Special Issue: The Impact of Upper Pleistocene Climatic and Environmental Change on Hominin Occupations and Landscape Use, Part 1

Is the Solutrean Linked to Climatic and Environmental Changes of the Upper Pleniglacial? Searching for the Drivers of the Changes in the Economy and Mobility of Solutrean Groups in Southwestern France

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ABSTRACT

In this paper, I examine the relationship between the emergence and development of the Solutrean and the climatic deterioration in western Europe from 26,500 to 22,000 cal BP. Through a study of the animal resource economy, I aim to identify potential differences in terms of prey choice, hunting and seasonality strategies, and the procurement and processing of animal resources between the Solutrean and the preceding and following cultures. My analysis of 49 faunal assemblages originating from 24 Solutrean sites in France demonstrates that there are no major differences between the Solutrean and these other cultures in terms of reindeer being the dominant prey and hunting strategies. In general, reindeer remained the dominant hunted prey from the end of the Gravettian to the end of the Middle Magdalenian. Any differences were above all regional, though the preference for reindeer was strongest in the Solutrean, at the same time as the prey diversity was the lowest. Reindeer hunting strategies remained non-selective from the Gravettian until the end of the Magdalenian, and the regions where this species was hunted year-round remained the same throughout this time. It is possible that the annual nomadic cycle was based on very low mobility during the cold season and specialized flint procurement during the warm season, but here again, this was probably not specific to the Solutrean. It thus appears that the Solutrean economic system, based on the exploitation of reindeer and lithic raw materials, was not affected by environmental constraints to the point of being significantly modified. To explain this relative economic stasis, I refer to the conditions of the Upper Pleniglacial, which, though it was extreme during the Solutrean, was very cold and dry throughout the period from 30,000 to 18,000 cal BP.

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INTRODUCTION

Humans in the past adapted and responded to climatic and environmental change in various ways. It is not always straightforward to relate changes in climate and environmental conditions to changes in the archaeological record. Archaeologists have for the longest time investigated questions like: How did Paleolithic human groups adapt to changing environments? Is it possible that some features (invention, borrowing, development, abandonment, modification) related to technology, habitat, settlement patterns, economy, or the emergence and disappearance of a culture, were responses to major environmental changes?

An excellent case study to explore the above questions are the responses of hunter-gatherer societies in western Europe between 26,000 and 22,000 cal BP. During the coldest and driest period of the Upper Paleolithic, when northern Europe was devoid of human occupation, human groups lived in southern/western France and on the Iberian Peninsula. They invented a new lithic technology and produced innovative lithic tools and hunting weapon components, as well as specific ornaments. Should we thus consider that these extreme climatic conditions are at the origin of Solutrean culture? More specifically, could the lithic production and technology, animal resource economy, and mobility be

linked to a changing environment to which the Solutrean people adapted? To address these questions, we must first identify the specific features of the Solutrean economic system. In this paper, I address this issue through a study of animal resource exploitation, a topic that is seldom considered in current research. I focus on Solutrean animal resource exploitation, hunting strategies, antler exploitation patterns, seasonal hunting-collecting patterns, and mobility strategies. I then compare these Solutrean features with Gravettian and Magdalenian ones to determine whether they are different and if they are linked to the changing environment.

QUESTIONS AND CONTEXT

CULTURE-ENVIRONMENT RELATIONSHIPS
The complexity of a study of culture-environment relationships begins with a global perspective involving research questions developed in prehistoric archaeology. What are these questions? In general, the task consists of detecting environmental changes, identifying the influence of climatic changes on technical behaviors and their variability, and chronologically correlating the cultural and environmental changes. This is achieved by compiling a multidisciplinary inventory of all the relevant data, sometimes accompanied by radiocarbon dates, to reveal possible correlations between different parameters. The conclusions of such endeavors often lead to two different scenarios. Either the environment is seen as a fundamental factor in the evolution of societies, and climatic fluctuations are correlated with cultural changes, or the environmental factor is negligible in the choices made by human groups who have long liberated themselves from environmental constraints through their ability to adapt their natural resource exploitation strategies and to invent new technical strategies, (e.g., for the Pleniglacial and Tardiglacial in France: Fontana 2018, 2019; Naudinot et al. 2019; Valentin 2008). The society-environment relationship is thus most often presented as an alternative, which is forcibly caricatural. It reduces the complexity of this relationship through time and space to the question of the influence of environmental conditions on humans and their capacity to address the challenges of that which will remain, or not, depending on the author, a dependence on nature.

If this type of approach does not sufficiently consider the complexity of the society-environment relationship, is it also the case for archaeological studies and the data they provide? Whatever the global questions and ideas underlying them, the data generated by archaeologists are used to respond to precise questions relative to the identification of the operational sequence (*chaîne opératoire*) of technological processes, hunted species and carcass processing. This information is then used to identify possible correlations with environmental conditions, whether this is a major topic of the study or not. However, is it reasonable to attempt to correlate such partial and sporadic data with the environmental data? For example, how can a tool production technique, or hunting strategy for which we do not know

the season or the apparent selection of a raw material, be linked to environmental conditions given that they are only one of the many components of an economic system? In the same manner, is it useful to separately consider aspects of each sub-division to observe them, even together, without identifying a global vision of the economic system in question? More precisely, what are challenges of such a study for the Solutrean period?

THE SOLUTREAN AND THE UPPER PLENIGLACIAL ENVIRONMENT
It is debated whether the Solutrean is an adaptation to specific climatic conditions (e.g., Banks et al., 2009; d'Errico et al. 2012; Fontana 2018; Otte and Noiret 2002; Straus 2013; Zilhão 2013). This debate is an ideal case to illustrate the complexity of identifying behavioral modifications and choices that could be linked to a changing environment. The nomadic hunter-gatherer societies in western Europe between 26,000 and 22,000 years cal BP[1] are a good example of the challenges of a study of society-environment relationships. In an environment marked by a major climatic degradation, that of the coldest and driest period of the Upper Paleolithic, some human groups used a new flint production technique that enabled them to manufacture very specific hunting weapon elements and other tools. The groups that adopted these practices were in the minority and were located in southern and western France, and on the Iberian Peninsula, while in the rest of Europe, groups originating from the same Gravettian tradition made different choices. This new entity, identified in 1863 at Laugerie-Haute, itself evolved over 6,000 years on the Iberian Peninsula and 4,000 years in France, as did the climatic conditions. The Proto-Solutreans appear to have been during the period of maximum cold and aridity, at the beginning of the Heinrich 2 event (26,000–24,300 cal BP), while the Solutreans and their successors lived during the Last Glacial Maximum, which was slightly warmer (24,000–18,000 cal BP) and less dry (Figure 1) (Banks et al. 2009; Fontana 2018; Zilhao 2013).

This rare example of the emergence of a Paleolithic culture during a time of significant climatic deterioration increases the challenge of studying the society-environment relationship. It could be formulated as follows: Did climatic deterioration have consequences for the human population? In other words, to what degree were the severe climatic conditions, the changes in lithic tools and their production techniques, or even the economy of animal resources and mobility, linked to each other? We can subdivide this initial challenge into several questions. Did climatic deterioration lead to a modification of the fauna and, consequently, the type of prey, its ethology, its geographic distribution, etc. and thus, the hunting strategies and/or techniques, the hunting weapons, or even the mobility of groups and the organization of their annual cycle in terms of the procurement of various resources and the seasonality of their activities?

These questions appear to boil down to two hypotheses to explain the major changes observed—there is a link between climatic degradation and other modifications (lithic
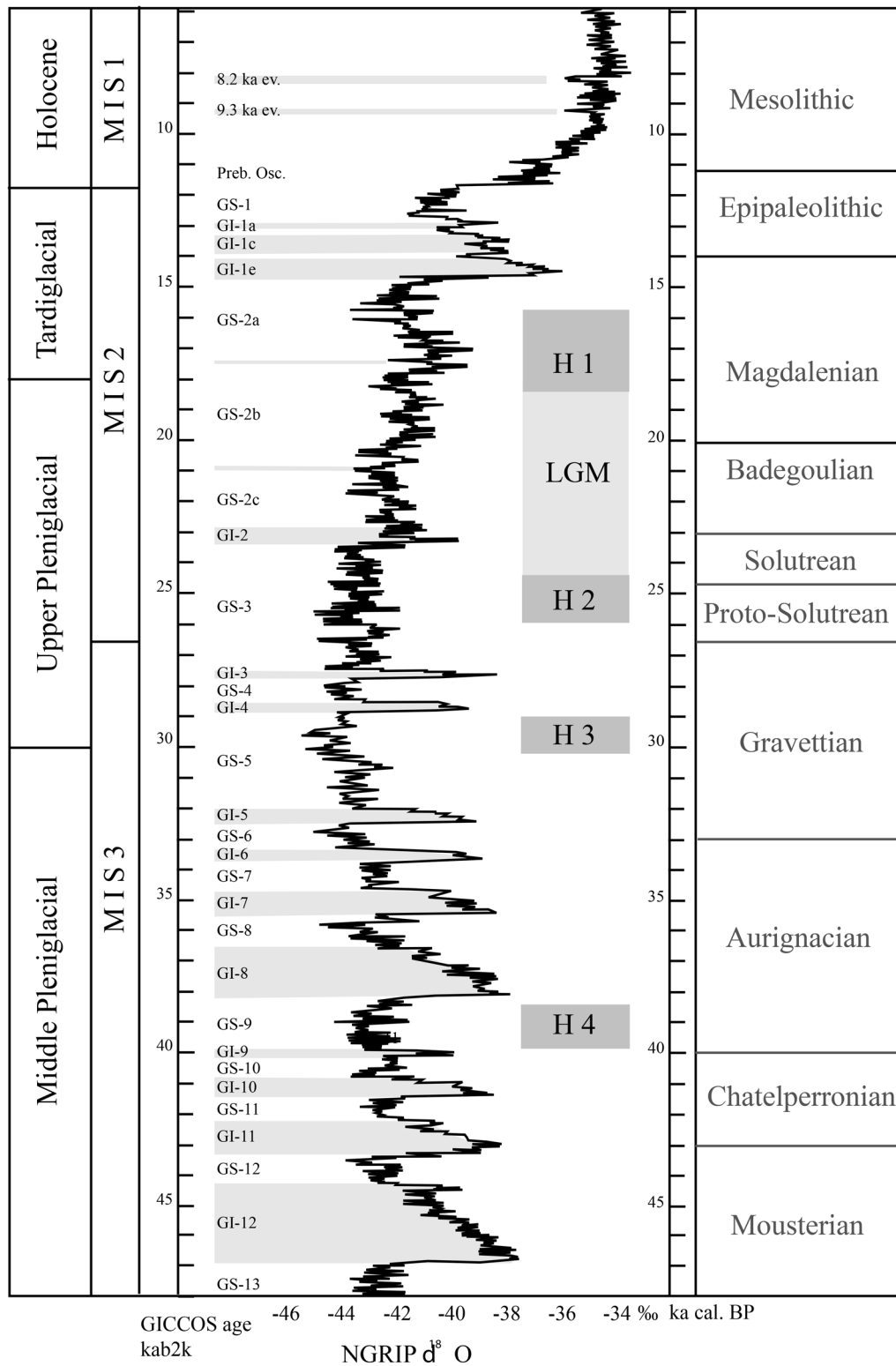
Figure 1. Chrono-climatic and chrono-cultural framework, after Aubry and Almeida (2013) and Blockley et al. (2012). Preb. Osc: preboreal oscillations; GI: Greenland interstadial; GS: Greenland stadial; ev: event.

and bone industries, subsistence, mobility, etc.) or there is not.

To begin, however, it is necessary to verify the existence of specificities in the Solutrean economy before looking for a possible link to the environment. This is my aim

in this paper.

The analysis of the proportion of the dominating game species (reindeer) and the diversity of hunts will make it possible to distinguish whether the Solutreans chose to diversify their subsistence or, on the contrary, to concentrate

their hunting on a single prey species. It is the study of the reindeer hunting strategy, by analyzing reindeer mortality profiles, that will make it possible to test whether a systematic selection of the most profitable individuals (in terms of meat weight, antler size, for example) was practiced. As for the mobility of human groups, which may have been very low (due to hard climatic conditions) or very high (due to presumed dispersed animal resources), this is addressed by studying data on seasonal hunting and the origin of siliceous raw materials.

At the scale of an animal resource exploitation system, I will consider the climatic and environmental features, analyze the data relative to prey animals, reindeer hunting strategies, antler procurement, and the seasonality of resource procurement. I will base this study on an analysis of the zooarchaeological and paleoclimatic data before questioning these data relative to other resources in order to propose a hypothesis concerning the Solutrean annual nomadic cycle.

