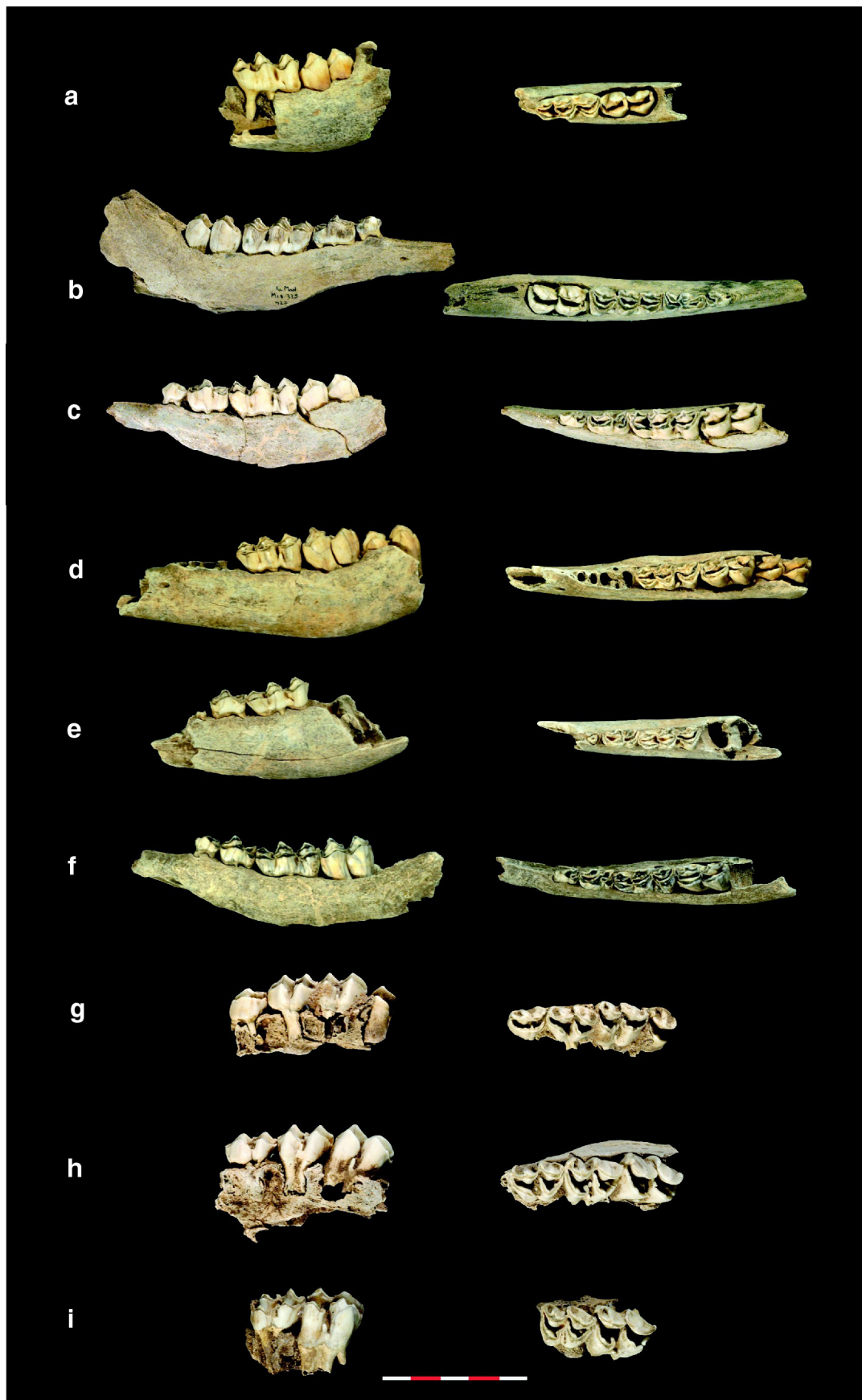


Fig. 2. La Madeleine cheek teeth a. M1 in crypt b. & c. M1 erupting d. M1 erupted with 2 wear stages and M2 in crypt e. DM3/DM4 worn f. M1 with 4 wear stages g. M¹ in crypt h. M¹ erupted unworn i. M¹ with 3 wear stages.
 (Photos Ph. Jugie, MNP Eyzies-de-Tayac)



Fig. 3. Unshed antlers a. adult male b. adult female c. adult female, with shedding line. (Photos Ph. Jugie, MNP Eyzies-de-Tayac)

(unshed antlers and M2) may indicate four to seven months. Therefore, the winter season is barely visible without fetal bones, and the summer season cannot be reliably identified if there are no M1 teeth in crypt present, which is a significant problem in both cases due to the poor preservation potential of these remains. Nevertheless, it is possible to obtain reliable data, at the scale of one, two or three months, when unworn M1 and fetal diaphyses are preserved, and from unshed male and female antlers with a shedding line. Each season can thus be identified from a well preserved and sieved³ sample.

The question now becomes how to interpret the complete data set from an archaeological level when the same time period is represented by many periods of imprecision. I will discuss this problem through a presentation of the data from two Magdalenian levels at La Madeleine.

2.2. The site and hunted species

The site of La Madeleine in the Dordogne region of southwestern France was discovered in 1863 by E. Lartet and H. Christy. It is a large rock shelter, 250 m long, located at the foot of a 45 m-high, south-facing cliff and extending over the right side of the Vézère river (Fig. 6). E. Lartet, L. Girod, E. Massenat and E. Rivière conducted excavations (in 1895 and 1901) in the central and the western parts of the site, covering only part of the deposits (Fig. 7). From 1910 to 1913, after removing the previous excavation backdirt, D. Peyrony undertook a large excavation extending across the entire length of the rock shelter, from the back to the edge of the overhang. In 1926, when he resumed excavations in the eastern part of the site, he discovered a child burial (Capitan and Peyrony, 1928; Bouvier, 1972). Three geological strata were identified and related to three archaeological units: the Lower unit (Magdalenian IV), Middle unit (Magdalenian V) and Upper unit (Magdalenian VI). These three units extended over the whole excavated area, except the easternmost zone (Upper level only). Between 1967 and 1983, Bouvier realized a test pit and a 50 square-meter excavation in the western part that was still undisturbed. His aim was to “refine the stratigraphic distinctions of the sedimentary levels and archaeological layers...” (Bouvier, 1977, p. 64). As illustrated in Fig. 8, three stratigraphic units

were identified by H. Laville (Laville, 1975): the Upper Unit (A: collapsed blocks 4.5 m thick) without any archaeological remains, the Middle Unit (B-I: cryoclastic scree) 3.5 m thick and containing thirteen archaeological layers (Magdalenian VI and V), and the Lower Unit (J-S: alluvial deposits) containing five archaeological layers (Magdalenian IV in J-N). The 18 archaeological layers⁴ were named C30 to C26 (MIV), C25 to C20 (MV), and C19 to C13 (MVI). The bedrock, reached for the first time by Bouvier across a small surface, was some meters deeper than the supposed bed rock (“*sol naturel*”) of Peyrony. Only four of the 18 layers have been dated (Bouvier, 1973; Delibrias et al., 1976; Bouvier, 1977, 1979): C19 (12,640 ± 260 BP Ly 919), C21 (12,750 ± 240 BP Ly 920), C25 (13,070 ± 190 BP Ly 921), C26 (13,440 ± 300 BP Ly 922). Since the oldest layer (C30) has not been dated, it is not known when first occupations took place.

