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Tooth Mark Artifacts and Survival of Bones in Animal Scavenged Human Skeletons

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ABSTRACT: Animal scavenging activity can result in production of tooth mark artifacts. Such activity can confound interpretation of skeletal material and the identification process. To date, these topics have received limited attention in the forensic science literature. This study discusses the nature of various animal tooth mark artifacts and typical damage to selected bony elements. This study also assesses survivability of various skeletal elements over time. Two major factors that affect which bones are recovered and the amount of damage are circumstances which shelter remains from animals and human population density of the area where the skeleton is recovered.

KEYWORDS: pathology and biology, tooth marks, postmortem interval, human identification, musculoskeletal system

Neither tooth mark artifacts nor survival of bones has received detailed attention in the forensic science literature; nevertheless, tooth marks were enumerated among a list of observations which can aid in an "impression" of the postmortem interval [*1*]. Krogman and Iscan [*2*] reported on gnawing of femoral and tibial condyles by the field mouse *(Peromyscus manaculatus).* Sorg [*3*] and Rodriguez [*4*] have noted the importance of recognizing and interpreting postmortem damage caused by animals. Rodriguez [*4*] has demonstrated the ability of medium sized dogs to transport human skulls, and Bass [*5*] has commented on nearly complete consumption of an elderly woman by three dogs. The most complete survey of bone defects caused by various animals is that of Morse [*6*]. He limited his comments to general effects of animal chewing and concluded that the amount of animal damage and the number of bones removed from remains may directly relate to the time of deposit. To date, however, no descriptive nomenclature of mammalian tooth mark artifacts has been presented in the forensic literature.

In contrast, paleontologists and archaeologists, in the subdiscipline of taphonomy, have devoted considerable attention to the postmortem fate of the mammalian skeleton. The term "taphonomy" was coined by Efremov [*7*] and literally means "laws of burial." Taphonomists are concerned with several lines of inquiry into the analysis and interpretation of bone assemblages. Of particular relevance to forensic investigations are disarticulation sequences of skeletons [*8-13*], postmortem artifacts produced by animal activity [*14-23*], animal scat-

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tering and environmental transport [*24-28*], weathering of bones [*29,30*], and survivability of various skeletal parts [*24*]. Of further interest are efforts to distinguish man-made from animal produced and environmentally caused artifacts [*31-34*]. Two overviews of taphonomy are presented by Gifford [*35*] and Johnson [*36*].

A variety of mammals have been documented in taphonometric studies as causing postmortem damage to bones. This inventory includes specific carnivores such as leopards [*14*], foxes and hyenas [*15*], and dogs and wolves [*5,16-20*]. Bears are mentioned as scavengers of artiodactyle carcasses [*16*]. Deer, sheep [*15,21*], and hogs [*6*] among the artiodactyls have also been cited as producing gnawing damage to bone [*15,21*]. Among the rodents, porcupines, mice, squirrels, and rats are known to gnaw on bones [*12,14*]. Among nonmammalian scavengers of human remains, crabs, turtles, fish, and birds have been indicated; however, their contribution to bone artifacts is not certain [*6*].

The manner in which bones are altered varies with the species of rodent, carnivore, or hoofed animal which produces damage. Haynes [*17*] presented a comparison of damage characteristic of canids, hyenas, bears, and felids and indicated general differences in their gnawing patterns. Their tooth morphology, jaw mechanics, and strength relative to the bone have bearing on the amount of damage animals can produce. The season, prey size, and number of animals feeding have also been cited as factors affecting carcass destruction [*12*]. Another factor, according to Haynes [*16*], is the amount of soft tissue and ease with which it is stripped from the bone. Relative freshness and softness of bone may also affect its alteration by animals.

