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Skeletal Manifestations of Bear Scavenging*

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ABSTRACT: In many partially or fully skeletonized forensic cases, postmortem animal damage is simply attributed to rodents or carnivores; little effort is made to determine the general size or assign a genus to the scavenger. As one of the largest wild carnivores to inhabit mountainous and forested areas throughout the continental United States, Alaska, and Canada, black bears (*Ursus americanus*) must be considered possible suspects when skeletonized remains are located showing marks of carnivore damage. Since 1995, three cases of known bear scavenging have been referred to the Maxwell Museum's Laboratory of Human Osteology by the New Mexico Office of the Medical Investigator for skeletal analysis. These cases comprise a total of seven individuals, and all of the remains were deposited in high altitude forests of New Mexico along the western border with Arizona with a minimum of 4 months exposure before recovery. When analyzed, all cases shared a similar pattern of element survivorship and damage. We suggest that bears can be distinguished from members of the canid family, the other common scavenger of human remains, based on the representation of skeletal elements at the scene. Rates and patterns of damage are not as accurate as element recovery in the discrimination of scavenger genus. Use of this information should allow forensic anthropologists to better understand the postmortem taphonomic processes that shaped the skeletal remains, and hopefully prevent misdiagnoses of perimortem trauma on elements not typically scavenged by canids.

KEYWORDS: forensic science, taphonomy, bear scavenging, carnivore scavenging, physical anthropology

In many partially or fully skeletonized forensic cases, postmortem animal damage is simply attributed to rodents or carnivores; little effort is made to determine the general size or assign a genus to the scavenger. As one of the largest wild carnivores to inhabit mountainous and forested areas throughout the continental United States, Alaska, and Canada, black bears (*Ursus americanus*) must be considered as possible culprits in cases of skeletonized remains with evidence of carnivore damage. Many of the forensic cases on which the Maxwell Museum's Laboratory of Human Osteology is asked to consult occur in rural areas of New Mexico. The environment of this state ranges from desert basin in the center and south, to forested mountains in the north and along the eastern and western borders. Much of the latter region is sparsely populated by humans, but wildlife, including wolves, coyotes, and black bears, is abundant (1). Although they used to enjoy a wide distribution, the last killing of a grizzly bear (*U. arctos horribilis*) in New Mexico occurred in the 1930s, and the final sighting in 1962 (1). We can therefore confidently rule out grizzlies as the scavengers of human remains in and around New Mexico.

Only about 25% of the black bear's diet consists of animal meat; it relies primarily on berries, nuts, grass, tree sap, and insects (2,3). Given the opportunity, however, the black bear will scavenge anything edible, from dead animal carcasses to human trash. The description of this animal as "a four-legged garbage grinder" (3) is obviously not far from the truth. When food cannot be scavenged, black bears will catch fish in streams or lakes or kill smaller animals (2). Rarely do they attack living humans; this usually occurs at campgrounds or rural settings when humans try to defend foodstuffs from hungry bears (3).

While the literature regarding animal scavenging of faunal carcasses and bones is abundant (4–10), there is a paucity of information on similar taphonomic modification to human remains (11). This previous research concentrates primarily on damage caused by canids (12–15) or rodents (16). Haynes (15) briefly describes bear scavenging of faunal carcasses, while Murad (17), Murad and Boddy (18), and Micozzi (19) report on damage to human remains. Micozzi (19) characterizes bears as being more likely to break open the diaphyses of long bones, while canids tend to attack articular ends. Although he does not describe the exact differences between bear- and canid-induced damage, Haynes (15) suggests that investigators rely on evidence the predators have left behind, including tracks, and the most obvious patterns of damage to the skeletal elements to discriminate between scavenging species. In this article we evaluate the skeletal remains of seven decedents that have been scavenged by bears, and suggest that postmortem damage caused by bears can be distinguished from that produced by canids, the carnivores to which most scavenging is attributed (12,13). We propose that discrimination of bear and canid scavenging should be based on the representation of certain elements in the recovered remains, because specific patterns of damage are not an accurate indicator of scavenger identity.

Materials and Methods

The frequencies of skeletal elements recovered and damaged from forensic cases involving black bear, and those previously published on polar bear (20) and canid scavenging (12,13), as well as unscavenged "open air" remains (12,13), are compared in tabular and graphical format. Similarities and differences in these frequencies are discussed for both individual elements and for generalized regions of the skeleton. We then quantify these differences by applying a Kolmogorov-Smirnov 2-tailed test (21) to the frequency distributions of open-air, carnivore, and bear damaged remains. Based on the cumulative ordinal proportions for each type of scavenging, the Kolmogorov-Smirnov test takes sample size into account during calculations.

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Finally, we compared the damage observed in the remains of an adult Native American male housed at the Maxwell Museum's Laboratory of Human Osteology to the data collected in this study. This individual, discovered near Gallup, McKinley County, New Mexico in April, 1980, was almost completely skeletonized and showed evidence of extensive carnivore scavenging. This case will be utilized to test the hypothesis that the genus of carnivore responsible for postmortem alteration of forensic skeletal remains can be identified based on the pattern of element representation.

Forensic Cases

Our skeletal sample consists of three bear-scavenged forensic cases representing a total of seven individuals. Faculty and graduate students from the Department of Anthropology, University of New Mexico recovered these remains between 1995 and 1997 in Catron County, New Mexico and the Chuska Mountains, Arizona (Fig. 1). All analyses took place at the State Office of the Medical Investigator, Albuquerque, New Mexico. Remains of the decedents were eventually returned to family members in two of the three cases.

