

## **Bearded Vulture *Gypaetus barbatus* contributions to the constitution of two different bone assemblages: Modern reference data and an archaeological example in Corsica**

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**Abstract.** The Bearded Vulture *Gypaetus barbatus* is a large raptor that accumulates bones at its nest. The latter is often in a cave large enough to accommodate humans. With the aim of creating a modern reference, the bone contents from 11 nests of modern Corsican Bearded Vulture are analysed from a taphonomic point of view. They are mainly characterised by overwhelming quantities of third phalanges from middle-size ruminants, abundance signs of digestion around the proximal articulations, and a few bone flakes. Bone flakes on the other hand, are very abundant at bone breaking areas or ossuaries (rocky slopes) used by the Bearded Vulture. Both types of accumulation are compared in this paper in order to understand the feeding behaviour of this raptor and its consequences to the formation of archaeological assemblages. The authors then compared these new, present-day reference data with the Late glacial faunal assemblages of Luri-Gritulu cave (Northern Corsica). This accumulation is mainly composed of third phalanges of *Megaloceros cazioti* (the endemic Corsican deer) with digestion marks and we can conclude that they have been accumulated by Late glacial Bearded Vultures and not by human beings or mammalian carnivores.

**Key words:** taphonomy, Bearded Vulture *Gypaetus barbatus*, digestion marks, Late Glacial, Corsica, *Megaloceros cazioti*.

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### I. INTRODUCTION

Assemblages accumulated by mammalian carnivores can be confused with those produced by prehistoric humans, causing many scholars to collect and describe modern reference materials accumulated by carnivores, especially spotted hyenas (BUNN 1983; KLEIN & CRUZ-URIBE 1984; HILL 1989; CRUZ-URIBE 1991; FOSSE 1996; BRUGAL et al. 1997), wolves (BINFORD 1978, 1981; HAYNES 1983) and foxes (STALLIBRASS 1984; MONDINI 1995, 2000; CASTEL 1999; ESTEVEZ &

MAMELI 2000). Modifications of small vertebrate bones by avian predators have also been discussed by various authors (DODSON & WEXLAR 1979; DENYS 1985; ANDREWS 1990; FERNANDEZ-JALVO & ANDREWS 1992). These studies have greatly increased our knowledge of the taphonomic signatures of various predators on the taxonomic composition, skeletal element representation, and on gnawing, crushing, breaking and digestion marks of bone assemblages. However, diagnostic criteria of this kind are still lacking for numerous ecological situations, and for some species that are potential bone accumulators.

This is especially true for the Bearded Vulture *Gypaetus barbatus* (LINNAEUS, 1758), which has two main features in common with prehistoric human habits: it lives (i.e. nests) in caves or rock shelters and feeds on large vertebrates (CRAMP & SIMMONS 1980).

This large raptor has the particular habit of feeding almost entirely (up to 90%) on bones from ungulate carcasses (BROWN & PLUG 1990) and dropping bones it had just scavenged from the air when these are too long to ingest. It uses the same places, called bone breaking sites or ossuaries, which are rocky oblique surfaces (BOUDOINT 1976; MARGALIDA & BERTRAN 2001). Adult Bearded Vultures repeat their action until bones are sufficiently fragmented and take these fragments back to the nest for their own consumption or for their chicks. Both nests and ossuaries are situated today in high mountains (between 800 and 3000 m a.s.l. in the Spanish and French Pyrenees) and are separated from each other by a short distance (average distance =  $789 \pm 377$  m in Spain).

Compared to nocturnal raptors and eagles (ANDREWS 1990), the Bearded Vulture has never drawn the taphonomists' attention. This is probably because it is now very rare and until this last decade, observations concerned mostly the spectacular bone-breaking activity and not the feeding behaviour at the ossuaries (specific choice of skeletal parts) and in the nest. In order to redress this lack of evidence, we present below a present-day reference dataset drawn from the contents of 11 nests and two ossuaries of modern Corsican Bearded Vultures.