Various damage to bones by animals has been described. Gnawing usually proceeds from the "soft" cancellous articular ends of long bones, and subadult epiphyses are particularly vulnerable. Features of bone which have been suggested as most affecting their durability and, hence, survivability, are density and, in the case of long bones, the time of epiphyseal fusion [*24,37*]. The spectrum of potential damage and loss produced by carnivores ranges from tooth mark impressions, crenulated, crushed, or splintered edges at damage margins, missing or broken-off portions, and absence as a result of ingestion [*5*] or transport [*12*]. Inability of the animal to break open the marrow cavity of long bones may result in "scooping," the licking out of its contents by the tongue from open ends of shafts [*38,39*]. Spiral fractures of long bones of elk and even bison have been produced by larger carnivores such as wolves [*18,20*], dogs [*20*], hyenas, and leopards [*24*]. Small bones and bone fragments may be eaten only later to be regurgitated or deposited by defecation [*38*].

Haynes [*18*] and Binford [*20*] recognized four characteristic types of carnivore tooth marks: punctures, pits, scoring, and furrows. Punctures are produced when bone collapses under a tooth and most often appear as perforations in thin portions of bones such as the scapula or in cancellous ends of long bones [*39*]. Both canine and carnasial teeth produce punctures. Pits are indentations caused by the tips of teeth as the animal bites down and occur when there is insufficient strength to penetrate the surface. Scoring is produced when teeth slip and drag over compact bone. Shafts of long bone are the most likely areas of these linear, often parallel scratches which are oriented transversely to the long axis of the bone. Such marks generally follow the contours of bones [*40*]. Furrows are channels in bone produced by cusps of cheek teeth and extend from the ends of long bones longitudinally into the marrow cavity [*16*].

This study examines animal tooth marks produced on scavenged human remains and analyzes patterns of damage on recovered skeletal elements. Such information may enable forensic science investigators to distinguish animal tooth artifacts from other types of injury to bone and may provide a more objective basis for estimation of the postmortem interval.

Method and Materials

A population of 37 partially to fully skeletonized human remains recovered from outdoor locations within the Seattle/King County area of Washington State between 1979 and 1987 were surveyed for evidence of animal tooth artifacts. Only identified remains, where the date of death was known, were considered.

Recovery efforts generally included a shoulder-to-shoulder, walk-through search of the area surrounding the principal skeletal discovery sites, denuding the areas of vegetation, followed by hands-and-knees search for bones. In addition, primary discovery sites of bone locations were processed by sifting the soil through multiple screens for recovery of teeth, small bones, and other evidential material. Relative locations of bones were plotted at the scene. Recovered materials were placed in numbered bags which corresponded to locations of discovery so they could be plotted on maps of the scene. Animal scavenger activity was determined by the presence of tooth marks, scattering of bones, scat deposits, animal tracks, and animals known to inhabit the area. On-scene observations were augmented by further meticulous examination of material and by a review of police, anthropologist, and medical examiner reports. All scene removals were attended by an individual trained in osteology (WDH).

Bones examined for this study consisted of skull, mandible, clavicles, scapulae, humeri, ulnae, radii, sternum, vertebral column, sacrum, ribs, hemipelvis, femora, tibiae, and fibulae. These bones were used individually or in combination for individual skeleton determinations and were used for survival calculations. Smaller bony elements such as carpals and tarsals are mentioned.

Population density figures for King County were obtained from the 1986 King County Annual Growth Report prepared by King County Department of Planning and Community Development and were based on U.S. Census Bureau figures for March 1981 [*41*].

Results

Twenty-four or sixty-five percent of the thirty-seven skeletons considered in this survey showed evidence of animal tooth marks. Sixteen individuals were between the ages of fourteen and nineteen years, seven were twenty-two to forty-six years, and one was a child of seven years. Thirteen (thirty-five percent) of the remains showed no evidence of tooth mark artifacts. The majority of animal artifacts were produced by coyotes and dogs as determined by scat deposits and tracks or by characteristic canid punctures, pits, scoring marks, and furrows. There was some evidence of rodent gnaw marks, but this was typically secondary to carnivore produced damage. No artiodactyl gnawing artifacts were noted, even though elk, deer, and domestic stock frequented many areas of skeletal discovery. Figure 1 correlates presence or absence of animal scavenging with human population density of the census tract in which each individual skeletal remains were found.