Case 1 involved the remains of four individuals, three males and a female, recovered from the scene and surrounding area of a small aircraft crash in the Chuska Mountains of northeastern Arizona, near the New Mexico border. The crash occurred in late April, 1995, but the remains were not recovered from the high altitude forest until the end of August, 1995. Prior to recovery, scavengers had scattered the human remains over an area of approximately 300 square yards, with additional skeletal elements found in a bear's den a short distance away. The single engine aircraft had not caught fire, but the bodies had been greatly modified by bears. Carnivore damage included large tooth indentations on the iliac fossa of one individual and scalloped margins on the articular surfaces and epiphyses of the recovered long bones. The extensive fracturing and damage to the three male crania was attributed to perimortem trauma inflicted by the aircraft crash. The cranium assigned to the female passenger was intact.

The second case consisted of the remains of two individuals, one male and one female, recovered from a high altitude piñon forest approximately 20 miles southwest of Quemado, New Mexico in early September, 1996 (Fig. 2a and b). Both decedents died of gunshot wounds to the head in December, 1995, and were subsequently buried in a common grave approximately 3.5 ft deep. The male was placed underneath the female, allowing the bears to access her body more readily. The remains were scattered over an area of approximately 255.5 square yards, and tooth indentations and punctures consistent with the size of bear teeth were evident on the scapulae, long bones and vertebrae. Nearby bear scat contained human hair, clothing, and a fragment of a vertebral transverse process that matched one of the decedent's damaged thoracic vertebra. The area

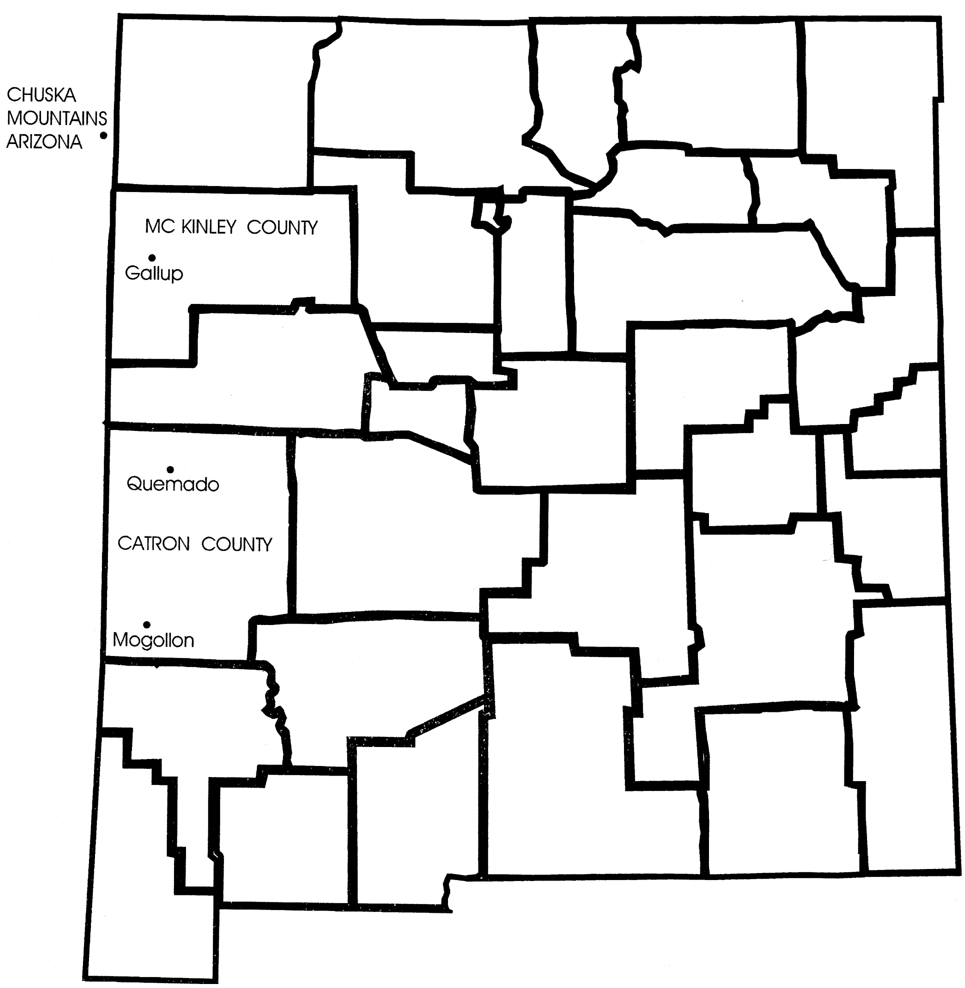

FIG. 1—*Map of New Mexico bear scavenged cases.*

A

FIG. 2—*Recovered skeletal remains of the Case 2 female (2a) and male (2b).*

surrounding the scene contained several bear nests with associated scat; additionally, the lower right fourth premolar identified as *U. americanus* was found amongst the human remains, broken just below the cemento-enamel junction. Unlike the previous case, both human crania sustained slight postmortem carnivore damage. The cranium of the male individual showed slight carnivore modification of the left maxilla and temporal bones, while that of the female displayed marks on the right palate and a fracture in the left mandible. All long bones recovered were damaged by carnivores, as evidenced by scalloped epiphyseal margins and radial fractures.

The final known case of bear scavenging involved a male discovered in a remote, heavily wooded region in the Mogollon mountains 60 miles southwest of Quemado, New Mexico. The individual apparently died of exposure after leaving his automobile on a snow-blocked road in December, 1996. His skeletal remains were not discovered until May, 1997. The remains were scattered over an area of approximately 100 square yards and were located 5.4 miles away from the individual's vehicle. This distance probably reflects both movement of the individual before death and postmortem carnivore transit of body parts. The decedent's clothes were shredded and strewn over a larger area, and the investigators initially called to the scene reported bears in the area. They felt it likely that bears had scavenged this individual either peri- or postmortem. All post-cranial skeletal elements display evidence of carnivore scavenging activity as indicated by the radial fractures of the long bone shafts, the scalloped edges of the fractures and the presence of canine punctures on the vertebrae and the *os coxa*. The cranium and mandible, however, did not suffer postmortem damage.