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## II. STUDY AREAS AND METHODS

Corsican Bearded Vultures spend most of their time in the central mountains of the island (THIBAULT & BONACCORSI 1999). Items have been exhaustively collected between 1985 and 2000 from 11 nesting eyries of Bearded Vultures and two bone breaking sites located in different subalpine valleys of Corsica (THIBAULT et al. 1993). These ossuaries are situated at 1500 m a.s.l. and their average surface area is about 200 m<sup>2</sup>. We deliberately do not give the exact names and locations of these places in order not to put this species in danger.

Hooves and horns from nests ( $n = 590$ , i.e. 40% of total items) have been then excluded from the study in order to be in accordance with archaeological and paleontological situations. Only isolated cleaned bones and bone fragments ( $n = 871$  in nests,  $n = 1456$  in ossuaries) have been taken into consideration.

Anatomical and taxonomic determinations have been made according to VIGNE (1988, 1995) and THIBAULT et al. (1993); The taxonomic composition of both fossil and modern assemblages has been established in terms of both Number of Identified Specimens (NISF) and Minimal Number of Individuals (MNI). The latter have been estimated on the basis of the most frequent right or left anatomical part (frequency MNI = MNIf; POPLIN 1976). Cumulative MNIf of the nesting eyries and ossuaries have been estimated by adding the MNIf of all individual nests, taking into account that

each nest is very distant from the others, both in space and time, and that it is consequently very unlikely that bones collected in different nests come from the same individual carcass.

Every mark on bone surfaces, especially digestion marks, have been registered for all bones.

### III. RESULTS

#### Nest remains

**Taxonomic composition.** Fig. 1a gives the cumulative taxonomic composition of the 11 bone assemblages. Among a minimum number of 105 individual carcasses, middle sized mammals are dominant, with 92.4% of the MNI. Cattle *Bos taurus*, mainly represented by calves, are the most important taxon in terms of NISP (49.1%) but represent only 25.7% of the MNI. Domestic and wild caprines (sheep *Ovis aries*, goats *Capra hircus*, wild moufflon *Ovis ammon musimon* and unidentified *Caprini*), both young and adult, make only 36.6% of the NISP, but they dominate in terms of MNI (56.2%). Undifferentiated pig or wild boar bones (*Sus scrofa* ssp.) constitute only 6.9% of the bone remains and 9.5% of the individuals. *Equus* sp. (probably a donkey *E. asinus*) is represented by only one phalanx. Small mammals are represented (NISP = 5.4%; MNI

