# AUTHOR QUERY FORM

| ELSEVIER | **Journal:** YJASC<br>**Article Number:** 3946 | **Please e-mail or fax your responses and any corrections to:**<br>**E-mail:** **corrections.esch@elsevier.tnq.co.in**<br>**Fax: +31 2048 52789** |
|---|---|---|

Dear Author,

Please check your proof carefully and mark all corrections at the appropriate place in the proof (e.g., by using on-screen annotation in the PDF file) or compile them in a separate list. Note: if you opt to annotate the file with software other than Adobe Reader then please also highlight the appropriate place in the PDF file. To ensure fast publication of your paper please return your corrections within 48 hours.

For correction or revision of any artwork, please consult http://www.elsevier.com/artworkinstructions.

Any queries or remarks that have arisen during the processing of your manuscript are listed below and highlighted by flags in the proof.

| **Location in article** | **Query / Remark: Click on the Q link to find the query's location in text**<br>**Please insert your reply or correction at the corresponding line in the proof** |
|---|---|
| **Q1** | Please check the layout of the Tables 1 to 9 and correct if necessary. |
| **Q2** | Please confirm that given names and surnames have been identified correctly. |
| | Please check this box or indicate your approval if you have no corrections to make to the PDF file ☐ |

Thank you for your assistance.

Journal of Archaeological Science xxx (2014) 1

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

## Highlights

- A taphonomic analysis is applied to the study of modern prey samples from Egyptian Vulture nests.
- A substantial diversity of taxa is represented in Egyptian Vulture nest accumulations.
- Anatomical representation varies greatly depending on the taxonomic group.
- A low rate of bone breakage and digestion was recorded.
- Many bones display beak marks. Birds were more affected by bone surface modifications than other prey.




http://dx.doi.org/10.1016/j.jas.2014.01.018

Please cite this article in press as: Lloveras, L., et al., The role of the Egyptian Vulture (*Neophron percnopterus*) as a bone accumulator in cliff rock shelters: an analysis of modern bone nest assemblages from North-eastern Iberia, Journal of Archaeological Science (2014), http://dx.doi.org/10.1016/j.jas.2014.01.018

Journal of Archaeological Science xxx (2014) 1–15

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

# The role of the Egyptian Vulture (*Neophron percnopterus*) as a bone accumulator in cliff rock shelters: an analysis of modern bone nest assemblages from North-eastern Iberia

Q2 Lluís Lloveras [a,b,*], Jordi Nadal [b], Marta Moreno-García [c], Richard Thomas [a], Jaume Anglada [d], Jordi Baucells [e], Carles Martorell [e], David Vilasís [e]

[a] School of Archaeology and Ancient History, University of Leicester, University Road, Leicester LE1 7RH, UK
[b] SERP, Departament de Prehistòria, Història Antiga i Arqueologia, Universitat de Barcelona, Montalegre 6-8, 08001 Barcelona, Spain
[c] IH, Centro de Ciencias Humanas y Sociales (CCHS), CSIC, Albasanz, 26-28, 28037 Madrid, Spain
[d] Unió Excursionista de Vic, C/de la Riera 22 Baixos, 08500 Vic, Spain
[e] Grup de Naturalistes d'Osona, Universitat de Vic, C/de la Laura 13, 08500 Vic, Spain

ARTICLE INFO

*Article history:*
Received 25 November 2013
Received in revised form
20 January 2014
Accepted 21 January 2014

*Keywords:*
Taphonomy
*Neophron percnopterus*
Accumulator agents
Anatomical representation
Breakage
Beak marks
Digested bones

ABSTRACT

The Egyptian Vulture (*Neophron percnopterus*) is one of the smallest vultures in the Old World. Today, this vulture is seasonal in Europe, spending winter in North Africa and returning to Europe in spring; however, some permanent populations reside in the south of the Iberian Peninsula and the Balearic Islands. These birds feed mainly on carrion but are opportunistic and will prey on small mammals, birds and reptiles. The remains of Egyptian Vultures have been found on archaeological sites dated to the Pleistocene and Holocene, raising the possibility that they may have been active bone accumulating agents in caves and shelters, a practice evidenced by contemporary observation. Taphonomic studies on prey remains consumed by this vulture are very scarce and its role as an agent responsible for bone accumulations on archaeological sites is not fully understood. In this paper, we analyse bone remains recovered from three well known Egyptian Vulture nests situated in cliff rock shelters from Osona and Ripollès regions (Northeast Spain) with the aim of characterising their accumulations. Specifically, we detail taxonomic and anatomical representation, bone breakage, beak marks and digestion damage. Results show that very diverse taxonomic groups can be accumulated in Egyptian Vulture nest assemblages. The anatomical representation pattern varies greatly depending on the size of prey. Skeletal remains show a low degree of fragmentation and digestion, whilst the proportion of beak marked bones is high. Comparisons with other agents of bone accumulation (birds of prey and terrestrial mammalian carnivores) reveal that the taphonomic signature of Egyptian Vultures differs from most predators.



## 1. Introduction

The Egyptian Vulture (*Neophron percnopterus*) is a medium-sized avian scavenger which is widely distributed through the Palearctic, from southern Europe through sub-Saharan Africa and the Middle East into central Asia and India (Cramp and Simmons, 1980). Most of these vultures are seasonal in Europe, spending the winter in North Africa and breeding in Europe in spring; 80% of the European population inhabits the Iberian Peninsula (Del Moral, 2009). Egyptian Vultures migrate to Iberia at the end of February, the chicks are born between April and May, and in September they return to Africa. However, some permanent populations reside in the south of the Iberian Peninsula and the Balearic Islands (Del Moral, 2009; Ferguson-Lees and Christie, 2001).

The Egyptian Vulture is the smallest of the European vultures and with an average weight of 2 kg it cannot compete with larger scavengers such as the Griffon Vulture (*Gyps fulvus*), the Black Vulture (*Aegypius monachus*) and the Bearded Vulture (*Gypaetus barbatus*). For this reason, Egyptian Vultures have a more generalised diet: they mainly exploit carcasses of small and medium-sized mammals and birds; but eggs, fish, snails, even mammal scats are also part of their diet (Donázar and Ceballos, 1988; García-Heras et al., 2013; Margalida et al., 2012). Moreover, some cases of hunting behaviour (i.e., small birds, rabbits, rodents and insects) have also been observed (Donázar and Ceballos, 1988; Margalida et al., 2012).

* Corresponding author. School of Archaeology and Ancient History, University of Leicester, University Road, Leicester LE1 7RH, UK.
*E-mail address:* lluislloveras@ub.edu (L. Lloveras).

0305-4403/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jas.2014.01.018

The Egyptian Vulture is gregarious and usually roosts communally on large trees in numbers that can be very high. In the North of Spain communal roosts of 200 individuals have been registered (Ceballos and Donázar, 1990; Donázar et al., 1996). Breeding takes place in holes in cliffs rock shelters of variable size where food leftovers and pellets can accumulate (Ceballos and Donázar, 1990; Donázar et al., 2002). In fact, bone remains of Egyptian Vultures have been identified in some Pleistocene archaeological faunal deposits from the Iberian Peninsula at Urtiaga Würm (Deba, Gipuzkoa) (Elorza, 1990) and Boquete de Zafarraya in Andalusia (Hernández Carrasquilla, 1994). Thus, vulture nests can occur in the same spaces frequented by prehistoric hunter-gatherer populations and the food remains of both may become intermingled. Indeed, at the base of the same cliff in which some of the nests we analysed are situated, several archaeological sites with late Pleistocene and early Holocene hunter-gatherers occupations have been discovered and excavated (El Castell, Cingle Vermell and Roc del Migdia (Vila, 1985)). This demonstrates the importance of recognising the taphonomic signature of this avian scavenger in order to distinguishing between human and vulture bone accumulations.

In the last few years, assessment of the origin of bone accumulations from archaeological sites has become an important line of research in taphonomic studies. Following the pioneering research of Andrews (1990) on small prey remains accumulated by different predators, several actualistic taphonomic studies have been conducted for terrestrial carnivores (Álvarez et al., 2012; Cochard, 2004a; Esteban-Nadal et al., 2010; Lloveras et al., 2008a, 2012a; Mallye et al., 2008; Mondini, 2002; Rodríguez-Hidalgo et al., 2013; Sanchis, 2000; Sanchis Serra and Pascual Benito, 2011; Schmitt and Juell, 1994; Stiner et al., 2012) and nocturnal and diurnal raptors (Bochenski, 2005; Cochard, 2004b; Costamagno et al., 2008; Hockett, 1996; Laroulandie, 2002; Lloveras et al., 2008b, 2009, 2012b; Marín Arroyo et al., 2009; Sanchis, 2000; Schmitt, 1995) to identify the agent responsible for medium and small-sized prey bone assemblages. These studies provide information regarding skeletal representation, fragmentation and digestion corrosion patterns, which have proved critical in the analysis and interpretation of sub-fossil bone assemblages that may have been accumulated by different agents. Only one recently published paper has focused on the Egyptian Vulture (Sanchis Serra et al., 2013). In their study, Sanchis Serra et al. (2013) analysed prey remains accumulated in an historical nest that was presumed to have been occupied by Egyptian Vultures since the medieval period. For comparison, we provide data about three active and controlled nests recently occupied by the vultures.

The aims of our work are to: deepen our understanding of the taphonomic patterns left on prey remains recovered from modern

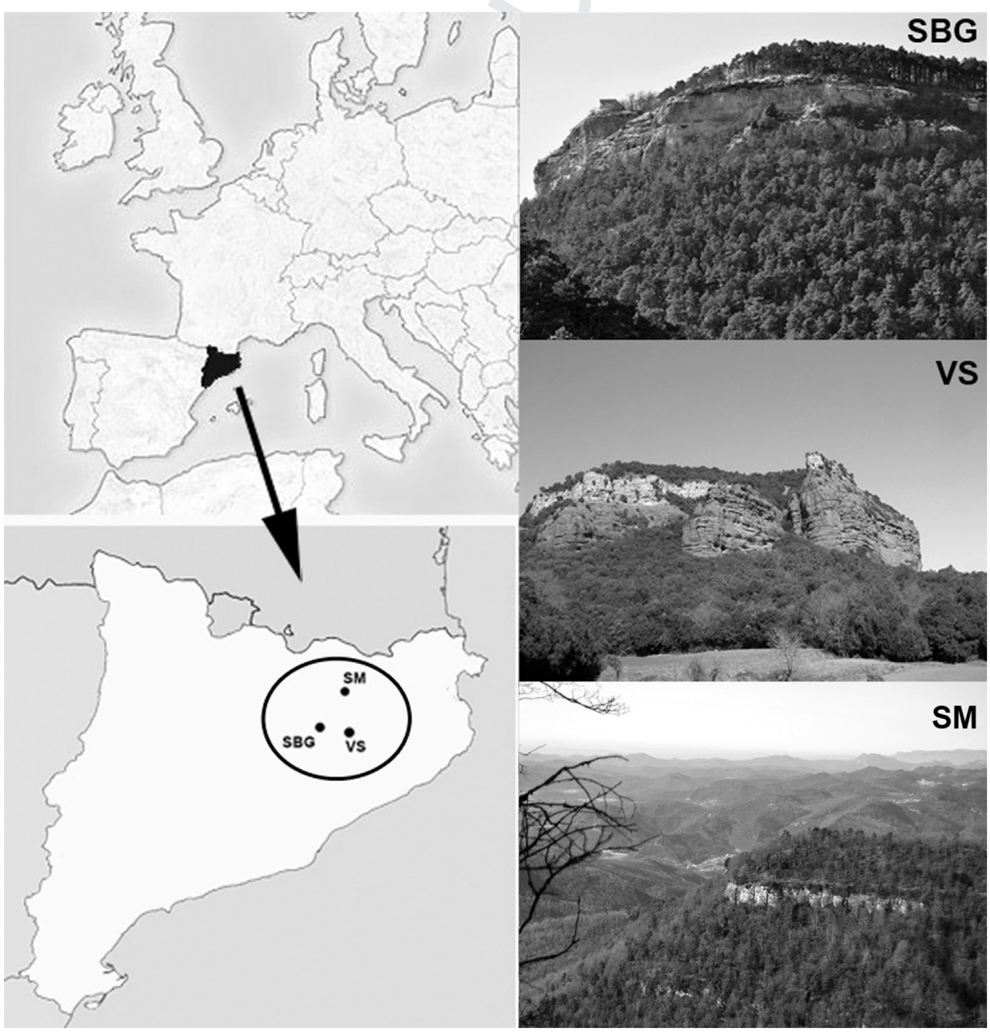


**Fig. 1.** Location of the three Egyptian Vulture nests where the samples analysed in the present study were collected. SBG: Sant Bartomeu del Grau, VS: Vilanova de Sau, SM: Serra de Milany.

Please cite this article in press as: Lloveras, L., et al., The role of the Egyptian Vulture (*Neophron percnopterus*) as a bone accumulator in cliff rock shelters: an analysis of modern bone nest assemblages from North-eastern Iberia, Journal of Archaeological Science (2014), http://dx.doi.org/10.1016/j.jas.2014.01.018

nests of Egyptian Vultures; and provide new data that establishes criteria by which their role as agents of bone accumulations in archaeological faunal assemblages can be evaluated.