THE ENVIRONMENT NORTH OF THE PYRENEES BETWEEN 26,000 AND 22,000 CAL BP

CLIMATE, VEGETATION AND LANDSCAPES
The Upper Paleolithic (40,000 to 11,700 cal BP) is contemporary with MIS 3 to 2, and H1 to H4 (see Figure 1). The synthesis of climate and environmental data for the concerned period (Duplessy and Ruddiman 1984; Harrison and Sanchez Goñi 2010; Magny 1995; Masson-Delmotte 2012; Rasmussen et al. 2014; Sanchez Goñi and Harrison 2010; Sanchez Goñi et al. 2002, 2008, 2012) makes it possible to draw up the following picture. The cooling that was accentuated from 400 ka in the Atlantic and Pacific basins did not prevent the significant warming that occurred on the European continent during the interpleniglacial (MIS 3). Cooling again began at 40,000, with a gradual increase in the volume of ice during OIS 2 (26 ka), contemporaneously with a gradual decrease in the temperatures of the atmosphere above Greenland and a weak rate of summer insolation at high altitudes. The ice cap was then stable until 19 ka. The variability of the Dansgaard-Oeschger events (DO: GI+GS, Dansgaard et al. 1984)[2] between 30 and 23 ka continued to modulate the climate, which then became relatively stable between 23 and 19 ka (between the end of H2 and start of H1). This latter period is traditionally called the Last Glacial Maximum (LGM)[3] even if it does not correspond to the most extreme climate of the last glacial period. The recorded values for the atmospheric temperatures above Greenland and the water surface of the western European coastlines are much higher than those of the Heinrich events and those of some interstadials. In reality, the maximum cold and aridity occurred around 26,000 and 25,000 cal BP. In Europe, between 25,000 and 23,000 cal BP, the environment was very dry and cold, the extension of the permafrost was at its greatest and the sea level at its lowest (-130m). The relative humidity then increased by stages until around 15,000 cal BP. An abrupt amelioration occurred at around 13,500 cal BP after a major glacial flood

and before the last cooling of the Younger Dryas at around 11,000 cal BP (see Figure 1).

The Solutrean groups thus lived during the Upper Pleniglacial period, which was characterized by the generalized development of continental ice caps in the northern hemisphere, lowering the sea level to its minimum. The coldest period is identified in middle Europe between 25,000 and 22,000 cal BP and a climatic amelioration episode has been identified. The low insolation rate during the spring and summer, as well as significant aridity, were associated with more or less continuous permafrost covering the whole of France except for the Mediterranean and Atlantic coastal zones (Andrieux et al 2016; Bertran et al 2013; Van Vliet Lanoë 2005, 2007; Van Vliet Lanoë et al. 2001, 2005, 2018) (Figure 2).

Whether originating from peat bogs, lakes[4] or marine cores, changes in vegetation are recorded mainly through high-resolution pollen and microcharcoal data analyses (e.g., Sanchez Goni and Harrison 2010). Even marine pollen assemblages thus provide a reliable image of the European regional vegetation, in contrast to samples originating from karst fills, whose interpretation in terms the vegetal environment remain controversial (e.g., Sanchez Goñi 1999). The study of western European marine cores thus indicates that each stage of the GS and Heinrich events was dominated a graminaceous steppe in western France and a semi-desertic environment south of the Iberian Peninsula. The coldest average monthly temperatures are estimated at 10°C below current temperatures, and the precipitations were less than half (400mm). Recent pollen analyses identify no warming between 25,000 and 15,000 cal BP, but a very cold and dry period (Elenga et al. 2000; Fletcher et al. 2010; Sanchez Goñi 1991, 1994, 1996). According to all the continuous Mediterranean and Euro-Siberian palynological sequences, all the landscapes were open, invalidating the hypotheses of the Laugerie and Lascaux interstadials (Leroi-Gourhan 1968). The vegetal response to climatic oscillations was immediate and rapid:

> "Pollen records from marine cores from the northern extratropics confirm that there is no lag between the change in climate and the vegetation response, within the limits of the dating resolution (50-100 years)" (Harrison and Sanchez Goñi 2010: 2957).

In a cold and dry steppe environment, the Solutreans (and Badegoulians) lived in an open steppe environment where the vegetation was dominated by herbaceous species[5], qualified as a cold steppe (d'Errico et al. 2012; Sanchez Goñi 1991, 1994, 1996, 1999). At 15,000 cal BP, the vegetation finally started to change from tundra to a shrub-steppe.

ANIMAL POPULATIONS
In cave and rock shelter deposits, the presence of micro-mammals and birds characteristic of cold environments[6] confirm the existence of very cold and dry environmental conditions between 24,000 and 15,000 cal BP (Chaline 1977; Jeannet 2010; Mourer-Chauviré 1975). In both cases, these
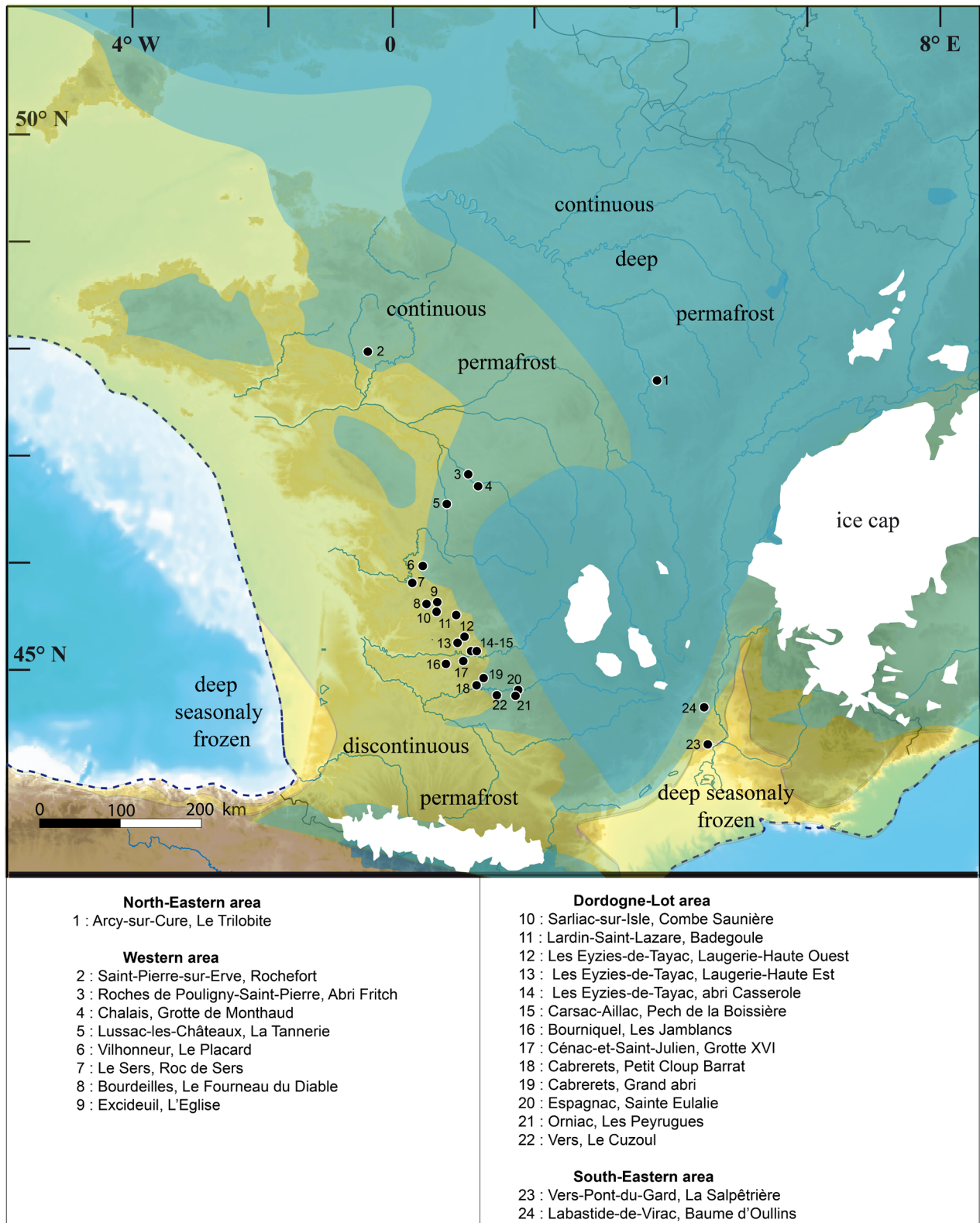
Figure 2. Map of Solutrean sites where the fauna is recorded (limits of permafrost after Van Vliet-Lanoë et al. 2018).

are cold species representing a Euro-Asian boreal faunal emigration. However, their presence, as well as the typical associations, is characteristic not only of this very cold period, 25,000–15,000 cal BP, as they have been identified at the end of the Würm III and in the Late Glacial as well.

The "mammoth steppe"—a cold steppe-type environment—of the European Pleistocene corresponds to an extinct ecosystem characterized by the coexistence of numerous large mammal species, which today exist in distinct environments (at least those taxa, which are not extinct).

The estimated biomass of this ecosystem is very high, and especially, far above that of current northern latitudes (Guthrie 1968, 2001). Below I investigate how this environment is represented in the 26,000–22,000 cal BP period by analyzing faunal remains from France.

Methods
To study the large mammal fauna, I collected published and unpublished data and assemblages were included in this databse based on the following criteria: (1) fauna is preserved; and, (2) species are identified and quantified or at least the dominating species is reported. Based on these criteria, my database included 55 assemblages[7] from 24 sites (Table 1). Only NISP (Number of Identified Specimen) is reported because MNI (Minimal Number of Individuals) are not available for a large part of the assemblages, which in turn prohibits the calculation of some indices.

I did not record the lagomorphs and carnivores other than Canids, due to the heterogeneity of the data linked to differential collection, species determination, and the non-anthropogenic origin of some remains. Moreover, I inventoried the Canids because they are identified in nearly all sites (see Table 1), but I had to record them in a single category because the species, i.e., arctic fox (*Alopex lagopus*), red fox (*Vulpes vulpes*) or wolf (*Canis lupus*), are not always mentioned or distinguished. I do not consider the lack of recording lagomorphs and small carnivores as a problem for my analysis, because normally these remains are very poorly represented in the assemblages, and, thus, not including them does not alter the representativeness of the calculated diversities[8].

All these sites are located in regions in which Solutrean sites have been identified, except for the Pyrenees (poorly documented, see Fontana 2018)—to the north-west in Mayenne, in the southern Paris Basin, the north/north-east of the Massif Central, the lower Rhone Valley, the Creuse Valley, and the greater South-West (see Figure 2).

Results
For the large herbivores, the data yield two main lines of information. First, reindeer (*Rangifer tarandus*) is the most frequently hunted large herbivore—it dominates in 47 of the 49 assemblages analyzed and it represents more than 50% of the remains in 46 assemblages, with the exception of Levels 5 and 6 at La Salpêtrière (Table 2). Second, its preponderance is overwhelming, reaching more than 62% in 42 of the 49 levels (Figure 3). This is a unique situation at the scale of the Upper Paleolithic in France, which has been previously noted (Fontana 2013), and which is confirmed as the study corpus is enlarged (Fontana 2018). While reindeer is present in the environment throughout the Upper Paleolithic, its populations increase at the beginning of the Upper Pleniglacial, which corresponds to the end of the Gravettian in France (Delpech et al. 2000; Delpech and Texier 2007). Finally, the abundance of reindeer is accompanied by the presence of horse, which is always the second most frequent ungulate represented. This reindeer-horse association represents more than 80% of the corpus in 44 of the

48 assemblages analyzed and between 70 and 80% in three levels at La Salpêtrière and in that of Pech de la Boissière (Figure 4).

The large fauna present in the environments frequented by the Solutreans living north of the Pyrenees is thus distinguished, at the scale of the Upper Paleolithic, by a formerly unknown dominance of reindeer, always followed by horse and associated with the new presence of saiga antelope. However, it is not possible to show an evolution of faunal groups during the period of 26 to 22 ka cal BP, which would represent an evolution of the environment and thus of the climatic conditions, because the study and comparison of the fauna in several Solutrean levels within a single site cannot yield reliable information unless certain conditions are met. These conditions are an understanding of the site formation processes; knowledge of the volumes excavated; AMS radiocarbon dates obtained from specifically determined osseous remains; and, testing of the significance of the supposed quantitative differences. The data corpus currently available for the Solutrean thus temporarily prohibits any attempt to show environmental changes, and the attempt by Delpech (2012) to define a "biostratigraphy" for Laugerie-Haute supports this idea. In effect, the NGrip recording that identified this severe cold at 26,000–22,000 cal BP indicates only one significant modification, at GI-2, in the form of a warming period at 23–22.5 ka cal BP, also identified in the loess sequences in northern Europe (e.g., Antoine et al. 2009; Haesaerts et al. 2016). Consequently, the supposed "gradation of the climate severity" (Delpech 2000) between the Early Solutrean and the Magdalenian 0, based on the study of the remains in the Solutrean sequence of Laugerie-Haute Est, is difficult to conceive, the end of the Solutrean indeed corresponding to the only warming of the 24,000–18,000 cal BP period (Antoine and Locht 2015).