Location, Extent of Damage, and Survival of Skeletal Remains

Figure 2 shows percentage of skeletal elements recovered and percentage of bones demonstrating animal artifacts.

Crania were found for 100% of animal scavenged remains of this study and exhibited little damage from animal activity except for punctures of the mastoid processes. Characteristics of severe damage to the mandible was removal of the rami, leaving only the corpus from the third molar forward. Minor damage to the scapula removed the vertebral margin, leaving crenulated, chewed, and crushed edges. Depressed fractures, associated with splintering, pits, and punctures, were also noted extending onto areas of the scapular blade (Fig. 3). Heavy gnawing damage destroyed all but the glenoid region and neck.

The axis and atlas were frequently undamaged and associated with the skull when it was disarticulated from the rest of the body. Severe scavenging often left transverse and spinous vertebral processes chewed away, with crushed, splintered margins. Similar features were noted on proximal remnants of ribs. All margins of the sacrum were often chewed. Primary

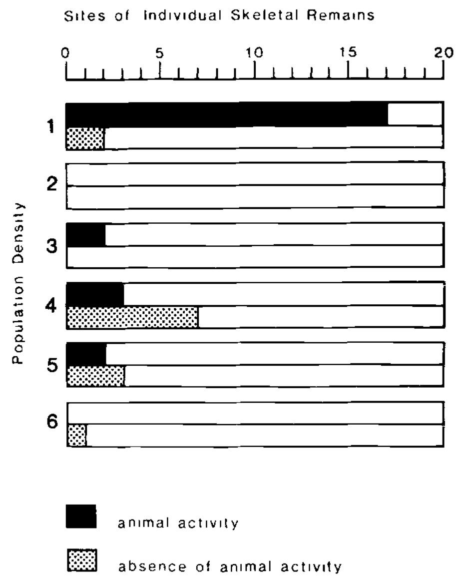

FIG. 1—*Population density of census tract where remains were discovered. (1 = 1-200 persons/square mile; 2 = 201-1000 persons/square mile; 3 = 1001-1500 persons/square mile; 4 = 1501-3000 persons/square mile; 5 = 3001-5000 persons/square mile; 6 = 5001-6000 persons/square mile.)*

areas of damage to slightly gnawed innominate bones were the iliac crest, ischial tuberosities, and pubic symphysis (Fig. 4). The acetabular rim was seldom altered.

The most likely site of initial destruction to the humerus was the head and greater tuberosity. In early stages of gnawing, both the capitulum and trochlea were also involved. Destruction of the ulna was initiated at the olecranon process. The radius and ulna showed spiral fractures in many instances. Spiral fractures were also noted in the fibulae. Lightly gnawed femora were attacked at the greater trochanter, and with moderate gnawing, the head and neck were destroyed as well as both condyles removed. Moderate scavenger chewing of the tibia involved the proximal tibial condylar margins and articular region. Scooping was frequently noted in long bones (Fig. 5), and recovered long bone shafts frequently showed scoring marks and furrows (Fig. 6).

Population Density and Sheltered Remains

Figure 7 shows the season and elapsed time of exposure for individual remains and percent survival for selected groups of skeletal elements. Human population density of the census tract where the body was discovered and special circumstances affording shelter to the remains are noted. Elapsed time from death to discovery ranged from 22 days to 52 months, and percentage of recovered skeletal elements per body ranged from 96 to 4%. Approximately 70% of all skeletal elements were recovered when the postmortem interval was 4½ months or less. After 6 months there was a notable decrease in recovery of expected bones. This was true for skeletons which were not sheltered in low human population density areas.