## 2. Materials and methods

The skeletal remains analysed in this study come from three Egyptian Vulture nests located in the North-east of the Iberian Peninsula (Fig. 1), specifically at: Sant Bartomeu del Grau (Barcelona, Spain), Vilanova de Sau (Barcelona, Spain) and Serra de Milany (Girona, Spain); henceforth SBG, VS and SM respectively. This geographical area is characterized by a landscape dominated by high limestone cliffs and outcrops. Large forested areas alternate with agricultural fields and meadows where livestock farming predominates.

The samples were collected by members of the Grup de Naturalistes d'Osona (GNO) with the help of professional climbers during the winter of 2012, before the breeding season, to avoid disturbing the birds. The nests were situated in protected shelters (Fig. 2) and the accumulated remains did not display any signs of disturbance by other predators. The rocky substrate in which the cavities had formed is limestone in SBG and SM, and sandstone in VS. At the VS nest site, a sample consisting of skeletal remains fallen from the nest was recovered at the bottom of the cliff, in addition to the materials collected in the nest. The Egyptian Vulture nests were identified by direct observation. All nests are active at present, VS has been occupied since 1999, SBG and SM since 2010. Thus, the samples here analysed correspond to a 13-year accumulation at VS, and two-year accumulations at SBG and SM. No occupations of these nests by Egyptian Vultures or other birds of prey are documented before prior to these dates.

The recovered material comprised sediment from the rock shelter (sand and small rocks), wool and twigs (nest construction materials) and skeletal prey remains of Egyptian Vultures comprising uneaten and regurgitated bones that are the focus of this study (Fig. 2). Pellets were found disaggregated, therefore counts were not possible. Material was dry-sieved through a 1.5 mm mesh in order to recover all prey remains.

Skeletal remains were identified to element, side and taxon whenever possible. Identifications were made using the animal bone reference collection of the Departament de Prehistòria, Història Antiga i Arqueologia, University of Barcelona. The Number of skeletal elements (N), Number of Identified Specimens (NISP), Minimum Number of Elements (MNE) and Minimum Number of Individuals (MNI) were calculated and relative frequencies plotted.

The age at death of the prey mammals was estimated taking into account the state of epiphyseal fusion of long bones (humerus, femur and tibia), metapodials, scapula, calcaneus and innominate, as well as tooth eruption and wear (Barone, 1976; Grant, 1982; Payne, 1987; Rogers, 1982).

To facilitate comparison of the taphocoenosis of the Egyptian Vultures with other predators, we follow the same criteria applied in previous works (Lloveras et al., 2008a, 2008b, 2009, 2012a):

### 2.1. Anatomical representation

Relative abundance was calculated using the formula advocated by Dodson and Wexlar (1979):

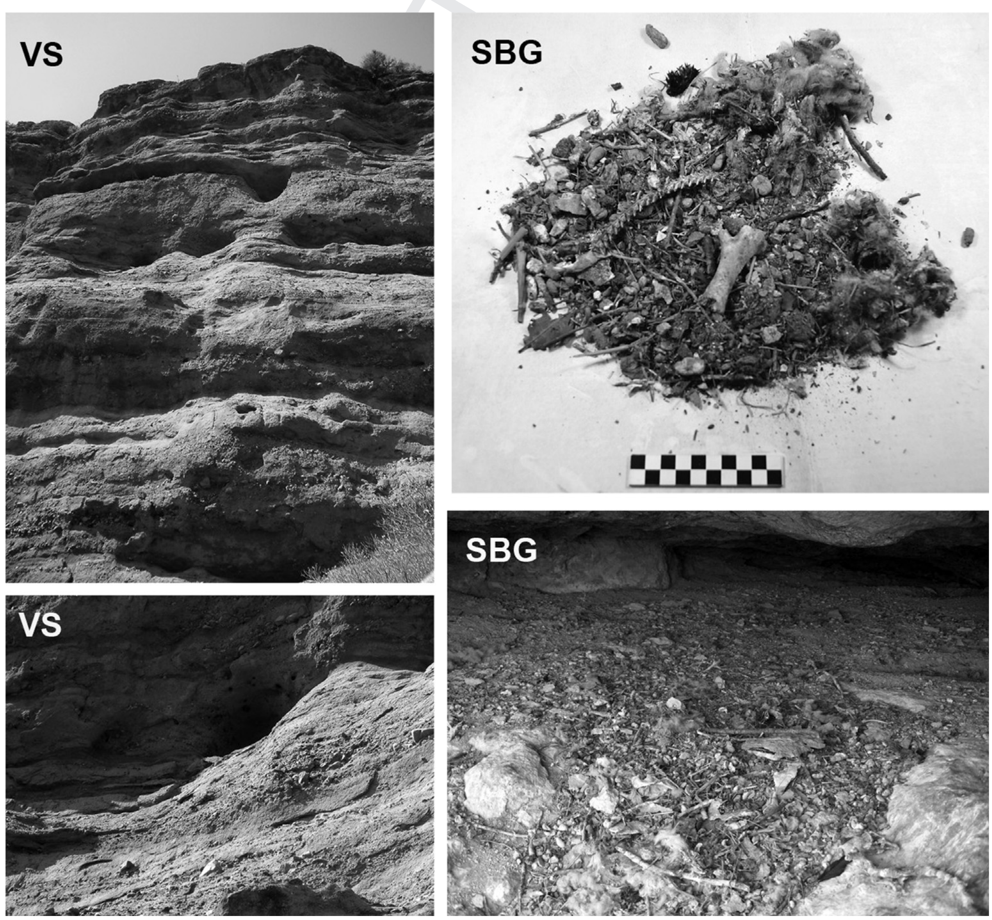


Fig. 2. Views of the cliff where the VS nest is located and the material accumulated on the surface of the SBG nest before and after collection.

$$RA_i = MNE_i/MNI \times E_i$$

($RA_i$ = the relative abundance of element $i$; $MNE_i$ = the minimum number of skeleton element $i$; MNI = the minimum number of individuals based on the highest number of any single element in the assemblage; $E_i$ = the number of elements $i$ in the prey skeleton).

Proportions of skeletal elements in mammals were evaluated using the following ratios (Andrews, 1990; Lloveras et al., 2008a):

(a) PCRT/CR – the total number of postcranial elements (limbs, vertebrae and ribs) compared with the total number of cranial elements (mandibles, maxillae and teeth);
(b) PCRAP/CR – the total number of limb elements (long bones, scapulae, innominate, patellae, metapodials, carpals, tarsals and phalanges) compared with the total number of cranial elements (mandibles, maxillae and teeth);
(c) PCRLB/CR – the total number of long bones (humerus, radius, ulna, femur and tibia) compared with the total number of cranial elements (mandibles and maxillae).

The following ratios were calculated for birds:

(a) To assess the differential representation of wings and legs (following Ericson, 1987), the number of wing fragments (humerus, ulna, carpometacarpus) was divided by the sum of wing and leg fragments (femur, tibiotarsus, tarsometatarsus), and expressed as a percentage.
(b) To evaluate the proportion of proximal and distal elements skeleton represented (Bochenski and Nekrasov, 2001), the number of proximal elements (scapula, coracoid, humerus, femur, tibiotarsus) was divided by the sum of proximal and distal fragments (ulna, radius, carpometacarpus, tarsometatarsus), and expressed as a percentage.
(c) To evaluate the proportions of core and limb elements (Bochenski, 2005), the number of core elements (sternum, pelvis, scapula, coracoid) was divided by the sum of core and limb elements (humerus, ulna, radius, carpometacarpus, femur, tibiotarsus, tarsometatarsus), and expressed as a percentage.

### 2.2. Breakage

The breakage pattern was described by the maximum length of all identified skeletal elements. Percentages of complete elements, isolated teeth (for mammals) and articulated elements were also calculated (Andrews, 1990). Fragmentation of bones was analysed using separate categories for mammals and birds. In the case of the mammals (small-mammals included), bone fragments were categorised according to bone type:

- Patellae, carpals, tarsals and ribs were classified as complete (C) or fragmented (F).
- Phalanges were recorded as complete (C), proximal (P) or distal (D) fragments. When distinguishing between proximal or distal was not possible, they were recorded just as fragments (F).
- Vertebrae were recorded as complete (C), vertebral body (VB), vertebral epiphysis (VE) or spinous process (SP).
- Breakage of teeth was calculated separately for isolated and "*in situ*" elements (Fernández-Jalvo and Andrews, 1992) and they were classified as complete (C) or fragmented (F).
- Breakage categories used for long bones, metapodials, mandibles, crania, scapulae and innominates follow those proposed by Lloveras et al. (2008a) and applied in subsequent studies (Lloveras et al., 2008b, 2009, 2012a).

For reptiles only two categories were taken into consideration for all skeletal elements, complete (C) and fragmented (F).

Fragmentation of bird bones was analysed using the methodology proposed by Bochenski et al. (1993). The ratio of proximal and distal portions of long bones (Bochenski, 2005) was calculated to observe the difference between whole bone and proximal parts as well as whole bone and distal parts.

### 2.3. Digestion

Damage to the bone surfaces was observed under light microscope ($\times 10$–$\times 40$ magnifications). Five degrees of digestion damage were distinguished for bones and teeth (Fernández-Jalvo and Andrews, 1992; Lloveras et al., 2008a, 2008b): null (0), light (1), moderate (2), heavy (3) and extreme (4).

### 2.4. Beak marks

Damage to the bone surfaces caused by the predator's beak was also noted and counted. Following the methodology used in previous studies (Lloveras et al., 2008a, 2008b, 2009, 2012a) beak marks were classified as scoring, notches, beak punctures/pits and crenulated/fractured edges (Andrews, 1990; Binford, 1981; Brain, 1981). In order distinguish beak marks from carnivore marks, punctures and pits were classified taking into account their distribution (unilateral or bilateral) and number (isolated or multiple) (Sanchis Serra et al., 2013).

## 3. Results

A total of 327 skeletal remains were analysed: 99 from SBG; 37 from SM; and 191 from VS where 131 remains came from inside the nest and 60 were recovered from nest materials at the bottom of the cliff. The samples are small and given the time spans mentioned above, it is clear that the rate of accumulation at Egyptian Vulture nests is low. This is particularly so when compared to the frequency of bones occurring in assemblages accumulated by other diurnal or nocturnal raptors, such as the Eagle Owl, the Golden Eagle or the Bearded Vulture (see for instance Lloveras et al., 2012b; Marín-Arroyo and Margalida, 2012).

The data from the three nest sites have been combined and analysed as a single assemblage; since the accumulating agent is the same for the three original samples it was assumed that the taphonomic pattern would not differ between them.

### 3.1. Taxonomic representation

Despite the small sample size a wide range of taxa was recorded (Table 1). They are grouped according to their taxonomic status: small-mammals (insectivores, rodents and bats), carnivores, leporids, domestic mammals, birds and reptiles. Carnivores were represented by fox (*Vulpes vulpes*), beech marten (*Martes foina*), badger (*Meles meles*) and European polecat (*Mustela putorius*). Domestic mammals were represented by cattle (*Bos taurus*), caprines (*Ovis/Capra*) and suid (*Sus* sp.) remains. The leporids, with the exception of one hare (*Lepus* sp.) bone, are rabbits (*Oryctolagus cuniculus*). The birds recovered include domestic chicken (*Gallus domesticus*), pigeon (*Columba* sp.), Yellow-legged Gull (*Larus michahellis*) and some unidentified corvid and passerine remains. Reptiles were mainly represented by Montpellier snake (*Malpolon monspessulanus*); a small species of an unidentified colubrid was also present.