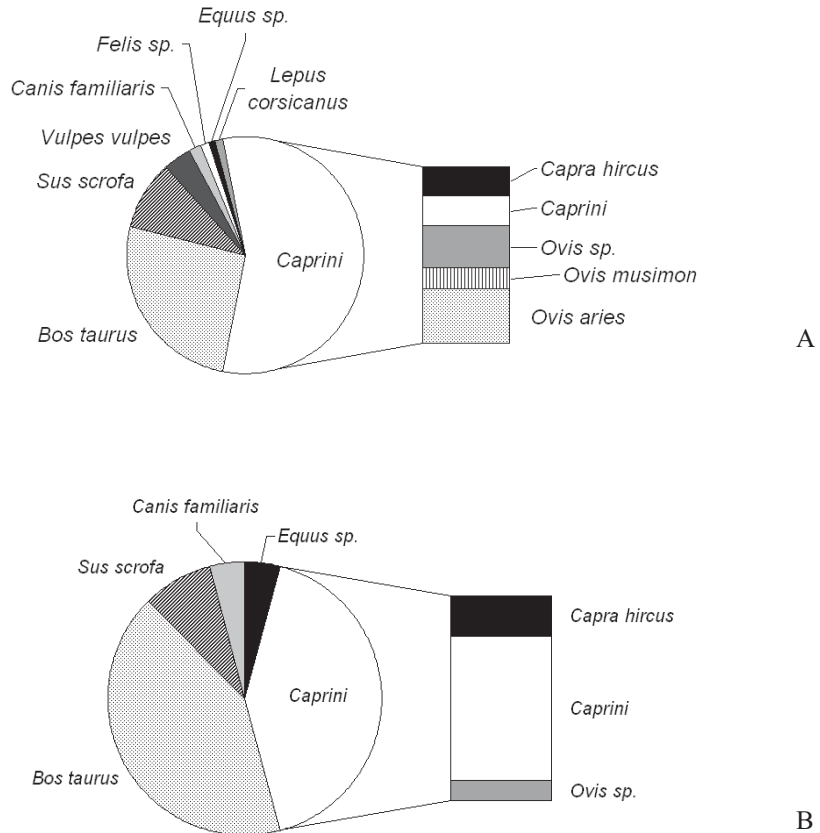


Fig. 1. A – Cumulative taxonomic composition of the 11 bone assemblages collected from the selected modern Corsican nests of Bearded Vultures. MNI (N = 105) Minimal Number of Individuals (frequency method; POPLIN 1976). B – Cumulative taxonomic composition of the 2 bone assemblages collected from the two Corsican ossuaries used by a pair of Bearded Vulture. MNI, Minimal Number of Individuals (N=24).

= 7.6%) by only four taxa: fox *Vulpes vulpes*, dominant; dog *Canis familiaris*, wild or domestic cat (*Felis* sp.) and hare *Lepus capensis corsicanus*. Although the Bearded Vulture brings quantities of small vertebrates to the nest (SUETENS 1989; THIBAUT et al. 1993; BERTRAN & MARGALIDA 1997), their bones are mainly digested and thus absent from bone assemblages. This taxonomic distribution fluctuates from one nest to another according to local husbandry practices (THIBAUT et al. 1993). With reference to the MNI, caprines, suids and cattle dominate in 7, 2 and 1 nests respectively, caprine and cattle being equal in the last nest.

**Skeletal part survival.** As for skeletal parts, ungulates being considered altogether, short and compact bones (tarsals, carpals, sesamoids and phalanges) are overwhelmingly dominant (Fig. 2) with 75% of the NISP. Long and flat bones make only 13 and 12%, respectively. First phalanges are less represented (20.5%) than second ones (34%), and third phalanges survived the best (98.5%). Distal extremities of first and second phalanges are overwhelmingly more abundant (90%) than proximal ones. This pattern does not change significantly from one nest to another, phalanges (and especially their distal extremities) being always predominant (from 42 to 73% of NISP) in the 11 evries.

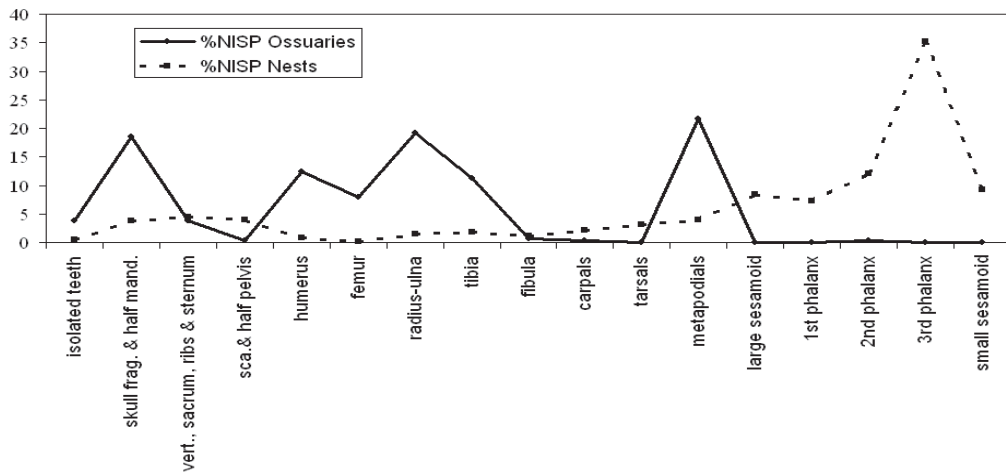


Fig. 2. Percentages of NISP of the skeletal parts of the sole ruminants (NISP = 747) collected from the selected 11 modern Corsican nests of Bearded Vultures and from the ossuaries.

