



Felid scavenging in forensic taphonomic research: An experimental approach

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ARTICLE INFO

Keywords:

Scavenging
Trace evidence
Taphonomy
Animal
Bone

ABSTRACT

Animal scavenging on human remains presents a major challenge at a forensic scene. These lasting changes can influence the interpretation of a post-mortem interval, the overall state of the remains and any associated evidence, impacting the integrity of the scene. Therefore, identifying taphonomic related changes due to animal scavenging is important to understand the post-deposition sequence of events. However, knowing where to look is challenging and animal scavenging studies are difficult to create. Therefore, this study worked in collaboration with zoological institutes in the UK to capture the scavenging changes to horse bone, focussing on the locations of scavenging on bone and the characteristics left. This study focused on large felid (cheetah, lion, tiger, leopard) scavenging, which is less documented in comparison to canine scavenging. This research demonstrated the distribution patterns of tooth activity associated with large felid scavenging is consistent with those reported in the taphonomic literature on lions. Specifically, pits, punctures, scalloping and furrowing were found and characteristics were frequently noted at the borders and flat regions of bones. This study adds to the forensic discussion of scavenging. While focussing on large cats, the work demonstrates anatomical regions that may be affected by scavenging and the visual cues that may help identify animal interaction over human.

1. Introduction

Vertebrate scavenging and modifications to human remains are frequent occurrences in forensic practice. For instance, a 27-yearlong study reported animal activity in 46 % of forensic anthropology cases [32]. Similarly, a 10-year survey in Switzerland and a 44-year survey in North America demonstrated 31.7 % and 15 % of cases respectively had been impacted by animal modification [25,55]. The key effect animals have when scavenging human remains is the modification of soft and hard tissues and the scattering of the remains over large areas [28].

One group of carnivorous animals that can severely impact humans, human remains, and their subsequent forensic analyses are cats (Carnivora: *Felidae*). Cats are abundant worldwide with only few exceptions and can be found in almost all major habitat types, often in large numbers [31]. Yet, felid scavenging is a less frequent occurrence in the forensic literature when compared to canids, and there is little research on their postmortem modification of human remains [47]. At present, there are some forensic reports on post-mortem scavenging by domestic cats (*Felis catus*, [6,8]; Garcia et al., 2019; [45,48,53]) and

bobcat (*Lynx rufus*, [43]). However, most publications cover felid attacks on live humans, e.g. by mountain lion (*Puma concolor*, [3,34,44]), tiger (*Panthera tigris*, [29]), and lion (*Panthera leo*, Āatko et al., 2014; [38]).

In forensic science, it is imperative that the forensic practitioner can identify scavenging activity to ensure the integrity of the scene and provide a robust rationale for the implementation of search and location strategies when the remains were scattered by animals [24]. Likewise, from a medico-legal perspective, obtaining an accurate post-mortem interval (PMI) for the body presents a major challenge due to the vast number of extrinsic and intrinsic variables that influence the decomposition process, including vertebrate scavengers [21]. Scavengers can significantly alter decomposition rate through removal of soft tissue while feeding, consequently misleading PMI estimations [36,50]. This situation has been compounded by an increase in the number of deadly human-animal encounters in recent years [2]. Characteristics created by scavenging can be misinterpreted as peri- or ante-mortem trauma and may destroy person-inflicted traumatic lesions and forensic evidence [49,57]. Detecting and interpreting scavenging-related characteristics is

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<https://doi.org/10.1016/j.forensiint.2024.112280>

Received 24 October 2023; Received in revised form 19 September 2024; Accepted 28 October 2024

Available online 4 November 2024

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imperative to avoid confusion with human intervention [15,55].

Felids may cause lesions during the course of predation [33], dismemberment [4], consumption of soft tissues [41], marrow or mineral content [14,37], or even just out of boredom [13,54]. The amount of carnivore activity varies and is dependent on the accessibility and location of the remains and the human population density in relation to the body [22].

Since soft tissues are malleable, stretch and deform [9], the scavenging that penetrates through the soft tissue and onto the bone, as well as the scavenging that occurs directly on bone will leave lasting changes that can be analysed by the forensic practitioner [16]. Large felid attacks are usually directed towards head, neck and torso, often resulting in fractures of the cervical spine, or injuries of the upper body [30,46]. Postmortem feeding was described to result in large tears of the soft tissue, similar to sharp force injuries [43]. Often, the skeleton is left defleshed but bones present with pits, punctures, scores and furrows, especially on bones of the upper body, but also the long bones of lower limbs (Domínguez-Rodrigo 1999; [27,58]). Felids are not usually interested in the bones themselves, thus the canid-typical destruction of long bone ends is uncommon. Frequent are also highly fragmented smaller bones affected by gastric acid corrosion that were eaten as a by-product of soft tissue feeding and passed through the digestive tract [24,35,52].

Previous attempts were made by the means of actualistic experiments to identify the species based on tooth mark dimensions and morphology on bone, with a vast record mainly in the archaeological field. However, there is a considerable overlap of tooth mark sizes between scavenger size, class and species [10,12,40,60], even within the felid group. Tooth mark dimension and morphology in isolation are therefore not specific enough to make species identifications, and additional information such as distribution patterns and contextual information are crucial [10,15].