**Table 1**
Summary of the analysed sample. Key: *N* – number of specimens; NISP – Number of Identified Specimens; MNE – Minimum Number of Elements; MNI – Minimum Number of Individuals; % – percentage of bone remains (*N*) recovered in each taxonomic group; Neo – neonate; Inf – infantile; Juv – juvenile; Ad – adult. The age at death values were determined using the MNI.

| Taxa | *N* | % | NISP | MNE | MNI | Age at death | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Neo. | Inf. | Juv. | Ad. |
| **Small mammals** | | | | | | | | | |
| *Erinaceus europaeus* | 1 | | 1 | 1 | 1 | | | | |
| *Chiroptera* | 13 | | 13 | 13 | 1 | | | | |
| *Rodentia* | 1 | | 1 | 1 | 1 | | | | |
| Muridae | 1 | | 1 | 1 | 1 | | | | |
| *Rattus norvegicus* | 4 | | 4 | 4 | 2 | | | | |
| *Rattus* sp. | 2 | | 2 | 2 | 2 | | | | |
| Unidentified | 2 | | | 2 | | | | | |
| Total | 24 | 7.3 | 22 | 24 | 8 | | | | |
| **Carnivores** | | | | | | | | | |
| *Vulpes vulpes* | 2 | | 2 | 2 | 2 | | | | |
| | | | | | | | | | 1 |
| *Mustela putorius* | 1 | | 1 | 1 | 1 | | | | |
| | | | | | | | | | 1 |
| *Martes foina* | 1 | | 1 | 1 | 1 | | | | |
| | | | | | | | | | 1 |
| *Meles meles* | 1 | | 1 | 1 | 1 | | | | |
| | | | | | | | | | 1 |
| Total | 5 | 1.5 | 5 | 5 | 5 | | | | |
| **Leporids** | | | | | | | | | |
| *Lepus europaeus* | 1 | | 1 | 1 | 1 | | | | |
| | | | | | | | | | 1 |
| *Oryctolagus cuniculus* | 132 | | 132 | 132 | 9 | | | | |
| | | | | | | | | | 9 |
| Total | 133 | 40.7 | 133 | 133 | 10 | | | | |
| **Domestic mammals** | | | | | | | | | |
| *Bos taurus* | 1 | | 1 | 1 | 1 | | | | |
| *Ovis/Capra* | 8 | | 8 | 8 | 2 | 1 | | | |
| *Sus* sp. | 33 | | 33 | 27 | 5 | 3 | 1 | | |
| Unidentified | 16 | | | 16 | | | | | |
| | | | | | | | | | 1 |
| Total | 58 | 17.7 | 42 | 52 | 8 | | | | |
| **Birds** | | | | | | | | | |
| Phasianidae | 1 | | 1 | 1 | 1 | | | | |
| *Gallus domesticus* | 7 | | 7 | 7 | 3 | | | | |
| *Columba* sp. | 27 | | 27 | 26 | 5 | | | | |
| *Larus michahellis* | 1 | | 1 | 1 | 1 | | | | |
| Corvidae | 5 | | 5 | 5 | 1 | | | | |
| *Passeriformes* | 4 | | 4 | 4 | 1 | | | | |
| Unidentified | 1 | | | 1 | | | | | |
| Total | 46 | 14.1 | 45 | 45 | 12 | | | | |
| **Reptiles** | | | | | | | | | |
| *Malpolon monspessulanus* | 60 | | 60 | 60 | 2 | | | | |
| Colubridae | 1 | | 1 | 1 | 1 | | | | |
| Total | 61 | 18.6 | 61 | 61 | 3 | | | | |
| Total whole sample | 327 | 100 | 308 | 320 | 46 | | | | |

The most abundant skeletal remains by group were leporids (40.7%) followed by reptiles (18.6%) and domestic mammals (17.7%) (Table 1). The best represented species were *O. cuniculus* with 40.4% of the total remains, *M. monspessulanus* (18.3%), *Sus* sp. (10%) and *Columba* sp. (8.3%). The greatest Minimum Number of Individuals (MNIs) was provided by *O. cuniculus* (9), *Columba* sp. (5) and *Sus* sp. (5).

Table 2 shows the taxa and the number of remains separately for each of the nests samples. Carnivores, domestic mammals and birds are represented in all of them. Colubrids and small mammals were not present at the SM nest site.

### 3.2. Age at death

Age at death varied among the mammalian taxa (Table 1). All carnivore and leporid individuals that could be aged were adult. However, domestic mammals were mostly represented by immature individuals, with four out of the six estimated individuals being neonates, one an infant and the other an adult.

**Table 2**
N, NISP, MNE and MNI by taxa recovered at each nest sample. SBG: Sant Bartomeu del Grau. VS: Vilanova de Sau. SM: Serra de Milany.

| ~~<!– Col Count:5 –>~~ | *N* | NISP | MNE | MNI |
|---|---|---|---|---|
| **SBG Taxa** | | | | |
| *Rattus* | 1 | 1 | 1 | 1 |
| *Erinaceus* | 1 | 1 | 1 | 1 |
| *Rodentia* | 1 | 1 | 1 | 1 |
| *Vulpes vulpes* | 1 | 1 | 1 | 1 |
| *Oryctolagus cuniculus* | 52 | 52 | 52 | 3 |
| *Sus* sp. | 16 | 16 | 16 | 2 |
| *Gallus* | 1 | 1 | 1 | 1 |
| *Passeriformes* | 4 | 4 | 4 | 1 |
| *Malpolon* | 21 | 21 | 21 | 1 |
| Colubridae | 1 | 1 | 1 | 1 |
| Total | 99 | 99 | 99 | 13 |
| **SM Taxa** | | | | |
| Micromammal unident. | 2 | | 2 | |
| *Vulpes vulpes* | 1 | 1 | 1 | 1 |
| *Oryctolagus cuniculus* | 14 | 14 | 14 | 2 |
| *Bos taurus* | 1 | 1 | 1 | 1 |
| *Ovis/Capra* | 5 | 5 | 5 | 1 |
| *Sus* sp. | 6 | 6 | 6 | 1 |
| Domestic mammal unident. | 6 | | 6 | |
| *Gallus gallus* | 2 | 2 | 2 | 1 |
| Total | 37 | 29 | 37 | 7 |
| **VS Taxa** | | | | |
| Muridae | 1 | 1 | 1 | 1 |
| *Rattus norvegicus* | 4 | 4 | 4 | 2 |
| *Rattus* sp | 1 | 1 | 1 | 1 |
| *Chiroptera* | 13 | 13 | 13 | 1 |
| *Martes foina* | 1 | 1 | 1 | 1 |
| *Meles meles* | 1 | 1 | 1 | 1 |
| *Mustela putorius* | 1 | 1 | 1 | 1 |
| *Oryctolagus cuniculus* | 66 | 66 | 66 | 4 |
| *Lepus europaeus* | 1 | 1 | 1 | 1 |
| *Ovis/Capra* | 3 | 3 | 3 | 1 |
| *Sus* sp. | 11 | 11 | 5 | 2 |
| Domestic mammal unident. | 10 | | 10 | |
| Phasianidae | 1 | 1 | 1 | 1 |
| *Gallus* | 4 | 4 | 3 | 1 |
| Corvidae | 5 | 5 | 5 | 1 |
| *Columba* sp | 27 | 27 | 26 | 5 |
| *Larus michahellis* | 1 | 1 | 1 | 1 |
| Bird unident. | 1 | | 1 | |
| *Malpolon* | 39 | 39 | 39 | 1 |
| Total | 191 | 180 | 183 | 26 |

### 3.3. Taphonomic analysis

Almost all skeletal elements were present, although their presence and frequency varied depending on the taxonomic group. Observation of breakage patterns revealed that prey remains were minimally fragmented. Only 7.8% of remains measured less than 10 mm and the average percentage of complete bones was 72.3%. Additionally, 30% of bones were still articulated and all teeth remained within their alveoli.

Only 6.1% of bones were affected by digestion damage and no teeth were digested. The low frequency of digested remains implies that very few derived from pellets and that most elements represented non-ingested remains. Most of the digested bones (50%) showed a moderate degree of digestion corrosion.

A high percentage of remains (16.4%) displayed beak damage. Punctures, beak pits, notches, crenulated and fractured edges and scores were registered on the surfaces of the recovered bones in frequencies that varied by taxonomic group. Birds, leporids and domestic mammals showed the highest frequency of beak marks. Pits and punctures were mostly isolated (80%) and unilateral

Please cite this article in press as: Lloveras, L., et al., The role of the Egyptian Vulture (*Neophron percnopterus*) as a bone accumulator in cliff rock shelters: an analysis of modern bone nest assemblages from North-eastern Iberia, Journal of Archaeological Science (2014), http://dx.doi.org/10.1016/j.jas.2014.01.018

(90.5%). Although previous access to the bones by terrestrial carnivores cannot be completely excluded, the lack of characteristic carnivore damage (such as gnawing and high rate of scrapes), as well as the characteristics and location of the mechanical alterations, indicate that bone surface damage was inflicted by Egyptian Vulture's (Lloveras et al., 2008a,b, 2009; Sanchis, 2012; Sanchis Serra et al., 2013).

Henceforth, each group was treated separately in the analysis to account for the potential that different taxa might exhibit different taphonomic patterns.

### 3.3.1. Carnivores

*3.3.1.1. Anatomical representation.* Cranial remains were not recovered; the only skeletal elements present were long bones (2), scapula (1), innominate (1) and vertebrae (1) (Tables 3 and 4). The numbers are too small to establish a specific pattern for anatomical representation.

*3.3.1.2. Breakage.* The average maximum length of the recovered remains was 60.4 mm, with values ranging between 49.3 and 81.7 mm. They were all complete (Table 5), with the exception of a *M. meles* scapula, which was partially damaged on the infraspinous fossa.

*3.3.1.3. Digestion and beak marks.* No digestion damage was observed on the surfaces of the carnivore skeletal remains. Traces left by beaks of Egyptian Vultures were observed on two bones (40%). They occurred on a scapula and a pelvis and the damage registered on each was in the form of fractured/crenulated edges and scoring.

### 3.3.2. Domestic mammals

*3.3.2.1. Anatomical representation.* The best represented skeletal elements were cranial and mandible fragments, vertebrae and ribs (Tables 3 and 4). Appendicular bones were very scarce, especially autopodia, only two metapodials were recovered. Relative abundance was calculated for *Sus* sp. because it is the taxon with the highest number of remains. Results show (Table 4, Fig. 3) that cranial fragments dominate (RA% = 80), followed by mandibles (RA% = 20) and innominates (RA% = 20). Indices that compare postcranial to cranial elements indicate that fewer postcranial elements were present than would be expected (PCRT/CR = 10.9, PCRAP/CR = 9.7, PCRLB/CR = 10).

*3.3.2.2. Breakage.* The size of the recovered remains varied with maximum lengths between 8.1 and 138.6 mm (average 47.5 mm). The average percentage of complete elements was 36.8%, which mainly corresponds to teeth and ribs (Table 5). Articulated elements were not found in this sample.

Breakage categories (Table 6) show that:

- skulls were never complete and they were always identified on parts of the neurocranium (NC);
- mandibles are represented by body fragments including the incisive part (MBI);
- all teeth were recovered *in situ* and they were always complete (100%);
- vertebrae were complete in 18.2% of cases, the most common fragments being vertebral bodies (VB); ribs were complete in 53.8% of cases;
- innominates were represented by fragments containing the acetabulum and ilium (AIL);
- scapulae were represented by only one fragment comprising the fossa;
- long bones and metapodials were complete in 28.6% of cases; different breakage categories, including fragments of proximal epiphysis (PES), shaft (S) and distal epiphysis (SDE) were recorded (Table 6).

A total of 11 bone fragments (19.3%) displaying butchery marks from a mechanical saw, included six vertebrae, and single examples of rib, humerus, femur, tibia and metapodial. This demonstrates

**Table 3**
Number of skeletal elements recovered by taxonomic group and species. Abbreviations: man – mandible; cra – cranium; inc – incisors; can – canines; mol – molars; hum – humerus; rad – radius; uln – ulna; fem – femur; tib – tibia; pat – patella; sc – scapula; inn – innominate; mtc – metacarpals; mts – metatarsals; mt – metapodial; phal – phalanges; cal – calcaneum; ast – astragalus; c/t – carpal/tarsal; ver – vertebrae; rib – rib; ind – indeterminate.

| Mammals and reptiles | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxa | man | cra | inc | can | mol | hum | rad | uln | fm | tib | pat | sc | inn | mtc | mts | mt | phal | cal | ast | c/t | ver | rib | ind |
| **Small mammals** | | | | | | | | | | | | | | | | | | | | | | | |
| Muridae | | 1 | | | | | | | | | | | | | | | | | | | | | |
| *Rattus norvegicus* | | | | | | | | | 1 | | | | 3 | | | | | | | | | | |
| *Rattus* sp. | | | | | | | | | | | | | | | 1 | | | | | | 1 | | |
| *Erinaceus europaeus* | | | | | | | | | | 1 | | | | | | | | | | | | | |
| *Rodentia* | | | | | | | | | 1 | | | | | | | | | | | | | | |
| *Chiroptera* | | | | | | | 1 | | | | | | | 5 | | | | | | 7 | | | |
| Unident. | | | | | | | | | | | | | | | | | | | | | | | 2 |
| **Carnivores** | | | | | | | | | | | | | | | | | | | | | | | |
| *Vulpes vulpes* | | | | | | | | | | | | | 1 | | | | | | | | 1 | | |
| *Martes foina* | | | | | | 1 | | | | | | | | | | | | | | | | | |
| *Meles meles* | | | | | | | | | | | | 1 | | | | | | | | | | | |
| *Mustela putorius* | | | | | | | | | | 1 | | | | | | | | | | | | | |
| **Leporids** | | | | | | | | | | | | | | | | | | | | | | | |
| *Oryctolagus cuniculus* | 12 | 4 | 10 | | 81 | | | | 1 | | | | 2 | | 4 | | | | | | 7 | 11 | |
| *Lepus europaeus* | | | | | | | | | | | | 1 | | | | | | | | | | | |
| **Domestic mammals** | | | | | | | | | | | | | | | | | | | | | | | |
| *Bos taurus* | | | | | | | | | | | | | | | | | | | | | | 1 | |
| *Ovis/Capra* | | | | | | | 1 | | | 1 | | | | | 1 | | | | | | 3 | 2 | |
| *Sus* sp. | 2 | 10 | 6 | 1 | 4 | 1 | | | | | | | 2 | | | 1 | | | | | 4 | 2 | |
| Unident. | | | | | | 1 | | | 1 | | | 1 | | | | | | | | | 4 | 8 | 1 |
| **Reptiles** | | | | | | | | | | | | | | | | | | | | | | | |
| *Malpolon monspessulanus* | | | | | | | | | | | | | | | | | | | | | 52 | 8 | |
| Colubridae | | | | | | | | | | | | | | | | | | | | | 1 | | |