**Digestion marks.** Digestion marks were observed on the surface of 486 (56.3%) bones and were much less frequent on long and flat bones (NISP = 213, 26.3% digested) than on short and compact ones (phalanges, sesamoids, tarsals, carpals and vertebrae: NISP = 645, 66.2% digested). Among the latter, they affect 76.1% of the phalanges, 60% of the vertebrae and only 45% of other bones.

The action of gastric juice is different on all three sorts of phalanges. The abaxial horny wall being thicker than the axial one, acids act asymmetrically on second and third phalanges, so that axial sides generally vanished first (Fig. 3).

These small items seem very diagnostic. 80% of the third phalanges are affected by digestion. 38.3% of them are only represented by the apex and the abaxial side of the palmar side, resulting from the perforation of the dorsal edge near the extensor process.

However, more occasionally, digestion marks also affect other bones, as illustrated by the caprine radius (Fig. 4). Cortex of long bones became very thin, rounded and almost transparent on the edges ("lacy" aspect), and natural foramina became enlarged. 29 of the 54 bone flakes found in modern nests, bear digestion marks.

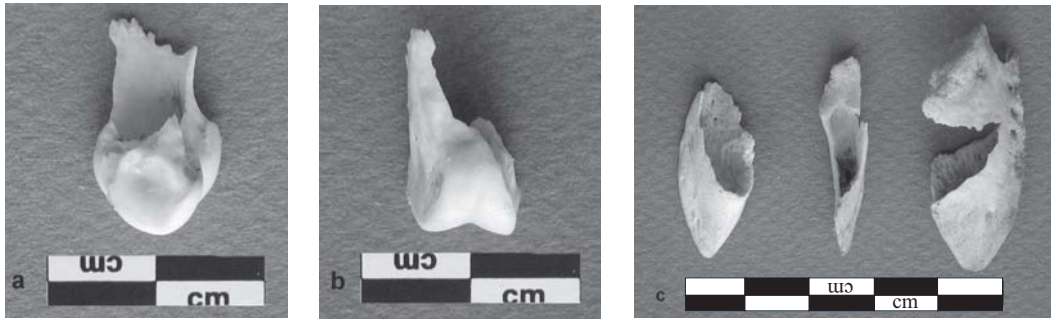


Fig. 3. Three regurgitated phalanges (second and third) with digestion marks from present-day nests of Corsican Bearded Vultures (photos I. R.).

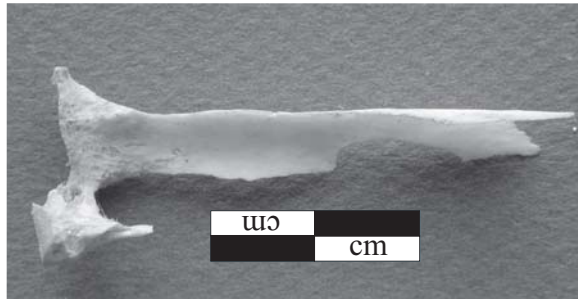


Fig. 4. Example of digestive attack on a regurgitated caprine radius from modern Bearded Vulture nest site (photo I.R.).

#### Items from ossuaries

**Taxonomic composition.** The analysis of items from ossuaries shows that medium-sized domestic ungulates are also very dominant in these sites (Fig. 1b). The number of caprines ( $n=10$ ) is equal to *Bos taurus* in term of MNIf. Undifferentiated pig or wild boar bones are represented by two individuals, and dog *Canis familiaris* by one, as is the case for equids.

**Skeletal part survival.** Parts of the axial skeleton are almost absent (Fig. 2), like hooves and sesamoids, and we found only one phalanx. We have not seen any complete bones on these bone breaking sites, and even isolated teeth were all fragmented. The major remark is that flakes from long bones diaphyses are overwhelming in ossuaries and represent in weight, half of the remains (4374g on a total of 8774g) and the larger part of the items (78%). The same observation was made by BOUDOINT (1976), who adds that he has not seen any epiphyses in these areas. In our study, we found some but in small numbers (Fig. 5) compared to numbers found in nests. Flake size varies from 9 to over 100 mm but the majority (74%) are between 10 and 50 mm.