While several publications have explored advancing and automating experimental design within forensic taphonomic research in general [17,36], undertaking scavenging studies can be difficult due to the added complication in getting actualistic data from wild animals. Creating an experiment is one aspect of the design, but encouraging wild animals to scavenge may be considered unrealistic, and depending on the ecology and behaviour of a particular animal throughout a specific period may mean scavenging is unpredictable. As a result, most large studies to date are case based summaries detailing the impact an animal has had on the human body due to predation and/or scavenging. However, the challenge with such case studies is the cross-sectional character, leaving room for interpretation about the actual cause for the lesions. Controlled experiments on the other hand allow longitudinal surveillance, including direct observation of cause and consequence. Taphonomic studies are region-specific because of variation in vertebrate scavenger guilds. Large felids in general populate most geographical areas worldwide; tigers (*Panthera tigris*) live in Southeast Asia, lions (*Panthera leo*) in Africa, leopards (*Panthera pardus*) are abundant in Africa and South Asia, and lynx (*Lynx lynx*) can be found in Europe and through Asia [31], for instance. Nevertheless, large felids are common inhabitants of animal parks worldwide, providing a geographically unbound source for cases as well as experimental taphonomic studies.

The aim of this research was to use a controlled environment where scavenging is predictable to assess the characteristics left on bone. The focus of this study was on large cat (felid) scavenging, especially patterns of inflicted marks on bone, to identify this group of animals upon their taphonomic signature. This could better inform practitioners of the visual changes on remains as a direct result of scavenging, for identification purposes.

2. Materials and methods

In order to acquire and analyse the scavenged remains of animal

carcasses, collaborations were initiated between Cranfield University and two zoological institutions: Longleat Safari Park, Wiltshire, UK, and Cotswold Wildlife Park, Oxfordshire, UK. Ethical approval was obtained for this study (CURES/7876/2019), and appropriate documentation from the Environmental Agency for the procedures relating to transport, storage and disposal were correctly in place (using the animal by-products licence). Data supporting this study, unless provided as supplementary information, cannot be made available due to commercial restrictions. This study took place between the January 2019 and March 2020.

For felids, at both Longleat Safari Park and Cotswold Wildlife Park, equid carcasses are mostly used as the feed. The horse is initially skinned, and then broken down into large parts to be placed within the enclosures. However, the leopards from this study are given considerably smaller parts in comparison to the other big cats. It should be noted that not full carcasses were placed within the enclosures. Therefore, where this study states only one particular skeletal element was recovered, this is because only that part of the animal was placed within the enclosure at this time. For this study, scavenged remains were collected from Longleat Safari Park from the cheetahs (*Acinonyx jubatus*), lions (*Panthera leo*), and tigers (*Panthera tigris*). From Cotswold's Wildlife Park, samples were collected from the lions as well as the leopards (*Panthera pardus*).

A total of 72 samples were collected. These were either individual bones or largely skeletonised limbs articulated with connective tissue. Samples were placed within biological hazard bags, sealed, and stored in a refrigerated container until they could be collected. These were then transported to Cranfield University and stored safely in a freezer marked with biological hazard labels. Each sample was labelled, re-bagged, photographed, and the individual characteristics associated with scavenging were documented. No cleaning or defleshing was undertaken in this process. If a bone sample had more than one of the same characteristics (for example, more than one tooth pit), it was still only attributed as to being 'present'. Fig. 1

Evidence of scavenging was attributed to one or more of the following categories following REF [5]:

- Pit: a depression in the architecture of the bone that one cannot see through or has not exposed the internal cavity within a bone. Normally oval or circular in shape.
- Puncture: a depression that has fully penetrated through the bone (one can see through it) or has exposed the internal cavity. Normally oval or circular in shape.
- Scalloping: A series of curves or waves that repeat several times along a bone's margin.
- Scoring: An abrasion across the bone's surface. These are shallower striations in comparison to that of a furrow, often the result of a beak or claws that have met the bone's surface, or from teeth where the long bone ends have been chewed off and the marrow is extracted via licking.
- Furrow: A groove that penetrates through the bone and is linear in profile. It is longer than it is wide and appears as a trough like formation.

The recording process was undertaken by the primary author [DE]. After the recording process, the evidence of scavenging was assessed to determine whether there was any relationship between the documented characteristics, bone elements (and location of characteristic on the bone), and the types of characteristics relating to species. In addition, the individual marks were tallied with regards to their location on individual bone elements. This was undertaken to create a heatmap that demonstrates the areas of scavenged bone in relation to the areas that remained unaltered. This was achieved with the intention to help examiners understand where the most likely areas of change after scavenged events could be, and in turn, where characteristics could be identified.

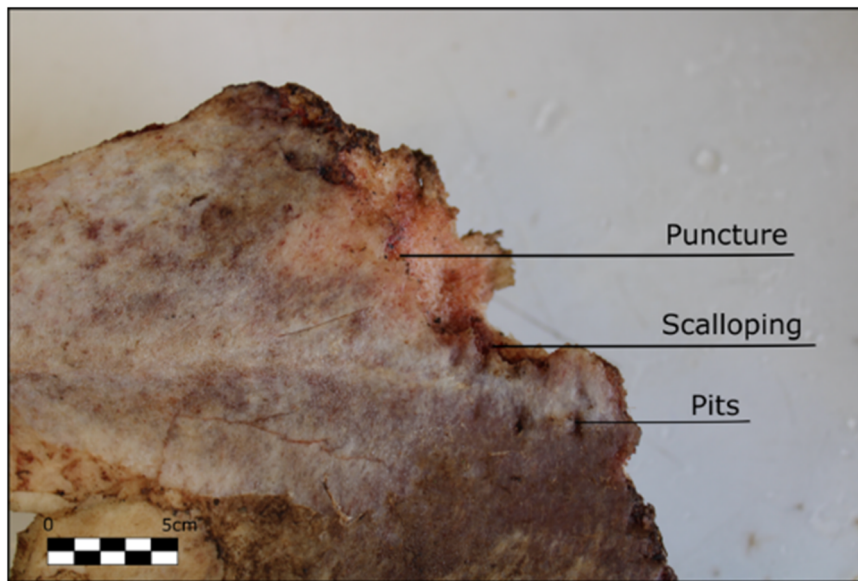


Fig. 1. Some characteristics attributed in this study.