**Table 4**
Skeletal elements recovered from Egyptian Vulture nests by taxonomic group. Key: *N* = number of skeletal elements; *N*% = percentage of skeletal elements percentage; MNE = minimum number of elements; RA = relative abundance. *Molars and premolars were counted together. For abbreviations see the caption for Table 3.

| | Small mammals | | | Carnivores | | | Leporids | | | | | Domestic mammals | | | | Reptiles | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | *N*% | MNE | *N* | *N*% | MNE | *N* | *N*% | MNE | RA% | *N* | *N* | *N*% | MNE | RA% | *N* | *N*% | MNE |
| man | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 9 | 12 | 60 | 12 | 12 | 9 | 12 | 60 | 0 | 0 | 0 |
| cra | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 3 | 2 | 20 | 4 | 4 | 3 | 2 | 20 | 0 | 0 | 0 |
| inc | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 7.5 | 10 | 16.7 | 10 | 10 | 7.5 | 10 | 16.7 | 0 | 0 | 0 |
| can | – | 0 | 0 | 0 | 0 | 0 | – | – | – | – | – | – | – | – | – | 0 | 0 | 0 |
| mol | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – | – | – | – | – | – | 0 | 0 | 0 |
| upper mol | – | – | – | – | – | – | 21 | 15.8 | 21 | 17.5 | 21 | 21 | 15.8 | 21 | 17.5 | – | – | – |
| lower mol | – | – | – | – | – | – | 60 | 45.1 | 60 | 60 | 60 | 60 | 45.1 | 60 | 60 | – | – | – |
| hum | 0 | 1 | 1 | 1 | 20 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – |
| rad | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – |
| uln | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – |
| fem | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0.8 | 1 | 5 | 1 | 1 | 0.8 | 1 | 5 | – | – | – |
| tib | 1 | 1 | 1 | 1 | 20 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – |
| pat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – |
| sc | 0 | 1 | 1 | 1 | 20 | 1 | 1 | 0.8 | 1 | 5 | 1 | 1 | 0.8 | 1 | 5 | – | – | – |
| inn | 3 | 1 | 1 | 1 | 20 | 1 | 2 | 1.5 | 2 | 10 | 2 | 2 | 1.5 | 2 | 10 | – | – | – |
| mtc | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – |
| mts | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | 4 | 5 | – | – | – |
| mt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | 0 | 0 | 0 | 0 | – | – | – | – |
| phal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – |
| cal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – |
| ast | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – |
| c/t | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – |
| ver | 1 | 1 | 1 | 1 | 20 | 1 | 7 | 5.2 | 7 | 1.5 | 7 | 7 | 5.2 | 7 | 1.5 | 53 | 86.9 | 53 |
| rib | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 8.3 | 11 | 4.6 | 11 | 11 | 8.3 | 11 | 4.6 | 8 | 13.1 | 8 |
| Total | 22 | 5 | 5 | 5 | – | 5 | 133 | – | 131 | – | 133 | 133 | – | 131 | – | 61 | – | 61 |

that most of the scavenged domestic mammals had previously been fragmented as a result of human activity. It is likely that these elements were acquired from a rubbish dump situated near the study area at which scavenging by Egyptian Vultures has been documented.

*3.3.2.3. Digestion and beak marks.* Digestion corrosion was observed on the surface of only four (7%) small fragments of long bones and vertebrae (Fig. 4). The degree of damage registered was: light (1); moderate (1); and strong (2).

Traces left by beaks were observed in eight bones (14%) from this sample (Fig. 5). Most were on ribs (4) and long bones (2); the rest were located on crania (1), mandible (1), and pelvis (1). Beak punctures (3) and crenulated/fractured edges (3) were the most common traces, followed by notches (2) and scoring (1).

### 3.3.3. Leporids

*3.3.3.1. Anatomical representation.* This sample was mainly composed of mandible and cranial fragments (accounting for over 80% of the remains), followed by ribs (8.3%) and vertebrae (5.2%). The appendicular skeleton was only represented by one femur, one scapula, two innominate and four metatarsals (Tables 3 and 4). The relative abundance of skeletal elements (RA%) is shown in Table 4 and Fig. 6. Results confirm that the skull (mandibles, cranium and teeth) was the best represented element. Innominate, scapula, femur, metatarsals, ribs and vertebrae were rarely preserved. Indices to evaluate the relative proportions of skeletal elements indicate far fewer postcranial compared to cranial remains (PCRT/CR = 4.8, PCRAP/CR = 2.1, PCRLB/CR = 2.9).

*3.3.3.2. Breakage.* The size of the leporid remains ranges between 26.3 and 70.1 mm; the average maximum length was 52.4 mm. Complete elements constituted 81.2%. The highest values were obtained for the small elements such as teeth, metapodials and vertebrae (Table 5). Breakage was more frequent on crania and mandibles. In the latter, fragmentation was mostly concentrated in the condylar process (Tables 5 and 6). A total of 21 (15.8%) skeletal remains within the entire leporid sample were recovered in articulation.

Breakage categories (Table 6) show that:

- skulls were complete in 25% of cases and their fragments were identified by parts of neurocranium (NC) and maxilla (M);
- mandibles were complete in 33.3% of cases, their fragments were represented by body portions including the incisive part (MBI and MBIB);
- all teeth remained *in situ* and they were always complete (100%);
- vertebrae were complete in 85.7% of cases, their fragments are represented by vertebral body (VB); ribs were never complete;
- innominates were complete in 50% of cases and their fragments were represented by portions containing the acetabulum, ischium and ilium (AISIL);
- scapulae were represented by only one complete element;
- long bones were represented by one femur fragment including the proximal epiphysis and shaft (PES), all metapodials were complete.

*3.3.3.3. Digestion and beak marks.* Only one fragmented scapula showed digestion (0.8% of leporid remains) with a moderate degree of damage.

Beak marks were observed on ten specimens (7.5%). Most of them occur on mandibles (5) and vertebrae (3), the rest being located on the innominate (1) and femur (1). Beak punctures (9) and beak pits (4) were the most common damage, followed by crenulated/fractured edges (2) and notches (1) (Fig. 5).

### 3.3.4. Small-mammals and reptiles

*3.3.4.1. Anatomical representation.* The autopodium, specifically carpal (31.8%) and metacarpal (22.7%) bones, is the best represented part in the small-mammal sample. This is due to the

**Table 5**
Numbers and percentages of complete skeletal remains by taxonomic group. For abbreviations see the caption for Table 3.

| | Small mammals | | | Carnivores | | | Leporids | | | Domestic mammals | | | Reptiles | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | *C* | *C%* | *N* | *C* | *C%* | *N* | *C* | *C%* | *N* | *C* | *C%* | *N* | *C* | *C%* |
| man | 0 | | | 0 | | | 12 | 4 | 33.3 | 2 | 0 | 0 | 0 | | |
| cra | 1 | 0 | 0 | 0 | | | 4 | 1 | 25 | 10 | 0 | 0 | 0 | | |
| inc | 0 | | | 0 | | | 10 | 10 | 100 | 6 | 6 | 100 | 0 | | |
| can | 0 | | | 0 | | | | | | 1 | 1 | 100 | 0 | | |
| mol | 0 | | | 0 | | | | | | 4 | 4 | 100 | 0 | | |
| upper mol | | | | | | | 21 | 21 | 100 | | | | | | |
| lower mol | | | | | | | 60 | 60 | 100 | | | | | | |
| hum | 0 | | | 1 | 1 | 100 | 0 | | | 2 | 0 | 0 | | | |
| rad | 1 | 1 | 100 | 0 | | | 0 | | | 1 | 1 | 100 | | | |
| uln | 0 | | | 0 | | | 0 | | | 0 | | | | | |
| fem | 2 | 2 | 100 | 0 | 1 | 100 | 1 | 0 | 0 | 1 | 0 | 0 | | | |
| tib | 1 | 0 | 0 | 1 | 1 | 100 | 0 | | | 1 | 0 | 0 | | | |
| pat | 0 | | | 0 | | | 0 | | | 0 | | | | | |
| sc | 0 | | | 1 | 0 | 0 | 1 | 1 | 100 | 1 | 0 | 0 | | | |
| inn | 3 | 1 | 33.3 | 1 | 1 | 100 | 2 | 1 | 50 | 2 | 0 | 0 | | | |
| mtc | 5 | 5 | 100 | 0 | | | 0 | | | 0 | | | | | |
| mts | 1 | 0 | 0 | 0 | | | 4 | 4 | 100 | 1 | 0 | 0 | | | |
| mt | 0 | | | 0 | | | 0 | | | 1 | 0 | 0 | | | |
| phal | 0 | | | 0 | | | 0 | | | 0 | | | | | |
| phal3 | 0 | | | 0 | | | 0 | | | 0 | | | | | |
| cal | 0 | | | 0 | | | 0 | | | 0 | | | | | |
| ast | 0 | | | 0 | | | 0 | | | 0 | | | | | |
| c/t | 7 | 7 | 100 | 0 | | | 0 | | | 0 | | | | | |
| ver | 1 | 0 | 0 | 1 | 1 | 100 | 7 | 6 | 85.7 | 11 | 2 | 18.2 | 53 | 53 | 100 |
| rib | 0 | | | 0 | | | 11 | 0 | 0 | 13 | 7 | 53.8 | 8 | 6 | 75 |
| Total | 22 | 16 | 72.7 | 5 | 4 | 80 | 133 | 108 | 81.2 | 57 | 21 | 36.8 | 61 | 59 | 96.7 |

recovery of an articulated bat wing (Tables 3 and 4). Innominate (13.6%) and some long bones (18.1%) were also present. Only one cranial fragment was recovered and the axial skeleton was represented by one vertebrae.

The skeletal profile of the reptiles is mainly based on the presence of vertebrae (86.9%), although a few ribs (13.1%) were also recovered. No cranial remains were found (Tables 3 and 4).

3.3.4.2. *Breakage.* The average maximum length of remains in the small-mammal group was 11.9 mm (values range 2.0 mm–45.2 mm). Most remains were recovered complete (i.e., all carpals and the metatarsal), the average percentage was 72.7%. In the case of the long bones and innominate the frequency of complete remains was 75% and 50%, respectively (Table 5). Innominate fragments were represented by portions containing the acetabulum,

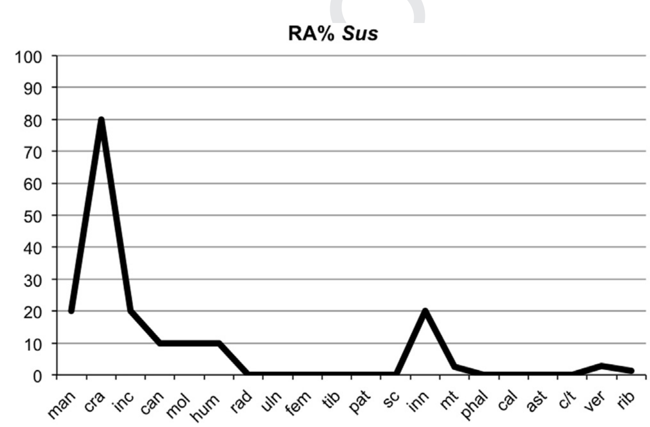


**Fig. 3.** Relative abundance of different parts of the skeleton for *Sus* sp. remains. For abbreviations see the caption for Table 3.

ischium and ilium (AISIL). The only cranial fragment recovered was a partial maxilla (M).

The maximum length of Colubrid remains was between 4.3 and 15.2 mm (average maximum length 6.7 mm). With the exception of two ribs, all the remains were complete (96.7%) with 85.2% being articulated ($N = 52$) (Table 5).

3.3.4.3. *Digestion and beak marks.* The surface of three small-mammal bones displayed signs of digestion (13.6%). The degrees of damage registered were: moderate (1); and extreme (2). In addition, the only remains damaged by vulture beak were the three innominates of the common rat (13.6%). They showed crenulated and fractured edges.

The reptile remains were not digested nor was there any beak damage.

### 3.3.5. *Birds*

3.3.5.1. *Anatomical representation.* With the exception of the furcula all parts of the avian skeleton were recovered (Table 7). The pectoral arch and wing bones showed the highest values, specifically scapula (13%), humerus (13%), coracoid (10.9%) and ulna (10.9%). Pelvis (10.9%) and tibiotarsus were also abundant (8.7%). Scapulae and coracoids were usually articulated. Relative abundance varied by skeletal element (Table 7, Fig. 7): fragments of the trunk (sternum and pelvis) were abundant (25% and 33% respectively), pectoral arch and wing bones also prevailed (Fig. 7). Crania were also well represented (25%) but only for *G. domesticus*, for which the other skeletal elements were rare.

Relative abundance was calculated separately for *Columba* sp. because this was the best represented taxon. Results show that the sternum, pelvis, scapula, coracoid and humerus were the most frequent elements; the femur and tibiotarsus were scarce, and other skeletal elements were absent (Table 7, Fig. 7).