**Marks on bones.** No visible marks of gastric juice action were seen on bones from ossuaries. Approximately half of collected fragments bear weathering marks as described by BEHRENSMEYER (1978) and LYMAN (1994: 356-7). The same ossuarie is used for many years by the same pair of vultures and bones may have stayed for more than four years before we collected them. In addition, carnivores (red foxes probably) have gnawed some of them before or after the breaking by the Bearded Vulture.

#### Taphonomic signatures

According to the bone remains from the 11 modern Corsican nests and the two ossuaries these two kinds of accumulations appear to be mainly characterised by four major features as summarised in Table I:

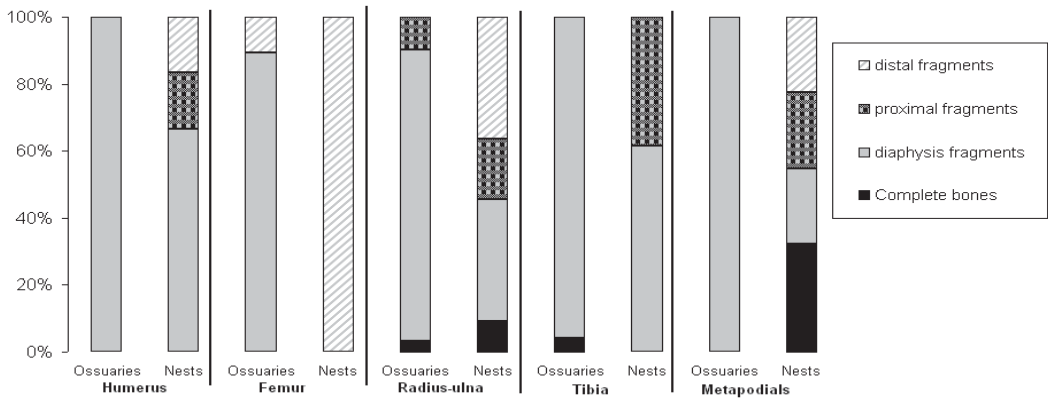


Fig. 5. Proportion of distal, proximal, diaphysial parts of long bones and proportion of complete bones present in modern Corsican nest compared to same kind of remains from ossuaries.

Table I

Taphonomic signatures of bone remains from nest sites and from ossuaries in Corsica

	Bone assemblage in nests	Bone assemblage in ossuaries
Species	Middle sized ungulates	Middle sized ungulates
Skeletal parts	Phalanges (specially third)	Long bones from limbs
Fragmentation	Very rare bone flakes	Massive quantity of flakes
Marks	Digestive attacks on phalanxes	Weathering marks

- middle-sized ungulates (i.e. caprines, calves and suids) are overwhelming;
- skeletal part frequencies are highly unbalanced in favour of (i) third phalanges, and, secondarily, of first and second phalanges, of scapulae and sesamoids in nests, (ii) long bones from limbs in ossuaries;
- strong digestion marks affect most of the proximal parts of second and third phalanges, at the very places where they are least sheltered by the hoof horny envelope and by the ligaments; weathering and gnawing marks are often visible on bones from ossuaries;
- In eyries, indeterminate bone flakes are few and often digested. In ossuaries it is the opposite: indeterminate flakes represent 78% of the remains;

Consequently, taphonomic signatures of the Bearded Vulture as defined by all these four features cannot be confused with any others, either animal or human. Altogether, these patterns appear to be very specific of the species *Gypaetus barbatus*, at least for Corsica or similar Mediterranean mountain areas with high numbers of ungulates.

## IV. DISCUSSION OF MODERN DATA

The characteristics of both kinds of assemblages can be explained by the Bearded Vulture feeding behaviour. This raptor takes what it needs in bone tissue proteins (osseine) and lipids (oleic acid) by dissolving them with the help of gastric juice. As explained by BINFORD (1978: 33), phalanges, metapodials and tarsals contain the highest quantity of white grease but considering their size and the longer processing time, these are less exploited by human groups. Bearded Vultures on the contrary are able to use this grease. The kind of bones they take on a carcass is not dictated by what other scavengers have left but by the best choice in terms of fat content.