Concerning the issue of the reindeer size variations, which could attest to changes in climatic conditions, if the reindeer contemporary with the Solutreans suffered from the cold and dry conditions between 26,000 and 23,000 cal BP, and if these severe conditions affected their size, this decrease would not have been recorded in the osseous remains until around 21,700 cal BP, at the start of the Magdalenian (Weinstock 2000). If this is confirmed, we would need to know if there is a link between the minimum size of reindeer at Laugerie-Haute and the minimum nitrogen 15 values ($\delta^{15}N$) of reindeer, also subsequent to the Solutrean (cf *infra*) at around 22,000 years.

To conclude, the large mammal species represented in the Solutrean sites located to the north of the Pyrenees confirm that the period from 26,000 to 22,500 was very cold and dry. We should note that the isotopic analyses of the faunal remains of large mammals, realized for the sites in south-western France, confirm the existence of a very cold climate, reaching its maximum during the Solutrean. The nitrogen 15 ($\delta^{15}N$) ground values, linked to a slowed microbiological activity, are particularly low in arctic environments. However, the $\delta^{15}N$ values for large herbivore collagen are at their lowest between 21,000 and 18,000 BP,

TABLE 1. COUNT OF THE TAXA IDENTIFIED IN THE 24 SOLUTREAN SITES RECORDED CONTAINING FAUNAL REMAINS (large herbivores and canids) AND SHANNON-WIENER DIVERSITY INDICES.

Sites/Assemblages - levels	Reind.	Horse	Bov.	Ibex	Cham.	Saiga	Red d.	Roe d.	W. b.	Mam.	Rhino	Canid	NISP	H
North-Eastern area														
1. Le Trilobite - 4 (Breuil 1911)	XXX	X	X							X		X		
Western area														
2. Rochefort (Bémilli & Hinguant 2012) - 4.1-4.4	475	306	2	24			7	4	3	3	2	31	857	1.047
3. Fritsch (Bayle 2000) - 7a-10b	491	36		3		17	1					16	564	0.542
4. Monthaud (Pradel 1967) - 3 levels	XXX	X	X	X	X		X					X		
5. La Tannerie (Pradel 1950)	XXX	X	X	X	X	X	X					X		
6. Le Placard (Griggo unpubl.)														
Placard Y - 5	551	97	5			18						7	678	0.6265
Placard Y - 6	228	45	1			4						3	281	0.6443
Placard Y - 7	44	8											52	0.4293
Placard Y - 8	92	15	2										109	0.4894
Placard Y - 9	95	1											96	0.3246
Placard Z - 1	207	106	3			2						3	321	0.768
Placard Z - 2	35	13				1							49	0.6718
Placard Z - 3	155	43	2			4						6	210	0.77
Placard Z - 4	112	32										16	160	0.8018
Placard Z - 5	162	103				3						38	306	1.008
Placard Z - 6	287	34				2						25	348	0.605
Placard Z - 7	232	3	1									2	238	0.1432
7. Roc de Sers TGR (Fontana et al. unpubl.)	3511	466	76	3		14						2	4072	0.4787
8. Fourneau du diable (Fontana 2001)														
FDD Lower terrace	559	86	5						1			3	654	0.4728
FDD Upper terrace - bottom level	466	116				1	1			1		1	586	0.546
FDD Upper terrace - middle level	963	278	11			1	11						1264	0.6285
FDD Upper terrace - upper level	1186	243	4	3		10						21	1467	0.593
9. L'Eglise - Up. Sol (Delpech 1983)	126	63	26				3	1	1			14	234	1.202
Dordogne-Lot area														
10. Combe Saunière - IV (Castel 1999)	3721	517	92	3	83	44	43		1			612	5116	0.943
11. Badegoule - Sol I-IV (Bouchud 1966)	XXX	X	X	X	X		X		X	X	X	X	6500	
12. Laugerie-Haute Ouest														
LH O - 1-3 Bordes exc. (Delpech 1983)	378	4	1				3			20		7	413	0.392
LH O - 4-7	1014	8								1		14	1037	0.124
LH O - 8-11	437	22		3						46		5	513	0.563
LH O - 11a	121	12		1						11		2	147	0.4164
LH O - 12a-b	1085	27		2			1			6		5	1126	0.195
LH O - 12c-d	537	10					1			7			555	0.171
LH O - Mid. Sol. Peyrony exc. (Madelaine 1989)	789	123	10	6	1	4	4			69		1	1007	0.766
13. Laugerie-Haute Est (Delpech 1983)														
LH E - 21-23	41	14										1	56	0.6467
LH E - 25-28	134	23		1								1	159	0.4876
LH E - 29-30	257	9	1	5									272	0.261
LH E - 31	319	23	2	6	2		2					2	356	0.461
14. Casserole - 7-8 (Castel 2013)	XXX	X	X										28	
15. Pech de la B. - Up. Sol II (Madelaine unpubl.)	29	1	4				1	6					41	0.934
16. Les Jamblancs - 3 (Drucker et al 2000)	354	58	12				1	8		1		3	437	0.6579
17. Grotte XVI - As (Grayson & Delpech 2003)	409	23	4	5	18	3	22	14	5				503	0.826
18. Petit Cloup Barrat - 8a (Castel et al 2006)	XXX	X		X									24	
19. Grand abri de Cabrerets (Castel 2013)	XXX	X		X	X								90	
20. Sainte Eulalie - IV (Delpech 1983)	51	1	2	3	1		1						59	0.6
21. Cuzoul de Vers - 29-31 (Castel 1999, 2013)	300	4		9	21							1	335	0.44
22. Les Peyrugues (Juillard unpubl., Castel 2013)														
Les Peyrugues - 10	31			3	2		1						37	0.607
Les Peyrugues - 11-14	94			11				1					106	0.386
South-Eastern area														
23. La Salpêtrière														
La Salpêtrière - d (Bémilli 1995)	242	94	1	18			1					1	357	0.815
La Salpêtrière - e (Rillardon 2010)	19	24	5	2								1	51	1.154
La Salpêtrière - i-v (Rillardon 2010)	2013	511	8	7	2		26					3	2570	0.607
La Salpêtrière - 24 (Rillardon 2010)	43	13		1									57	0.621
La Salpêtrière - 6 (Rillardon 2010)	65	107	6	55	3							4	240	1.267
La Salpêtrière - 5 (Rillardon 2010)	20	19	2	13	1								55	1.269
La Salpêtrière - 18-7 (Rillardon 2010)	33	13	2				11						59	1.086
24. La Baume d'Oullins (Bémilli 1995)														
La baume d'Oullins - d	450	23	1	45	27		24						570	0.806
La Baune d'Oullins - LCR1	39	1		9									49	0.573

X: present (if NISP not reported in literature), XXX: present and dominant species (if NISP not reported in literature), Reind: Reindeer, Bov: Bovid, Cham: Chamois, Red d: Red deer, Roe d: Roe deer, Wb: Wild boar, Mam: Mammoth, Rhino: Woolly Rhino, H.: Shannon-Weaver Index

TABLE 2. REINDEER PROPORTION IN THE
49 SOLUTREAN ASSEMBLAGES (18 sites) RECORDED.

SITES	Total	Ungulates	Reindeer	Rein/Ung	Reindeer/T
49 assemblages	NISP	NISP	NISP	% NISP	% NISP
Rochefort levels 4.1-4.4	857	826	475	57.51	55.43
Fritsch levels 7a-10b	564	548	491	89.6	87.06
Le Placard. area Y					
level 5	678	671	551	82.12	81.27
level 6	281	278	228	82.01	81.14
level 7	52	52	44	84.62	84.62
level 8	109	109	92	84.4	84.40
level 9	96	96	95	98.96	98.96
Le Placard. area Z					
level 1	321	318	207	65.09	64.49
level 2	49	49	35	71.43	71.43
level 3	210	204	155	75.98	73.81
level 4	160	144	112	77.78	70.00
level 5	306	268	162	60.45	52.94
level 6	348	323	287	88.85	82.47
level 7	238	236	232	98.31	97.48
Roc de Sers TGR	4072	4070	3511	86.27	86.22
Fourneau du diable					
lower terrace	654	651	559	85.87	85.47
upper terrace. bottom level	586	585	466	79.66	79.52
upper terrace. middle level	1264	1264	963	76.19	76.19
upper terrace. upper level	1467	1446	1186	82.02	80.85
Combe Saunière level IV	5116	4504	3721	82.62	72.73
L'Eglise Upper Sol.	234	220	126	57.27	53.85
Badegoule Sol. IV	6500	6400	6200	96.88	95.38
Laugerie-Haute Ouest					
levels 12a et 12b	1126	1121	1085	96.79	96.36
levels 12c et 12d	555	555	537	96.76	96.76
level 11 A	147	145	121	83.45	82.31
levels 11-8	513	508	437	86.02	85.19
levels 7-4	1037	1023	1014	99.12	97.78
levels 3-1	413	406	378	93.1	91.53
f. Peyrony Middle Sol.	1007	1006	789	78.43	78.35
Laugerie-Haute Est					
level 31	356	354	319	90.11	89.61
levels 30-29	272	272	257	94.49	94.49
levels 28-25	159	158	134	84.81	84.28
levels 23-21	56	55	41	74.55	73.21
Pech de la Boissière Upper Sol. II	41	41	29	70.73	70.73
Les Jamblancs level 3	437	434	354	81.57	81.01
Grotte XVI level AS	503	503	409	81.31	81.31
Ste Eulalie level IV	59	59	51	86.44	86.44
Cuzoul de Vers levels 30-31	335	334	300	89.82	89.55

**TABLE 2. REINDEER PROPORTION IN THE
49 SOLUTREAN ASSEMBLAGES (18 sites) RECORDED (continued).**

SITES	Total	Ungulates	Reindeer	Rein/Ung	Reindeer/T
49 assemblages	NISP	NISP	NISP	% NISP	% NISP
Les Peyrugues					
level 10	37	37	31	83.78	83.78
levels 11-14	106	106	94	88.68	88.68
Salpêtrière					
level d	357	356	242	67.98	67.79
level e	51	50	19	38	37.25
levels i-v	2570	2567	2013	78.42	78.33
level 24	57	57	43	75.44	75.44
level 6	240	236	65	27.54	27.08
level 5	55	55	20	36.36	36.36
levels 18-7	59	59	33	55.93	55.93
Baume d'Oullins					
level d	570	570	450	78.95	78.95
level LCR1	49	49	39	79.59	79.59

or 25,200 and 21,500 cal BP, for all species except reindeer, whose values are nonetheless very low and continued to decrease during the subsequent 2000 years (Drucker 2001). The carbon-13 values ($\delta^{13}C$), representative of diet, confirm the specificity of reindeer, whose $\delta^{13}C$ is always higher due to their consumption of lichen.

Nevertheless, according to current knowledge, these fauna do not represent the maximum cold and aridity that occurred in the first half of the period. Reindeer, the dominant large herbivore, occupied this steppe-tundra environment where lichen was abundant, along with horses, which evolved in partly different areas to feed on high grasses. Bovids, ibex, chamois, and red deer were less frequent,

while saiga antelope was the only species in competition with reindeer, as is shown by the similarity of their $\delta^{13}C$[9] values (Drucker 2001).