The faunal collections of Lartet, Peyrony and Bouvier have been studied several times (Milne-Edwards, 1875; Harlé, Newton in Capitan and Peyrony, 1928; Bouchud, 1966; Delpech, 1975; Donard, 1982; Delpech, 1983; Gordon, 1988; Madelaine, 1989; Boyle, 1994; Bonnissent, 1993; Burke, 1995; Weinstock, 2000; Fontana and Chauvière, 2007; Braëm, 2008). Since Bouvier’s collection had never been totally studied, I began the zooarchaeological study of the Magdalenian IV and V layers (levels 30 to 20),⁵ with the initial aim of identifying the reindeer hunting strategies. I sorted the entire Bouvier collection (at least 12,000 bone fragments), examining each piece, especially to find the deciduous teeth and fetal long-bone diaphyses that were collected through sieving. Before presenting our results concerning the reindeer hunting seasons for the two main levels associated with the Magdalenian IV and V, namely C27 and C25, we will present the other species identified and their proportions.

As indicated in Fig. 9, reindeer (*Rangifer tarandus*) was the most frequently hunted species in layers C25 and C27. Reindeer bones, teeth and antlers comprise 95% of the 4283 identified remains in C25, and 87% of the 3667 in C27. Therefore, very few animals of other species were

⁴ They were renamed (18 to 1) after 1975. I will retain the initial level names in this article.

⁵ This faunal assemblage, originally kept at the Institut du Quaternaire (Bordeaux), has been located at the National Museum of Prehistory (Les Eyzies) since 2002, like the Peyrony collection that I have also examined.

³ Sieving using a 2 and 1 mm sieve, if no search for microfauna.



Fig. 4. La Madeleine Bouvier's excavations - Fetal long-bone diaphysis a. Tibia (Level 27) b. Femur (Levels 25, 27, 28) c. Humerus (Levels 25, 27). (photos Ph. Jugie, MNP Eyzies-de-Tayac)

killed, with the exception of horse (*Equus caballus*) in C27, whose remains comprise 15%. The most frequent species among the remaining ones is the arctic hare (*Lepus timidus*), especially in C27 (3.1%). Large bovids, ibex, chamois, red deer and carnivores are present in very small

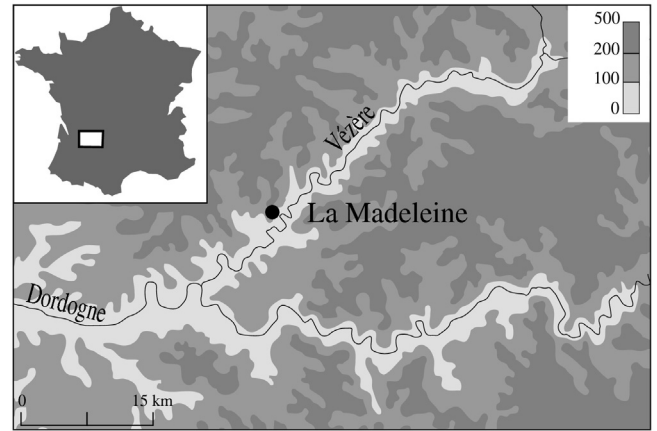


Fig. 6. Location of La Madeleine (lat. 44° 58' 5, N; long. 1° 1' 56,29" E).

numbers. While this large proportion of reindeer, up to 87%, is common in the Solutrean and Magdalenian occupations in this region, there is much less evidence for the hunting of arctic hare. At La Madeleine, this animal was hunted mostly for its fur, as well as for bones used to manufacture bone implements, as our study of the Bouvier and Peyrony collections has confirmed (Fontana and Chauvière, 2007). La Madeleine is one of only three Magdalenian sites where, during the Oldest Dryas, this large hare species was trapped, though less often than at Gazel Cave and Kesslerloch (Heierli, 1907; Fontana, 1998, 2003, 2004).

3. Results

Among the 522 reindeer teeth, antlers and fetal bones from layer C25, 54 were analyzed: 11 cheek teeth, 40 antler bases and 3 fetal long-bones. For C27, which yielded 407 reindeer teeth, antlers and fetal bones, 34 pieces were analyzed: 8 cheek teeth, 17 antler bases and 9 fetal long-bones (Fig. 10). These two assemblages of 88 remains are very well-preserved, even if highly fractured.

The results are the same for the two archaeological layers, as can be seen in Figs. 11 and 12: several periods of the year are represented and they partly overlap due to the variability of modern reindeer data. A high proportion of the remains were thus identified at the scale of several months, which may indicate seasonal hunting at the same time, or many events throughout this period. It therefore appeared to us that it is not possible to identify every period in the course of a year when reindeer were hunted, and the only way to interpret such data is to determine a minimum number of seasonal hunting events.

In the C25 and C27 results, at least five periods (in grey in the figures) during the course of the year were identified (Figs. 11 and 12). Some reindeer were killed in the summer, either from June to August or only July or August. Many teeth and antlers also indicate an autumn hunt, in October in the minimum assumption. Winter is identified, as clearly in February as in March, by fetal long-bone diaphyses (Fig. 13;

	SAMPLE FEATURES	CHEEK TEETH	ANTLERS	FETAL LG BONES
		CHARACTERISTICS		
A	Preservation	rather good	very good	very bad
	Fragmentation	low (mandible)/high (isolated)	low	low
	Sample size	rather small	small	extremely small
B	Part of the remain	Entire teeth/fract. mandibles	Only basis	Only diaphysis
C	Part of the population (age/sex)	Only fawns	Adults males & females	Only pregnant adult females
D	Kind of remains and activity	waste of skeletal expl.	in part, waste of bone industry	waste of skeletal expl.
E	Visibility on site	brought on site from ks on site	brought on site from ks in part carried away	some on killing site? on site

Fig. 5. Characteristics of three kinds of faunal remains according to variables which modify their representativity.

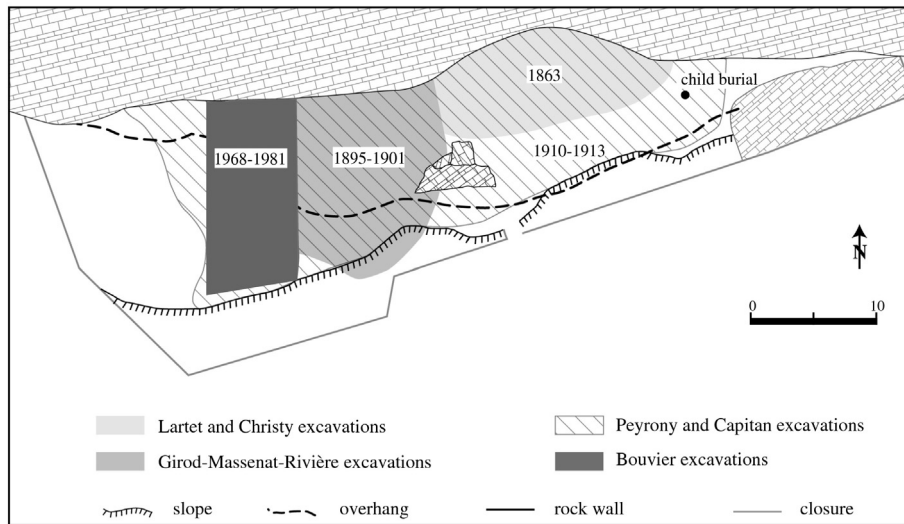


Fig. 7. Map of La Madeleine and location of the excavations.

see also Fig. 4), as is spring, by adult female antlers which in April or/and May were about to shed, as is indicated by shedding lines.