The ratio of wing to leg elements indicates that wing bones account for 66.7% of the sum of wing and leg bones. The deviation

**Table 6**
Numbers and percentages of parts of the skeleton included in each breakage category for domestic mammals and leporids. **Long bones**, **metacarpal** and **metatarsal** bones were classified as: complete (C); proximal epiphysis (PE); proximal epiphysis + shaft (PES); shaft (S); shaft + distal epiphysis (SDE); and distal epiphysis (DE). **Mandible** as: complete (C); incisive part (IP); mandible body + incisive part (MBI); mandible body (MB); mandible body + branch (MBB); and condylary process (CP). **Cranium** as: complete (C); incisive bone (IB); incisive bone + maxilla (IBM); maxilla (M); zygomatic arch (ZA); and neurocranium (NC). **Innominate** as: complete (C); acetabulum (A); acetabulum + ischium (AIS); acetabulum + ischium + ilium (AISIL); acetabulum + ilium (AIL); ischium (IS); and ilium (IL). **Scapula** as: complete (C); glenoid cavity (GC); glenoid cavity + neck (GCN); neck + fossa (NF); and fossa (F). **Vertebrae** as: complete (C); vertebral body (VB); vertebral epiphysis (VE); and spinous process (SP). **Phalanges** as: complete (C); proximal fragment (P); distal fragment (D); and fragment (F). **Patella, carpal/tarsal, calcaneum, astragalus, ribs and teeth** as: complete (C); and fragment (F).

Domestic mammals

| Long bones and metapodial | C | | PE | | PES | | S | | SDE | | DE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | % | *N* | % | *N* | % | *N* | % | *N* | % | *N* | % |
| Humerus | 0 | 0 | 1 | 50 | 0 | 0 | 0 | 0 | 1 | 50 | 0 | 0 |
| Radius | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ulna | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Femur | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tibia | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 100 | 0 | 0 | 0 | 0 |
| Metapodial | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 50 | 1 | 50 | 0 | 0 |

| Mandible | *N* | % | Cranium | *N* | % | Innominate | *N* | % | Scapula | *N* | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C | 0 | 0 | C | 0 | 0 | C | 0 | 0 | C | 0 | 0 |
| IP | 0 | 0 | IB | 0 | 0 | A | 0 | 0 | GC | 0 | 0 |
| MBI | 2 | 100 | IBM | 0 | 0 | AIS | 0 | 0 | GCN | 0 | 0 |
| MB | 0 | 0 | M | 0 | 0 | AISIL | 0 | 0 | NF | 0 | 0 |
| MBB | 0 | 0 | ZA | 0 | 0 | AIL | 2 | 100 | F | 1 | 100 |
| PC | 0 | 0 | NC | 10 | 100 | IS | 0 | 0 | | | |
| | | | | | | IL | 0 | 0 | | | |

| Vertebrae | *N* | % | Ribs | *N* | % | Teeth | Incisors | | Canines | | Molars | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | *N* | % | *N* | % | *N* | % |
| C | 2 | 18.2 | C | 7 | 53.8 | | | | | | | |
| VB | 7 | 63.6 | F | 6 | 46.2 | C | 6 | 100 | 1 | 100 | 4 | 100 |
| VE | 0 | 0 | | | | F | 0 | 0 | 0 | 0 | 0 | 0 |
| SP | 2 | 18.2 | | | | | | | | | | |

Leporids

| Long bones and metapodial | C | | PE | | PES | | S | | SDE | | DE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | % | *N* | % | *N* | % | *N* | % | *N* | % | *N* | % |
| Humerus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Radius | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ulna | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Femur | 0 | 0 | 0 | 0 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tibia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Metacarpus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Metatarsus | 4 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Mandible | *N* | % | Cranium | *N* | % | Innominate | *N* | % | Scapula | *N* | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C | 4 | 33.3 | C | 1 | 25 | C | 1 | 50 | C | 1 | 100 |
| IP | 0 | 0 | IB | 0 | 0 | A | 0 | 0 | GC | 0 | 0 |
| MBI | 1 | 8.3 | IBM | 0 | 0 | AIS | 0 | 0 | GCN | 0 | 0 |
| MB | 0 | 0 | M | 1 | 25 | AISIL | 1 | 50 | NF | 0 | 0 |
| MBB | 7 | 58.3 | ZA | 0 | 0 | AIL | 0 | 0 | F | 0 | 0 |
| PC | 0 | 0 | NC | 2 | 50 | IS | 0 | 0 | | | |

| Vertebrae | *N* | % | Ribs | *N* | % | Teeth | Incisors | | Upper molars | | Lower molars | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | *N* | % | *N* | % | *N* | % |
| C | 6 | 85.7 | C | 0 | 0 | | | | | | | |
| VB | 1 | 14.3 | F | 11 | 100 | C | 10 | 100 | 12 | 100 | 60 | 100 |
| VE | 0 | 0 | | | | F | 0 | 0 | 0 | 0 | 0 | 0 |
| SP | 0 | 0 | | | | | | | | | | |

from the expected 50% (1:1 proportion) evidences a higher representation of wing bones. The ratio of proximal to distal bones was 73.3%, so the predominance of proximal bones is confirmed. Finally, the ratio of the core to limb elements was 78.6%, pointing to a major presence of central elements.

3.3.5.2. *Breakage.* The size of the recovered remains ranged between 5.1 and 82.2 mm (average maximum length 38.1 mm). The degree of fragmentation was low; on average 58.7% of the elements were complete, with mandibles, crania and sternum being the least fragmented (Table 7). Ten (21.7%) skeletal remains (Passeriformes and *Columba* sp.) were articulated; most being coracoids articulated to scapulae ($N = 6$; 13%).

Breakage categories (Table 8) show that:

- most long bones (including the scapula and coracoid) were recovered complete (73.3%);
- percentages of proximal and distal ends (data pooled for all long bones: Table 8) were low (13.3% and 6.7% respectively), shafts (fragments without articular ends) were also poorly represented (6.7%), and fragments of scapula were always proximal;
- skulls were represented by different type of fragments including always the brain case;
- mandibles were represented by only one fragment of *pars symphysialis*;
- all pelvis fragments included the *synsacrum* and both ilium-ischia-pubis bones;
- all sternum fragments included the *rostrum* and more than half of the element.

3.3.5.3. *Digestion and beak marks.* Birds were the taxa most affected by digestion damage (Fig. 4): 11 remains (23.9%) that include mostly long bones (90.9% of cases). All showed a light (36.4%) or moderate (63.6%) degree of digestion.

Traces left by beaks were observed in 13 bones, 28.3% of the sample (Fig. 5). Most of them occurred on the pelvis (4) and sternum (3). The rest were located on crania (1), coracoid (1), scapula (1), humerus (1), tibiotarsus (1) and vertebrae (1). Beak punctures (11) were the most common damage, followed by beak pits (3), crenulated/fractured edges (3) and notches (2).

## 4. Discussion

Biological studies conducted on the feeding habits of the Egyptian Vulture have described its diet as extremely varied (Ceballos and Donázar, 1990). Our results match with the taxonomic representation presented in these works (Ceballos and Donázar, 1990; Donázar and Ceballos, 1988; Hidalgo et al., 2005; Oró, 1992). Depending on the area of study, the dominant prey varies according to the availability of food and opportunities for scavenging. However, all studies include remains of wild animals, probably from naturally dead animals, road kills and predation upon ill or immature/old individuals; which always includes carnivores, leporids (rabbits usually form a significant part of Iberian vultures diets), small-mammals, birds and reptiles. The most common domestic mammals are caprines and pigs, while cattle and horses are less well represented. A considerable proportion of domestic prey is most likely taken from feeding points and rubbish dumps (Hidalgo et al., 2005).

Sanchis Serra et al. (2013) also found a great diversity of taxa in Egyptian Vulture nest accumulations. The same taxonomic groups are represented in our samples; however, the relative importance varies: leporids, birds and large domestic mammals (in this order) are the best represented (by MNI) in this study, whilst Sanchis Serra et al. (2013) observed that large domestic mammals, carnivores and leporids were most abundant. This confirms that taxonomic representation in this raptor nests varies according to the area of study and prey availability. However, our study also revealed (Table 2) that taxonomic diversity increases over time : the 13-year

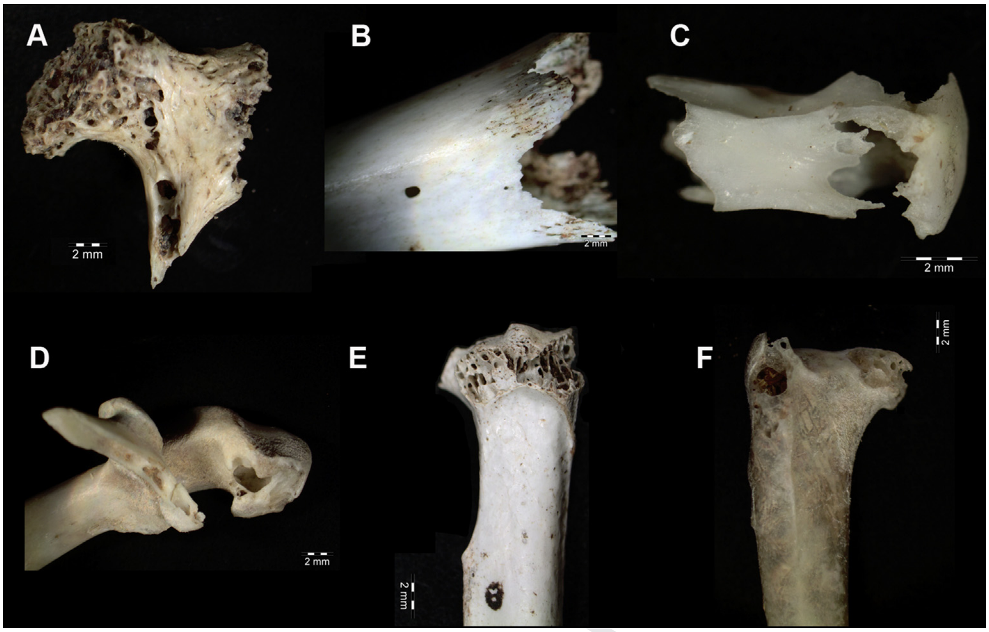


Fig. 4. Examples of digestion corrosion damage caused by the Egyptian Vulture in mammal (A, B, C) and bird (D, E, F) remains. A: fragment of domestic mammal vertebrae, B: ovicaprine metapodial, C: *Rattus* sp. vertebrae, D: *Columba* sp. coracoide, E: Corvidae tibiotarsus, F: *Columba* sp. femur.

accumulation (VS) shows a higher diversity than the two-year accumulations.

The prey diversity identified in our three nest samples is a characteristic feature of this avian scavenger. When analysing archaeological samples of different periods, it should be taken into account that such diversity may also accrue as a result of seasonal availability of resources.

In relation to the age at death of prey, differences among diverse mammal taxonomic groups were evident. Given the opportunistic feeding habits of Egyptian Vulture it is to be assumed that they would take advantage of the available prey, independently of the age-class. Domestic mammals, especially *Sus* sp., were mostly represented by very young individuals. These remains probably came from dead individuals taken from rubbish dumps receiving farm and slaughterhouse refuse. In contrast, carnivores and leporids were mostly represented by adult individuals. Similar mortality profiles were registered by Sanchis Serra et al. (2013).

Body part representation at the nests varied with taxonomic group or species. The present study recorded differential transportation of parts of the prey carcasses to the nest. Domestic mammals and rabbits were mainly represented by cranial remains while almost all skeletal parts of birds were found. The greatest frequency of particular skeletal elements accumulated in the nests may be related to the availability of anatomical parts in scavengable remains. However, the size of the prey also appears to be an important factor. Small prey, such as small-mammals, young rabbits or small-sized birds, is usually transported to the nest whole, whereas when vultures feed on medium-sized prey such as adult rabbits or large birds they usually only transport skulls or limb bones. When they scavenge on large prey, such as ungulates, only isolated bones (vertebrae, ribs, appendicular bones, etc.) are transported (J.A. Donázar, personal communication). Thus, it may be concluded that the anatomical pattern obtained is strongly related to the feeding behaviour of Egyptian Vultures (Hidalgo et al., 2005).

With respect to breakage, all variables analysed indicate that Egyptian Vultures do not frequently fragment the bones of their prey. The percentage of complete elements is high for all taxonomic groups (leporids: 81.2%, small-mammals: 72.7%, reptiles: 96.7%, birds: 58.7%) with the exception of domestic mammals (36.8%) where fragmentation relates to the anthropic activities from which they derive. The size of prey remains recovered also confirms the low occurrence of broken elements: only 7.8% of the total assemblage was less than 10 mm in length. In addition, the frequency of articulated remains was also high (30%) and all teeth were recovered *in situ*; this is related to the fact that flesh was removed from most bones, but that they were not ingested. The sample analysed consisted mostly of non-ingested remains; although pellets are commonly produced by Egyptian Vultures (see for instance Ceballos and Donázar, 1990), very few of them are accumulated in nests (J.A. Donázar, personal communication). Furthermore, these vultures have a long and sharp beak, ideally adapted for picking the small bits of meat remaining on the bones and do not break and ingest large amounts of bones as do other larger vultures species (Donázar and Ceballos, 1988; Hidalgo et al., 2005). Our results are consistent with the data provided by Sanchis Serra et al. (2013), which also showed a high proportion of complete bones (average 45.1%) and abundance of articulated skeletal remains (30.3%) as well as the scarcity of pellets.

