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Title: Reindeer Feeding ecology and Hunting strategies by Magdalenians from Pincevent (Paris Basin, France): New Insights from Dental Microwear Textural Analyses.

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Abstract:

*In Pincevent (Paris Basin), archaeozoologists have observed a variation of hunting strategies between Magdalenian levels IV0 and IV20. Previous works on human-prey interaction showed that hunters modeled their behavior on their prey; therefore, reconstructing animal behavior in order to reconstruct human strategies could enable better interpretation of these levels. This study aims to contribute to a global understanding of the variation between these level's hunting strategies using microwear texture analysis. This proxy, which can be used to reconstruct diet, will enable to detect changes in the behavior pattern of the prey. The decision was made to focus this study on reindeer (*Rangifer tarandus*) as it was one of the two most exploited resources on this site, alongside horses. The enamel surface of teeth from two populations of reindeer, hunted and found in levels IV0 and IV20, showed a variation of diet between levels. Environmental and ecological matters are discussed with an aim to understanding this variation of behavior in reindeer populations and highlight a change of strategic behavior among hunters.*

Keywords: Reindeer, Pincevent, Paris Basin, Upper Magdalenian, Dental Microwear Textural Analyses, Animal exploitation.

28

29 **1- INTRODUCTION**

30 The Paris Basin is a privileged region to study Magdalenian societies at the end of the
31 Paleolithic period (Late Glacial, 13,000–12,000 years BP; Figure 1A and Table 1). Among
32 the sites of this region, Pincevent occupation floors are a reference for exploring variations
33 over a very short time period due to its well-preserved stratigraphic sequence, resulting from
34 several overflows of silt or sandy silt from the Seine deposits (Figure 1b; Orliac 2006, 2014).
35 Based on archeological remains, paleo-ethnology studies were developed in Pincevent to
36 study Magdalenian occupations and reconstruct their way of life, their activities and their
37 social organization, all of which were linked to their subsistence strategies (Leroi-Gourhan &
38 Brézillon, 1966; 1972; Julien & Karlin, 2014). The huge number of faunal remains from
39 reindeer (*Rangifer tarandus*) and horses (*Equus caballus arcelini s.l.*, Bignon *et al.*, 2006), in
40 almost every level at Pincevent, and in many other sites of the region, indicates that the
41 Magdalenian economy was based on these two key prey (David, 1994; Enloe, 1998; Bignon,
42 2008; David *et al.*, 2014). This research underlines a coevolutionary link between prey–species
43 and prehistoric hunters during the Late Glacial in the Paris Basin (Bignon-Lau, 2014).

44 Dental microwear texture analysis was applied to assess the dietary spectrum of
45 Pincevent's reindeer, in order to support hunting strategy changes and, most notably, the
46 season in which reindeer were most often slaughtered. As a ruminant, extant reindeer are
47 selective while their feeding behavior shows a relative plasticity. And they are described as
48 regional mixed feeder whose food component varies spatially and seasonally (Leader-
49 Williams, 1988; Skogland, 1984, 1989; Syroechkovskii, 1995; Semprebon and Solounias,
50 2002; Danell *et al.*, 2006): from lichen consumption throughout the year to other resources
51 depending on their availability in the environment (reconstructed by stomach content studies
52 ; Kuntz, 2011). During mastication, food items wear dental enamel, resulting in the so-called

dental microwear. When the animal dies, the dental microwear allows us to assess the food properties of the animal from its last few days or weeks (Teaford et al, 1989a, 2017). When applied to vegetarian species, diet mirrors vegetal resource availability, which highlights habitat condition (Merceron et al., 2010).

Applied to a large range of species in the last 15 years, Dental microwear textural analysis (Scott et al. 2005, Merceron et al. 2016, 2018) aims to assess differences in dietary habits between inter- and intra-population scales (Percher et al. 2017; Berlioz et al. 2018; Scott, 2012). Here, the method is applied on the archeological dental material from the two levels excavated at Pincevent: level IV0 and level IV20. Each level is interpreted to characterize a very distinctive faunal spectrum (Bignon *et al.*, 2006; Bignon, 2008; David *et al.*, 2014; Bignon-Lau, 2014; Debout *et al.*, 2012): level IV20 represents a massive reindeer killing in a single season (fall), whereas the level IV0 assemblages represent an association of reindeer and horses hunted and killed over a period of approximatively a year.