3. Results

The 72 samples comprised bones scavenged by leopard (3; 4.2 %), tiger (27; 37.5 %), lion (12; 16.7 %), and cheetah (30; 41.7 %). From the 72 samples, 54 samples (75.0 %) had identifiable scavenging marks and were fully documented (Fig. 2). 18 samples had no identifiable changes that could be attributed to scavenging, despite soft tissue damage. These samples were photographed and disposed of. Of the sub-sample included in this study (54), 3 (5.6 %) originated from the leopards, 22 (40.7 %) originated from the tigers, 12 (22.2 %) originated from the lions, and 17 (31.5 %) originated from the cheetahs.

These samples are further broken down into felid type vs. bone sample (Table 1). Scapula was the only bone type that was obtained from each felid. No long bones were recovered from the leopards, and no cranial fragments were recovered from the lions. Only ribs were recovered from the tigers and two pelvis samples from the lions. Finally, one mandible was recovered from the cheetahs. The acquisition of specific samples is down to what the animals were fed and what was recovered on a given day.

The skeletal elements recovered varied and depended on the feed for each day (Table 2). The skeletal regions recovered with identifiable marks were the 'scapula' (16; 29.6 %), 'skull' including just the cranium

when a mandible could not be attributed to it (9; 16.7 %), 'mandible' when a cranium could not be attributed to a jaw (1; 1.9 %), 'long bones' including single epiphyses (21; 38.9 %), 'ribs' (5; 9.3 %), and 'pelvis' (2; 3.7 %).

Regarding the frequency of scavenging identifiers, scalloping was the most common characteristic found on the scavenged remains (47; 87.0 %). Following this, pits were the second most common characteristic (27; 50.0 %), with punctures being third (18; 33.3 %). Only a small number of samples exhibited furrows (5; 9.3 %), while no samples had any evidence of scoring (0; 0 %). Interestingly, every sample that exhibited a puncture also had evidence of scalloping. This was unlike the other identifiers (furrows, pits, and scalloping) as these were observed as single entities on a sample or as part of a combination of characteristics.

3.1. Results by skeletal element

3.1.1. Scapula

Almost every scapula sample displayed evidence of scalloped edges (15/16; 93.8 %). These characteristics were identified around the proximal border of the scapula, across the cranial and caudal angle, and along the cranial and caudal borders (Fig. 3). These marks seemed to terminate around the mid-section and were not present on the distal

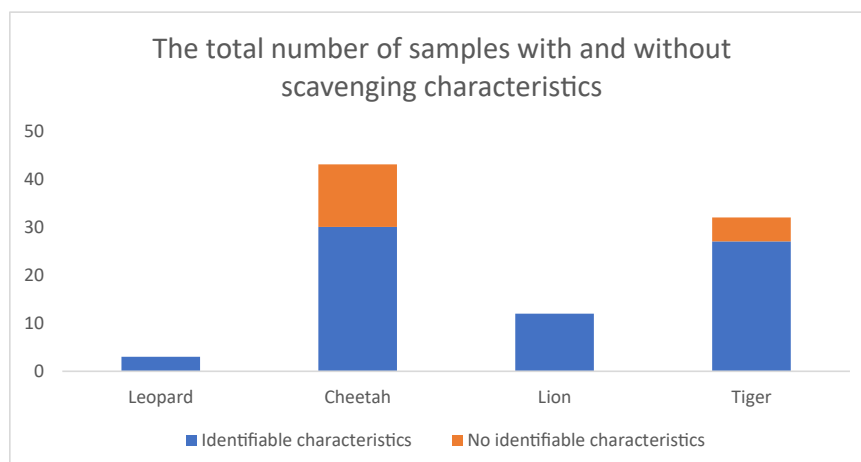


Fig. 2. The total number of samples demonstrating the relationship between evidence of scavenging against those that had none.

Table 1
Breakdown of retained bone against animal species.

	Scapula	Cranium / Skull	Mandible	Long Bones	Ribs	Pelvis	Total
Leopard	1	2	-	-	-	-	3
Cheetah	9	2	1	5	-	-	17
Lion	4	-	-	6	-	2	12
Tiger	2	5	-	10	5	-	22
Total	16	9	1	21	5	2	54

Table 2
The number of samples (individual bones) with characteristics associated with scavenging identified on.

	Scapula	Cranium / Skull	Mandible	Long Bones	Ribs	Pelvis	Total
No. of samples	16	9	1	21	5	2	54
Pits	14	1	-	10	1	1	27
Punctures	8	5	1	3	-	1	18
Scallop	15	7	-	18	5	2	47
Furrow	-	-	-	5	-	-	5
Scoring	-	-	-	-	-	-	-

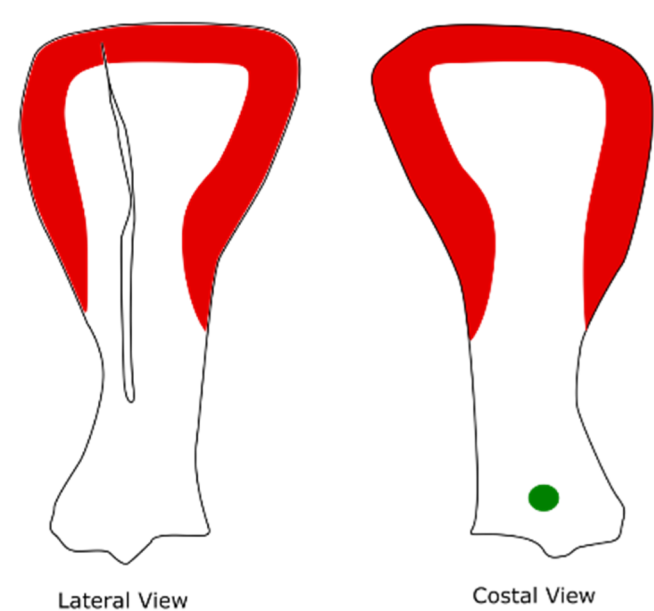


Fig. 3. Image demonstrating the most common areas of scavenging on the scapula by felids. Red is scalloping, pits and punctures. The green represents a small cluster of pits on the costal side of one of the samples.

ends of the scapula. In some instances, the scavenging had reduced this proximal border by several centimetres. On the bone's remaining border, the samples (14/16; 87.5 %) exhibited a series of pits and punctures (8/16; 50.0 %), with one sample (1/16; 6.3 %) having a cluster of pits on the costal side, at the distal end of the bone.