What about the presence of taxa indicating temperate environments such as wild boar (*Sus scrofa*) and roe deer (*Capreolus capreolus*) and to a lesser degree, chamois (*Rupicapra rupicapra*) and red deer (*Cervus elaphus*)? Of 55 qualitatively documented assemblages, wild boar is present in 6 of them and roe deer in 4 levels, the chamois in 17, and the red deer in 25 (see Table 1). The existence of areas subject to less dramatic climatic conditions, where temperate species (roe deer, wild boar, forest carnivores) could take refuge, has
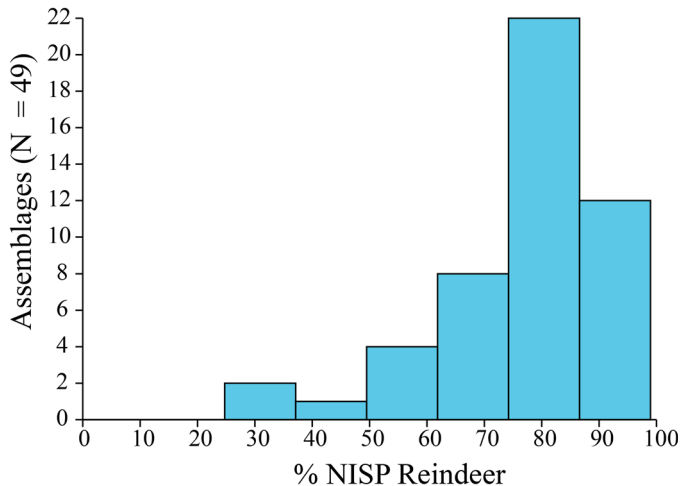
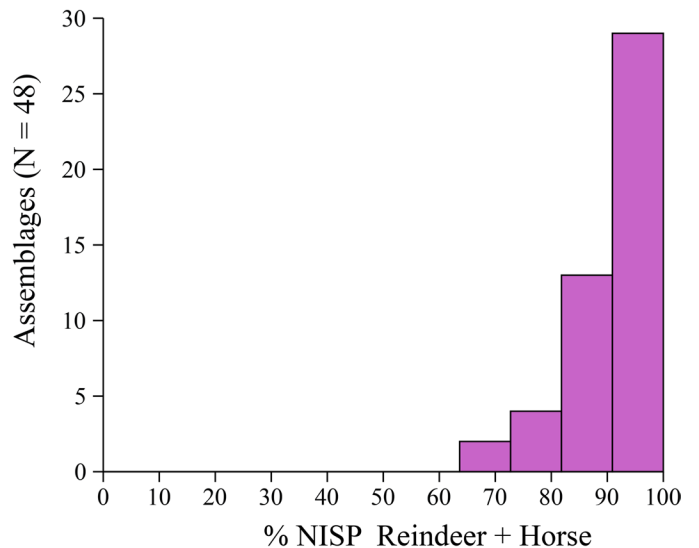Figure 3. Proportion (%NISP) of reindeer in the 49 Solutrean assemblages.

Figure 4. Proportion (%NISP) of reindeer and horse together in the 48 Solutrean assemblages.

Sites (levels)	Total	Chamois	
	NISP	NISP	% NISP
Combe Saunière (IV)	5116	83	1.62
LHO (middle Sol.)	1007	1	0.10
LHE (31)	356	2	0.56
Grotte XVI (As)	503	18	3.58
Sainte Eulalie (IV)	59	1	1.69
Cuzoul de Vers (29-31)	335	21	6.27
Les Peyrugues (10)	37	2	5.41
La Salpêtrière (i-v)	2570	2	0.08
La Salpêtrière (6)	240	3	1.25
La Salpêtrière (5)	55	1	1.82
Oullins (d)	570	27	4.74
NQ : Tannerie, Monthaud, Badegoule (3 levels), Cabrerets			

Sites (levels)	Total	Red deer	
	NISP	NISP	% NISP
Rochefort (4.1-4.4)	857	7	0.82
Fritsch (7a-10b)	564	1	0.18
FDD up.ter .(middle)	1264	11	0.87
FDD up.ter. (bottom)	586	1	0.17
Combe Saunière (IV)	5116	43	0.84
LH O (1-3)	413	3	0.73
LH O (12a-b)	1126	1	0.09
LH O (12c-d)	555	1	0.18
LHO (middle Sol.)	1007	4	0.40
LH E (31)	356	2	0.56
L'Eglise (upper Sol.)	234	3	1.28
Pech (upper Sol. II)	41	6	14.63
Les Jamblancs (3)	437	8	1.83
Grotte XVI (As)	503	22	4.37
Sainte Eulalie (IV)	59	1	1.69
Les Peyrugues (10)	37	1	2.70
La Salpêtrière (d)	357	1	0.28
La Salpêtrière (i-v)	2570	26	1.01
La Salpêtrière (18-7)	59	11	18.64
Oullins (d)	570	24	4.21
NQ : Monthaud, Tannerie, Badegoule, (2 levels), Oullins CCL1			

Sites (levels)	Total	Wild boar	
	NISP	NISP	% NISP
Rochefort (4.1-4.4)	857	3	0.35
FDD low.ter.	654	1	0.15
Combe Saunière (IV)	5116	1	0.02
L'Eglise (upper Sol.)	234	1	0.43
Grotte XVI (As)	503	5	0.99
NQ : Badegoule (1 level.)			

Sites (levels)	Total	Roe deer	
	NISP	NISP	% NISP
Rochefort (4.1-4)	8547	4	0.05
L'Eglise (upper Sol.)	234	1	0.43
Grotte XVI (As)	503	14	2.78
Les Peyrugues (11-14)	106	1	0.94

*Figure 5. Frequency (NISP) and proportion (%NISP) of chamois (*Rupicapra rupicapra*), wild boar (*Sus scrofa*), roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) in Solutrean sites.*

not been demonstrated. First of all, these remains are always limited to a few and never represent more than 1% for wild boar, 2.78% for roe deer, 6.27% for chamois, and 5% for red deer—with two exceptions related to assemblages with low sample size, i.e., less than 60 specimens (Figure 5). Secondly, these four species are not systematically associated, even two by two. Finally, it is possible that in the few Solutrean levels topped by contemporary levels of more temperate environments (as an example, during the Upper Magdalenian in the Bölling), the origin of some remains might be intrusive, just as in the case of reworked layers. The radiocarbon dating of the remains of such species has to become systematic in the sites where the wildlife spectrum of Solutrean levels is specific[10]. This is the only way to settle the question of the existence of supposed refuges or more temperate zones, which is a persistent idea, despite the studies of animals and plants, off-site or intra-site, which demonstrate that it is the proportion, and not the presence, of these mesophilic or temperate taxa that is significant (e.g., Mourer-Chauviré 1975; Sanchez Goñi 1999).

Let us now attempt to determine if the Solutreans se-lected a specific prey animal, and to what degree they represent the exploitation of animal resources, the economic system, and the mobility of human groups between 26,000 and 22,000 cal BP.

ANIMAL RESOURCE ECONOMY ANDMOBILITY: SPECIFIC SOLUTREAN FEATURES?

Did the Solutreans make specific choices in terms of resource procurement (availability, accessibility, techniques), resource exploitation (organization of seasonal activities, manufacturing techniques, selection and management of products), mobility (living and habitable spaces, frequency and duration of movements), and habitation (location, modifications)? I do not intend to respond to all aspects of this question, but to reveal possible differences relative to the preceding periods in terms of the hunted species, hunting strategies, and antler exploitation, before proposing a hypothesis concerning the annual nomadic cycle of the Solutreans.
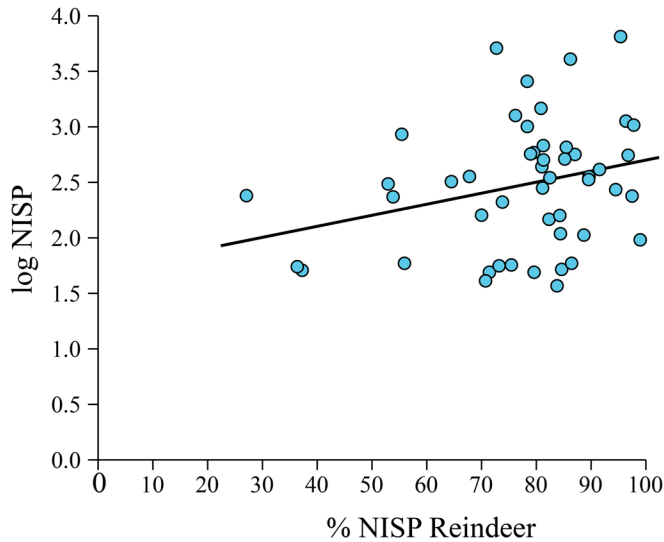
Figure 6. Relationship between the reindeer proportion (%NISP) and the sample size (log NISP) of the 49 Solutrean assemblages.
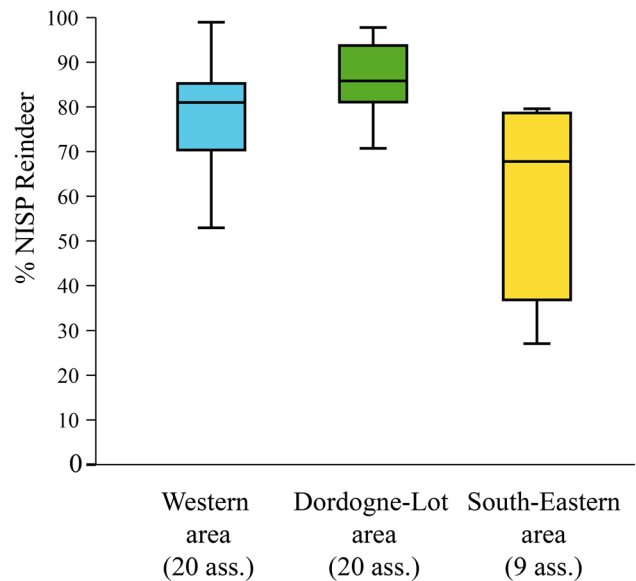

Figure 7. Range of reindeer proportion (%NISP) in the Solutrean assemblages of the three areas.

THE LARGE FAUNA HUNTED NORTH OF THE PYRENEES BETWEEN 26,000 AND 22,000 CAL BP

Hunted Species

Reindeer was the most hunted animal at all sites except for La Salpêtrière (in three out of seven assemblages), and it was hunted in very high numbers, representing more than 50% of the remains in 46 of the 49 levels analyzed (see Table 2 and Figure 3). This is true regardless of the number and duration of the occupations because there is no relationship between the faunal samples sizes and the proportion of reindeer as shown in Figure 6[11] (r^2=0.07, p=0.067). The proportion varies in the recorded regions, with significant differences as evidenced by the Mann-Whitney U test—between the South-Eastern and Western areas (U=31; p=0.0079), between the Dordogne-Lot and South-Eastern areas (U=18; p=0.00075) and between the Western and Dordogne-Lot areas (U=127; p=0.04986) (Figure 7 and see Figure 2). Reindeer is more often hunted in the great West area (western and Dordogne-Lot) than in the South-Eastern area where the number of reindeer hunted is also more variable. Furthermore, the proportion of reindeer is slightly lower and more variable in the center-west relative to the Dordogne-Lot sites. These differences apply to horse as well, as it is systematically the second most dominant prey when it is not the first. Horse remains never reach 45% and are below 23% in 38 of the 48 assemblages analyzed (Figure 8 and see Table 1). The regional differences are just as clear—horse is more often hunted in South-Eastern area, and with great variability, though its proportion is never higher than 15%, except for one case in the Dordogne-Lot region, which is well below the proportion in the Western area, which attains 36% at the Rochefort Cave (Figure 9). The Mann-Whitney U test clarifies this trend—there is a significant difference between the Western and Dordogne-

Lot areas (U=59; p=0.0002) and between the Dordogne-Lot and South-Eastern areas (U=24; p=0.0027), while there is no significant difference between the Western and South-Eastern areas (U=60; p=0.1643).

The number of large herbivore species hunted varies from two to nine. In this study, I do not include the three large herbivores for which hunting is not demonstrated (muskox, mammoth, woolly rhinoceros), or canids, whose origin and mode of procurement is still poorly understood. More than two-thirds of the 48 assemblages (71%) contain between three and five taxa (Figure 10), while only four sites contain seven to nine taxa (Rochefort, Combe Saunière, Grotte XVI, Laugerie-Haute Ouest Middle Solutrean). The relationship between the number of identified taxa and the sample size is usually asymptotic—the number of taxa increases linearly with the NISP up to a certain threshold, and from this point on, increases much more slowly (Lyman 2008). This is not the case for the corpus of Solutrean sites recorded as shown in Figure 11 (r^2=0.208; p=0.001)—the majority of sites (71%) have three to six taxa, regardless of their NISP (from 37 to 4,072) and among the eight sites for which the NISP is greater than 1000, only two have more than six taxa. While, in this corpus, the number of taxa thus does not depend on the sample size, it is difficult to know why, because they are very different (recent excavations/sieving, intrusive pieces and/or disturbances, several levels in one). Finally, no significant regional difference is observable in terms of the number of taxa.