Discussion

Carnivore damage to long bones in this study was more frequent in less dense, cancellous portions. Once articular surfaces of long bones were removed, there was progressive reduc-

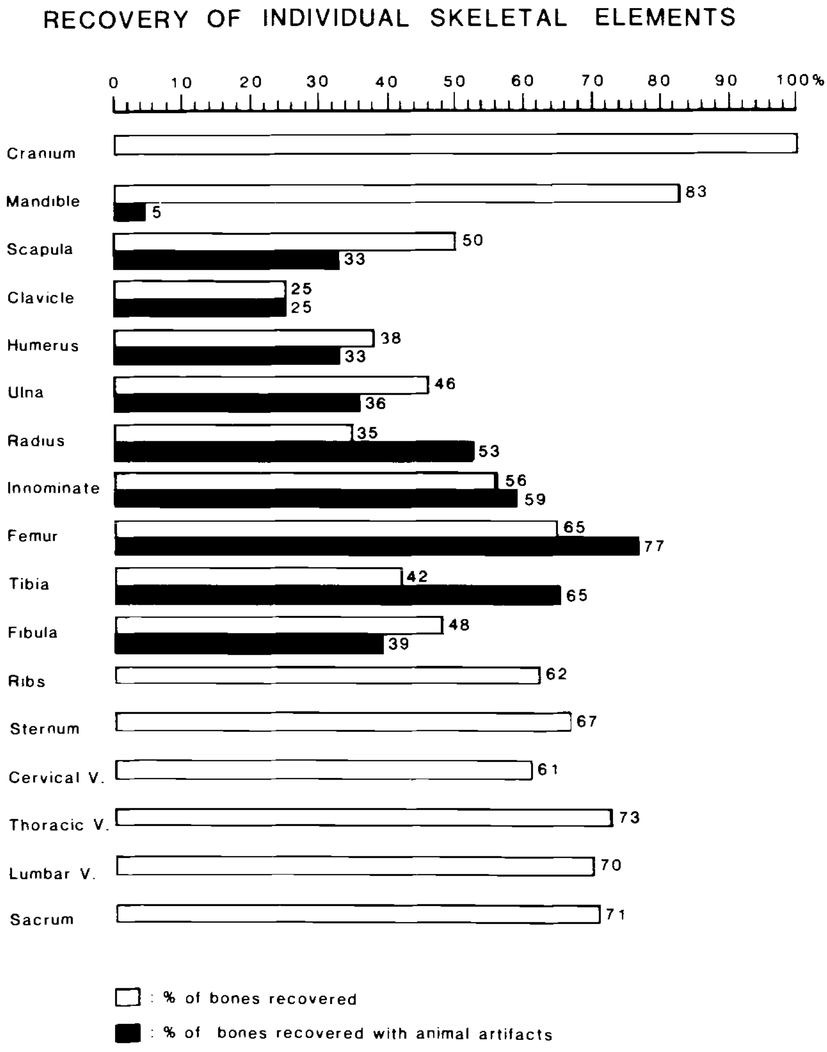

FIG. 2—*Survival of skeletal elements indicated by bones recovered and number of recovered bones with animal damage. (Complete assessment of damage was not available for ribs, sternum, sacrum, or vertebrae.)*

FIG. 3—*Carnivore damage showing depressed fractures, splintering, and chewed margins of vertebral border of scapula. Also note pits and punctures.*

tion of shaft length until the bone was totally destroyed. This usually resulted from progressive furrowing up the length of the shaft. Punctures and pits, which often caused depressed fractures with shattered and crushed margins, were commonly found short distances from the edges of damages (Figs. 3 and 4). Pits and scoring were most often noted on surfaces near the ends of larger compact bones (Fig. 6).