On several of the samples the bone exhibited longitudinal fractures (Fig. 4) in the form of a splintering effect. This appears to be due to the mechanical properties of the bone when it has been broken up (sawn) for feed, as opposed to a direct characteristic of scavenging.

3.1.2. Skull, cranium, and mandible

There was one individual mandible recovered [sample 48] from the cheetah enclosure. This exhibited three large puncture marks around the gonion angle. No other marks were present. On the crania that were recovered, the marks exhibited were on the flatter areas of the bone. This included along the nasal opening, around the eye sockets, and on the parietal bones. Gnawing characteristics were displayed by a series of scalloping, pits, and punctures (Fig. 5).



Fig. 4. Bone splintering.

3.1.3. Long bones

There were 19 long bones and two individual epiphyses counted within this category (N=21). For the long bones, as expected, most characteristics identified were at the proximal and distal ends, with very little changes documented on the midshaft (Figs. 6 and 7). Around the proximal and distal ends of the bones, scalloping was identified on 18/19 samples (94.7 %), with the reduction of the bone in places being quite considerable. For instance, one example [sample 52] had the greater trochanter of the femur completely scavenged, and in other cases the end of the bone up to the metaphysis were also completely scavenged. 8/19 samples (42.1 %) exhibited pits, mostly at the border margins where the scalloping terminated, or around the head of the femur or the humerus. Similarly, only one pit (1/19; 5.3 %) was identified and was also located on the neck of a femur [Sample 42]. For the two individual epiphyses, both exhibited a series of pits, punctures, and furrows, however no scalloping was present.

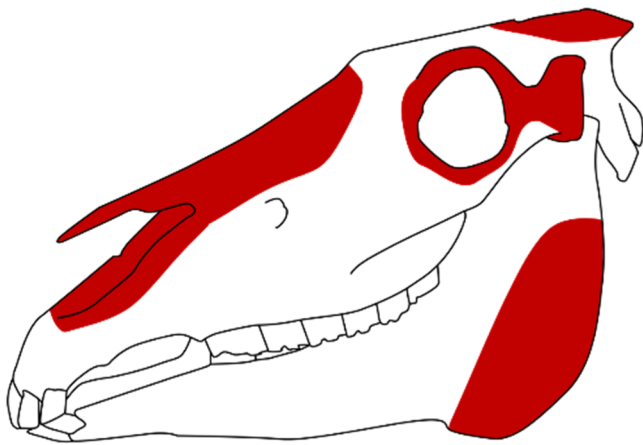


Fig. 5. Horse skull with areas of scavenged marks.

3.1.4. Ribs

All five rib samples were recovered from the tiger enclosure. No rib recovered was complete, with four of the examples having both the proximal and distal ends removed. All five samples (100 %) exhibited scalloping, with only one of the examples (1/5; 20.0 %) exhibiting pits at the gnawed margin.

3.1.5. Pelvis

Both samples were recovered from the lion enclosure. One of the samples was a complete innominate bone while the other was the innominate with the ilium removed prior the feed. The complete sample exhibited changes (pits, punctures, and scalloping) around the crest of

the ilium and the iliac border (Fig. 8). The partial sample exhibited only scalloping and this was located on the tuber ischii.

4. Discussion

Understanding the nature of scavenging marks from felids is important for interpreting medico-legal contexts and differentiating human violent actions from different animal activity. In general, our findings are similar to those reported by previous studies with comparable experimental designs [11,27,39,52]. In the following, the observations are discussed by skeletal element.

The observed distribution pattern of tooth marks on the scapulae, especially the damage along the borders, is consistent with those reported in the taphonomy literature for scavenging by lions [11], and mountain lions [52]. However, some authors note damage along the scapular spine [11] which was not the case in this study. Alvarez et al. studied Geoffroy's cat (*Leopardus geoffroyi*) and noted that the majority of tooth marks created were punctures and pits, followed by crenulated edges, scoring and furrows. Here we also observe a small number of scores and furrows in comparison to punctures and pits [1]. The authors however did observe an increased amount of crenulated / scalloped edges, but this could be due to the captive nature of the animal and perhaps an increased state of boredom.

In some published studies, damage on the skull is largely absent, e.g. with lions [11] and mountain lions [52]. However, more often skull structures are damaged. Then, punctures and sporadic scores occur in the nasal and orbit region, the occipital condyles or lateral maxillary bones, sometimes causing a widening of the nasal aperture [11,52]. The mandible is missing [52] or still articulated to the skull with damage in the gonion region or coronoid processes [11]. Similarly in our study, punctures and scalloping was observed around the nasal and orbits, as