On the other hand, the presence of two marginal species could attest to regional variations in environment. Chamois is less well represented in the Western area (two or three sites out of nine) than in the Dordogne-Lot sector (nine sites out of 13, see Figure 5). Saïga antelope, absent in all the levels of the two sites analyzed in South-Eastern area, is present in five of the nine sites in the Western area,
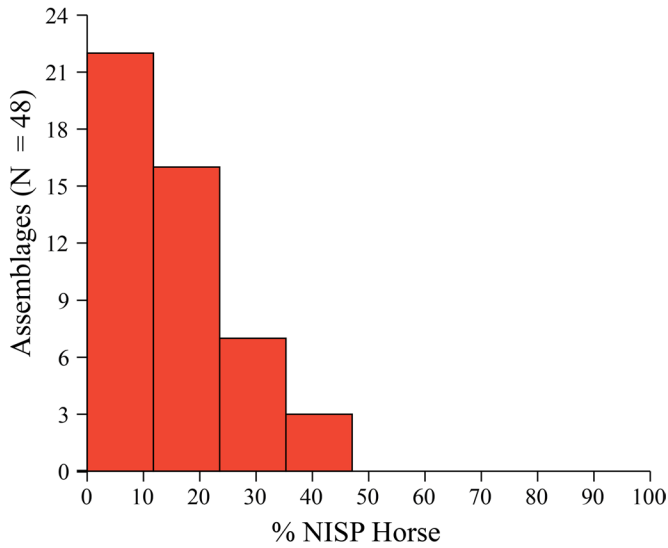
Figure 8. Horse proportion (%NISP) in the 48 Solutrean assemblages recorded.
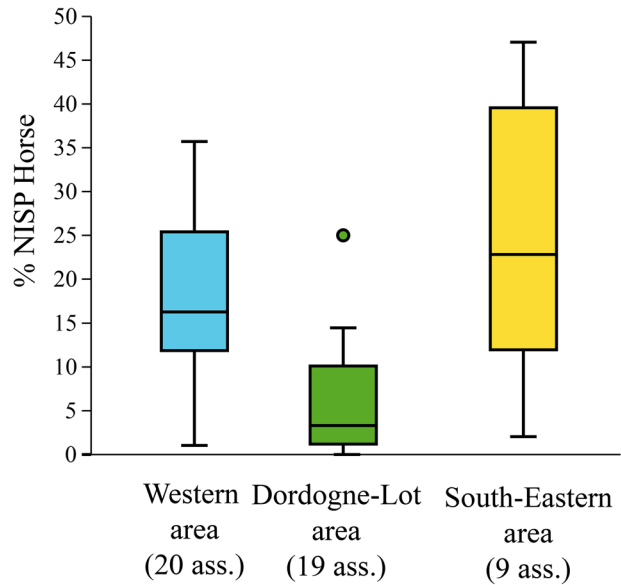

Figure 9. Range of horse proportion (%NISP) in the Solutrean assemblages of the three areas.

which is much greater than in the South-West (five out of 13) (see Table 1). Figure 12, which presents the faunal spectra of three sites, illustrates the qualitative and quantitative characteristics of these three areas.

The species hunted by the Solutreans are identical to those hunted throughout the Upper Paleolithic[12] (Delpech 1981, Fontana 2018), with reindeer being the dominant prey in the recorded occupations. Indeed, a recent study, based on 256 assemblages from 17 sites (Fontana 2019) has demonstrated that reindeer remained the dominant hunted prey (50% to 80% NISP, as an average of each period) from the end of the Middle/final Gravettian (date to be determined, ca 26,000 cal BP) to the end of the Middle Magdalenian (14,500 cal BP). But if there is no *major* change during the Solutrean, as reindeer is still the main hunted game, there is a difference in the low variability of hunts, as rein-

deer %NISP is between 50% and 80%, except for three of the 49 assemblages (Figure 13)[13].

Diversity

Let us now look at the diversity of the hunted animals. There are many ways to quantify diversity (e.g., Daget 1976; Hammer and Harper 2006; Legendre and Legendre 1984, 1998; Magurran 1988). Here, we quantify diversity using the Shannon index (H), which is much less dependent on the actual number of taxa (Shannon and Weaver 1949; Spellerberg and Fedor 2003). In fact, only the real number of individuals (which is not the MNI) should be used, but archaeozoologists usually only have NISP counts, as it is the case for most Solutrean series.
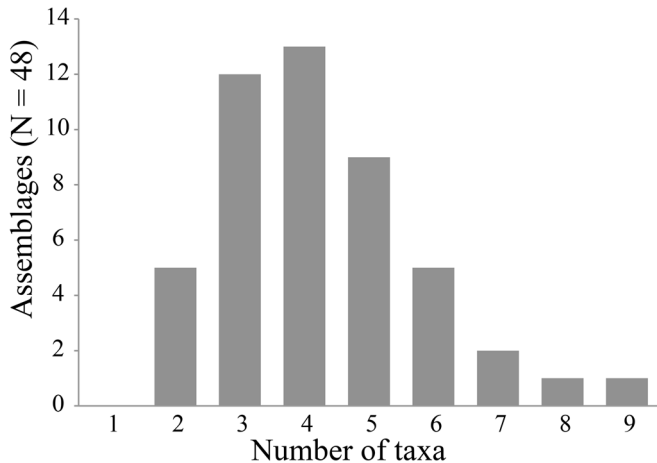
Figure 10. Representation of the number of taxa for the 48 Solutrean assemblages.
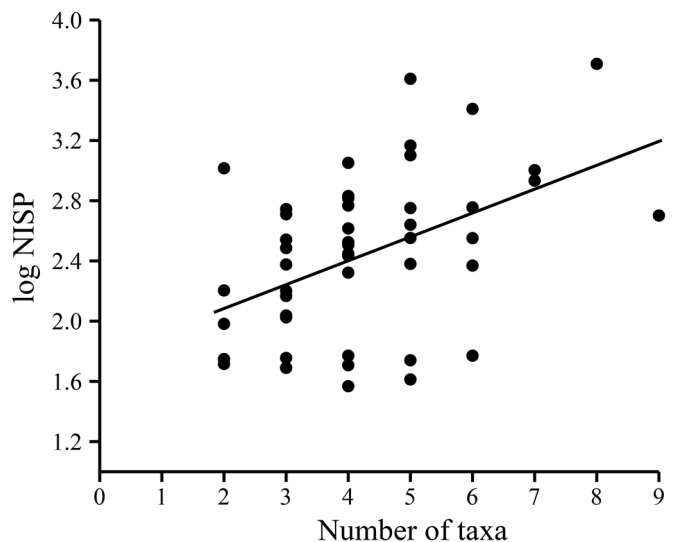

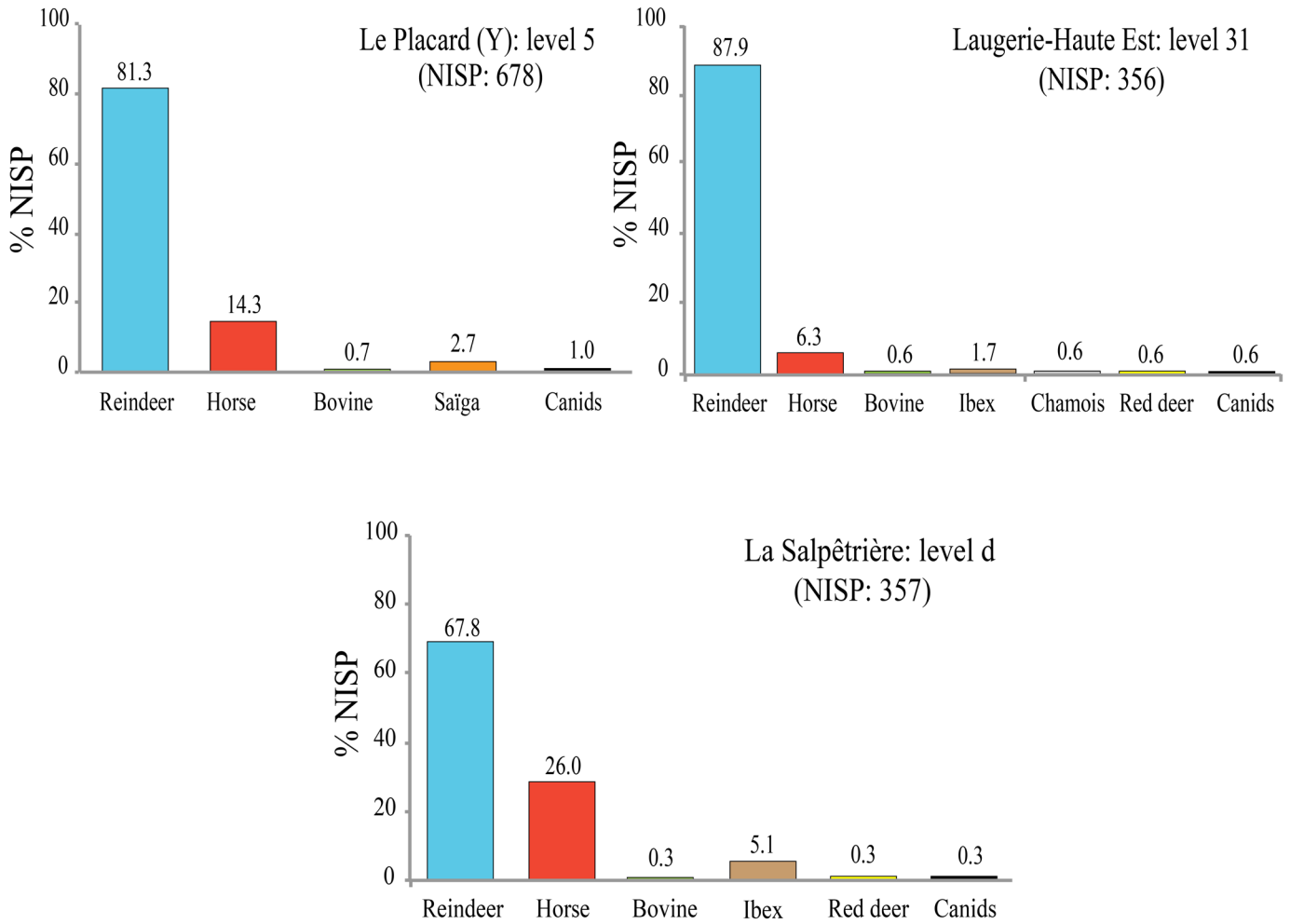Figure 11. Relationship between the number of taxa and the NISP (log NISP).

Figure 12. Proportions (%NISP) of the species hunted at Le Placard (Zone Y, Level 5), Laugerie-Haute Est (Level 31) and La Salpêtrière (Level d) (after Griggo 1995 and unpublished; Delpech 1983; Bémilli 1995).
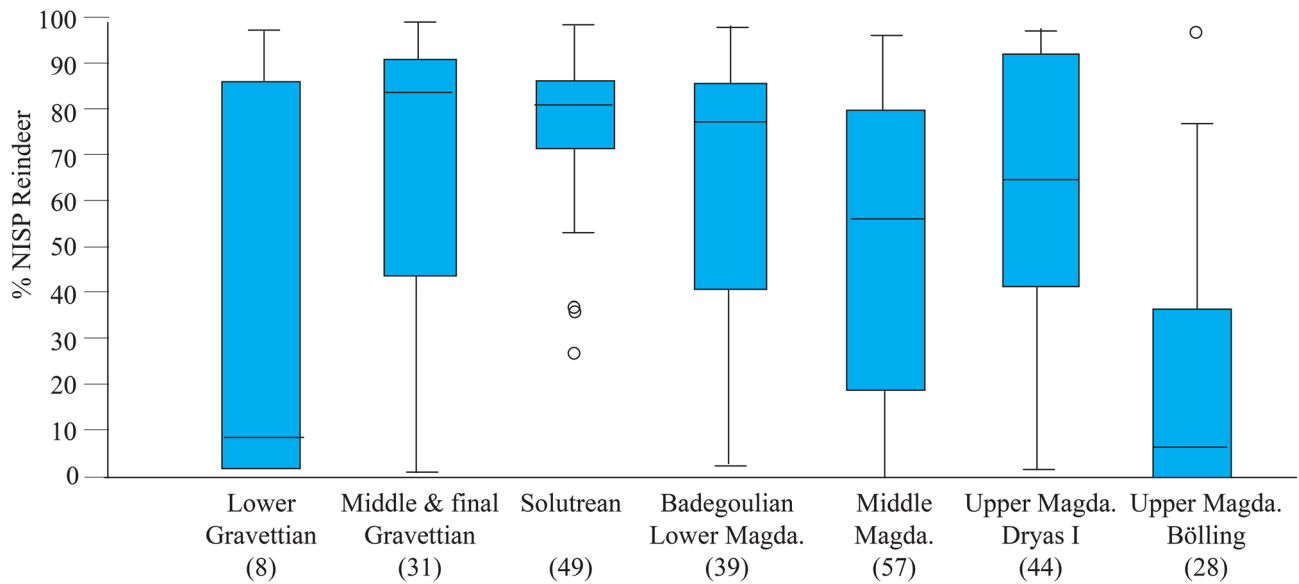

Figure 13. Reindeer proportion in 117 French Upper Palaeolithic sites (256 Gravettian to Magdalenian assemblages) (Fontana 2019).
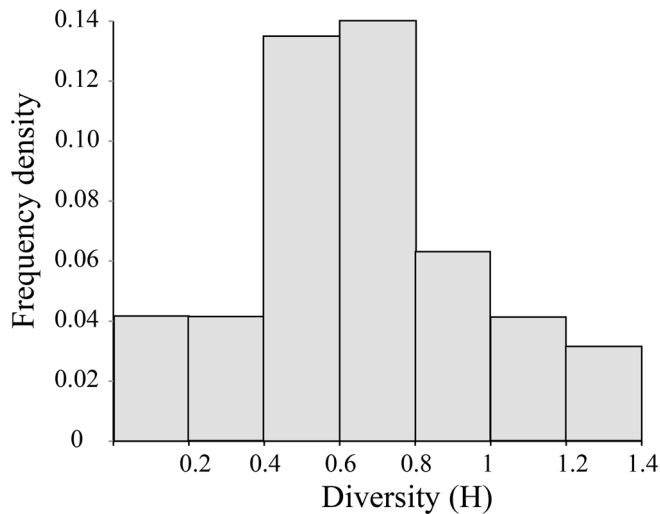
Figure 14. Diversity (Shannon-Wiener index) of the 48 Solutrean assemblages.