Bone surface alterations are undoubtedly one of the important distinctive features used to identify accumulating agents. In the case of Egyptian Vulture nest accumulations, the scarce number of remains from pellets implies a low percentage of digested remains (only 6.1%). However, differences were found between taxa; for example, birds were the group most likely affected by digestion damage (23.9%). This fact is related to the feeding behaviour of the Egyptian Vulture, which usually ingests small prey bones but rejects the bones of larger prey (J.A. Donázar, personal communication). The percentage of digested remains recorded by Sanchis Serra et al. (2013), although higher than the value obtained in the present study, was also low (11%).

Beak marks mainly comprised punctures and pits, occurring on diverse parts of skeletal remains; and fractures, crenulations and notches affecting edges of bones (Fig. 5). All taxa, with the exception of reptiles, were affected by beak marks, but birds were again the most damaged. Sanchis Serra et al. (2013) found a higher proportion of beak marks on Egyptian Vulture accumulations from Valencia (26.7%). We also found variation in the frequency of



Please cite this article in press as: Lloveras, L., et al., The role of the Egyptian Vulture (*Neophron percnopterus*) as a bone accumulator in cliff rock shelters: an analysis of modern bone nest assemblages from North-eastern Iberia, Journal of Archaeological Science (2014), http://dx.doi.org/10.1016/j.jas.2014.01.018

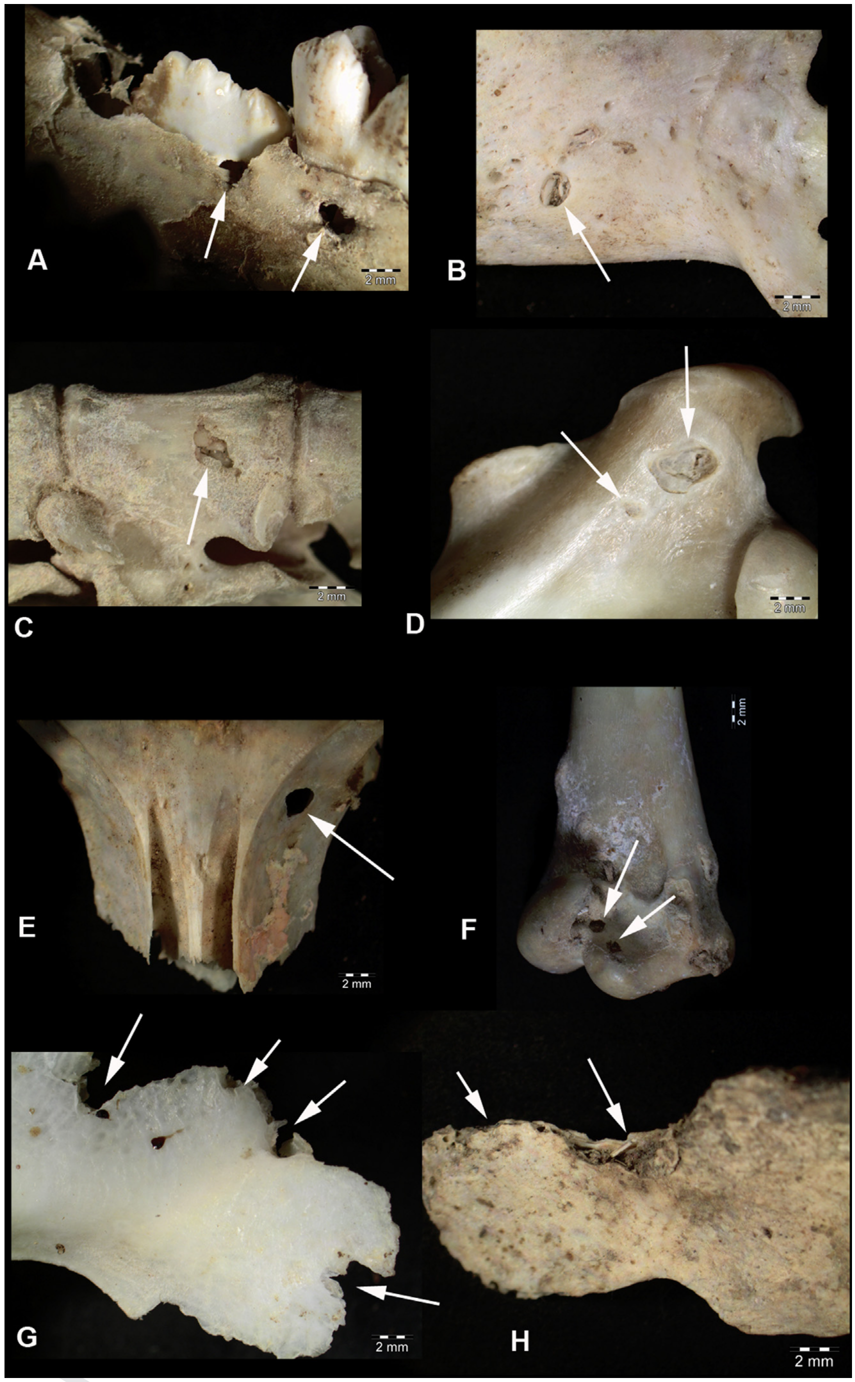


**Fig. 5.** Examples of beak marks produced by the Egyptian Vulture on the surface of bones including: punctures and pits on mammal (A–E) and bird (E–F) remains; notches and crenulated edges on mammals (H) and birds (G). A: *Sus* sp. mandible, B: *Oryctolagus cuniculus* mandible, C: *Oryctolagus cuniculus* vertebrae, D: *Oryctolagus cuniculus* femur, E: *Columba* sp. pelvis, F: *Columba* sp. humerous, G: *Columba* sp. sternum, H: *Oryctolagus cuniculus* innominate.

different kinds of beak damage in this study, punctures being more abundant than pits (30% vs 10%), whereas Sanchis Serra et al. observed the reverse pattern (39.9% vs 11.5%). Some differences can be related to the methodological approach followed, but they are also a result of the variability that can be found in the taphonomic signature of this predator.

## 4.1. Egyptian Vulture and other predators

The main goal of this kind of actualistic taphonomic studies is to identify the diagnostic signatures for each predator in order to identify their contributions when analysing archaeological assemblages. To achieve this objective, comparisons with different kind of predators are presented below.

### 4.1.1. Egyptian Vulture and other vultures

Only Bearded Vulture (*G. barbatus*) nest bone accumulations have been analysed from a taphonomic point of view (Marín-Arroyo and Margalida, 2012; Robert and Vigne, 2002; Robert et al., 2002). Data provided in these studies showed that this vulture can accumulate large numbers of bones, principally from medium-sized ungulates. The skeletal profile derived from a

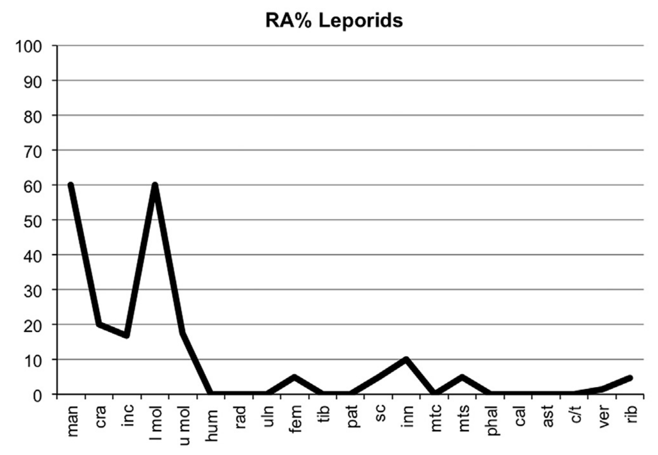


**Fig. 6.** Relative abundance of different parts of the skeleton in the leporid remains sample. For abbreviations see the caption of Table 3.

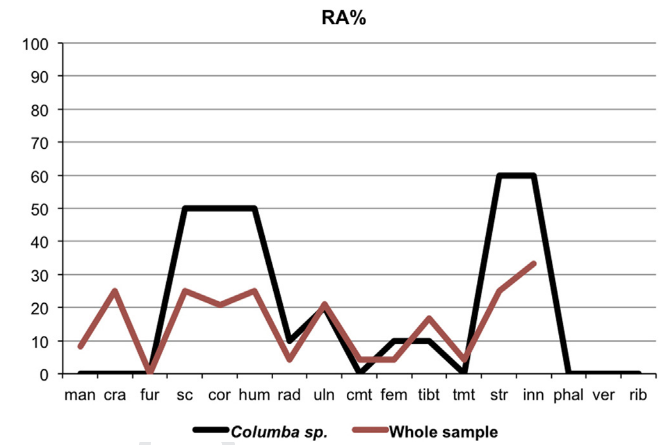


**Fig. 7.** Relative abundance of different parts of the skeleton in the birds and *Columba* sp. samples. For abbreviations see the caption for Table 3.

Bearded Vulture accumulation is characterised by a higher presence of fatty and small elements, especially feet, metapodials and long bones. A high rate of long bone breakage and digestion damage was also registered. All parameters differ greatly from the results obtained in the present study with Egyptian Vultures.

Griffon Vulture (*G. fulvus*) has also been described as a bone nest accumulator. Bone breakage, ingestion and regurgitation of digested skeletal elements have been documented (Benson et al., 2004; Fernández, 1977; Richardson et al., 1986). From these data it could be suggested that the taphonomic signature of the Griffon Vulture also differs from the Egyptian Vulture; however, no taphonomic study currently quantifies taphonomic variables for this predator.

### *4.1.2. Egyptian Vulture and other leporid remains accumulators*

It should be taken into account that the leporid sample here analysed is quite small ($N = 133$) and results should therefore be interpreted with caution. However, the trends observed on the leporid sample are consistent with the feeding behaviour of this predator and provide interesting preliminary data about this type of accumulation. The main taphonomic features observed point to anatomical representation characterized by an abundance of skull remains, a low degree of breakage (81.2% of bones were complete), a very low degree of digested remains (0.8%) and a comparatively high incidence of beak marks (7.5%).

**Table 7**
Bird skeletal elements recovered from Egyptian Vulture nests. Key: *N* – number of skeletal elements; *N%* – percentage of skeletal elements; MNE – minimum number of elements; RA – relative abundance; *C* – numbers of complete elements; *C%* – percentages of complete elements.

| | Birds – whole sample | | | | | | *Columba* sp. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | *N%* | NME | RA% | *C* | *C%* | *N* | *N%* | NME | RA% |
| Mandible | 1 | 2.2 | 1 | 8.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cranium | 3 | 6.5 | 3 | 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| Furcula | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| Scapula | 6 | 13 | 6 | 25 | 4 | 66.7 | 5 | 18.5 | 5 | 50 |
| Coracoid | 5 | 10.9 | 5 | 20.8 | 5 | 100 | 5 | 18.5 | 5 | 50 |
| Humerus | 6 | 13 | 6 | 25 | 5 | 83.3 | 5 | 18.5 | 5 | 50 |
| Radius | 1 | 2.2 | 1 | 4.2 | 0 | 0 | 1 | 3.7 | 1 | 10 |
| Ulna | 5 | 10.9 | 5 | 21 | 3 | 60 | 2 | 7.4 | 2 | 20 |
| Carpometacarpus | 1 | 2.2 | 1 | 4.2 | 1 | 100 | 0 | 0 | 0 | 0 |
| Femur | 1 | 2.2 | 1 | 4.2 | 1 | 100 | 1 | 3.7 | 1 | 10 |
| Tibiotarsus | 4 | 8.7 | 4 | 16.7 | 2 | 50 | 1 | 3.7 | 1 | 10 |
| Tarsometatarsus | 1 | 2.2 | 1 | 4.2 | 1 | 100 | 0 | 0 | 0 | 0 |
| Sternum | 3 | 6.5 | 3 | 25 | 0 | 0 | 3 | 11.1 | 3 | 60 |
| Innominate | 5 | 10.9 | 4 | 33.3 | 1 | 20 | 4 | 14.8 | 3 | 60 |
| Phalanges | 2 | 4.3 | 2 | | 2 | 100 | 0 | 0 | 0 | 0 |
| Vertebrae | 1 | 2.2 | 1 | | 1 | 100 | 0 | 0 | 0 | 0 |
| Ribs | 1 | 2.2 | 1 | | 1 | 100 | 0 | 0 | 0 | 0 |
| Total | 46 | | 45 | | 27 | 58.7 | 27 | | 26 | |

To facilitate comparisons, we present a summary of results obtained from different leporid predators, where the data have been collected using the same methodological approach (Table 9). This comparison reveals that the taphonomic signature of Egyptian Vulture nest accumulations differs from other predators. The predominance of teeth and cranial remains observed in the present study is higher than that recorded for all other predators, even Iberian lynx scat and Spanish Imperial Eagle pellet samples, which are characterized by high values of cranial remains. However, our results on anatomical representation differ from those obtained by Sanchis Serra et al. (2013). In their sample, practically all skeletal elements were present and femur, pelvis, radius/ulna and metatarsus were the best represented. Differences could be related to the age profile with its high frequency of immature individuals (almost 60%), which were probably transported to the nest whole. This highlights the important variability that leporid assemblages accumulated by Egyptian Vulture may display, probably related to age of prey. More studies are needed to confirm whether different profiles of anatomical representation can be established through the age profiles of leporids. For the time-being, the main feature of anatomical representation in leporid remains accumulated by this vulture seems to be variability, so this is not the best distinguishing character from other predators.

