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Was it the deer or the fox?

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ABSTRACT

Herbivores, as taphonomic agents, can modify and consume bones and antlers for no nutritive purpose. This unusual behavior is due to a nutritional dysfunction (osteophagia) that allows them to supplement a lack of minerals in their diet through ingestion of minerals contained in bones. When chewing, herbivores change skeletal element morphology and produce a characteristic forked shape. At an incipient stage of modification, herbivore chewing may mimic that of carnivores. In this paper, we provide diagnostic criteria to distinguish bone modification made by herbivores from that produced by other taphonomic agents, mainly carnivores.

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1. Introduction

This paper studies a taphonomic modification of biological origin that may be misinterpreted at archaeological sites. Herbivores, in a nutrient-deficient environment, have been observed to chew and consume bones and antlers to obtain minerals lacking in their diet (Fish, 1950; Gordon, 1970; Barrette, 1985; Barnes et al., 1990; Johns and Duquette, 1991; Grasman and Hellgren, 1993; Richard and Juliá, 2001; Mitchell et al., 2005; Bredin, 2006; Bredin et al., 2008). This is defined as a non-nutritional behavior, in which access to bones occurs when fat is gone and bone is dry (weathered), a behavior that may be innate in herbivores (Denton et al., 1985). It appears to be similar to the action of rodents, who, although they may chew bones primarily to wear down their constantly-growing teeth (Brain, 1981; Kibii, 2009), also chew bones to ingest minerals (Laudet and Fosse, 2001; Klippel and Synstelien, 2007).

Termed “pica” by veterenarians, this eating dysfunction leads to significant health problems in herbivores. Perhaps the main concern among specialists is botulism, which can lead to the death of the animal. Traditionally, Calcium (Ca) was considered as the deficient mineral as it was related to antler production in males and gestation periods in females (Fish, 1950). However, more recent studies have related this type of behavior primarily to a deficiency of phosphorus (P) and to a lesser extent, sodium (Na) (Barrette, 1985; Johns and Duquette, 1991; Grasman and Hellgren, 1993; Richard and Juliá, 2001). Barrette (1985) suggests that osteophagia compensates for phosphate deficiencies. As the metabolism of P and Ca are closely linked, it is reasonable to assume that osteophagia may be linked to maintaining the balance between these two minerals.

Grasman and Hellgren (1993) emphasized the importance of the environment and the substrate in which different populations live. These authors, who have observed osteophagic behaviors in different species of Cervidae, noted that animals in dry environments lack P and Ca, and that among foraging reindeer in the Arctic tundra osteophagia is associated with deficiencies of Ca and Na.

These observations suggest that osteophagia is more closely related to nutritional deficiencies *sensu stricto* than with the production of antlers or gestation periods. Mitchell et al. (2005) suggest that among female giraffes, the most frequent practice of osteophagia occurs during gestation periods and after birth. This period, however, coincides seasonally with the time when nutritional resources are at their lowest (winter) which might indicate soil impoverishment as one of the determining factors in osteophagia. Bredin (2006) suggests that soils with high levels of calcium, aluminum (Al) or iron (Fe) reduce the phosphorus content,

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so that bones and antlers are an important source of phosphates necessary for herbivore diet.

Sutcliffe (1973, 1977), Brothwell (1976) and Johnson (1985) were the first to notice that herbivores could induce bone modifications, caused by osteophagia, and create morphologies that can be confused with bone implements or tools made by humans. These bone shapes were identified as intentional humanly-made artefacts by Tokugana (1936a; 1936b), who considered that repetitive morphologies could not normally arise as a result of natural processes.

Sutcliffe (1977) described how ungulates take bones in their mouth lengthways and sideways, like a cigar and with the zigzag movements of their jaws produce the fork shape. Bones sometimes have indented and uneven edges with rounded ends. Brothwell (1976) noted that it was common to find multiple parallel grooves on herbivore-chewed bones caused by the sawing movement of their molars.

The ability of herbivores to alter bones is now recognized, and has been identified in archaeological sites as biological modification (Justus and Turner, 1990; Kierdorf, 1993, 1994; Ramis and Bover, 2001; Guerrero, 2001). However, herbivore action on bones and antlers continues to be related exclusively to forked morphologies. For this reason, damage that occurs before the fork shape is formed can remain unnoticed or misinterpreted.

A study undertaken in natural reserve of Bosque de Riofrío (Segovia, Spain) has provided a significant collection of remains affected by herbivores (fallow deer and red deer). Analysis of this collection allowed us to describe the successive stages that occur when herbivores chew bones from incipient to intensive damage. We also aimed to establish diagnostic criteria to distinguish between such damage and that caused by other taphonomic agents - mainly carnivores.

2. The Bosque de Riofrío

The Bosque de Riofrío is a natural forest of about 625 ha located in the foothills of the Northern slope of the Guadarrama Mountain in Segovia (Spain). Both its location in the central part of the Iberian Peninsula and altitude (1.000 m a.s.l.), indicate a Continental-Mediterranean climate with great temperature fluctuations between summer and winter. The forest was traditionally used for hunting expeditions but became a natural reserve in 1951; today hunting practices are forbidden. The perimeter of the forest is enclosed by a wall to prevent entry of predators from outside the reserve and dispersal of game inside the forest to the city and highways (Fig. 1).