The diversity of the 48 Solutrean assemblages varies between 0.12 and 1.27, more than half (56%) of them fall between 0.4 and 0.8, and more than two thirds (67%) of them between 0.4 and 1 (Figure 14[14]). These indices are low compared to those calculated for 56 Magdalenian and Azilian assemblages from Pyrenean sites (see details in Fontana and Brochier 2009)—the upper limit of the latter is 1.99 and half of them fall between 0.5 and 1.3, which shows a significantly higher diversity (Figure 15).

H in our dataset is not correlated with the sample size (NISP) (r²=0.028; p=0.258) (Figure 16), allowing us to confidently analyze the diversity of the assemblages despite a degree of variability. This is not surprising given that two species (reindeer and horse) systematically represent more than 70% of the faunal remains (see Figure 4), the other species and their proportions thus having little effect on the
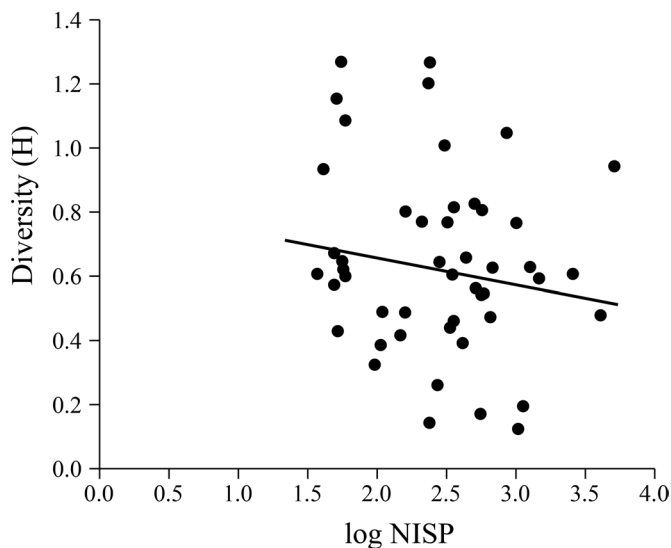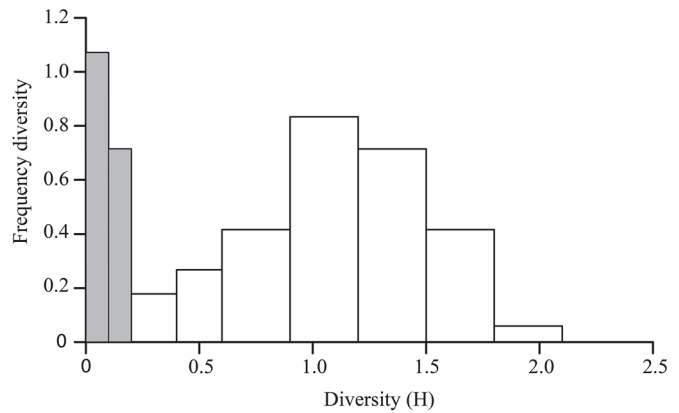

Figure 15. Diversity (Shannon-Wiener index) of 56 Magdalenian and Azilian faunal assemblages from the French Pyrénées (Fontana and Brochier 2009). In this corpus, the 0.20 value is chosen as being the upper limit of low diversity values (in grey).

diversity.

The highest proportions are greater than 1 in seven assemblages (Rochefort Cave, Level 5 of Le Placard Sector Z, and Levels e/6/5/18-7 of La Salpêtrière), and they are explained by the conjunction of two factors. First, in these assemblages, the reindeer proportion is less than 56% (see Figure 3), making the reindeer/horse proportion more balanced. Second, the proportion of the third taxon—ibex, bovid, red deer, or canid—is higher than that in the other assemblages, between 10% and 24%, except for at Rochefort Cave where the fourth taxon is equivalent to other sites (Table 3, Figure 17). Therefore, the profile of the hunted species spectra is very different from the 41 others (see Figure 12). The very low diversities are above all due to the reindeer proportion, which is never below 94.5% for the five diversities lower than 0.3 (four levels at Laugerie-Haute and one at Le Placard).

Because the reindeer proportion is the main factor driving the diversity of the Solutrean assemblages, it is not surprising to find regional difference in H. In effect, the levels of the two sites in the South-Eastern area are distinct, with a higher and more variable diversity than in the two other regions where the hunting diversities are lower and less variable (Figure 18). The Mann-Whitney U test confirms this trend since there are significant differences between the South-Eastern and the two others areas (Western: U=40, p=0.0196; Dordogne-Lot: U=26,5, p=0.0040). On the contrary, there is no significant difference between the Western and Dordogne-Lot areas (U=138, p=0.1479).

Does the very high reindeer proportion, associated with very low diversity, mean that reindeer hunting was dominant and that hunting diversity was very low in the Solutrean? In other words, are the data from the 24 sites studied representative of all the Solutrean occupations? Theoretically, they are so only if they represent the entire seasonal cycle, all habitat types, all phases (procurement, exploitation, consumption) of all activities, and the entire period considered. In the case of hunting, and more globally, the exploitation of animal resources, certain types of in-

Figure 16. Relationship between the Shannon-Wiener index and the sample size (log NISP) for the 48 Solutrean assemblages.

TABLE 3. FREQUENCY (NISP) AND PROPORTION (% NISP) OF THE THREE FIRST TAXA, AND SHANNON-WIENER DIVERSITY INDICES (H) RELATED TO THE SEVEN ASSEMBLAGES WITH A DIVERSITY GREATER THAN 1.

7 assemblages	NISP	% NISP				H
		Reindeer	Horse	3rd taxa	Total	
1. Rochefort	857	55.43	35.71	3.62 (Cd)	94.76	1.047
2. Placard Z C5	306	52.94	33.66	12.42 (Cd)	99.02	1.008
3. L'Eglise	234	53.85	26.92	11.11 (Bv)	91.88	1.202
4. Salpêtrière (e.)	51	37.25	47.06	9.8 (Bv)	94.11	1.154
5. Salpêtrière (6)	240	27.08	44.58	22.92 (I)	94.58	1.267
6. Salpêtrière (5)	55	36.36	34.55	23.64 (I)	94.55	1.269
7. Salpêtrière (18-7)	59	55.93	22.03	18.64 (Rd)	96.6	1.086

Cd: Canid, BV: Bovine, I: Ibex, Rd: Red deer
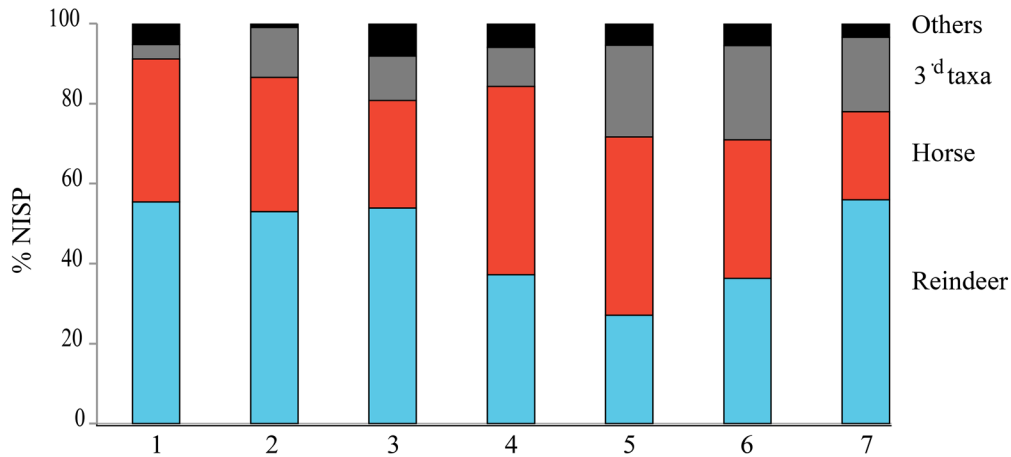
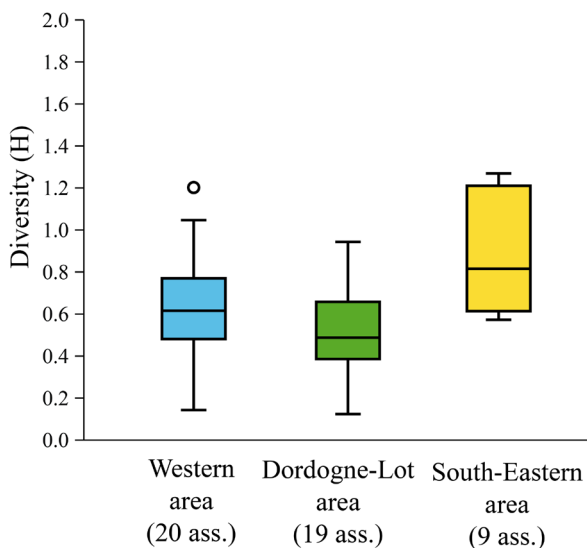Figure 17. Faunal spectra of the seven assemblages with a diversity greater than 1.

Figure 18. Range of the Shannon-Wiener index of the Solutrean assemblages in the three geographic areas.

formation are necessary to estimate the representativeness of the data and to understand the functioning of the economic system. That is what I will do now, in next section.

HUNTING STRATEGIES AND SEASONS
We have seen that the Solutreans hunted, above all the game of their environment, the most adapted to the climatic conditions, but do their animal resource procurement strategies, including antler procurement, reveal any specificity in terms of the age and sex of the animals selected, and the hunting seasons? In a very cold and dry environment, where the proportion of large herbivores necessarily decreases, these strategies could attest to choices made to ensure and anticipate a procurement strategy that would not suffer from unanticipated conditions.

Method
Only the data on the age of the slaughtered reindeer are currently usable, by analyzing the mortality profiles con-
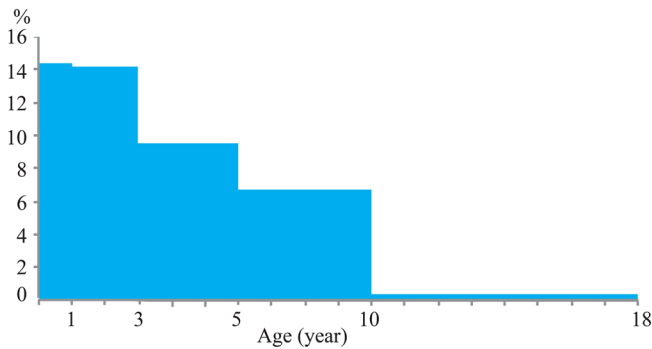
Figure 19. Reindeer living profile for Kaminuriak Caribous (Parker 1972).

structed from the lower jaw teeth. Sex ratio data do exist but are very rare for Solutrean sites. The method for determining the age of reindeer is based on the dates of current reindeer dental eruption, and for the assemblages I studied (Laugerie-Haute Ouest and Fourneau du diable), a reassessment of J. Bouchud's stages of wear (Bouchud 1953, 1966) from a photographic corpus of current Kaminuriak caribou mandibles (Miller 1974) of known age. This corpus presents several individuals for the same age, which allowed estimation of the variability. It is also based on a registration method aimed at reconstituting a minimum number of individuals taking into account the age of the individuals (MNIc: Poplin 1981). The interpretation of age-at-death profiles obtained from the lower teeth was based on a comparison with the age profile of a current caribou population (Figure 19). The method and the discussion of problems inherent in archaeological samples (representativeness of all kinds) was discussed in detail in a first synthesis of 33 assemblages from 18 French sites (Fontana 2000)—quantification criteria (NISP, teeth number, MNI), types of remains used (isolated teeth, mandibles), age classification and life expectancy of the reindeer, weighting of the numbers, question of the differential wear between populations and individual variability, and interpretation of the differences between my archaeological profiles and those of J. Bouchud.

The archaeological remains used in the identification of hunting seasons provide evidence of skeletal and antler 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, and fetal long-bone diaphyses (for details and discussion see Fontana 2017).