What can be said about the possible lack of hunting at the end of autumn and start of winter? This seems unlikely since all wear stages of fawn first molars were identified, from M1 in crypt to four wear stages. Similarly, while a few fourth premolars (DM4) are measurable in C27, they are more numerous in C25 and the crown height measurements show a continuous wear. This absence of any wear stage on molars and premolars suggests that there were hunts between December and January. We should also mention the shed antlers of adult males: they are numerous and while we cannot prove that they were collected during this period at the end of autumn and/or start of winter (as I have suggested, see Fontana, 2012), it is possible.

There is therefore no doubt that all seasons are represented: reindeer were killed in every season at or near this site in the Vézère valley at around $15,631 \pm 285$ (1sigma) cal BP (C25), and between $16,186 \pm 446$ (1sigma) cal BP (C26) and the start of Magdalenian IV at 18,200 cal BP. Before discussing the implications of these results, let us estimate their representativity.

Firstly, could such data, based on the study of a selected sample composed of three kinds of remains (54 and 34), selected from a total corpus of 3600 reindeer remains, be representative of hunting seasons? I tend to think that they are since even if a time of year is identified by a single remain, it still constitutes real data. But can the proportion of remains from a time of year reveal the intensity of the occupation at this time? I do not agree with Bouchud and many zooarchaeologists who think that this is obvious. In effect, the proportion of these remains relates first of all to their state of preservation, as well as fragmentation, and their status at the site (left at the site or taken away after the occupation). These three factors differ for antlers, cheek teeth and long-bone diaphyses and for the same kind of remains. This means that if a hunting season is identified by only one or two remains, it may be due to the poor preservation of the specific remain that could have been used to identify this season (for example, newborn reindeer premolars), or their exportation (antler bases). The opposite is true as well, since the times that are represented by many remains may reflect the better preservation of the remains used to identify this time, such as antler bases. In fact, the representativity relative to the sample size is not a major issue for La Madeleine since every season is represented; it simply raises the question of identifying short periods that could be missing (December–January): could they have been identified with more numerous remains? Likewise, the fact that the remains come from 50 square meters pits is not problematic; we should mention that the results of the study of the Peyrony sample (Fontana, in press) are the same as those of the Bouvier sample for the

level C27, except for the absence of fetal bones, which were probably not collected, thus preventing the identification of winter hunt.

Antler fragments from C27 are numerous (96) and belong to adult males and females, and fawns and sub-adults. The circumferences of the 10 complete adult antler bases confirm that both males and females were hunted (Fig. 14a). In C25, the 191 antler fragments yield the same results, with a higher proportion of adult females among the 21 bases (Fig. 14b). As noted (see above and Fig. 5), it is difficult to assess the representativity of the quantitative data of antlers since this is a “mobile” resource, which was probably carried from site to site. We may just mention that the Peyrony samples yielded the rather same results (M IV, Fig. 14c; M V, Fig. 14d), even if these old samples are known to be incomplete. I analyzed the osteometric data by univariate diagrams, in this study, distal humerus and distal talus (Fig. 15). The sample of the Magdalenian IV (Fig. 15a and b) includes the small Bouvier C27 measurable sample and the larger Peyrony lower level sample, while the Magdalenian V sample (Fig. 15c and d) includes only the remains from C25. The results confirm that adult males and females were hunted, in proportions that differ among the skeletal parts.

The results obtained from Bouvier’s excavation, layers C25 and C27, are representative of reindeer hunting seasons at La Madeleine, at least during the Oldest Dryas occupations, for many reasons: 1) the very good preservation of faunal remains, favoring the fragile ones (fetal long-bones and fawn teeth), 2) the similar results between the large Bouvier assemblage (from a small but modern excavation) and the selected Peyrony collection from a very large portion of the site, and 3) the osteometric data confirming that adult males and females were hunted.

As a final argument in favor of these results, I will now compare the La Madeleine data to other sites in three regions where only a part of the year has been identified (the Paris Basin, the Massif Central and the Aude Basin), to measure the extent to which La Madeleine data are different (Fig. 16).

4. Discussion

4.1. Reindeer hunting seasons in other regions in France

The best documented Magdalenian sites in the Paris Basin have yielded data concerning reindeer hunting seasons. As indicated in Fig. 17, the results from Pincevent (level IV-20, Upper Magdalenian, Bölling) are very different from those of La Madeleine: no fetal bones, even though other skeletal parts with very low bone densities are represented (such as the sternum and hyoids), fawn mandibles with the M1 just erupting or fully erupted and just coming into occlusion, mandibles

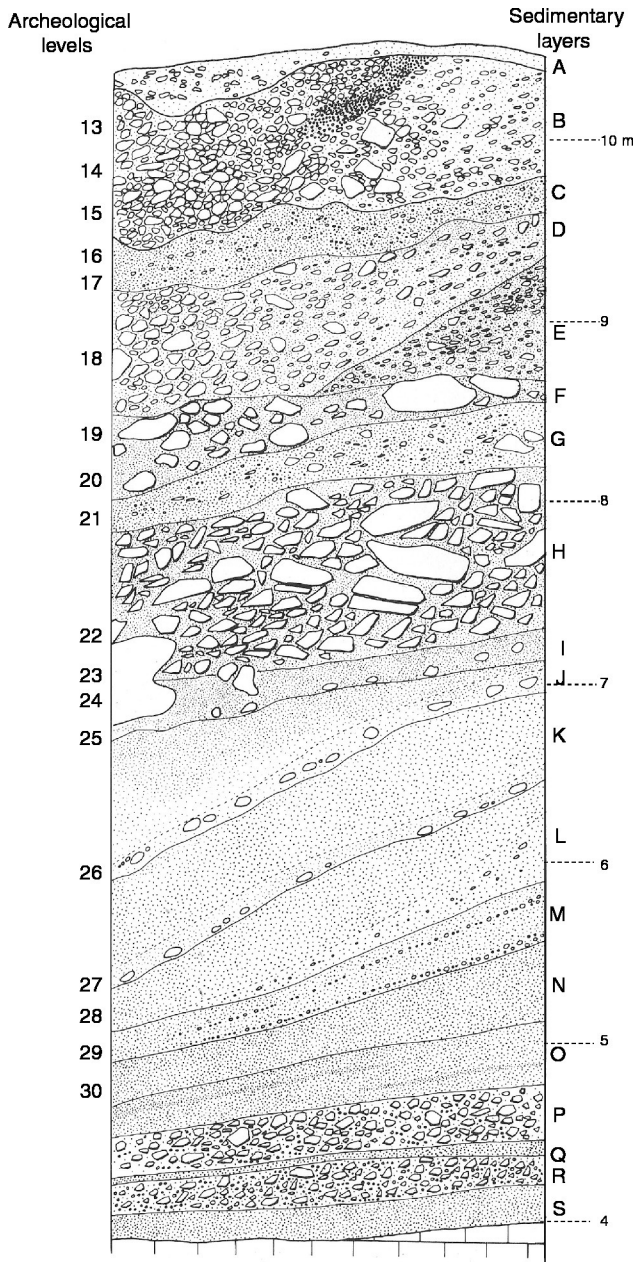


Fig. 8. La Madeleine - Sagittal stratigraphic section of the western part Bouvier's excavations (from Laville, 1975).

with fully erupted M2s, sometimes with initial wear on the first and second facets. Moreover, there is no cast antler but only unshed male and female antlers with no shedding line. All of these data indicate an autumn hunt, as confirmed by the measurements of 29 fourth premolar (DM4) crown height, which lacks wear (Enloe, 2007). According to the authors, "If there had been a winter occupation, we should have found some fetal remains; if there had been a spring occupation we should have found (...) second molars in eruption. None of these were found at Pincevent" (p. 62), while they do exist at La Madeleine. The data are similar for Verberie (Enloe and David, 1997).