Carnivore tooth damage, with its characteristic locations and constellation of pits, punctures, scoring, and furrows, usually allows ready distinction from other artifacts to bone. Unlike scoring, which follows contours of bones, cut marks usually follow a straight, rigid course. The linear lines from sediment abrasions tend to be fine and have a smoothing effect

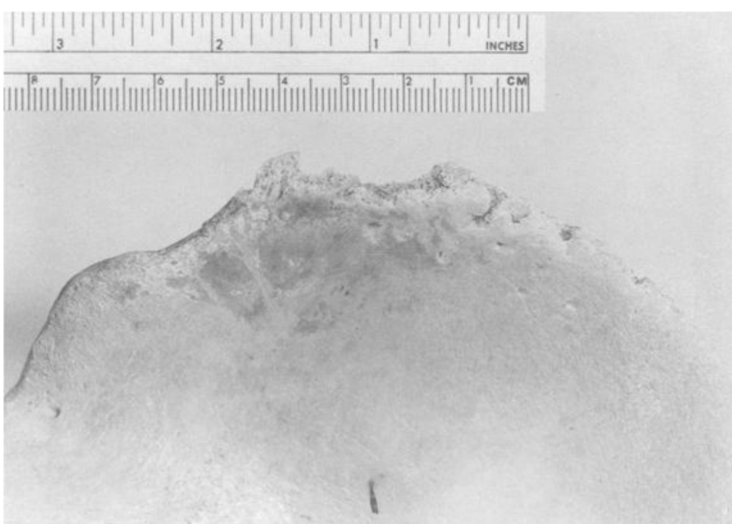

FIG. 4—*Punctures and pits produced by carnivores along the anterior margin of the iliac crest.*

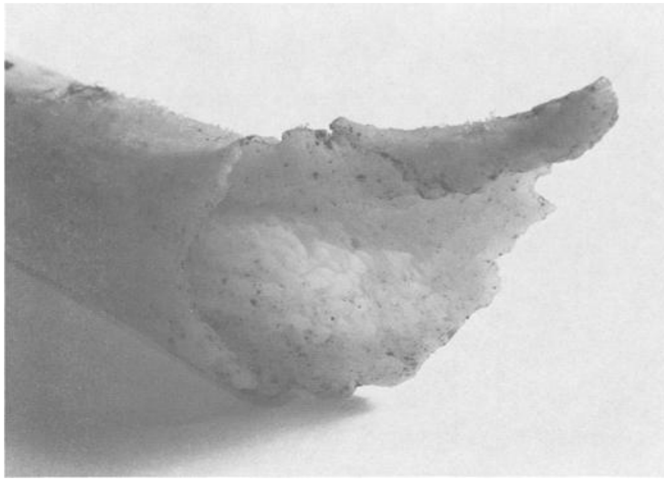

FIG. 5—*Scooping out of marrow cavity of proximal femur.*

on sharp features of bone. The filigree-like lines caused by etching of roots on bone are often associated with the causative root mass and are usually more intricate, multidirectional than scoring marks. Pits, not associated with the usual suite of carnivore gnawing marks, are most problematic and may not be readily distinguished with certainty.

Bones retrieved from areas inhabited by dogs were significantly more gnawed and pitted than those found in areas of coyote scavenging. The increased gnawing damage produced by dogs is also a finding observed by Binford [*12*]. He suggested "boredom" of yard confined dogs to be a factor of increased gnawing activity, a rationale he also noted for bones found in the vicinity of wolf denning areas.