Results
The scarce data relevant to reindeer hunting confirm those previously published for the sites of Combe Saunière and

Fourneau du Diable (Castel 1999; Fontana 2001). The profiles are indeed similar at La Salpêtrière (assemblage i-v: Rillardon 2010) and Laugerie-Haute Ouest (level 12a: Fontana 2019)[15], as is shown in Figure 20. These catastrophic profiles, meaning that they are similar to the survival profile of modern reindeer and caribou populations, indicate non-selective hunting (for more detail see Fontana 1998, 1999, 2000, 2012a, 2017, 2019). This is also true for the Gravettian, Badegoulian and Magdalenian hunts, as highlighted by the recent analysis of the 64 recorded assemblages (Fontana 2019) which confirms the first published data (Fontana 2000, 2012a) (Figure 21).

These scarce data thus indicate that despite the specificity of the fauna and the environment, the Solutrean hunting strategy shows no specific traits. The choice to hunt reindeer with no age or sex[16] distinction, meaning while killing nearly one-fourth of the fawns, indicates a choice was made not to select a specific type of individuals, such as adults, which have more meat and, especially, antlers in certain seasons. This implies that no major constraint led to such a modification of hunting strategies in terms of animal selection.

Hunting seasonality data are even more scarce and are localized in a single area comprised of the southern Charente and northern Dordogne. This area yielded reliable data thanks to the studies of Badegoule, Laugerie-Haute, Combe Saunière, Fourneau du Diable and Roc de Sers. They are based on first-year reindeer dental remains, and adult hunted antler—and, at Badegoule, on numerous prickets, which J. Bouchud x-rayed. These studies show an identical situation in these five sites—reindeer were hunted throughout several seasons. This is the case for Fourneau du Diable, with several seasons identified (throughout the year for Bouchud [1966], without summer for Fontana [2001]), and Badegoule, mainly in autumn and spring (Bouchud 1966; Fontana 2001). At Laugerie-Haute, reindeer were killed at several times during the year between late summer and late spring, at least (Agoudjil 2005; Bouchud 1966; Fontana 2019). At Combe Saunière, most of the reindeer were killed from mid-winter to spring, along with a few in late summer and throughout autumn (Castel 1999), as they were at Roc de Sers (Agoudjil 2004; Fontana 2019; Green 2005). These results yield several types of information[17]. First, while the multiplicity of hunting seasons is undeniable, it is still difficult to demonstrate that at some sites humans hunted reindeer several times a year since we do not know the time duration represented by the archaeological levels. It would be very interesting to know if this is the case in other regions as well. Secondly, does the very low representation of summer hunting, common to all five sites, reflect the absence of reindeer during two months of the warm season? It could also reflect low archeological visibility linked to the difficulty of identifying a season based on fawn teeth[18], and the absence of antlers for females and the sub-adults of both sexes, which comprise three-quarters of the population. Finally, and especially, despite the inter-site variations observed in the importance of certain seasons, the hunting age profiles are globally similar, indicating that the hunting
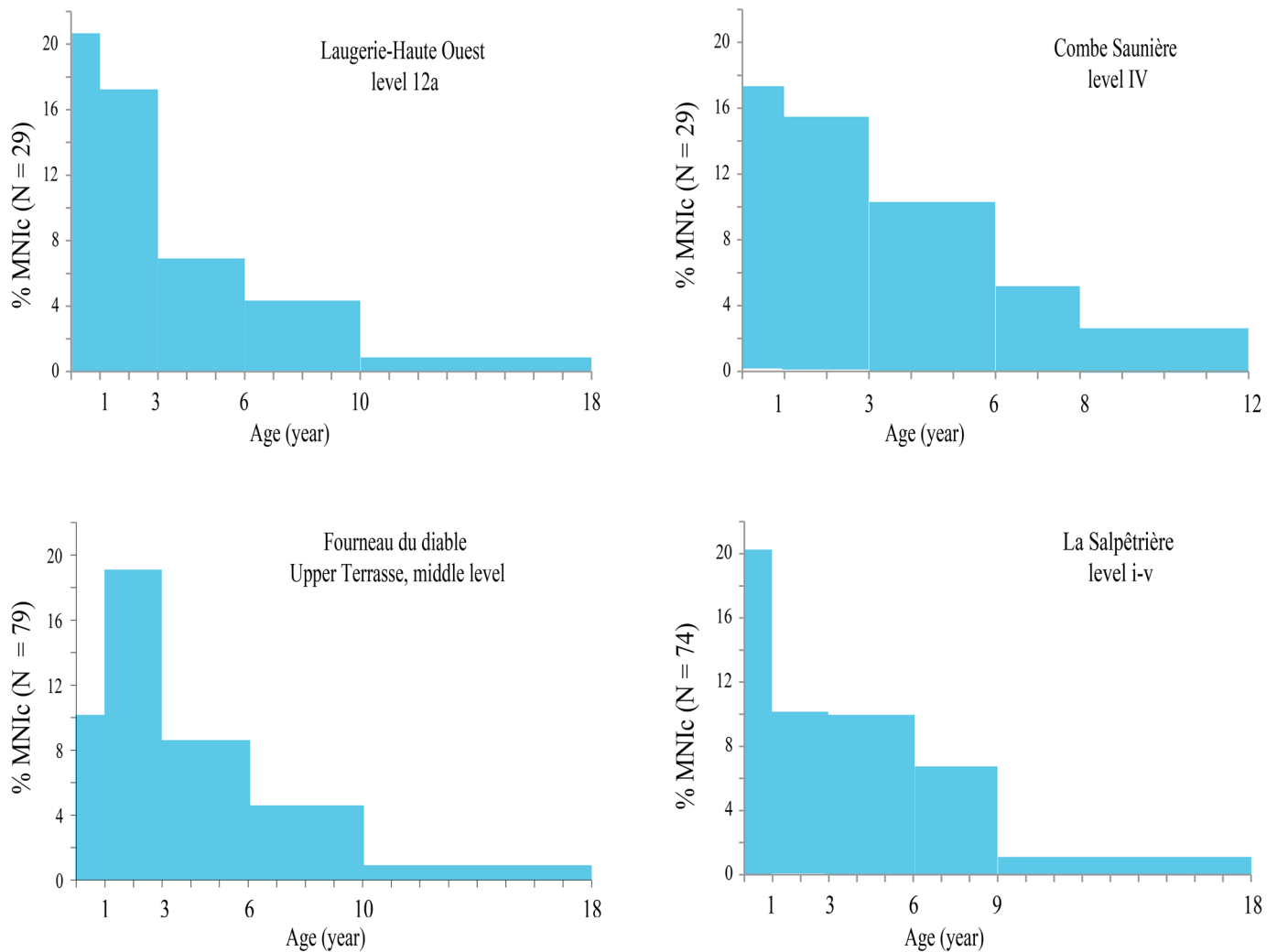
Figure 20. Reindeer age-at-death profiles for Solutrean sites: Fourneau du Diable (Upper terrace, Fontana 2001), Combe Saunière (after Castel 1999), Laugerie-Haute Ouest (Fontana, unpublished) and La Salpêtrière (Rillardon 2010), expressed as % of the Minimum Number of Individuals (MNIc).

strategy, which is not unique to the Solutrean, also does not differ in terms of seasonality.

Once again, these scarce data are identical to those associated with other periods (Fontana 2000, 2012a, 2017, 2019). The situation is the same at the Magdalenian site of La Madeleine (Fontana 2017), in the same region, and in the Gravettian occupations at Laugerie-Haute (Fontana, 2019)—it is a matter of the region, not time, and thus, not climate. Whether the scarcity or absence of hunting during the summer months in the area in question is real or not, the visibility of the annual cycle is nearly complete. Consequently, the data, in this area at least, can be considered as representative of Solutrean hunting. Reindeer, the nearly exclusive prey in the West, and the dominant one in eastern Languedoc, was a major dietary source for the Solutreans throughout the year.

THE EXPLOITATION OF REINDEER OSSEOUS MATERIALS

The last synthesis of the Solutrean osseous industry con-firms the non-diagnostic nature of their osseous equipment, which is comprised mostly of knapping tools and diverse points, among which pressure flakers and soft hammers on a reindeer antler base may constitute a "Solutrean particularity" (Baumann 2014; Bordes 1975; Rigaud et al. 2013), along with the diagonistic eyed needles, and the pressure flakers of the Upper Solutrean. The as yet unquantified variability of weapon implements appears to be great, and there is no typical Solutrean spear type, spearthrower elements being rare (Cattelain 1989). The use of osseous materials in portable art has been recorded at very few sites, including recently at Rochefort Cave (Hinguant et al. 2012). It is still difficult to determine the proportion of reindeer, which we know to be the majority, in osseous material productions. The procurement modalities are becoming clearer but we must quantify the respective proportions of shed antler and hunted adult male antler and confirm the small proportion of female (shed) antler (on going study). The exploitation modalities remain partly unknown due to the missing elements in the assemblages. If osseous mate-
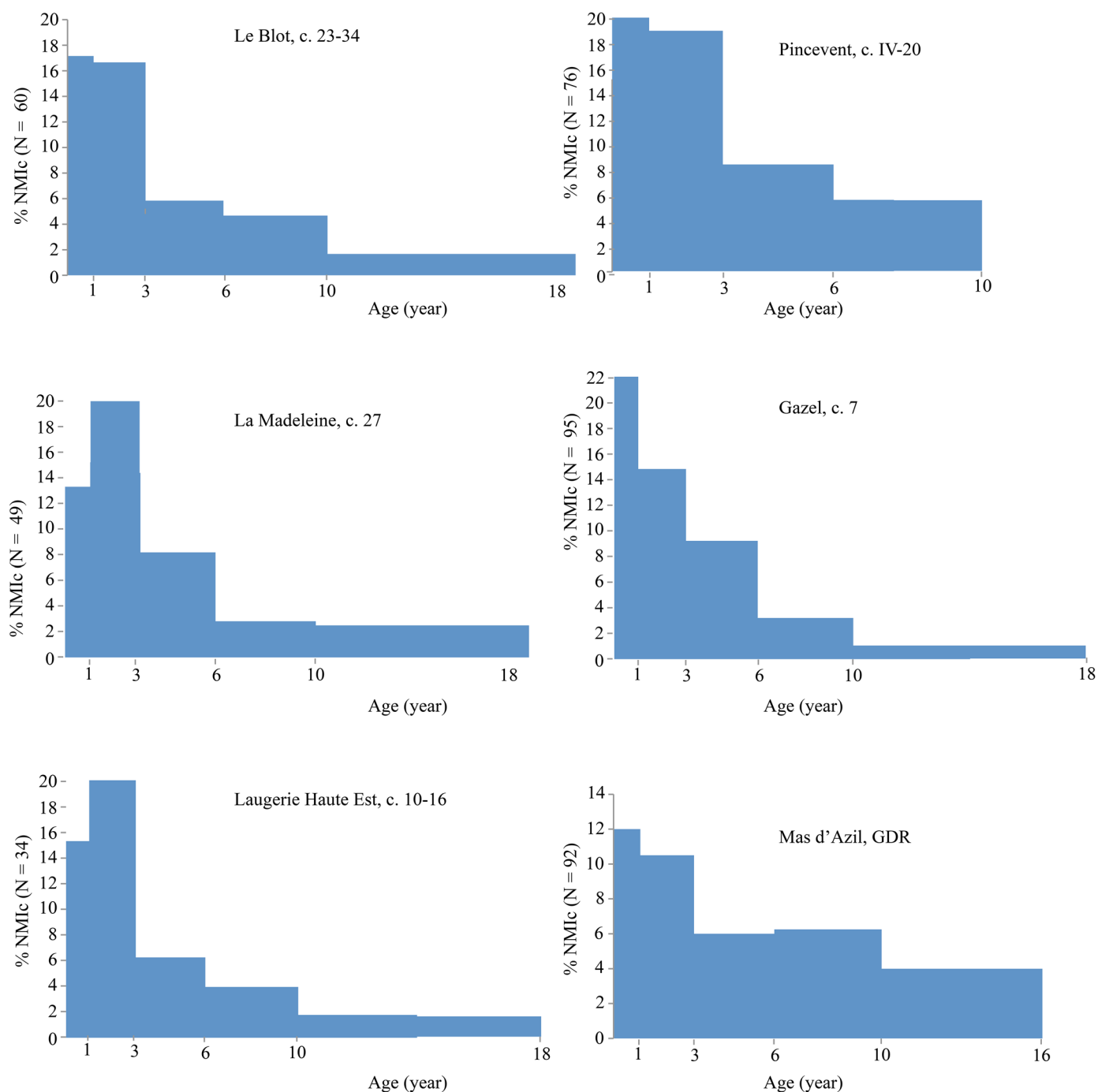
Figure 21. Reindeer age-at-death profiles for Le Blot (final Gravettian, Fontana 2019), Laugerie-Haute Est (Badegoulian and Lower Magdalenian, Fontana 2019), La Madeleine (Middle Magdalenian, Fontana 2019), Gazel (Middle Magdalenian, Fontana 1998, 1999), Le Mas d'Azil (Middle Magdalenian, after Patou 1984), and Pincevent (Upper Magdalenian, after David and Enloe 1995), expressed as % of the Minimum Number of Individuals (MNIc).

rial exploitation, and particularly reindeer antler, has a few specific features, they are not currently detectable. Finally, we should note that the exploitation modes cover not only the manufacturing processes, which are always recorded in great detail, but other aspects as well (as transport of antlers and objects, and annual cycle of nomadism), which could provide information on the organization of the exploitation of animal resources, mobility and habitat (Castel et al. 1998,

2005, 2006; Fontana 2012b; Fontana et al. 2009, 2018).