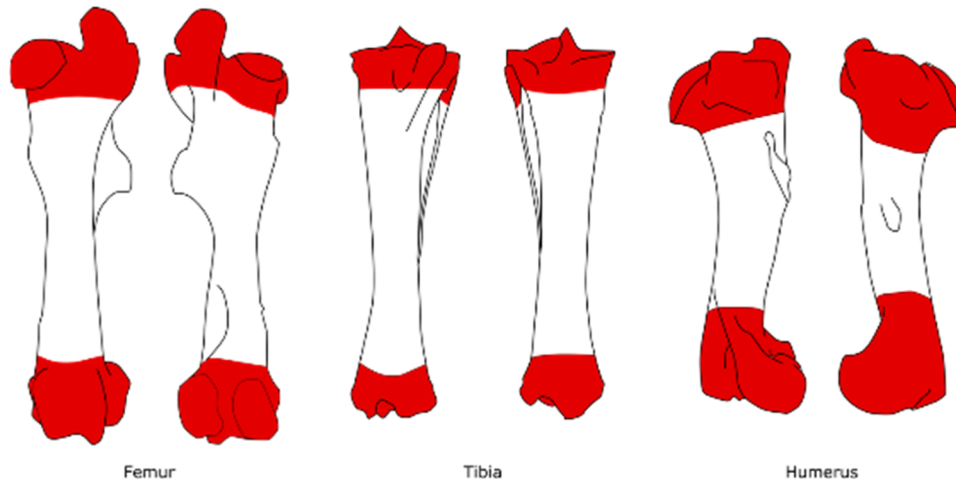


Fig. 6. Most common areas for scavenging on the long bones.



Fig. 7. Cylinder like bone [sample 14] caused by tiger scavenging at the proximal and distal bone ends.

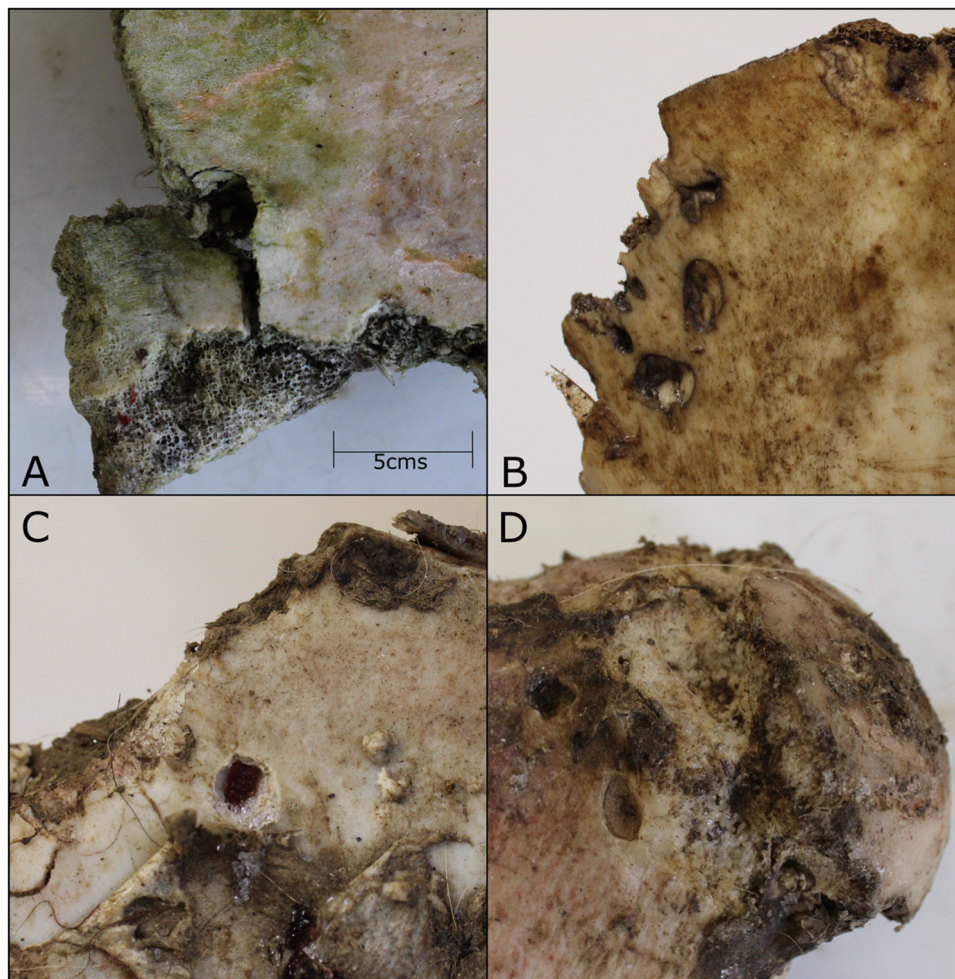


Fig. 8. Animal scavenging on the flat bones. A: Leopard scavenging on a scapula showing a puncture. B: Cheetah scavenging on a scapula showing punctures and pits. C: Lion scavenging on iliac bone showing a puncture. D: Lion scavenging on humerus showing pits and punctures.

well as the gonian region of the mandible.

The long bones in this study were modified at the proximal and distal ends, sometimes entailing considerable bone loss. The areas are similar but the damages more severe compared to those reported for other large cat scavenging [11,39,52]. However, felids are usually more interested in soft tissue rather than bones, and severe bone damage as typically observed with canids, e.g. when they hollow out the long bone ends to reach the marrow, is uncommon [11]. The findings here may possibly point to a deviant behaviour found in captive animals, and other studies with captive felids and separated carcasses show similarly heavily gnawed long bone ends with marks largely absent on the shafts [39]. While in the wild, big cats lose interest in defleshed bones soon [11], but they may continue chewing on them in captive environments due to boredom [15,20]. Furthermore, the equid remains were broken up before feeding, while a body in the wild is entire, possibly changing accessibility to some of the long bones and causing a different pattern.

The ribs recovered exhibited damaged bone ends. Several studies note that only few ribs are recovered after big cats scavenged, and that they are heavily gnawed resulting in considerable bone loss [11,52] or exhibit pits and scores [27]. Their small and flat nature makes them easy to break and due to their location, they are damaged when cats access inner soft tissue structures, and therefore, the distal ends are particularly susceptible to bone loss [11,52].