All the skeletal parts in the ossuaries represent what Bearded Vultures do not want, especially long bone diaphyses (BOUDOINT 1976). Epiphyses which are rich in lipids (54% of dry matter against 3% in diaphyses) are rarely found on these sites.

Recent biological studies carried out in South Africa (BROWN & PLUG 1990), Corsica (THIBAULT et al. 1993) and Spain (BERTRAN & MARGALIDA 1997) demonstrate that not all bones brought to the nest by adults are swallowed by the young, and that some swallowed bones can escape digestion and be regurgitated (VIGNE 1995), especially if they are protected in horns or hooves by keratin envelopes which better withstand gastric juices (MONDINI 1995: 158). This is the case for ungulates' third phalanges found inside nests.

We also found, inside and around eyries, (i) bones it has ingested and then regurgitated, (ii) intact bones: probable food reserve for the adult and/or the young and (iii) uningested scapulae from which adults had probably removed the meat and small fragments of bones (easy to break) to feed the chick.

## V. ARCHAEOLOGICAL EXAMPLE: FOSSIL ASSEMBLAGE AT LURI-GRÍTULU CAVE

## Luri-Grítulu cave and its Late Glacial vertebrate fauna

The Luri-Grítulu cave, located in the Cap Corse, near the northern end of Corsica, is situated at 150 m asl. The cave is about 12 m long. The width at the entrance is approximately 3 m, and the height decreases from 2.5 (front) to 0.8 m (back). A small rocky horizontal and flat ledge (0.5 m wide, 2 m long, less than 1m high) on the western wall is situated 2 m above the Late Glacial deposits. Excavations were conducted in 1996 and 1998 (MAGDELEINE & VIGNE 1994, 1996, 1997; PREFACTH, in press: fig. 1). We studied large faunal remains from Late glacial Middle Deposit located between Late Wechselian (Early Late Glacial nearly sterile clay layers, probably accumulated when the cave was not accessible to large vertebrates) and Holocene layers from the Mesolithic with stone artefacts (Ly-823 (OxA):  $8130 \pm 70$  BP, i.e. [7313-6805] cal. BC) to Middle Neolithic.

Since the Middle Deposit is composed of two different geological layers: the Early Middle Deposit ("EMD") and the Late Middle Deposit ("LMD") we studied them separately.

Among small vertebrate species, *Prolagus sardus* was extremely dominant, followed by *Rhagomys orthodon*, *Tyrrhenicola henseli*, *Episoriculus corsicanus*, birds, reptiles and amphibians probably mainly accumulated in the cave by the endemic dwarf horned owl (*Bubo insularis*). In addition, we have collected 38 remains of the extinct canid *Cynotherium sardous* (MALATESTA 1970; EISENMANN & VAN DER GEER 1999) and 751 remains of the small extinct deer, *Megaloceros cazioti*, which was the size of a modern European fallow deer (CALOI & MALATESTA 1974).

Preliminary identifications has shown a strong dominance of phalanges of this species. Although there were no convincing artefacts and no hearths or significant amounts of charcoal in "Middle Deposits", these materials raised the question of a possible human occupation at Grítulu (MAGDELEINE & VIGNE 1994, 1996), and, more generally, of the likeliness of the presence of prehistoric hunters in Corsica during the Late Glacial (for reviews, see VIGNE 1996, 1999).

Because of the large quantity of *Megaloceros cazioti* third phalanges and the presence of 32 fossil bones of the Bearded Vulture in this cave, we then decided to compare the Bearded Vulture modern nest referential with the fossil assemblage of Grítulu to see if this raptor can have been responsible for the endemic deer accumulation. This interpretation would also be consistent with the presence of a cornice inside the cave that could support a large nest, and the high concentration of both *Gypaetus* and *Megaloceros* bone remains in the excavation squares situated just below this cornice.

#### Comparison between fossil and modern bone assemblages

*Megaloceros cazioti* is overwhelming in Middle Deposit layers. In “EMD” it represent 91.6% of NISP and 100% in “LMD”. The endemic deer is present in the same proportion as domestic ungulates in modern nests.