The large Middle Magdalenian occupations (Oldest Dryas) in the Aude Basin illustrate a different type of seasonal reindeer hunting activity (Fig. 18). For instance, at Canecaude cave (level II), among the numerous and very well-preserved bones, every identified fawn is older than seven-eight months (no M1s with less than three worn facets, DM already worn). There are no cast antlers and among the unshed antlers, some with a shedding line and only adult females and young are

represented, as osteometric data confirm. In addition, we have identified 24 fetal long-bone diaphyses that indicate three growth stages. These data indicate hunting events between November and May (Fontana, 1998, 1999, 2005), which are similar to other sites located in the same area (Montagne noire), such as Gazel cave (Fontana, *ibid.*).

The last scenario is associated with the site of Le Blot, located in the southern Massif Central, which is a rock shelter occupied mostly at the end of the Gravettian period (formerly called Protomagdalenian in France), dated to between $26,395 \pm 280$ (level 27) and $25,577 \pm 230$ (level 28) cal BP.⁶ The assemblage (levels 22 to 34) of rather well-preserved faunal remains does not yield many information, as often in the Massif Central sites, and contain no remains belonging to reindeer killed in autumn and winter (Fig. 19): no antler bases (either shed or unshed) and only one tine fragment,⁷ no fetal long-bones, one M1 in crypt and all others fully worn (four facets) (Fontana, unpublished results; Chauvière and Fontana, 2005). These data indicate summer hunts, reflecting the full range of Massif central sites whose occupations have always been identified as occurring between April and October (Fontana, 2000b, 2012; Fontana and Chauvière, 2009), with few antlers or bone implements (except two sites), thus reducing the visibility of antler procurement and exploitation (Fontana and Chauvière, 2009; Chauvière, 2012).

The data from these three areas are thus different from the La Madeleine data since reindeer hunting occurred: 1) at a single moment during autumn (Paris Basin), and 2) many times between either October–November and May (Aude Basin), or between April and October (Massif Central). In contrast to La Madeleine (layers C25 and C27), year-round reindeer hunting has never been identified in these three regions, and the absence of two or three seasons (a large part of the year) is not due to taphonomic factors or sample sizes.

4.2. Three hypotheses

There is thus no doubt that reindeer were hunted near La Madeleine during at least five periods of the year, covering all seasons. What are the implications of this finding for human settlement and reindeer mobility? Since we consider that the remains within an archaeological layer may reflect several occupations of varying lengths, these data lead us to consider three hypotheses.

In the first hypothesis, the occupations may have taken place at the same moments of year during several annual cycles, whether discontinuously (five separate periods? two distinct longer periods?) or not. In this case, Magdalenian people would have occupied La Madeleine during at least five periods in all seasons. This would imply that reindeer also lived year-round in the region, even if they moved at a short distance (for calving and during loss of antlers) for two or three weeks. This would mean that the reindeer living in this part of the Vézère Valley did not migrate and maybe moved to the Massif Central foothills.

According to the second hypothesis, the La Madeleine occupations occurred at different times of the year during several annual cycles (spring over x amount of years, and then winter over the following x amount of years...). In this case, the remains of these occupations would have been disturbed and then found together in what we call an archaeological unit. In the case of Magdalenian occupations that varied over time, the area surrounding La Madeleine would have been either a winter range, or a summer range, or a spring range, or even an autumn range for migrating reindeer.

Finally, in the third hypothesis, Magdalenian people lived at La Madeleine throughout all four seasons within a single annual cycle, and reindeer were also living year-round in this region but did not belong to the same population and were migrating. This has been argued by Lacorre

⁶ These are two of the six dates obtained from the faunal remains sampled (from C22, 23, 24, 27, 28, 32), which are still unpublished.

⁷ Two worked fragments have also been identified in two levels: a long beam fragment (C24) and a small beam or tine fragment (C27), both belonging to an adult female or young male (Chauvière, 2012).

Archeological units	Level 25		Level 27	
	NISP	%	NISP	%
<i>Equus sp.</i>	150	3.50	350	9.54
<i>Rangifer tarandus</i>	4051	94.58	3189	86.96
<i>Cervus elaphus</i>	1	0.02	1	0.03
<i>Bos/Bison</i>	20	0.47	10	0.27
<i>Capra ibex</i>	0	0.00	1	0.03
<i>Rupicapra rupicapra</i>	4	0.09	0	0.00
<i>Lepus timidus</i>	49	1.14	114	3.11
<i>Canis lupus</i>	3	0.07	0	0.00
<i>Vulpes vulpes</i>	2	0.05	1	0.03
<i>Gulo gulo</i>	3	0.07	0	0.00
<i>Ursus sp.</i>	0	0.00	1	0.03
Total NISP	4283		3667	

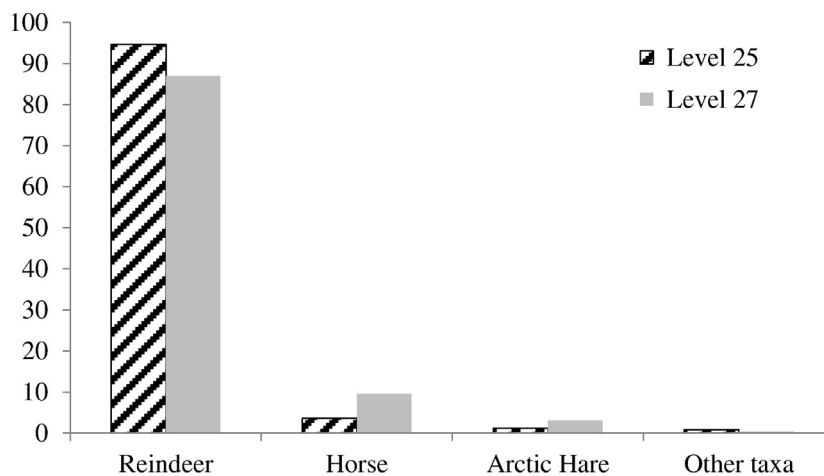


Fig. 9. La Madeleine Bouvier's excavations levels 27 & 25 - representation of hunted species (Fontana, on-going study).

(1953) who thought that the presence of reindeer during four seasons near the site of Badegoule was due to the presence of two subspecies, with differently shaped antlers, which lived in this part of the Dordogne region at different times: forest reindeer in spring and summer (migrating to south for the cold season) and tundra reindeer in autumn and winter (arriving from northern regions where they lived the rest of the year).

So there are three possible scenarios related to reindeer behavior in the Vézère Valley during the Oldest Dryas: 1) a single species of reindeer did not migrate and moved very little, 2) a single species of reindeer migrated with a great instability, resulting in a highly variable seasonal use of the area, or 3) reindeer migrated in a stable manner, but the visibility of four seasons is the result of two migrating reindeer populations that occupied the same range during different seasons. Which of these possibilities is the most likely? In response to Lacorre's hypothesis (the third one), Bouchud immediately argued that if the Badegoule antlers indeed belonged to two reindeer "varieties", they were present at the same

times and thus lived together in this region, as the X-rays and cross-sections of the Badegoule pedicles have demonstrated (Bouchud, 1954a, 1954b). It may be added that Delpech's osteometric data led her to disprove this distinction between two subspecies which would have coexisted in France during the upper Pleistocene (Delpech, 1983).