As far as breakage patterns are concerned, the high percentage of complete elements in the Egyptian Vulture sample is only comparable to those obtained with terrestrial carnivore samples of non-ingested remains. Both, Iberian lynx and fox produce similar percentages of complete bones (73.2% and 89.4% respectively) compared with the Egyptian Vulture (81.2%). However, in non-ingested carnivore samples, digested remains are absent (Lloveras et al., 2012a; Rodríguez-Hidalgo et al., 2013). In the present sample and also in the study by Sanchis Serra et al. (2013), the percentage of digestion was low but enough to establish a difference (Table 9).

With regards to the percentage of bones with beak marks (present study 7.5%; Sanchis Serra et al. (2013) 10.4%), only in non-ingested remains accumulated by foxes was the frequency of tooth-marked bones similar (9.5%). All other predators displayed lower values. On the other hand, the lack of gnawing damage and location of the puncture marks is not typical of the action of carnivores but of birds of prey (Sanchis Serra et al., 2013).

**Table 8**
Numbers and percentages of parts of the skeleton included in each breakage category for birds.

| Birds – breakage categories | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mandible | *N* | % | Skull | *N* | % | Pelvis | *N* | % | Sternum | *N* | % |
| Whole | 0 | 0 | Whole | 0 | 0 | Synsacrum + ilium-ischii-pubis | 5 | 100 | More 1/2 with rostrum | 3 | 100 |
| One branch | 0 | 0 | Beak + brain case without back part | 1 | 33.3 | Ilium-ischii-pubis | 0 | 0 | Less 1/2 with rostrum | 0 | 0 |
| Articular part | 0 | 0 | Brain case without back part | 1 | 33.3 | Synsacrum | 0 | 0 | Fragment without rostrum | 0 | 0 |
| Pars symphysialis | 1 | 100 | Brain case | 1 | 33.3 | Acetabulum | 0 | 0 | | | |
| Middle part branch | 0 | 0 | Beak | 0 | 0 | | | | | | |

| | Whole | | Proximal part | | Distal part | | Shaft | | | Complete | | Fragment | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | % | *N* | % | *N* | % | *N* | % | | *N* | % | *N* | % |
| **Scapula** | 4 | 66.7 | 2 | 33.3 | 0 | 0 | 0 | 0 | **Phalanges** | 2 | 100 | 0 | 0 |
| **Coracoid** | 5 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | **Vertebrae** | 1 | 100 | 0 | 0 |
| **Humerus** | 5 | 83.3 | 0 | 0 | 0 | 0 | 1 | 16.7 | **Ribs** | 1 | 100 | 0 | 0 |
| **Radius** | 0 | 0 | 1 | 100 | 0 | 0 | 0 | 0 | | | | | |
| **Ulna** | 3 | 60 | 0 | 0 | 1 | 20 | 1 | 20 | | | | | |
| **Carpometacarpus** | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| **Femur** | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| **Tibiotarsus** | 2 | 50 | 1 | 25 | 1 | 25 | 0 | 0 | | | | | |
| **Tarsometatarsus** | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |

### 4.1.3. *Egyptian Vulture and other accumulators of bird remains*

This study provides the first detailed observations on bird bones accumulated by Egyptian Vultures. Among the remains recovered pelves, sterna, scapulae, coracoids and humeri were the most abundant. The same elements were the best represented in non-ingested assemblages from diurnal raptors (Imperial Eagle, Golden Eagle, Gyrfalcon, Crested Caracara) studied by Bochenski (2005), Bochenski et al. (1998, 1999, 2009) and Montalvo et al. (2011). Bochenski (2005) indicates that the high frequencies of the sterna are characteristic of non-ingested prey remains of a diurnal birds of prey. In contrast, tarsometatarsus or cranium (or both) are the best represented on pellet assemblages of diurnal and nocturnal raptors (Bochenski, 2005; Laroulandie, 2002).

Results from the wing/leg ratio indicate a higher abundance of wing elements. When comparing these data with other studies (Bochenski, 2005; Bochenski et al., 1997, 1999; Laroulandie, 2002; Montalvo et al., 2011), it is clear that this is a feature shared with non-ingested assemblages accumulated by other diurnal raptors. A predominance of proximal and core elements has also been recorded in non-ingested Golden Eagle samples (Bochenski, 2005; Bochenski et al., 1999).

When considering the fragmentation of bird bones by Egyptian Vultures our results are similar to assemblages of uneaten remains

**Table 9**
Anatomical representation, breakage, digestion and teeth/beak marks data for leporid remains accumulated by different types of predators (nocturnal raptors, diurnal raptors, terrestrial carnivores) compared with the results obtained for the Egyptian Vulture in the present study.

| Leporid comparisons | Eagle Owl *Bubo bubo* | | Spanish imperial Eagle *Aquila adalberti* | Iberian lynx *Lynx pardinus* | | Fox *Vulpes vulpes* | | Egyptian vulture *Neophron percnopterus* | |
|---|---|---|---|---|---|---|---|---|---|
| Reference | Lloveras et al., 2009a | | Lloveras et al., 2008b | Lloveras et al., 2008a | Rodríguez-Hidalgo et al., 2013b | Lloveras et al., 2012a | | Sanchis Serra et al., 2013 | Present study |
| Origin | Nest | Nest | Pellet | Scat | Non-ingested | Scat | Non-ingested | Nest | Nest |
| N | 1808 | 1932 | 824 | 1522 | 9564 | 265 | 639 | 269 | 133 |
| RA% >values | pat-cal-in-fem | cal-in-tib-mts | phal 3-um-tib | man-teeth-cr | tib-cal-mts-ast | long bones-sc-cr | mts-cal-ast-tib | fem,-inn-rad-uln-mts | man-cra-teeth |
| RA% <values | mtc-c/t | rad-c/t-mtc | rib-fem-rad-ver | c/t-ver-rib | sc-ver-hum-rib-fem | mtc-c/t-in | cr-sc-rib-in-ver | rib-cra | phal-c/t-long bone- ver |
| PCRT/CR | +postcranial | = | +cranial | +cranial | +postcranial | = | +postcranial | +postcranial | +cranial |
| P/D | +proximal | +proximal | +distal | +proximal | +distal | +proximal | +distal | – | – |
| AN/PO | +hindlimb | +hindlimb | +hindlimb | +forelimb | +hindlimb | +hindlimb | +hindlimb | – | – |
| **Complete elements %** | | | | | | | | | |
| Mean value long bones | 14.6 | 10.8 | 0 | 2.5 | 37.6 | 0 | 5.4 | – | – |
| Mean value total | 53.9 | 45.9 | 27 | 43 | 73.2 | 12 | 89.4 | 80 | 81.2 |
| **Length (in mm.)** | | | | | | | | | |
| Minimum | 2.3 | 2.5 | 1.8 | 1.1 | 3 | 3 | 4 | – | 26.3 |
| Maximum | 86.3 | 90 | 36.1 | 30.1 | 69 | 26.8 | 86.2 | – | 70.1 |
| %<10 mm. | 49 | 40 | 73 | 80 | 19.7 | 61 | 28 | – | 52.4 |
| % Digested remains | 68.8 | 65.6 | 98 | 97.2 | – | 99.5 | – | 1.1 | 0.8 |
| % Digested long bones | 88.9 | 83.9 | 100 | 100 | – | 100 | – | 2.8 | – |
| **Degree** | | | | | | | | | |
| Null | 31.2 | 34.4 | 2 | 2.8 | – | 0 | – | – | 99.2 |
| Light | 40.2 | 40.2 | 18.2 | 12 | – | 6 | – | – | 0 |
| Moderate | 19.8 | 19.8 | 46.8 | 22 | – | 26 | – | – | 0.8 |
| Heavy | 8 | 5.3 | 27.4 | 43.8 | – | 43 | – | – | 0 |
| Extreme | 0.7 | 0.15 | 5.6 | 19.3 | – | 25 | – | – | 0 |
| Teeth/beak marks | 2 | 1.34 | 0.5 | 0.26 | 0.9 | 3 | 9.5 | 10.4 | 7.5 |
| Age % of adults | 50 | 50 | – | 21.4 | – | 87 | – | 41.7 | 100 |

created by diurnal birds of prey. The percentage of complete long bones was 73.3% compared with the values above 60% reported by Bochenski (2005) for Peregrine Falcon, Gyrfalcon, Imperial Eagle and Golden Eagle.

The coracoid, scapula and tibiotarsus were the most frequently elements affected by digestion whereas the pelvis and sternum were never damaged, despite being well represented in the sample, indicating that these elements were not usually ingested by the vultures. At present the limited observations on the corrosive digestive damage on bird bones precludes any comparison (Bochenski, 2005; Laroulandie, 2002).

The discovery that most beak marks were located on pelves and sterna is replicated on uneaten assemblages left by other diurnal birds of prey. In the present study, punctures were registered on 66.7% of sterna and 60% of pelves. Bochenski et al. (2009) found punctures on 70% of sterna and 38% of pelves in White-tailed Eagle assemblages and punctures were observed on 39% of sterna, 51% of pelves and 52% of humeri in Golden Eagles.

Overall, most taphonomic features observed on birds accumulated by the Egyptian Vulture are shared by other diurnal birds of prey. Therefore, they cannot be considered truly diagnostic of a specific predator.

## 5. Conclusions

Egyptian Vultures used the same or similar shelters and caves as human groups in the past. Therefore, bone remains accumulated at their nests could result in the formation of faunal deposits mixed with human or other predator-derived assemblages. Results from this analysis help to identify and classify the most important characteristics of prey bones, which have been accumulated by this raptor, and to distinguish their presence in archaeological contexts.

The main features observed are:

1) Egyptian Vulture diet is focused on a wide range of species. They do not accumulate large amounts of bones at their nests as do other birds of prey, but a diversity of taxa are represented. The most important prey are: ungulates, rabbits, birds, medium and small carnivores. Of less importance but usually represented are small-mammals, reptiles, amphibians and sometimes fish.
2) Skeletal remains accumulated in Egyptian Vulture nests are mostly non-ingested elements; only a small part comes from pellets.
3) Anatomical representation varies greatly depending on the taxonomic group. Only small prey are transported complete to the nest, for this reason, even within the same taxa the age and size of prey are important variables that affect taphonomic patterns.
4) The breakage pattern is characterized by a low degree of bone fragmentation. High percentages of complete bones were registered for all taxonomic groups (average 72.3%).
5) Digested remains are scarce (average 6.1%) and a high percentage of bones display beak marks (average 16.4%). Birds are the taxonomic group most affected by bone surface modifications.

The observations and results obtained through this study showed that damage caused by the Egyptian Vulture on prey differs from that of other vultures. The pattern observed on leporid remains also varies from other predators. For birds, most features coincide with those registered by other diurnal birds of prey accumulations of non-ingested remains, the only difference being the presence of digested remains on Egyptian Vulture nest assemblages.

We are aware that samples analysed are small and some results should be taken with caution. Nevertheless, the use of criteria presented in this study can help to successfully attribute examined archaeological material to Egyptian Vulture.

## Acknowledgements

We thank the anonymous reviewers for their helpful comments on the manuscript. We would like to thank J.A. Donázar for his insightful comments about Egyptian Vultures feeding behaviour. Ll. Lloveras was funded by a postdoctoral grant (BP-A 00334 2011) from the Secretaria d'Universitats i Recerca Del Departament d'Economia i Coneixement de la Generalitat de Catalunya. Financial support from research projects HAR2011-26193 from the Ministerio de Ciencia e Innovación (MICINN) and SGR2009-1145 from the Generalitat de Catalunya are gratefully acknowledged.

## References

Álvarez, M.C., Kaufmann, C.A., Massigoge, A., Gutiérrez, M.A., Rafuse, D.J., Scheifler, N.A., González, M.E., 2012. Bone modification and destruction patterns of leporid carcasses by Geoffroy's cat (*Leopardus geoffroyi*): an experimental study. Quat. Int. 278, 71–80.

Andrews, P., 1990. Owls, Caves and Fossils. Natural History Museum, London.

Barone, R., 1976. Anatomie comparée des mammifères domestiques. In: Ostéologie, Tome 1. Ed. Vigot.

Benson, P.C., Plug, I., Dobbs, J.C., 2004. An analysis of bones and other materials collected by Cape Vultures at the Kransberg and Blouberg colonies, Limpopo Province, South Africa. Ostrich 75 (3), 118–132.

Binford, L.R., 1981. Bones: Ancient Men and Modern Myths. Academic Press, New York.