The damage observed on the innominates in this study are also consistent with the literature for big cat scavenging, e.g. lions [11], and mountain lions [52]. This mainly occurred around the ilium (Fig. 8: Image B), in particular parallel to the iliac crest. The scavenging in these

areas manifested in pits and punctures and have noted similarities to other examples of carnivorous scavenging [7], and although such scavenging by canids have rarely been recorded, it is not uncommon for canids to penetrate through thinner areas of bone [18,51].

On some samples, the bone was able to capture the dimensions of the dentition. There are several variables that effect the size and shape of tooth marks left behind, as well as the ranges of inter-canine difference in some species [56]. However, the interpretation of this information may be valuable to a forensic investigation. For instance, this information may help rule out scavengers from having altered the forensic scene. The interpretation of these types of marks may require specialist knowledge. Therefore, a recommendation is the collaboration with specialists working within veterinary science, such as the veterinary pathologist [56].

In indoor death scenes, domestic animals may scavenge upon human remains. However, merely based on morphology, it is challenging to distinguish between domestic cat and small dog scavenging [26]. When compared to domestic cat scavenging, the present study resulted in considerably more bone damage and larger marks [19,45,53]. This can be explained with the smaller body size of domestic cats (e.g. they may not be able to puncture large bones), but also with the study design that provided the large cats with disarticulated body parts while the small cat case studies showed entire human cadavers. In addition, captive animals are used to the given type of nutrition while human cadavers are an exceptional food source for domestic cats. Therefore, this study should not be used to inform forensic questions involving small cats.

This study examined selected skeletal elements and thus, a

comparison of overall scavenging patterns by other taxa is not suitable. However, when comparing this study with dog scavenging studies of similar experimental setups, some notes can be made. For instance, jackals created only small and superficial marks, and wild dogs entirely consumed most ribs and inflicted pits and scores on ribs and long bones, as well as furrows on a greater humeral trochanter [27]. Interestingly, the large cats (leopard, lion, caracal) in the same study inflicted more and heavier bone trauma than the canids, similar to the present observations [27]. On the other hand, the detected bone marks are similar to canid scavenging marks [42], but we found less scoring. It is possible that the lack of scoring is due to the breaking down of the animal carcass prior its placement in the enclosures and therefore a lack of necessity to 'hold' the skeletal elements.

It should be noted that there are limitations to this study. It could be argued that the placement of bones in a 'controlled' environment is not indicative of a real forensic case, particularly regarding the pre-dismemberment of the carcass. Similarly, the animals that were involved in this study were not truly wild. Regardless, it is difficult to undertake this type of study in a wild environment given the dangers posed, and the marks left on the bones here are still comparable. Despite differences in behaviour between captive and wild conspecifics [15,20], the use of animals within a zoological environment is an underused resource and could be utilised for more research that focusses on scavenging effects on remains. Hence, some characteristics may not be representative due to an increase in boredom presented by captive animals. It is recommended that further research could be undertaken on complete carcasses to examine the pattern of dismemberment as well as comparing this between species. This could be further monitored using wildlife camera traps.

A further limitation in this study is that horse remains were used as feed, and thus differ from that of a human body. However, other studies have used other animals as proxies such as deer [59] and pigs (see [24]). Furthermore, although a captive animal's diet will differ [23], the feeding habits and the way an animal consumes its food or nutrients may not. Nevertheless, in this study, the characteristics left behind as a direct result of scavenging do not significantly vary from that described within the current literature. Thus, again, reiterating the potential for collaboration with such zoological institutes.

5. Conclusion

This study showed that the distribution patterns of tooth activity associated with scavenging is consistent with those reported in the taphonomy literature by lions. Specifically, the characteristics are frequently noted at the borders and flat regions of bones. Such examples include the ends of long bones and the scapula and pelvic border edges. This work will contribute to the sparse taphonomy literature on scavenging behaviour, assisting the interpretation of felid scavenging characteristics on bone, and while there are some limitations to this study that are highlighted, the benefit in collaborating with zoological institutions is demonstrated.

Declaration of Competing Interest

There are no conflicts of interest.