Is the second hypothesis the more likely? Could studies of modern reindeer populations show whether reindeer could have migrated with great instability, resulting in a highly variable seasonal use of the space? First, considering current studies in reindeer ecology, it seems clear that "Despite recent advances (Bergerud, 1996) the dynamics of migratory caribou remain incompletely understood" (Mahoney and Schaefer, 2002, p. 957). This is why it is very difficult, based on modern ethology, to identify features that could contribute to our understanding of the mobility patterns of reindeer during the Upper Pleistocene. This is particularly true since the environmental conditions, a basic parameter of animal ecology, during the Upper Pleistocene in France, were not the same as those in current circumpolar environments where reindeer live.⁸ Nevertheless, some studies of caribou ecology provide valuable information from our perspective. For example, changes in species

Archeological units	Level 25		Level 27	
	NISP	Season	NISP	Season
<i>Rangifer tarandus</i>				
Teeth	328	11	299	8
Antlers	191	40	96	13
Fetal long-bones	3	3	12	9
Other skeletal parts	3529		2782	
Total NISP	4051	54	3189	30

Fig. 10. La Madeleine Bouvier's excavations levels 27 & 25 - detailed sample used for hunting season identification.

⁸ The environment of northern Eurasia and America was composed of species (plants and animals) not found in association today. This biome, without any modern analogs, was called Mammoth Steppe by Guthrie (1968, 1982, 2001) and it included large herbivores, which lived at different latitudes since the start of the Holocene. In Eurasia, some of them moved to colder northern regions (reindeer, moose, saiga antelope, bison, muskoxen, woolly mammoth), while others became extinct (woolly rhinoceros, megaceros, large carnivores) during the Late Pleistocene and others lived in temperate environments before becoming extinct (aurochs, horse), or continuing to exist (red deer).

REINDEER	LA MADELEINE BOUVIER EXCAVATIONS LEVEL 27											NISP	
Skeletal parts	J	J	A	S	O	N	D	J	F	M	A	M	30
Teeth													
M1 in crypt													1
M1 erupting													1
DM high relief wear													3
M1 erupted & unworn													0
M1 erupted, 1 ws													0
M2 in crypt, M1 3 ws													2
M2 erupting													0
M2 1 ws													1
Unshed antlers													
Adult male													5
With shedding line													0
Adult female													2
With shedding line													7
Fetal long bones													
Diaphysis 47-77 days													0
Diaphysis 78-108 days													0
Diaphysis 109-136 days													2
Diaphysis 137-167 days													7
Diaphysis 168-197													0
Shed antlers													
Adult male													3
Adult female													0
Min.nb. of hunting events		1			2				3	4		5	

Fig. 11. La Madeleine Bouvier's excavations level 27 - data of reindeer hunting seasons.

distribution are always driven by various factors (e.g. Messier et al., 1988; Crête and Huot, 1993; Couturier et al., 2010; Mahoney et al., 2011; Schaefer and Mahoney, 2013). Some drive changes in the rate of reindeer movements and the timing of migrations, sometimes leading to shifts in calving grounds or in summering areas (see Newton et al., 2015), but no one has observed them resulting in a very large shift in migration sites where winter ranges would become summer ranges, probably because biological and climatic factors are held rather constant. We therefore have no data to support the assumption that the evidence for year-round reindeer hunting at La Madeleine would be

the result of several different seasonal occupations over centuries, and would indicate a great instability of migration ranges.

What about the first hypothesis of non-migrating reindeer which would have lived in an area including La Madeleine, and perhaps moved between close areas? First, even if the great majority of reindeer and caribou are currently long-lived and mobile animals, a minority of them does not migrate, such as the Peary Caribou (*Rangifer tarandus pearyi*) and the Migratory Woodland Caribou (*Rangifer tarandus caribou*), which are woodland and mountain ecotypes. It is therefore also possible that some Pleistocene reindeer did not migrate. What could

REINDEER	LA MADELEINE LEVEL 25											NISP	
Skeletal parts	J	J	A	S	O	N	D	J	F	M	A	M	54
Teeth													
M1 in crypt													1
M1 erupting													4
DM high relief wear													2
M1 erupted & unworn													0
M1 erupted, 1 ws													2
M2 in crypt, M1 3 ws													2
M2 erupting													0
M2 erupted & unworn													0
Unshed antlers													
Adult male													3
With shedding line													0
Adult female													13
With shedding line													7
Fetal long bones													
Diaphysis 47-77 days													0
Diaphysis 78-108 days													0
Diaphysis 109-136 days													1
Diaphysis 137-167 days													2
Diaphysis 168-197													0
Shed antlers													
Adult male													17
Adult female													0
Min. nb. of hunting events		1			2				3	4		5	

Fig. 12. La Madeleine Bouvier's excavations level 25 - data of reindeer hunting seasons.

LEVEL	DIAPHYSIS		LENGTH mm	TOTAL L mm	LG Hindfoot mm	AGE days	SEASON month
	long-bone (S)	remain					
27	Femur (R.)	distal	45.49	56.12	112.46	126	end FEB
	Femur (R.)	mid	44.54	52.12	104.45	122	mid FEB
	Femur (R.)	proximal	25.17	52.12	104.45	122	mid FEB
	Tibia (L.)	whole	70.57	71.94	126.65	133	end FEB
	Tibia (L.)	whole	65.73	65.73	115.72	128	end FEB
	Tibia (L.)	whole	71.53	71.53	125.93	133	end FEB
	Tibia (L.)	proximal	44.35	73.18	128.84	134	end FEB
	Tibia (L.)	distal	43.61	71.74	126.30	133	end FEB
	Humerus L	mid	60.20	61.21	169.56	155	mid MARCH
25	Femur (R.)	whole	67.69	67.69	135.65	138	st MARCH
	Humerus (L.)	distal	27.87				mid FEB?
	Humerus (R.)	mid	48.75	60.21	166.79	153	mid MARCH

Fig. 13. La Madeleine Bouvier's excavations levels 27 and 25 - measurements of Reindeer fetal long-bones diaphyses and seasonal data.

have caused such a discrepancy? This is difficult to answer without knowledge of the geographic and chronological boundaries of their supposed range; the questions of where, when and why are thus correlated with each other.

To know “where”, it is first necessary to determine if reindeer were hunted year-round at sites other than La Madeleine. According to Bouchud and Guillion, at least nine such occupations did exist in the

Dordogne and four in the nearby Charente region (data in Bouchud, 1966). Since these numerous data were in need of revision (see above), I undertook zooarchaeological studies on three of these sites: Fourneau du Diable (Solutrean, 60 km north), Badegoule (Badegoulian and Solutrean 30 km north, Vézère), and Laugerie-Haute (Lower Magdalenian and Solutrean 10 km south, Vézère). Whether the study has been completed (early excavations of Le Fourneau du Diable, Fontana,