Bochenski, Z.M., 2005. Owls, diurnal raptors and humans: signatures on avian bones. In: O'Connor, T. (Ed.), Biosphere to Lithosphere. New Studies in Vertebrate Taphonomy. Oxbow Books, Oxford, pp. 31–45.

Bochenski, Z.M., Nekrasov, A.E., 2001. The taphonomy of Sub-Atlantic bird remains from Bazhukovo III, Ural Mountains, Russia. Acta Zool. Cracoviensia 44, 93–106.

Bochenski, Z.M., Boev, Z., Mitev, I., Tomek, T., 1993. Patterns of bird bone fragmentation in pellets of the Tawny Owl (*Strix aluco*) and the Eagle Owl (*Bubo bubo*) and their taphonomical implications. Acta Zool. Cracoviensia 36 (2), 313–328.

Bochenski, Z.M., Huhtala, K., Jussila, P., Pulliainen, E., Tornberg, R., Tunkkari, P.S., 1998. Damage to bird bones in pellets of Gyrfalcon *Falco rusticolus*. J. Archaeol. Sci. 25, 425–433.

Bochenski, Z.M., Huhtala, K., Sulkava, S., Tornberg, R., 1999. Fragmentation and preservation of bird bones in food remains of the golden eagle *Aquila chrysaetos*. Archaeofauna 8, 31–39.

Bochenski, Z.M., Korovin, V.A., Nekrasov, A.E., Tomek, T., 1997. Fragmentation of bird bones in food remains of imperial eagles *Aquila heliaca*. Int. J. Osteoarchaeol. 7 (2), 165–171.

Bochenski, Z.M., Tomek, T., Tornberg, R., Wertz, K., 2009. Distinguishing nonhuman predation on birds: pattern of damage done by the white-tailed eagle *Haliaetus albicilla*, with comments on the punctures made by the golden eagle *Aquila chrysaetos*. J. Archaeol. Sci. 36, 122–129.

Brain, C.K., 1981. The Hunters or the Hunted? An Introduction to African Cave Taphonomy. University of Chicago Press, Chicago.

Ceballos, O., Donázar, J.A., 1990. Roost-tree characteristics, food habits and seasonal abundance of roosting Egyptian vultures in northern Spain. Raptor Res. Found. 24 (1–2), 19–25.

Cochard, D., 2004a. Étude taphonomique des léporidés d'une tanière de renard actuelle: apport d'un référentiel à la reconnaisance des accumulations anthropiques. Rev. Paléobiol. 23 (2), 659–673.

Cochard, D., 2004b. Les léporidés dans la subsistance Paléolithique du sud de la France (Thèse de doctorat). Université Bordeaux I, Bordeaux.

Costamagno, S., Robert, I., Laroulandie, V., Mourre, V., Thiébaut, C., 2008. Rôle du gypaète barbu (*Gypaetus barbatus*) dans la constitution de l'assemblage osseux de la grotte du Noisetier (Fréchet-Aure, Hautes-Pyrénées, France). Ann. Paléontol. 94, 245–265.

Cramp, S., Simmons, K.E.L., 1980. The Birds of Western Palearctic, vol. 2. Oxford University Press, Oxford, U.K.

Dodson, P., Wexlar, D., 1979. Taphonomic investigations of owl pellets. Paleobiology 5, 275–284.

Donázar, J.A., Ceballos, O., 1988. Alimentación y tasas reproductoras del alimoche (*Neophron percnopterus*) en Navarra. Ardeola 35, 3–14.

Donázar, J.A., Ceballos, O., Tella, J.L., 1996. Communal roosts of Egyptian Vulture (*Neophron percnocterus*): dynamics and implications for the species conservation. In: Muntaner, J., Mayol, J. (Eds.), Biología y conservación de las rapaces mediterráneas, Monografía, vol. 4. SEO/BirdLife, Madrid, pp. 189–201.

Donázar, J.A., Palacios, C.J., Gangoso, L., Ceballos, O., Gonzalez, M.J., Hiraldo, F., 2002. Conservation status and limiting factors in the endangered population of Egyptian vulture (*Neophron percnopterus*) in the Canary Islands. Biol. Conserv. 107, 89–97.

Del Moral, J.C., 2009. El alimoche común en España. Población reproductora en 2008 y método de censo. SEO/BirdLife, Madrid, p. 185.
Elorza, M., 1990. Restos de aves en los yacimientos prehistóricos vascos. Estudios realizados. Munibe (Antropol.-Arkeol.) 42, 263–267.
Ericson, P., 1987. Interpretations of archeological bird remains: a taphonomic approach. J. Archaeol. Sci. 14, 65–75.
Esteban-Nadal, M., Cáceres, I., Fosse, Ph, 2010. Characterization of a current coprogenic sample originated by *Canis lupus* as a tool for identifying a taphonomic agent. J. Archaeol. Sci. 37, 2959–2970.
Ferguson-Lees, J., Christie, D.A., 2001. Raptors of the World. Christopher Helm, London, p. 992.
Fernández, J.A., 1977. Comportamiento del Buitre Leonado (*Gyps f. fulvus*) en nido. Ardeola 22, 29–54.
Fernández-Jalvo, Y., Andrews, P., 1992. Small mammal taphonomy of Gran Dolina, Atapuerca (Burgos), Spain. J. Archaeol. Sci. 19, 407–428.
García-Heras, M.S., Cortés-Avizanda, A., Donázar, J.A., 2013. Who are we feeding? Asymmetric individual use of surplus food resources in an Insular population of the endangered Egyptian vulture *Neophron percnopterus*. PLoS ONE 8 (11), e80523. http://dx.doi.org/10.1371/journal.pone.0080523.
Grant, A., 1982. The use of tooth wear as a guide to the age of domestic ungulates. In: Wilson, B., Grigson, C., Payne, S. (Eds.), Ageing and Sexing Animal Bones from Archaeological Sites, BAR British Series 109, pp. 91–108.
Hernández Carrasquilla, F., 1994. Addenda al catálogo provisional de yacimientos con aves del cuaternario de la Península Ibérica. Archaeofauna 3, 77–92.
Hidalgo, S., Zabala, J., Zuberogoitia, I., Azkona, A., Castillo, I., 2005. Food of the Egyptian vulture (*Neophron percnopterus*) in Biscay. Buteo 14, 23–29.
Hockett, B.S., 1996. Corroded, thinned and polished bones created by Golden Eagles (*Aquila chrysaetos*): taphonomic implications for archaeological interpretations. J. Archaeol. Sci. 23, 587–591.
Laroulandie, V., 2002. Damage to pigeon long bones in pellets of the eagle owl *Bubo bubo* and food remains of peregrine falcon *Falco peregrinus*: zooarchaeological implications. In: Bochenski, Z.M., Bochenski, Z., Stewart, J.R. (Eds.), Proceedings of the 4th Meeting of the ICAZ Bird Working Group. Acta Zool. Cracoviensia 45, 331–339.
Lloveras, Ll, Moreno-García, M., Nadal, J., 2008a. Taphonomic analysis of leporid remains obtained from modern Iberian lynx (*Lynx pardinus*) scats. J. Archaeol. Sci. 35, 1–13.
Lloveras, Ll, Moreno-García, M., Nadal, J., 2008b. Taphonomic study of leporid remains accumulated by Spanish Imperial Eagle (*Aquila adalberti*). Geobios 41, 91–100.
Lloveras, Ll, Moreno-García, M., Nadal, J., 2009. The Eagle Owl (*Bubo bubo*) as a leporid remains accumulator. Taphonomic analysis of modern rabbit remains recovered from nests of this predator. Int. J. Osteoarchaeol. 19, 573–592.
Lloveras, Ll, Moreno-García, M., Nadal, J., 2012a. Feeding the foxes: an experimental study to assess their taphonomic signature on leporid remains. Int. J. Osteoarchaeol. 22, 577–590.
Lloveras, Ll, Moreno-García, M., Nadal, J., 2012b. Assessing the variability in taphonomic studies of modern leporid remains from Eagle Owl (*Bubo bubo*) nest assemblages: the importance of age of prey. J. Archaeol. Sci. 39, 3754–3764.
Mallye, J.B., Cochard, D., Laroulandie, V., 2008. Accumulations osseuses en périphérérie de terriers de petits carnivores: les stigmates de prédation et de fréquentation. Ann. Paléontologie 94, 187–208.
Margalida, A., Benítez, J.R., Sánchez-Zapata, J.A., Ávila, E., Arenas, R., Donázar, J.A., 2012. Long-term relationship between diet breadth and breeding success in a declining population of Egyptian Vultures *Neophron percnopterus*. Ibis 154, 184–188.
Marín Arroyo, A.B., Fosse, P., Vigne, J.D., 2009. Probable evidences of bone accumulation by Pleistocene bearded vulture at the archaeological site of El Mirón Cave (Spain). J. Archaeol. Sci. 36, 284–296.
Marín-Arroyo, A.B., Margalida, A., 2012. Distinguishing bearded vulture activities within archaeological contexts: identification guidelines. Int. J. Osteoarchaeol. 22 (5), 563–576.
Mondini, M., 2002. Carnivore taphonomy and the early human occupations in the, Andes. J. Archaeol. Sci. 29, 791–801.
Montalvo, C., Tallade, P.O., Fernández, F., Moreira, G.J., Rafuse, D.J., De Santis, L., 2011. Bone damage patterns found in the avian prey remains of crested caracara *Caracara plancus* (Aves, Falconiformes). J. Archaeol. Sci. 38, 3541–3548.
Oró, D., 1992. A preliminary study of the diet of the Egyptian vulture *Neophron percnopterus* on Minorca (Balearic Islands). Butll. GCA 9, 25–27.
Payne, S., 1987. Reference codes for wear states in the mandibular cheek teeth of sheep and goats. J. Archaeol. Sci. 14, 609–614.
Richardson, P.R., Mundy, P.J., Plug, I., 1986. Bone crushing carnivores and their significance to osteodystrophy in griffon vulture chicks. J. Zool. 210 (1), 23–43.
Robert, I., Margalida, A., Seguin, J.F., 2002. Contribution à l'étude du régime alimentaire du gypaète barbu (*Gypaetus barbatus*): analyse comparée des restes prélevés dans les nids et les aires de cassage en Corse et en Espagne. In: LPO Fir (Ed.), Actes du Colloque International Conservation et gestion des populations de Gypaète barbu. LPO, Paris, pp. 75–82.
Robert, I., Vigne, J.D., 2002. The bearded vulture (*Gypaetus barbatus*) as an accumulator of archaeological bones. Late Glacial assemblages and present-day reference data in Corsica (Western Mediterranean). J. Archaeol. Sci. 29, 763–777.
Rodríguez-Hidalgo, A., Lloveras, Ll., Moreno-García, M., Saladié, P., Canals, A., Nadal, J., 2013. Feeding behaviour and taphonomic characterization of non-ingested rabbit remains produced by the Iberian lynx (*Lynx pardinus*). J. Archaeol. Sci. 40, 3031–3045.
Rogers, P., 1982. Reliability of epiphyseal fusion as an indicator of age in rabbits. Mammalia 46 (2), 267–269.
Sanchis, A., 2000. Los restos de *Oryctolagus cuniculus* en las tafocenosis de *Bubo bubo* y *Vulpes vulpes* y su aplicación a la caracterización de registro faunístico arqueológico. Saguntum 32, 31–50.
Sanchis, A., 2012. Los lagomorfos del Paleolítico medio en la vertiente mediterránea ibérica. Humanos y otros predadores como agentes de aporte y alteración de los restos óseos en yacimientos arqueológicos. In: Serie de Trabajos Varios del Servicio de Investigación Prehistórica, vol. 115 (Valencia).
Sanchis Serra, A., Pascual Benito, J., 2011. Análisis de las acumulaciones óseas de una guarida de pequeños mamíferos carnívoros (Sitjar Baix, Onda, Castellón): implicaciones arqueológicas. Archaeofauna 20, 47–71.
Sanchis Serra, A., Real Margalef, C., Morales Pérez, J.V., Pérez Ripoll, M., Tormo Cuñat, C., Carrión Marco, Y., Pérez Jordá, G., Ribera Gómez, A., Bolufer Marqués, J., Villaverde Bonilla, V., 2013. Towards the identification of a new taphonomic agent: an analysis of bone accumulations obtained from modern Egyptian vulture (*Neophron percnopterus*) nests. Quat. Int. http://dx.doi.org/10.1016/j.quaint.2013.10.047.
Schmitt, D.N., 1995. The taphonomy of Golden Eagle prey accumulations at Great Basin roosts. J. Ethnobiol. 15, 237–256.
Schmitt, D.N., Juell, K.E., 1994. Toward the identification of coyote scatological faunal accumulations in archaeological context. J. Archaeol. Sci. 21, 249–262.
Stiner, M., Munro, N., Sanz, M., 2012. Carcass damage and digested bone from mountain lions (*Felis concolor*): implications for carcass persistence on landscapes as a function of prey age. J. Archaeol. Sci. 39, 896–907.
Vila, A., 1985. El Cingle Vermell: assentament de caçadors-recol·lectors del Xè mil·leni B.P.. In: Excavacions Arqueològiques a Catalunya 5 Departament de Cultura de la Generalitat de Catalunya.