References

- [1] M.C. Alvaraz, C.A. Kaufmann, A. Massigoge, M.A. Gutiérrez, D.J. Rafuse, N. A. Scheifler, M.E. González, Bone modification and destruction patterns of leporid carcasses by Geoffroy's cat (*Leopardus geoffroyi*): An experimental study, *Quat. Int.* 278 (2012) 71–80, <https://doi.org/10.1016/j.quaint.2011.11.029>.
- [2] C.L. Barrios, V. Aguirre-Olea, C. Bustos-López, S. Pérez-Vergara, S. Claros-Alegría, Characterization of the variables related to reports of death due to canine bites in scientific articles during the years 2013–2017: a scoping review, *Animals* 11 (2021) 2654.
- [3] P. Beier, Cougar attacks on humans in the United States and Canada, *Wildl. Soc. Bull.* 19 (1991) 403–412.
- [4] H.E. Berryman, Disarticulation pattern and tooth mark artifacts associated with pig scavenging of human remains: a case study, in: W.D. Haglund, M.H. Sorg (Eds.), *Adv. Forensic Taphon.: Method, Theory, Archaeol. Perspect.* Eds 2002 (2002) 487–495.
- [5] L.R. Binford, *Bones ancient men and modern myths*, Academic Press, Orlando, FL, USA, 1987.
- [6] R.W. Byard, Postmortem predation by a clowder of domestic cats, *Forensic Sci., Med. Pathol.* 17 (1) (2021) 144–147.
- [7] T. Colard, Y. Delannoy, S. Naji, S. Rottier, J. Blondiaux, The utilisation of carnivore scavenging evidence in the interpretation of a protohistoric French pit burial, *J. Archaeol. Sci.* 52 (2014) 108–115.
- [8] M. Ďatko, T. Vojtíšek, P. Hejna, A fatal lion attack, *Forensic Sci., Med., Pathol.* 11 (2015) 300–302.
- [9] T. Delabarde, B. Ludes, Missing in Amazonian jungle: a case report of skeletal evidence for dismemberment, *J. Forensic Sci.* 55 (4) (2010) 1105–1110.
- [10] C. Delaney-Rivera, T.W. Plummer, J.A. Hodgson, F. Forrest, F. Hertel, J.S. Oliver, Pits and pitfalls: taxonomic variability and patterning in tooth mark dimensions, *J. Archaeol. Sci.* 36 (11) (2009) 2597–2608.
- [11] M. Domínguez-Rodrigo, Flesh availability and bone modifications in carcasses consumed by lions: paleoecological relevance in hominid foraging patterns, *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 149 (1–4) (1999) 373–388.
- [12] M. Domínguez-Rodrigo, A. Piqueras, The use of tooth pits to identify carnivore taxa in tooth-marked archaeofaunas and their relevance to reconstruct hominid carcass processing behaviours, *J. Archaeol. Sci.* 30 (11) (2003) 1385–1391.
- [13] S.D. Domínguez-Solera, M. Domínguez-Rodrigo, A taphonomic study of bone modification and of tooth mark patterns on long limb bone portions by suids, *Int. J. Osteoarchaeol.* 19 (2009) 345–363.
- [14] A.G. Duthie, J.D. Skinner, Osteophagia in the Cape porcupine *Hystrix africaustralis*, *South Afr. J. Zool.* 21 (1986) 316–318.
- [15] C.P. Egeland, T.R. Pickering, Cruel traces: bone surface modifications and their relevance to forensic science, *Wiley Interdiscip. Rev.: Forensic Sci.* 3 (3) (2020) e1400.
- [16] D. Errickson, T.J.U. Thompson, Animal attacks and injuries: anthropological findings, *Encyclopedia of forensic and legal medicine*, 2nd eds, Elsevier, 2016, pp. 143–147.
- [17] D.A. Finaughty, M. Spies, J. Pead, V. Gibbon, Automation: a golden ticket for taphonomic research? *Forensic Sci. Int.* 312 (2020) 110276.
- [18] G.M. Fonseca, E. Mora, J. Lucena, M. Cantin, Forensic studies of dog attacks on humans: a focus on bite mark analysis, *Res. Rep. Forensic Med. Sci.* 5 (2015) 39–51.
- [19] S. Garcia, A. Smith, C. Baigent, M. Connor, The scavenging patterns of feral cats on human remains in an outdoor setting, *J. Forensic Sci.* 65 (3) (2020) 948–952.
- [20] A. Gidna, J. Yravedra, M. Domínguez-Rodrigo, A cautionary note on the use of captive carnivores to model wild predator behavior: a comparison of bone modification patterns on long bones by captive and wild lions, *J. Archaeol. Sci.* 40 (4) (2013) 1903–1910.
- [21] S.B. Giles, D. Errickson, N. Marquez-Grant, A retrospective comparative study to evaluate the reliability of post-mortem interval sources in UK and US medico-legal death investigations, *Sci. Justice* 62 (2) (2022) 246–261.
- [22] W.D. Haglund, D.T. Reay, D.R. Swindler, Tooth mark artifacts and survival of bones in animal scavenged human skeletons, *J. Forensic Sci.* 33 (1988) 985–997.
- [23] A. Hartstone-Rose, H. Selvey, J.R. Villari, M. Atwell, T. Schmidt, The three-dimensional morphological effects of captivity, *PLoS One* 9 (11) (2014) e113437.
- [24] L. Indra, D. Errickson, A. Young, S. Lösch, Uncovering forensic taphonomic agents: animal scavenging in the European context, *Biology* 11 (4) (2022) 601.
- [25] L. Indra, S. Lösch, Forensic anthropology casework from Switzerland (Bern): taphonomic implications for the future, *Forensic Sci. Int.: Rep.* 4 (2021) 100222.
- [26] Indra, L., Schyma, C., & Lösch, S. 2023. Cat and dog scavenging at indoor forensic scenes: strategies for documentation and detection. *Forensic Science, Medicine and Pathology*.
- [27] C.A. Keyes, J. Myburgh, D. Brits, Taphonomic bone trauma caused by Southern African scavengers, *Int. J. Leg. Med.* 134 (2020) 1227–1238.
- [28] C.A. Keyes, J. Myburgh, D. Brits, Identifying forensically relevant urban scavengers in Johannesburg, South Africa, *Sci. Justice* 62 (3) (2022) 399–409.
- [29] S. Khanna, F. Karjodkar, Wild cat bite – a narrow escape, *Int. Dent. J.* 54 (1) (2004) 52–54.
- [30] J. Kirtland, J.L. Tremoleda, C. Trivedy, Traumatic injury patterns in humans from large feline predators: a systematic review and descriptive analysis, *Trauma* 26 (1) (2022) 28–42.
- [31] D.G. Kleiman, V. Geist, M.C. McDade, *Grzimek's Animal Life Encyclopedia: Mammals III*, Gale Group, Farmington Hills, 2003.
- [32] D.A. Komar, Twenty-seven years of forensic anthropology casework in New Mexico, *J. Forensic Sci.* 48 (2003) 521–524.
- [33] H. Kruuk, Hunter and hunted: relationships between carnivores and people, Cambridge University Press, Cambridge, UK, 2002.
- [34] T.M. Larabee, J. Forke, P. Beier, Mountain lion attacks in the United States: 1950 through May 2009, *Wilderness Environ. Med.* 21 (4) (2010) 375.
- [35] L. Lloveras, M. Moreno-García, J. Nadal, Taphonomic analysis of leporid remains obtained from modern Iberian lynx (*Lynx pardinus*) scats, *J. Archaeol. Sci.* 35 (2008) 1–13.
- [36] K.L. Miles, D.A. Finaughty, V.E. Gibbon, A review of experimental design in forensic taphonomy: moving towards forensic realism, *Forensic Sci. Res.* 5 (4) (2020) 249–259.
- [37] E. Morin, Fat composition and Nunamiut decision-making a new look at the marrow and bone grease indices, *J. Archaeol. Sci.* 34 (2007) 69–82.