FIG. 6—*Scoring linear artifacts* (a) *and furrows* (b) *on proximal human femur shaft produced by carnivores.*

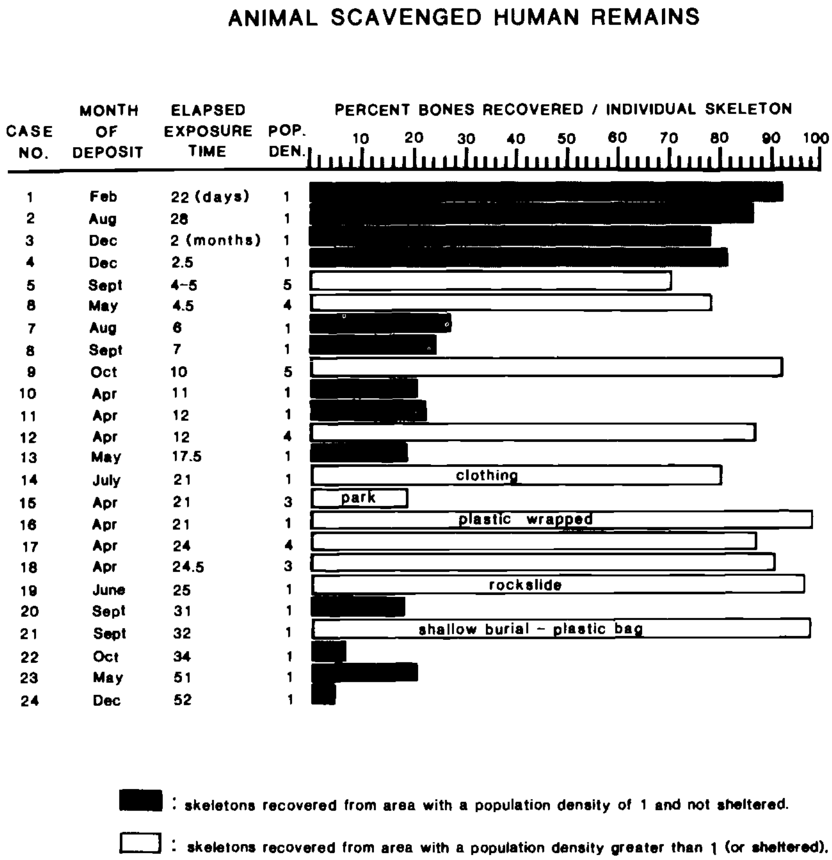

FIG. 7—*Percent survival of selected skeletal elements for individual skeletal remains. Shaded cases indicate those remains in census tract population density areas of 1 and which were not sheltered. Sheltered circumstances consisted of: Case 15, clothing; Case 16, wrapped in plastic; Case 19, partial burial by rockslide; Case 21, shallow burial. (1 = 1-200 persons/square mile; 2 = 201-1000 persons/square mile; 3 = 1000-1500 persons/square mile; 4 = 1500-3000 persons square mile; 5 = 3001-5000 persons/square mile; 6 = 5000-6000 persons/square mile.)*

Gnawing by rodents such as mice could be distinguished from that of carnivores by the characteristic parallel series of incisor furrows (Fig. 8). These furrows were found delineating margins of damage. A further characteristic of such margins was their relatively uniform pitch extending from outer to inner tables of bone (Fig. 9). Margins of carnivore damage were less regular, often rounded, with no uniform pitch from inner to outer surface (Fig. 10). A frequent observation of rodent gnawed bones of subadult skeletons was destruction of epiphyseal cartilage and adjacent areas of cancellous bone, which left distal or proximal ends of bone pedestaled to the shaft.

Inferences as to the survivability of individual bones are limited by the thoroughness of the recovery effort. Because of the high recognition value of the human skull, its discovery usually triggers the report of a human skeletal find. It very well may be that other skeletal elements often go unnoticed or are missed by a cursory search. Therefore, the apparent survival rate of the cranium might be an artifact of discovery and recognition. It could be that the crucial nature of the cranium and mandible for identification purposes adds additional impetus for their recovery. The authors are aware of recovered incomplete skulls showing ani-