With this paper, our main goal is to use this very rich and complex archaeological grounds of these two exceptional preserved Magdalenian levels of Pincevent to show how DMTA can bring relevant data highlighting both reindeer behavior and hunting strategies. Two populations of present-day reindeer, with a total of 102 individuals living under different habitat conditions in Norway, were used as comparative baselines (alpine tundra reindeer; Bignon-Lau *et al.*, 2017).

2- ARCHEOLOGICAL CONTEXTS

2.1 - Magdalenian of the Paris Basin

The Late Magdalenian (13,300–11,950 cal BC, Valentin, 2008; Debout *et al.*, 2011) is currently the best-known period of the Pleistocene in the Paris Basin, with more than over forty known sites. Most of these are highly concentrated in the south of Paris, in the Seine

Valley, with fewer settlement expansions in the northern and western zones of the region (Figure 1a). Magdalenian sites provide some well-preserved occupations where the remains are almost unaltered and found in their original position. For instance, the open-air sites of Etiolles, Pincevent, Verberie and the sites of the Seine-Yonne confluence are stratified with between five and fifteen occupation levels. These occupations are separated by thin deposits of alluvia which have rapidly piled up due to the annual overflows of the River Seine. The formation of these sequences is estimated to have occurred over a few generations, during an instable climatic period, but it seems that the same individuals came back repeatedly (Bodu 2010; Julien and Karlin 2002; Rodriguez and Roblin-Jouve 2004). The successive return visits to the same place confirm the regularity of displacements and allow functional variability of the occupations within the same site to be studied. The environment around the sites has been studied at sites such as Pincevent, Tureau-des-Gardes, Verberie, Etiolles, providing well-preserved fauna remains.

The Magdalenian sites were studied using the paleo-ethnographic approach elaborated by André Leroi-Gourhan at Pincevent (Leroi-Gourhan and Brézillon 1966, 1972; see Supplementary Information for details).

2.2 - Pincevent

Pincevent is an open-air site located in the middle Seine valley which offers very well preserved archeological levels (Figure 1b). Among the Magdalenian sites of this region, it remains a reference for exploring variations over a very short time period due to its well-preserved stratigraphic sequence, covering at least one century (Figure 1b; Orliac, 2006). Every year since its discovery in 1964, the site has been explored via the same planimetric excavation method: every artifact is recorded on a square plan and in 3 dimensions, with altitudes before removal. Today, this method is applied all over the world in open-air site

archeology. These meticulous excavation conditions allowed us to identify twenty-three occupation levels attributed to the Upper Magdalenian (Orliac, 1975; 2006; Ballinger *et al.*, 2014).

Figure 1: Map of Magdalenian sites of the Paris Basin (A) and environments and hunting season according to the hunting spectra in each stratigraphic level studied (B)

The two best-known levels on the site were excavated during several decades: level IV20 from 1967 to 1995, and level IV0 from 1989 to 2016. In each level of occupation, the synchronicity of the features is demonstrated by flint and heated stone refits that show a dense network of relationships (Bodu et al., 1993, 2014; SI, map of level IV20) and stratigraphic

control (Orliac, 2006, 2014).

All of the Magdalenian group occupations at Pincevent are attributed to the Upper Magdalenian period between 14 000 and 11 800 calBC (Table 1; Valladas, 1994; Debout *et al.*, 2012). The different occupations preserved in the overflow of silt from the Seine indicate seasonal inputs of stream sediments (Roblin-Jouve, 1994), and the strength of the streams suggest precipitations probably due to melting snow (Orliac, 1994). Grain size analysis of the stratigraphic levels indicate environmental fluctuations linked to the Seine's watercourse (Orliac, 2006; Bignon, 2008). These environmental oscillations seem to vary with the high activity of the river, according to the seasons and other environmental factors (Bignon, *ibid*).