B

FIG. 2—*(continued)*

Comparative Data

We compared data on element representation and damage patterns in the known cases of bear scavenging to those published on polar bear and canid taphonomy by Merbs (20), Haglund (12), and Haglund et al. (13). Due to a lack of standardization in reporting the elements recovered, we chose to publish the raw number of each skeletal element present following Haglund (12) for each case of bear scavenging in New Mexico.

In the comparison of element recovery of bear scavenged remains with those from canid and polar bear scavenged and open air cases, the percentages of vertebral, manual and pedal elements were calculated assuming the normal element count per individual. While we did not follow Haglund (12) in dividing the bear scavenged cases into discrete stages based on the overall pattern of damage and time since death, the condition of the black bear scavenged remains most closely represents those described as stages 3 and 4 from Haglund's canid study (12). Each of the New Mexico forensic cases had a postmortem exposure interval of at least 4 months prior to discovery and were almost completely disarticulated; these conditions characterize the latter two stages of canid scavenging (12). Unless otherwise noted, an "average" canid result for element presence represents the mean of stages 3 and 4 from Haglund (12). The percentage of elements recovered in the cases of polar bear scavenging are averages of the three individuals reported by Merbs (20); the same procedure is used for black bear scavenged remains from New Mexico.

This detailed breakdown of canid scavenging stages was also available for the analysis of canid damage patterns per element, but these data were drawn from an earlier data set (13) that included fewer cases in stages 3 and 4 than Haglund's 1997 dataset (12). While this renders the elemental recovery and skeletal damage data on canids somewhat incomparable, we felt it was important to maintain the use of the stages that best represented the black bear scavenged remains. Therefore, the average canid damage pattern is calculated as a percentage of the damaged elements out of all those recovered from individuals classified into both stages 3 and 4 (13).

Additionally, the enumeration of elements damaged by canids (13) is published in a slightly different format from Haglund's 1997 article (12); the presence of at least one element from the categories of hands, feet, cervical, thoracic, and lumbar vertebrae was counted as "presence" of that entire category. To make the bear scavenged data comparable, we recalculated the average percent of recovered but damaged skeletal elements in this manner. Damage attributed to polar bears (20) was not described in enough detail to allow for inclusion in the analysis of element specific damage patterns.

Results

Element Recovery and Damage Rates

Table 1 compares the percentage of skeletal elements recovered from Haglund's two most severe stages (12) of canid scavenging with the three cases of taphonomic damage caused by black bears in New Mexico. In both Cases 2 and 3 of bear scavenging (Table 1), the fragmentary nature of the ribs prevented an accurate estimation of the percent representation of these elements. A cursory comparison of the percentage of bones recovered in each of the black bear scavenged cases with the stages of canid modification confirms that the bear damage most closely represents stages 3 and 4 of canid scavenging.

Stages 3 and 4 of canid scavenging are averaged in Table 2 to obtain a typical pattern of element representation in cases showing canid damage and those damaged by black and polar bears (20). In addition, element representation data collected from cases in which the remains were exposed to the open air, with no carnivore or rodent scavenging evident (13,16), are presented in Table 2. These data are depicted graphically in Fig. 3. With the exception of the *os coxae*, femur, and ulna, the canid scavenged individuals show a higher or nearly equal rate of element recovery compared to cases in which black bears are the perpetrators.

The difference in recovery of the vertebral elements is particularly striking; an average of 77.4% more thoracic vertebrae were located over the 22 canid scavenged individuals than were recovered in the black bear cases. The difference for lumbar vertebrae was 23.8% and for sacra, 20.7%. In both cases, bears were more likely to remove or consume these elements than were canids. Additionally, sterna were absent from all seven of the bear scavenged

TABLE 1—*Element representation of canid* and bear scavenging cases.*

Element	# Per Indiv.	Canid Stage 3 N = 4 %	Canid Stage 4 N = 18 %	Bear Case 1 N = 4 %	Bear Case 2 N = 2 %	Bear Case 3 N = 1 %
Cranium	1	100.0	100.0	100.0	100.0	100.0
Mandible	1	75.0	83.0	75.0	100.0	100.0
Hyoid	1	0.0	16.0	0.0	0.0	0.0
Atlas (C1)	1	50.0	72.2	50.0	100.0	100.0
Axis (C2)	1	25.0	55.5	50.0	100.0	100.0
Cervical Vertebrae 3–7	5	35.0	48.8	20.0	20.0	40.0
Thoracic Vertebrae 1–12	12	62.5	98.1	8.3	12.5	66.7
Lumbar Vertebrae 1–5	5	65.0	60.0	50.0	10.0	40.0
Sacrum	1	50.0	66.6	50.0	50.0	0.0
Coccyx	1	25.0	33.3	0.0	0.0	0.0
Sternum	1	25.0	38.8	0.0	0.0	0.0
Ribs	24	25.0	52.7	7.3	—	—
Clavicle	2	25.0	47.2	12.5	50.0	50.0
Scapula	2	25.0	47.2	25.0	75.0	50.0
Humerus	2	25.0	41.6	25.0	25.0	50.0
Ulna	2	25.0	25.0	37.5	25.0	0.0
Radius	2	12.4	38.0	12.5	25.0	0.0
Carpals	16	0.0	13.8	0.0	3.1	0.0
Metacarpals, hand phalanges	38	0.0	10.9	9.2	11.8	0.0
Os coxa	2	50.0	58.3	75.0	50.0	100.0
Femur	2	62.5	61.1	87.5	50.0	50.0
Patella	2	0.0	8.3	12.5	50.0	0.0
Tibia	2	25.0	50.0	50.0	25.0	50.0
Fibula	2	25.0	50.0	50.0	25.0	0.0
Talus	2	0.0	16.6	25.0	25.0	0.0
Calcaneus	2	0.0	16.6	0.0	0.0	0.0
Other tarsals	10	0.0	7.1	0.0	30.0	0.0
Metatarsals, pedal phalanges	38	0.0	10.9	0.0	11.8	0.0

* After Haglund (12).

individuals, while this element was recovered in 36.4% of the canid damaged cases. The differences between bears and canids are smaller for the recovery of extremity elements, and as stated, femora and *os coxae* were found, respectively, in 10 and 14.6% more of the cases involving black bears. Canids and bears shared high recovery rates for crania and mandibles, but very few manual or pedal elements were located.