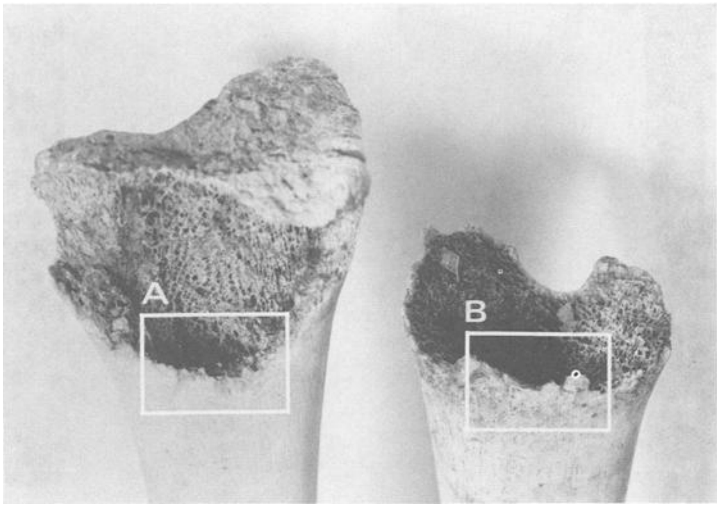

FIG. 8—*Comparison of rodent* (left, a) *and carnivore* (right, b) *gnawing of proximal femur.*

mal tooth marks. This seems to be more frequent when extensive head trauma existed before death. Preliminary observations indicate the skull is less likely to be recovered from bodies partially skeletonized in open bodies of water. The skull of the mammalian carcass naturally separates from the body early in the disarticulation process [*9*], which increases its likelihood of transport by scavengers.

Generally, bones of the upper extremity, which include scapulae and clavicles, were recovered less frequently than those of the lower extremity. Recovery rate for bones of the upper extremity ranged from a high of 50% for the scapula to a low of 25% for the clavicle, while those of the lower extremity, including both innominates, ranged from a high of 65% for the

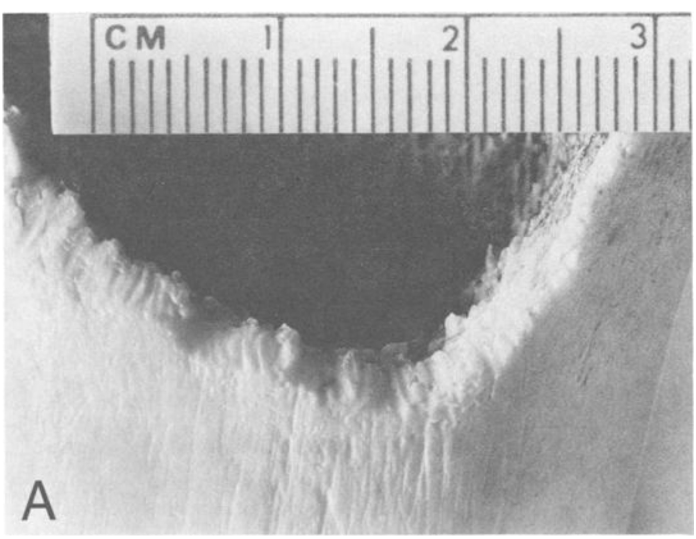

FIG. 9—*Close-up of margin of rodent damage represented in Fig.* 8a *demonstrating parallel incisor tooth marks and relatively uniform pitch of gnawed surface.*

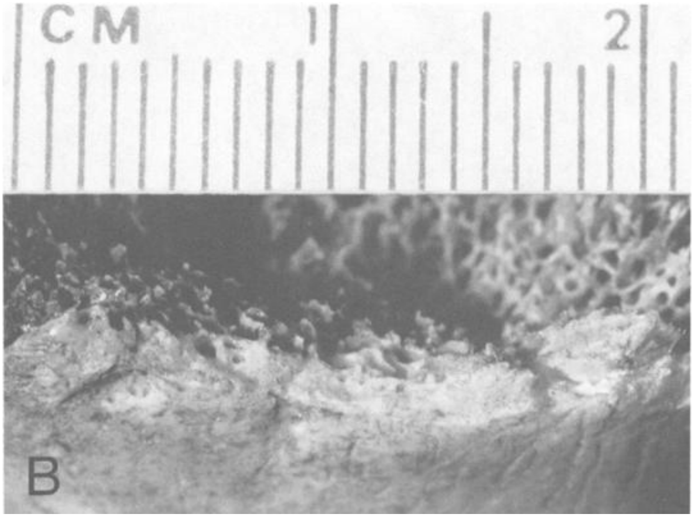

FIG. 10—*Close-up of carnivore damage represented in Fig.* 8b *demonstrating irregularity of margin of damage.*