Table 1: Dating Magdalenian levels IV20 and IV0 studied here

Level	14C BP dates (*AMS)	CalBC dates	Nature of sample	Reference	Bibliography
IV20	12 120 ± 130	12 494-11 926	Charcoal	Gif 6283	Valladas (1994), p. 66
	12 600 ± 200*	13 407-12 551	Bone	OxA 148	Valladas (1994), p. 66
	12 250 ± 160*	12 860-12 072	Charcoal	OxA 467	Valladas (1994), p. 66
	12 450 ± 45*	13 082-12 456	Charcoal	ETH 37119	Bodu <i>et al.</i> (2009), p. 93
IV0	12 460 ± 70	13 084-12 202	Tooth	Lyon-9397	Orliac <i>et al.</i> (2013), p. 77
	12 440 ± 60	13 053-12 193	Bone	Lyon-9398	Orliac <i>et al.</i> (2013), p. 77
	12 580 ± 60	13 228-12 293	Tooth	Lyon-9399	Orliac <i>et al.</i> (2013), p. 77

The Pincevent site is located upstream of a fluvial bottleneck corridor (Figure 1A). Such location, providing constant water and large floodplains, could have favoured concentration of megafauna not far from human occupation; within an ecological community, multiple species of large mammals (especially large herbivores) can coexist in a mosaic landscape (Guthrie, 1982). And the simultaneous occurrence of reindeer and horse in the faunal spectrum in Pincevent emphasizes the scenario presented by Bignon (2008). Indeed, there is

an alternation between two types of spectrum associating horses and reindeer (for instance in level IV0) and the favoring of one species (mass killing of reindeer on level IV20; Enloe et David, 2014; Bignon, 2007; Bignon-Lau, 2014). The site of Pincevent presents these two types of hunting spectrum, which is why it is interesting to focus on this site to interpret the change of tactics from a precise point of view.

Reconstructing the diet of the reindeer killed and consumed in Pincevent was applied to the two most studied levels (IV0 and IV20), reflecting two hunting strategies. As they were most likely hunted either all year round or targeted in a single short time span, and as their dental microwear textures result from the mastication of the food items (and possibly exogeneous particles ingested), we may expect differences between reindeer samples from IV20 and IV0 levels.

Level IV20 was a short-term occupation of Magdalenians in Pincevent (see SI). The predominance of reindeer (*Rangifer tarandus*) was attested by 98% of the total amount of bones identified (4,542 bones, David *et al.*, 2014). Identification and ageing of these cervids show a mortality profile very close of natural populations even if 3-5 years old adults seems slightly overrepresented as well as male vs female adults (respectively 58 vs 42 %, considering morphometric data). Moreover, the amount of reindeer found at this level (MNI = 76 - Minimum Number of Individual - Table 2; Enloe & David, 2014), is likely to have been the result of one or a very few massive hunting episode(s). Such hunting activities happened during a very short window of time, in early fall, considering a set of considerations (David *et al.*, 2014):

- this seasonality is consistent with observations of teeth composition and wear (eruption rate of juveniles; Miller, 1974; Enloe & David, 2014);
- no foetal or new born bones have been found, indicating winter or spring occupations;

- only antler from hunted animals, both males and females were found (no shed ones), meaning that these specimens were killed between summer and early winter periods; however, only fall migration can provide such massive fusion of smallest male or female bands.

Besides these archaeozoological arguments, it has been established that the lithic production reflects an occupation lasting no more than two or three weeks (Julien, Karlin, 2014); such estimation of duration is in agreement with the clear spatial organization of units showing a few rates of rearrangements (areas of specialized work, toss zones, cleaning processes, etc.). Considering the whole set of archaeological data, the Magdalenian occupation of the level IV20 has been interpreted as a residential camp set up at a reindeer fall migration route, exhibiting a massive interception of such animal resource. We expect DMTA (Dental Microwear Texture Analysis) to characterize feeding ecology of reindeer at this period of the year.

Table 2: Faunal and other remains' data for IV20 and IV0 levels in Pincevent (locus regrouped)

Occupation level		IV20	IV0
Fauna	Excavated surface (m ²)	4 500	1500
	NR	4 643	22 076
	NRD	4 600	2 870
	NR (%)	<i>Rangifer</i>	98
		<i>Equus</i>	0.8
	MNI	<i>Rangifer</i>	76
		<i>Equus</i>	2
Heated stone	NR		13 000
	Weight total (tonnes)		1.5
Ornament	NR		298
	Shells (NR)		270
Lithic remains	NR	30 000/4 500 m2	18 000/1 400 m2