The original profile of skeletal parts is strongly unbalanced in favour of third phalanges, secondarily of first and second ones, and does not differ from the pattern in modern nests (Fig. 6) the only difference being that there are less teeth and many more small sesamoids in the modern nests. The sesamoids are mainly from the limbs of cattle still in articulation, which have not been swallowed; they represent what we named previously “food reserve for the adult or the young” and are absent in Grítulu. Higher numbers of teeth in the fossil assemblages probably results from high levels of post-depositional fragmentation. In addition scapulae appear to be significantly ( $e = 4.4 > 1.96$ , at the 5% threshold) more frequent in modern than in Grítulu assemblages.

Proportions of bone flakes are the same in both fossil and modern assemblages (5 and 6.2%, respectively;  $e = 1.09 < 1.96$ , at the 5% threshold). Conversely, phalanges excepted, complete bones are much less frequent in the former (29.8%) than in the latter (70.6%). They are probably also a part

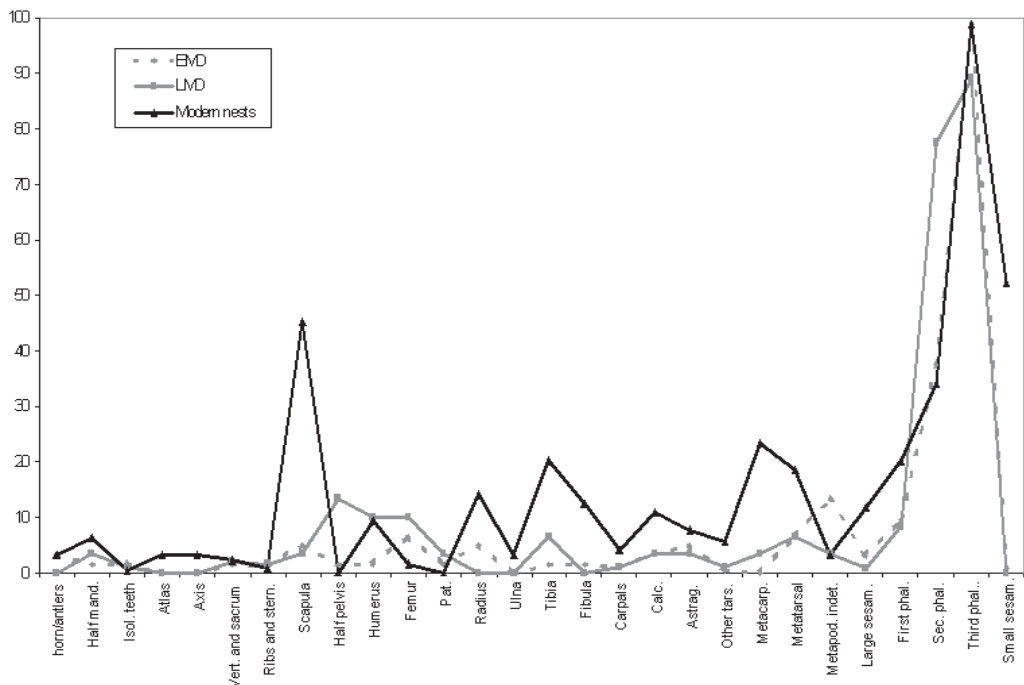


Fig. 6. Percentages of NISP of the skeletal parts of the sole ruminants collected from the selected 11 modern Corsican nests of Bearded Vultures (NISP = 747) and from Grítulu Late glacial assemblage.



of the “food reserve”, according to observations made in South Africa (PICKFORD et al. 1990) and the Pyrenees (MARGALIDA pers. comm.).