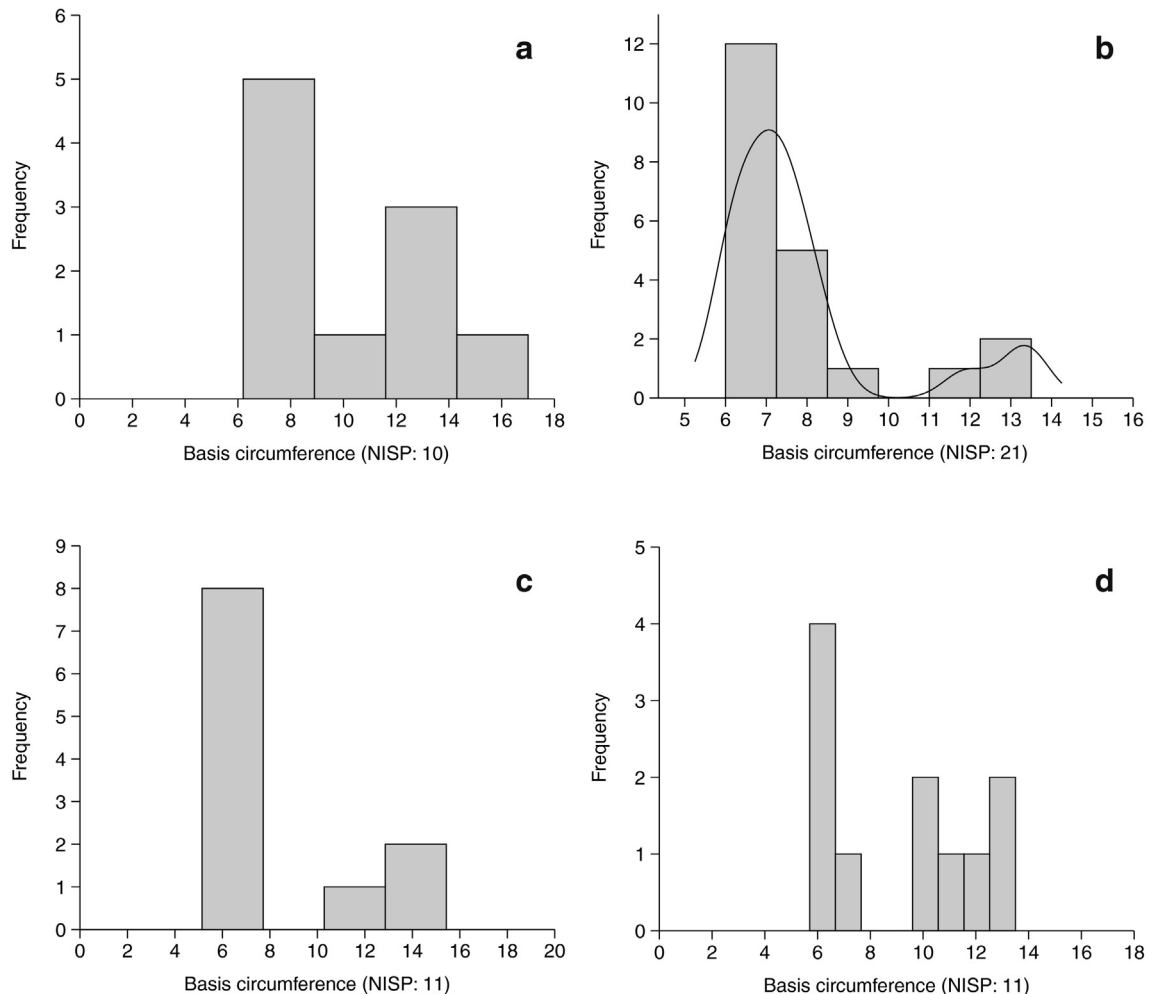


Fig. 14. La Madeleine - circumferences of unshed reindeer antler bases a. Bouvier's excavations level 27 b. Bouvier's excavations level 25 c. Peyrony's excavations lower level d. Peyrony's excavations middle level.

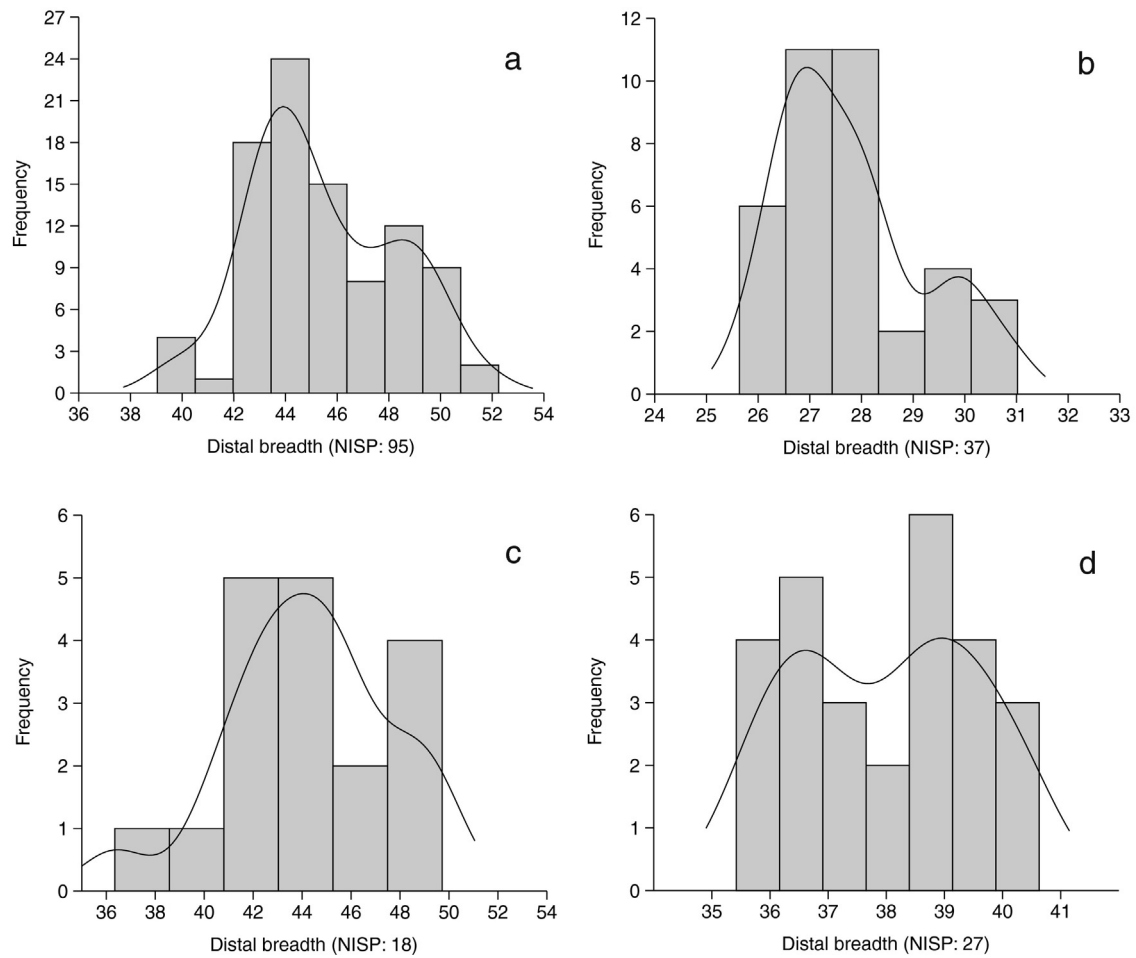


Fig. 15. La Madeleine - a. Bouvier (C27) and Peyrony (lower level) excavations: Reindeer humerus measurement b. Bouvier (C27) and Peyrony (lower level) excavations: Reindeer talus measurement c. Bouvier C25: Reindeer humerus measurement d. Bouvier C25: Reindeer talus measurement.