The element recovery pattern for polar bear scavenged remains was somewhat more erratic. Although vertebrae were recovered at a frequency similar to that of black bears, the reported polar bear cases showed a more frequent presence of upper extremity elements, and a lower recovery rate for the lower extremity, than either black bear or canids (Fig. 3). The Kolmogorov-Smirnov tests revealed that canid and bear scavenging patterns are significantly different ($p = 0.0388$ for both polar and black bears vs. canids). However, element recovery patterns for polar vs. black bears were not significantly different ($p = 0.6874$).

Table 3 and Fig. 4 present the percentage of elements modified by each carnivore type. As previously stated, reported rates of elemental damage for canids were averaged across stages 3 and 4; these and the open-air damage figures were taken from Haglund et al. (13). Results are adjusted to represent the percentage of damaged elements only from those bones recovered, and not from the complete number of cases. Because the assignation of damaged and fragmentary ribs to specific individuals was not possible for the bear-scavenged cases with multiple sets of remains (Cases 1 and 2 above), percentages of ribs recovered and damaged are not included in Tables 2 or 3.

With the exception of the cervical, thoracic, and lumbar vertebrae, canids consistently inflicted more observable damage to the human remains than did black bears (Fig. 4). This is especially noticeable in the upper and lower extremities; 100% of the recovered radii, ulnae, femora, tibiae, and fibulae from canid scavenged individuals exhibit damage inflicted by dogs, coyotes, and wolves. Black bears, on the other hand, damaged 50% of the recovered ulnae, radii, and tibiae, 90% of femora, and only 20% of fibulae. Although some of these differences are clearly driven by an overall paucity of recovered elements, they suggest preferential scavenging of the extremities by canids, as well as a propensity by these carnivores to gnaw at easily accessible elements. The two-tailed Kolmogorov-Smirnov tests of differences in frequency distributions for Table 3 resulted in significant differences between all three taphonomic agents. Clearly, open-air cases can be differentiated from scavenged remains in the pattern of element damage ($p < 0.001$ for canids; $p < 0.0001$ for bears). The overall pattern of damage for canid vs. bear cases was also statistically significant ($p = 0.0132$). However, while these results indicate that the absolute frequencies of modification differ, the overall appearance of damage patterns by canids and bears is quite similar.

Comparison of Patterns of Damage in Bear and Canid Scavenged Remains

Much of the damage we have attributed to *U. americanus* resembles that documented by Haglund et al. (22) in their study of domesticated dog, wolf, and coyote scavenging. Many of the re-

TABLE 2—*Element representation for scavenged and unscavenged remains.*

Element	Open Air* N = 16 %	Average Canid† N = 22 %	Average Polar Bear‡ N = 3 %	Average Black Bear N = 7 %
Cranium	100.0	100.0	66.6	100.0
Mandible	100.0	81.8	66.6	85.7
Cervical vertebra 1–7	100.0	50.0	33.3	42.9
Thoracic vertebra 1–12	100.0	91.7	33.3	14.3
Lumbar vertebra 1–5	100.0	60.9	20.0	37.1
Sacrum	100.0	63.6	33.3	42.9
Sternum	100.0	36.4	0.0	0.0
Clavicle	96.9	43.2	50.0	28.6
Scapula	93.8	43.2	50.0	42.9
Humerus	100.0	38.6	66.6	28.6
Radius	93.8	34.1	50.0	14.3
Ulna	96.9	25.0	50.0	28.6
Hand elements	87.5	8.0	0.0	6.3
Os coxae	100.0	56.8	0.0	71.4
Femur	100.0	61.4	33.3	71.4
Tibia	100.0	45.5	33.3	42.9
Fibula	100.0	45.5	33.3	35.7
Foot element	87.5	8.7	0.01	4.1

Kolmogorov-Smirnov 2-Sample Test Results

Comparison	*p*-Value	Maximum Difference
Open Air—Canid	< 0.0001	0.926
Open Air—Polar Bear	< 0.0001	0.981
Open Air—Black Bear	< 0.0001	0.926
Canid—Polar Bear	0.0388	0.444
Canid—Black Bear	0.0388	0.444
Polar Bear—Black Bear	0.6874	0.222
Canid—Test Case	0.0388	0.444
Polar Bear—Test Case	0.0388	0.444
Black Bear —Test Case	0.0978	0.389

* After Haglund et al. (13).
† After Haglund (12).
‡ After Merbs (20)

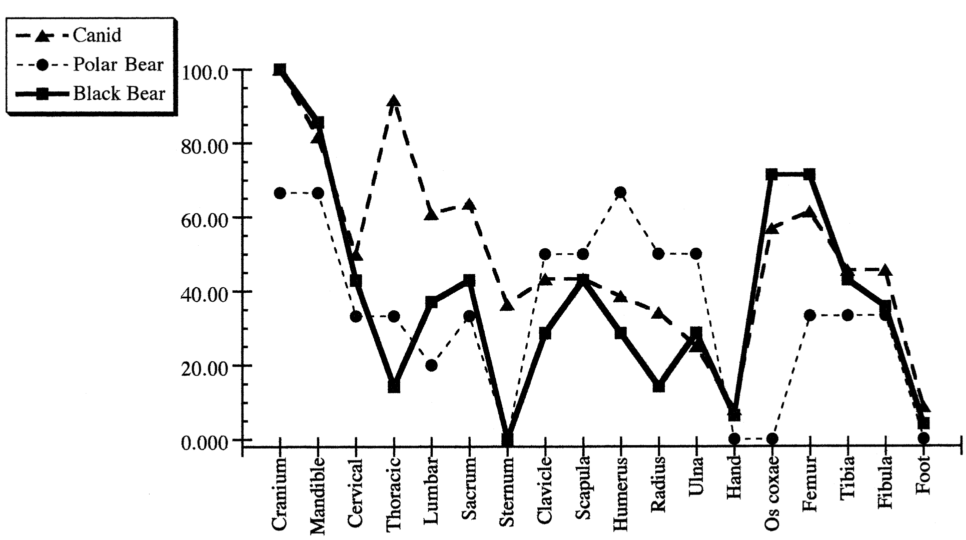

FIG. 3—*Graph of recovered elements from canid, polar and black bear scavenged cases.*