Table 3: *Taphonomy of level IV0 and IV20 – weathering (from A.K. Behrensmeyer, 1978) and destruction of the surface of the bone by the roots (B) – in David et al., 2014 p.79.*

	Taphonomy	IV0 (%)	IV20 (%)
(A)	1	3.96	49.9
	2	11.08	35.6
	3	54.59	10.8
	4	25.88	2.9
	5	4.49	0.6
(B)	1	3.09	45.9
	2	3.92	34.6
	3	6.53	15.2
	4	86.46	4.2

Level IV0 represents the very last Magdalenian occupation preserved at Pincevent (Bodu *et al.*, 2006). According to the sandy silt count from that level, there is around twenty year difference between the occupation of level IV20 and the occupation of level IV0, which is slightly inferior to the radiocarbon dating resolution for the Paleolithic period (Orliac, 2006 ; 2014). At this level, the camp seems to have been, uncommonly, heavily structured by heated stones. This partially excavated camp was organized according to four units linked by refits of heated stones and/or lithic productions (Bodu, 2013). Unit 43-T125 was published in 2006 and the recent work on all units (35-M103, 35-D110 and 25-V97) will be published in a monography currently in preparation (pers. com.).

In some localized parts of the level (20–30 cm under the surface), low and localized bioturbation is due to vegetation and burrowing animals (Table 3). Despite this situation, the occupation repartition and bioturbations did not impede economical interpretations concerning Magdalenian choices. With an almost equal amount of reindeer and horse remains (Reindeer: MNI = 43; Horses: MNI = 33, Table 2), hunting strategies were most likely different. The occupation on this level is typical of a “predominant association of horse-reindeer”: these two species represented almost 85% of the total number of remains (Table 2, Bignon, 2007; Bignon-Lau, 2014).

Seasonality indications were provided from teeth ageing (deciduous teeth vs permanent teeth), dental crown height method and dental stage wear (Miller, 1974; crown-height method; Bignon-Lau, 2006, 2007). In level IV0, it appears that the animals were killed during multiple non-massive hunts throughout the year (Figure 1b). In contrast with archaeozoological data in level IV0, the amount of lithic production is similar to level IV20. This level shows a massive and entangled organization with numerous activities and phases of waste disposal regrouped. Finally, it very likely seems that, a serie of multiple brief occupations results in such seasonality data and the level IV0 spatial organization of remains (Bodu et al., 2006; Debout, 2012).

We expect DMTA to reflect a largest variability of feeding habits and help us to consider possibly a greater landscape image where happened these different hunting strategies.

3 – MATERIAL AND METHOD

3.1 - Material

We selected only teeth that presented an optimal enamel surface conservation, that is similar at the scale of 3D scanning of surfaces to the ones of modern reindeer teeth. Faunal remains from level IV20 were better preserved than those from level IV0 (Table 3), but in accordance with our selection criteria, such different taphonomic contexts did not have any effect on specimens analysed. However, more pronounced taphonomic alterations on level IV0 lead to a much higher rate of rejected specimens. This greatest selection process from level IV0 have been amplified because its MNI is smaller than from level IV20. For level IV0, we selected 13 teeth from a total of 46 individuals (Bignon-Lau, 2019). For level IV20, 55 out of 76 individuals (from sections 36 and 27; Julien & Karlin, 2014) were selected to be analyzed.

Archeological samples were compared with two present-day populations of

Norwegian tundra adult reindeer from Knutshø (N=48) and Hardangervidda (N=54; Bignon-Lau *et al.*, 2017), to interpret any intraspecific diet signal variations or mobility pattern variations of regional population from present and past reindeer populations. The reindeer populations in Knutshø and Hardangervidda belong to the Norwegian National Monitoring Program for wild cervids. As part of this program, lower jaws are collected from animals shot during the regular hunting season (the middle of August to the beginning of October).

3.2 - Method

DMTA was performed on disto-labial facets on the protoconid of lower molars (Figure 2A). Priority was given on M2 and complement was made with homologous dental facets on third or first molars following Ramdarshan *et al.* (2017) recommendations.