- [38] C. Packer, D. Ikanda, B. Kissui, H. Kushnir, Lion attacks on humans in Tanzania, *Nature* 436 (7053) (2005) 927–928.
- [39] J.A. Parkinson, T. Plummer, A. Hartstone-Rose, Characterizing felid tooth marking and gross bone damage patterns using GIS image analysis: An experimental feeding study with large felids, *J. Hum. Evol.* 80 (2015) 114–134.
- [40] T.R. Pickering, M. Domínguez-Rodrigo, C.P. Egeland, C.K. Brain, Beyond leopards: tooth marks and the contribution of multiple carnivore taxa to the accumulation of the Swartkrans Member 3 fossil assemblage, *J. Hum. Evol.* 46 (5) (2004) 595–604.
- [41] B.L. Pobiner, Paleoecological information in predator tooth marks, *J. Taphon.* 6 (3–4) (2007) 373–397.
- [42] J.T. Pokines, in: J.T. Pokines, S.A. Symes (Eds.), *Faunal dispersal, reconcentration, and gnawing damage to bone in terrestrial environments*, 2013, *Manuel of Forensic Taphonomy*. Boca Raton, 2013.
- [43] A. Rippley, N.C. Larison, K.E. Moss, J.D. Kelly, J.A. Bytheway, Scavenging behavior of *Lynx rufus* on human remains during the winter months of Southeast Texas, *J. Forensic Sci.* 57 (3) (2012) 699–705.
- [44] C.E. Rollins, D.E. Spencer, A fatality and the American mountain lion: bite mark analysis and profile of the offending lion, *J. Forensic Sci.* 40 (1995) 486–489.
- [45] M.L. Rossi, A.W. Shahrom, R.C. Chapman, P. Vanezis, Postmortem injuries by indoor pets, *Am. J. Forensic Med. Pathol.* 15 (2) (1994) 105–109.
- [46] S.M. Shepherd, A. Mills, W.H. Shoff, Human attacks by large felid carnivores in captivity and in the wild, *Wilderness Environ. Med.* 25 (2014) 220–230.
- [47] S.N. Sincerbox, E.A. DiGangi, *Forensic Taphonomy and Ecology of North American Scavengers*, Elsevier Academic Press, London, UK, 2018.
- [48] J.P. Spermhake, M. Tsokos, Postmortem bite injuries caused by a domestic cat, *Arch. F. üR. Kriminol.* 208 (3–4) (2001) 114–119.
- [49] M.J. Spies, V.E. Gibbon, D.A. Finaughty, Forensic taphonomy: vertebrate scavenging in the temperate southwestern Cape, South Africa, *Forensic Sci. Int.* 290 (2018) 62–69.
- [50] D.A. Steadman, A. Dautartas, M.W. Kenyhercz, L.M. Jantz, A. Mundorff, G. M. Vidoli, Differential scavenging among pig, rabbit, and human subjects, *J. Forensic Sci.* 63 (2018) 1684–1691.
- [51] D.W. Steadman, H. Worne, Canine scavenging of human remains in an indoor setting, *Forensic Sci. Int.* 173 (2007) 78–82.
- [52] M.C. Stiner, N.D. Munro, M. Sanz, 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 (2012) 896–907.
- [53] A. Suntrukpong, R.W. Mann, J.R. DeFreytas, Postmortem scavenging of human remains by domestic cats, *Siriraj Med. J.* 69 (6) (2017) 384–387.
- [54] V. Toledo González, F. Ortega Ojeda, G.M. Fonseca, C. García-Ruiz, P. Pérez-Lloret, Analysis of tooth mark patterns on bone remains caused by wolves (*Canis lupus*) and domestic dogs (*Canis lupus familiaris*) for taxonomic identification: A scoping review focused on their value as a forensic tool, *Appl. Anim. Behav. Sci.* 240 (2021) 105356.
- [55] D.H. Ubelaker, C.M. DeGaglia, The impact of scavenging: perspective from casework in forensic taphonomy, *Forensic Sci. Res.* 5 (1) (2020) 32–37.
- [56] J. Viciano, S. López-Lázaro, C. Tanga, Post-mortem dental profile as a powerful tool in animal forensic investigations – a review, *Animals* 12 (16) (2022) 2038.
- [57] P. Willey, L.M. Snyder, Canid modification of human remains: implications for time-since-death estimations, *J. Forensic Sci.* 34 (1989) 894–901.
- [58] A. Young, The Effects of Terrestrial Mammalian Scavenging and Avian Scavenging on the Body, in: Schotsmans, et al. (Eds.), *Taphonomy of Human Remains: Forensic Analysis of the Dead and the Depositional Environment*, John Wiley and Sons, Chichester, 2017, pp. 212–234.
- [59] A. Young, R. Stillman, M.J. Smith, A.H. Korstjens, An experimental study of vertebrae scavenging behaviour in northwest European woodland context, *J. Forensic Sci.* 59 (5) (2014) 1333–1342.
- [60] A. Young, R. Stillman, M.J. Smith, A.H. Korstjens, Scavenger species-typical alteration to bone: using bite mark dimensions to identify scavengers, *J. Forensic Sci.* 60 (6) (2015) 1426–1435.



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2024-12-01

Elsevier

<https://doi.org/10.1016/j.forsciint.2024.112280>

Errickson D, Lawrence L, Indra L, Thompson TJU. (2024) Felid scavenging in forensic taphonomic research: an experimental approach. Forensic Science International, Volume 365, December 2024, Article number 112280