TABLE 3—*Element damage rates open air, canid, and bear scavenged cases.*

Element	Open Air* Total N = 16 individuals			Average Canid* Total N = 13 individuals			Average Black Bear Total N = 7 individuals		
	Number Recovered	Number Damaged	Percent Damaged	Number Recovered	Number Damaged	Percent Damaged	Number Recovered	Number Damaged	Percent Damaged
Cranium	16	0	0.0	13	1	7.7	7	2	28.6
Mandible	16	0	0.0	13	0	0.0	6	0	0.0
Cervical vertebra	16	0	0.0	4	2	50.0	5	3	60.0
Thoracic vertebra	16	0	0.0	4	2	50.0	3	2	66.6
Lumbar vertebra	16	0	0.0	4	1	25.0	5	2	40.0
Sacrum	16	0	0.0	4	2	50.0	3	1	33.3
Sternum	16	0	0.0	1	0	0.0	0	0	0.0
Clavicle	31	0	0.0	3	3	100.0	4	3	75.0
Scapula	30	0	0.0	7	6	87.5	6	4	66.7
Humerus	32	2	6.3	5	4	80.0	4	2	50.0
Radius	31	1	3.3	8	8	100.0	2	1	50.0
Ulna	30	0	0.0	7	7	100.0	4	2	50.0
Hand elements	28	5	17.9	1	1	100.0	3	2	66.6
Os coxae	32	0	0.0	12	11	90.9	10	8	80.0
Femur	32	1	3.1	13	13	100.0	10	9	90.0
Tibia	32	2	6.3	4	4	100.0	6	3	50.0
Fibula	32	2	6.3	6	6	100.0	5	1	20.0
Foot elements	28	3	10.7	1	1	100.0	3	2	66.6

Kolmogorov-Smirnov 2-Sample Test Results

Comparison	*p*-Value	Maximum Difference
Open Air—Canid	< 0.0001	0.833
Open Air—Black Bear	< 0.0001	0.889
Canid—Black Bear	0.0132	0.500

* After Haglund et al. (13).

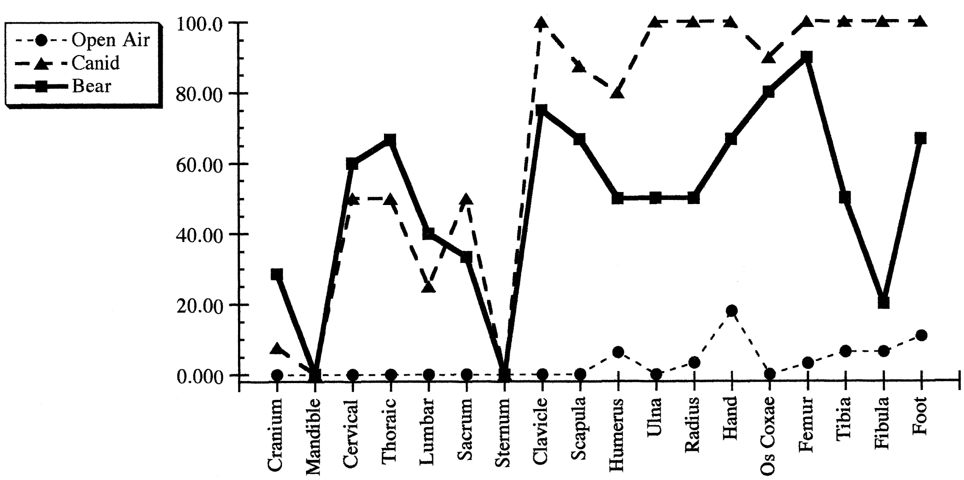

FIG. 4—*Graph of damaged elements from open air, canid and black bear scavenged cases.*

covered vertebrae from the seven bear scavenged individuals showed splintered margins where the transverse and spinous processes were removed, as did the rib fragments. As was the case with canids, pits and tooth impressions were numerous near the edges of long bone shaft margins. In most cases, bears removed both the proximal and distal articular surfaces from the larger limb bones, and began to work their way toward the center of the long bone shaft, breaking off splinters of cortical bone in the process. The *os coxae* sustained most damage to the iliac crest and ischial tuberosity, although portions of the *os pubis* were removed in three of the bear scavenged cases.