Digestion marks (55.7%) are much less frequent in present day assemblages than in both EMD (74.2%;  $e = 6.9$ ) and LMD (84.8%;  $e = 7.9$ ), but the pattern of localisation of digestion marks is identical to the modern assemblage from nests (Fig. 7). Generally speaking, undigested phalanges are significantly ( $e > 1.96$ ) more frequent in the modern samples than in the fossil ones. This is true for first (3.0 and 41.2%, respectively), second (1.6 and 38.7%) and third (2.9 and 13.2%) phalanges as well. This phenomenon has the same explanation as the presence of complete bones and the large quantity of small sesamoids in nests (“food reserve”), but it can also be due to re-swallowing behaviours, such as those observed by MARGALIDA and BERTRAN (1996) in Spain. Indeed, Bearded Vulture were seen to re-eat their own pellets after regurgitation, if they still contained some bone. Such behaviour may also explain the small survival and the high digestion level on bones, especially on first and second phalanges at Gritulu, third phalanges being still sheltered by hooves.

We can then conclude that apart from small discrepancies, possibly due to differences in food composition and availability during modern and Late Glacial times, the main taphonomic characteristics of the Late Glacial assemblage of endemic *Megaloceros* remains at Gritulu cave are consistent with the ones of the present-day reference. This confirms that Bearded Vulture, nesting on a cornice of the cave porch, was the main accumulator of *Megaloceros* bones in it.

#### Utilisation of the Bearded Vulture behaviour in archaeological research

The Late Glacial assemblage of *Megaloceros* remains at Gritulu cave is probably the first one recognised as a fossil Bearded Vulture bone assemblage. It confirms that these birds are able to accumulate bones of ungulates in sites which may also be settled by human beings and/or mammalian carnivores like *Cynotherium sardus* at Gritulu. The endemic canid, which also dwelled and died in the cave, contributed only a low extent to the large mammal bone accumulation, but there seems to be a relationship between terrestrial carnivores and Bearded Vultures. We can almost talk about prey search facilitation and we must not forget that only such carnivores can dismember ungulate carcasses and make the action of Bearded Vultures possible. It is the case in South Africa with the Hyena; in Corsica and the Pyrenees there is probably the same relationship with the red fox *Vulpes vulpes*. In Austria, in Wendbach valley, a small cave was excavated in 1986 and remains were studied by Dr. H. FREY (Veterinary University) and Dr. K. BAUER (Natural History Museum) in Vienna. The cave was identified as a historical nest of the Bearded Vulture (FREY, pers. com.) dated to the early Middle Ages (ca. 1000 AC). The cavity was used as a den by a canid (presence of coprolites and deciduous teeth). This association between mammalian carnivores and the Bearded Vulture should be taken into account when taphonomical studies are undertaken in a cave.



Fig. 7. Comparison of third phalanges with similar digestion marks coming from modern nests of Bearded Vulture and from Gritulu cave. Modern *Capra hircus* on the right and Late Glacial (*Megaloceros cazioti*) on the left (photo I.R.).

The altitude of nests is also important for archaeological research. Today ornithologists usually locate nest sites in alpine levels of vegetation. But the presence of the Bearded Vulture is attested at low altitude in numerous West Mediterranean Late Glacial and Holocene paleontological and archaeological sites (e.g. VILLETTE 1983; HERNANDEZ & MORALES 1995; TYRBERG 1998). Gritulu cave is at 150m. a.s.l. (approximately 180 to 205 m during the Late Glacial period) and the Austrian historical nest at 600m. The Bearded Vulture followed the evolution of the vegetation to find open land with grass or rocky areas. In the early Middle Ages, Wendbach valley was a location for iron industry. It needed a high quantity of trees and therefore transformed the forest landscape into open areas, favourable to the Bearded Vulture (FREY pers. com.)

## VI. CONCLUSION

Bone accumulations in caves and open rocky areas by the Bearded Vulture having been now described, we cannot continue to ignore its possible contribution to Prehistoric bone assemblages. Some assemblages, assumed to result from carnivores or human activities, should probably be revisited in the light of this "new" and proven accumulator. However, the peculiar Late Glacial context of Corsica (with only two large endemic mammals and probably no Late Glacial human hunters, at least in Gritulu cave) offered particularly good conditions for recognising Bearded Vulture bone accumulations. It will probably be more difficult to separate them from other possible origins on the mainland, where faunal spectra are larger and the number of carnivores higher.

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