Following standard procedures, teeth were cleaned and molded with a polyvinyl siloxane (Coltène Whaledent, President Regular Body). Rather than producing a transparent resin-based cast, the molds were scanned directly using the “TRIDENT” confocal surface profilometer DCM8 Leica Microsystems, housed at the Palevoprim laboratory (CNRS-INEE and the University of Poitiers). The profilometer was equipped with a 100× lens (Numerical aperture = 0.90; working distance = 0.9 μm) and a 331 × 251 μm area was scanned for each specimen. From this, four sub-adjacent surfaces (140 × 100 μm) were generated following procedures shown in Berlioz *et al.* (2018), and pre-treated following Merceron *et al.* (2016) and saved as Plμ files. The lateral sampling interval was 0.129 μm and the vertical spacing was 0.002 μm. Further analyzes to generate DMTA variables were conducted with Toothfrax, following procedures and settings provided by Scott *et al.* (2006).

Here, we focused on the four DMTA variables of the five detailed by Scott *et al.* (2006): complexity (Asfc), anisotropy (epLsar) and heterogeneity of complexity (HASfc9 ; Table 4; Scott 2012). Scott (2012) concludes that complexity (Asfc) is positively correlated with the lignified tissues of woody vegetation, and negatively correlated to the amount of

abrasive (silica-bearing) monocots in a diet, whereas the anisotropy of the texture (epLsar) is positively correlated to the amount of tough vegetation such as grasses or mature tree leaves in the diet (see also Ungar *et al.*, 2007). According to previous studies on extant species and sheep raised and fed in captivity (Merceron *et al.*, 2014; Souron *et al.*, 2015; Ramdarshan & Merceron, 2016), the heterogeneity of complexity is positively correlated to the diversity of diet. Variations in dental microwear textures among the archeological and modern populations of reindeer were tested using Statistica software, by combining non-parametric Kruskal Wallis analysis of variances and post-hoc comparisons of mean ranks of all pairs of groups with a Bonferroni adjustment (Table 5).

Table 4: Textural data on levels studied at Pincevent.

Sites	n	Asfc			epLsarx10 ⁻³			HAsfc 9		
		mean	s.d.	s.e.m.	mean	s.d.	s.e.m.	mean	s.d.	s.e.m.
Level IV0	13	1.716	0.724	0.201	3.520	1.858	0.515	0.587	0.212	0.059
Level IV20	55	1.169	0.489	0.066	5.453	1.876	0.253	0.389	0.205	0.028
Hardangervidda	54	2.344	1.043	0.142	3.255	1.393	0.190	0.525	0.195	0.026
Knutshø	48	1.865	0.641	0.092	4.361	1.867	0.270	0.513	0.161	0.023

Table 5: Results of the non-parametric Kruskal Wallis analysis of variances and synthetic results of the post hoc multicomparisons test including reindeer from level IV20, level IV0 and the two Norwegian dataset (Knutshø and Hardangervidda).

Variables	K	Df	p-value
<i>Asfc</i>	52.30433	3	< 0.0001
<i>epLsar</i>	34.86051	3	< 0.0001
<i>HAsfc₉</i>	29.47611	3	< 0.0001

	Hardangervidda	Knutshø	Level-IV0	Level-IV20
Hardangervidda				
Knutshø	epLsar			
Level-IV0				
Level-IV20	Asfc. epLsar. HAsfc ₉	Asfc. epLsar. HAsfc ₉	epLsar. HAsfc ₉	

4 – RESULTS - *Pincevent's reindeer diet*

The Kruskal-Wallis analysis of variance detected significant variations for all of the texture parameters (Table 4 and 5). The observed differences between the reindeer from the IV20 level and the two modern samples were all significant (Table 5, Figure 2). The reindeer from the level IV0 does not differ the modern population for any of the textural parameters. The reindeer from the IV20 level showed significantly higher value in anisotropy (epLsar) and lower one in heterogeneity of complexity (HASfc9) compared with the cervids from level IV0 (Table 5, Figure 2).

Figure 2: Sampling (in red) of an adult specimen (CAD - A. Lau-Bignon) (A), complexity in the anisotropy of dental microwear texture and diet of reindeer found in levels IV20 and IV0, with dataset from Scott, 2012 used as an illustrative reference (B).