Minor differences, undoubtedly arising in part from the small sample size of the bear cases, were noted in the patterns of damage to the cranium and long bones. Haglund et al. (22) reported that cranial modification by canids was rare, and was confined to the mastoid processes when present. Neither of the two damaged cra-

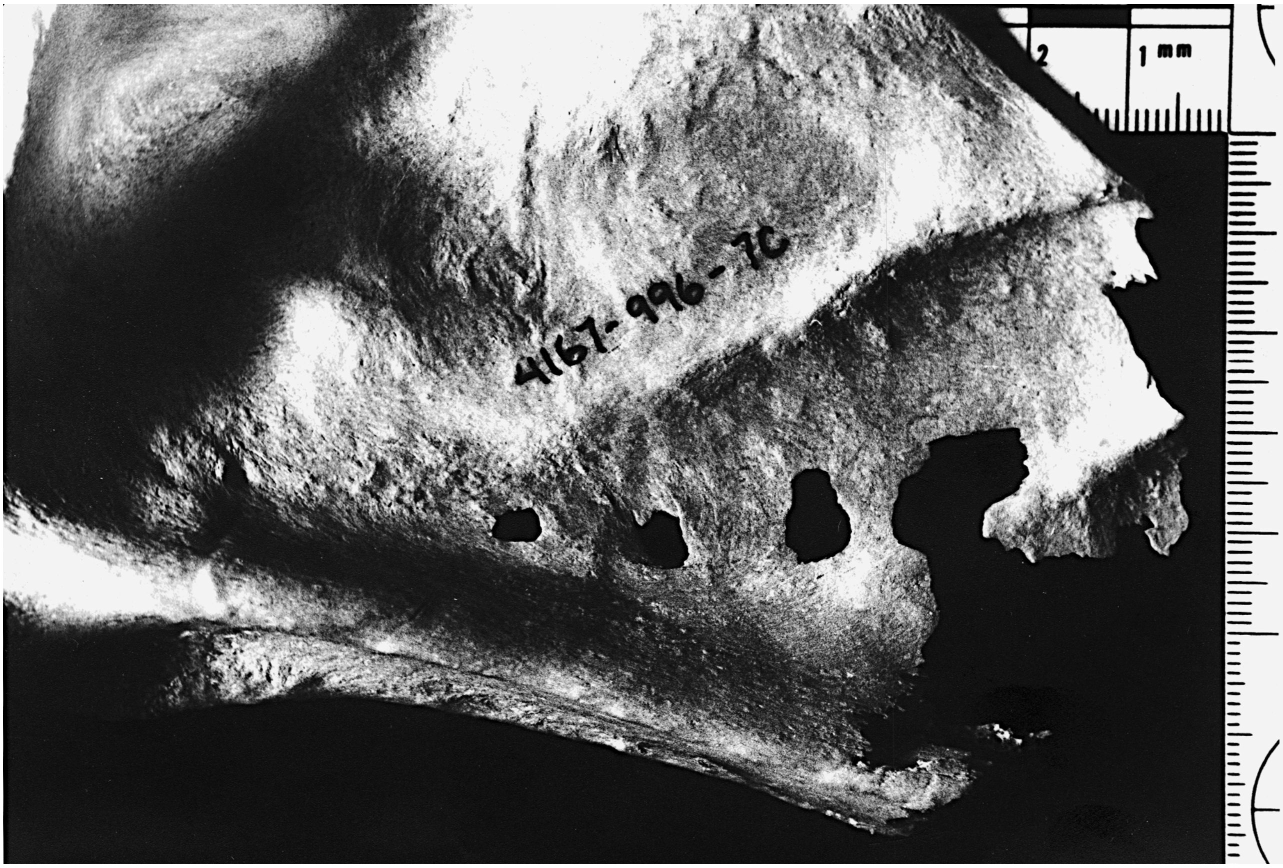

FIG. 5—*Right scapula of the male individual from Case 2 of bear scavenging. The bear's tooth row penetrated the scapular body.*

FIG. 6—*Right and left* os coxae *of the Case 2 male. The iliac crests, ischia, and pubic faces of both elements show evidence of bear scavenging.*

nia recovered from rural New Mexico displayed damage of the mastoids; instead, the maxilla, temporals, and palate were the elements involved. Additionally, spiral fractures in human long bones caused by canid scavengers were limited to the smaller limb bones, the ulna, radius, and fibula (22). While these elements showed spiral fractures in the bear scavenged cases studied, the proximal ends of the left femur and tibia of one New Mexico decedent also displayed this type of breakage. Haglund et al. (22) noted that larger carnivores with greater jaw strength would be able to cause spiral fractures in the bigger long bones. We would therefore expect to see a higher frequency of spiral fractures to the humerus, femur, and tibia in bear scavenged cases.

Perhaps the most striking difference is the 61–73% recovery rate of axial skeletal elements of decedents scavenged by canids (21). Bears left no sterna, and less than 50% of the vertebrae in the New Mexico cases. Thus, it appears that actual element recovery, rather than specific patterns of damage, is more useful in distinguishing scavenging by bears from scavenging by canids. While we cannot rule out postmortem damage to the human remains by members of the canid family, the majority of scavenging can be attributed to a larger carnivore.

Test Case

The two decedents from Case 2 described above typify the patterns of damage and element representation caused by bear scavenging in the other New Mexico cases (Figs. 2a, 2b, 5, 6). The male decedent used as an unknown test case displays a pattern of element recovery consistent with that observed in the bear scavenged individuals previously presented (Fig. 7). The shafts of long bones

FIG. 7—*Recovered skeletal remains of the test case individual.*

of the arms were intact, as were the femoral shafts. Articular ends of these elements were missing. In addition, damage to the test case individual's skeletal elements, particularly the scapulae (Fig. 8), closely resembles that seen in Case 2. While the extent of damage to the long bones, scapulae, and *os coxae* is severe, no mention of spiral fractures was made in the initial anthropological analysis.