ıemur to a low of 42% for the tibia. This largely reflects the sequence of animal scavenger disarticulation of human remains [*42*]. With the exception of the cranium and mandible, bones of the axial skeleton were recovered between 73 and 61% of the time. Axial skeletal elements were usually found scattered about the original site of discovery. This was in contrast to extremities, which once disarticulated from the body can be easily removed as a unit which facilitates transport by animals. Hands and feet were not recovered for this same reason. For Cases 1 and 10, bones of one hand were recovered, and in Cases 1, 2, 10, and 17, all or some foot bones were recovered.

Although spiral fractures of most major long bones, especially when fed upon by larger carnivores, have been reported by many authors [*18,20*], such fractures in the present study were restricted to the fibula, radius, and ulna. The most likely explanation for the lack of spiral fractures in larger long bones is the weaker jaw strength of coyotes compared with that of Eskimo dogs and wolves for which spiral fractures have been reported. This same observation of lighter damage and decrease of spiral fractures for other smaller carnivores such as jackals has been noted [*12*].

In this study, several variables were identified as influencing the extent and type of tooth mark artifacts observed on scavenged human bones. As previously noted, the architecture of the bone itself is of primary importance: cortical thickness and amount of compact bone relative to cancellous bone. This is dependent upon the age and size of the individual. Binford [*20*] points out that the amount of soft tissue plays a role in damage to underlying bone. Other factors which must be considered include body location in relation to human population density, protection from animals offered by position or covering of the remains, state of decomposition of the remains, and finally, the scavenging animal species, including their size, number, and behavior.

Decreased animal activity on human skeletons found in higher human population density areas is consistent with fewer animals and smaller animal group sizes in inhabited areas. Human remains are also discovered sooner in more populated areas. Circumstances which accounted for protection of remains in this study included partial burial in a shallow grave and a rockslide. Heavy clothing and a body wrapped in a plastic tarp were additional situations which limited body exposure. With partial protection from exposure, damage to or absence of bones on the unprotected side of the body is to be expected. Rigor mortis, while still present, may limit body access, especially to smaller scavengers.[4] Freezing of the body could have a similar limiting effect [*43*]. The present study did not indicate whether frozen remains influenced their scavenging by animals.

Season of the year affects the following: amount of clothing worn by the deceased, ground cover of the area in which the body was deposited, rate of decomposition, and behavior of the potential scavengers. Protection offered by heavy clothing may provide a considerable barrier to scavengers; however, remains in this study did not reflect expected seasonal garb, because many bodies were deposited with little or no clothing, regardless of season. For some animals, notably those which hibernate, such as bears and certain rodents, damage would be absent or significantly lower in colder months. For coyotes, the seasonal nature of food sources influences their social behavior. In summer, when coyotes sustain themselves on rodents, they are less social than in winter, when greater food sources are available to support larger group sizes [*44*].

Conclusion

The longer the elapsed time between body deposition and recovery, the fewer and more heavily damaged bones are recovered from animal scavenged bodies. Modifications of these findings arise when bodies are in sheltered circumstances or areas of high population density. It must be emphasized that the results of this study are specific to the Pacific Northwest. Local estimates of rate and time of death of skeletal material should be made with extreme caution and should be based on local experience with animal scavengers and environmental conditions of the particular region of recovery.

Acknowledgments

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