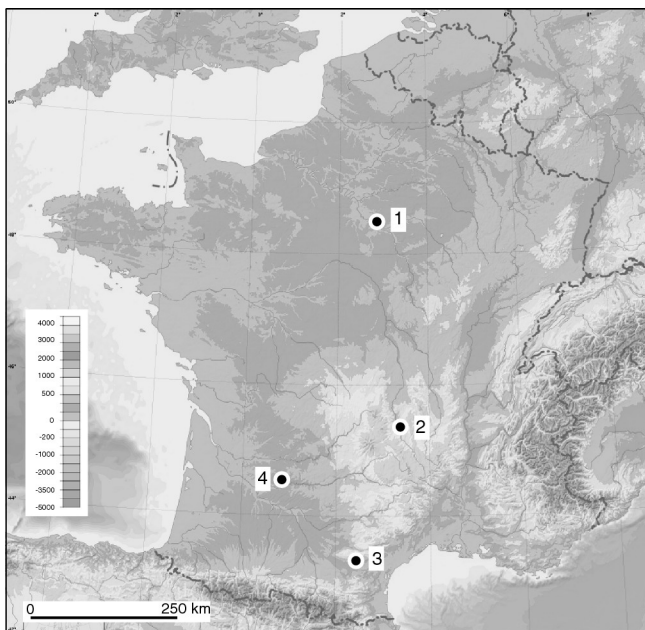


Fig. 16. Map of the four mentioned sites. 1. Pincevent (La grande paroisse) 2. Le Blot (Cerzat) 3. Canecau (Villardonnell) 4. La Madeleine (Tursac).

2001) or is on-going, the results are similar, indicating year-round reindeer hunting, and were obtained by the same method described above. Likewise, the data from the Abri Pataud, whose faunal remains have been reexamined (Cho, 1998; Sekhr, 1998; Vannoorenberghe, 2004), have confirmed Bouchud's results (Bouchud, 1966, 1975): they are similar to the new data from La Madeleine, at least for the Gravettian levels (C2 to C5).⁹ It therefore appears that, in addition to La Madeleine, the data from four other sites are very similar, showing the presence of reindeer during all four seasons, discontinuously at the scale of sites and continuously at the scale of a region. How do we define the boundaries of such a region? These five sites are located in the Vézère and Dronne valleys (Fig. 20), in a temporary zone. If this area was larger, perhaps including other Dordogne and Charente sites, it would still be necessary to reexamine faunal samples. But whether it is larger or not, the year-round presence of reindeer is a characteristic feature that makes this region different from other ones, such as the Paris Basin, Massif Central or Aude Basin. We should note that the reindeer hunting seasons are unclear at the site of Combe Saunière, which is also located in this zone, since useful faunal remains are not numerous there, and are highly fractured (Castel, 1999).¹⁰ This information is therefore essential for such a Solutrean site, whose occupation patterns (short occupations directly

⁹ In one of the Aurignacian levels, four seasons are identified, but these data must be re-examined.

¹⁰ However, from the data and illustrations in Castel, 1999, it seems to us that at least three seasons are represented, and perhaps four (including summer).

REINDEER	PINCEVENT (Level IV-20)											
SKELETAL PARTS	J	J	A	S	O	N	D	J	F	M	A	M
Teeth												
M1 in crypt												
M1 erupting												
DM high relief wear												
M1 erupted												
M1 erupted, 1 ws												
M2 in crypt , M1 3 ws												
M2 erupting												
M2 erupted, 1-2 ws												
Unshed antlers												
Adult male												
With shedding line												
Adult female												
With shedding line												
Fetal long bones												
Diaphysis 47-77 days												
Diaphysis 78-108 days												
Diaphysis 109-136 days												
Diaphysis 137-167 days												
Diaphysis 168-197												
Shed antlers												
Adult male												
Adult female												

Based on end of may calving & mid october mating
ws : worn surface

Fig. 17. Pincevent (IV-20: Upper Magdalenian) - data of Reindeer hunting seasons (since Enloe and David, 1997).

linked to hunting, after Chadelle et al., 1991) could have been different from those at Fourneau du Diable and Laugerie-Haute.

This zone, temporarily bounded to the south by the Vézère valley (between Les Eyzies and Badegoule) and to the North by Fourneau du Diable in the Dronne valley, would be the only identified region in

France where non migrating reindeer would have lived, but it is difficult to determine exactly why and when. There is no easy answer to these questions because once again, these are preliminary chronological boundaries delimited by the sites with available data. Nevertheless, though it may be difficult to identify the cause of this changing mobility,

REINDEER	CANECAUDE (Level II)											
SKELETAL PARTS	J	J	A	S	O	N	D	J	F	M	A	M
Teeth												
M1 in crypt												
M1 erupting												
DM high relief wear												
M1 erupted & unworn												
M1 erupted, 1 ws												
M2 in crypt , M1 3 ws												
M2 erupting												
M2 erupted & unworn/ 1 ws												
Unshed antlers												
Adult male												
With shedding line												
Adult female												
With shedding line												
Fetal long bones												
Diaphysis 47-77 days												
Diaphysis 78-108 days												
Diaphysis 109-136 days												
Diaphysis 137-167 days												
Diaphysis 168-197												
Shed antlers												
Adult male												
Adult female												

Based on end of may calving & mid october mating
ws : worn surface

Fig. 18. Canecaude (CII: Mid Magdalenian) - data of reindeer hunting seasons (since Fontana, 1998, 1999, 2000a).

REINDEER	LE BLOT (Levels 22-34)											
SKELETAL PARTS	J	J	A	S	O	N	D	J	F	M	A	M
Teeth												
M1 in crypt												
M1 erupting												
DM high relief wear												
M1 erupted & unworn												
M1 erupted, 1 ws												
M2 in crypt, M1 3 ws												
M2 erupting												
M2 erupted & unworn/ 1 ws												
Unshed antlers												
Adult male												
With shedding line												
Adult female												
With shedding line												
Fetal long bones												
Diaphysis 47-77 days												
Diaphysis 78-108 days												
Diaphysis 109-136 days												
Diaphysis 137-167 days												
Diaphysis 168-197												
Shed antlers												
Adult male												
Adult female												

Based on end of may calving & mid october mating
ws : worn surface

Fig. 19. Le Blot (C22-34, Protomagdalenian) - data of reindeer hunting seasons (Fontana, unpublished results).

due to a lack of clear chronological limits, we do have indications of what did not cause it. Four of the five mentioned sites where reindeer were hunted year-round were occupied at least during the Gravettian (Abri Pataud), Solutrean (Lauerie-Haute, Badegoule, Fourneau du Diable), Badegoulian (Badegoule) and Magdalenian (Lauerie-Haute, La Madeleine) periods between 30,000 and 15,000 cal BP. It does not appear that these occupations could be correlated to particular climatic events, such as the coldest periods (H1 and H2), since the Gravettian

occupations were earlier. Moreover, if part of the Aurignacian occupations at Abri Pataud indeed show year-round hunting (see above), the lower limit would be in the Middle Pleistocene. For the moment therefore, climatic factors do not seem to offer a clear explanation. Lastly, even if this were the case, how would this correlate with the lower mobility of reindeer?