Because both canids and bears tend to attack articular portions of long bones, we cannot completely rule out the possibility that a canid scavenger was involved in the modification of this decedent using only the pattern of damage. The element representation, however, resembles that of the previously discussed bear scavenged cases (Fig. 9). Using element representation for this single case, the

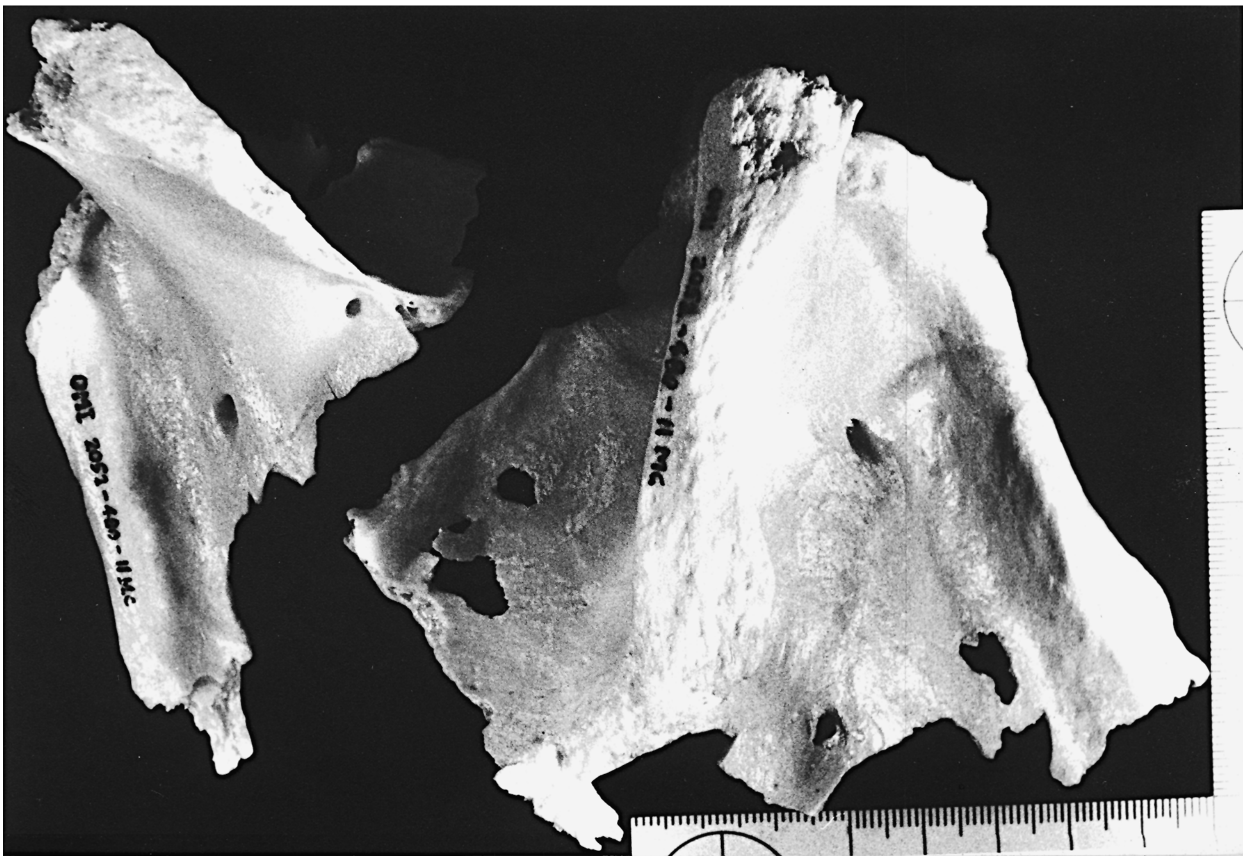

FIG. 8—*Left and right scapulae of the test case individual.*

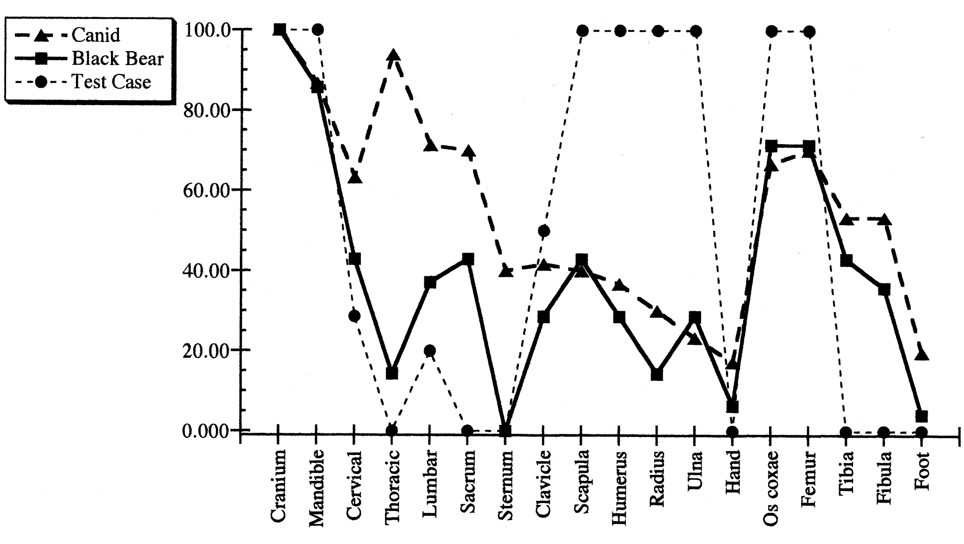

FIG. 9—*Comparison of recovered elements from the test case to those in known canid and bear scavenged cases.*

overall pattern of the frequency distribution can be distinguished from the canid ($p = 0.0388$) and from the polar bear ($p = 0.0388$) patterns, but not from the black bear pattern ($p = 0.0978$) at the 0.05 level of significance. Based on these results and on the overall lack of axial skeletal elements, we predict that this individual was scavenged by one or several members of *U. americanus.*

Discussion

Bears and canids exploit human remains in different manners. While both carnivores use similar mechanical techniques to break bone, the portions of the body scavenged are not the same, as evidenced by differences in element recovery. Bears are more likely to carry off or consume portions of the upper limb and axillary skeleton, while they leave the bones of the lower extremity at the scene, albeit severely damaged in most cases. Canids, however, do not appear to exploit the area around the vertebral column; these elements are often left at the scene and when recovered, show lower rates of damage than other skeletal elements. The region around the human vertebral column has relatively little muscle or fat compared to the thighs or stomach, and the meat in this region is difficult to remove due to the configuration of vertebrae and ribs. While this might be one reason for canids to avoid scavenging this part of the body, other explanations include the order in which a particular carnivore eats, its ability to move portions of the remains from the area of initial deposition, and/or the tendency of a carnivore to make multiple scavenging trips.