5 - DISCUSSION

5.1. Diet of reindeer and environments

The dental microwear textures of the reindeer from level IV0 supported similarities in dietary bolus with the two modern populations, which inhabit alpine tundra landscapes. Their winter diet is dominated by lichens (62%), woody plants (16.3%), low percentages of mosses (8.6%), and herbaceous monocotyledons (grasses, sedges, rushes; 6.3%, Skogland, 1984; Bignon-Lau et al., 2017). However, these reindeer were slaughtered in late summer (from late August till early October) a period during which the diet is more balanced with herbaceous monocots (more than 45%), lichens (about 16%) and shrubs (11%) of the stomach content. Bignon-Lau et al. (2017) have shown that the dental microwear textures of the two modern populations of reindeer reflect these mixed feeding habits in late summer, although the Knutshø population are more engaged in grazing in herbaceous monocotyledons than the Hardangervidda samples. Differences in population density are most likely the main parameter controlling the dietary spectrum; thus, explaining the differences in dental microwear textures between the two populations. Due to a higher individual competition for access to food resources, the individuals of the Hardangervidda population probably had to enlarge their dietary spectrum to include more browsing and more lichens than the Knutshø population. There is no doubt, therefore, that the reindeer from level IV0 were engaged in both grazing and browsing.

The reindeer from level IV20 were significantly more engaged in grazing than the Knutshø ones (Figure 2b). When plotting the reindeer data on the "complexity versus anisotropy" continuum based on the African bovidea data (which are used as illustrative reference for herbivores living in pasture ecosystem), Figure 2; Scott, 2012), the reindeer from level IV20 fell between variable and obligate grazers. Such dental microwear textures support either that the food resources were abundant enough to provide full access to the preferred food

resources, or that the reindeer herds were not large enough to avoid individual competition for food resources. Taking into account the archeological context, the former hypothesis seems to be correct.

Paleoenvironmental reconstruction in the Paris Basin during the Late Glacial indicates a mammoth steppe ecosystem, characterized by an association of communities of megaherbivores and a mosaic landscape (Guthrie, 1982, 1984, 1990; Bignon, 2008). This is confirmed by pollinic analyzes conducted in Bazoches-les-Brès, 5 kilometers from the Pincevent site. The pollen spectrum attests to a steppic type of flora with a dominance of herbaceous dicots (zone Baz a,b,c between 15 and 20% of *Rubiaceae* and *Compositae* ; Leroyer *et al.*, 2014) and monocots (zone Baz a,b,c between 30 and 40% of *Poaceae* and *Cyperaceae* ; Leroyer *et al.*, 2014). This is consistent with isotopic analysis conducted on these regional sites which depicted an open environment without dense tree cover (tundra, grasslands; Drucker, 2001). The herbivores found in the Paris Basin sites would have frequented a tundra-like environment (with less lignified or semi-lignified shrubs and bushes, however). They actually have higher $\delta^{13}\text{C}$ values of collagen than herbivores from dense tree cover landscapes (Drucker, 2001). In the case of the IV0 and IV20 levels, reindeer “mean values of $^{13}\text{C}_{\text{coll}}$ are set between -19.5 et -20.5 ‰” (Drucker, 2007; translated from French by the authors, p. 251), indicating that they undoubtedly frequented an open environment.

5.2. A shift in reindeer behavior

In Pincevent, researchers generally tend to place the culling event of the IV20 occupation during the animals’ fall migration (mortality profile, sex-ratio, seasonal arguments, short-term occupation indicated by low flint production and spatial organization), which indicates that the herd was looking for more abundant food resources (David *et al.*, 2014). The tactic developed by Magdalenian people at this time of year is consistent with the mortality

profile of a natural population: seasonal information (age of juveniles), the reindeer's MNI, as well as the short duration of the camp (see SI for details; Julien, Karlin, 2014). Dental microwear textural analyses of the IV20 reindeer show a strikingly narrow inter-individual variability, an homogeneity that fits well with the short period of the fall culling event (Figure 2B).