Are we to conclude that with no chronological and geographical boundaries it is impossible to identify the causes of a limited reindeer

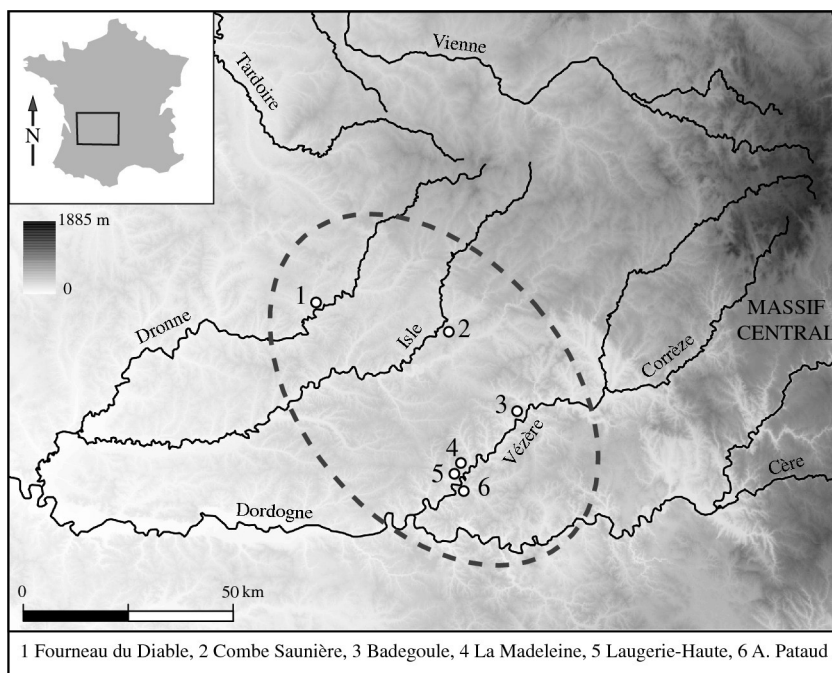


Fig. 20. Temporary zone of Upper Paleolithic sites where reindeer were hunted year-round. Combe Saunière is mentioned because it is located within the area but the data need to be revised.

mobility? Not exactly, because it is first of all associated with a single region. So what characteristic of this region could explain this phenomenon, at least between 30,000 and 15,000 cal BP? Its mild Atlantic climate, in relation to its geographical location, is probably a critical factor: “the Atlantic climate (attenuated temperature amplitude, equability of precipitation) and remotes from glacial fronts (250 km from the Pyrénées, 150 km from the Massif Central) resulted in what can be considered as an attenuated periglacial environment” (Campy et al., 1994). This specific climate of the Dordogne region (and even a larger part of the southwest, see Delpech, 1990) is documented, in addition to sedimentary analyses of karstic deposits (see above), by the discontinuous/seasonal permafrost (Bertran et al., 2013), which is quite different in the Massif Central and Paris Basin. Likewise, the south-western vegetation is described as steppic Mediterranean, in contrast to the Northern environment.¹¹ We should also add that the topographical contrast of the Dordogne zone, with incised valleys surrounded by cliffs, implies diverse environments. If there was a wide variety of food resources close together between the Vézère valley and the western flank region bordering the Massif Central, it is likely that the reindeer did not need to move a lot (Fig. 20). And finally, we should mention the proximity to the first foothills of a mountain range, which constituted a cooler area to which reindeer may have moved in the summer. I believe that this combination of climatic features, topographic characteristics and the proximity to the Massif Central is more significant than each characteristic itself: it would have produced diverse environments within a limited zone (still to be delineated), which would have enabled reindeer to not be long-lived mobile animals.

5. Conclusions

In this article, I had two main objectives. First, to identify the reindeer hunting seasons at the major Magdalenian site of La Madeleine, and to describe and explain my proposed method for reindeer age estimation based on archaeological antlers, cheek teeth and fetal long-bone diaphyses. Second, to present the assumptions I derived from the results of this study in terms of reindeer mobility and the annual nomadic cycle of Upper Paleolithic human populations in the Dordogne region.

My investigation of the validity and accuracy of reindeer hunting season estimations underlined that: 1) the combined use of antlers, teeth, and fetal bones is indispensable for determining all four seasons; 2) hunting seasons are deduced from the minimum number of identified moments; 3) summer hunts are the most difficult to identify, and may go unnoticed in small or poorly preserved samples; 4) winter is difficult to identify without fetal long-bone diaphyses.

The La Madeleine results are similar for levels C25 (Upper Magdalenian) and C27 (Middle Magdalenian), providing evidence of reindeer hunting throughout the year, during all four seasons. These results confirm those of four other sites (with Gravettian to Magdalenian occupations), all of which are located in the same area at distances between 2 and 60 km from La Madeleine. No data from some other well-documented regions (i.e. Paris Basin, Massif Central, Aude Basin) have showed so far year-round reindeer hunting. This suggests that if these data reflect the reality of non-migrating reindeer (rather than a high instability of seasonal ranges, currently not documented among caribou), at least between 30,000 and 15,000 cal. BP, this phenomenon is related to a specific area, temporarily bordered by the Dronne and the Vézère valleys. I hypothesized that this zone (still to be delineated), with an Atlantic climate in the Mammoth Steppe biome during (at least) the Upper Pleniglacial and Oldest Dryas, was a zone of varied landscapes where the living conditions of reindeer would have limited their mobility, perhaps up to the close foothills of the Massif Central. We should note that the existence of diverse environments, suggested by overly dispersed studies (e.g. Campy et al., 1994; Laville et al., 1983, 1986;

Antoine et al., 2016; Moine, 2014), had little effect on reindeer populations between 30 and 12 ka in the Mammoth Steppe biome. In effect, even if reindeer were sometimes less often hunted than other large herbivores (e.g. Saïga in Guyenne sites during the Oldest Dryas, Delpech, 1983), these situations are quite rare and have never been observed at Solutrean sites (H2) where reindeer was always the main hunted prey (Fontana, 2013, in press). But could it be possible that the environmental differences within the Mammoth Steppe biome, between several French zones, did not influence the proportions of species, but rather their behavior, including reindeer mobility?

Finally, future research concerning the behavioral ecology of reindeer during the Middle and Upper Pleistocene is necessary. Unfortunately, it is unlikely that strontium analyses (see Britton et al., 2009, 2011) help to answer the question of migration for the Dordogne valley because the Massif Central (where reindeer could have moved) is an adjacent region: even with strontium values indicating this area, it will be impossible to know the distance of reindeer movements (60 or 300 km?). The view of reindeer as a long-lived mobile species in every region and at all times has long prevailed, starting from early research on Paleolithic societies, and even when Bouchud and Guillien provided evidence of multi-season hunting at many Upper and Middle Paleolithic sites in the Dordogne, Charente and Pyrénées regions. The criticism of Bouchud's method focused on obvious errors related to age determination (Binford, 1973; Delpech, 1983), though this was not especially problematic and his method could be criticized for several other reasons (see detailed discussion in Fontana, 2000a, 2000b). Furthermore, the view of low mobility reindeer did not correspond to our image of the arctic reindeer hunting populations so well documented by Mauss and Beuchat (1904–1905) and used by prehistorians as a model in the absence of valid alternatives, especially concerning reindeer behavioral ecology. Likewise, the settlement and mobility patterns of human groups have never been thoroughly reconsidered since Bouchud's results, and there is thus no alternative to the prevailing conception of highly mobile groups, even in regions such as the Dordogne where the other main resource, flint, was abundant. Given these conditions, who would dare to propose, at least for some of the large rock shelter sites in the Dordogne, that occupations lasted for several months, or even longer? Now, however, in light of the results from La Madeleine and four other sites, which leave no doubt that reindeer were hunted year-round, during all four seasons, our view of the annual nomadic cycle should be revised, beginning with the Solutrean and Magdalenian populations in this zone.

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¹¹ There are very few data from alluvial deposits; the only published study includes the Dronne valley where only three cores document the Oldest Dryas (Leroyer et al., 2006).

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