Haglund et al. (13) observed that coyotes and dogs in the Pacific Northwest initiate their scavenging of human remains by separating the soft tissue of the head and neck from the underlying bone in those regions. Canids then move inferiorly to gain access to the thorax by gnawing through the clavicles, sternum, and ribs. These actions not only expose the thoracic organs, they also assist with detachment of the upper extremities, which can then be carried to a secondary site for consumption. Canids consume the soft tissue of the lower limbs while still attached to the *os coxae*; according to Haglund et al. (13), these elements are detached through the disarticulation of the vertebral column or pelvic cavity. While our data do not refute this observed scavenging sequence, we suggest that black bears consume human decedents in a different manner then canids.

Explanations for the patterns of damage and presence of elements in bear and canid scavenged human remains can be drawn from observations on non-human remains, particularly sheep. Griffel and Basile (23) report that bears began to consume sheep carcasses at the udder or flank, eating the internal organs located in the stomach and chest before removing the hide and moving up to the shoulder region via the sternum and costal rib articulations. Coyotes and dogs, in contrast, often penetrated the flank anterior to one of the hind limbs and avoided scavenging the less muscular and fatty portions of the sheep, including the legs. The posterior extremities, if exploited, were the last areas consumed by bears, presumably because of the relative lack of meat in this region of the sheep carcass. In cases where the fore and hind limbs were eaten, bears often completely consumed the bones of these extremities, while this was not observed for canids (23).

Humans obviously have more muscular upper and lower extremities than do sheep, making these regions attractive to scavengers. If, however, human remains are consumed by bears in a pattern similar to that employed on sheep carcasses, some discrepancies in the element recovery and damage rates observed in the present study could be explained. No sterna were found for the seven individuals scavenged by black bears; this is consistent with the observation that bears chew through a sheep's sternum and ribs to reach the shoulder girdle. Additionally, bears may be completely consuming smaller human bones such as the clavicle or sternum, while canids discard such elements.

The absence of some skeletal elements in bear scavenged human remains, particularly the vertebrae, could also reflect the ability of bears to move the axillary skeleton further away from the scene of initial deposition. Bears were observed to drag the majority of sheep carcasses at least 75 ft, while coyotes failed to move the remains above 3 ft (23) (although Haglund et al. (13) note several cases in which dogs have moved individual human elements for distances comparable to bears). In addition, the study of bear and coyote scavenging of sheep carcasses reported that bears returned more than once to the site of a sheep carcass; Haynes (15) confirmed this behavior among bears scavenging bison, moose, and deer carcasses. Coyotes, on the other hand, always completed their consumption during the initial scavenging interval (23). This behavior, if reflective of the scavenging of human remains, could account for the paucity of small to medium sized bones in the bear scavenged assemblages. Return trips would allow bears further chances to consume or carry away these elements. The presence of several bear sleeping beds in the area immediately adjacent to the grave of one of the New Mexico forensic cases supports the assessment of repeated and prolonged scavenging of the human remains.

The differences between bear and canid damage patterns in recovered bones are more difficult to explain than the element representation pattern. Our data do not support the observations of Micozzi (19), drawn from Murad and Boddy (18), that canids exploit the articular ends of long bones, while bears preferentially open the diaphyses. A comparison of Figs. 2b, 9, and 12 with photographs in Murad and Boddy (18) revealed that the damage attributed to bears in all these cases is very similar. Bears, like other carnivores, appear to attack the articular ends of long bones. In some cases, this activity results in breaks along the shafts at the proximal or distal thirds of the long bones.

Clearly, canids consistently gnaw on every element of the upper and lower limb. This trend is more erratic and occurs at a lower rate in the bear scavenged cases. It is probable that similar types of damage could be created by canids and bears over different periods of time. Differential jaw strength allows bears access to the long bone medullary space after gnawing only a few times, while a canid requires extended gnawing to achieve the same result. For this reason, we feel that extreme caution should be exercised when attempting to identify the genus of carnivore and estimate time since death based solely on the relative amount or pattern of damage to human bones. Instead, differential exploitation of elements yields more information about the carnivore's behavior and ability to scavenge certain regions of the body.

Sample size is, of course, a problem in the analyses presented here. Each of the samples of human remains modified by canids, black bears, and polar bears is much too small for drawing broad generalizations regarding the scavenging behavior of these carnivores. Unfortunately, it is rare to find conditions in forensic cases that allow us to identify with certainty the genus of carnivore responsible for scavenging to the exclusion of other such genera. We can only assume that the seven cases presented here are a representative sample of the patterns that result when black bears scavenge human remains, and simply compare this to the most severe stages of canid modification (12) for which similar assumptions have been made. If these assumptions are valid, it appears that black bears can best be distinguished from canids in cases of carnivore scavenged human remains based on the pattern of element representation.

Conclusions

Our study suggests that, given an appropriate estimate of time since death, black bears can be distinguished from canid species as the scavengers of human remains based primarily on the presence or absence of certain skeletal elements at or around the scene. Bears are more likely to exploit the axillary skeleton, consuming, removing, or damaging vertebrae, ribs, and sterna, while canids scavenge the extremities and organ cavities, ignoring the less muscular region around the vertebral column. The rates and patterns of damage to recovered elements are not particularly diagnostic of scavenger species, as they can resemble one another over time. Forensic anthropologists, as well as those investigating historic and prehistoric skeletons, should use caution when analyzing human remains that have been modified by carnivores, as some scavenging could be mistaken for perimortem trauma. An understanding of the skeletal elements expected to be missing or damaged in bear and canid scavenged remains can help prevent such erroneous analyses.

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