On the contrary, less massive tactics were developed twenty years later during the IV0 occupation, with multiple hunting events occurring all year round. This yields a more complex reindeer mortality profile (underrepresentation of juveniles, while young adults are overrepresented) and denser units revealing the inner reorganization dynamics of the camp (SI; Bodu *et al.*, 2006, 2011; Debout, 2012). We noted that the species targeted also changed: in level IV20, reindeer represent almost all of the faunal spectrum, whereas level IV0 was shared between reindeer and horses. When one is considering the largest period of reindeer hunts from level IV0, embracing all seasons, it is not surprising to find a significantly greater inter-individual variability of microwear values compared to level IV20 specimens (Figure 2b). In addition, beyond the range of inter-individual diet variability we pointed out that there was no significant overlap of the data (including standard deviation for $Asfc$ and $epLsar \times 10^{-3}$ in Figure 2b, table 4) between level IV20 and IV0. Though several reindeer were hunted in fall in both levels (unit 43-T125 for level IV0; Debout *et al.*, 2006), the diet variability highlighted in this paper was not restricted to cyclic seasonal fluctuations. These considerations, therefore, lead us to consider that such targeted animals changed their feeding behavior during a short timespan of twenty years.

5.3. Consequences and causes of changes in reindeer behavior

From a Magdalenian hunter's point of view, such a significant shift in behavior concerning one of their key-species was crucial for their whole settlement pattern and potentially for their survival. We may hypothesize that resource availability influenced animal distribution and density due to their movements or migrations (Skogland, 1989; Bennett, Provan, 2008;

Hopcraft *et al.*, 2010). In turn, reindeer availability and density all year round, or at some predictable moments in case of migration, depends on hunting tactics, a collaborative amount of people needed and the patterns of mobility of Magdalenian hunter-gatherers (Binford, 1978; Bignon, 2008; Julien, Karlin, 2014). In extant reindeer populations, we can observe different type of migratory behavior. *Rangifer tarandus* can be sedentary when they are not predated or live without demographic pressure, or can be generally sedentary-migratory when only a part of the population is migratory (Reimers, 1983; Tyler and Oritsland, 1989; Geist, 1999; Loe et al., 2007; Kuntz, 2011). Migratory reindeer (entire herds) can cover very long distance through winter or summer pastures.

Regarding resource availability, we know that abiotic factors (such as rainfall or soil nutrients) can impact forage quality and abundance, resulting in herbivores of different sizes (Hopcraft *et al.*, 2010). During the Magdalenian occupation, the environment was open but fluctuations were registered during the Bölling period, according to sedimentology studies (Orliac, 2006). In fact, slight modifications of sediment composition occurred between the silt deposit of IV20 level and the sandy silt deposit corresponding to IV0 level (Orliac, 2006). The latter sediment composition indicates slightly more force than the Seine, due to higher rainfall or snowfall rates (Orliac, 2006). Regarding such fluctuations, rain/snowfall variation are of importance for plant's composition and abundance: reindeer could have been helped by searching for more quality foraging. Would the paleoenvironmental conditions that could have favored a shift in reindeer feeding behavior might also have led to migratory behavior?

Regarding level IV20, this very well preserved camp strongly suggests that the reindeer were migrating (David et al, 2014). Conversely, the dental microwear texture of reindeer on level IV0 is closer to the two Norwegian extant populations (Figure 2b, Table 5): different seasons with different vegetal resources. We can therefore hypothesize that the reindeer from level IV0 were less migratory than the reindeer from level IV20. But at this point, several

complementary analyzes (DMTA for broader spectrum of sites, and confrontation with intra-tooth oxygen, carbon and strontium isotope variations) are needed to precise which scenario could be the best one:

- level IV20 specimens were migratory but level IV0 ones were sedentary;
- level IV20 specimens were migratory but level IV0 ones became mixed sedentary-migratory population;
- specimens of both levels were mixed sedentary-migratory populations and Magdalenian changed their hunting tactics while reindeer got better physical condition.

6 - CONCLUSION

By analyzing the dental microwear texture of the 68 reindeer hunted by Magdalenians and found in Pincevent, we have been able to identify variations of diet in reindeer between levels IV0 and IV20. The signal provided complements those provided by the isotopic analyzes of bone collagen applied on the same levels. Variability of reindeer behavior suggests variability among hunting strategies during the Upper Paleolithic period. To establish hunting strategies people must have gathered a thorough knowledge of reindeer and horse ethology (migration paths, calving grounds). The hunters probably knew where to find their prey, which is why reconstructing animal ethology with proxies, such as dental microwear texture or isotopic analyzes, is important for reconstructing hunting strategies. Reconstructing diet behavior in reindeer helped us define the Magdalenian's way of life in the Paris Basin more precisely, and enabled the coevolution bond that persisted throughout this period to be established.

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