THE ANNUAL NOMADIC CYCLE AND ECONOMIC SYSTEM

For Solutrean groups, what are the challenges, and what can we say today about the organization of their economic system at the scale of the annual cycle, meaning the locations and frequencies of resource procurement, and the

distribution in time and space of activities linked to exploitation phases?

Concerning Solutrean lithic raw material procurement, which was mostly autochthonous, the visibility and access to this resource were probably very limited in winter due to the snow cover and frozen ground. Following this line of reasoning, Aubry et al. (2004) proposed that the site of Les Maitreaux was occupied mostly in spring. It is possible that this constraint restricted the procurement periods to part of the year (late spring and/or summer?), thus requiring the constitution of reserves. Aubry (2013) proposes the hypothesis of a lithic raw material procurement system based on workshops dispersed at raw material sites, with the production of laminar blanks and the creation of reserves. The fixed nature of this resource, the decrease in its accessibility and the modification of its properties (by the climatic conditions) presented significant constraints; did these constraints also determine the procurement organization for other resources? Shed male antler, indispensable for the production of many tools and weapon elements, was also a fixed resource and, especially, one that degraded rapidly, but this is not specific to this period. Hunting was based on reindeer, which does not seem, at least during this period, to have been a migrating animal as it is today (Bouchud 1966; Fontana 2012a, 2017, 2019; Fontana and Chauvière 2018). In effect, if reindeer migrated at least two times per year, some other sites would show a substantial consumption of other prey, but this is not the case. It is thus probable that the food and non-food products (soft products as well, such as hide and tendons) of reindeer were procured throughout the year, perhaps with the exception of part of the summer in one area. The space frequented by human groups to satisfy their needs was thus not necessarily very large.

Two types of data are necessary to determine the distribution, in space and in the annual cycle, of activities linked to the various exploitations—the seasons of site occupation and identifications of the activities represented. While it is increasingly possible to determine the former (see below), this is not the case for the latter. To characterize the exploitation of antler from an economic perspective, the indispensable information is relative to the proportion and nature of the manufacturing in place. Indeed, the presence of blanks, waste-products and unworked antlers in a single archaeological assemblage does not necessarily imply manufacturing in place, regardless of their abundance. For this reason, it is indispensable to qualitatively and quantitatively compare the elements of these three categories, as well as the antler procurement modes and the season of occupation. Only this procedure can demonstrate an *insitu* procurement of antler destined for exportation, or, on the other hand, the discard of unusable pieces all manufactured elsewhere (Chauvière and Fontana 2005; Fontana and Chauvière 2009, 2018, in press). Concerning lithic raw material exploitation, the fragmentation of operational sequences is possible, with some sites specialized in procurement and others in manufacturing (Aubry 2013; Aubry and Zilhao 2018), which I believe would correspond well with

limited access in the annual cycle of a few months.

All the data analyzed, though not numerous, partial and rarely integrated, enable me to propose a scenario concerning the annual nomadic cycle and the economic system of the Solutreans in the Western and Dordogne-Lot areas. It is possible that during this period, which was colder and dryer than any other during the Upper Paleolithic, the annual cycle was based on a significant dichotomy between the cold season and the warm season. This choice, imposed by the climatic conditions (very severe at the beginning of the period), would have led to a more marked seasonality in the procurement of some resources, such as lithic raw material, and thus a specialization of habitats, at least at certain times, also linked to a greater fragmentation of manufacturing activities. In this case, the three to four months of the warm season would have been devoted to the procurement and manufacturing of lithic blanks, and perhaps the production of lithic raw material reserves, as well as sporadic hunting (of reindeer or other species), which was perhaps exceptionally opportunistic.

If mobility was mainly linked, economically speaking, to lithic raw material procurement and the distribution of the products acquired and transformed, it depended on the number and proximity of the procurement sites. It is probable that shed and hunted antler, from adult males, was procured in autumn, the hunts thus focusing on mixed groups comprised of the total reindeer population. In winter, which is the season of vast matriarchal herds, the procurement of food and non-food products by reindeer hunting was probably accompanied by the processing of some of the materials obtained (meat preservation, hide preparation). Mountain hare and fox fur, which is generally not visible at the sites, was perhaps obtained at the procurement sites. If the occupation duration was greater and mobility was lesser during the cold season, it is probable that this time of year was devoted to manufacturing a large part of the osseous equipment. The lithic raw material procurement and production, always difficult in very cold conditions (see above), would have thus benefitted from a sedentary lifeway during three or four months.

CONCLUSION

The Solutrean societies north of the Pyrenees lived in a cold and dry steppe environment, also known by the last Gravettians and, to a lesser degree, the Badegoulians. Only the Proto-Solutrean groups, still poorly known in France, lived in the most drastic conditions. The data analyzed in this article indicate that despite this particular environment, human groups did not modify their animal resource exploitation system. Whether in the choice of reindeer, hunting strategies, antler procurement modes or even in their osseous tools and hunting weapons, no major specific features characterize the Solutreans. In general, reindeer remained the dominant hunted prey from the end of the Gravettian (date to be determined) to the end of the Middle Magdalenian, with any differences being mostly regional. The reindeer hunting strategy remained non-selective from the Aurignacian until the end of the Magdalenian, and the

sectors in which it was hunted year-round were the same throughout this long period. Reindeer antler continued to be abundantly exploited as well, and if this economy was specific in any way during the Solutrean, it has not yet been demonstrated. In the same manner, no data currently show a specific mode of exploiting of reindeer carcasses (Fontana, 2019 and ongoing study). For all these reasons, I cannot identify any potential "subsistence intensification" or any other major difference during the Solutrean.

Concerning the lithic raw material economy, there are some specificities in the Solutrean. The first is linked to their production and retouching techniques, based on which the Solutrean is defined. These features do not seem to have any relationship to the specific climatic conditions, however, because we cannot envision how they would have favored this type of industry, even indirectly. On the contrary, this factor also corresponds to the second specificity in Solutrean lithic raw material procurement and exploitation strategies. The very cold and dry environment reduced the accessibility of this resource and created constraints in association with the knapping technique used, at least during the largest part of the year. The only relationship that I detect between the climatic conditions and resource exploitation concerns an aspect of the lithic raw material economy. Concerning the annual cycle, it is still too early to know whether it was based on very low mobility during the cold season and on specialized lithic raw material procurement during the warm season.

It thus seems that the Solutrean economic system, based on the exploitation of reindeer and lithic raw material, was not affected by environmental constraints to the point of being significantly modified. Some aspects were nonetheless affected by the cold and dry climate, such as lithic raw material accessibility and the ability to knap it without major constraints; the exploitation of this resource was thus reorganized to adapt to this context. Other features, such as lithic and osseous material productions, do not show any direct relationship to the environment.

Most importantly, this global vision of the Solutrean economy indicates that the differences in the economic systems of nomadic hunter-gatherers during the Upper Paleolithic are not related to differences in environment. From the Early Gravettian to the Middle Magdalenian, the economic system in western Europe seems to have been based on the same foundations, with chronological or regional differences that do not significantly challenge it. It is thus possible that the major difference in the society-environment relationship exists between the societies that lived in a reindeer ecosystem and those who did not, i.e. those before and after the beginning of the Upper Pleniglacial. This difference in terms of the reindeer economy is indeed not entirely equivalent to the climatic distinction—what is significant is not the difference in terms of environments, but in the annual cycle. This aspect is necessarily different because it is based on the exploitation of animal species whose ethology differs and in part imposes an annual procurement and consumption schedule (*sensu lato*). Nevertheless, many aspects of the Solutrean economy remain

to be identified, which would permit testing, or perhaps clarification, of my proposed scenario, and a clearer understanding of the regional, and perhaps chronological, differences.

ENDNOTES

[1]All dates were calibrated using the IntCal13 calibration curve (Reimer et al. 2013).

[2]"The GS and GI periods are the Greenland expressions of the characteristic Dansgaard–Oeschger events that represent cold and warm phases of the North Atlantic region, respectively" (Rasmussen et al. 2014).

[3]Last NorthGrip chronological order: 24,300–18,000. In fact, the middle latitude glaciers are exposed to brutal warmings with heavy precipitation, and they flood, such as at 20 ka, creating ice streams.

[4]In France, La Grande Pile, Les Echets, Le Bouchet: Beaulieu and Reille (1984, 1992); Beaulieu et al. (1988); Guiot (1987, 1990); Guiot et al. (1993); Pons et al. (1992); Reille and Beaulieu (1988); Woillard (1978).

[5]Grasses: Mugworts (*Artemisia*), Poaceae and Chenopodiaceae. Trees and shrubs: Pine (*Pinus*), Juniper (*Juniperus*), Birch (*Betula*), Willow (*Salix*).

[6]Micro mammals: Arctic Lemming (*Dicrostonyx torquatus*), Norway Lemming (*Lemmus lemmus*), Souslik (*Citellus superciliosu*s), Narrow-headed Vole (*Microtus gregalis*). Birds: Rock Ptarmigan (*Lagopus mutus*), Willow Ptarmigan (*Lagopus lagopus*), Gyrfalcon (*Falco rusticolus*), Snowy Owl (*Nyctea scandiaca*), Alpine Chough (*Pyrrhocorax graculus*), Snow Bunting (*Plectrophenax nivalis*), Western Capercaillie (*Tetrao urogallus*).

[7]Forty-eight assemblages yielded quantitative data, 49 including Level IV at Badegoule, for which J. Bouchud counted only the remains of reindeer.

[8]The only exception is Combe Saunière, where red fox represents 11% of the identified remains and the artic fox, 6% (Castel 1999).

[9]Saiga antelope probably did not consume salt-tolerant (halophyte) plants as they do today—this is indicated by the significant differences in the nitrogen 15 and carbon 13 values between modern individuals and the French Upper Paleolithic ones that have been studied (Drücker 2001). Paleolithic antelopes probably consumed more grasses.

[10]The association, that still remains unique to this day, of all the ungulate species in the Solutrean Level As of the Grotte XVI is very surprising and requires, according to us, to be verified, as far as the parts of wild boar and roe deer, though small (0.99% and 2.78%), are the highest documented in Solutrean sites (Grayson and Delpech 2005). In the case of the Rochefort cave, the identification of forest carnivores and brown bear remains within Solutrean levels of which one third of the radiocarbon dates are greater than 21,000 cal BP (Hinguant et al 2013) would merit dating of certain species to ensure their effective presence during Solutrean occupation.

[11]We can moreover suppose that the reindeer proportion is underestimated among the large herbivores due to the risk of confusion in the determination of some diaphysis fragments that could belong to reindeer or ibex, and which are classed as indeterminate in a category of reindeer or as reindeer/ibex.

[12]The chronological attribution of the rare species (wild boar, roe deer, muskox, woolly rhinoceros, mammoth), a few remains of which have been identified in one to five sites, currently prevents their identification as Solutrean prey animals.

[13]For a full discussion regarding the proportion of reindeer between 30,000 et 14,000 cal BP, see Fontana (2019).

[14]Frequency density is generally defined as the ratio of the frequency of a class to its width, e,g,, 15 NISP in a class 1-2 (width : 1) is not the same as 15 NISP in a class 1-5 (width : 4).

[15]The unpublished data of the other Solutrean levels at Laugerie Haute Ouest, Laugerie Haute Est, and Roc de Sers are similar. The study of Rochefort Cave (in progress) identifies five killed reindeer less than 4 years-old, and ten older ones, whose precise age will enable a confirmation of the profile in progress.

[16]Adult males are always represented in accordance with their presence in the seasonal structure in question (Bouchud 1966; Fontana 2001, 2012a)—absent or nearly absent in the matriarchal herds of winter,

well represented in the autumn hunts just before the rut when males and females are together; this like at other Magdalenian sites (e.g., Fontana 1998; Magniez 2010).

[17] For methodological details, see Fontana (2017).

[18] The summer fawns are newborns with 12 very fragile deciduous premolars (see Bouchud 1966).

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