The forest is dominated by *Quercus ilex* (holm oak) and *Fraxinus angustifolia* (narrow-leaf ash) while *Juniperus thurifera* (Spanish juniper) and *Pinus sylvestris* (scotch pine)are found at higher elevations but bushy undergrowth is limited due to the abundance of ruminants.

Dama dama (fallow deer) is the most abundant species followed by *Cervus elaphus* (red deer). Other mammals such as *Vulpes vulpes (fox)*, *Meles meles* (european badger), *Genetta genetta* (civet cat), *Martes foina* (marten) and *Erinaceus europeus* (hedgehog) are also present. Raptors are the most abundant of the bird species in this area, and include *Hieraaetus pennatus* (booted eagle), *Circaëtus gallicus* (short-toed Eagle), *Accipiter gentilis* (goshawk), *Milvus milvus (kite)*, *Milvus migrans* (black kite), *Strix aluco* (tawny owl), *Asio otus* (long-eared owl) and *Bubo bubo* (eagle owl). Other raptors that breed in the surrounding area are *Aegypius monachus (black vulture)*, *Gyps fulvus* (griffon vulture) and *Aquila chrysaëtos* (golden eagle). In addition to birds of prey other bird species present include *Upupa epops* (hoopoe), *Merops apiaster* (bee-eater), *Picus*

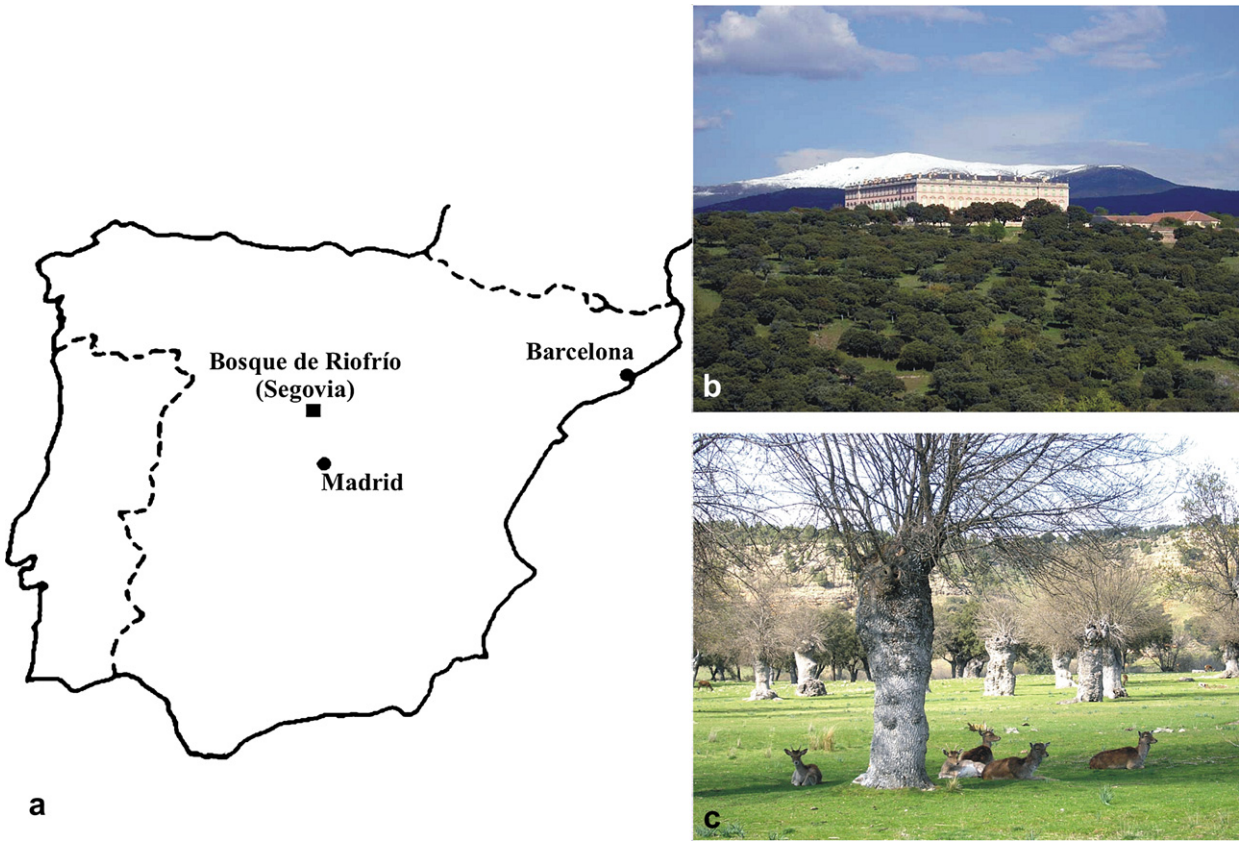

Fig. 1. Bosque de Riofrío (Segovia, Spain) a) Geographical location of the Natural Reserve of Bosque de Riofrío in the Iberian Peninsula. b) General view of Bosque de Riofrío and the Royal Palace. c) Fallow deer in a meadow area of the forest.

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